OWNER'S MANUAL

PYRANOMETER

Models SP-212 and SP-215

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CERTIFICATE OF COMPLIANCE

EU Declaration of Conformity

This declaration of conformity is issued under the sole responsibility of the manufacturer:

Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

for the following product(s):

Models: SP-212, SP-215
Type: Pyranometer

The object of the declaration described above is in conformity with the relevant Union harmonization legislation:

2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Hazardous Substances (RoHS 2) Directive

Standards referenced during compliance assessment:

EN 61326-1:2013	Electrical equipment for measurement, control and laboratory use – EMC requirements
EN 50581:2012	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials including cadmium, hexavalent chromium, lead, mercury, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE).

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but rely on the information provided to us by our material suppliers.

Signed for and on behalf of:
Apogee Instruments, May 2016

Bruce Bugbee
President
Apogee Instruments, Inc.

INTRODUCTION

Solar radiation at Earth's surface is typically defined as total radiation across a wavelength range of 280 to 4000 nm (shortwave radiation). Total solar radiation, direct beam and diffuse, incident on a horizontal surface is defined as global shortwave radiation, or shortwave irradiance (incident radiant flux), and is expressed in Watts per square meter (W m^{-2}, equal to Joules per second per square meter).

Pyranometers are sensors that measure global shortwave radiation. Apogee SP series pyranometers are silicon-cell pyranometers, and are only sensitive to a portion of the solar spectrum, approximately 350-1100 nm (approximately 80 % of total shortwave radiation is within this range). However, silicon-cell pyranometers are calibrated to estimate total shortwave radiation across the entire solar spectrum. Silicon-cell pyranometer specifications compare favorably to specifications for World Meteorological Organization (WMO) moderate and good quality classifications and specifications for International Organization of Standardization (ISO) second class and first class classifications, but because of limited spectral sensitivity, they do not meet the spectral specification necessary for WMO or ISO certification.

Typical applications of silicon-cell pyranometers include incoming shortwave radiation measurement in agricultural, ecological, and hydrological weather networks, and solar panel arrays.

Apogee Instruments SP series pyranometers consist of a cast acrylic diffuser (filter), photodiode, and signal processing circuitry mounted in an anodized aluminum housing, and a cable to connect the sensor to a measurement device. Sensors are potted solid with no internal air space and are designed for continuous total shortwave radiation measurement on a planar surface in outdoor environments. SP series sensors output an analog voltage that is directly proportional to total shortwave radiation from the sun. The voltage signal from the sensor is directly proportional to radiation incident on a planar surface (does not have to be horizontal), where the radiation emanates from all angles of a hemisphere.

SENSOR MODELS

This manual covers model SP-212 and SP-215 pyranometer sensors that provide a voltage output. For additional models see manuals SP-110/SP-300 and SP-214.

Model	Signal
SP-212	**0-2.5 V**
SP-215	**0-5 V**
SP-110	Self-powered
SP-214	4-20 mA
SP-230	Self-powered
SP-422	USB

Sensor model number and serial number are located near the pigtail leads on the sensor cable. If you need the manufacturing date of your sensor, please contact Apogee Instruments with the serial number of your sensor.

