



## OWNER'S MANUAL

# Field Spectroradiometer

SS-200-SS

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APOGEE INSTRUMENTS, INC. | 721 WEST 1800 NORTH, LOGAN, UTAH 84321, USA  
TEL: (435) 792-4700 | FAX: (435) 787-8268 | WEB: APOGEEINSTRUMENTS.COM

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## INTRODUCTION

Spectral (i.e., wavelength-dependent) radiation is the intensity of output from a radiation source (e.g., sun, electric lamp, reflected radiation from a surface of interest) as a function of wavelength. Radiation spectra vary for different radiation sources and conditions. Radiation spectra can be used to characterize radiation sources.

Spectrometers measure relative spectral radiation over a specified wavelength range. Spectroradiometers are spectrometers calibrated to output spectral measurements in absolute units (e.g., energy flux density in  $\text{W m}^{-2} \text{nm}^{-1}$  or photon flux density in  $\mu\text{mol m}^{-2} \text{s}^{-1} \text{nm}^{-1}$ ). Typical applications of spectroradiometers include measurement of spectral output from radiation sources used to grow plants, algae, and corals (e.g., in greenhouses, growth chambers, and aquariums), measurement of solar spectra with changing atmospheric conditions, and measurement of spectral reflectance on stationary (e.g., agricultural or ecological weather stations and flux towers) and mobile (e.g., plant phenotyping) platforms.

Apogee Instruments model SS-200-SS (350 to 850 nm measurement range) spectroradiometers are small, lightweight units designed for laboratory and outdoor field use. Each spectroradiometer consists of a line-scan photodetector array and diffuser mounted in an anodized aluminum housing. Each unit is calibrated to provide spectral measurements in absolute units. Onboard circuitry allows for output via USB-C or Modbus.

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## CERTIFICATE OF COMPLIANCE

## SPECIFICATIONS

|                                     |                                                                                                                                                                                                                                                                                         |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cosine Response                     | ± 5 % at 75° zenith angle                                                                                                                                                                                                                                                               |
| Wavelength Range                    | 350-849 nm                                                                                                                                                                                                                                                                              |
| Measurement Reporting Options       | Isolated Wavelengths, PAR, Red/Far-red Ratio, Lux, and more                                                                                                                                                                                                                             |
| Ingress Protection Rating           | IP65                                                                                                                                                                                                                                                                                    |
| Wavelength Data Increment           | 1 nm interpolated values                                                                                                                                                                                                                                                                |
| Spectral Bandwidth                  | 12 nm                                                                                                                                                                                                                                                                                   |
| Wavelength Accuracy                 | ± 2 nm                                                                                                                                                                                                                                                                                  |
| Temperature Stability               | ± 2 %                                                                                                                                                                                                                                                                                   |
| Non-linearity                       | Less than 1 % (up to 4000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ )                                                                                                                                                                                                                        |
| Pixel Resolution                    | Approximately 2 nm                                                                                                                                                                                                                                                                      |
| Measurement Range                   | PPFD: 0.1 to 3,500 $\mu\text{mol m}^{-2} \text{s}^{-1}$ ; Lux: 5 to 190,000 lx                                                                                                                                                                                                          |
| Calibration Uncertainty             | ± 10% (400-800 nm)                                                                                                                                                                                                                                                                      |
| Measurement Repeatability           | Less than 1%                                                                                                                                                                                                                                                                            |
| Sampling Speed                      | 100 ms plus the integration time                                                                                                                                                                                                                                                        |
| Automatic Integration Time Range    | Up to 1,000 ms                                                                                                                                                                                                                                                                          |
| Automatic Integration Time Response | 5 to 25 seconds                                                                                                                                                                                                                                                                         |
| Startup Time                        | Up to 30 seconds                                                                                                                                                                                                                                                                        |
| Operating Environment               | -20 to 50°C, 0 to 100% relative humidity                                                                                                                                                                                                                                                |
| Storage Temperature                 | -10 to 40°C, relative humidity 70 % or less without condensation                                                                                                                                                                                                                        |
| Calculations                        | Calculates 16 metrics/indices: PFD UV (350-399 nm), PFD Blue (400-499), PFD Green (500-599), PFD Red (600-700), PFD FR (701-800), PFD PFR (701-750), PAR (400-700), ePAR (400-750), Total PFD (350-850), YPFD, PPE, iPPE, Lux, Foot Candle, Far Red Fraction, and Red to Far Red Ratio. |
| Measurement Units                   | Watts/m <sup>2</sup> , $\mu\text{mol/m}^2$ , and Relative                                                                                                                                                                                                                               |
| Detector                            | CMOS Linear Image Sensor                                                                                                                                                                                                                                                                |
| Housing                             | Aluminum with Cerakote and anodized finishes; Sintered quartz diffuser                                                                                                                                                                                                                  |
| Current Usage                       | 58-62 mA DC at 12 V                                                                                                                                                                                                                                                                     |
| Cable                               | 6-conductor (5 wire), shielded, twisted-pair wire; TPR jacket; pigtail lead wires; stainless steel 316 connector                                                                                                                                                                        |
| Field Reliability/Adaptation        | Auto integration and temperature compensation                                                                                                                                                                                                                                           |
| Output                              | USB-C, Modbus RS485, and Modbus RS232                                                                                                                                                                                                                                                   |
| Input Voltage Range                 | 5 to 24 VDC                                                                                                                                                                                                                                                                             |
| Mass                                | 158 grams                                                                                                                                                                                                                                                                               |
| Dimensions                          | 48.8 mm length, 48.8 mm width, 45.8 mm height                                                                                                                                                                                                                                           |
| Warranty                            | 4 Years                                                                                                                                                                                                                                                                                 |
| Support                             | Firmware Updates, Apogee Connect App                                                                                                                                                                                                                                                    |

