OWNER'S MANUAL

USB QUANTUM SENSOR

Model JSQ-420

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CERTIFICATE OF COMPLIANCE

EU Declaration of Conformity

Models: JSQ-420
Type: Quantum Sensor

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).

INTRODUCTION

Radiation that drives photosynthesis is called photosynthetically active radiation (PAR) and is typically defined as total radiation between 400 and 700 nm. PAR is often expressed as photosynthetic photon flux density (PPFD): 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 PPFD as µmol m^{-2} s^{-1} is preferred.

The acronym PPF is also widely used and refers to the photosynthetic photon flux. The acronyms PPF and PPFD refer to the same parameter. The two terms have co-evolved because there is not a universal definition of the term “flux”. Some physicists define flux as per unit area per unit time. Others define flux only as per unit time. We have used PPFD in this manual because we feel that it is better to be more complete and possibly redundant.

Sensors that measure PPFD are often called **quantum sensors**. A quantum is the minimum quantity of radiation (one photon), necessary to cause a physical, electrical, or chemical reaction (e.g., absorption by photosynthetic pigments). So one photon is a single quantum of radiation.

The Quantum Sensor consists 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. The sensor is potted solid with no internal air space. It is designed for continuous PPFD measurement in indoor, outdoor and underwater environments. The JSQ-420 sensor output increases linearly with PPFD under sunlight (natural setting) or electric lights (electric setting). The signal from the sensor is directly proportional to radiation incident on a flat surface where the radiation comes from all angles of a hemisphere.

SENSOR MODELS

This manual covers the USB quantum sensor model JSQ-420. For additional models see JSQ-100/JSQ-300 series, JSQ-212/SQ-222 and JSQ-215/JSQ-225, and JSQ-214/JSQ-224 manuals.

Model	Signal	Calibration
HSQ-420	**USB**	**Sunlight and Electric light**
JSQ-110	Self-powered	Sunlight
JSQ-120	Self-powered	Electric light
JSQ-212	0-2.5 V	Sunlight
JSQ-222	0-2.5 V	Electric light
JSQ-214	4-20 mA	Sunlight
JSQ-224	4-20 mA	Electric light
JSQ-215	0-5 V	Sunlight
JSQ-225	0-5 V	Electric light
JSQ-311	Self-powered	Sunlight
JSQ-321	Self-powered	Electric light
JSQ-313	Self-powered	Sunlight
JSQ-323	Self-powered	Electric light
JSQ-316	Self-powered	Sunlight
JSQ-326	Self-powered	Electric light

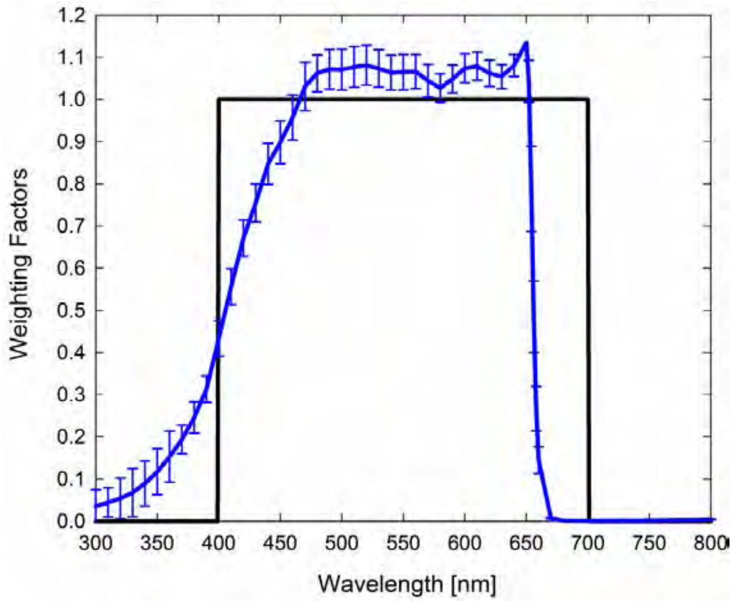
SPECIFICATIONS

	JSQ-420
Resolution	0.1 µmol m^{-2} s^{-1}
Calibration Factor	Custom for each sensor and stored in the firmware
Calibration Uncertainty	± 5 % (see calibration Traceability below)
Measurement Repeatability	Less than 1 %
Long-term Drift (Non-stability)	Less than 2 % per year
Non-linearity	Less than 1 % (up to 3000 µmol m^{-2} s^{-1})
Response Time	Software updates every second
Field of View	180º
Spectral Range	410 to 655 nm (wavelengths where response is greater than 50 % of maximum; see Spectral Response below)
Directional (Cosine) Response	± 5 % at 75º 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	24 mm diameter; 28 mm height
Mass	Sensor head weighs 90 g
USB Cable	4.6 m (15 ft)
Current Draw (when Logging)	2.1 mA

