apogee®

INSTRUMENTS

OWNER'S MANUAL

INFRARED RADIOMETER

Models SI-211, SI-221, SI-231, and SI-2H1

Rev: 22-June-2026

APOGEE INSTRUMENTS, INC. | 721 WEST 1800 NORTH, LOGAN, UTAH 84321, USA
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DECLARATION OF CONFORMITY

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: SI-411, SI-421, SI-431, SI-4H1
Type: Infrared Radiometer

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
2015/863/EU	Amending Annex II to Directive 2011/65/EU (RoHS 3)

Standards referenced during compliance assessment:

EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
EN 63000:2018	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 lead (see note below), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE), bis (2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP). However, please note that articles containing greater than 0.1 % lead concentration are RoHS 3 compliant using exemption 6c.

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 we rely on the information provided to us by our material suppliers.

Signed for and on behalf of:
Apogee Instruments, June 2024

Bruce Bugbee
President
Apogee Instruments, Inc.

CE

DECLARATION OF CONFORMITY

UK 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: SI-411, SI-421, SI-431, SI-4H1
Type: Infrared Radiometer

The object of the declaration described above is in conformity with the relevant UK Statutory Instruments and their amendments:

2016 No. 1091	The Electromagnetic Compatibility Regulations 2016
2012 No. 3032	The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

Standards referenced during compliance assessment:

BS EN 61326-1:2013	Electrical equipment for measurement, control, and laboratory use – EMC requirements
BS EN 63000:2018	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances

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Bruce Bugbee
President
Apogee Instruments, Inc.

INTRODUCTION

All objects with a temperature above absolute zero emit electromagnetic radiation. The wavelengths and intensity of radiation emitted are related to the temperature of the object. Terrestrial surfaces (e.g., soil, plant canopies, water, snow) emit radiation in the mid infrared portion of the electromagnetic spectrum (approximately 4-50 µm).

Infrared radiometers are sensors that measure infrared radiation, which is used to determine surface temperature without touching the surface (when using sensors that must be in contact with the surface, it can be difficult to maintain thermal equilibrium without altering surface temperature). Infrared radiometers are often called infrared thermometers because temperature is the desired quantity, even though the sensors detect radiation.

Typical applications of infrared radiometers include plant canopy temperature measurement for use in plant water status estimation, road surface temperature measurement for determination of icing conditions, and terrestrial surface (soil, vegetation, water, snow) temperature measurement in energy balance studies.

Apogee Instruments SI series infrared radiometers consist of a thermopile detector, germanium filter, precision thermistor (for detector reference temperature measurement), and signal processing circuitry mounted in an anodized aluminum housing, and a cable to connect the sensor to a measurement device. All radiometers also come with a radiation shield designed to minimize absorbed solar radiation, but still allowing natural ventilation. The radiation shield insulates the radiometer from rapid temperature changes and keeps the temperature of the radiometer closer to the target temperature. Sensors are potted solid with no internal air space and are designed for continuous temperature measurement of terrestrial surfaces in indoor and outdoor environments. SI-200 series sensors output a 4-20 mA signal.

SENSOR MODELS

Model	Output
SI-100 Series	Voltage
SI-200 Series	Current
SI-400 Series	SDI-12
SI-500 Series	Modbus

A sensor's model number and serial number are located on a label 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.

The four FOV options and associated model numbers are shown below:

SI-231 SI-221 SI-211 SI-2H1

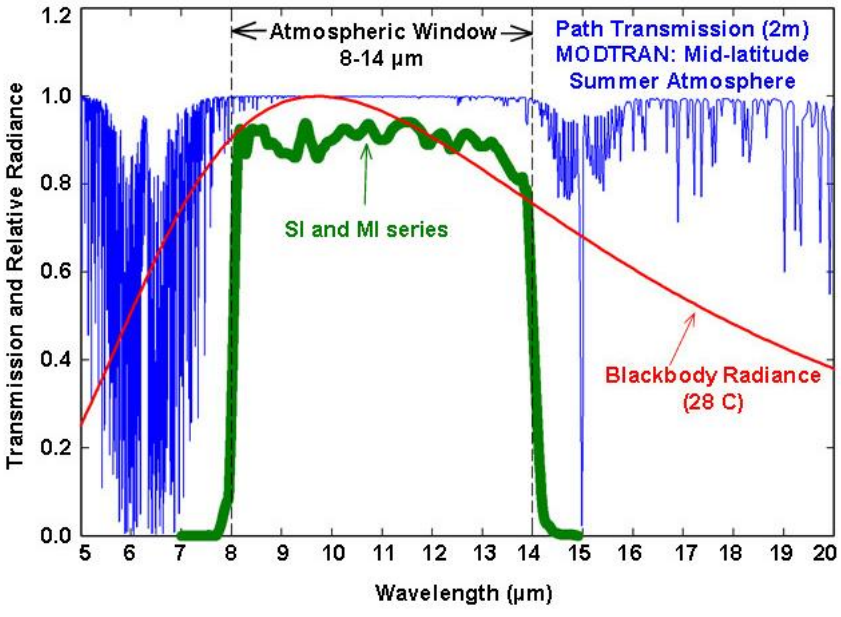
SPECIFICATIONS

	SI-211-SS	SI-221-SS	SI-231-SS	SI-2H1-SS
Analog Model Output (Difference between Target and Detector)	0.267 mA DC per C (3.75 C per 1 mA DC)			
Input Voltage Requirement	5.5 to 24 V DC			
Current Drain	12 mA at 5.5 VDC, 7 mA at 12 VDC, 8 mA at 24 VDC			
Calibration Uncertainty (-30 to 50 C), when target and detector temperature are within 20 C	0.2 C	0.2 C	0.3 C	0.2 C
Measurement Repeatability	Less than 0.05 C			
Stability (Long-term Drift)	Less than 2 % change in slope per year when germanium filter is maintained in a clean condition (see Maintenance and Recalibration section below)			
Response Time	0.6 s, time for detector signal to reach 95 % following a step change; fastest data transmission rate for SDI-12 circuitry is 1 s			
Field of View	22° half angle	18° half angle	14° half angle	32° horizontal half angle; 13° vertical half angle
Spectral Range	8 to 14 µm; atmospheric window (see Spectral Response below)			
Operating Environment	-50 to 80 C; 0 to 100 % relative humidity (non-condensing)			
Dimensions	23 mm diameter; 60 mm length			
Mass	192 g (with 5m of lead wire)			
Cable	Two-conductor, shielded, twisted-pair wire; TPR jacket (high water resistance, high UV stability, flexibility in cold conditions); pigtail lead wires; stainless steel (316) M8 connector located 30 cm from sensor head next to in-cable unit.			

Calibration Traceability

Apogee SI series infrared radiometers are calibrated to the temperature of a custom blackbody cone held at multiple fixed temperatures over a range of radiometer (detector/sensor body) temperatures. The temperature of the blackbody cone is measured with replicate precision thermistors thermally bonded to the cone surface. The precision thermistors are calibrated for absolute temperature measurement against a platinum resistance thermometer (PRT) in a constant temperature bath. The PRT calibration is directly traceable to the NIST.

Spectral Response



Spectral response of SI series infrared radiometers. Spectral response (green line) is determined by the germanium filter and corresponds closely to the atmospheric window of 8-14 µm, minimizing interference from atmospheric absorption/emission bands (blue line) below 8 µm and above 14 µm. Typical terrestrial surfaces have temperatures that yield maximum radiation emission within the atmospheric window, as shown by the blackbody curve for a radiator at 28 C (red line).

DEPLOYMENT AND INSTALLATION

The mounting geometry (distance from target surface, angle of orientation relative to target surface) is determined by the desired area of surface to be measured. The field of view extends unbroken from the sensor to the target surface. Sensors must be carefully mounted in order to view the desired target and avoid including unwanted surfaces/objects in the field of view, thereby averaging unwanted temperatures with the target temperature (see Field of View below). **Once mounted, the green cap must be removed.** The green cap can be used as a protective covering for the sensor, when it is not in use.

The sensor housing is compatible with the **AM-220** and **AM-250** mounting brackets, which both allow for adjustment of the angle of the sensor with respect to the target.


