OWNER'S MANUAL

INFRARED RADIOMETER

Models SI-111, SI-121, SI-131, and SI-1H1

(including SS models)

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CERTIFICATE OF COMPLIANCE

EU Declaration of Conformity

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

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

for the following product(s):

Models: SI-111, SI-121, SI-131, SI-1H1
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

Standards referenced during compliance assessment:

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

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

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

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

Bruce Bugbee
President
Apogee Instruments, Inc.

INTRODUCTION

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-100 series sensors output an analog voltage that is directly proportional to the infrared radiation balance of the target (surface or object the sensor is pointed at) and detector, where the radiation balance between target and detector is related to the temperature difference between the two.

SENSOR MODELS

Model	Output
SI-100 Series	**Voltage**
SI-400 Series	SDI-12

Sensor 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-131 SI-121 SI-111 SI-1H1

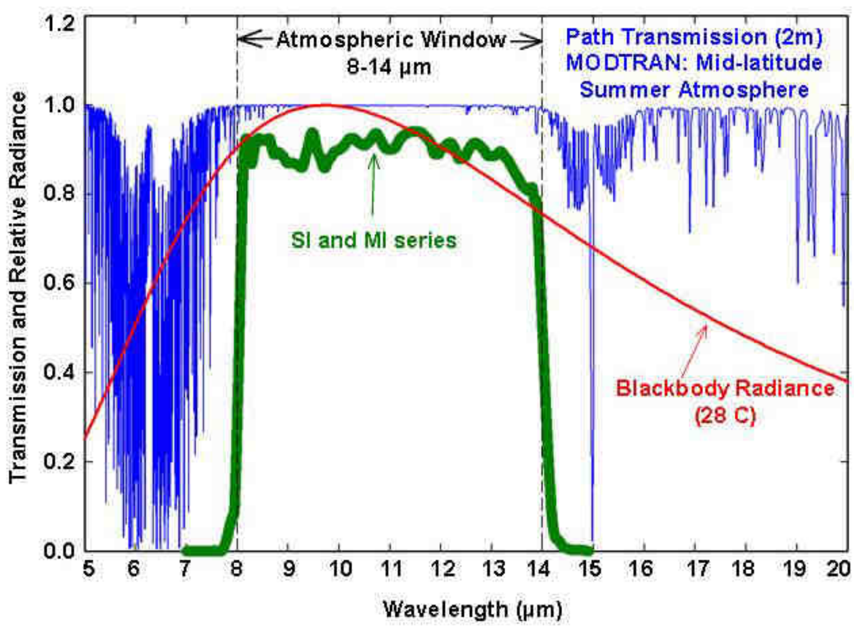
SPECIFICATIONS

	SI-111	SI-121	SI-131	SI-1H1
Approximate Sensitivity	60 µV per C difference between target and detector temperature	40 µV per C difference between target and detector temperature	20 µV per C difference between target and detector temperature	40 µV per C difference between target and detector temperature
Output from Thermopile	Approximately -3.3 to 3.3 mV for a temperature difference from -55 to 55 C	Approximately -2.2 to 2.2 mV for a temperature difference from -55 to 55 C	Approximately -1.1 to 1.1 mV for a temperature difference from -55 to 55 C	Approximately -2.2 to 2.2 mV for a temperature difference from -55 to 55 C
Output from Thermistor	0 to 2500 mV (typical, depends on input voltage)			
Input Voltage Requirement	2500 mV excitation (typical, other voltages can be used)			
Calibration Uncertainty (-20 to 65 C), when target and detector temperature are within 20 C	0.2 C	0.2 C	0.3 C	0.2 C
Calibration Uncertainty (-40 to 80 C), when target and detector temperate are different by more than 20 C (see Calibration Traceability below)	0.5 C	0.5 C	0.6 C	0.5 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			
Field of View	22º half angle	18º half angle	14º half angle	32º horizontal half angle; 13º vertical half angle
Spectral Range	8 to 14 µm; atmospheric window (see Spectral Response below)			
Operating Environment	-55 to 80 C; 0 to 100 % relative humidity (non-condensing)			
Dimensions	23 mm diameter; 60 mm length			
Mass	190 g (with 5m of lead wire)			
Cable	5 m of four conductor, shielded, twisted-pair wire; additional cable available in multiples of 5 m; santoprene rubber jacket (high water resistance, high UV stability, flexibility in cold conditions); pigtail lead wires			

Calibration Traceability

Apogee 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.