Calibration Traceability

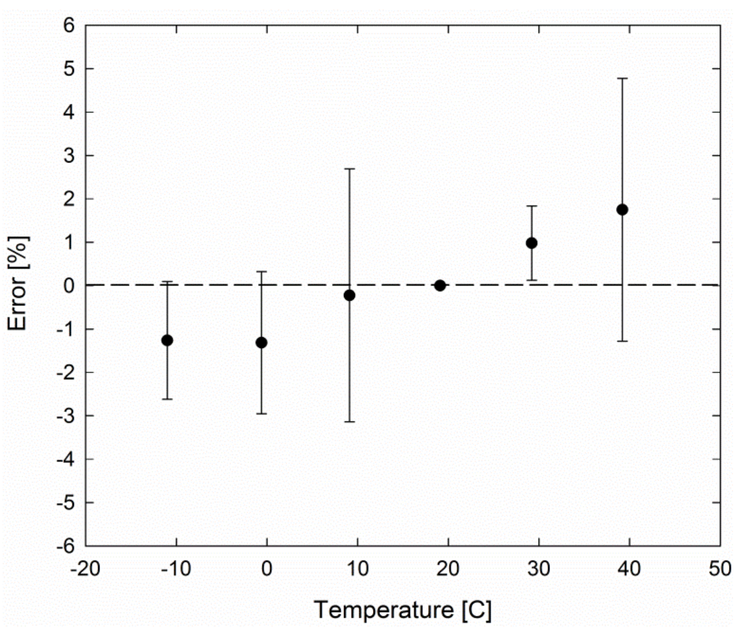
JSQ series sensors are calibrated through side-by-side comparison to the mean of four Apogee model SQ-110 or SQ-120 transfer standard quantum sensors under high output T5 cool white fluorescent lamps. The transfer standard quantum sensors are calibrated through side-by-side comparison to the mean of at least three LI-COR model LI-190R reference quantum sensors under high output T5 cool white fluorescent lamps. The reference quantum sensors are recalibrated every 6 months 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



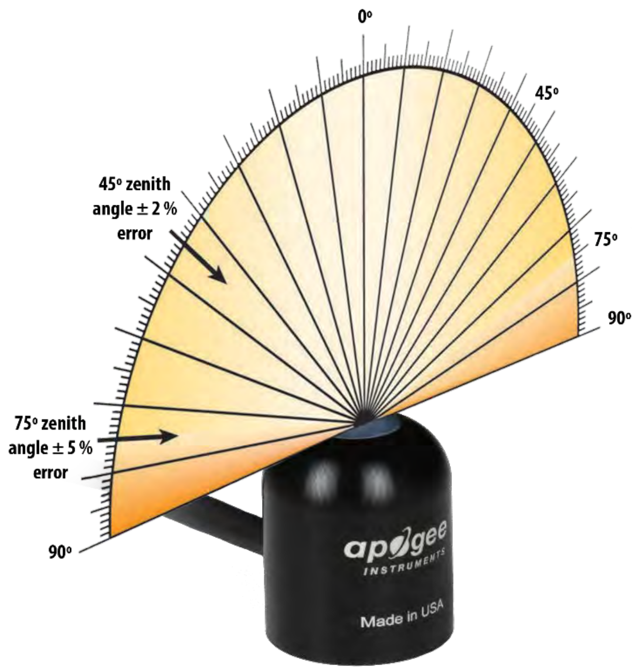
Mean spectral response of six sensors (***error bars represent two standard deviations above and below mean***) compared to PAR (PPFD) weighting function. Spectral response measurements were made at 10 nm increments across a wavelength range of 300 to 800 nm in a monochromator with an attached electric 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

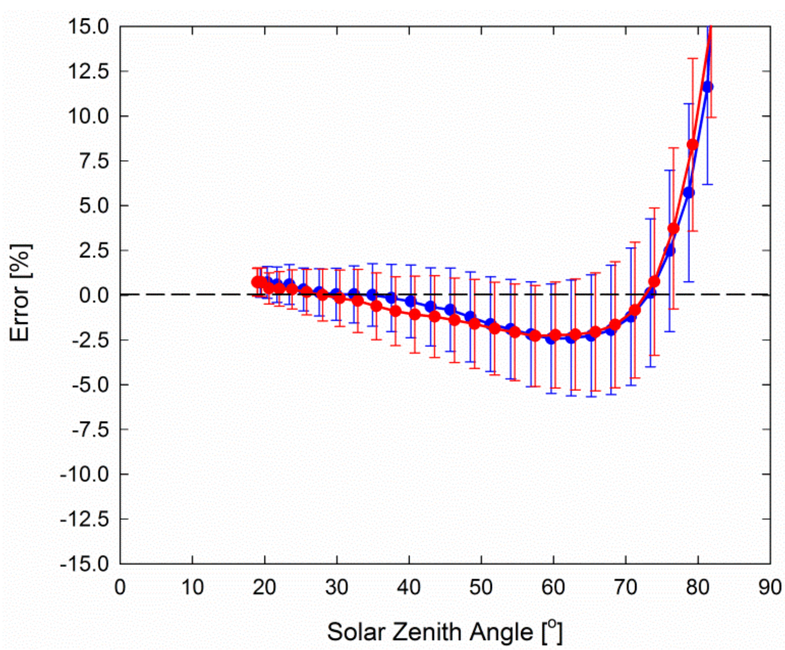


Mean temperature response of eight replicate sensors (***errors bars represent two standard deviations above and below mean***). Temperature response measurements were made at 10 C intervals across a temperature range of -10 to 40 C in a temperature controlled chamber under a fixed, broad spectrum, electric 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 measurements.

