apogee® INSTRUMENTS

2020 Catalog

This 2020 catalog marks the launch of several new products. Among these, we're especially excited for the µCache Bluetooth Micro Logger (pronounced microCache), a stand-alone logging device allowing Apogee sensors to be read on smart devices with elegant graphing features and data management tools built in. The unique name µCache has a special dual meaning. As you might know, the word cache means a hidden and secure storage place for valuable items, in this case data. However, the word Cache is also a nod to our beloved and beautiful Cache Valley, Utah, the home of Apogee Instruments. If you ever get a chance to visit Cache Valley, you'll see why we're so proud to call it home.

Apogee Instruments. Designed by scientists, for scientists.

Product Line

µCache Bluetooth® Micro Logger

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

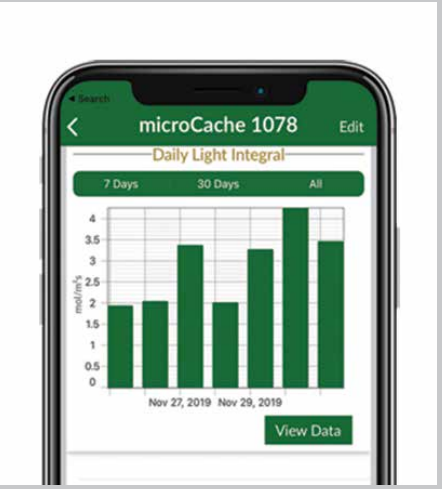
	AT-100
Communication Protocol	**Bluetooth**® Low Energy (Bluetooth 4.0+)
Bluetooth Range	Approx. 45 m (line-of-sight)
Data Logging Capability	Logging Interval: 1-60 minutes Sampling Interval: ≥ 1 second
Data Log Capacity	Over 400,000 entries (approx. 9 months at a 1-minute logging interval)
Time Accuracy	± 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 w/ 10-second sampling interval averaging 5 minutes daily connected time; Approx. 2 years w/ 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 bits
Warranty	1 year against defects in materials and workmanship

Overview

The new Apogee µCache (microCache) is a rugged, battery-powered, **Bluetooth**® Low Energy, single-sensor datalogging device that currently interfaces with most Apogee sensors. When used as a standalone field-logging device, the unit features enough memory to store 9 months of 1-minute data using the internal battery. Data can be viewed on your mobile device using our free Apogee Connect App software for iOS and Android devices, with a Wi-Fi gateway coming soon. Apogee Connect features live meter mode, real-time graphing, and the ability to electronically (wirelessly) transmit datasets to your computer.

Features

- Live meter and datalogger modes
- Stores and transmits real-time data to iOS and Android devices
- View and download data with Apogee Connect app for mobile devices
- Programmable sampling and logging intervals
- Large capacity: 9 months of data at a 1-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
- Wi-Fi gateway device coming soon



Net Radiometer

Accurate measurement in a compact design

High Accuracy

Measure all four components of net radiation with a digital output that saves datalogger channels. Comparable accuracy to industry-leading competition in long-term field testing with a smaller housing and at a fraction of the price.

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** are used by **Alaska Electric Light & Power** in avalanche forecasting.

	SN-500-SS
Input Voltage Range	5.5 to 16 V DC (heaters are optimized to run at 12 V DC)
Current Draw (12 V DC supply voltage)	Heaters on, communication enabled: 63 mA; Heaters off, communication enabled: 5 mA; Heaters off, communication disabled: 4 mA
Response Time (using SDI-12 protocol)	1 s (SDI-12 data transfer rate; detector response times are 0.5 s)
Heaters (sensors individually heated)	63 mA current draw and 740 mW power requirement at 12 V DC
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)
Cable	M8 connector (IP68 rating) to interface to sensor housing; 5 m of four conductor, shielded, twisted-pair wire with TPR jacket; pigtail lead wires
Warranty	4 years against defects in materials and workmanship

*For individual sensor specifications, view the thermopile pyranometer and pyrgeometer pages.

Photo credit: Alaska Electric Light & Power

Thermopile Pyranometers

Blackbody accuracy with a compact design

	SP-510-SS (Upward-Looking)	SP-610-SS (Downward-Looking)
ISO 9060:2018	Class C	N/A
Sensitivity (variable from sensor to sensor, typical values listed)	0.057 mV per W m^{-2}	0.15 mV per W m^{-2}
Calibration Factor (variable from sensor to sensor, typical values listed)	20 W m^{-2} per mV	6.7 W m^{-2} per mV
Calibration Uncertainty	± 5 %	
Output Type	0 to 114 mV	0 to 300 mV
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	
Field of View	180°	150°
Spectral Range (50 % points)	385 to 2105 nm	295 to 2685 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 5 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	
Uncertainty in Daily Total	Less than 5 %	
Dimensions	23.5 mm diameter, 28.7 mm height	
Mass	90 g	100 g
Warranty	4 years against defects in materials and workmanship	

Cost-Effective Design

The thermopile, blackbody detector results in significant spectral response improvements over silicon-cell pyranometers. A small design keeps the price low and optimizes power requirement for the 0.2 W heater that minimizes errors from dew, frost, and snow.

Accurate, Stable Measurements

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

Outputs and Options

0 to 114 mV range. A downward sensor is available for measuring shortwave reflectance, or can be combined with an upward-looking sensor to measure albedo.

Silicon-cell Pyranometers and Meters

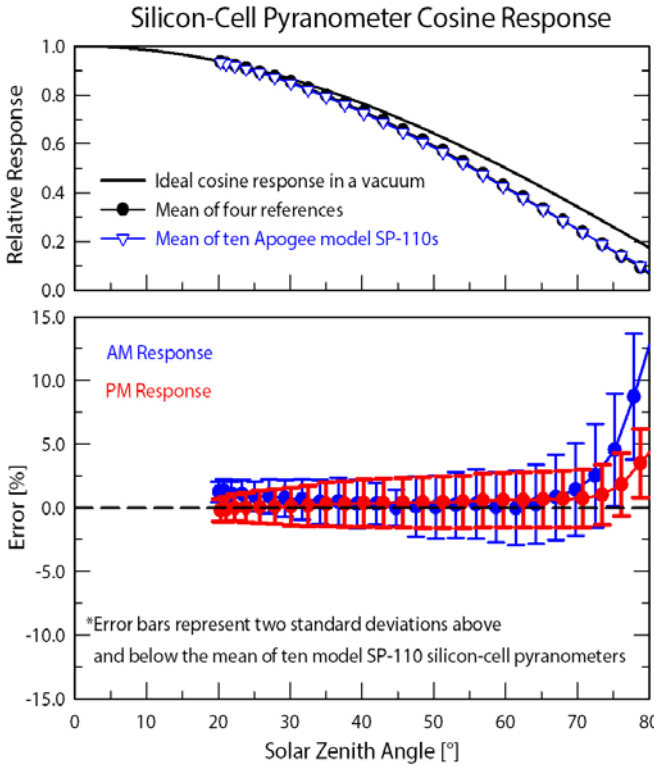
Accurate and stable global shortwave radiation measurement

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

Korea Water Resource Corporation uses a configuration of eight **Apogee SP-110 Silicon-cell Pyranometers** and weather data from wind, temperature, and humidity sensors to find the best location for floating photovoltaic power plants.