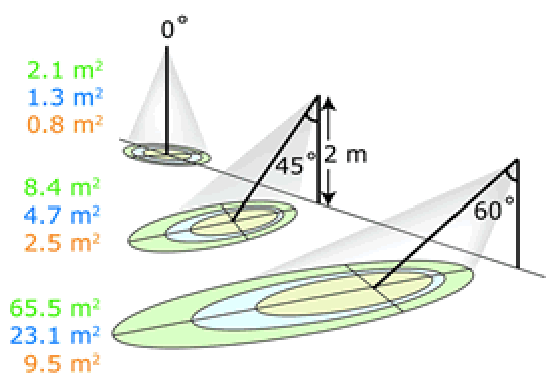
An Apogee Instruments model AM-210 mounting bracket is recommended for mounting the sensor to a cross arm or pole. The AM-210 allows adjustment of the angle of the sensor with respect to the target and accommodates the radiation shield designed for all SI series infrared radiometers.

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.

Type	Model	Half Angle
Standard	SI-111	22°
Narrow	SI-121	18°
Ultra-Narrow	SI-131	14°



A simple FOV calculator for determining target dimensions based on infrared radiometer model, mounting height, and mounting angle, is available on the Apogee website: http://www.apogeeinstruments.com/using-your-apogee-instruments-infrared-radiometer/.

CABLE CONNECTORS

Apogee started offering in-line cable connectors on some bare-lead sensors in March 2018 to simplify the process of removing sensors from weather stations for calibration by not requiring the full cable to be uninstalled back to the data logger.

The ruggedized M8 connectors are rated IP67, 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)

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 data logger connection, we remove the unused pigtail lead colors at the data logger end of the cable.

If you ever need a replacement cable, please contact us directly to ensure ordering the proper pigtail configuration.

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

Alignment: When reconnecting your 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.

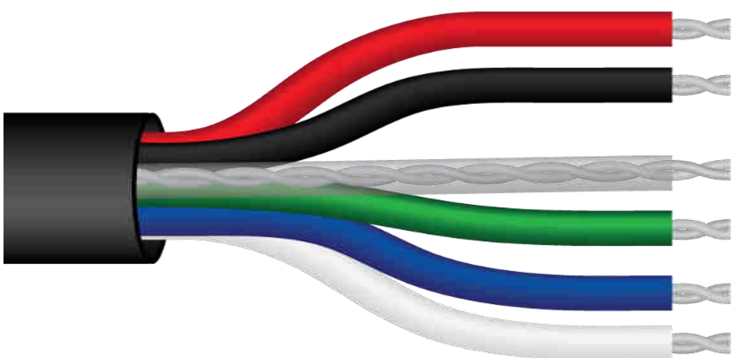
Finger-tighten firmly

OPERATION AND MEASUREMENT

All SI-100 series radiometers output two signals: a voltage from the thermopile radiation detector (proportional to the radiation balance between target and detector) and a voltage from the thermistor (proportional to the magnitude of the excitation voltage and resistance of thermistor). The voltage output from the thermopile is an electrically-isolated bipolar (polarity is dependent on temperature difference between sensor and target) signal in the microvolt range and requires a high resolution differential measurement. The voltage output from the thermistor can be measured with a single-ended measurement. 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 infrared radiometer. **DO NOT connect the thermopile (white and black wires) to a power source. The detector is self-powered and applying voltage will damage it.** Only the red wire should be connected to a power source.