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.

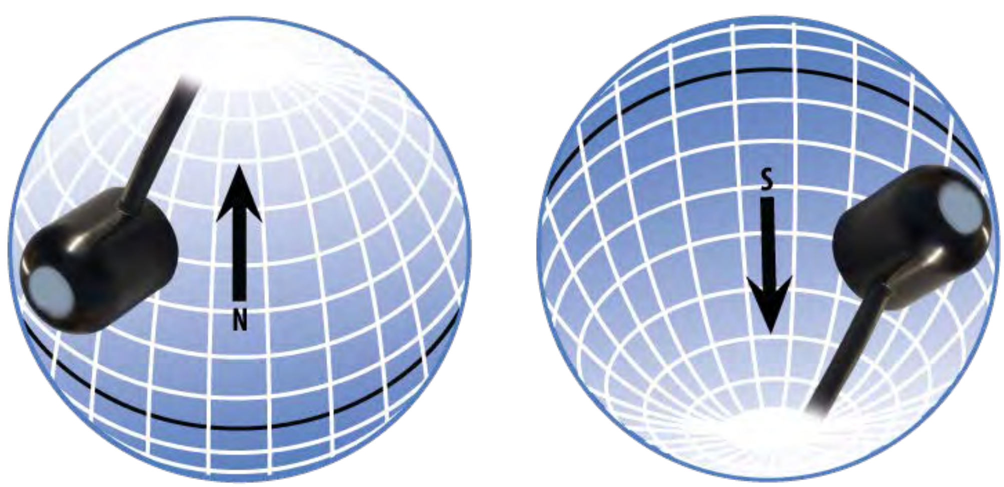


Mean cosine response of twenty-three replicate sensors (***error bars represent two standard deviations above and below mean***). Cosine response measurements were made by direct side-by-side comparison to the mean of four reference thermopile pyranometers, with solar zenith angle-dependent factors applied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

DEPLOYMENT AND INSTALLATION

Mount the sensor to a solid surface with the nylon mounting screw provided. To accurately measure PPFD 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.

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.

SOFTWARE INSTALLATION

Installing the software on a PC

1. Double click on the installer package:
2. On the 'Welcome' screen, please click 'Next' to continue.
3. Select the radio button next to "I Agree" to the UELA… and click 'Next' to continue.
4. On the 'Ready to Install the Program' screen, click 'Install' to continue.
5. Click 'Finish' to complete the installation. There are shortcuts on your desktop and in your start bar.

Installing the software on a Mac

The software will automatically download.

OPERATION AND MEASUREMENT

Spectral Errors and Yield Photon Flux Measurements

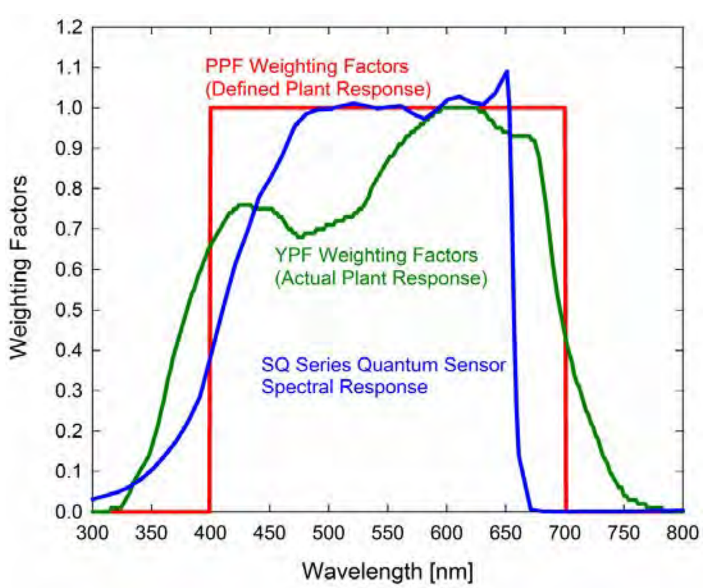
Apogee quantum sensors are calibrated to measure PPFD for either sunlight or electric light. The difference between the calibrations is 12 %. A sensor calibrated for electric lights (calibration source is T5 cool white fluorescent lamps) will read approximately 12 % low in sunlight.

In addition to PPFD measurements, JSQ series quantum sensors can also be used to measure yield photon flux density (YPFD): photon flux weighted according to the plant photosynthetic action spectrum (McCree, 1972) and summed. YPFD is also expressed in units of µmol m^{-2} s^{-1}, and is similar to PPFD, but is typically more closely correlated to photosynthesis than PPFD. PPFD is usually measured and reported because the PPFD 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, PPFD is widely accepted. The calibration factor for YPFD is 10 % lower than the calibration factor for PPFD.