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.

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 350 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							
Power Supply	Self-powered	3.3 to 24 V DC	7 to 24 V DC	5.5 to 24 V DC	12 V DC for heater	5 V	5.5 to 24 V DC	
Current Draw	–	10 µA	22 mA maximum; 2 mA quiescent	10 µA	15.4 mA	61 mA when logging	0.6 mA (quiescent); 1.3 mA (active)	20 mA maximum
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}	–	–	–
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	2.5 W m^{-2} per mV	5 W m^{-2} per mV	Custom for each sensor and stored in firmware		
Calibration Uncertainty	± 5 %							
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	–
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							

Pyrgeometers

Incoming and outgoing longwave radiation measurement

	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	

Accurate, Stable Measurements

Long-term drift is less than 2 % per year.

Rugged, Self-Cleaning Housing

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

Photometric Sensors

Measure light with the sensitivity of the human eye

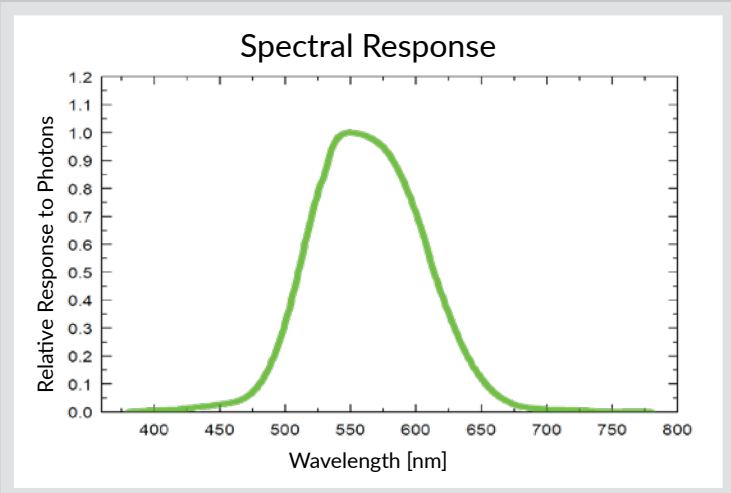
	SE-100-SS	SE-202-SS	SE-205-SS	SE-212-SS	SE-215-SS	SE-421-SS
Power Supply	–	3.3 to 24 V DC	5.5 to 24 V DC	3.3 to 24 V DC	5.5 to 24 V DC	
Current Draw	–	maximum of 10 µA				1.4 mA quiescent; 1.8 mA active
Output (sensitivity)	0.001 mV per lux	0.5 mV per lux	1 mV per lux	0.0167 mV per lux	0.033 mV per lux	–
Calibration Factor	1000 lux per mV	2 lux per mV	1 lux per mV	60 lux per mV	30 lux per mV	Custom for each sensor and stored in firmware
Calibration Uncertainty	± 5 %					
Output Range	0 to 200 mV	0 to 2500 mV	0 to 5000 mV	0 to 2500 mV	0 to 5000 mV	SDI-12
Measurement Range	0 to 150000 lux	0 to 5000 lux		0 to 150000 lux		
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					
Spectral Range	CIE 1931 luminous efficiency function					
Field of View	180°					
Directional (cosine) Response	± 2 % at 45°, ± 5 % at 75°					
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	140 g (with 5 m of cable)					
Warranty	4 years against defects in materials and workmanship					

Overview

Apogee photometric sensors use a photodetector with a spectral response that closely matches the sensitivity of the human eye. The sensors include a diffuser to properly weight light incident from any angle. Apogee photometric sensors provide highly accurate illuminance measurements (lux or footcandles) at an affordable price.

Output Options

Sensors are available in multiple analog options and as a digital sensor that uses SDI-12 communication.



Field Spectroradiometers

Perfect for horticultural and near-infrared applications

	SS-110	SS-120
Wavelength Range	340 to 820 nm	635 to 1100 nm
Wavelength Measurement Interval	1 nm	
Wavelength Resolution	3 nm (full-width half-maximum)	
Wavelength Accuracy	± 0.5 nm	
Wavelength Repeatability	± 0.2 nm	
Analog to Digital Resolution	14 bit	
Signal to Noise Ratio	1500:1 (at maximum signal)	
Stray Light	≤ 0.25 % at 590 nm	≤ 0.25 % at 850 nm
Dark Noise	≤ 3 counts	
Integration Time Range	10 ms to 10 s	
Measurement Sensitivity	Greater than 10 % of max sensitivity for wavelengths greater than 380 nm	Greater than 10 % of max sensitivity for wavelengths less than 1030 nm
Measurement Repeatability	Less than 1 % (wavelengths greater than 400 nm)	Less than 1 % (wavelengths less than 1020 nm)
Directional (cosine) Response	± 5 % at 75° zenith angle	
Field of View	180° (upward-facing); 25° or 150° (downward-facing)	
Temperature Response	-0.1 ± 0.1 % per C	
Irradiance Calibration Uncertainty	± 5 %	
Current Draw	190 mA during measurement and when idle (USB)	
Power Requirement	1 W (USB)	
Interface Cable	5 m PVC jacket with USB (for computer)	
Software	Apogee Spectrovision (Windows compatible, XP and later; Mac compatible, 10.9 and later)	
Operating Environment	-20 to 70 C, 0 to 100 % relative humidity	
Thread Size (for mounting)	¼"-20	
Dimensions	89.3 mm height, 50.8 mm width, 38.1 mm depth	
Mass	300 g	
Warranty	1 year against defects in materials and workmanship	

Wavelength Range Options

340 to 820 nm (SS-110) and 635 to 1100 nm (SS-120) wavelengths.

Complete Package

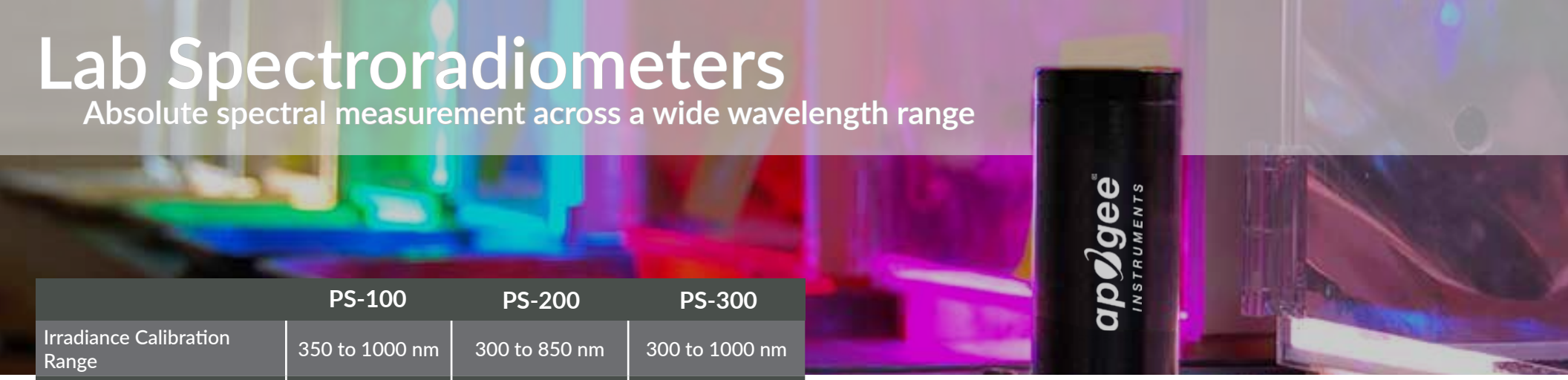
Includes spectroradiometer and cosine-corrected detector mounted in the housing, 180° FOV head, AL-200 leveling plate, USB cable for computer interface, carrying case, and USB drive with required drivers and software (Windows compatible, XP and later; Mac compatible, 10.9 and later).

