OWNER'S MANUAL

QUANTUM SENSOR

Model JSQ-200 Series

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DECLARATION OF CONFORMITY

CE and ROHS Certificate of Compliance

Declare under our sole responsibility that the products:

M odels:JSQ-212,JSQ-222,JSQ-215,JSQ-225
Type: Quantum Sensor

are in conformity with the following standards and relevant EC directives:

Emissions: EN 61326-1:2013
Immunity: EN 61326-1:2013
Safety: EN 61010-1:2010

EU directive 2004/108/EC, EMC
EU directive 2002/95/EC, RoHS (Restriction of Hazardous Substances)
EU directive 2011/65/EU, RoHS2

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).

INTRODUCTION

Radiation that drives photosynthesis is called photosynthetically active radiation (PAR) and is typically defined as total radiation across a range of 400 to 700 nm. PAR is often expressed as photosynthetic photon flux (PPF): photon flux in units of micromoles per square meter per second (μmol m^{-2} s^{-1}, equal to microEinsteins per square meter per second) summed from 400 to 700 nm (total number of photons from 400 to 700 nm). While Einsteins and micromoles are equal (one Einstein = one mole of photons), the Einstein is not an SI unit, so expressing PPF as μmol m^{-2} s^{-1} is preferred.

Sensors that measure PPF are often called quantum sensors due to the quantized nature of radiation. A quantum refers to the minimum quantity of radiation, one photon, involved in physical interactions (e.g., absorption by photosynthetic pigments). In other words, one photon is a single quantum of radiation.

Typical applications of quantum sensors include incoming PPF measurement over plant canopies in outdoor environments or in greenhouses and growth chambers, and reflected or under-canopy (transmitted) PPF measurement in the same environments.

JSQ series quantum sensors 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 PPF measurement in indoor or outdoor environments. JSQ series sensors output an analog voltage that is directly proportional to PPF under sunlight (e.g., model JSQ-215) or electric lights (e.g., model JSQ-225). 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.

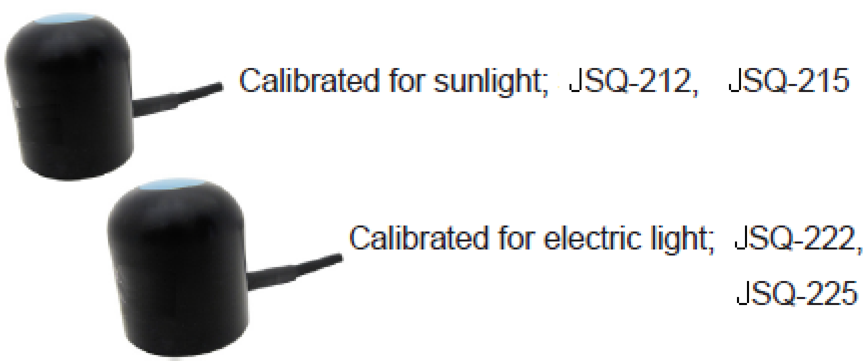
SENSOR MODELS

The JSQ-200 series quantum sensor models covered in this manual are amplified versions. Un-amplified models are also available, which are self-powered and provide millivolt signals; see manual for JSQ-100 and JSQ-300 series quantum sensors.

Sensor model number, serial number, production date, and calibration factor are located near the pigtail leads on the sensor cable.

Quantum Sensor Models

US Patent No. D519,860



SPECIFICATIONS

Power Supply: 5-24 VDC with a nominal current draw of 300 μA

Sensitivity: JSQ-212, -222: 1.0 mV per μmol m^{-2} s^{-1}
JSQ-215, -225: 2.0 mV per μmol m^{-2} s^{-1}

Calibration Factor: JSQ-212, -222: 1.0 μmol m^{-2} s^{-1} per mV (reciprocal of sensitivity)
JSQ-215, -225: 0.5 μmol m^{-2} s^{-1} per mV (reciprocal of sensitivity)

Calibration Uncertainty: ± 5 % (see Calibration Traceability below)

Measurement Repeatability: < 1 %

Non-stability (Long-term Drift): < 2 % per year

Non-linearity: < 1 % (up to 2500 μmol m^{-2} s^{-1}; maximum PPF measurement is 2500 μmol m^{-2} s^{-1})

Response Time: < 1 ms

Field of View: 180°

Spectral Range: 410 nm to 655 nm (wavelengths where response is greater than 50 % of maximum; see Spectral Response below)