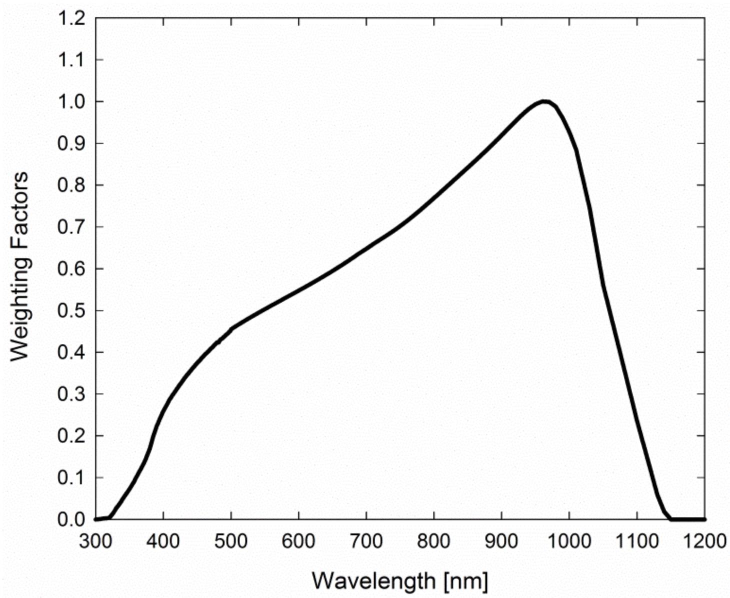
SPECIFICATIONS

	SP-212	SP-215
Power Supply	5.0-24 V DC with a nominal current draw of 300 µA	5.5-24 V DC** with a nominal current draw of 300 µA **Sensors with a serial number smaller than 4502 should not be powered with more than 5 V DC
Sensitivity	2.0 mV per W m^{-2}	4.0 mV per W m^{-2}
Calibration Factor (Reciprocal of Sensitivity)	0.5 W m^{-2} per mV	0.25 W m^{-2} per mV
Calibration Uncertainty	± 5 % (see Calibration Traceability below)	
Calibrated Output Range	0 to 2.5 V	0 to 5.0 V
Measurement Repeatability	Less than 1 %	
Long-term Drift (Non-stability)	Less than 2 % per year	
Non-linearity	Less than 1 % (up to 1250 W m^{-2}; maximum radiation measurement is 1250 W m^{-2})	
Response Time	Less than 1 ms	
Field of View	180°	
Spectral Range	360 to 1120 nm (wavelengths where response is 10% of maximum; see Spectral Response below)	
Directional (Cosine) Response	± 5 % at 75° zenith angle (see Cosine Response below)	
Temperature Response	0.04 ± 0.04 % per C (see Temperature Response below)	
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; 28 mm height	
Mass	90 g (with 5m of lead wire)	
Cable	5 m of two conductor, shielded, twisted-pair wire; additional cable available in multiples of 5 m; santoprene rubber jacket (high water resistance, high UV stability, flexibility in cold conditions); pigtail lead wires	

Calibration Traceability

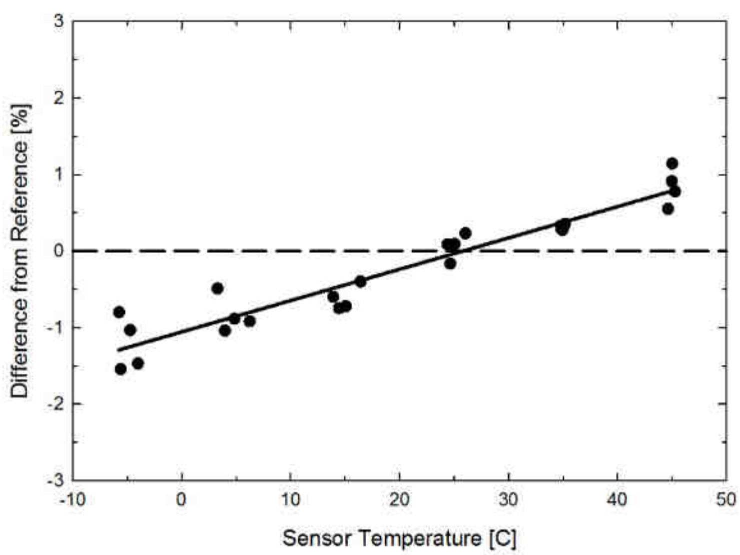
Apogee Instruments SP series pyranometers are calibrated through side-by-side comparison to the mean of four Apogee model SP-110 transfer standard pyranometers (shortwave radiation reference) under high intensity discharge metal halide lamps. The transfer standard pyranometers are calibrated through side-by-side comparison to the mean of at least two ISO-classified reference pyranometers under sunlight (clear sky conditions) in Logan, Utah. Each of four ISO-classified reference pyranometers are recalibrated on an alternating year schedule (two instruments each year) at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. NREL reference standards are calibrated to the World Radiometric Reference (WRR) in Davos, Switzerland.