The weighting functions for PPFD and YPFD are shown in the graph below, along with the spectral response of JSQ series quantum sensors. The closer the spectral response matches the defined PPFD or YPFD spectral weighting functions, the smaller spectral errors will be. The table below provides spectral error estimates for PPFD and YPFD 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 PPFD and YPFD 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.

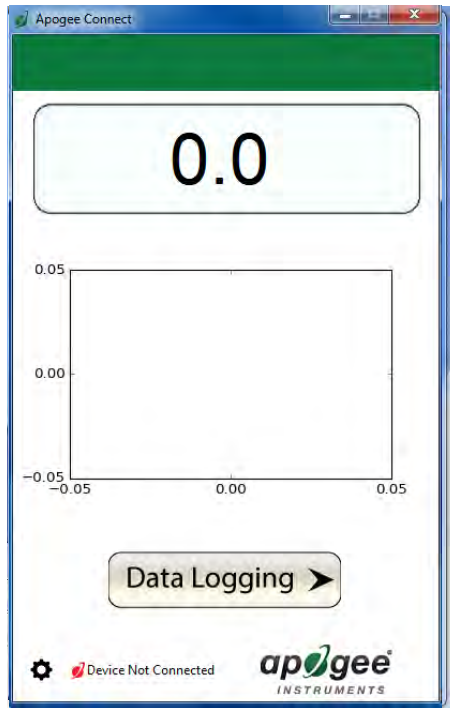
McCree, K. J., 1972. The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. Agricultural Meteorology 9:191-216.



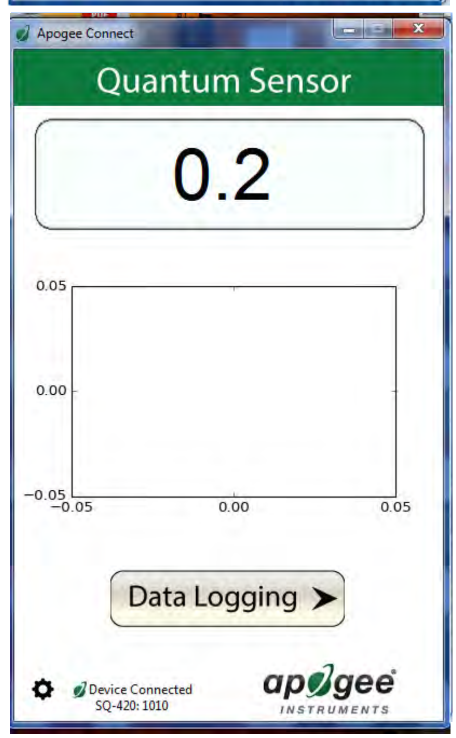
Radiation weighting factors for PPFD (defined plant response to radiation), YPFD (measured plant response to radiation), and JSQ Series quantum sensors (sensor sensitivity to different wavelengths of radiation).

WINDOWS SOFTWARE

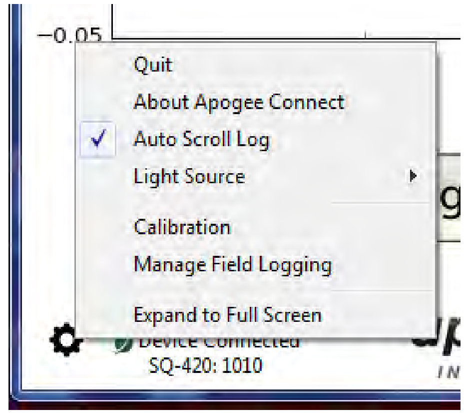
When the JSQ-420 sensor is not plugged into the USB port, the software will display a message in the lower left corner, “Device Not Connected,” indicating it cannot establish communication with the sensor.



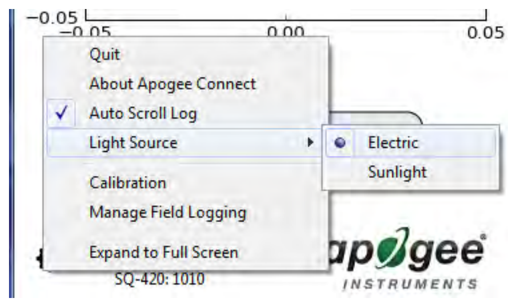
Plug the sensor into a USB port and allow some time for the sensor to automatically establish communication with the software. Once established, the message in the lower left corner will display “Device Connected SN: ####” and real-time PAR readings will update on the screen. Moving the sensor closer to a light source should increase the readings, while blocking all light from the sensor should drop the reading to zero.



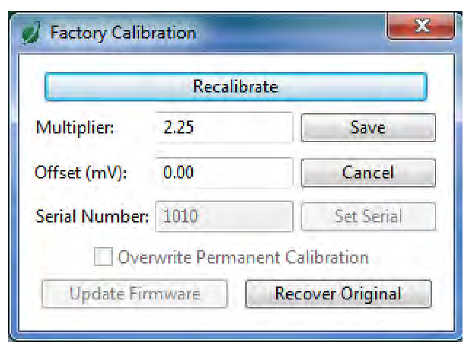
Click the '**Settings**' icon to display the software options.