## DEPLOYMENT AND INSTALLATION

### Mounting Hardware

The field spectroradiometer is compatible with the AL-110 leveling plate, the AL-140 mounting bracket (pictured below), and the AM-410 spectroradiometer angling/downward bracket (pictured below).



AL-140

AL-140



### Accessories

The Aurora field spectroradiometer can be mounted in any direction, including towards a surface to measure its reflectance. Common applications include crop and vegetation monitoring, water quality assessment, snow and ice characterization, soil and mineral mapping, building material studies, and satellite calibration and validation. We recommend using the AS-005 Field of View Restrictor to obtain better reflectance data. This restricts the field of view from 180° to approximately 30°.

### Software (USB Communication)

To use the spectroradiometer's USB communication with a computer, download the latest Apogee Connect software at <https://www.apogeeinstruments.com/downloads/>. This has download options for both Windows and Mac.

An Apogee Connect user guide is found in the Operation and Measurement portion of this manual.

### Wiring (Modbus Communication)

Apogee's Field Spectroradiometer utilizes Modbus output, where measurements are returned in digital format. This requires a measurement device with a Modbus interface that supports the Read Holding Registers (0x03) function.



The Green wire should be connected to Ground to enable RS-485 communication, or it should be connected to 12 V power for RS-232 communication. Text for the White and Blue wires above refers to the port that the wires should be connected to.

Modbus instructions are found in the Operation and Measurement portion of this manual.

### Sensor Calibration

Each Apogee Aurora field spectroradiometer has sensor-specific calibration factors determined during the custom calibration process. An array of 500 wavelength calibration factors and a sensor-specific temperature response regression equation for temperature corrections are programmed into the sensor at the factory.

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## OPERATION AND MEASUREMENT

### Modbus Overview

The primary idea of the Modbus interface is that each sensor exists at an address and appears as a table of values. These values are called Registers. Each value in the table has an associated index, and that index is used to identify which value in the table is being accessed.

### Modbus Interface

The following is a brief explanation of the Modbus protocol instructions used in Apogee SQ-522 quantum sensors. For questions on the implementation of this protocol, please refer to the official serial line implementation of the Modbus protocol: <https://www.modbus.org/file/secure/modbusoverserial.pdf> (2006) and the general Modbus protocol specification: <https://www.modbus.org/file/secure/modbusprotocollspecification.pdf> (2012). Further information can be found at: <https://www.modbus.org/modbus-specifications>

### Sensor addresses

Each sensor is given an address from 1 to 247. Apogee sensors are shipped with a default address of 1. If using multiple sensors on the same Modbus line, the sensor's address will have to be changed by writing the Slave Address register.

