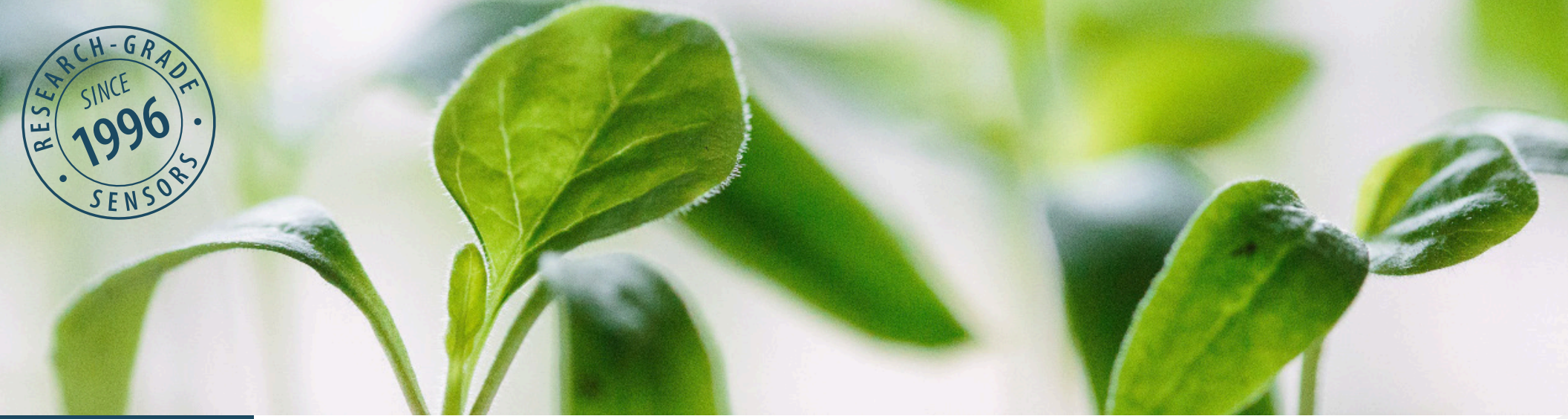

apogee®
INSTRUMENTS
2023 Catalog



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PAR, Daily Light Integral, & Photoperiod Meters

Spot check PPFD/ePPFD and record DLI and photoperiod

NEW!

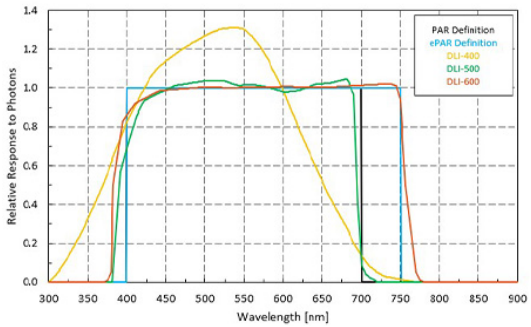
Great for spot checking PAR levels and tracking DLI and photoperiod!

Overview

New for 2022, Apogee DLI meters are a rugged, simple-to-use device for spot checking PAR or ePAR levels while automatically recording the daily light integral and hours of light (photoperiod) for up to 99 days. The data can be viewed on-screen by toggling the button or by downloading via the included USB-C cable.

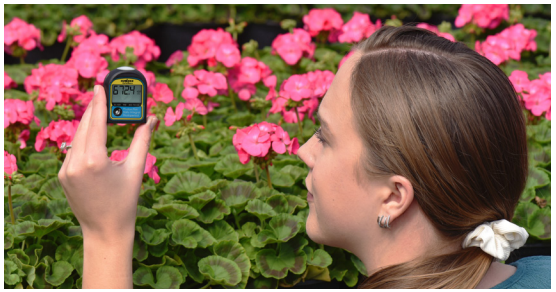
Three Models

- **DLI-400**: Lowest-cost option is accurate for measuring 400-700 nm only in sunlight and under some broadband light sources.
- **DLI-500**: Full-spectrum is accurate for measuring 400-700 nm under all light sources including LEDs.
- **DLI-600**: ePAR is accurate for measuring the newly discovered extended PAR (ePAR) 400-750 nm range under all light sources.



Spectral Range

The spectral responses of DLI-400 (yellow), DLI-500 (green), and DLI-600 (orange) can be seen in the graph.

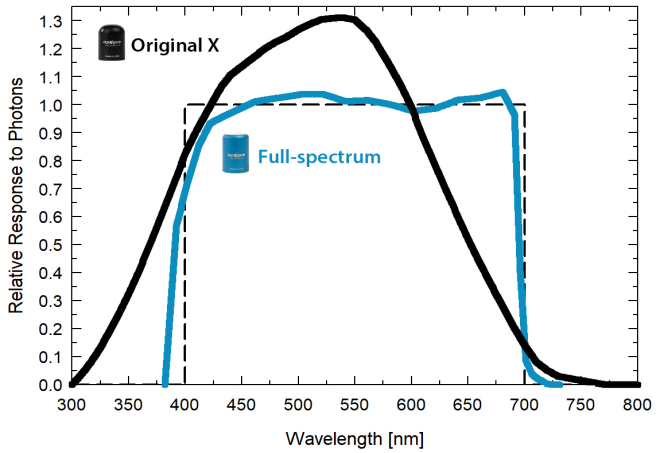


	DLI-400	DLI-500	DLI-600
Calibration Uncertainty	± 5 %		
Measurement Repeatability	Less than 0.5 %		
Display Range	0 to 4000 µmol m^{-2} s^{-1}		
Long-term Drift	Less than 2 % per year		
Field of View	180°		
Spectral Measurement Range (± 5 nm)	370 to 650 nm (sunlight only)	389 to 692 nm	383 to 757 nm
Directional (Cosine) Response	± 5 % at 75° zenith angle		
Temperature Response	-0.04 % per C	-0.11 ± 0.04 % per C	
Response Time	2.5 seconds		
Data Log Capacity	99 days (DLI & Photoperiod), 10 days (30 min PPFD/ ePPFD averages)		
Non-linearity	Less than 1 % (up to 2500 µmol m^{-2} s^{-1})	Less than 1 % (up to 4000 µmol m^{-2} s^{-1})	
Stored Data Resolution (PPFD/ePPFD)	0.1 µmol m^{-2} s^{-1} (when ≥ 1000, the screen will not display the decimal)		
Stored Data Resolution (DLI)	0.1 mol m^{-2} day^{-1}		
Stored Data Resolution (Photoperiod)	0.1 hours		
Operating Environment	-10 to 60 C; 0 to 100 % relative humidity	-40 to 70 C; 0 to 100 % relative humidity	
IP Rating	IP65		
Dimensions	1.91 W x 2.31 H x 0.93 D (inches)		
Mass	67 g		
Warranty	4 years against defects in materials and workmanship		

Quantum Sensors and Meters

The photosynthetically active radiation measurement tool of choice for lighting researchers

Apogee Instruments Quantum Sensors are the tool of choice for researchers and agricultural professionals measuring photosynthetically active radiation (PAR) all over the world. Apogee offers two types of quantum sensors to measure the traditional 400-700 nm PAR range: our high accuracy **Full-spectrum Quantum** and our less accurate, but more economical, **Original X Quantum**. Our Apogee **ePar Sensor** is used to measure the extended PAR range of 400-750 nm (see page 8). Consult our spectral response graph and table with photosynthetic photon flux density (PPFD) errors to decide which model is right for your application.



Above: Spectral response of **original X quantum sensor (black)** and **full-spectrum quantum sensor (blue)** compared to defined response of plants to radiation (dashed).

Radiation Source	Original (SQ-100X Series) PPFD Error [%]	Full-Spectrum (SQ-500 Series) PPFD Error [%]
Sun (clear sky)	0.0	0.0
Sun (cloudy sky)	0.2	0.1
Reflected from Grass Canopy	5.0	-0.3
Transmitted below Wheat Canopy	7.0	0.1
Cool White Fluorescent (T5)	7.2	0.1
Metal Halide	6.9	0.9
Ceramic Metal Halide	-8.8	0.3
High Pressure Sodium	3.3	0.1
Blue LED (448 nm peak, 20 nm full-width half-max)	14.5	-0.7
Green LED (524 nm peak, 30 nm full-width half-max)	29.6	3.2
Red LED (635 nm peak, 20 nm full-width half-max)	-30.9	0.8
Red LED (667 nm peak, 20 nm full-width half-max)	-56.7	2.8
Red, Blue LED Mixture (84 % Red, 16 % Blue)	-21.2	-3.9
Red, White LED Mixture	-29.7	-2.0
Cool White LED	7.3	0.5
Warm White LED	-7.8	0.2

Accurate, Stable Measurements

Cost-effective, **original X quantum sensors** work well for broadband radiation sources (sun, high-pressure sodium, metal halide, cool white fluorescent lamps). **Full-spectrum sensors** are good for all light sources, including LEDs. Both sensors offer a self-cleaning, cosine-corrected head that is fully-potted for a waterproof design.

Output Options

Sensors are available in multiple analog options: attached to a hand-held meter with a digital output; as a "smart" sensor that uses USB communication and custom software; SDI-12 or Modbus protocols; or with Apogee's new µCache device.

Full-spectrum Models

SQ-500	Self-powered 0 to 40 mV
SQ-512	0 to 2.5 V
SQ-514	4 to 20 mA
SQ-515	0 to 5 V
SQ-520	USB
SQ-521	SDI-12
SQ-522	Modbus
MQ-500	Meter, separate sensor
MQ-501	Meter, attached sensor
MQ-510	Meter, underwater calibration

Original X Models

SQ-100X	Self-powered 0 to 400 mV
SQ-202X	Amplified 0 to 2.5 V
SQ-204X	Amplified 4 to 20 mA
SQ-205X	Amplified 0 to 5.0 V
SQ-420X	USB
SQ-421X	SDI-12
SQ-422X	Modbus
MQ-100X	Meter, attached sensor
MQ-200X	Meter, separate sensor
MQ-210X	Meter, underwater calibration

Line Quantum Models (0 to 250 mV)

SQ-301X	10 Sensors	Sun Calibration
MQ-301X	Meter, 10 Sensors	Sun Calibration

NEW DESIGN!

Case Study

The **Kuwait Institute for Scientific Research** models algal species in the **Kuwait Bay**. The study helps advance our understanding of the frequent algal bloom and fish kill incidents particularly occurring during the summer season. They used an **Apogee MQ-510 underwater full-spectrum quantum sensor** for continuous PAR field measurements.

Full-Spectrum Quantum Sensors

Accurate PAR measurements under all light sources, including LEDs

	SQ-500-SS	SQ-512-SS	SQ-514-SS	SQ-515-SS	SQ-520	SQ-521-SS	SQ-522-SS
Power Supply	Self-powered	5 to 24 V DC	12 to 24 V DC	5.5 to 24 V DC	5 V USB power source	5.5 to 24 V DC	
Current Draw	–	At 12 V is 57 µA	maximum of 20 mA	At 12 V is 57 µA	61 mA when logging	1.4 mA (quiescent), 1.8 mA (active)	RS-232 37 mA; RS-485 quiescent 37 mA, active 42 mA
Output (sensitivity)	0.01 mV per µmol m^{-2} s^{-1}	0.625 mV per µmol m^{-2} s^{-1}	0.004 µmol m^{-2} s^{-1} per mA	1.25 mV per µmol m^{-2} s^{-1}	–		
Calibration Factor (reciprocal of output)	100 µmol m^{-2} s^{-1} per mV	1.6 µmol m^{-2} s^{-1} per mV	250 µmol m^{-2} s^{-1} per mA	0.8 µmol m^{-2} s^{-1} per mV	Custom for each sensor and stored in the firmware		
Calibration Uncertainty	± 5 %						
Output Range	0 to 40 mV	0 to 2.5 V	4 to 20 mA	0 to 5 V	USB	SDI-12	Modbus
Measurement Repeatability	Less than 0.5 %						
Long-term Drift	Less than 2 % per year						
Non-linearity	Less than 1 % (up to 4000 µmol m^{-2} s^{-1})						
Response Time	Less than 1 ms				Software updates every second	Less than 0.6 s	Less than 200 ms
Field of View	180°						
Spectral Range	389 to 692 nm ± 5 nm (wavelengths where response is greater than 50 %)						
Directional (cosine) Response	± 5 % at 75° zenith angle						
Temperature Response	-0.11 ± 0.04 % per C						
IP Rating	IP68						
Operating Environment	-40 to 70 C; 0 to 100 % relative humidity; can be submerged in water up to depths of 30 m						
Dimensions	24 mm diameter, 37 mm height	30.5 mm diameter, 37 mm height			24 mm diameter, 37 mm height	30.5 mm diameter, 37 mm height	
Mass (5 m of cable)	100 g	140 g			100 g	140 g	
Warranty	4 years against defects in materials and workmanship						