VERY IMPORTANT: Apogee changed all wiring colors of our bare-lead sensors in March 2018 in conjunction with the release of inline cable connectors on some sensors. To ensure proper connection to your data device, please note your serial number or if your sensor has a stainless-steel connector 30 cm from the sensor head then use the appropriate wiring configuration below.

Wiring for SI-100 Series with Serial Numbers range 0-7282



Red: High side of differential channel (positive thermopile lead)

Black: Low side of differential channel (negative thermopile lead)

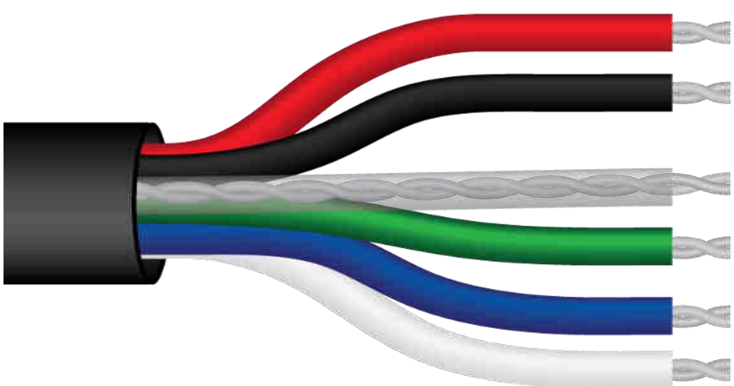
Clear: Analog ground (thermopile ground)

Green: Single-ended channel (positive thermistor lead)

Blue: Analog ground (negative thermistor lead)

White: Excitation channel (excitation for thermistor)

Wiring for SI-100 Series with Serial Numbers 7283 and above or has a cable connector



Red: Excitation channel (excitation for thermistor)

Black: Low side of differential channel (negative thermopile lead)

Clear: Shield/Ground

Green: Single-ended channel (positive thermistor lead)

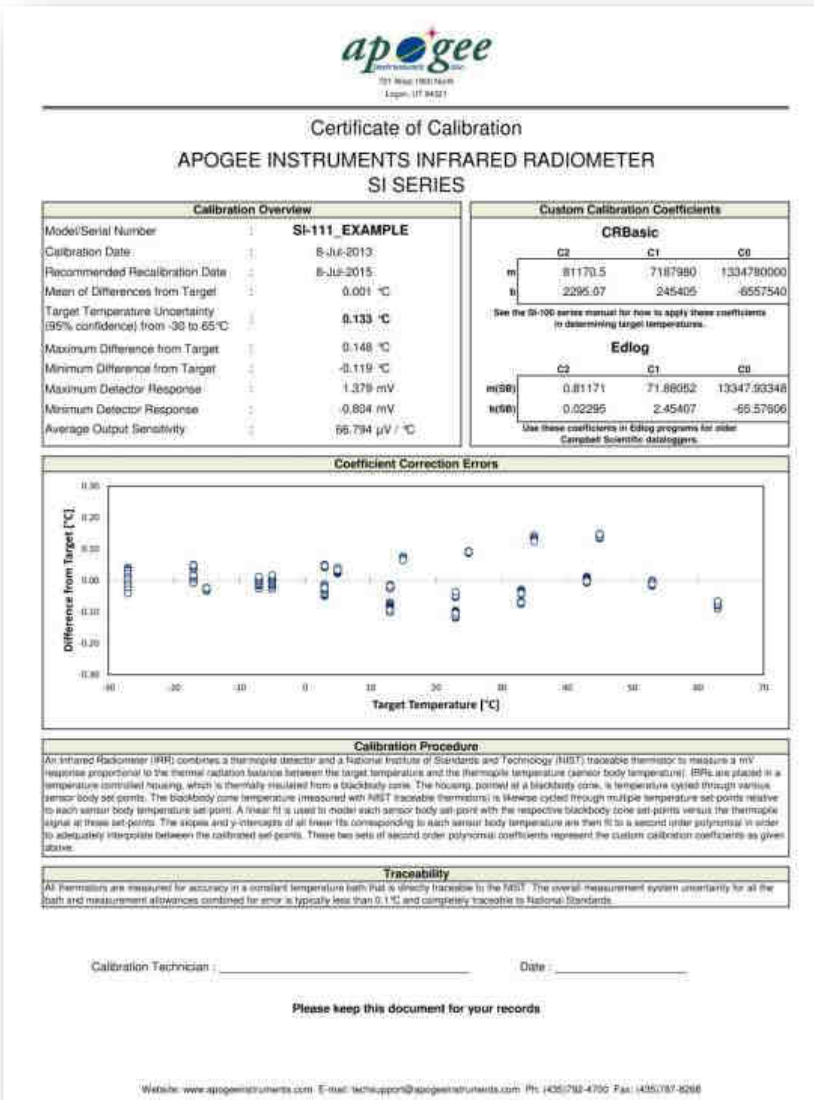
Blue: Analog ground (negative thermistor lead)