Field Measurements

Spectroradiometer is small and lightweight with all measurement components contained in the durable, waterproof housing. Power consumption is low (1 W at 12 V DC) with automatic temperature compensation.

Lab Spectroradiometers

Absolute spectral measurement across a wide wavelength range



	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		

Three Wavelength Options

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

Complete Package

Includes 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 32-bit and 64-bit 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.

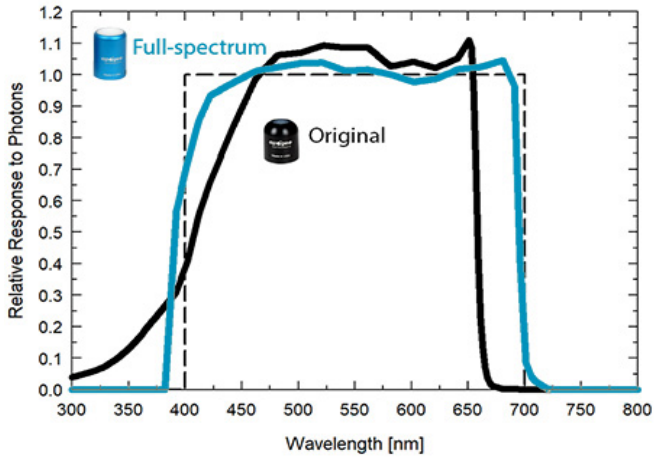
Portable Lab and Field Measurements

Features a small design with a rugged housing and no moving parts. Spectroradiometer is powered through the USB port on a computer allowing mobile measurements.

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: a **Full-spectrum Quantum (previously gold)** and **Original Quantum Sensor.** 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 quantum sensor (black)** and **full-spectrum quantum sensor (blue)** compared to defined response of plants to radiation (dashed).

Radiation Source	Original (sun calibration) PPFD Error [%]	Original (electric calibration) PPFD Error [%]	Full-Spectrum (SQ-500 Series) PPFD Error [%]
Sun (clear sky)	0.0	-15.0	0.0
Sun (cloudy sky)	0.2	-14.9	0.1
Reflected from Grass Canopy	3.8	-10.5	-0.3
Transmitted below Wheat Canopy	4.5	-10.5	0.1
Cool White Fluorescent (T5)	14.9	0.0	0.1
Metal Halide	12.2	-2.8	0.9
Ceramic Metal Halide	-1.1	-16.1	0.3
High Pressure Sodium	15.2	0.2	0.1
Blue LED (448 nm peak, 20 nm full-width half-max)	4.5	-10.5	-0.7
Green LED (524 nm peak, 30 nm full-width half-max)	23.8	8.8	3.2
Red LED (635 nm peak, 20 nm full-width half-max)	17.6	2.6	0.8
Red LED (667 nm peak, 20 nm full-width half-max)	-47.1	-62.1	2.8
Red, Blue LED Mixture (84 % Red, 16 % Blue)	-57.8	-72.8	-3.9
Red, White LED Mixture	-20.5	-35.5	-2.0
Cool White LED	11.7	-3.3	0.5
Warm White LED	6.1	-8.9	0.2
Neutral White LED	9.9	-5.1	0.5
Blue Plus T5 (cool white fluorescent)	8.2	-6.8	-0.1

Accurate, Stable Measurements

Cost-effective, original quantum sensors work well for broadband radiation sources (sun, high-pressure sodium, metal halide, cool white fluorescent lamps), while full-spectrum sensors are good for all light sources, including LEDs. Offers 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, and as a "smart" sensor that uses USB communication and custom software.

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 Sensor Models

		Calibration
SQ-110	Self-powered 0 to 800 mV	Sun
SQ-120	Self-powered 0 to 800 mV	Electric
SQ-212	Amplified 0 to 2.5 V	Sun
SQ-222	Amplified 0 to 2.5 V	Electric
SQ-214	Amplified 4 to 20 mA	Sun
SQ-224	Amplified 4 to 20 mA	Electric
SQ-215	Amplified 0 to 5.0 V	Sun
SQ-225	Amplified 0 to 5.0 V	Electric
SQ-420	USB	Sun/Electric
SQ-421	SDI-12	Sun/Electric
SQ-422	Modbus	Sun/Electric

Original Meter Models

MQ-100	Integrated Sensor
MQ-200	Separate Sensor
MQ-303	Line Quantum Meter - 3 Sensors
MQ-306	Line Quantum Meter - 6 Sensors
MQ-301	Line Quantum Meter - 10 Sensors

Line Quantum Models (0 to 800 mV)

SQ-313	3 Sensor	Sun Calibration
SQ-316	6 Sensor	Sun Calibration
SQ-311	10 Sensor	Sun Calibration


SQ-311

Case Study

The **Center for Andean Forestry Research and Extension (CIEFAP)** studies forest systems and land suitable for forestry in the Andean region of **Patagonia, Argentina**. The study is determining the % of PAR related to survival and initial growth of differing species. CIEFAP measured under canopy PAR using an **Apogee MQ-301 line quantum sensor.**

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	3.3 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 quiescent 36.87 mA, active 37.06 mA; RS-485 quiescent 37.37 mA, active 42.30 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}	–	–	–
Resolution	–	–	–	–	0.1 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 %	Less than 1 %	Less than 0.5 %	Less than 1 %	Less than 0.5 %	Less than 1 %	
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	–
Field of View	180°						
Spectral Range	389 to 692 nm ± 5 nm (wavelengths where response is greater than 50 %)						
Spectral Selectivity	Less than 10 % from 412 to 682 nm ± 5 nm						
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	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 Quantum Sensors

Measure photosynthetically active radiation for broadband light sources

SQ-110

	SQ-110/120-SS	SQ-212/222-SS	SQ-214/224-SS	SQ-215/225-SS	SQ-300 Series	SQ-420	SQ-421-SS	SQ-422-SS
Power Supply	Self-powered	3.3 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 quiescent 36.87 mA, active 37.06 mA; RS-485 quiescent 37.37 mA, active 42.30 mA
Output (sensitivity)	0.2 mV per µmol m^{-2} s^{-1}	0.625 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}	0.2 mV per µmol m^{-2} s^{-1}	–	–	–
Calibration Factor (reciprocal of output)	5 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	5 µmol m^{-2} s^{-1} per mV	Custom for each sensor and stored in the firmware		
Calibration for Uncertainty	± 5 %							
Output Range	0 to 800 mV	0 to 2.5 V	4 to 20 mA	0 to 5 V	0 to 800 mV	USB	SDI-12	Modbus
Measurement Repeatability	Less than 0.5 %						Less than 1 %	
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	–
Field of View	180°							
Spectral Range	410 to 655 nm (wavelengths where response is greater than 50 % maximum)							
Spectral Selectivity	Less than 10 % from 469 to 655 nm							
Directional (cosine) Response	± 5 % at 75° zenith angle							
Temperature Response	0.06 ± 0.06 % 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			500 x 15 x 15 mm; SQ-311/321: 700 x 15 x 15 mm	24 mm diameter, 33 mm height	30.5 mm diameter, 37 mm height	
Mass (5 m of cable)	90 g	140 g			275 g; SQ-311/321: 375 g	90 g	140 g	
Warranty	4 years against defects in materials and workmanship							

Extended Range PFD Sensors

Measure photon flux density (PFD) from 340-1040 nm

NEW!