### Register Index

Each register in a sensor represents a value in the sensor, such as a measurement or a configuration parameter. Some registers can only be read, some registers can only be written, and some can be both read and written. Each register exists at a specified index in the table for the sensor. Often this index is called an address, which is a separate address than the sensor address, but can be easily confused with the sensor address.

However, there are two different indexing schemes used for Modbus sensors, though translating between them is simple. One indexing scheme is called one-based numbering, where the first register is given the index of 1, and is thereby accessed by requesting access to register 1. The other indexing scheme is called zero-based numbering, where the first register is given the index 0, and is thereby accessed by requesting access to register 0. Apogee Sensors use zero-based numbering. However, if using the sensor in a system that uses one-based numbering, such as using a CR1000X logger, adding 1 to the zero-based address will produce the one-based address for the register.

### Register Format

According to the Modbus protocol specification, Holding Registers (the type registers Apogee sensors contain) are defined to be 16 bits wide. However, when making scientific measurements, it is desirable to obtain a more precise value than 16 bits allows. Thus, several Modbus implementations will use two 16-bit registers to act as one 32-bit register. Apogee Modbus sensors use this 32-bit implementation to provide measurement values as 32-bit IEEE 754 floating point numbers.

Apogee Modbus sensors also contain a redundant, duplicate set of registers that use 16-bit signed integers to represent values as decimal-shifted numbers. It is recommended to use the 32-bit values, if possible, as they contain more precise values.

### Communication Parameters

Apogee Sensors communicate using the Modbus RTU variant of the Modbus protocol. The default communication parameters are as follows:

Slave address: 1  
Baudrate: 19200  
Data bits: 8  
Stop bits: 1  
Parity: Even

Byte Order: Big-Endian (most significant byte sent first)

The baudrate and slave address are user configurable. **Valid slave addresses are 1 to 247. Since the address 0 is reserved as the broadcast address, setting the slave address to 0 will actually set the slave address to 1.** (This will also reset factory-calibrated values and should **NOT** be done by the user unless otherwise instructed.)

### Reading Measurements

To retrieve a measurement, the 'Take Measurement' command (register 76, see table below) must be written first. Each read requires this sequence to be repeated: write register 76, then write the desired register.

### Modbus Registers

Note: Some registers return values that are scaled to maintain decimal precision. For example, a measurement normally expressed as 1.234 may be reported as 1234 (in other words, it was multiplied by 1000). In these cases, a scale factor is listed. Divide the received number by the listed factor to obtain the actual value.

| Read Only Registers (function code 0x3) |                                                           |                   |                                         |
|-----------------------------------------|-----------------------------------------------------------|-------------------|-----------------------------------------|
| Float Registers                         |                                                           | Integer Registers |                                         |
| 0<br>1                                  | PFD_Ultra_Violet                                          | 80                | PFD_Ultra_Violet<br>Factor: 10          |
| 2<br>3                                  | PFD_Blue                                                  | 81                | PFD_Blue<br>Factor: 10                  |
| 4<br>5                                  | PFD_Green                                                 | 82                | PFD_Green<br>Factor: 10                 |
| 6<br>7                                  | PFD_Red                                                   | 83                | PFD_Red<br>Factor: 10                   |
| 8<br>9                                  | PFD_Far_red                                               | 84                | PFD_Far_red<br>Factor: 10               |
| 10<br>11                                | PFD_Total                                                 | 85                | PFD_Total<br>Factor: 10                 |
| 12<br>13                                | PAR                                                       | 86                | PAR<br>Factor: 10                       |
| 14<br>15                                | ePAR [mmol m <sup>-2</sup> s <sup>-1</sup> ] (400-750 nm) | 87                | YPFD<br>Factor: 10                      |
| 16<br>17                                | YPFD                                                      | 88                | Hardware version<br>Factor: 10          |
| 18<br>19                                | PPE                                                       | 89                | PPE<br>Factor: 100                      |
| 20<br>21                                | Ippe                                                      | 90                | Ippe<br>Factor: 100                     |
| 22<br>23                                | Far Red Fraction                                          | 91                | Far Red Fraction<br>Factor: 100         |
| 24<br>25                                | Red to Far Red Ratio                                      | 92                | Red to Far Red Ratio<br>Factor: 100     |
| 26<br>27                                | Lux (lm m <sup>2</sup> )                                  | 93                | Lux (lm m <sup>2</sup> )<br>Factor: 0.1 |
| 28<br>29                                | Foot Candle (lm ft <sup>2</sup> )                         | 94                | Foot Candle (lm ft <sup>2</sup> )       |
| 30<br>31                                | Body Temperature                                          | 95                | Body Temperature                        |
| 32<br>33                                | Status                                                    | 96                | Status                                  |
| 46<br>47                                | Firmware Version                                          | 103               | Firmware Version<br>Factor: 10          |
| 48<br>49                                | Hardware Version                                          | 104               | Hardware Version                        |