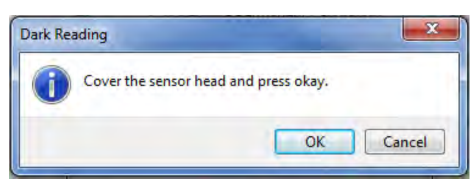
Clicking **'Light Source'** will allow the user to change the sensor's default calibration reference from Electric to Sunlight. Electric should be selected when measuring most indoor artificial light sources, while Sunlight should be selected when measuring sunlight (such as when evaluating the need for recalibration).



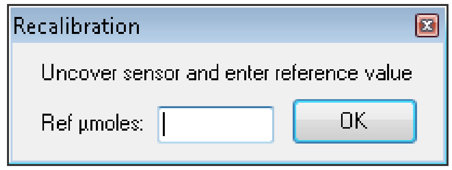
Clicking **'Calibration'** will display the factory calibrated multiplier and offset values. These values are saved in firmware and can be recovered by clicking the 'Recover Original' button. Deriving a new calibration multiplier and offset is accomplished by clicking the 'Recalibrate' button. This is applicable if users want to calibrate the sensor to their own specific light source. Note that a reference PAR value of the light source is required to complete a recalibration.



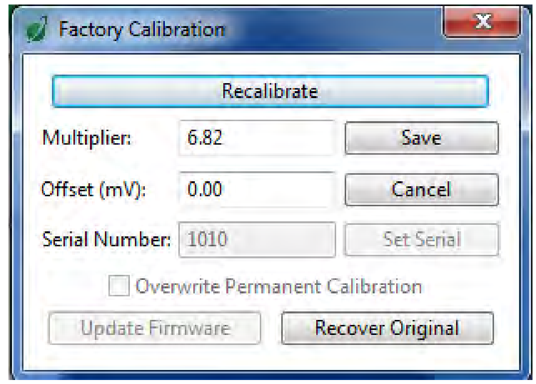
After clicking the 'Recalibate' button the user will be prompted to cover the sensor. Place a dark cap over the sensor and wait for the real-time PAR reading to settle at zero. Click OK.



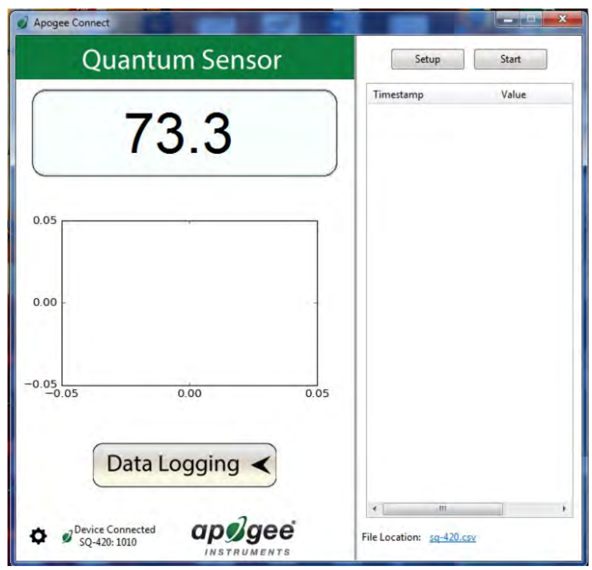
Uncover the sensor and wait for the PAR reading to settle ***before*** entering the reference value. Click OK.



The multiplier and offset values will automatically calculate and update in the appropriate field. Be sure to click 'Save' to retain the new multiplier and offset.

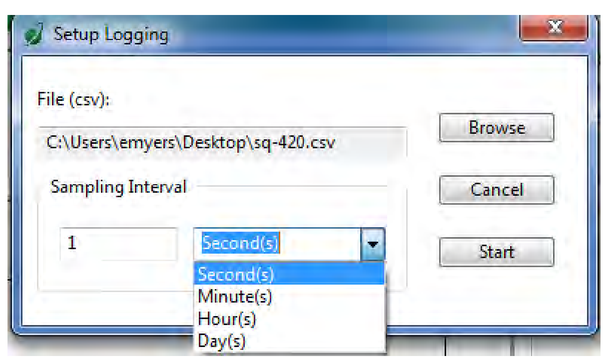


Clicking **'Data Logging'** will allow the user to log interval measurements in a csv file while the software is open and communicating with the sensor.