	SQ-620-SS	SQ-624-SS	SQ-626	SQ-627-SS
Power Supply	Self-powered	12 to 24 V DC	5 V USB power source	5.5 to 24 V DC
Sensitivity	0.05 mV per µmol m^{-2} s^{-1}	0.004 mA per µmol m^{-2} s^{-1}	–	
Calibration Factor (reciprocal of sensitivity)	20 µmol m^{-2} s^{-1} per mV	250 µmol m^{-2} s^{-1} per mA	Custom for each sensor and stored in the firmware	
Calibration Uncertainty	± 5 %			
Calibrated Output Range	0 to 200 mV	4 to 20 mA	USB	SDI-12
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		Software updates every second	Less than 0.6 s
Field of View	180°			
Spectral Range (see graph to the right)	340 to 1040 nm ± 5 nm			
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			
Housing	Anodized aluminum body with acrylic diffuser			
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	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

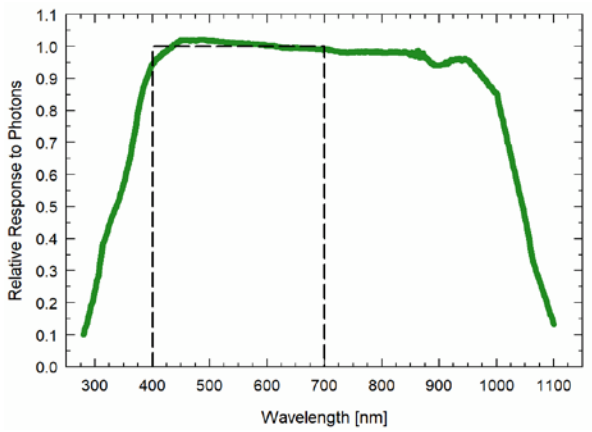
Apogee Extended Range PFD sensors are for measuring the newest generation of LED grow lights with wavelengths outside the traditional 400-700 nm PAR range. Research has shown the value of adding UV and far-red LEDs to achieve various disease control and photomorphogenic effects. The extended range filter of the SQ-620 allows it to measure photons from UV, far-red, and even IR security lights, which can affect plants during their dark periods. The 1040 nm top cutoff also means the sensor will measure the thermal output of HPS fixtures and other broad-spectrum lights above the range that influences plants.

Typical Applications

- Intended only for use in LED environments
- Incoming PPFD measurement over plant canopies in indoor environments and growth chambers

Output Options

Apogee offers multiple analog models, SDI-12 digital output, as well as a handheld meter with digital readout with more options available soon.



Above: The Extended Range PFD sensors have a spectral range of 340 to 1040 nm ± 5 nm. The extended spectral response increases the accuracy of LED measurements.

Quantum Light Pollution Sensors

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

NEW!

	SQ-640-SS	SQ-644-SS	SQ-646	SQ-647-SS
Power Supply	Self-powered	12 to 24 V DC	5 V USB power source	5.5 to 24 V DC
Sensitivity	1 mV per µmol m^{-2} s^{-1}	0.08 mA per µmol m^{-2} s^{-1}	–	
Calibration Factor (reciprocal of sensitivity)	1 µmol m^{-2} s^{-1} per mV	12.5 µmol m^{-2} s^{-1} per mA	Custom for each sensor and stored in the firmware	
Calibration Uncertainty	± 5 %			
Calibrated Output Range	0 to 200 mV	4 to 20 mA	USB	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		Software updates every second	Less than 0.6 s
Field of View	180°			
Spectral Range (see graph to the right)	340 to 1040 nm ± 5 nm			
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			
Housing	Anodized aluminum body with acrylic diffuser			
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	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

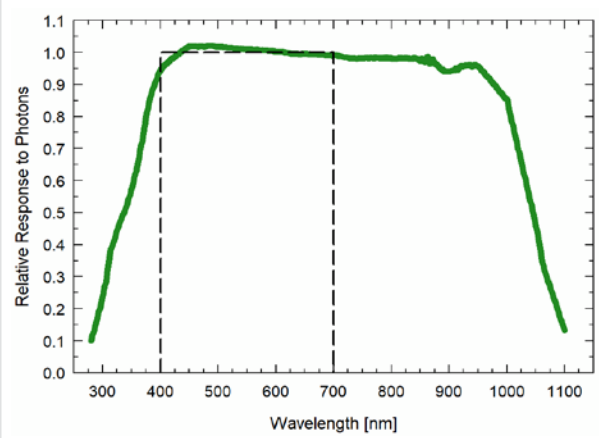
Many plants are affected by interruptions in dark periods even by extremely dim light. Apogee's new Quantum Light Pollution Sensor is designed to detect photons from 340-1040 nm that are below the sensitivity level of a typical quantum sensor. Detecting stray photons that disrupt the night is critical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

Output Options

Apogee offers multiple analog models and SDI-12 digital output with more options available soon.



Above: The Quantum Light Pollution sensor (model SQ-640) has a spectral range of 340 to 1040 nm ± 5 nm. The spectral responses can be seen in this graph.

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 quiescent 36.87 mA, active 37.06 mA; RS-485 quiescent 37.37 mA, active 42.30 mA
Output (sensitivity)	0.01 mV per µmol m^{-2} s^{-1} (PAR) 0.02 mV per µmol m^{-2} s^{-1} (Far-red)	–	
Calibration Factor (reciprocal of sensitivity)	100 µmol m^{-2} s^{-1} per mV (PAR) 50 µmol m^{-2} s^{-1} per mV (Far-red)	Custom for each sensor and stored in firmware	
Calibration Uncertainty	± 5 %		
Output Range	0 to 40 mV (PAR) 0 to 20 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 (see graph to the right)	389 to 692 nm ± 5 nm (PAR) 702 to 761 nm ± 5 nm (Far-red)		
Directional (cosine) 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		
Mass (with 5 m of cable)	140 g		
Warranty	4 years against defects in materials and workmanship		

Overview

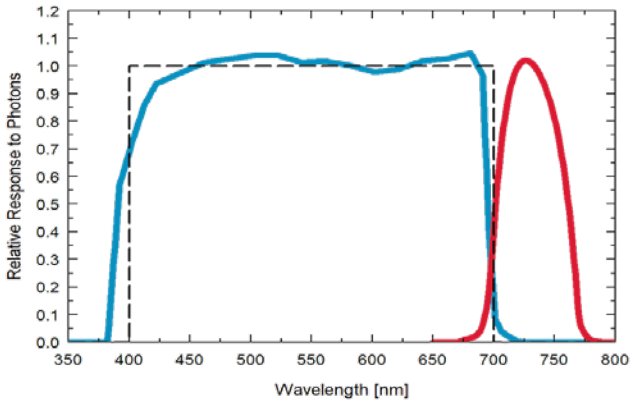
The new Apogee PAR-FAR sensor is a research-grade tool for measuring both the traditional PPFD photosynthetic photon flux and separately quantifying the photon flux of far-red photons (700-760 nm). The outputs include the traditional quantum flux, the far-red photon flux, and the far-red fraction (far-red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

Typical Applications

- Monitoring plant light environments
- Research plant morphogenic activity
- Photobiology studies

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).