Spectral Response



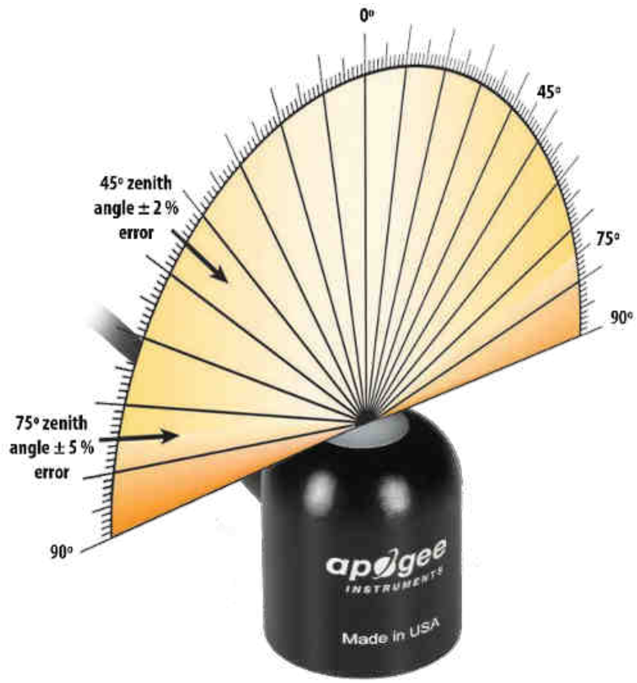
Spectral response estimate of Apogee silicon-cell pyranometers. Spectral response was estimated by multiplying the spectral response of the photodiode, diffuser, and adhesive. Spectral response measurements of diffuser and adhesive were made with a spectrometer, and spectral response data for the photodiode were obtained from the manufacturer.

Temperature Response

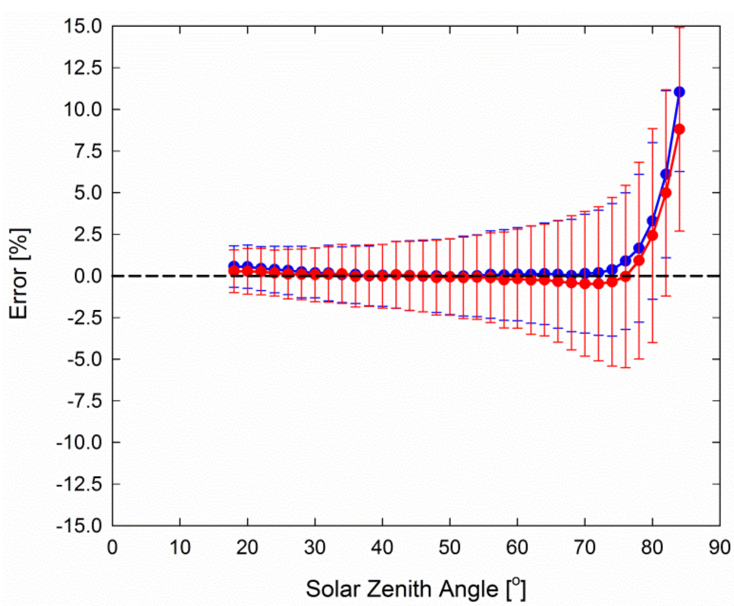


Mean temperature response of four Apogee silicon-cell pyranometers. Temperature response measurements were made at approximately 10 C intervals across a temperature range of approximately -10 to 50 C under sunlight. Each pyranometer had an internal thermistor to measure temperature. At each temperature set point, a reference blackbody pyranometer was used to measure solar intensity.

Cosine Response



Directional, or cosine, response is defined as the measurement error at a specific angle of radiation incidence. Error for Apogee silicon-cell pyranometers is approximately ± 2 % and ± 5 % at solar zenith angles of 45° and 75°, respectively.