White: High side of differential channel (positive thermopile lead)

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 -15 C to 45 C (set points at 10 C increments). Data are collected at each detector temperature set point, after detectors and target reach constant temperatures.

All Apogee analog infrared radiometer models (SI-100 series) have sensor-specific calibration coefficients determined during the custom calibration process. Unique coefficients for each sensor are provided on a coefficient certificate (example shown below).


apogee

Certificate of Calibration

APOGEE INSTRUMENTS INFRARED RADIOMETER
SI SERIES

Calibration Overview

Model/Serial Number	:	**SI-111_EXAMPLE**
Calibration Date	:	8-Jul-2013
Recommended Recalibration Date	:	8-Jul-2015
Mean of Differences from Target	:	0.001 °C
Target Temperature Uncertainty (95% confidence) from -30 to 65°C	:	**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

Custom Calibration Coefficients

CRBasic

	C2	C1	C0
m	81170.5	7187980	1334780000
b	2295.07	245405	-6557540

See the SI-100 series manual for how to apply these coefficients in determining target temperatures.

Edlog

	C2	C1	C0
m(SB)	0.81171	71.88052	13347.93348
b(SB)	0.02295	2.45407	-65.57606

Use these coefficients in Edlog programs for older Campbell Scientific dataloggers.

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 these 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.

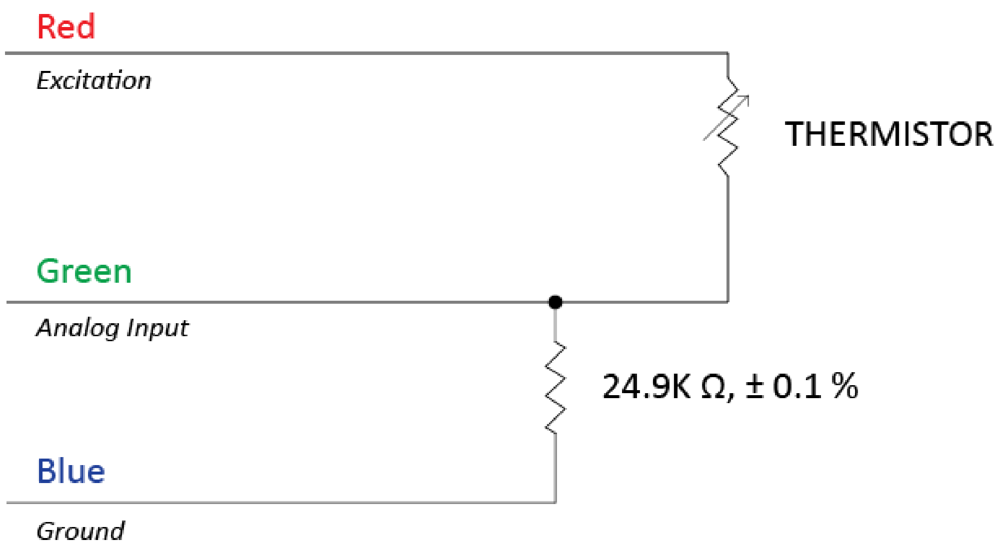
Calibration Technician : ______________________ Date : ______________