Original X Quantum Sensors

Measure photosynthetically active radiation for broadband light sources

SQ-100X

	SQ-100X-SS	SQ-202X-SS	SQ-204X-SS	SQ-205X-SS	SQ-301X	SQ-420X	SQ-421X-SS	SQ-422X-SS
Power Supply	Self-powered	5 to 24 V DC	7 to 24 V DC	5.5 to 24 V DC	Self-powered	5 V USB power source	5.5 to 24 V DC	
Current Draw	–	10 µA	22 mA maximum; 2 mA quiescent	10 µA	–	61 mA when logging	1.4 mA (quiescent), 1.8 mA (active)	RS-232 37 mA; RS-485 quiescent 37 mA, active 42 mA
Output (sensitivity)	0.1 mV per µmol m^{-2} s^{-1}	0.6 mV per µmol m^{-2} s^{-1}	0.004 mA per µmol m^{-2} s^{-1}	1.25 mV per µmol m^{-2} s^{-1}	0.1 mV per µmol m^{-2} s^{-1}	–		
Calibration Factor (reciprocal of output)	10 µmol m^{-2} s^{-1} per mV	1.6 µmol m^{-2} s^{-1} per mV	250 µmol m^{-2} s^{-1} per mA	0.8 µmol m^{-2} s^{-1} per mV	10 µmol m^{-2} s^{-1} per mV	Custom for each sensor and stored in the firmware		
Calibration for Uncertainty	± 5 %							
Output Range	0 to 250 mV	0 to 2.5 V	4 to 20 mA	0 to 5 V	0 to 250 mV	USB	SDI-12	Modbus
Measurement Repeatability	Less than 0.5 %							
Long-term Drift	Less than 2 % per year							
Non-linearity	Less than 1 % (up to 2500 µmol m^{-2} s^{-1})	Less than 1 % (up to 4000 µmol m^{-2} s^{-1})			Less than 1 % (up to 2500 µmol m^{-2} s^{-1})			
Response Time	Less than 1 ms					Software updates every second	Less than 0.6 s	Less than 200 ms
Field of View	180°							
Spectral Range	370 to 650 nm (wavelengths where response is greater than 50 % maximum)							
Directional (cosine) Response	± 5 % at 75° zenith angle							
Temperature Response	-0.04 % per C							
Operating Environment	-10 to 60 C; 0 to 100 % relative humidity; can be submerged in water up to 30 m							
Dimensions	24 mm diameter, 33 mm height	30.5 mm diameter, 37 mm height			616.4 mm length, 13.6 mm height, 16.5 mm width	24 mm diameter, 33 mm height	30.5 mm diameter, 37 mm height	
Mass (5 m of cable)	90 g	140 g			310 g	90 g	140 g	

ePAR Sensors

Measures the newly defined ePAR range of 400-750 nm under all light sources

MQ-610

	SQ-610-SS	MQ-610
Power Supply	Self-powered	CR 2320 coin cell battery
Sensitivity	0.01 mV per µmol m^{-2} s^{-1}	–
Calibration Factor (reciprocal of sensitivity)	100 µmol m^{-2} s^{-1} per mV	–
Calibration Uncertainty	± 5 %	
Calibrated Output Range	0 to 40 mV	–
Measurement Range	0 to 4000 µmol m^{-2} s^{-1}	
Measurement Repeatability	Less than 0.5 %	
Long-term Drift	Less than 2 % per year	
Non-linearity	Less than 1 % (up to 4000 µmol m^{-2} s^{-1})	
Response Time	Less than 1 ms	
Field of View	180°	
Spectral Range	383 to 757 nm ± 5 nm (wavelengths where response is greater than 50 % of maximum)	
Directional (cosine) Response	± 2 % at 45°; ± 5 % at 75° zenith angle	
Azimuth Error	Less than 0.5 %	
Tilt Error	Less than 0.5 %	
Temperature Response	-0.11 ± 0.04 % per C	
Operating Environment	-40 to 70 C; 0 to 100 % relative humidity, can be submerged in water up to depths of 30 m	0 to 50 C; less than 90 % non-condensing relative humidity up to 30 C; separate sensor can be submerged in water up to depth of 30 m
Sensor Dimensions	30.5 mm diameter, 37 mm height	
Meter Dimensions	–	126 mm length, 70 mm width, 24 mm height
Mass (with 5 m of cable)	140 g	
Warranty	4 years against defects in materials and workmanship	

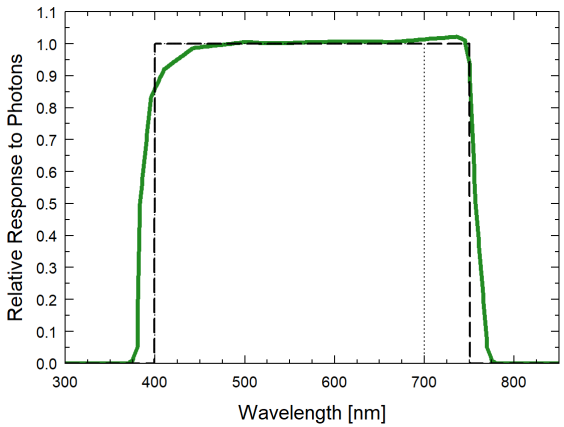
Overview

The new Apogee ePAR sensor was created to measure the newly defined 400-750 nm ePAR radiation range. Emerging research is showing this new range to be photosynthetically active beyond the traditional 400-700 nm range. Much of the transformative work to define the ePAR range was conducted by Dr. Shuyang Zhen and Dr. Bruce Bugbee at Utah State University's Crop Physiology Laboratory. Amplified and digital outputs are also available for the sensors (similar to the full-spectrum quantum sensor series, page 6). See other ePAR models on our website.

Typical Applications

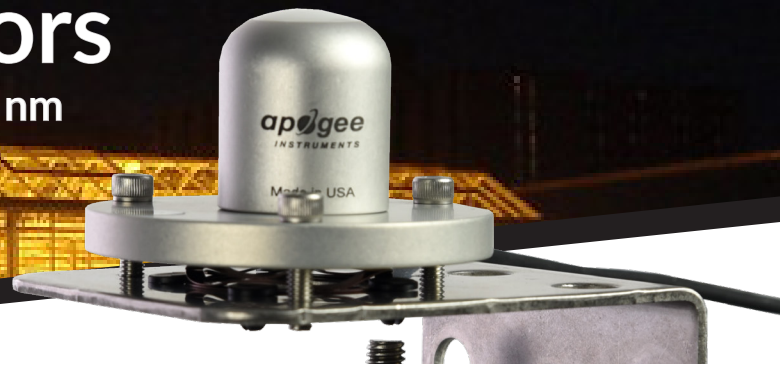
- Total ePAR intensity measurements over plant canopies in all growing environments
- Monitor and adjust grow lights
- Research plant morphogenic activity
- Photobiology studies

Right: Spectral response of the new ePAR sensor (green) compared to the"ePAR" target response (dashed) and the traditional PAR response (dotted).

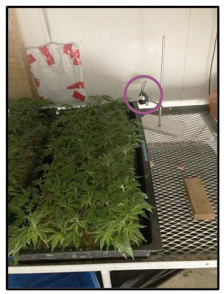


Quantum Light Pollution Sensors

Designed to detect trace amounts of stray light from 340-1040 nm



	SQ-640-SS	SQ-642-SS	SQ-644-SS	SQ-645-SS	SQ-647-SS
Power Supply	Self-powered	5 to 24 V DC	12 to 24 V DC	5.5 to 24 V DC	
Sensitivity	1 mV per µmol m^{-2} s^{-1}	12.5 mV per µmol m^{-2} s^{-1}	0.08 mA per µmol m^{-2} s^{-1}	25 mV per µmol m^{-2} s^{-1}	–
Calibration Factor (reciprocal of sensitivity)	1 µmol m^{-2} s^{-1} per mV	0.08 µmol m^{-2} s^{-1} per mV	12.5 µmol m^{-2} s^{-1} per mA	0.04 µmol m^{-2} s^{-1} per mV	Custom for each sensor
Calibration Uncertainty	± 5 %				
Calibrated Output Range	0 to 200 mV	0 to 2.5 V	4 to 20 mA	0 to 5 V	SDI-12
Measurement Range	0 to 200 µmol m^{-2} s^{-1}				
Measurement Repeatability	Less than 0.5 %				
Long-term Drift	Less than 2 % per year				
Non-linearity	Less than 1 % (up to 200 µmol m^{-2} s^{-1})				
Response Time	Less than 1 ms				Less than 0.6 s
Field of View	180°				
Spectral Range	340 to 1040 nm ± 5 nm (wavelengths response is greater than 50 % of maximum)				
Directional (cosine) Response	± 2 % at 45°; ± 5 % at 75° zenith angle				
Temperature Response	-0.11 ± 0.04 % per C				
Operating Environment	-40 to 70 C; 0 to 100 % relative humidity, can be submerged in water up to depths of 30 m				
Dimensions	30.5 mm diameter, 37 mm height				
Mass (with 5 m of cable)	140 g				
Warranty	4 years against defects in materials and workmanship				



Case Study

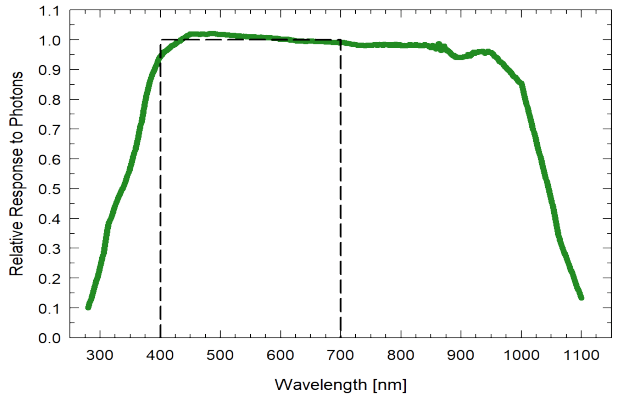
An Apogee **SQ-640 and a µCache Bluetooth Micro Logger** on a retort stand directionally-characterized stray light pollution in cannabis photoperiod treatment plots at the **University of Guelph**.

Overview

Many plants are affected by interruptions in dark periods, even by extremely dim light. Apogee's new Quantum Light Pollution Sensor is designed to detect photons from 340-1040 nm that are below the sensitivity level of a typical quantum sensor. Detecting stray photons that disrupt the night period is critical in preventing negative effects in plants, such as hermaphroditism and poor flowering.

Typical Applications

- Preventing dark period disruptions for sensitive plants like cannabis
- Incoming PFD measurement of combined UV-A, PAR, and Far-red light
- Measuring light leaks and light pollution in greenhouses and growth chambers



Above: The Quantum Light Pollution sensors have a spectral range of 340 to 1040 nm ± 5 nm.

Infrared Radiometers

High-accuracy, non-contact surface temperature measurement in harsh environmental conditions. Models include both research-grade or commercial-grade accuracy options

High Accuracy

Uncertainty of ± 0.2 C from 30 to 65 C when the sensor (detector) temperature is within 20 C of the target. Radiometers are only sensitive from 8 to 14 µm (atmospheric window) to minimize the influence of water vapor and CO_2 on the measurement.

Five Field of View Options

Three circular and two horizontal apertures are available, including our new Narrow Horizontal FOV (SI-4HR-SS) for road surface measurements.

Rugged Housing

Anodized aluminum body with fully-potted electronics. The outer radiation shield reduces thermal fluctuations.

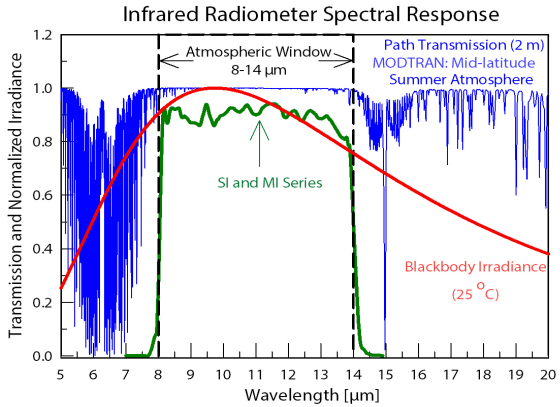
Commercial-Grade Option

Economical SIL models have a single field of view and ± 0.5 C from 0 to 50 C.

Outputs

Analog and digital output options include unamplified voltage, SDI-12 communication protocol, Modbus RS-232 and RS-485 protocols, and an attached hand-held meter with digital readout.