|              |                                              |      |                                          |
|--------------|----------------------------------------------|------|------------------------------------------|
| 500<br>501   | Start of calibrated output (500-1498)        | 3000 | Start of calibrated output<br>Factor: 10 |
| 1500<br>1501 | Start of wavelength registers<br>(1500-2498) | 3500 | Start of wavelength registers            |

| Read/Write Registers (function codes 0x3 and 0x10) |                                                                                                           |                   |                                                                                                           |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------|
| Float Registers                                    |                                                                                                           | Integer Registers |                                                                                                           |
| 50<br>51                                           | Integration Time (ms)                                                                                     | 105               | Integration Time (ms)<br>Factor: 100                                                                      |
| 52<br>53                                           | Enable Auto Integration<br>(0 = disable, 1 = enable, must disable<br>before setting the integration time) | 106               | Enable Auto Integration<br>(0 = disable, 1 = enable, must disable<br>before setting the integration time) |
| 56<br>57                                           | Slave Address                                                                                             | 108               | Slave Address                                                                                             |
| 58<br>59                                           | Model Number*                                                                                             | 109               | Model Number*                                                                                             |
| 60<br>61                                           | Serial Number*                                                                                            | 110               | Serial Number*                                                                                            |
| 62<br>63                                           | baudrate (0 = 115200, 1 = 57600,<br>2 = 38400, 3 = 19200, 4 = 9600)<br>(Power Cycle Required after write) | 111               | baudrate (0 = 115200, 1 = 57600,<br>2 = 38400, 3 = 19200, 4 = 9600)<br>(Power Cycle Required after write) |
| 64<br>65                                           | parity<br>(0 = none, 1 = odd, 2 = even)<br>(Power Cycle Required after write)                             | 112               | parity<br>(0 = none, 1 = odd, 2 = even)<br>(Power Cycle Required after write)                             |
| 66<br>67                                           | number of stopbits<br>(1 or 2)<br>(Power Cycle Required after write)                                      | 113               | number of stopbits<br>(1 or 2)<br>(Power Cycle Required after write)                                      |
| 68<br>69                                           | Running Average                                                                                           | 114               | Running Average                                                                                           |
| 70<br>71                                           | Unit select (0 = W/m <sup>2</sup> , 1 = $\mu$ mol)                                                        | 115               | Unit select (0 = W/m <sup>2</sup> , 1 = $\mu$ mol)                                                        |

**\*Registers marked with an asterisk (\*) cannot be written to unless a specific procedure is followed. Contact Apogee Instruments to receive the procedure for writing these registers.**

| Write Only Registers (function codes 0x3 and 0x10) |                                  |                   |                                  |
|----------------------------------------------------|----------------------------------|-------------------|----------------------------------|
| Float Registers                                    |                                  | Integer Registers |                                  |
| 76<br>77                                           | Update Modbus data**             | 118               | Update Modbus Data**             |
| 78<br>79                                           | Dark Offset (0 = clear, 1 = set) | 119               | Dark Offset (0 = clear, 1 = set) |

**\*\*Before reading data from a register, write a value to the Update Modbus data register to refresh readings in the sensor memory.**

#### Packet Framing:

Apogee sensors use Modbus RTU packets and tend to adhere to the following pattern:

Slave Address (1 byte), Function Code (1 byte), Starting Address (2 bytes), Number of Registers (2 bytes), Data Length (1 byte, optional) Data (n bytes, optional)

Modbus RTU packets use the zero-based address when addressing registers.