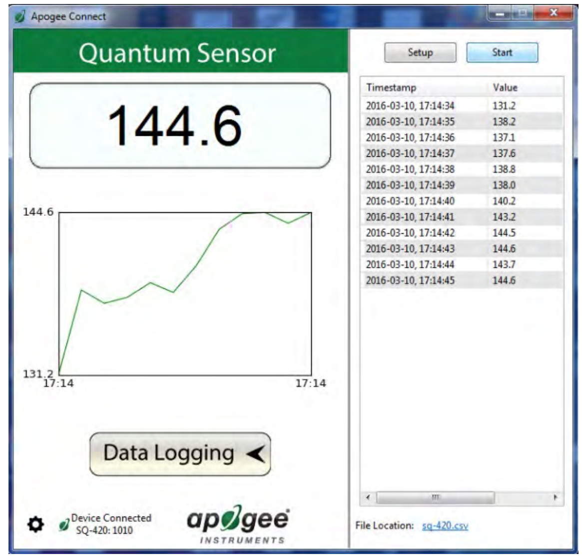
Click 'Setup' and the Setup Logging window appears. Click the 'Browse' button to create or select a csv file.

Select the desired sampling interval. Note that 1 second is the minimum interval allowed. Click 'Start'.



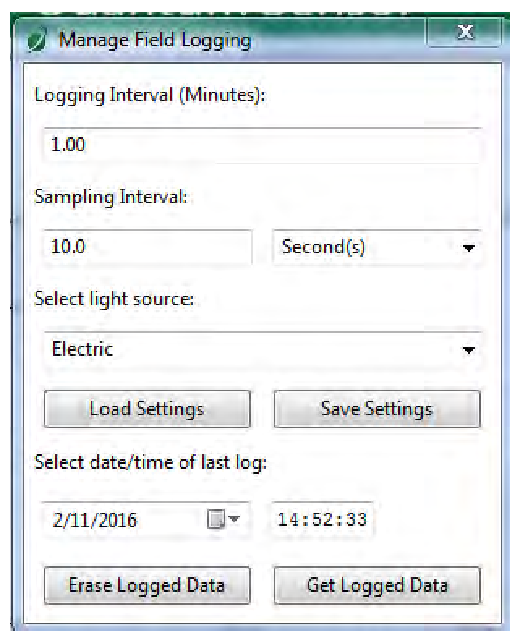
The data logging window will start to update at the specified sampling interval and display the Timestamp, Light Source, and Data Value. At the same time, data will be written to the csv file. Note that if the csv file is open in another program new data will not be saved to it.

The data logging window can be closed without affecting logged data by clicking the 'Exit' button. The 'Stop' button must be clicked to end data logging.

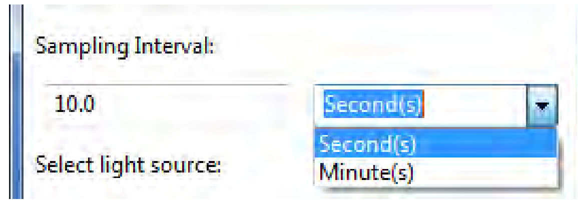


The about screen tells you the software and firmware versions. These can be used to help troubleshoot if problems arise.

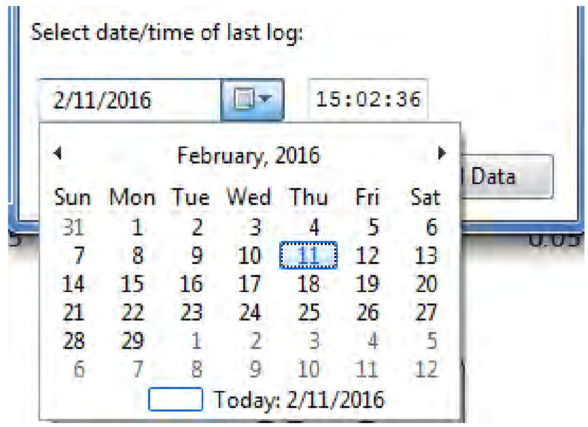
'Manage Field Logging' is used to setup the JSQ-420 for use in the field. When the JSQ-420 is supplied power from a USB power source it will log data which you can retrieve. Choose the interval that data is saved as well as the interval that data is sampled and the light source used. The shortest sampling interval is 1 second. The longest sampling or logging interval is 1440 minutes (1 day). Click 'Load Settings' to see current settings and 'Save Settings' to save the settings you want to the sensor. Note: If you don't click save the sensor won't change the settings.



Set the sampling interval in minutes or seconds. The sampling interval is how often a measurement is taken and logging interval is how often the data is saved. The logged data is the average of the samples. The logging interval must be evenly divided by the sampling interval. For example if the logging interval is 5 minutes and the sampling interval is 2 minutes it causes an error. But a sampling interval of 1 minute is acceptable.



Before clicking 'Get Logged Data' it is important to set the time of the last logged data point. This is used to back calculate the timestamps for the remaining data points. If you just unplugged the sensor and plugged it into the computer the preloaded day and time should be sufficient.



Click **'Get Logged Data'** to save the data to your computer. You will be asked where you want to save the data.

Click **'Erase Data'** to erase all the saved data. This can't be undone.

To use additional JSQ-420 devices, open additional ApogeeConnect software windows. The device serial number will display in the lower left hand corner of the corresponding software window. Devices may be selected by serial number in the tool bar.