Mean cosine response of eleven Apogee silicon-cell pyranometers (***error bars represent two standard deviations above and below mean***). Cosine response measurements were made during broadband outdoor radiometer calibrations (BORCAL) performed during two different years at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. Cosine response was calculated as the relative difference of pyranometer sensitivity at each solar zenith angle to sensitivity at 45° solar zenith angle. The blue symbols are AM measurements, the red symbols are PM measurements. The error bars represent two standard deviations from the mean.

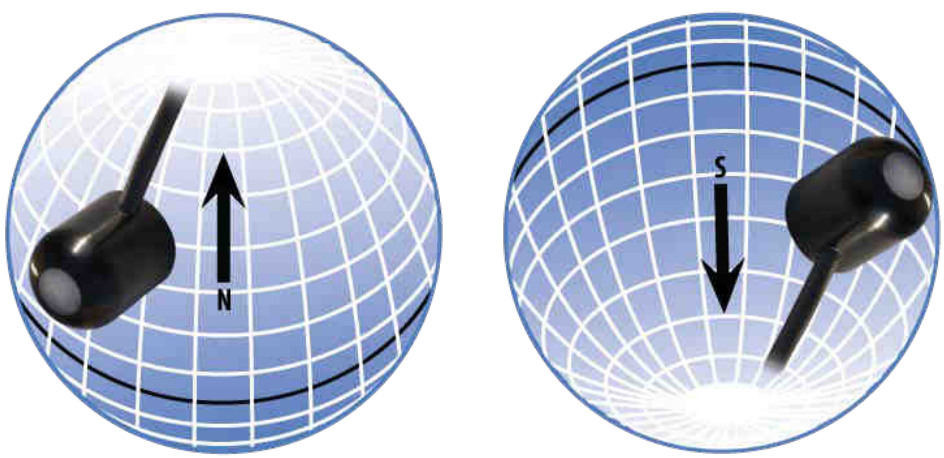
DEPLOYMENT AND INSTALLATION

Mount the sensor to a solid surface with the nylon mounting screw provided. To accurately measure total shortwave radiation incident on a horizontal surface, the sensor must be level. An Apogee Instruments model AL-100 leveling plate is recommended for this purpose. To facilitate mounting on a cross arm, an Apogee Instruments model AM-110 mounting bracket is recommended.

Nylon Screw: 10-32x3/8

Model AL-100

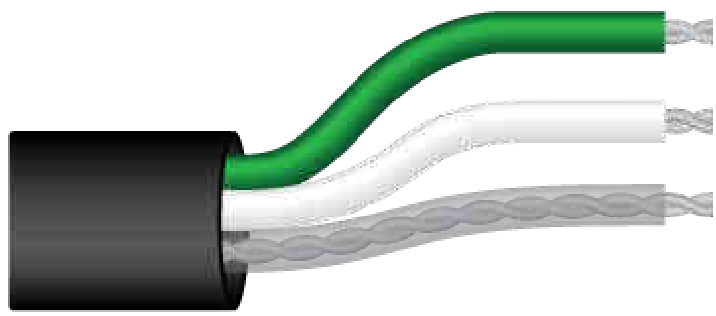
To minimize azimuth error, the sensor should be mounted with the cable pointing toward true north in the northern hemisphere or true south in the southern hemisphere. Azimuth error is typically less than 1 %, but it is easy to minimize by proper cable orientation.



In addition to orienting the cable to point toward the nearest pole, the sensor should also be mounted such that obstructions (e.g., weather station tripod/tower or other instrumentation) do not shade the sensor. **Once mounted, the green cap should be removed from the sensor.** The green cap can be used as a protective covering for the sensor when it is not in use.