Directional (Cosine) Response: ± 5 % at 75° zenith angle (see Cosine Response below)

Temperature Response: 0.06 ± 0.06 % 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: 2.4 cm diameter and 2.8 cm height

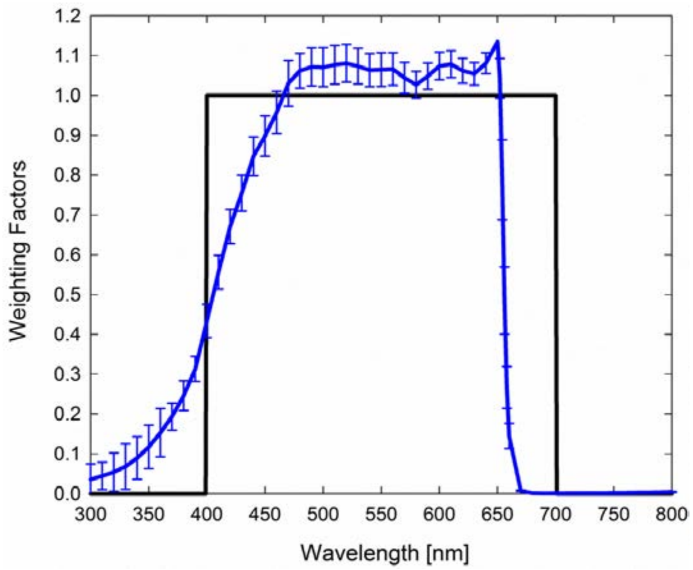
Mass: 90 g (with 5 m of lead wire)

Cable: 5 m of 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:

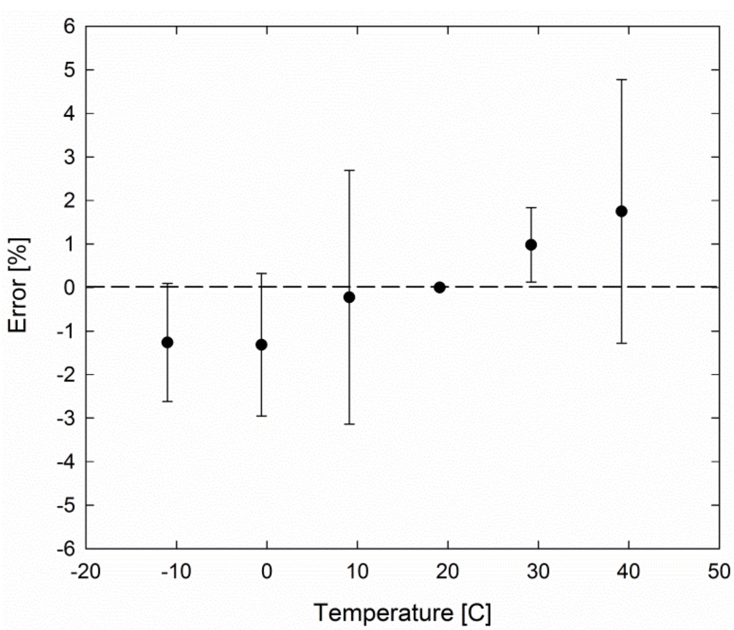
JSQ series quantum sensors are calibrated through side-by-side comparison to the mean of four model JSQ-110 or JSQ-120 transfer standard quantum sensors under high output T5 cool white fluorescent lamps. The transfer standard quantum sensors are calibrated through side-by-side comparison to the mean of at least three LI-COR model LI-190 reference quantum sensors under high output T5 cool white fluorescent lamps. The reference quantum sensors are recalibrated on a biannual schedule with a LI-COR model 1800-02 Optical Radiation Calibrator using a 200 W quartz halogen lamp. The 1800-02 and quartz halogen lamp are traceable to the National Institute of Standards and Technology (NIST).