IR sensor with
AM-250 bracket


IR sensor with
AM-250 bracket

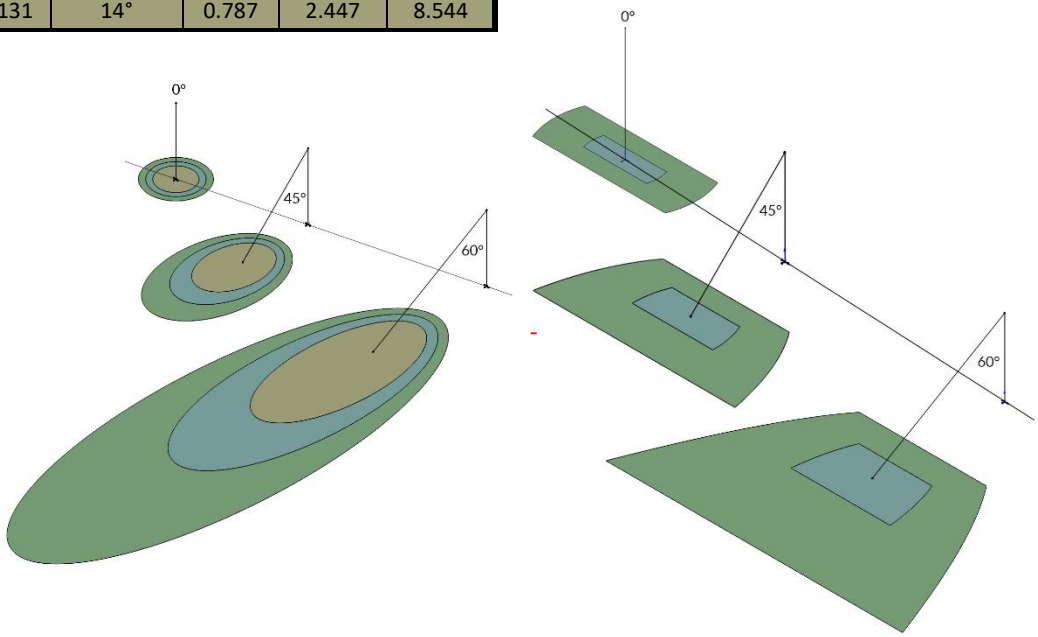

IR Sensor with older
AM-220 Bracket

Field of View

The field of view (FOV) is reported as the half-angle of the apex of the cone formed by the target surface (cone base) and the detector (cone apex), as shown below, where the target is defined as a circle from which 98 % of the radiation detected by the radiometer is emitted.

Sensor FOV, distance to target, and sensor mounting angle in relation to the target will determine target area. Different mounting geometries (distance and angle combinations) produce different target shapes and areas, as shown below.

CIRCULAR						HORIZONTAL						
			FOV Area (m²)					Half Angle		FOV Area (m²)		
Type	**Model**	**Half Angle**	**0 Deg**	**45 Deg**	**60 Deg**	**Type**	**Model**	**Horizontal**	**Vertical**	**0 Deg**	**45 Deg**	**60 Deg**
Standard	SI-111	22°	2.069	7.627	45.211	Standard	SI-1H1	32°	13°	2.276	7.148	45.512
Narrow	SI-121	18°	1.337	4.461	18.865	Narrow	SI-4HR	16°	5°	0.403	1.15	3.341
Ultra-Narrow	SI-131	14°	0.787	2.447	8.544							



A simple FOV calculator for determining target dimensions based on infrared radiometer model, mounting height, and mounting angle, is available on the Apogee website: https://www.apogeeinstruments.com/irr-calculators.

CABLE CONNECTORS

Apogee sensors offer cable connectors to simplify the process of removing sensors from weather stations for calibration (the entire cable does **not** have to be removed from the station and shipped with the sensor).