Ultra Narrow 14° | Narrow 18° | Standard 22° | Horizontal 13° x 32°



Spectral response of Apogee SI-100 and SI-400 infrared radiometers compared to atmospheric transmittance and blackbody irradiance.

Analog Models

SI/SIF-111-SS	Standard FOV
SI/SIF-121-SS	Narrow FOV
SI-131-SS	Ultra-Narrow FOV
SI/SIF-1H1-SS	Horizontal FOV
SIL-111	Standard FOV

Digital SDI-12/Modbus Models

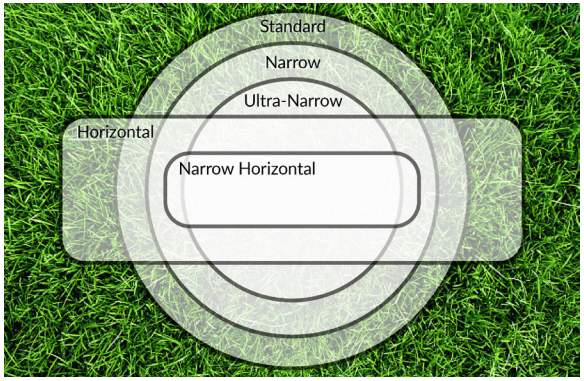
SI-411-SS	Standard FOV
SI-421-SS	Narrow FOV
SI-431-SS	Ultra-Narrow FOV
SI-4H1-SS	Horizontal FOV
SI-4HR-SS	Narrow Horizontal FOV
SI-511-SS	Standard FOV
SI-521-SS	Narrow FOV
SI-531-SS	Ultra-Narrow FOV
SI-5H1-SS	Horizontal FOV
SI-5HR-SS	Narrow Horizontal FOV
SIL-411	Standard FOV

Meter Models

MI-210	Standard FOV
MI-220	Narrow FOV
MI-2H0	Horizontal FOV

Case Study

Apogee **infrared radiometers** are being used on the **International Space Station's Adanced Plant Habitat** module to measure canopy temperature of food crops, such as dwarf Apogee wheat meant for space travel.



Field of View Options

Case Study

Dr. William Quinton of the University of Wilfrid Laurier in the Yukon Territory of Canada selected Apogee Instruments' **SI-111 Infrared Radiometer** to measure ground surface temperature and analyze snowmelt runoff, which contributes to local hydrology.

Analog Models	SI-111-SS	SI-121-SS	SI-131-SS	SI-1H1-SS	SIF-111-SS	SIF-121-SS	SIF-1H1-SS	SIL-111
Analog Model Output (difference between target and detector)	≈ 50 µV per C	≈ 30 µV per C	≈ 15 µV per C	≈ 30 µV per C	≈ 15 µV per C	≈ 10 µV per C		≈ 50 µV per C
Input Voltage Requirement	2500 mV thermistor excitation (typical, other voltages can be used)							
Analog Output from Thermistor	0 to 2500 mV (typical, depends on input voltage)							
Calibration Uncertainty (0 to 50 C), when target and detector ΔT are < 20 C	0.2 C		0.3 C	0.2 C	-			0.5 C
Calibration Uncertainty (-30 to 65 C), when target and detector ΔT are < 20 C	0.2 C		0.3 C	0.2 C				–
Calibration Uncertainty (-40 to 80 C), when target and detector ΔT are > 20 C	0.5 C		0.6 C	0.5 C				–
Measurement Repeatability	Less than 0.05 C							
Long-term Drift	Less than 2 % change in slope per year when germanium filter is maintained in clean condition							
Field of View (half-angle)	22°	18°	14°	32° horizontal; 13° vertical	22°	18°	32° horizontal; 13° vertical	22°
Response Time	0.6 s, time for detector signal to reach 95 % following a step change				0.2 s, time for detector signal to reach 95 % following a step change			0.6 s
Spectral Range	8 to 14 µm; atmospheric window							
Operating Environment	-50 to 80 C; 0 to 100 % relative humidity (non-condensing)							
Dimensions	23 mm diameter, 60 mm length							
Mass	190 g (with 5 m of lead wire)							
Warranty	4 years against defects in materials and workmanship							

Commercial-Grade Infrared Radiometer

Apogee's new "commercial-grade" line of infrared radiometers are a slightly less accurate, but lower priced alternative to the research-grade infrared radiometer line we offer. These new sensors feature a measurement uncertainty of ± 0.5 C from 0 to 50 C when the sensor is within 20 C of the surface target. They are an excellent option for measuring non-contact surface temperature when the the sensor does not need our research-grade ± 0.2 C accuracy, but still needs to perform in the harshest conditions.

Available in SDI-12 output (SIL-411) and an analog version (SIL-111).

Commercial-Grade (SIL-111/411)
22° half-angle

Digital Models	SI-411	SI-421	SI-431	SI-4H1	SI-4HR	SI-511	SI-521	SI-531	SI-5H1	SI-5HR	SIL-411
Digital Input Voltage Requirement	5.5 to 24 V DC										
Average Current Draw	1.5 mA (quiescent), 2.0 mA (active)					RS-232 37 mA; RS-485 37 mA (quiescent), 42 mA (active)					1.5 mA (quiescent), 2.0 mA (active)
Calibration Uncertainty (0 to 50 C), when target and detector ΔT are < 20 C	0.2 C		0.3 C	0.2 C	0.3 C	0.2 C		0.3 C	0.2 C	0.5 C	
Calibration Uncertainty (-30 to 65 C), when target and detector ΔT are < 20 C	0.2 C		0.3 C	0.2 C	0.3 C	0.2 C		0.3 C	0.2 C	0.5 C	—
Calibration Uncertainty (-40 to 80 C), when target and detector ΔT are > 20 C	0.5 C		0.6 C	0.5 C				0.6 C	0.5 C	1 C	—
Measurement Repeatability	Less than 0.05 C										
Long-term Drift	Less than 2 % change in slope per year when germanium filter is maintained										
Field of View (half-angle)	22°	18°	14°	32° horizontal; 13° vertical	16° horizontal; 5° vertical	22°	18°	14°	32° horizontal; 13° vertical	16° horizontal; 5° vertical	22°
Response Time	0.6 s, time for detector signal to reach 95 % following a step change					—					0.6 s
Spectral Range	8 to 14 µm; atmospheric window										
Operating Environment	-50 to 80 C; 0 to 100 % relative humidity (non-condensing)										
Dimensions	23 mm diameter, 60 mm length				23 mm diameter; 76 mm length	23 mm diameter, 60 mm length				23 mm diameter; 76 mm length	23 mm diameter, 60 mm length
Mass (with 5 m of cable)	190 g				219 g	190 g				219 g	190 g
Warranty	4 years against defects in materials and workmanship										

Net Radiometer

Dual upward & downward pyranometers & pyrgeometers in a compact design

Downward-looking pyrgeometer and pyranometer

NEW OUTPUT!

Now available with Modbus RS-232/RS-485 outputs (model SN-522-SS).

High Accuracy

Measure all four components of net radiation with a single digital output, conserving datalogger ports. It has comparable accuracy to other industry-leading competition in long-term field testing, but with a smaller housing and at a fraction of the price.

	SN-500-SS	SN-522-SS
Input Voltage Range	5.5 to 24 V DC (heaters are optimized to run at 12 V DC)	
Output Type	SDI-12	Modbus
Current Draw (12 V DC supply voltage)	Heaters on, communication enabled: 63 mA; Heaters off, communication enabled: 1.5 mA; Heaters off, communication disabled: 0.6 mA	Heaters on: 72 mA; Heaters off: 13.5 mA
Response Time	1 s (SDI-12 data transfer rate; detector response times are 0.5 s)	750 ms to digitize all sensor signals
Operating Environment	-50 to 80 C; 0 to 100 % relative humidity	
Dimensions	116 mm length, 45 mm width, 66 mm height	
Mass	320 g (with mounting rod and 5 m of lead wire)	
Warranty	4 years against defects in materials and workmanship	

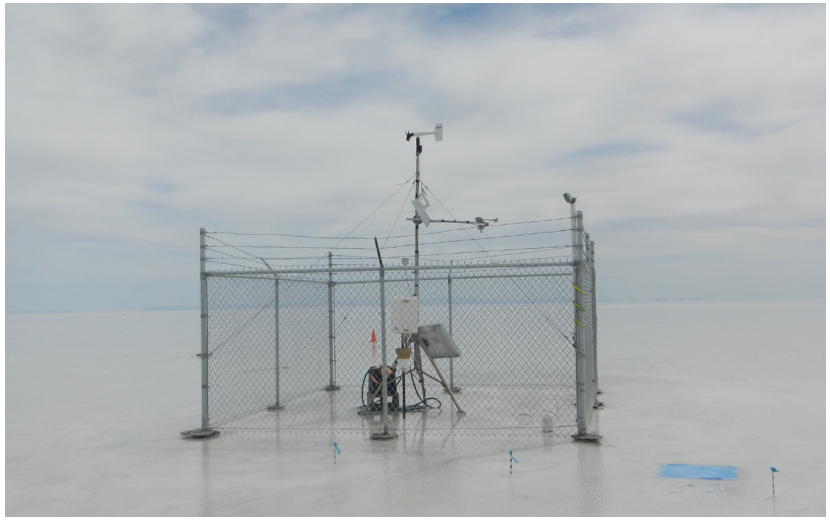
*For individual sensor specifications, view the thermopile pyranometer (15) and pyrgeometer (25) pages.

Heated Sensors

Each sensor includes a 0.2 W heater to minimize errors from dew, frost, rain, and snow that can block the radiation path.

Case Study

Apogee Instruments' **net radiometers** were used by **The University of Utah Department of Atmospheric Sciences** for a multidisciplinary study at the **Bonneville Salt Flats** to research the effect of changing surface albedos during flooding and desiccation cycles.



Albedometers

Horizontal and plane of array performance monitoring of bifacial solar panels and more


SP-722-SS

	SP-722-SS Upward-looking	SP-722-SS Downward-looking
ISO 9060:2018	**Class C (fast response)**	N/A
Power Supply	5.5 to 24 V	
Current Draw	RS-232 quiescent 37 mA; active 37 mA RS-485 quiescent 37 mA, active 42 mA	
Calibration Uncertainty at 1000 W m^{-2}	Less than 3 %	
Output Type	Modbus	
Measurement Range	0 to 2000 W m^{-2} (net shortwave irradiance)	
Measurement Repeatability	Less than 1 %	
Long-term Drift	Less than 2 % per year	
Non-linearity	Less than 1 %	
Field of View	180°	150°
Spectral Range (50 % points)	385 nm to 2105 nm	370 nm to 2240 nm
Directional (Cosine) Response	Less than 30 W m^{-2} at 80° solar zenith	Less than 20 % for angles between 0 and 60°
Temperature Response	Less than 5 % from -15 to 45 C	
Zero Offset A	Less than 2 W m^{-2}; Less than 10 W m^{-2} (heated)	
Zero Offset B	Less than 5 W m^{-2}	
Uncertainty with Daily Total	Less than 5 %	
Operating Environment	-50 to 80 C; 0 to 100 % relative humidity	
Heater	30.8 mA current draw and 370 mW power requirement at 12 V DC	
Dimensions	66.5 mm height, 74.4 mm length, 33 mm width	
Mass	116 g	
Warranty	4 year against defects in materials and workmanship	

*For SP-510-SS (upward-facing) and SP-610-SS (downward-facing) individual sensor specifications, view thermopile pyranometers (page 15)

Overview

Albedometers measure the broadband shortwave reflectivity of materials and are used to monitor bifacial solar panels, understand heat retention in urban and architectural settings, and study climate and weather. Apogee's albedometer sensor package (SP-710-SS) provides highly accurate albedo measurements at an affordable price. Modbus RS-232/RS-485 outputs (SP-722-SS) are now available.

Output Options

- **SP-710-SS Albedometer Sensor Package:** SP-510-SS thermopile pyranometer, SP-610-SS thermopile pyranometer, AY-001 differential splitter, and AW-605-SS 5 m cable.
- **SP-722-SS Modbus Albedometer:** a cost-effective solution for horizontal and plane of array performance monitoring of bifacial solar panels. The SP-722-SS can be easily mounted to a mast or directly to a solar panel with one of the available mounting brackets.

SP-710-SS

Thermopile Pyranometers

Blackbody accuracy with a cost-effective design

Unique Design

The thermopile, blackbody detector produces significant spectral response improvements over silicon-cell pyranometers. The design keeps the price low and optimizes power requirement for the 0.2 W heater to minimize errors from dew, frost, and snow.

Accurate, Stable Measurements

Directional errors are less than 30 W m^{-2} at 80° solar zenith angle. Long-term drift is less than 2 % per year.