Spectral Response:



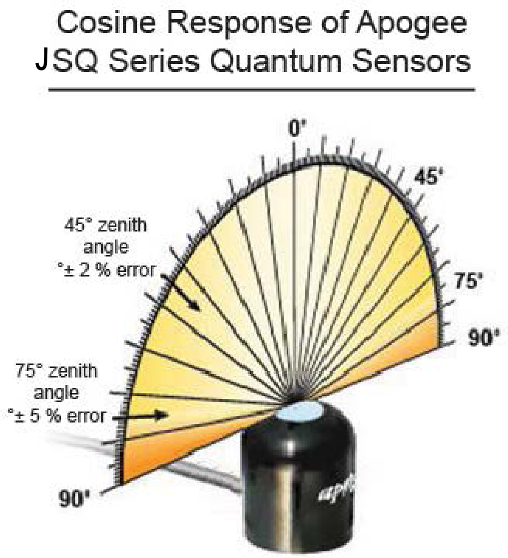
Mean spectral response of six JSQ series quantum sensors (*error bars represent two standard deviations above and below mean*) compared to PPF weighting function. Spectral response measurements were made at 10 nm increments across a wavelength range of 300 to 800 nm in a monochromator with an attached electric light source. Measured spectral data from each quantum sensor were normalized by the measured spectral response of the monochromator/electric light combination, which was measured with a spectroradiometer.

Temperature response:

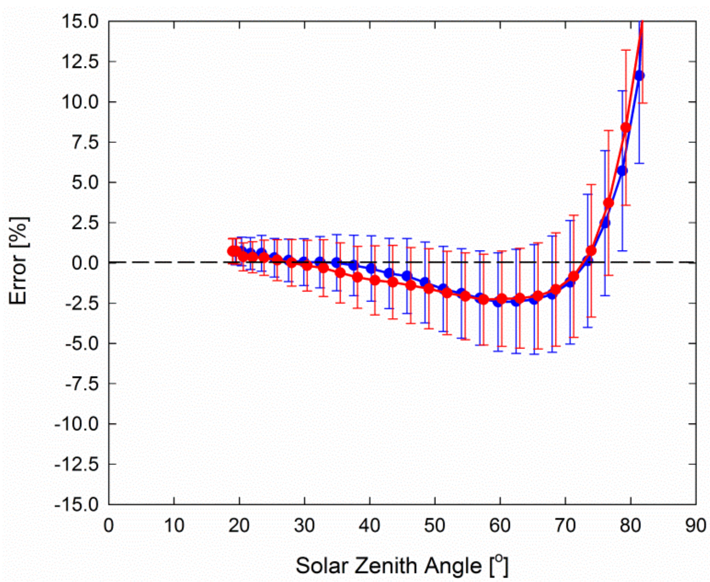


Mean temperature response of eight JSQ series quantum sensors (*errors bars represent two standard deviations above and below mean*). Temperature response measurements were made at 10 C intervals across a temperature range of approximately -10 to 40 C in a temperature controlled chamber under a fixed, broad spectrum, electric lamp. At each temperature set point, a spectroradiometer was used to measure light intensity from the lamp and all quantum sensors were compared to the spectroradiometer. The spectroradiometer was mounted external to the temperature control chamber and remained at room temperature during the experiment.

Cosine Response:



Directional, or cosine,response is defined as the measurement error at a specific angle of radiation incidence. Error for JSQ series quantum sensors is approximately ± 2 % and ± 5 % at solar zenith angles of °45 and 75°, respectively.



Mean cosine response of twenty-three JSQ series quantum sensors (*error bars represent two standard deviations above and below mean*). Cosine response measurements were made by direct side-by-side comparison to the mean of four reference thermopile pyranometers, with solar zenith angle-dependent factors applied to convert total shortwave radiation to PPF. Blue points represent the AM response and red points represent the PM response.

DEPLOYMENT AND INSTALLATION

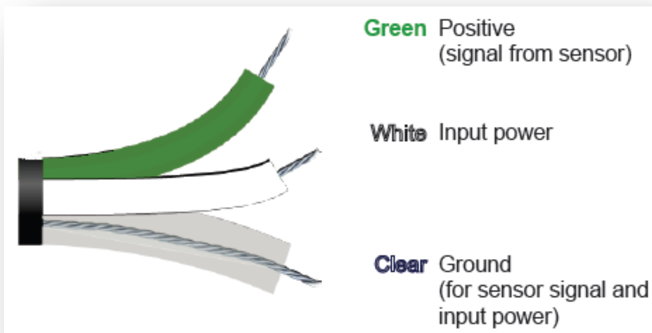
M ount the sensor to a solid surface with the nylon mounting screw provided. To accurately measure PPF incident on a horizontal surface, the sensor must be level. An model AL-100 leveling plate is recommended for this purpose. To facilitate mounting on a cross arm, an model AM-110 mounting bracket is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

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 PPF 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 quantum sensor. **DO NOT connect the sensor to a power source greater than 24 VDC.**