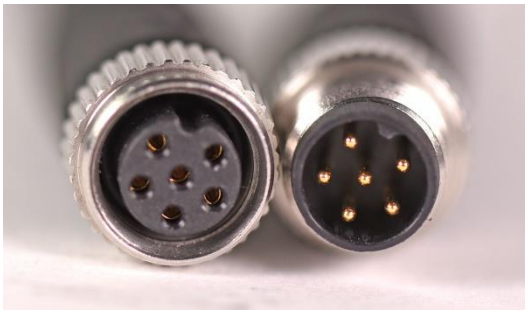
The ruggedized M8 connectors are rated IP68, made of corrosion-resistant marine-grade stainless-steel, and designed for extended use in harsh environmental conditions.

Inline cable connectors are installed 30 cm from the head
(pyranometer pictured as example)

Instructions

Pins and Wiring Colors: All Apogee connectors have six pins, but not all pins are used for every sensor. There may also be unused wire colors inside the cable. To simplify datalogger connection, we remove the unused pigtail lead colors at the datalogger end of the cable.

If a replacement cable is required, please contact Apogee directly to ensure ordering the proper pigtail configuration.



A reference notch inside the connector ensures proper alignment before tightening.

Alignment: When reconnecting a sensor, arrows on the connector jacket and an aligning notch ensure proper orientation.

Disconnection for extended periods: When disconnecting the sensor for an extended period of time from a station, protect the remaining half of the connector still on the station from water and dirt with electrical tape or other method.

When sending sensors in for calibration, only send the short end of the cable and half the connector.

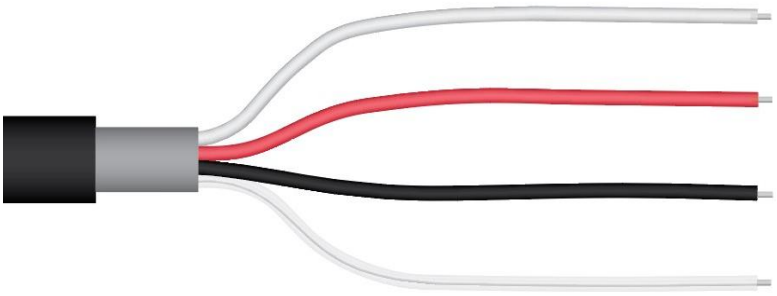
Tightening: Connectors are designed to be firmly finger-tightened only. There is an O-ring inside the connector that can be overly compressed if a wrench is used. Pay attention to thread alignment to avoid cross-threading. When fully tightened, 1-2 threads may still be visible.

Finger-tighten firmly

OPERATION AND MEASUREMENT

All SI-400 series radiometers have an SDI-12 output, where target and detector temperatures are returned in digital format. Measurement of SI-400 series radiometers requires a measurement device with SDI-12 functionality that includes the M or C command.

Wiring for SI-400 Series with Serial Numbers 3057 and above or with a cable connector



White: 4-20 mA Output

Red: Power In (4.5-24 V DC)