Outputs and Options

0 to 90 mV range. A downward sensor is available for measuring shortwave reflectance and can be combined with an upward-looking sensor to measure albedo (see model SP-710-SS, page 14).

Case Study

Apogee **thermopile pyranometers** studied a method of cooling by chilling surfaces and using thermal radiation.

Completed Cold Tube

	SP-510-SS (Upward-Looking)	SP-610-SS (Downward-Looking)	SP-522-SS (Upward-Looking)
ISO 9060:2018	Class C (fast response)	N/A	Class C (fast response)
Input Voltage Requirement	–		5.5 to 24 V
Average Max Current Draw	–		RS-232 19 mA; RS-485 72 mA
Sensitivity (variable from sensor to sensor, typical values listed)	0.045 mV per W m^{-2}	0.035 mV per W m^{-2}	–
Calibration Factor (variable from sensor to sensor, typical values listed)	22 W m^{-2} per mV	28.5 W m^{-2} per mV	–
Calibration Uncertainty at 1000 W m^{-2}	Less than 3 %		
Output Type	0 to 90 mV	0 to 70 mV	Modbus
Measurement Range	0 to 2000 W m^{-2} (net shortwave irradiance)		
Measurement Repeatability	Less than 1 %		
Long-term Drift	Less than 2 % per year		
Non-linearity	Less than 1 %		
Detector Response Time	0.5 s		0.5 s (baudrate dependent)
Field of View	180°	150°	180°
Spectral Range (50 % points)	385 to 2105 nm	370 to 2240 nm	385 to 2105 nm
Directional (cosine) Response	Less than 30 W m^{-2} at 80° solar zenith	Less than 20 % for angles between 0 and 60°	Less than 30 W m^{-2} at 80° solar zenith
Temperature Response	Less than 5 % from -15 to 45 C		
Zero Offset A	Less than 2 W m^{-2}; Less than 10 W m^{-2} (heated)	Less than 2 W m^{-2}; Less than 10 W m^{-2} (heated)	Less than 2 W m^{-2}; Less than 10 W m^{-2} (heated)
Zero Offset B	Less than 5 W m^{-2}		
Operating Environment	-50 to 80 C; 0 to 100 % relative humidity		
Heater	780 Ω, 15.4 mA current draw and 185 mW power requirement at 12 V DC		4 mA (heater off); 30 mA (heater on)
Dimensions	23.5 mm diameter, 28.7 mm height	23.5 mm diameter, 27.5 mm height	30.5 mm diameter, 37 mm height
Mass (with 5 m of cable)	90 g	100 g	140 g
Warranty	4 years against defects in materials and workmanship		

Silicon-cell Pyranometers and Meters

Accurate and stable global shortwave radiation measurement

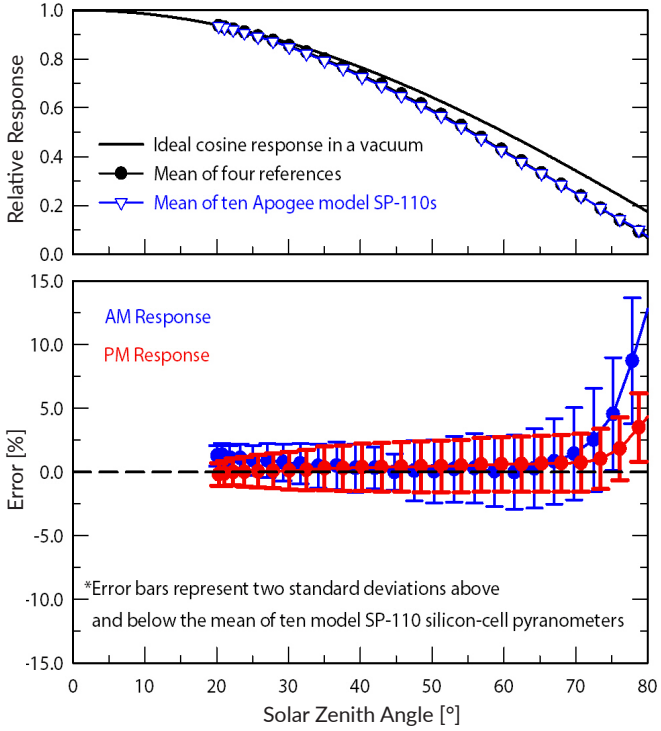
Proven Design

An accurate, cosine-corrected patented design sheds water and dirt for a self-cleaning performance. A heated option (SP-230) is available with a 0.2 W heater to minimize errors caused by dew, frost, or snow.

Case Study

The Institute of Agroalimentary Research and Technology in Catalonia, Spain uses **Apogee Silicon-cell Pyranometers** mounted on a model train to collect measurements in orchards. This allows them to study the irrigation and nutrient needs of the fruit trees.

Silicon-cell Pyranometer Cosine Response



Top: Mean relative response of ten Apogee model SP-110 pyranometers and mean relative response of four reference pyranometers (Kipp & Zonen models CM11, CMP11, CM21; Hukseflux model SR20) compared to ideal angular (cosine) response in a vacuum. Differences from the ideal response are caused by atmospheric attenuation of solar radiation, which increases as solar zenith angle increases.

Bottom: Mean angular response (error as function of solar zenith angle) of ten Apogee model SP-110 pyranometers, where the mean of the four reference pyranometers was used as the reference.

Heated vs Unheated

Apogee offers the SP-230 sensors with an internal 0.2 W heater. This helps melt frost or snow to ensure your sensor continues to take accurate measurements, even in extreme conditions.

SP-230

Sensor Models

SP-110	0 to 400 mV	Self-powered
SP-212	0 to 2.5 V	Amplified
SP-214	4 to 20 mA	Amplified
SP-215	0 to 5 V	Amplified
SP-230	0 to 400 mV	All-season Heated
SP-420	USB	Digital
SP-421	SDI-12	Digital
SP-422	Modbus	Digital

Meter Models

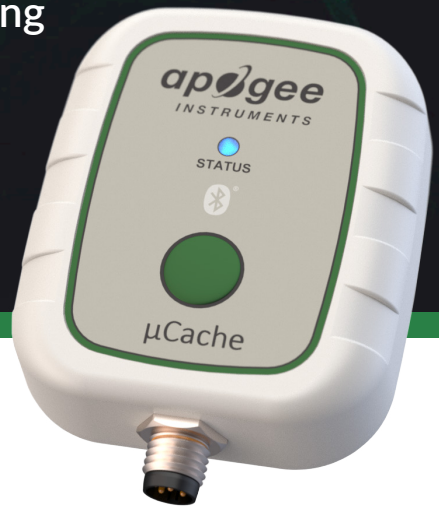
MP-100	Integrated Sensor
MP-200	Separate Sensor

MP-200

	SP-110-SS	SP-212-SS	SP-214-SS	SP-215-SS	SP-230-SS	SP-420	SP-421-SS	SP-422-SS
ISO 9060:2018	Class C (fast response)							
Power Supply	Self-powered	5 to 24 V DC	7 to 24 V DC	5.5 to 24 V DC	12 V DC for heater	5 V USBS	5.5 to 24 V DC	
Current Draw	–	300 µA	22 mA maximum; 2 mA quiescent	300 µA	15.4 mA	61 mA when logging	1.5 mA (quiescent); 1.9 mA (active)	RS-232 37 mA; RS-485 quiescent 37 mA, active 42 mA
Output (sensitivity)	0.2 mV per W m^{-2}	1.25 mV per W m^{-2}	0.008 mA per W m^{-2}	2.5 mV per W m^{-2}	0.2 mV per W m^{-2}	USB	SDI-12	Modbus
Output Type	0 to 400 mV	0 to 2.5 V	4 to 20 mA	0 to 5 V	0 to 400 mV	USB	SDI-12	Modbus
Calibration Factor (reciprocal of output)	5 W m^{-2} per mV	0.8 W m^{-2} per mV	125 W m^{-2} per mA, 4 mA offset	0.4 W m^{-2} per mV	5 W m^{-2} per mV	Custom for each sensor and stored in firmware		
Calibration Uncertainty at 1000 W m^{-2}	Less than 3 %							
Measurement Repeatability	Less than 1 %							
Long-term Drift	Less than 2 % per year							
Non-linearity	Less than 1 % up to 2000 W m^{-2}							
Response Time	Less than 1 ms					Software updates every second	Less than 0.6 s	Less than 200 ms
Field of View	180°							
Spectral Range	360 to 1120 nm							
Directional (cosine) Response	± 5 % at 75° zenith angle							
Temperature Response	0.04 ± 0.04 % per C							
Operating Environment	-40 to 70 C; 0 to 100 % relative humidity; can be submerged in water up to 30 m							
Dimensions	24 mm diameter, 33 mm height	30.5 mm diameter, 37 mm height			24 mm diameter, 33 mm height	30.5 mm diameter, 37 mm height		
Mass (with 5 m of cable)	90 g	140 g			90 g	140 g		
Warranty	4 years against defects in materials and workmanship							

µCache Bluetooth® Micro Logger

Connects directly to many Apogee sensors for live measurements and field logging



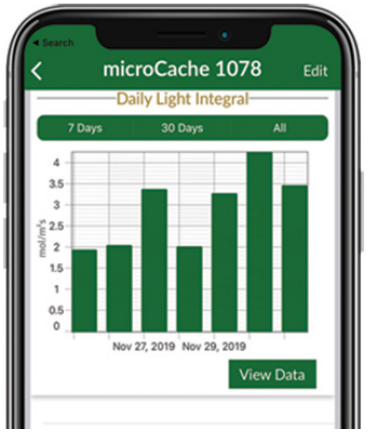
Overview

The Apogee µCache (microCache) is a rugged, battery-powered, low energy*, **Bluetooth**® datalogging device that currently interfaces with most Apogee analog sensors. When used as a standalone field-logging device, the unit contains enough memory to store nine months of one-minute data using the internal battery. Data can be viewed on your mobile device using our free ApogeeConnect App software for iOS and Android devices. ApogeeConnect features live meter mode, real-time graphing, and the ability to wirelessly transmit datasets to your computer.

*µCache is only low energy when with longer sampling intervals

Features

- Stores and transmits real-time data to iOS and Android devices
- View and download data with ApogeeConnect app for mobile devices
- Programmable sampling and logging intervals
- Live meter and datalogger modes
- Large capacity: nine months of data at a one-minute logging interval
- High resolution 24 bit analog-to-digital converter
- IP67 rated for harsh environments
- Works with Apogee quantums, pyranometers, infrared radiometers. and more. See our website for a current list of compatible sensors.



	AT-100
Communication Protocol	**Bluetooth**® Low Energy (Bluetooth 4.0+)
Bluetooth Range	Approx. 45 m (line-of-sight)
Data Logging Capability	Logging Interval: 1 second—60 minutes Sampling Interval: ≥ 1 second
Data Log Capacity	Over 400,000 entries (approx. 9 months at a 1-minute logging interval)
Time Accuracy	± 30 seconds per month at 0° C—70° C
Battery Type	2/3 AA 3.6 Volt Lithium Battery
Battery Life (impacted by sampling interval and amount of time connected to a mobile app)	Approx. 1 year with 10-second sampling interval averaging 5 minutes daily connected time; Approx. 2 years with 60-second sampling interval averaging 5 minutes daily connected time
Operating Environment	-40 to 85 C
Dimensions	66 mm length, 55 mm width, 18 mm height
Weight	52 g
IP Rating	IP67
Connector Type	M8
ADC Resolution	24 bit
Warranty	4 years against defects in materials and workmanship

µCache Packages

Promotional Packages

Each promotional package includes an analog sensor with a 30 cm or 2 m cable, a µCache Bluetooth Micro Logger, a protective neoprene case, an extra µCache battery, and an Apogee PVC sensor platform. When paired, these devices become a powerful tool for measurements with research-grade accuracy for a wide array of applications.

µCache Sensor Packages Quick Reference					
	Sensor	Wavelengths	DLI	Recommended for LEDs?	Sensor Cable Length
PQ-100X	SQ-100X	370-650 nm	Y	N	30 cm
PQ-110X	SQ-100X	370-650 nm	Y	N	2 m
PQ-500	SQ-500	400-700 nm	Y	Y	30 cm
PQ-510	SQ-500	400-700 nm	Y	Y	2m
PQ-610	SQ-610	380-760 nm	Y	Y	30 cm
PQ-612	SQ-610	380-760 nm	Y	Y	2 m
PQ-640	SQ-640	340-1040 nm	N	Y	30 cm
P2-141	S2-141	400-700, 700-760 nm	Y	Y	30 cm
P2-142	S2-141	400-700, 700-760 nm	Y	Y	2 m
PP-100	SP-110	360-1120 nm	N	–	30 cm
PP-500	SP-510	385-2105 nm	N	–	30 cm
PE-100	SE-100	CIE 1931 luminous efficiency funtion	N	Y	30 cm
PU-200	SU-200	305 to 390 nm	N	Y	30 cm
PU-300	SU-300	283-323 nm	N	–	30 cm

PQ-500

Full-spectrum Quantum

P2-142

PAR-FAR Sensor

See our website for other available packages

Fan-Aspirated Radiation Shield

Accurate measurement of air temperature and/or relative humidity with minimal power draw

NEW 24 V DC OPTION!