OPERATION AND MEASUREMENT

Connect the sensor to a measurement device (meter, datalogger, controller) capable of measuring and displaying or recording a voltage signal (an input measurement range of 0-2.5 V or 0-5 V is required to cover the entire range of total shortwave radiation from the sun). In order to maximize measurement resolution and signal-to-noise ratio, the input range of the measurement device should closely match the output range of the pyranometer. **DO NOT connect the sensor to a power source greater than 24 VDC.**



Green: Positive (signal from sensor)

White: Input power

Clear: Ground (from sensor signal and input power)

Sensor Calibration

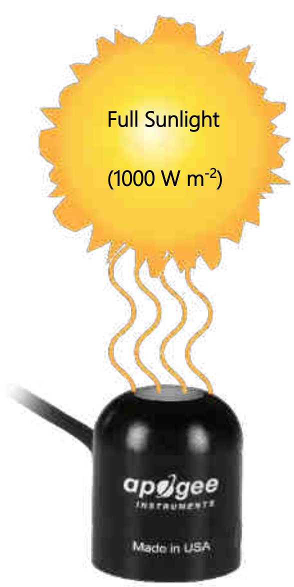
Apogee amplified pyranometer models have a standard calibration factor of exactly:

SP-212: 0.5 W m^{-2} per mV
SP-215: 0.25 W m^{-2} per mV

Multiply this calibration factor by the measured mV signal to convert sensor output to total shortwave radiation in units of W m^{-2}:

Calibration Factor (0.5 W m^{-2} per mV) * Sensor Output Signal (mV) = Shortwave Radiation (W m^{-2})

0.5 * 2000 = 1000

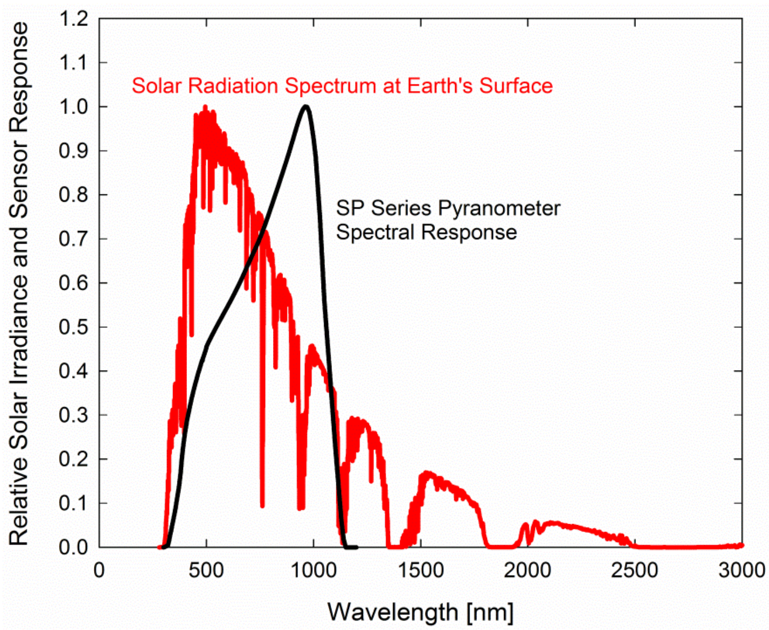


Sensor Output
2000 mV

Example of total shortwave radiation measurement with an Apogee SP-212 pyranometer. Full sunlight yields total shortwave radiation on a horizontal plane at the Earth's surface of approximately 1000 W m^{-2} s^{-1}. This yields an output signal of 2000 mV. The signal is converted to shortwave radiation by multiplying by the calibration factor of 0.5 W m^{-2} per mV.