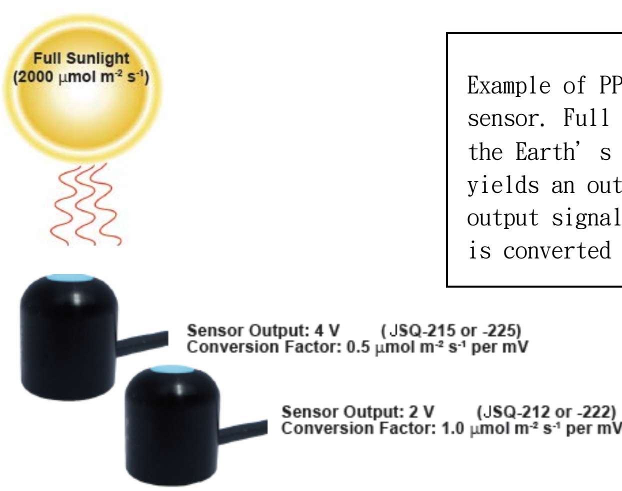
Quantum sensor models have a standard PPF calibration factor of exactly:

JSQ -212, JSQ -222: 1.0 µmol m^{-2} s^{-1} per mV
JSQ -215, JSQ -225: 0.5 µmol m^{-2} s^{-1} per mV

Multiply this calibration factor by the measured mV signal to convert sensor output to PPF in units of µmol m^{-2} s^{-1}:

Calibration Factor (0.5 µmol m^{-2} s^{-1} per mV) * Sensor Output Signal (mV) = PPF (µmol m^{-2} s^{-1})

0.5 * 4000 = 2000



Example of PPF measurement with an quantum sensor. Full sunlight yields a PPF on a horizontal plane at the Earth's surface of approximately 2000 µmol m^{-2} s^{-1}. This yields an output signal of 4000 mV for the 0-5 V option or an output signal of 2000 mV for the 0-2.5 V option The signal is converted to PPF by multiplying by the calibration factor.

Spectral Errors and Yield Photon Flux Measurements:

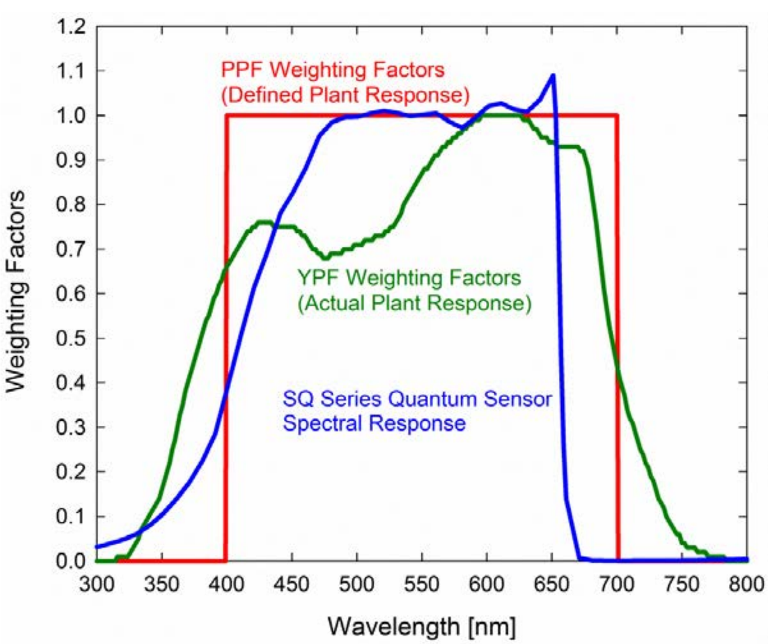
Quantum sensors are calibrated to measure PPF for either sunlight or electric light. The difference between the calibrations is 14 %. A sensor calibrated for electric lights (calibration source is T5 cool white fluorescent lamps) will read approximately 14 % low in sunlight.

In addition to PPF measurements, JSQ series quantum sensors can also be used to measure yield photon flux (YPF): photon flux weighted according to the plant photosynthetic action spectrum (McCree, 1972) and summed. YPF is also expressed in units of μmol m^{-2} s^{-1}, and is similar to PPF, but is typically more closely correlated to photosynthesis than PPF. PPF is usually measured and reported because the PPF spectral weighting function (equal weight given to all photons between 400 and 700 nm; no weight given to photons outside this range) is easier to define and measure, and as a result, PPF is widely accepted. The calibration factor for YPF is 0.9 μmol m^{-2} s^{-1} per mV for models JSQ-212 and JSQ-222, or 0.45 μmol m^{-2} s^{-1} per mV for models JSQ-215 and JSQ-225.