MAC SOFTWARE

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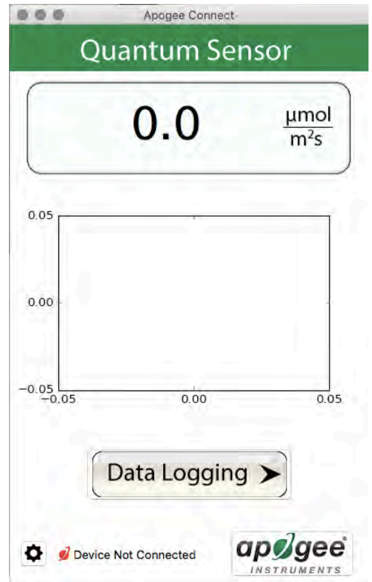
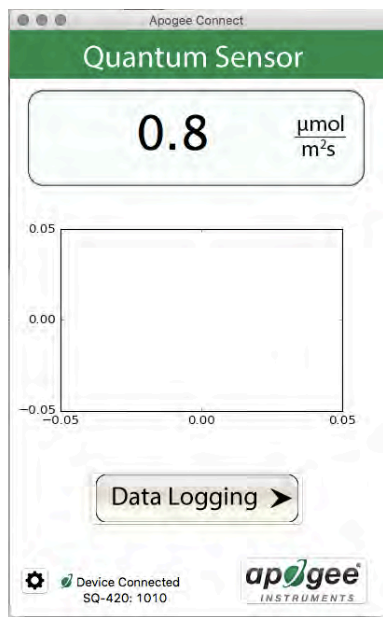


Plug the sensor into a USB port and allow some time for the sensor to automatically establish communication with the software. Once established, the message in the lower left corner will display “Device Connected Model: SN ####” and real-time PAR readings will update on the screen. Moving the sensor closer to a light source should increase the readings, while blocking all light from the sensor should drop the reading to zero.



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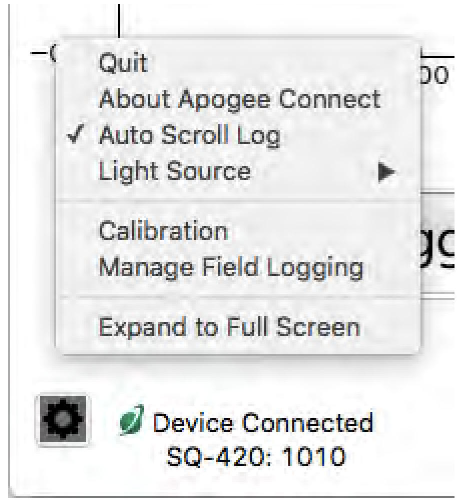

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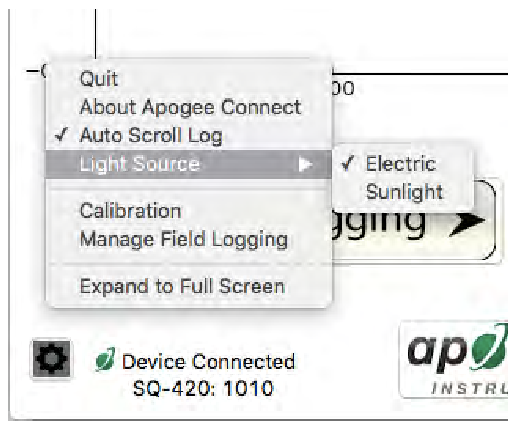

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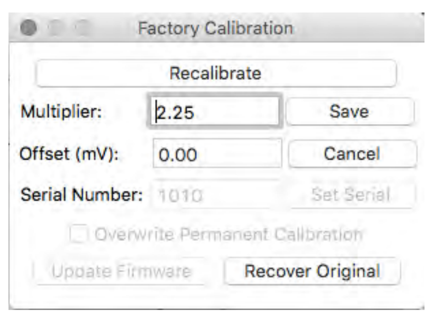

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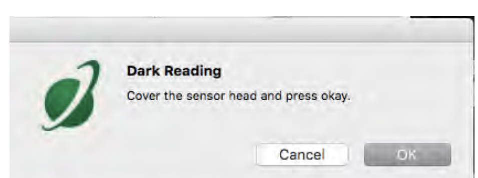

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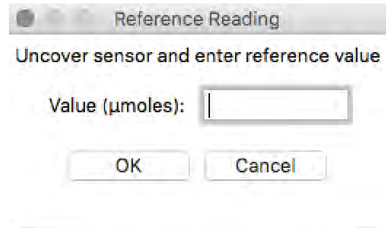

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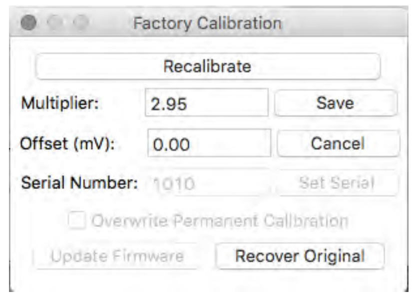