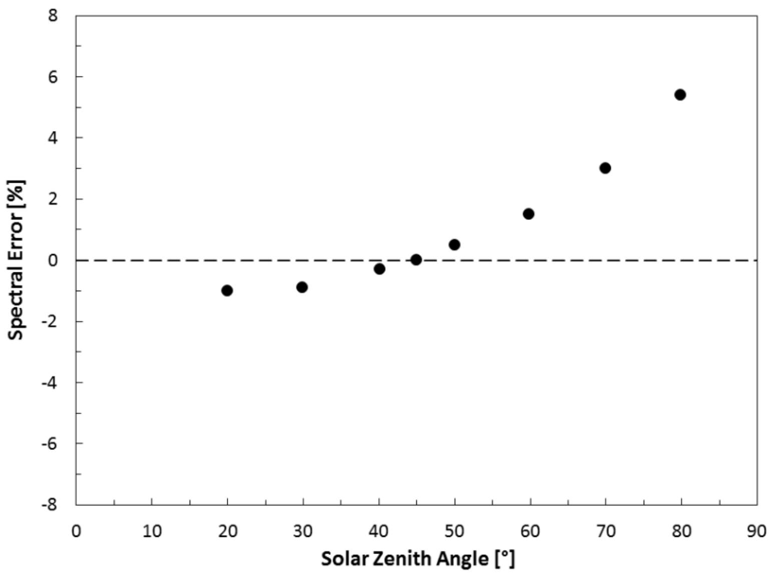
Spectral Errors for Measurements with Silicon-cell Pyranometers

Apogee SP series pyranometers are calibrated under electric lamps in a calibration laboratory. The calibration procedure simulates calibration under clear sky conditions at a solar zenith angle of approximately 45°. However, due to the limited spectral sensitivity of silicon-cell pyranometers compared to the solar radiation spectrum (see graph below), spectral errors occur when measurements are made in conditions that differ from conditions the sensor was calibrated under (e.g., the solar spectrum differs in clear sky and cloudy conditions, thus measurements in cloudy conditions result in spectral error because sensors are calibrated in clear sky conditions).

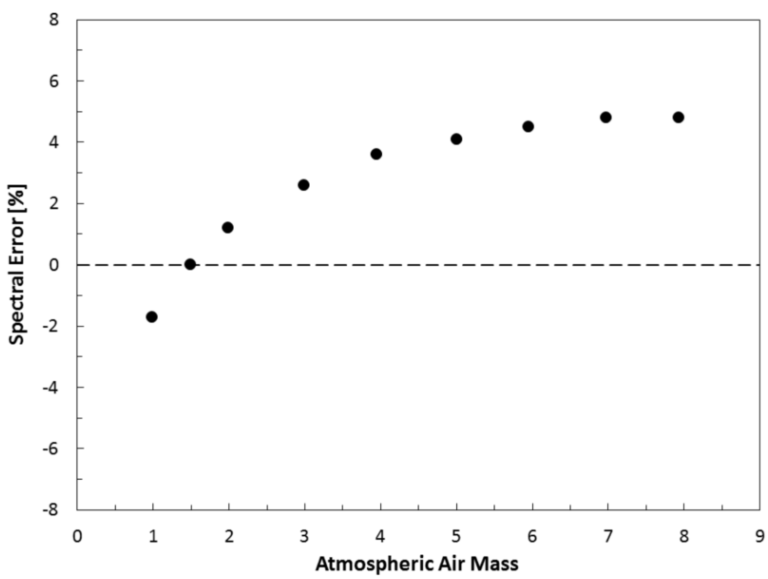


Spectral response of Apogee SP series pyranometers compared to solar radiation spectrum at Earth's surface. Silicon-cell pyranometers, such as Apogee SP series, are only sensitive to the wavelength range of approximately 350-1100 nm, and are not equally sensitive to all wavelengths within this range. As a result, when the spectral content of solar radiation is significantly different than the spectrum that silicon-cell pyranometers were calibrated to, spectral errors result.

Silicon-cell pyranometers can still be used to measure shortwave radiation in conditions other than clear sky or from radiation sources other than incoming sunlight, but spectral errors occur when measuring radiation with silicon-cell pyranometers in these conditions. The graphs below show spectral error estimates for Apogee silicon-cell pyranometers at varying solar zenith angles and varying atmospheric air mass. The diffuser is optimized to minimize directional errors, thus the cosine response graph in the Specifications section shows the actual directional errors in practice (which includes contributions from the spectral shift that occurs as solar zenith angle and atmospheric air mass change with time of day and time of year). The table below provides spectral error estimates for shortwave radiation measurements from shortwave radiation sources other than clear sky solar radiation.