For information on Modbus RTU framing, see the official documentation at  
<https://www.modbus.org/file/secure/modbusprotocollspecification.pdf>

#### Example Packets:

An example of a data packet sent from the controller to the sensor using function code 0x3 reading register address 0. Each pair of square brackets indicates one byte.

[Slave Address][Function][Starting Address High Byte][Starting Address Low Byte][No of Registers High Byte][No of Registers Low Byte][CRC High Byte][CRC Low Byte]

0x01 0x03 0x00 0x00 0x00 0x02 0xC4 0x0B

An example of a data packet sent from the controller to the sensor using function code 0x10 writing a 1 to register 26. Each pair of square brackets indicates one byte.

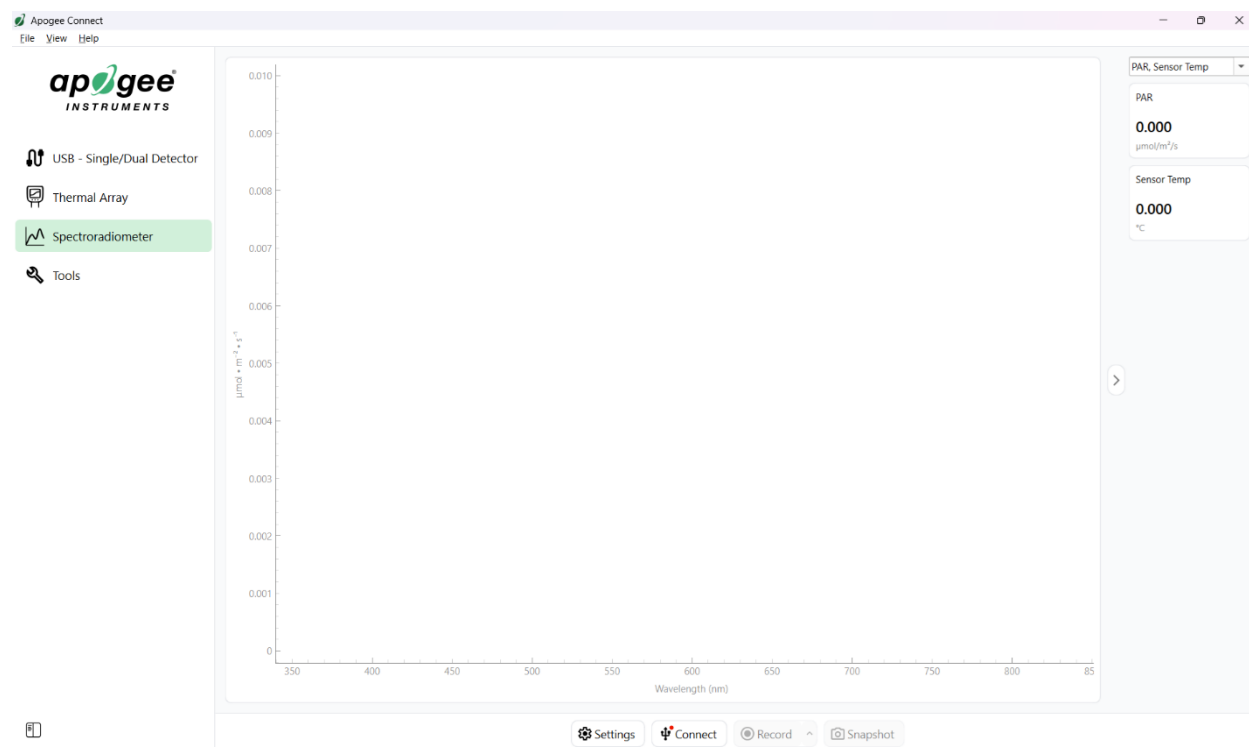
[Slave Address][Function][Starting Address High Byte][Starting Address Low Byte][No of Registers High Byte][No of Registers Low Byte][Byte Count][Data High Byte][Data Low Byte][Data High Byte][Data Low Byte][CRC High Byte][CRC Low Byte]

0x01 0x10 0x00 0x1A 0x00 0x02 0x04 0x3f 0x80 0x00 0x00 0x7f 0x20

## USB Setup and software

Step 1. Download the Apogee Connect software at <https://www.apogeeinstruments.com/downloads/>