Case Study

Eight **TS-100 Fan-Aspirated Radiation Shields** provide air temperature measurements to monitor long-term ecological health dynamics within wet eucalyptus forest at the **Warra long-term ecological research site (LTER)** in **Tasmania, Australia**.

	TS-100	TS-200
Difference Among Individual Replicate Shields	Less than 0.1 C	
Aspiration Rate	6 m s^{-1} at full-speed; 3 m s^{-1} at half-speed	
Fan Input Voltage Requirement	10.8 to 13.2 V DC	14.0 to 27.6 V DC
Fan Current Draw	80 mA at full-speed; 25 mA at half-speed	
IP Rating	IP55	
Dimensions	220 mm height, 270 mm diameter	
Mass	840 g	

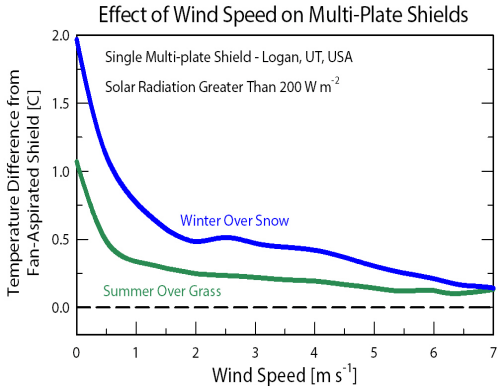
Optimized Design for Efficiency and Durability

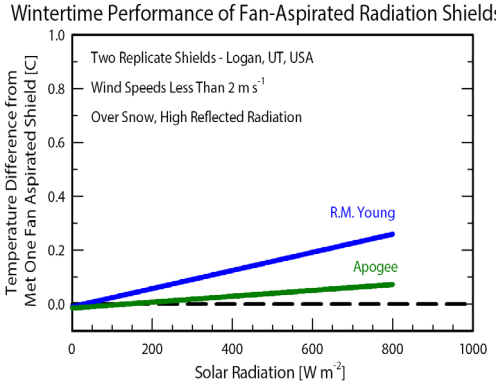
A curved inlet redirects air into the shield and funnels it past the sensing area, which allows for a lower power requirement than other fan-aspirated shields on the market. The fan has an ingress protection rating of IP55, which minimizes moisture and dust ingress. Fan speed and power can be further reduced when warranted by environmental conditions.

Sensor Compatibility

The shield accommodates multiple sensor options: air temperature sensors, air temperature/relative humidity probes, or combinations of both categories. **New for 2022, Apogee now offers a 24 V DC fan option (TS-200 series).**

See our website for available sensor packages





Left: Naturally-aspirated shields are subject to significant measurement errors when wind speeds are less than 3 m s^{-1}. Errors increase when snow covers ground surface. **Right**: The performance of Apogee (model TS-100) and R.M. Young (model 43502) fan-aspirated shields relative to a Met One (model 076B) fan-aspirated shield.

Humidity Probe

Improved version of the popular EE08 probe from E+E Elektronik

EE08-SS	
Input Voltage	7 to 30 V DC
Current Draw	Less than 1.3 mA
Start-up Time	2 s
Housing	Polycarbonate, IP65
Filter	Stainless steel wire mesh, 30 micron pore size
Connector	M12, IP67
Dimensions	83 mm length, 12 mm diameter
Mass with 5 m Cable	270 g
Operating Environment	-40 to 80 C; 0 to 100 % relative humidity
Cable	M12 connector (IP67 rating) to interface to sensor housing, 5 m of four conductor, shielded, twisted-pair wire, white TPR jacket (high water resistance, high UV stability, flexibility in cold conditions), pigtail lead wires

Overview

The EE08-SS air temperature/relative humidity probe is manufactured by E+E Elektronik in Austria. The upgraded version sold by Apogee includes a stainless steel connector and custom cable with a ninety degree connector that optimizes the fit of the probe inside the Apogee TS-100 fan-aspirated radiation shield. The EE08-SS offered by Apogee also includes a proprietary coating from E+E for the relative humidity sensing element that provides maximum long-term stability.

Fan Aspiration

Fan aspiration of humidity probes can improve accuracy over passive shields. The **TS-100/TS-200** shield (pictured) is an excellent choice for accomplishing this and is available at a special package price when purchased together (**TS-120/ TS-220**). To see these sensor packages, please visit our website.

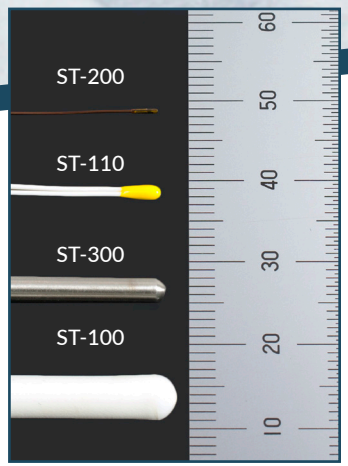
Temperature Measurement	
Sensor	PT1000 (Class A)
Measurement Range	-40 to 60 C
Output Signal Range	0 to 2.5 V DC
Slope	0.04 C per mV
Intercept	-40 C
Accuracy at 20 C	± 0.2 C
Long-term Stability	Less than 0.1 C per year
Time Constant	Less than 30 s

Relative Humidity Measurement	
Sensor	Capacitance Chip
Measurement Range	0 to 100 %
Output Signal Range	0 to 2.5 V DC
Slope	0.04 % per mV
Intercept	0.00 %
Accuracy at 20 C	± 2 % from 0 to 90 %; ± 3 % from 90 to 100 %
Temperature Response	Less than -0.05 % per C
Long-term Stability	Less than 1 % per year
Time Constant	Less than 30 s

TS-120 Fan-aspirated radiation shield with EE08-SS

Temperature Sensors

Wide measurement range of -60 to 80 C



Models

The **ST-200 fine wire thermistor** measures delicate or small surfaces with a fast response time. The **ST-110 thermistor** minimizes solar load and thermal conduction to accurately measure air temperature. The **ST-300 PRT** minimizes solar load and thermal mass. The **ST-100 thermistor** has a waterproof housing and is designed for measuring soil and water temperature.

	ST-100	ST-110	ST-200	ST-300
Measurement Range	-60 to 80 C			
Measurement Uncertainty	0.1 C (0 to 70 C) 0.2 C (-25 to 0 C) 0.4 C (-50 to -25 C)	0.1 C (0 to 70 C) 0.15 C (-50 to 0 C)	0.2 C (0 to 70 C) 0.4 C (-50 to 0 C)	0.1 C (-40 to 60 C), 1/10 DIN
Measurement Repeatability	Less than 0.05 C	Less than 0.01 C	Less than 0.05 C	Less than 0.01 C
Long-term Drift	Less than 0.02 C per year			Less than 0.05 C per year
Equilibration Time	30 s	4 s	1 s	15 s
Self-heating	Less than 0.01 C (typical, assuming pulsed excitation of 2.5 V DC), 0.08 C at 5 C (max. assuming continuous input excitation of 2.5 V DC)			Less than 0.003 C (typical, assuming pulsed excitation of 2.1 V DC), 0.09 C at 5 C (max. assuming continuous input excitation of 2.1 V DC)
Operating Environment	-60 to 80 C; 0 to 100 % relative humidity			
Input Voltage Requirement	2.5 V DC excitation (recommended)			2.1 V DC excitation (recommended)
Output Voltage Requirement	0 to 2.5 V DC (assuming input excitation of 2.5 V DC)			16 to 27 mV DC (excitation of 2.1 V DC)
Dimensions	100 mm length, 6 mm diameter	80 mm length, 4 mm diameter	25 mm length, 1 mm diameter	65 mm length, 3 mm diameter
Mass	60 g			95 g

Barometric Pressure Sensor

Sensor Stability

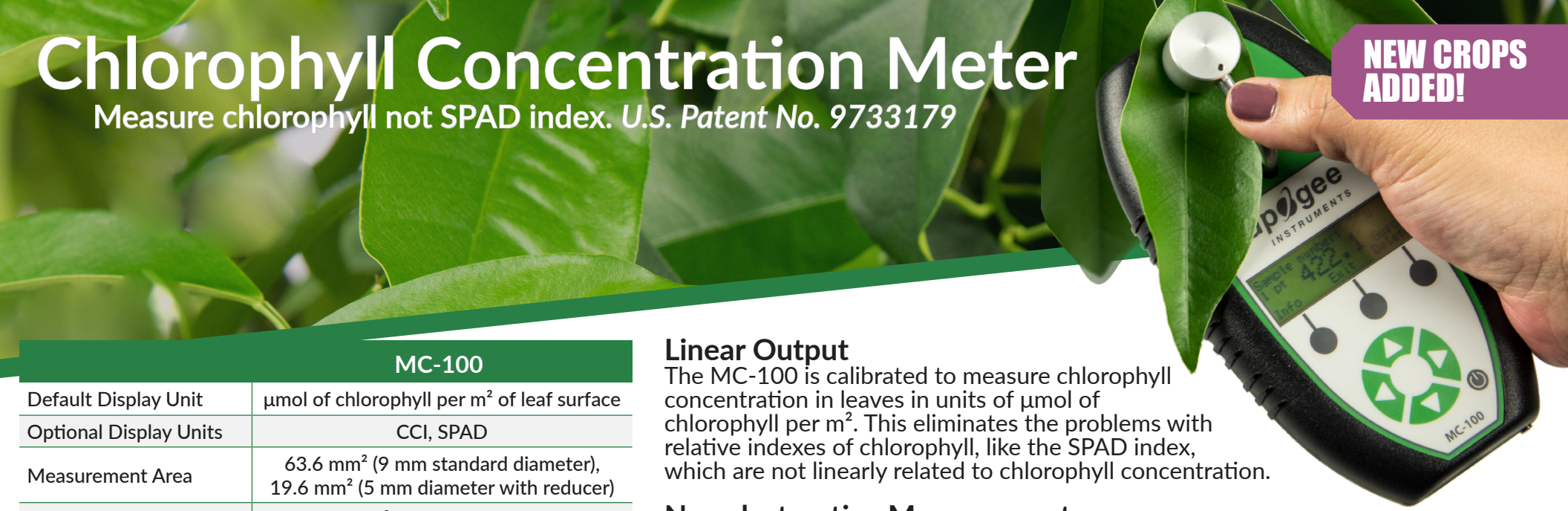
Long-term non-stability has been measured continuously indoors and in natural conditions (with sensors mounted inside a datalogger enclosure) for multiple sensors and is less than 0.5 % per year.

	SB-100
Measurement Range	15 to 115 kPa (approximate)
Maximum Pressure Exposure	400 kPa (exposure beyond limit may permanently damage sensor)
Sensitivity	45.9 mV per kPa; 0.459 mV per 0.01 kPa (approximate)
Measurement Uncertainty	± 1.5 kPa (with generic calibration coefficients)
Measurement Repeatability	Less than 0.1 %
Non-linearity	Less than 1 %
Warm-up Time	20 ms
Response Time	1 ms
Temperature Response	Less than 0.002 % per C for temperatures greater than 0 C; -0.015 % per C for temperatures less than 0 C
Operating Environment	-40 to 80 C; 0 to 100 % relative humidity (non-condensing)
Input Voltage Requirement	5 V DC
Output Voltage Range	0 to 5 V DC
Current Draw	7 mA DC
Dimensions	16 mm diameter
Mass	5 g

Chlorophyll Concentration Meter

Measure chlorophyll not SPAD index. *U.S. Patent No. 9733179*

NEW CROPS ADDED!



	MC-100
Default Display Unit	µmol of chlorophyll per m^2 of leaf surface
Optional Display Units	CCI, SPAD
Measurement Area	63.6 mm^2 (9 mm standard diameter), 19.6 mm^2 (5 mm diameter with reducer)
Resolution	± 10 µmol m^{-2} chlorophyll concentration using generic equation
Linearity	± 1 %
Repeatability	± 1 %
Sample Acquisition Time	Less than 3 s
Storage Capacity	8 MB for up to 160,000 data measurements
Internal GPS Storage	8 MB for up to 94,000 data measurements
User Interface	50 mm by 15 mm graphic display screen, 8 push buttons for control and data manipulation
Data Output	Mini-B USB port provided for main data transfer
Operating Temperature	0 to 50 C
Temperature Drift	Temperature compensated source and detector circuitry over full range
Power Requirement	Standard 9 V DC alkaline battery
Dimensions	152 mm length, 82 mm width, 25 mm height
Mass	210 g
Warranty	1 year against defects in materials and workmanship

Linear Output

The MC-100 is calibrated to measure chlorophyll concentration in leaves in units of µmol of chlorophyll per m^2. This eliminates the problems with relative indexes of chlorophyll, like the SPAD index, which are not linearly related to chlorophyll concentration.