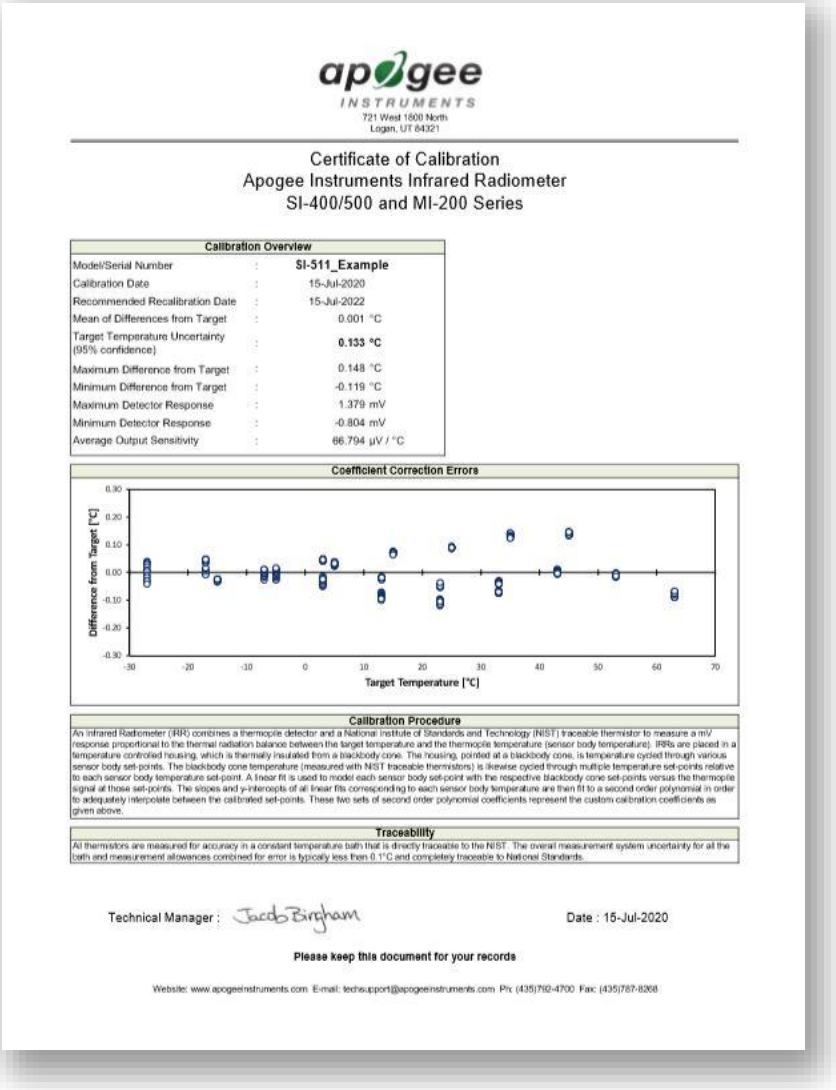
Black: Ground (for sensor signal and input power)

Clear: Shield/Ground

Sensor Calibration

Apogee SI series infrared radiometers are calibrated in a temperature-controlled chamber that houses a custom-built blackbody cone (target) for the radiation source. During calibration, infrared radiometers (detectors) are held in a fixture at the opening of the blackbody cone but are thermally insulated from the cone. Detector and target temperature are controlled independently. At each calibration set point, detectors are held at a constant temperature while the blackbody cone is controlled at temperatures below (12 C), above (18 C), and equal to the detector temperature. The range of detector temperatures is -10 C to 50 C (set points at 10 C increments). Data are collected at each detector temperature set point, after detectors and target reach constant temperatures.

Calibration coefficients are programmed into the sensor memory at the factory. Calibration data for each sensor are provided on a calibration certificate (example shown on following page).



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Certificate of Calibration
Apogee Instruments Infrared Radiometer
SI-400/500 and MI-200 Series

Calibration Overview		
Model/Serial Number	:	SI-511_Example
Calibration Date	:	15-Jul-2020
Recommended Recalibration Date	:	15-Jul-2022
Mean of Differences from Target	:	0.001 °C
Target Temperature Uncertainty (95% confidence)	:	0.133 °C
Maximum Difference from Target	:	0.148 °C
Minimum Difference from Target	:	-0.119 °C
Maximum Detector Response	:	1.379 mV
Minimum Detector Response	:	-0.804 mV
Average Output Sensitivity	:	66.794 µV / °C

Coefficient Correction Errors

Calibration Procedure

An infrared Radiometer (IRR) combines a thermopile detector and a National Institute of Standards and Technology (NIST) traceable thermistor to measure a mV response proportional to the thermal radiation balance between the target temperature and the thermopile temperature (sensor body temperature). IRRs are placed in a temperature controlled housing, which is thermally insulated from a blackbody cone. The housing, pointed at a blackbody cone, is temperature cycled through various sensor body set-points. The blackbody cone temperature (measured with NIST traceable thermistors) is likewise cycled through multiple temperature set-points relative to each sensor body temperature set-point. A linear fit is used to model each sensor body set-point with the respective blackbody cone set-points versus the thermopile signal at those set-points. The slopes and y-intercepts of all linear fits corresponding to each sensor body temperature are then fit to a second order polynomial in order to adequately interpolate between the calibrated set-points. These two sets of second order polynomial coefficients represent the custom calibration coefficients as given above.