Spectral error for Apogee SP series pyranometers as a function of solar zenith angle, assuming calibration at a zenith angle of 45°.



Spectral error for Apogee SP series pyranometers as a function of atmospheric air mass, assuming calibration at an air mass of 1.5.

Spectral Errors for Shortwave Radiation Measurements with Apogee SP Series Pyranometers

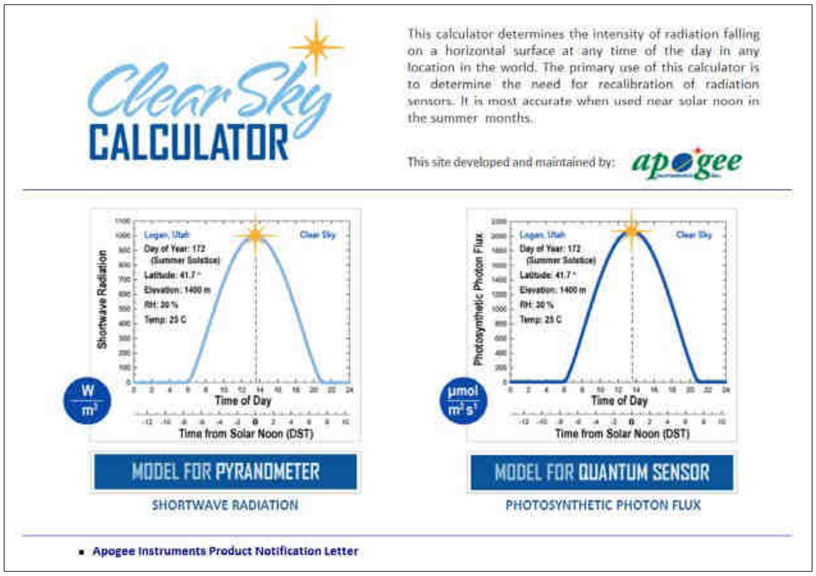
Radiation Source (Error Calculated Relative to Sun, Clear Sky)	Error [%]
Sun (Clear Sky)	0.0
Sun (Cloudy Sky)	9.6
Reflected from Grass Canopy	14.6
Reflected from Deciduous Canopy	16.0
Reflected from Conifer Canopy	19.2
Reflected from Agricultural Soil	-12.1
Reflected from Forest Soil	-4.1
Reflected from Desert Soil	3.0
Reflected from Water	6.6
Reflected from Ice	0.3
Reflected from Snow	13.7

MAINTENANCE AND RECALIBRATION

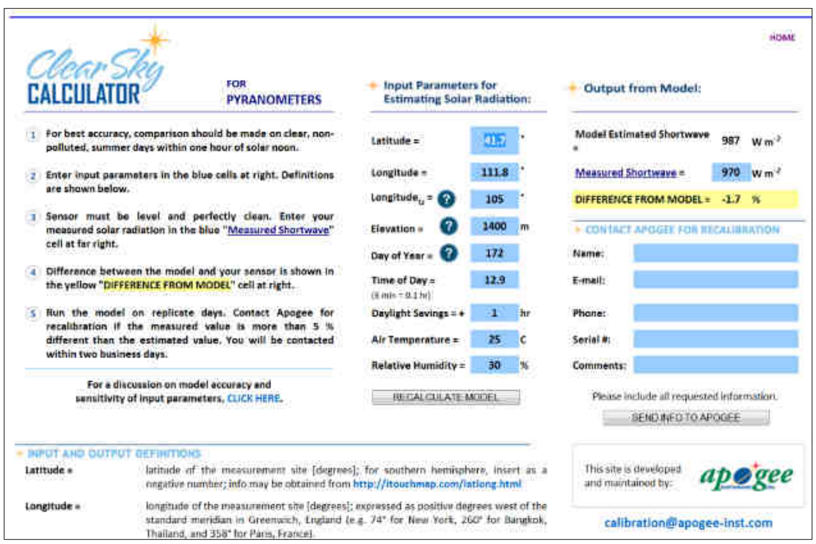
Moisture or debris on the diffuser is a common cause of low readings. The sensor has a domed diffuser and housing for improved self-cleaning from rainfall, but materials can accumulate on the diffuser (e.g., dust during periods of low rainfall, salt deposits from evaporation of sea spray or sprinkler irrigation water) and partially block the optical path. Dust or organic deposits are best removed using water or window cleaner and a soft cloth or cotton swab. Salt deposits should be dissolved with vinegar and removed with a soft cloth or cotton swab. **Never use an abrasive material or cleaner on the diffuser.**