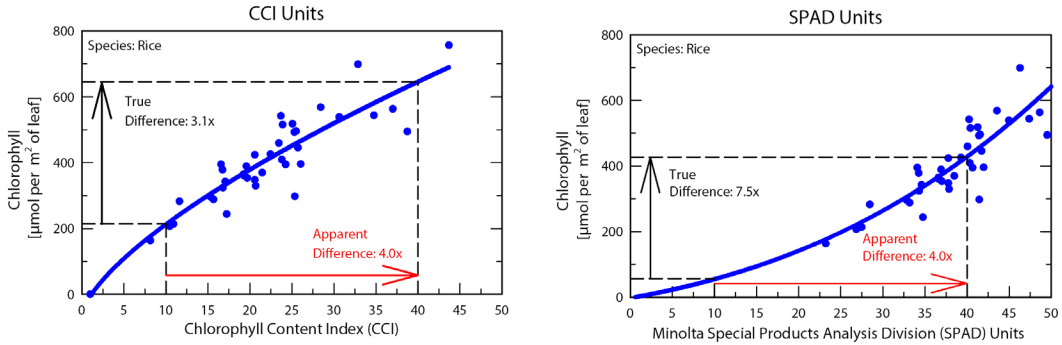
Non-destructive Measurements

The meter optically measures the ratio of red and near infrared transmittance with a sample rate of less than three seconds. This results in measurements that are non-destructive and nearly instantaneous. The meter facilitates rapid measurement of multiple leaves and monitoring of the same leaves over time.

See our website for over 35 available species-specific settings:

Arugula, barley, blackberry, boxelder, buttercunch lettuce, cannabis, cherry, coffee, collard greens, corn, crab apple, crimson king maple, european birch, forsythia, grapevine, hops, japanese maple, kale, kohlrabi, lilac, norway maple, paper birch, peas, peppers, purple leaf sand cherry, quaking aspen, rice, romaine lettuce, sorghum, soybean, spinach, strawberry, swiss chard, timothy hay, tomato, waldmann's green lettuce, and wheat.

*New crops added in 2022



Above: Older chlorophyll indexes such as CCI (left) and SPAD (right) do not have a linear relationship to chlorophyll concentration. Parry C., Blonquist Jr., J.M., & Bugbee, B. 2014. *Plant, Cell and Environment 37:2508-2520.*

Radiation Frost Detector

Effective prediction of leaf temperatures for orchards

NEW, IMPROVED DESIGN!

Monitor Radiation Frost Events

This detector is a new and improved design for measuring and detecting radiation frost events. On calm, clear nights, leaf temperatures can drop well below air temperature. Radiation frost occurs when frost forms at the surface before the air temperature reaches freezing. The radiation frost detector contains a high-accuracy thermistor in a rugged housing. The sensor mimics a leaf, which provides estimates of leaf temperatures to monitor radiation frost events.

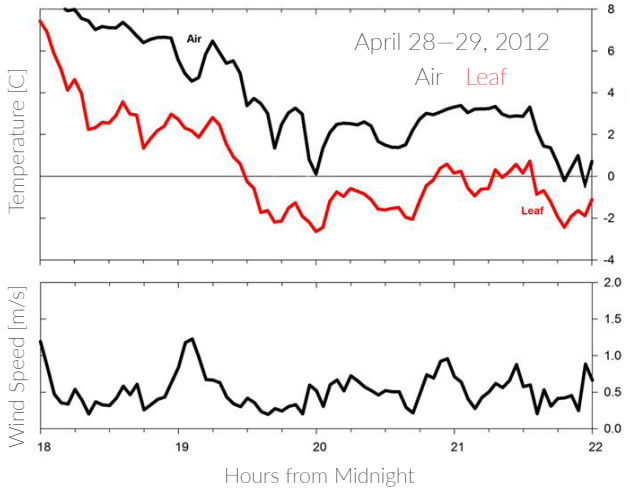
	SF-110	SF-421
Measurement Range	-50 to 70 C	
Measurement Uncertainty	0.1 C (from 0 to 70 C), 0.2 C (from -25 to 0 C), 0.4 C (from -50 to -25 C)	
Measurement Repeatability	Less than 0.05 C	
Long-term Drift (non-stability)	Less than 0.02 C per year (when used in non-condensing environments where the annual average temperature is less than 30 C; continuously high temperatures or continuously humid environments increase drift rate)	
Equilibration Time	10 s	
Self-heating	Less than 0.01 C (typical, assuming pulsed excitation of 2.5 V DC), 0.08 C at 5 C (maximum, assuming continuous input excitation of 2.5 V DC)	Less than 0.01 C
Operating Environment	-50 to 70 C; 0 to 100 % relative humidity	
Input Voltage Requirement	2.5 V DC excitation	5.5 to 24 V DC
Output Voltage Range	0 to 2.5 V DC (assuming input excitation of 2.5 V DC)	—
Current Draw	0.1 mA DC at 70 C (maximum, assuming continuous input excitation at 2.5 V DC)	1.56 mA (quiescent), 1.93 mA (active)
Dimensions	17.5 cm length, 2.2 cm pipe diameter, 6.0 cm disk diameter	
Mass	75 g	
Warranty	4 years against defects in materials and workmanship	

Wide Range, Accurate Measurements

Thermistor accuracy is ± 0.1 C across a range of 0 to 70 C, providing accurate measurements at temperatures near zero where frost damage is likely to occur.

Models

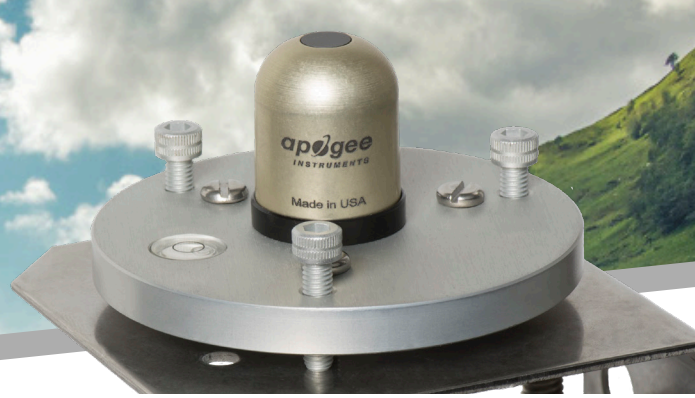
SF-110	Analog output
SF-421	Digital (SDI-12)



Above: Leaf temperature approximations measured with an Apogee SF-110 compared to air temperature (top panel) and wind speed (bottom panel) on the evening of April 28, 2012. Leaf temperatures were below air temperature after 8 P.M. and reached freezing 6 hours before the air temperature.

Pyrgeometers

Incoming and outgoing longwave radiation measurement



Accurate, Stable Measurements
Long-term drift is less than 2 % per year.

Rugged, Self-Cleaning Housing
The pyrgeometer features a rugged, anodized aluminum body and fully-potted electronics.

On-board Heater
A 0.2 W heater keeps water off the sensor and minimizes errors caused by dew, frost, rain, or snow blocking the radiation path.

Unique Design
The filter, blackbody thermopile detector, and thermistor (to measure detector temperature) are all contained in a compact housing that provides improved thermal coupling.

Upward and Downward Option

SL-510

SL-610

	SL-510-SS (Upward-looking)	SL-610-SS (Downward-looking)
Sensitivity	0.12 mV per W m^{-2} (variable from sensor to sensor, typical value listed)	
Calibration Factor (reciprocal of sensitivity)	8.5 W m^{-2} (variable from sensor to sensor, typical value listed)	
Calibration Uncertainty	± 5 %	
Measurement Range	-200 to 200 W m^{-2} (net longwave irradiance)	
Measurement Repeatability	Less than 1 %	
Long-term Drift	Less than 2 % change in sensitivity per year	
Non-linearity	Less than 1 %	
Response Time	Less than 0.5 s	
Field of View	180°	150°
Spectral Range	5 to 30 µm	
Temperature Response	Less than 5 % from -15 to 45 C	
Window Heating Offset	Less than 10 W m^{-2}	
Zero Offset B	Less than 5 W m^{-2}	
Tilt Error	Less than 0.5 %	
Uncertainty in Daily Total	± 5 %	
Temperature Sensor	30 kΩ thermistor, ± 1 C tolerance at 25 C	
Output from Thermistor	0 to 2500 mV (typical, other voltages can be used)	
Input Voltage Requirement for Thermistor	2500 mV excitation (typical, other voltages can be used)	
Heater	780 Ω, 15.4 mA current draw and 185 mW power requirement at 12 V DC	
Dimensions	27.5 mm height, 23.5 mm diameter	
Mass	90 g	100 g
Warranty	4 years against defects in materials and workmanship	

InSight Handheld Spectroradiometer

NEW!

Spectroradiometer from 380 to 780 nm with advanced photobiology metrics

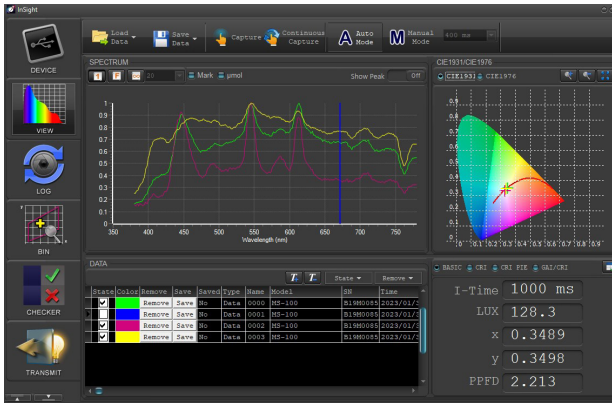
	MS-100	
Wavelength Sensitivity	380 to 780 nm	
Spectral Bandwidth	Approximately 12 nm (half bandwidth)	
Wavelength Reproducibility	± 1 nm	
Measurement Range	PPFD: 0.1 to 3,500 µmol m^{-2} s^{-1}; Lux: 5 to 190,000 lx	
Illuminance Accuracy	Illuminant A @ 2,856 K at 20,000 lx	± 5 %
Color Accuracy		± 0.0025 in CIE 1931 x, y
Color Repeatability		± 0.0005 in CIE 1931 x, y
CCT Accuracy		± 2 %
CRI Accuracy @ Ra	± 1.5 %	
Stray Light	- 25 dB max	
Integration Time Range	6 to 1,000 ms	
Operating Temperature	0 to 35˚C, relative humidity 70 % or less without condensation	
Storage Temperature	-10 to 40˚C, relative humidity 70 % or less without condensation	
Operation Mode	Standalone Mode/Bluetooth Mode/USB Mode (PC Connection)	
Display	0.96" 128x64 mono OLED	
Maximum Files	1.2 million files @ 8 GB Micro-SD card (Excel)	
Data Interface	Mini USB port (USB 2.0); Bluetooth 3.0 and 4.0 compatible with iOS and Android	
Software	Apogee InSight (available for PC, iOS, and Android)	

Powerful Photobiology Tool

Self-powered and portable, the InSight instantly measures and displays the most important metrics for serious growers. View basic data on the unit's screen, see enhanced graphs on your PC or phone, and take sample or log measurements over time.