The weighting functions for PPF and YPF are shown in the graph below, along with the spectral response of JSQ series quantum sensors. The closer the spectral response matches the defined PPF or YPF spectral weighting functions, the smaller spectral errors will be. The table below provides spectral error estimates for PPF and YPF measurements from light sources different than the calibration source. The method of Federer and Tanner (1966) was used to determine spectral errors based on the PPF and YPF spectral weighting functions, measured sensor spectral response, and radiation source spectral outputs (measured with a spectroradiometer). This method calculates spectral error and does not consider calibration, cosine, and temperature errors.

Federer, C. A., and C. B. Tanner, 1966. Sensors for measuring light available for photosynthesis. Ecology 47:654-657.

McCree, K. J., 1972. The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. Agricultural Meteorology 9:191-216.



Radiation weighting factors for PPF (defined plant response to radiation), YPF (measured plant response to radiation), and JSQ Series quantum sensors (sensor sensitivity to different wavelengths of radiation).

Spectral Errors for PPF and YPF Measurements with JSQ Series Quantum Sensors

Radiation Source (Error Calculated Relative to Sun, Clear Sky)	PPF Error [%]	YPF Error [%]
Sun (Clear Sky)	0.0	0.0
Sun (Cloudy Sky)	1.4	1.6
Reflected from Grass Canopy	5.7	-6.3
Reflected from Deciduous Canopy	4.9	-7.0
Reflected from Conifer Canopy	5.5	-6.8
Transmitted below Grass Canopy	6.4	-4.5
Transmitted below Deciduous Canopy	6.8	-5.4
Transmitted below Conifer Canopy	5.3	2.6
Radiation Source (Error Calculated Relative to Cool White Fluorescent, T5)		
Cool White Fluorescent (T5)	0.0	0.0
Cool White Fluorescent (T8)	-0.3	-1.2
Cool White Fluorescent (T12)	-1.4	-2.0
Compact Fluorescent	-0.5	-5.3
Metal Halide	-3.7	-3.7
Ceramic Metal Halide	-6.0	-6.4
High Pressure Sodium	0.8	-7.2
Blue LED (448 nm peak, 20 nm full-width half-maximum)	-12.7	8.0
Green LED (524 nm peak, 30 nm full-width half-maximum)	8.0	26.2
Red LED (635 nm peak, 20 nm full-width half-maximum)	4.8	-6.2
Red, Blue LED Mixture (85 % Red, 15 % Blue)	2.4	-4.4
Red, Green, Blue LED Mixture (72 % Red, 16 % Green, 12 % Blue)	3.4	0.2
Cool White Fluorescent LED	-4.6	-0.6
Neutral White Fluorescent LED	-6.7	-5.2
Warm White Fluorescent LED	-10.9	-13.0

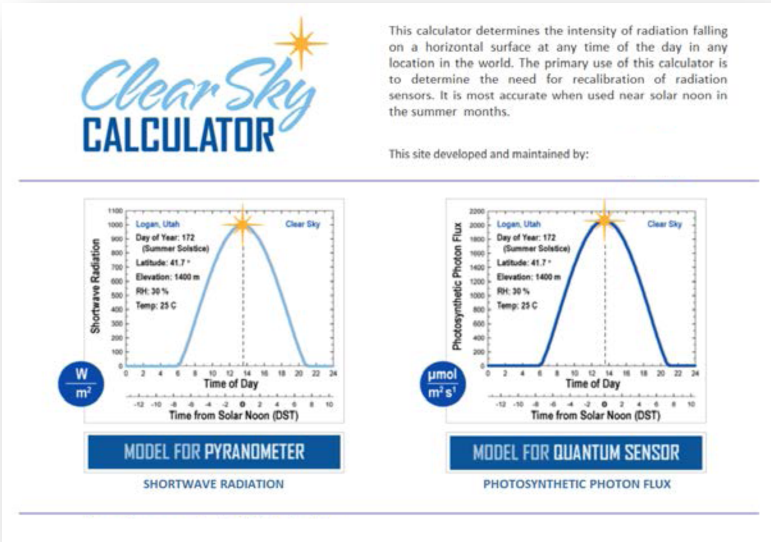
Quantum sensors can be a very practical means of measuring PPF and YPF from multiple radiation sources, but spectral errors must be considered. The spectral errors in the table above can be used as correction factors for individual radiation sources.