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 quiescent 36.87 mA, active 37.06 mA; RS-485 quiescent 37.37 mA, active 42.30 mA
Output (sensitivity)	0.01 mV per µmol m^{-2} s^{-1}	–	
Calibration Factor (recipricol of sensitivity)	100 µmol m^{-2} s^{-1} per mV	Custom for each sensor and stored in firmware	
Calibration Uncertainty	± 5 %		
Output Range	0 to 4 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		
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		
Mass (with 5 m of cable)	140 g		
Warranty	4 years against defects in materials and workmanship		

Overview

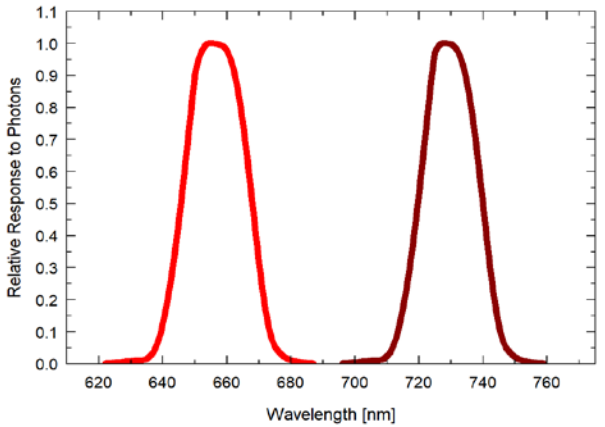
This sensor is a research-grade, cost-effective two-channel sensor for monitoring plant light environments, including calculation of the Red to Far-red Ratio (red photon flux density / far-red photon flux density) and Far-red Fraction (far-red photon flux density / sum of red and far-red photon flux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

Typical Applications

- Ecological research
- Effect of spectral quality on phytochrome
- Monitoring plant light environments
- Research plant morphogenic activity
- Photobiology studies

Key Features

Available in digital SDI-12 output 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).

NDVI Sensors

Two-band radiometer to calculate normalized difference vegetation index

	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)	5 mV per W m^{-2} (Red) 6.67 mV per W m^{-2} (NIR)	10 mV per W m^{-2} (Red) 6.67 mV per W m^{-2} (NIR)	—	
Calibration Factor (recipricol of sensitivity)	0.2 W m^{-2} (Red) 0.15 W m^{-2} (NIR)	0.1 W m^{-2} (Red) 0.15 W m^{-2} (NIR)	Custom for each sensor and stored in firmware	
Calibration Uncertainty	± 5 %			
Output Range	18.5 mV (Red) 26 mV (NIR)	20 mV (Red) 20 mV (NIR)	SDI-12	
Wavelength Ranges	Red detector = 650 nm with 10 nm FWHM* NIR detector = 810 nm with 10 nm 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°	40°	180°	40°
Directional (cosine) 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	23.5 mm diameter, 40 mm height	30.5 mm diameter, 37 mm height	23.5 mm diameter, 40 mm height
Mass (with 5 m of cable)	140 g	110 g	140 g	110 g
Warranty	4 years against defects in materials and workmanship			

*FWHM = full-width half-maximum

Overview

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

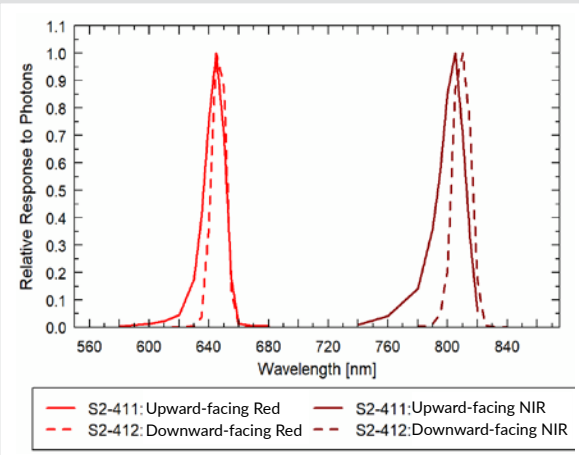
Key Features

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.



PRI Sensors

Two-band radiometers inform environment and plant health

	Analog Output		Digital Output	
	S2-121-SS (Upward-Looking)	S2-122-SS (Downward-Looking)	S2-421-SS (Upward-Looking)	S2-422-SS (Downward-Looking)
Power Supply	Self-powered		5.5 to 24 V DC	
Output (sensitivity)	1.43 mV per W m^{-2} (Green and Yellow)	14.3 mV per W m^{-2} (Green and Yellow)	—	
Calibration Factor (recipricol of sensitivity)	0.7 W m^{-2} per mV (Green and Yellow)	0.07 W m^{-2} per mV (Green and Yellow)	Custom for each sensor and stored in firmware	
Calibration Uncertainty	± 5 %			
Output Range	5 mV (Green) 5 mV (Yellow)	10 mV (Green) 10 mV (Yellow)	SDI-12	
Wavelength Ranges	Green detector = 532 nm with 10 nm FWHM* Yellow detector = 570 nm with 10 nm 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°	40°	180°	40°
Directional (cosine) 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	23.5 mm diameter, 40 mm height	30.5 mm diameter, 37 mm height	23.5 mm diameter, 40 mm height
Mass (with 5 m of cable)	140 g	110 g	140 g	110 g
Warranty	4 years against defects in materials and workmanship			

*FWHM = full-width half-maximum

Overview

This two-band radiometer is designed to continuously measure reflectance for calculation of photochemical reflectance index (PRI) of plant canopies. PRI is related to canopy light use efficiency and is often used in studies of canopy photosynthesis and response to stress.