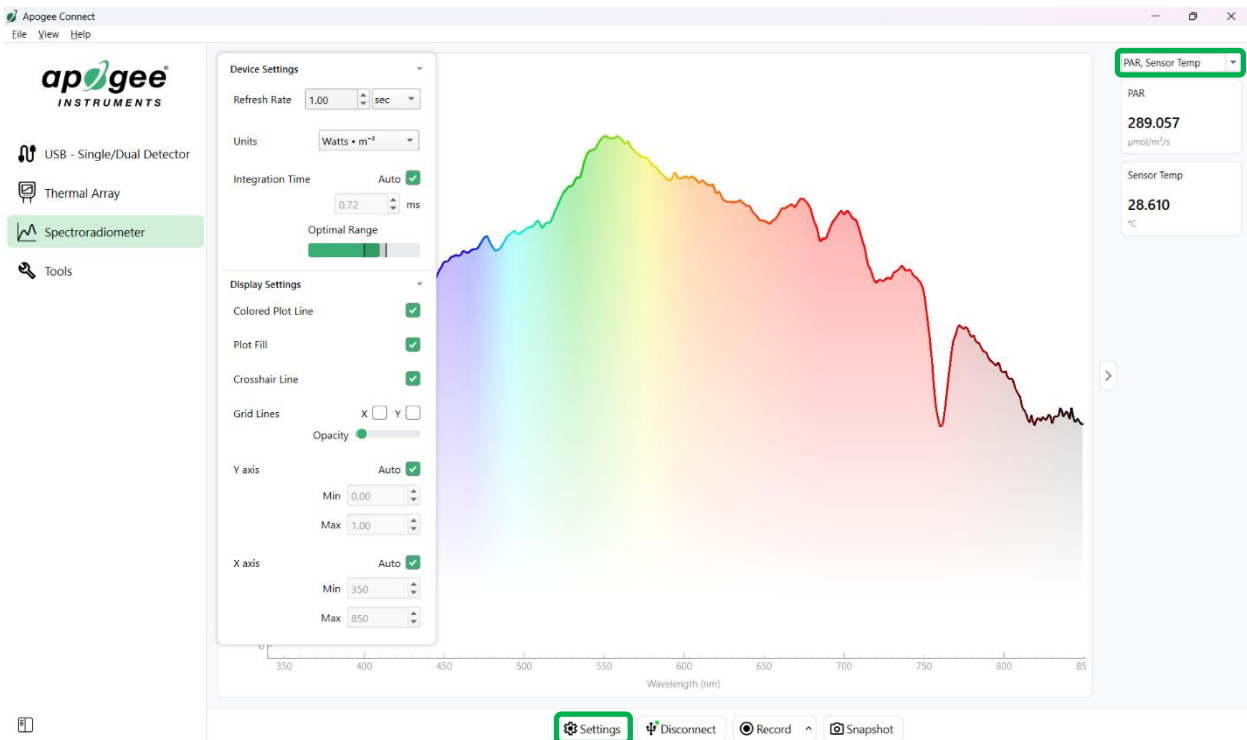
Step 2. Navigate to the spectroradiometer mode as pictured below.



Step 3. Select “Connect” to connect a spectroradiometer plugged into the USB port, as shown below.



Step 4. The picture below shows the display of the interface with a sensor connected. Use the “Settings” button and insights dropdown to customize your view. “Refresh Rate” sets screen refresh and logging interval rate, “Units” selects the unit of measurement, “Integration time” adjusts the sensor to current light levels (auto is recommended for this setting), and “Display Settings” adjusts graph display options.



Step 5. Use the “Record” and “Snapshot” buttons to capture and store data. When recording data, customize the start and stop time as shown below. Logging will save data at the same rate as the refresh rate setting from step 4.



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## RETURN AND WARRANTY POLICY

### RETURN POLICY

Apogee Instruments will accept returns within 30 days of purchase as long as the product is in new condition (as determined by Apogee). Returns are subject to a 10 % restocking fee.

The PS series spectroradiometers are non-refundable. Any custom-built product is non-refundable.