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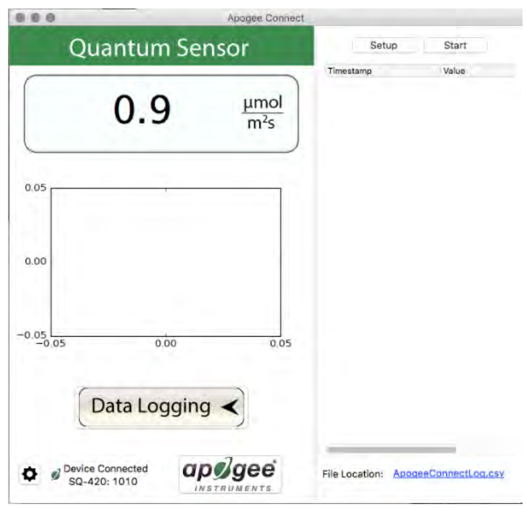

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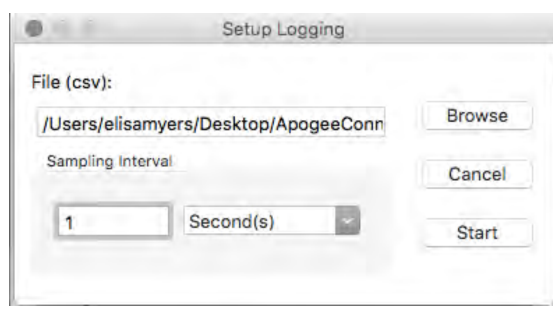

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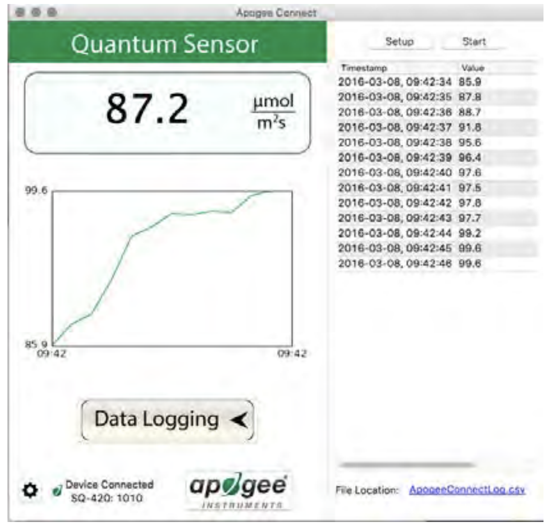

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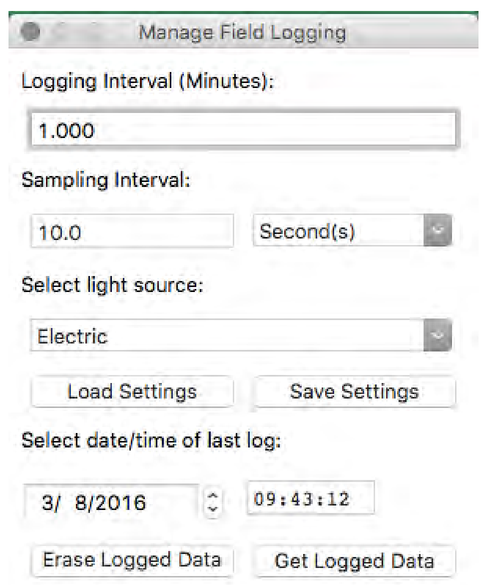

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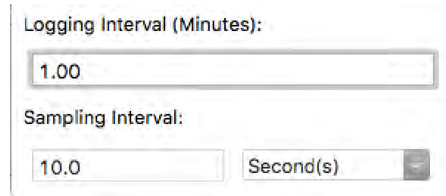
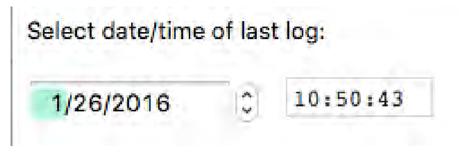


Before clicking 'Get Logged Data' it is important to set the time of the last logged data point. This is used to back calculate the timestamps for the remaining data points. If you just unplugged the sensor and plugged it into the computer the preloaded day and time should be sufficient.



Click '**Get Logged Data**' to save the data to your computer. You will be asked where you want to save the data.

Click '**Erase Data**' to erase all the save data. This can't be undone.

To use additional JSQ-420 devices, open additional ApogeeConnect software windows. The device serial number will display in the lower left hand corner of the corresponding software window. Devices may be selected by serial number in the tool bar.

Spectral Errors for PAR Measurements with HSQ Quantum Sensors

The JSQ-420 quantum sensors are calibrated to measure PAR for either sunlight (natural setting) or electric light. The difference between the calibrations is 12 %. A sensor calibrated for electric lights (calibration source is T5 cool white fluorescent lamps) will read approximately 12 % low in sunlight (natural setting).

Radiation Source (Error Calculated Relative to Sun, Clear Sky)	**PPFD Error [%]**	**YPFD 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 PAR 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.