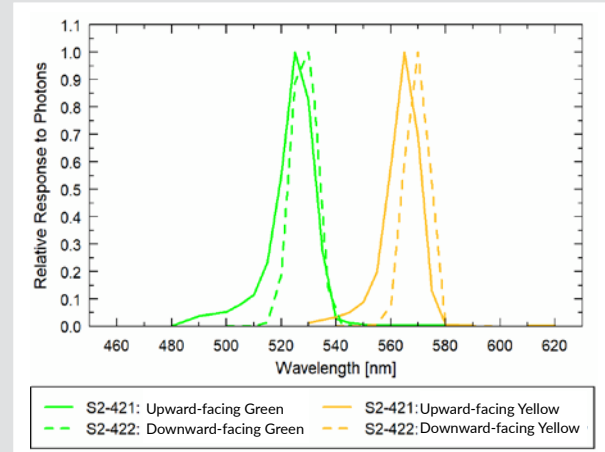
Key Features

A domed diffuser promotes self-cleaning to minimize errors from dust and debris.

$$PRI = \frac{\rho_{Green} - \rho_{Yellow}}{\rho_{Green} + \rho_{Yellow}}$$

Output Types

Available as an analog option or SDI-12 digital output. Paired upward- and downward-looking models are necessary to calculate PRI.



UV-A Sensors

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

NEW!

	SU-200-SS	SU-202-SS	SU-205-SS
Power Supply	Self-powered	3.3 to 24 V DC	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}
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
Calibration Uncertainty	± 10 %		
Output Range	0 to 10 mV	0 to 2.5 V	0 to 5 V
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		
Field of View	180°		
Spectral Range	300 to 400 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

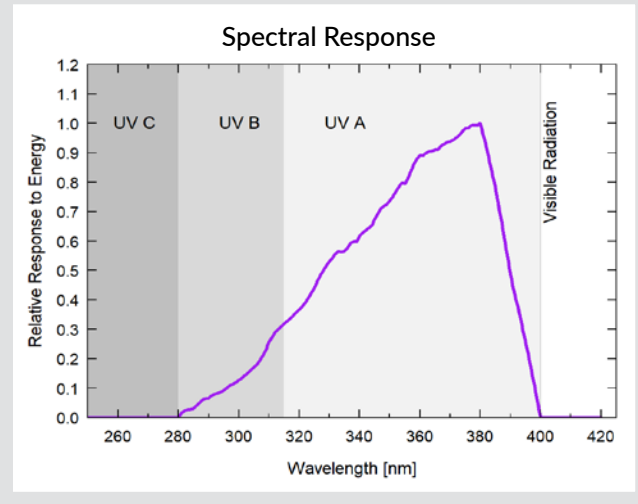
UV-A radiation is important in material sciences and has numerous photobiological effects. For example, exposure to UV radiation can cause plants to produce secondary compounds, including flavonoids and antioxidants. Apogee's new UV-A sensors offer a low-cost option for detecting UV radiation from 300 to 400 nm and are calibrated in energy flux units of Watts per square meter.

Typical Applications

- Monitor the filtering ability and stability of various materials
- Measure UV-A radiation in outdoor and laboratory
- Monitor UV radiation in horticultural operations environments

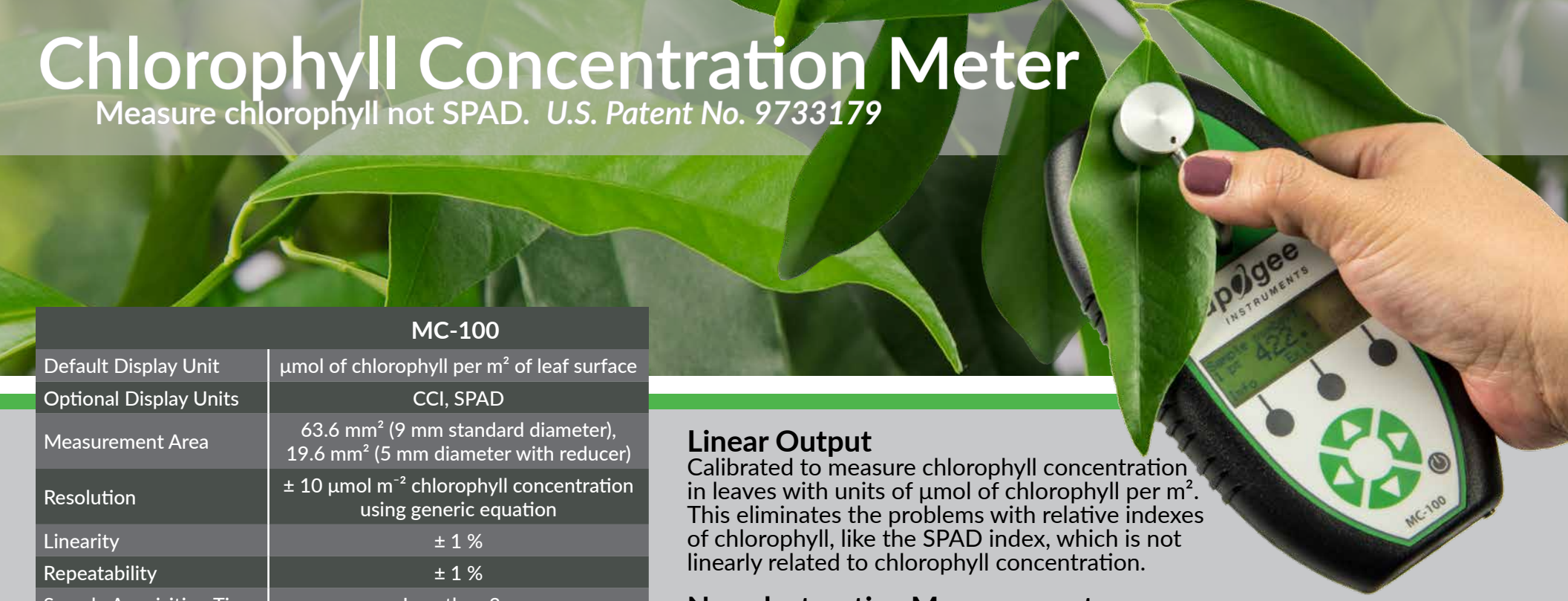
Key Features

Sensor features an anodized aluminum body with fully-potted electronics. The dome-shaped sensor head minimizes errors by shedding dust and water for a self-cleaning performance.



Chlorophyll Concentration Meter

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



	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; 94,000 data measurements with GPS data entries
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
External GPS Option	RS-232 port (GPS location data is saved with each measurement)
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

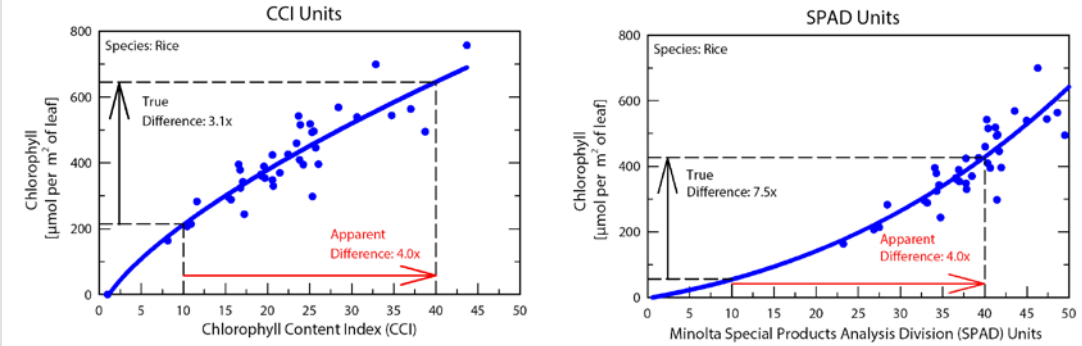
Linear Output

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

Non-destructive Measurements

The meter measures the ratio of red and near infrared transmittance with a sample rate of less than 3 seconds, resulting in measurements that are non-destructive and nearly instantaneous. This facilitates rapid measurement of multiple leaves and monitoring of the same leaves over time.