### WARRANTY POLICY

#### What is Covered

All products manufactured by Apogee Instruments 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 by Apogee.

Products not manufactured by Apogee are covered for a period of one (1) year, which applies to the following products:

- PS-series spectroradiometers
- MS-100 InSight
- SS-110 and SS-120 spectroradiometers
- MC-100 chlorophyll content meters
- EE08-SS humidity probes
- TEROS-12 modbus soil moisture sensors
- Aranet transmitters and base stations
- Brackets, rods, leveling plates, and adapters

Third-party accessories—like batteries, fans, and splitters—carry the original manufacturer's warranty.

Sensor wands have a 30-day warranty.

#### What is Not Covered

Neoprene pouches, carrying cases, and sensor caps are not covered under warranty.

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, use, or abuse.
2. Operation of the instrument outside of its specified operating environment.
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 Apogee Will Do

At no charge Apogee 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. (If the customer elects to use different or expedited shipping methods, it will be at the customer's expense.)

### How To Return an Item

1. Please do not send any products back to Apogee Instruments until you have received a Return Merchandise Authorization (RMA) number from our technical support department by submitting an online RMA form at [www.apogeeinstruments.com/tech-support-recalibration-repairs/](http://www.apogeeinstruments.com/tech-support-recalibration-repairs/). We will use your RMA number to track the service item. Call (435) 245-8012 or email techsupport@apogeeinstruments.com with questions.
2. For warranty evaluations, send all RMA sensors and meters back in the following condition: Clean the sensor's exterior and cord. Do not modify the sensors or wires, including splicing, cutting wire leads, etc. If a connector has been attached to the cable end, please include the mating connector – otherwise the sensor connector will be removed in order to complete the repair/recalibration. **Note:** *When sending back sensors for routine calibration that have Apogee's standard stainless-steel connectors, you only need to send the sensor with the 30 cm section of cable and one-half of the connector. We have mating connectors at our factory that can be used for calibrating the sensor.*
3. Please write the RMA number on the outside of the shipping container.
4. Return the item with freight pre-paid and fully insured to our factory address shown below. We are not responsible for any costs associated with the transportation of products across international borders.

**Apogee Instruments, Inc.**  
**721 West 1800 North Logan, UT**  
**84321, USA**

5. Upon receipt, Apogee Instruments will determine the cause of failure. If the product is found to be defective in terms of operation under the published specifications due to a failure of product materials or craftsmanship, Apogee Instruments will repair or replace the items free of charge. If it is determined that your product is not covered under warranty, you will be informed and given an estimated repair/replacement cost.

## PRODUCTS BEYOND THE WARRANTY PERIOD

For issues with sensors beyond the warranty period, please contact Apogee at [techsupport@apogeeinstruments.com](mailto:techsupport@apogeeinstruments.com) to discuss repair or replacement options.

## OTHER TERMS

The available remedy of defects under this warranty is for the repair or replacement of the original product, and Apogee Instruments is not responsible for any direct, indirect, incidental, or consequential damages, including but not limited to loss of income, loss of revenue, loss of profit, loss of data, loss of wages, loss of time, loss of sales, accrual of debts or expenses, injury to personal property, or injury to any person or any other type of damage or loss.

This limited warranty and any disputes arising out of or in connection with this limited warranty ("Disputes") shall be governed by the laws of the State of Utah, USA, excluding conflicts of law principles and excluding the Convention for the International Sale of Goods. The courts located in the State of Utah, USA, shall have exclusive jurisdiction over any Disputes.

This limited warranty gives you specific legal rights, and you may also have other rights, which vary from state to state and jurisdiction to jurisdiction, and which shall not be affected by this limited warranty. This warranty extends only to you and cannot be transferred or assigned. If any provision of this limited warranty is unlawful, void, or unenforceable, that provision shall be deemed severable and shall not affect any remaining provisions. In case of any inconsistency between the English and other versions of this limited warranty, the English version shall prevail.

This warranty cannot be changed, assumed, or amended by any other person or agreement.

**APOGEE INSTRUMENTS, INC.** | 721 WEST 1800 NORTH LOGAN, UTAH 84321, USA  
TEL: (435) 792-4700 | FAX: (435) 787-8268 | WEB: APOGEEINSTRUMENTS.COM  
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