Traceability

All thermistors are measured for accuracy in a constant temperature bath that is directly traceable to the NIST. The overall measurement system uncertainty for all the bath and measurement allowances combined for error is typically less than 0.1°C and completely traceable to National Standards.

Technical Manager : Jacob Bingham Date : 15-Jul-2020

Please keep this document for your records

Website: www.apogeeinstruments.com E-mail: techsupport@apogeeinstruments.com Ph: (435)792-4700 Fax: (435)787-8268

Calibration overview data are listed in box in upper left-hand corner, temperature errors are shown in graph, and calibration date is listed below descriptions of calibration procedure and traceability.

Temperature Calculation

The linear response output provided by the sensor can be converted to temperature using the equation below:

$$T = (X - 4) * 3.75 \quad (1)$$

where

- T is temperature and
- X is the mA output provided by the sensor

MAINTENANCE AND RECALIBRATION

Blocking of the optical path between the target and detector, often due to moisture or debris on the filter, is a common cause of inaccurate measurements. The filter in SI series radiometers is inset in an aperture, but can become partially blocked in four ways:

1. Dew or frost formation on the filter.
2. Salt deposit accumulation on the filter, due to evaporating irrigation water or sea spray. This leaves a thin white film on the filter surface. Salt deposits can be removed with a dilute acid (e.g., vinegar). **Salt deposits cannot be removed with solvents such as alcohol or acetone.**
3. Dust and dirt deposition in the aperture and on the filter (usually a larger problem in windy environments). Dust and dirt are best removed with deionized water, rubbing alcohol, or in extreme cases, acetone.
4. Spiders/insects and/or nests in the aperture leading to the filter. If spiders/insects are a problem, repellent should be applied around the aperture entrance (not on the filter).

Clean inner threads of the aperture and the filter with a cotton swab dipped in the appropriate solvent. **Never use an abrasive material on the filter.** Use only gentle pressure when cleaning the filter with a cotton swab, to avoid scratching the outer surface. The solvent should be allowed to do the cleaning, not mechanical force.

It is recommended that infrared radiometers be recalibrated every two years. See the Apogee webpage for details regarding return of sensors for recalibration (http://www.apogeeinstruments.com/tech-support-recalibration-repairs/).

TROUBLESHOOTING AND CUSTOMER SUPPORT

Independent Verification of Functionality

The simplest way to check sensor functionality is the aM2! command. This command returns detector temperature and detector voltage output. Detector temperature should read very near room temperature. When the aperature of the sensor is covered with aluminum foil, the voltage output should read very near 0 mV.

If the sensor does not communicate with the datalogger, use an ammeter to check the current drain. It should be near 1.5 mA when the sensor is not communicating and spike to approximately 2.0 mA when the sensor is communicating. Any current drain greater than approximately 6 mA indicates a problem with power supply to the sensors, wiring of the sensor, or sensor electronics.

Compatible Measurement Devices (Dataloggers/Controllers/Meters)

Any datalogger or meter with SDI-12 functionality that includes the M or C command.

An example datalogger program for Campbell Scientific dataloggers can be found on the Apogee webpage at http://www.apogeeinstruments.com/content/Infrared-Radiometer-Digital.CR1.

Modifying Cable Length

SDI-12 protocol limits cable length to 60 meters. For multiple sensors connected to the same data line, the maximum is 600 meters of total cable (e.g., ten sensors with 60 meters of cable per sensor). See Apogee webpage for details on how to extend sensor cable length (http://www.apogeeinstruments.com/how-to-make-a-weatherproof-cable-splice/).

Signal Interference

In instances where SI-400 series radiometers are being used in close proximity to communications (near an antenna or antenna wiring), it may be necessary to alternate the data recording and data transmitting functions (i.e., measurements should not be made when data are being transmitted wirelessly). If EMI is suspected, place a tinfoil cap over the front of the sensor and monitor the signal voltage from the detector. The signal voltage should remain stable at (or very near) zero.

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 (to be determined by Apogee). Returns are subject to a 10 % restocking fee.

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
- 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 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 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/. We will use your RMA number for tracking of 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 to 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 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, accruement 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 by 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.

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