MAINTENANCE AND RECALIBRATION

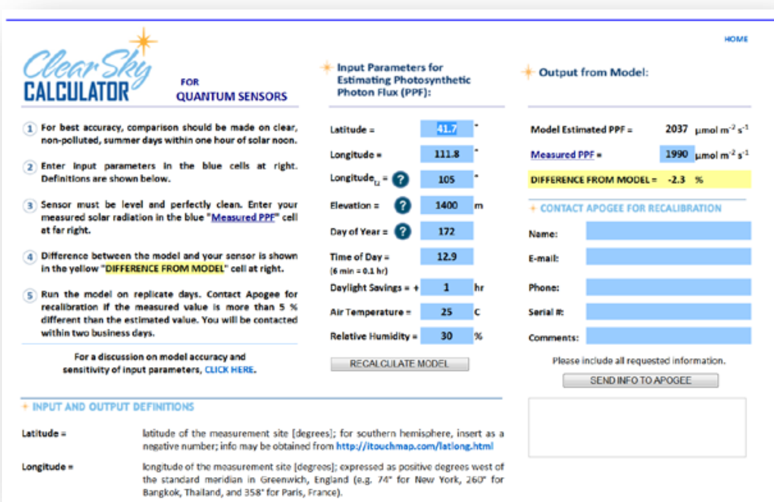
Moisture or debris on the diffuser is a common cause of low readings. The sensor has a domed diffuser and housing for improved self-cleaning from rainfall, but materials can accumulate on the diffuser (e.g., dust during periods of low rainfall, salt deposits from evaporation of sea spray or sprinkler 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 quantum sensor recalibration. It determines PPF 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 PPF can exceed values predicted by the Clear Sky Calculator due to reflection from the sides and edges of clouds. This reflection increases the incoming 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 PPF measureme nts to calculated PPF values for a clear sky. If sensor PPF 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.



Homepage of the Clear Sky Calculator. Two calculators are available: one for quantum sensors (PPF) and one for pyranometers (total shortwave radiation).



Clear Sky Calculator for quantum sensors. Site data are input in blue cells in middle of page and an estimate of PPF is returned on right-hand side of page.

TROUBLESHOOTING AND CUSTOMER SUPPORT

Independent Verification of Functionality:

JSQ-200 series quantum sensors provide an amplified voltage output that is proportional to incident PPF. 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):

JSQ-200 series quantum sensors are calibrated with a standard calibration factor of 1.0 µmol m^{-2} s^{-1} per mV (JSQ-212 and JSQ-222) or 0.5 µmol m^{-2} s^{-1} per mV (JSQ-215 and JSQ-225), yielding a sensitivity of 1 mV per µmol m^{-2} s^{-1} or 2mV per µmol m^{-2} s^{-1}, respectively. Thus, a compatible measurement device (e.g., datalogger or controller) should have resolution of at least 1 mV in order to provide PPF resolution of 1 µmol m^{-2} s^{-1}.

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 greater than 1 mega-ohm there is negligible effect on the calibration, even after adding up to 100 m of cable. All sensors use shielded, twisted pair cable to minimize electromagnetic interference. For best measurements, the shield wire must be connected to an earth ground. This is particularly important when using the sensor with long lead lengths in electromagnetically noisy environments.

Unit Conversion Charts:

JSQ series quantum sensors are calibrated to measure PPF in units of µmol m^{-2} s^{-1}. It is possible to convert the PPF value to units of light quantity (e.g., footcandles or lux), but it requires conversion factors that are specific to the radiation source of interest. These conversion factors can be found in the Knowledge.

WARRANTY POLICY

What is Covered

All products manufactured are warranted to be free from defects in materials and craftsmanship for a period of four (4) years from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated either at our factory or by an authorized distributor.

What is Not Covered

The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation or abuse.

2. Operation of the instrument outside of its specified operating range.

3. Natural occurrences such as lightning, fire, etc.

4. Unauthorized modification.

5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

Who is Covered

This warranty covers the original purchaser of the product or other party who may own it during the warranty period.

What We Will Do

At no charge we will:

1. Either repair or replace (at our discretion) the item under warranty.

2. Ship the item back to the customer by the carrier of our choice.

Different or expedited shipping methods will be at the customer’s expense.