Measurement Modes

- PPFD
- ePPFD
- YPFD
- TPFD
- PFD-UV
- PFD-B
- PFD-G
- PFD-R
- PFD-FR
- FR F
- PPE
- iPPE
- CFI
- CRI
- CCT
- Lux
- R F-R R
- Foot candle
- LambdaP
- LambdaD
- CIE 1931 x & y
- CIE 1976 u' & v'

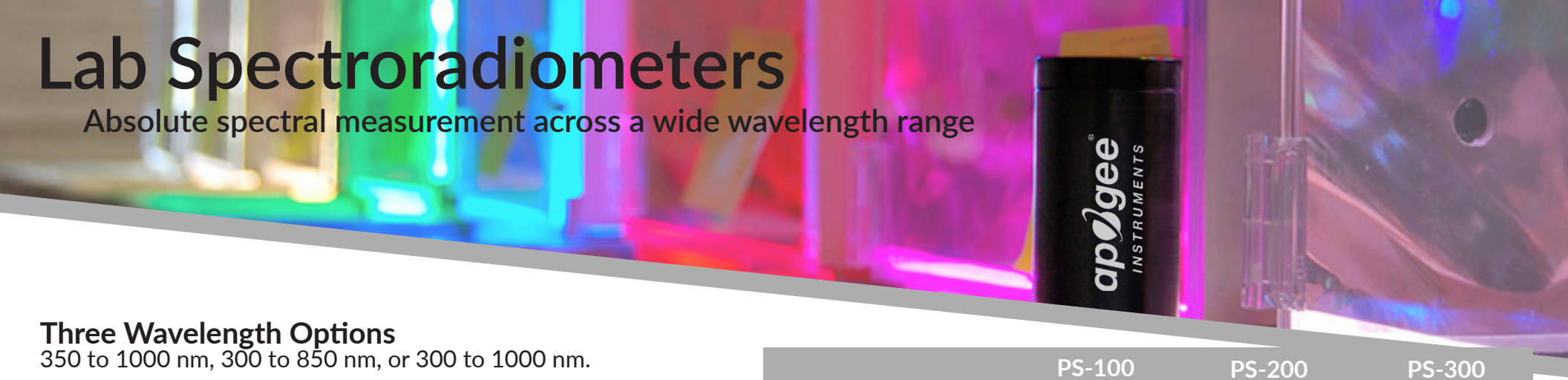


InSight Software

Connect to your PC to view and analyze measurements with the Apogee InSight software or use the app (iOS or Android). apogeeinstruments.com/downloads/.

Lab Spectroradiometers

Absolute spectral measurement across a wide wavelength range



Three Wavelength Options

350 to 1000 nm, 300 to 850 nm, or 300 to 1000 nm.

Complete Package

The package includes a spectroradiometer, two meter fiber-optic cable, cosine-corrected detector, AL-200 leveling plate, USB cable, USB drive with required drivers and software (compatible with all Windows operating systems), and shoulder bag (functions as a carrying case and field measurement pack). A reflectance probe and reflectance standard are available as accessories.

Portable Lab and Field Measurements

The instrument features a small design with a rugged housing and no moving parts. The spectroradiometer is powered through the USB port on a computer, allowing mobile measurements.

Case Study

An Apogee **spectroradiometer** studied the growth and productivity of 20 different tomato breeds in greenhouses and residential spaces at the **University of Florida**.

	PS-100	PS-200	PS-300
Irradiance Calibration Range	350 to 1000 nm	300 to 850 nm	300 to 1000 nm
Wavelength Sensitivity	350 to 1150 nm	190 to 850 nm	220 to 1100 nm
Wavelength Resolution	1 nm	0.85 nm	1.5 nm
Detector Type	CCD, 2048 pixel		
Grating Type	Holographic & Ruled, 600 g/nm	Holographic and aberration-corrected, 590 g/nm	
Digitizer	16-bit		
Signal to Noise Ratio	1000:1		
Stray Light	0.1 % at 435 nm, 0.5 % at 600 nm	0.02 % at 435 nm, 0.2 % at 200 nm	0.02 % at 435 nm, 0.2 % at 220 nm
Measurement Repeatability	Less than 1 %		
Irradiance Calibration Uncertainty	± 10 %		
Detector Integration (Exposure) Range	1 ms to 65 s		
Directional (cosine) Response	± 5 % at 80° zenith angle		
Software	Windows compatible, included		
Computer Interface	USB 2.0		
Power Requirement	100 mA at 5 V DC, supplied via USB cable		
Operating Temperature	0 to 60 C		
Optical Cable	2 m armored fiber-optic		
Base Unit Size	25 mm x 75 mm x 125 mm	69 mm x 100 mm x 150 mm	
Mass	500 g	900 g	
Warranty	1 year against defects in materials and workmanship		

Red - Far-red Sensors

Two-channel sensor for measuring the Red / Far-red ratio (RFR)

	S2-131-SS	S2-431-SS	S2-432-SS
Power Supply	Self-powered	5.5 to 24 V DC	
Current Draw	–	1.4 mA (quiescent), 1.8 mA (active)	RS-232 37 mA; RS-485 quiescent 37 mA, active 42 mA
Output (sensitivity)	0.08 mV per µmol m^{-2} s^{-1}	–	
Calibration Factor (recipricol of sensitivity)	12 µmol m^{-2} s^{-1} per mV	Custom for each sensor and stored in firmware	
Calibration Uncertainty	± 5 %		
Output Range	0 to 33 mV	SDI-12	Modbus
Wavelength Ranges	645 to 665 nm ± 5 nm (Red) 720 to 740 nm ± 5 nm (Far-red)		
Measurement Range	0 to 400 µmol m^{-2} s^{-1}		
Measurement Repeatability	Less than 1 %		
Long-term Drift	Less than 2 % per year		
Response Time	Less than 1 ms	Less than 0.6 s	–
Non-linearity	Less than 1 % (up to 400 µmol m^{-2} s^{-1})		
Field of View	180°		
Directional (cosine) Response	± 2 % at 45°; ± 5 % at 75° zenith angle		
Temperature Response	Less than 0.1 % per C		
Operating Environment	-40 to 70 C; 0 to 100 % relative humidity		
Dimensions	30.5 mm diameter, 37 mm height		
Mass (with 5 m of cable)	140 g		
Warranty	4 years against defects in materials and workmanship		

Overview

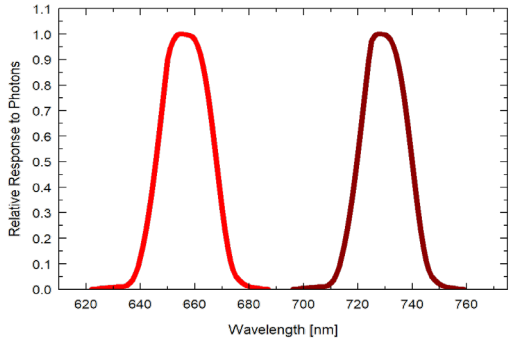
This sensor is a research-grade, cost-effective, two-channel sensor for monitoring plant light environments. It can calculate the red to far-red ratio (red photon flux density / far-red photon flux density) and far-red fraction (far-red photon flux density / sum of red and far-red photon flux densities). The FR ratio influences plant height, leaf expansion rates, and other photobiology and plant morphogenic responses.

Typical Applications

- Investigating the effect of spectral quality on phytochrome
- Monitoring plant light environments
- Analyzing plant morphogenic activity
- Studying photobiology
- Researching ecology

Key Features

Available in digital SDI-12 output, digital Modbus, or with an analog output. A domed diffuser promotes self-cleaning to minimize errors from dust and debris.



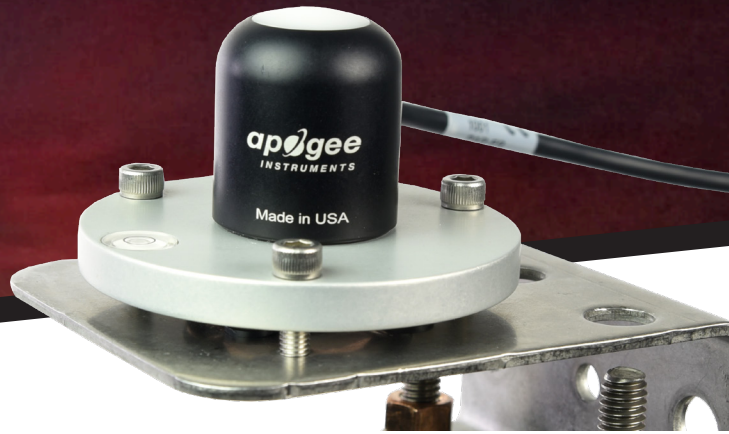
Spectral response of **Red detector (red)** and **Far-red detector (maroon)**.

Case Study

Apogee **Red - Far-red sensors** and **AL-120 leveling plates** are used at the **Toolik Field Station** in **Alaska.**

PAR-FAR Sensors

Two-band sensor for measuring both PAR and Far-red light



	S2-141-SS	S2-441-SS	S2-442-SS
Power Supply	Self-powered	5.5 to 24 V DC	
Current Draw	–	1.4 mA (quiescent), 1.8 mA (active)	RS-232 37 mA; RS-485 quiescent 37 mA, active 42 mA
Output (sensitivity)	0.02 mV per µmol m^{-2} s^{-1} (PAR) 0.03 mV µmol m^{-2} s^{-1} (Far-red) [typical values; variable from sensor to sensor]	–	
Calibration Factor (reciprocal of sensitivity)	60 µmol m^{-2} s^{-1} per mV (PAR) 40 µmol m^{-2} s^{-1} per mV (Far-red) [typical values; variable from sensor to sensor]	Custom for each sensor and stored in firmware	
Calibration Uncertainty	± 5 %		
Output Range	0 to 67 mV (PAR) 0 to 25 mV (Far-red)	SDI-12	Modbus
Measurement Repeatability	Less than 1 %		
Long-term Drift	Less than 2 % per year		
Non-linearity	Less than 1 % (up to 4000 µmol m^{-2} s^{-1}) (PAR) Less than 1 % (up to 1000 µmol m^{-2} s^{-1}) (Far-red)		
Response Time	Less than 1 ms	Less than 0.6 s	–
Field of View	180°		
Spectral Ranges	389 to 692 nm ± 5 nm (PAR) 700 to 750 nm ± 5 nm (Far-red)		
Directional (cosine) Response	± 2 % at 45°; ± 5 % at 75° zenith angle		
Temperature Response	Less than 0.1 % per C		
Operating Environment	-40 to 70 C; 0 to 100 % relative humidity		
Dimensions	30.5 mm diameter, 37 mm height		
Mass (with 5 m of cable)	140 g		
Warranty	4 years against defects in materials and workmanship		

Overview

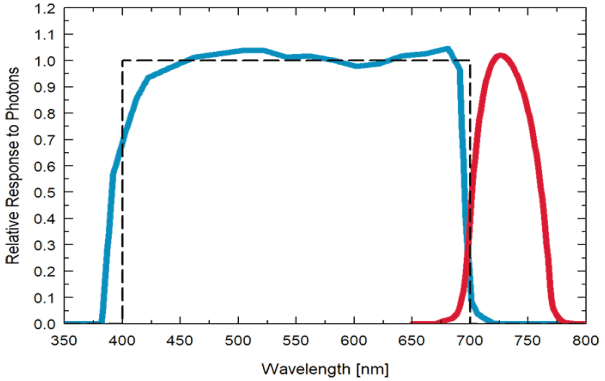
The Apogee PAR-FAR sensor is a research-grade tool for measuring both the traditional PPFD photosynthetic photon flux and separately quantifying the photon flux of far-red photons (700-760 nm). The outputs include the traditional quantum flux, the far-red photon flux, and the far-red fraction (far-red photon flux density / sum of PPFD and far-red photon flux density). For many applications, this sensor reduces the need for more complex measurements from a spectroradiometer.

Typical Applications

- Monitoring plant light environments
- Researching plant morphogenic activity
- Studying photobiology

Key Features

Available in digital SDI-12 output, digital Modbus, or with an analog output. A domed diffuser promotes self-cleaning to minimize errors from dust and debris.



Spectral response of PAR detector (blue) and Far-red detector (red) compared to defined response of plants to radiation (dashed).

UV-A Sensors

Cost-effective measurement of UV radiation from 300 to 400 nm

	SU-200-SS	SU-202-SS	SU-205-SS	SU-220	SU-221-SS
Power Supply	Self-powered	5 to 24 V DC	5.5 to 24 V DC	5 V USB power source	5.5 to 24 V DC
Output (sensitivity)	0.1 mV per W m^{-2}; 0.03 mV per µmol m^{-2} s^{-1}	25 mV per W m^{-2}; 8.33 mV per µmol m^{-2} s^{-1}	50 mV per W m^{-2}; 16.67 mV per µmol m^{-2} s^{-1}	Custom for each sensor and stored in the firmware	
Calibration Factor (reciprocal of sensitivity)	10 W m^{-2} per mV; 30 µmol m^{-2} s^{-1} per mV	0.04 W m^{-2} per mV; 0.12 µmol m^{-2} s^{-1} per mV	0.02 W m^{-2} per mV; 0.06 µmol m^{-2} s^{-1} per mV	Custom for each sensor and stored in the firmware	
Calibration Uncertainty	± 5 %				
Output Range	0 to 10 mV	0 to 2.5 V	0 to 5 V	USB	SDI-12
Measurement Range	0 to 100 W m^{-2}				
Measurement Repeatability	Less than 0.5 %				
Long-term Drift	Less than 2 % per year				
Non-linearity	Less than 1 %				
Response Time	Less than 1 ms				Less than 0.6 s
Field of View	180°				
Spectral Range	305 to 390 nm (wavelengths where response is greater than 10 % of maximum)				
Directional (cosine) Response	± 2 % at 45°; ± 5 % at 75° zenith angle				
Temperature Response	0.1 % per C				
Operating Environment	-30 to 85 C; 0 to 100 % relative humidity				
Dimensions	30.5 mm diameter, 37 mm height				
Mass	140 g (with 5 m of lead wire)				
Warranty	4 years against defects in materials and workmanship				

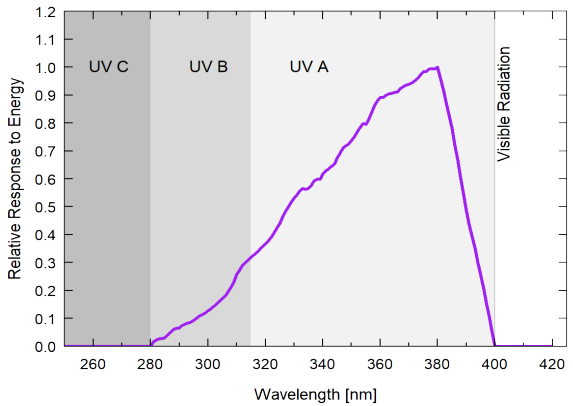
Overview

Apogee's new UV-A sensors offer a low-cost option for detecting UV radiation from 300 to 400 nm and are calibrated in energy flux units of Watts per square meter.