See our website for over 25 available species-specific settings



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.*

Infrared Radiometers

High-accuracy, non-contact surface temperature measurement in harsh environmental conditions

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, 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.

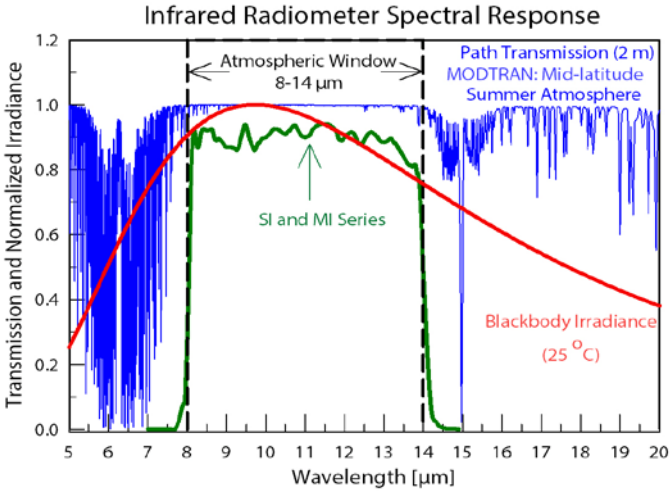
High Speed Options

Fast response (SIF) analog models have a 0.2 second response time.

Outputs

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

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



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

Analog Models

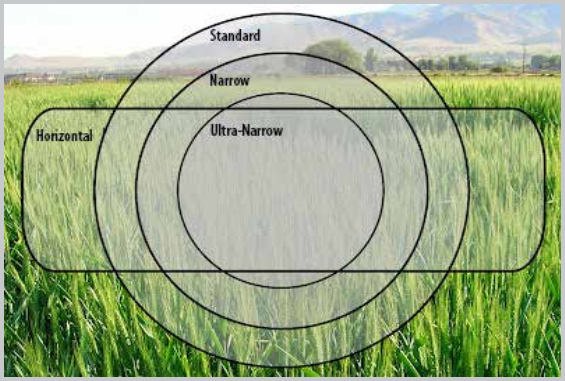
SI/SIF-111-SS	Standard FOV
SI/SIF-121-SS	Narrow FOV
SI-131-SS	Ultra-Narrow FOV
SI/SIF-1H1-SS	Horizontal FOV

Digital SDI-12 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

Meter Models

MI-210	Standard FOV
MI-220	Narrow FOV
MI-230	Ultra-Narrow FOV
MI-2H0	Horizontal FOV



Case Studies

Apogee Instruments' SI-131 Infrared Radiometer was selected to be part of a multi-sensor high throughput field phenotyping system for soybean and wheat breeding by the **University of Nebraska-Lincoln**.

In **València, Spain** researchers at **Universitat Politècnica de València (UPV)** selected Apogee Instruments' **SI-411 Infrared Radiometer** to be part of an autonomous vineyard monitoring robot to generate maps of temperature and vigor of the plants in real time.

All Models -SS	SI-111	SI-121	SI-131	SI-1H1	SIF-111	SIF-121	SIF-1H1	SI-411	SI-421	SI-431	SI-4H1	SI-4HR
Analog Model Output (difference between target and detector)	≈ 60 µV per C	≈ 40 µV per C	≈ 20 µV per C	≈ 40 µV per C	≈ 15 µV per C	≈ 10 µV per C		Digital Models (SDI-12)				
Input Voltage Requirement	2500 mV thermistor excitation (typical, other voltages can be used)							5.5 to 24 V DC with current draw of 1.5 mA (quiescent), 2.0 mA (active)				
Analog Output from Thermistor	0 to 2500 mV (typical, depends on input voltage)							–				
Calibration Uncertainty (-20 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
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	
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	22°	18°	32° horizontal; 13° vertical	22°	18°	14°	32° horizontal; 13° vertical	16° horizontal; 5° vertical
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, time for detector signal to reach 95 % following a step change				
Spectral Range	8 to 14 µm; atmospheric window											
Operating Environment	-55 to 80 C; 0 to 100 % relative humidity (non-condensing)											
Dimensions	23 mm diameter, 60 mm length											23 mm diameter; 76 mm length
Mass	190 g (with 5 m of lead wire)											219 g (with 5m of lead wire)
Warranty	4 years against defects in materials and workmanship											

Fan-Aspirated Radiation Shield

Accurate measurement of air temperature with minimal power draw

Case Study

The **Virginia Tech Department of Geography** has begun the development of regional mountaintop mesonets in the **Appalachian Mountains** of Virginia and West Virginia. The **TS-100** is being used to house temperature sensors for each installation.

Optimized Design for Efficiency and Durability

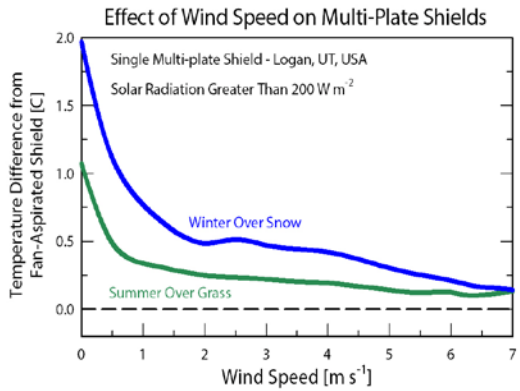
A curved inlet redirects air into the shield and funnels it past the sensing area, which allows for a lower power requirement than other fan-aspirated shields on the market. The fan has an ingress protection rating of IP55, which minimizes moisture and dust ingress. Fan speed and power can be further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

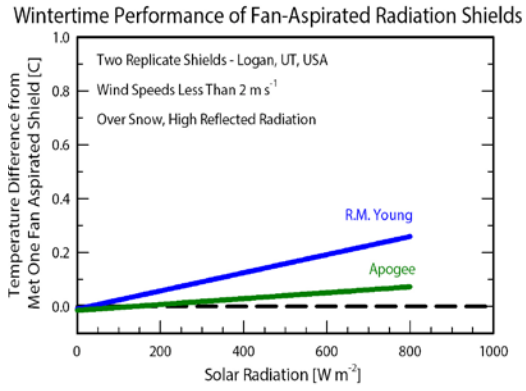
Sensor Compatibility

The shield accommodates multiple sensor options: air temperature sensors, air temperature/relative humidity probes, or combinations of both categories. For maximum accuracy we recommend redundant measurements of air temperature.