The Clear Sky Calculator (www.clearskycalculator.com) can be used to determine the need for pyranometer recalibration. It determines total shortwave radiation incident on a horizontal surface at any time of day at any location in the world. It is most accurate when used near solar noon in spring and summer months, where accuracy over multiple clear and unpolluted days is estimated to be ± 4 % in all climates and locations around the world. For best accuracy, the sky must be completely clear, as reflected radiation from clouds causes incoming radiation to increase above the value predicted by the clear sky calculator. Measured values of total shortwave radiation can exceed values predicted by the Clear Sky Calculator due to reflection from thin, high clouds and edges of clouds, which enhances incoming shortwave radiation. The influence of high clouds typically shows up as spikes above clear sky values, not a constant offset greater than clear sky values.

To determine recalibration need, input site conditions into the calculator and compare total shortwave radiation measurements to calculated values for a clear sky. If sensor shortwave radiation measurements over multiple days near solar noon are consistently different than calculated values (by more than 6 %), the sensor should be cleaned and re-leveled. If measurements are still different after a second test, email calibration@apogeeinstruments.com to discuss test results and possible return of sensor(s).



Homepage of the Clear Sky Calculator. Two calculators are available: One for pyranometers (total shortwave radiation) and one for quantum sensors (photosynthetic photon flux density).



Clear Sky Calculator for pyranometers. Site data are input in blue cells in middle of page and an estimate of total shortwave radiation is returned on right-hand side of page.

TROUBLESHOOTING AND CUSTOMER SUPPORT

Apogee SP-200 series pyranometers provide an amplified voltage output that is proportional to incident total shortwave radiation. A quick and easy check of sensor functionality can be determined using a DC power supply and a voltmeter. Power the sensor with a DC voltage by connecting the positive voltage signal to the white wire from the sensor and the negative (or common) to the clear wire from the sensor. Use the voltmeter to measure across the green wire (output signal) and clear wire. Direct the sensor head toward a light source and verify the sensor provides a signal. Increase and decrease the distance from the sensor head to the light source to verify that the signal changes proportionally (decreasing signal with increasing distance and increasing signal with decreasing distance). Blocking all radiation from the sensor should force the sensor signal to zero.

Compatible Measurement Devices (Dataloggers/Controllers/Meters)

SP-200 series pyranometers are calibrated with a standard calibration factor of 0.5 W m^{-2} per mV (SP-212) or 0.25 W m^{-2} per mV (SP-215), yielding a sensitivity of 2.0 mV per W m^{-2} or 4.0 mV per W m^{-2}, respectively. Thus, a compatible measurement device (e.g., datalogger or controller) should have resolution of at least 2 mV, in order to provide shortwave radiation resolution of 1 W m^{-2}.

Effect of Cable Length

When the sensor is connected to a measurement device with high input impedance, sensor output signals are not changed by shortening the cable or splicing on additional cable in the field. Tests have shown that if the input impedance of the measurements device is 1 mega-ohm or higher then there is negligible effect on the pyranometer calibration, even after adding up to 100 m of cable. Apogee model SP series pyranometers use shielded, twisted pair cable, which minimizes electromagnetic interference. This is particularly important for long lead lengths in electromagnetically noisy environments.

Modifying Cable Length

See Apogee webpage for details on how to extend sensor cable length (http://www.apogeeinstruments.com/how-to-make-a-weatherproof-cable-splice/).