Typical Applications

- Monitoring the filtering ability and stability of various materials
- Measuring UV-A radiation outdoors and in the laboratory
- Monitoring UV radiation in horticultural environments

Spectral Response



Case Study

Cyanobacterial blooms in **Lake Champlain** are monitored using an Apogee **UV-A sensor.**

NDVI Sensors

Radiometer to calculate normalized difference vegetation index

Overview

Designed to continuously measure reflectance for calculating the normalized difference vegetation index (NDVI). NDVI provides an approximation of canopy chlorophyll content and leaf area and is used to monitor green-up in the spring and senescence in the fall.

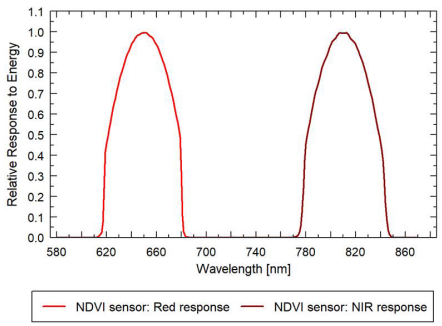
Key Features

Available as an analog option or SDI-12 digital output. A domed diffuser promotes self-cleaning to minimize errors from dust and debris.

$$NDVI = \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + \rho_{Red}}$$

Output Types

Available as an analog option or SDI-12 digital output. Best measurements come from pairing upward- and downward-looking models.



	Analog Output		Digital Output	
	S2-111-SS (Upward-Looking)	S2-112-SS (Downward-Looking)	S2-411-SS (Upward-Looking)	S2-412-SS (Downward-Looking)
Power Supply	Self-powered		5.5 to 24 V DC	
Output (sensitivity)	14 mV per W m^{-2} nm^{-1} (Red) 20 mV per W m^{-2} nm^{-1} (NIR)	12.5 mV per W m^{-2} nm^{-1} sr^{-1} (Red) 25 mV per W m^{-2} nm^{-1} sr^{-1} (NIR)	—	
Calibration Factor (recipricol of sensitivity)	0.07 W m^{-2} nm^{-1} per mV (Red) 0.05 W m^{-2} nm^{-1} per mV (NIR)	0.08 W m^{-2} nm^{-1} sr^{-1} per mV (Red) 0.04 W m^{-2} nm^{-1} sr^{-1} per mV (NIR)	Custom for each sensor and stored in firmware	
Calibration Uncertainty	± 5 %			
Output Range	40 mV (Red) 40 mV (NIR)	15 mV (Red) 15 mV (NIR)	SDI-12	
Wavelength Ranges	Red detector = 650 nm ± 5 nm with 65 FWHM* NIR detector = 810 nm ± 5 nm with 65 FWHM*			
Measurement Range	2x full sunlight			
Measurement Repeatability	Less than 1 %			
Long-term Drift	Less than 2 % per year			
Response Time	Less than 1 ms		Less than 0.6 s	
Field of View	180°	30°	180°	30°
Directional (co-sine) Response	± 2 % at 45°; ± 5 % at 75° zenith angle			
Temperature Response	Less than 0.1 % per C			
Housing	Anodized aluminum body with acrylic diffuser			
IP Rating	IP68			
Operating Environment	-40 to 70 C; 0 to 100 % relative humidity			
Dimensions	30.5 mm diameter, 37 mm height	30.5 mm diameter, 34.5 mm height	30.5 mm diameter, 37 mm height	30.5 mm diameter, 34.5 mm height
Mass (5 m cable)	140 g			
Warranty	4 years against defects in materials and workmanship			

*FWHM = full-width half-maximum

Oxygen Sensors and Meters

Measure gaseous O_2 in the laboratory and porous media. PPE housing for use in even harsh, acidic, and caustic environments

	SO-110	SO-210	SO-411	SO-421
Input Voltage Requirement	–		5.5 to 24 V DC	
Current Draw	–		0.6 mA (quiescent); 1.3 mA (active)	
Input Voltage (heater and thermistor)	12 V DC continuous (for heater); 2.5 V DC excitation (for thermistor)			
Heater Current Draw	6.2 mA (74 mW power requirement when powered with 12 V DC source)			
Thermistor Current Draw	0.1 mA DC at 70 C (maximum, assuming input excitation of 2.5 V DC)			
Measurement Range	0 to 100 % O_2			
Output (Sensitivity)	2.6 mV per % O_2	0.6 mV per % O_2	Digital SDI-12 output	
Output at 0 % O_2	5 % of output at 20.95 % O_2	2 % of output at 20.95 % O_2	–	
Measurement Repeatability	Less than 0.1 % of mV output at 20.95 % O_2			
Non-linearity	Less than 1 %			
Long-term Drift (non-stability)	1 mV per year	0.8 mV per year	1 mV per year	0.8 mV per year
Oxygen Consumption Rate	0.1 µmol O_2 per day at 20.95 % O_2 and 23 C			
Response Time	60 s	14 s	60 s	14 s
Operating Environment	-20 to 60 C; 0 to 100 % relative humidity (non-condensing); 60 to 140 kPa			
Dimensions	32 mm diameter, 68 mm length			
Mass	175 g (with 5 m of lead wire)			
Warranty	4 years against defects in materials and workmanship			

Simple Calibration

Output is proportional to oxygen concentration, which enables on-site calibration in open air conditions.

Heated Detector

The protective membrane can be heated to prevent water from condensing and blocking the diffusion path. The heater is typically used when sensors are deployed in soil or compost where relative humidity is close to 100 %.

Output Options

Available as an analog version with unamplified voltage output or digital version with SDI-12 communication protocol. The sensor is also available attached to a hand-held meter for easy spot measurements.

Case Study

Apogee **SO-110 units** measured the oxygen levels of waterlogged soil to understand the effects of excessive moisture on corn development.

Cloudburst Weighing Precipitation Gauge

Solid and mixed precipitation rates at 3000 mm per hour

NEW!

	Preliminary Specifications
Precipitation Type	Liquid, solid, mixed
Capacity	30 L / 8 gal
Precipitation Depth	1500 mm/60 in (WMO); 900 mm/35 in (NWS)
Rate (Intensity) Range	0 to 3,000 mm $hour^{-1}$
Calibration Accuracy	± 0.1 mm
Output	SDI-12
Output Interval	1 min (unfiltered data); 10 min (filtered data)
Temperature Sensitivity	± 0.01 mm C^{-1}
Long-term Drift (Non-stability)	< 4 mm yr^{-1} (< 0.5 % of capacity per year)
Non-linearity	Less than 0.1 mm
Transducer	Stainless steel strain-gauge bridge load cell
Operating Environment	-20 to 60 C; 0 to 100 % relative humidity
IP Rating	IP67 (load cell and circuitry)
Dimensions/Mass	38 cm diameter, 80 cm height / 12 kg (empty bucket)
Cable	5 m of 3-conductor wire, M8 connector (IP67)
Mounting	Holes for 15.24 cm wood post; Adapter for 10.16 cm pipe
Inlet Heater Voltage/Power Requirements	24 V DC / 50 W (maximum)
Inlet Heater Current Draw	2.1 A

Weighing Gauge

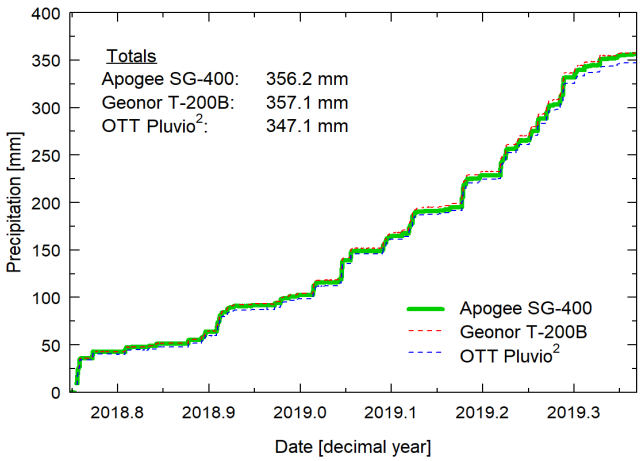
Rugged, large capacity, all-weather weighing precipitation gauge with no moving parts.

Features

- High-accuracy, stable, stainless steel load cell
- Proprietary algorithm to filter the influences of evaporation, vibration, and temperature

Multiple Options

- 8 inch (900 mm / 35 inch capacity) inlet option to match NWS recommendations
- 200 cm^2 (1500 mm / 60 inch capacity) inlet option to match WMO recommendations
- Multiple models with SDI-12 and Modbus outputs



Guardian CEA Multi-Sensor

NEW!

Monitors PAR or ePAR, DLI, humidity, CO_2, VPD, and air temperature

Introduction

- Accurate measurements of the most important indoor environmental parameters in one elegant device
- Works as a stand-alone device or integrates into systems for greenhouses, grow rooms, and vertical farms

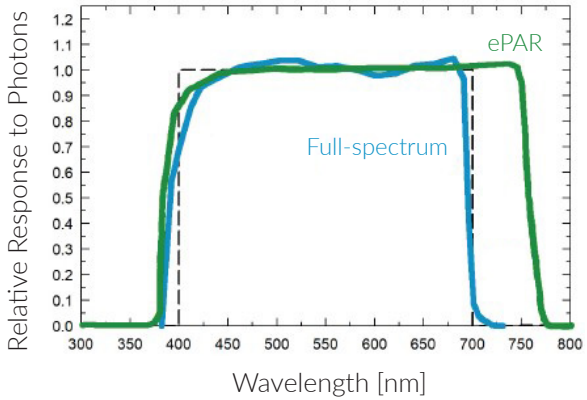
Features

- User-friendly, accurate datalogger with multiple integrated sensors
- PAR or extended PAR sensor options
- Data can download to smartphones or dataloggers via Modbus or Bluetooth
- Graphical summaries of data over days, weeks, or months with the ApogeeConnect app for iOS and Android
- Hangs by thin wires or mounts to a mast
- Integrators should contact Apogee for deployment opportunities

Measurements

- Fan-aspirated air temperature
- Instantaneous PAR or ePAR
- Daily light integral (DLI)*
- Photoperiod*
- Humidity
- Vapor pressure deficit and dewpoint
- CO_2 concentration
- Barometric pressure

*DLI and photoperiod measurements are only accessible via Bluetooth



	SM-500 (PAR)	SM-600 (ePAR)	Temperature	Relative Humidity	CO_2	Barometric Pressure
Calibration Uncertainty	± 5 %		± 0.2 C	± 3 % from 20 to 80	± 50 ppm + 2 % of the measured value	-
Long-term Drift (non-stability)	Less than 2 % per year		Less than 0.02 C	-		
Measurement Range	0 to 4000 µmol m^{-2} s^{-1}		-60 to 80 C	0 to 95 %	0 to 2000 ppm	70 to 110 kPa
Spectral Range	389 to 692 nm	383 to 757 nm	-			
Temperature Response	-0.11 % ± % per C		-			
Operating Environment	-40 to 60 C with 0 to 95 % relative humidity					
Connectivity	Modbus (RS232 and RS485) and/or Bluetooth					
Current Draw	Typical: 92 mA at 12 V; Peak: 500 mA at 12V					
Data Storage	9 months of 1 min data					
IP Rating	IP53					


apogee
67.24
Photon Flux
Daily Integral
Photoperiod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