See our website for available sensor packages

	TS-100
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
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





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 60 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 manufactered by E+E Elektronik in Austria. The version sold by Apogee Instruments 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

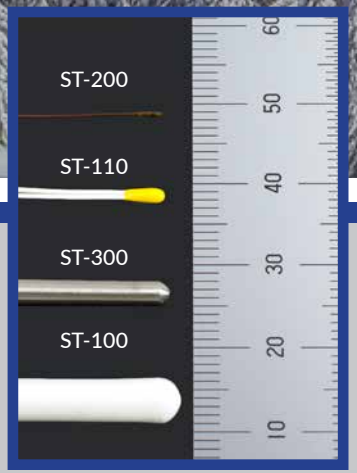
Fan aspiration of humidity probes can improve accuracy over passive shields. The **TS-100** shield (pictured) is an excellent choice for accomplishing this and is available at a special package price when purchased together. To see these sensor packages, please visit our website.

Temperature Measurement		Relative Humidity Measurement	
Sensor	PT1000 (Class A)	Sensor	Capacitance Chip
Measurement Range	-40 to 60 C	Measurement Range	0 to 100 %
Output Signal Range	0 to 2.5 V DC	Output Signal Range	0 to 2.5 V DC
Accuracy at 20 C	± 0.2 C	Accuracy at 20 C	± 2 % from 0 to 90 %; ± 3 % from 90 to 100 %
Long-term Stability	Less than 0.1 C per year	Temperature Response	Less than -0.05 % per C
Time Constant	Less than 30 s	Long-term Stability	Less than 1 % per year
		Time Constant	Less than 30 s

TS-120
Fan with EE08-SS

Temperature Sensors

Wide measurement range of -50 to 70 C



Models

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

	ST-100	ST-110	ST-200	ST-300
Measurement Range	-50 to 70 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 (-40 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 0.01 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	-50 to 70 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)
Current Draw	0.1 mA DC at 70 C (max. with steady excitation of 2.5 V DC)			0.21 mA DC (max. with steady 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)
Calibration Factor	0.0218 kPa per mV (generic slope; reciprocal of sensitivity) and 11.4 kPa (generic intercept)
Measurement Uncertainty	± 1.5 % (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

Leaf and Bud Temperature Sensor

Effective prediction of leaf and bud temperatures for orchards

Monitor Radiation Frost Events

On calm, clear nights leaf and bud temperatures can drop well below air temperature. A radiation frost occurs when frost forms at the surface before the air temperature reaches freezing. The Apogee leaf and bud temperature sensor is a combination of two high accuracy thermistors mounted in a single housing: sensors mimic a leaf and bud, which provides estimates of leaf and bud temperatures to monitor radiation frost events.

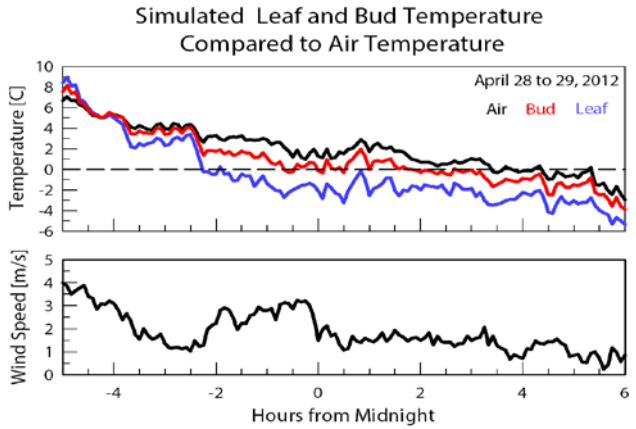
	SF-110	SF-421
Measurement Range	-50 to 70 C	
Measurement Uncertainty	0.1 C (from 0 to 70 C), 0.2 C (from -25 to 0 C), 0.4 C (from -50 to -25 C)	
Measurement Repeatability	Less than 0.05 C	
Long-term Drift (non-stability)	Less than 0.02 C per year (when used in non-condensing environments where the annual 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 (per thermistor) at 70 C (maximum, assuming continuous input excitation at 2.5 V DC)	0.6 mA (quiescent), 1.3 mA (active)
Dimensions	570 mm length, 21 mm pipe diameter, 70 mm disk diameter	
Mass	400 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 and bud 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 and bud temperatures were both below air temperature after 8 P.M. and reached freezing 6 (leaf) and 4 (bud) hours before the air temperature.

Oxygen Sensors and Meters

PPE housing for use in acidic and caustic environments

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.

AO-002 Flow Through Head

	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	–	
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	2.2 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			

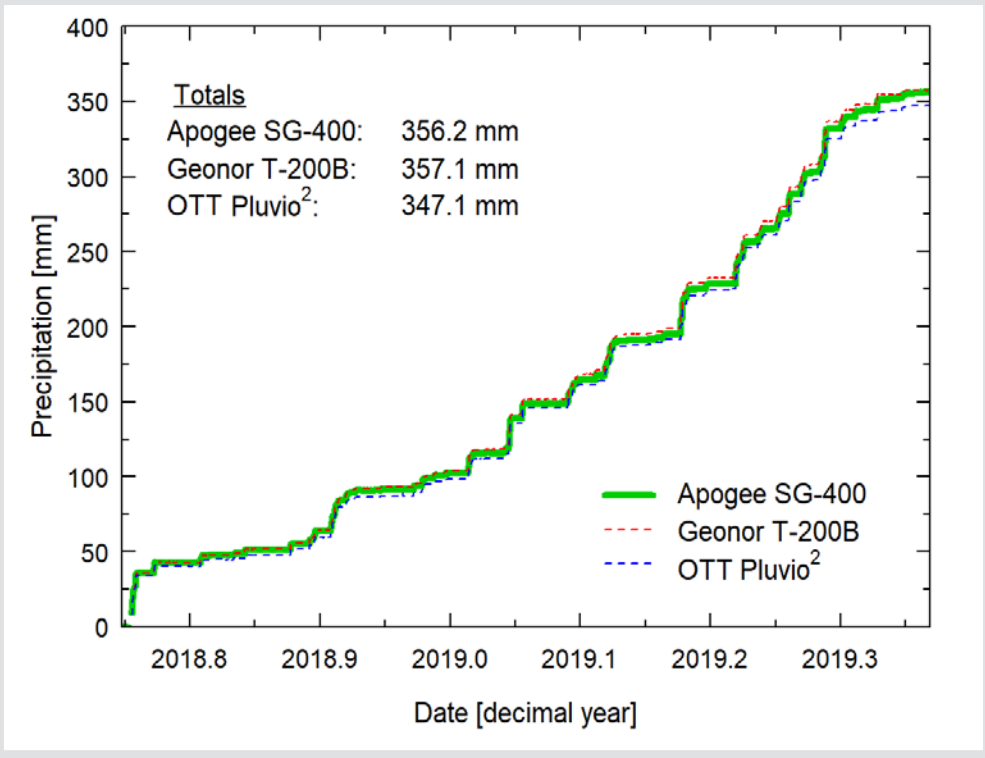
Weighing Precipitation Gauge

coming soon

Overview

- Measures total precipitation from rain, snow, sleet, and hail
- Algorithm to correct for temperature, evaporation, and vibration
- SDI-12 and Modbus outputs
- Inlet options include: 8 inch (900 mm / 35 inch capacity) or 200 cm² (1500 mm / 60 inch capacity) openings to meet WMO and NWS recommendations
- Heater option

Precipitation Gauge Comparisons



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