Please keep this document for your records

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

Temperature Measurement with Internal Thermistor

Measurement devices (e.g., datalogger, controller) do not measure resistance directly, but determine resistance from a half-bridge measurement, where an excitation voltage is input across the thermistor and an output voltage is measured across the bridge resistor.



An excitation voltage of 2.5 V DC is recommended to minimize self-heating and current drain, while still maintaining adequate measurement sensitivity (mV output from thermistor per C). However, other excitation voltages can be used. Decreasing the excitation voltage will decrease self-heating and current drain, but will also decrease thermistor measurement sensitivity. Increasing the excitation voltage will increase thermistor measurement sensitivity, but will also increase self-heating and current drain.

The internal thermistor provides a temperature reference for calculation of target temperature. Resistance of the thermistor changes with temperature. Thermistor resistance (R_T, in Ω) is measured with a half-bridge measurement, requiring an excitation voltage input (V_{EX}) and a measurement of output voltage (V_{OUT}):

$$R_T = 24900\left(\frac{V_{EX}}{V_{OUT}} - 1\right) \qquad (1)$$

where 24900 is the resistance of the bridge resistor in Ω. From resistance, temperature (T_K, in Kelvin) is calculated with the Steinhart-Hart equation and thermistor specific coefficients:

$$T_K = \frac{1}{A + B\ln(R_T) + C(\ln(R_T))^3} \qquad (2)$$

where A = 1.129241 x 10^{-3}, B = 2.341077 x 10^{-4}, and C = 8.775468 x 10^{-8} (Steinhart-Hart coefficients).

If desired, measured temperature in Kelvin can be converted to Celsius (T_C):

$$T_C = T_K - 273.15\,. \qquad (3)$$

Target Temperature Measurement

The detector output from SI-100 series radiometers follows the fundamental physics of the Stefan-Boltzmann Law, where radiation transfer is proportional to the fourth power of absolute temperature. A modified form of the Stefan-Boltzmann equation is used to calibrate sensors, and subsequently, calculate target temperature:

$$\mathrm{T_T}^4 - \mathrm{T_D}^4 = \mathrm{m} \cdot \mathrm{S_D} + \mathrm{b} \qquad (1)$$

where T_T is target temperature [K], T_D is detector temperature [K], S_D is the millivolt signal from the detector, m is slope, and b is intercept. The mV signal from the detector is linearly proportional to the energy balance between the target and detector, analogous to energy emission being linearly proportional to the fourth power of temperature in the Stefan-Boltzmann Law.

During the calibration process, m and b are determined at each detector temperature set point (10 C increments across a -15 C to 45 C range) by plotting measurements of $T_T^4 - T_D^4$ versus mV. The derived m and b coefficients are then plotted as function of T_D and second order polynomials are fitted to the results to produce equations that determine m and b at any T_D:

$$\mathrm{m} = \mathrm{C2} \cdot \mathrm{T_D}^2 + \mathrm{C1} \cdot \mathrm{T_D} + \mathrm{C0} \qquad (2)$$

$$\mathrm{b} = \mathrm{C2} \cdot \mathrm{T_D}^2 + \mathrm{C1} \cdot \mathrm{T_D} + \mathrm{C0} \qquad (3)$$

Where C2, C1, and C0 are the custom calibration coefficients listed on the calibration certificate (shown above) that comes with each SI-100 series radiometer (there are two sets of polynomial coefficients, one set for m and one set for b). Note that T_D is converted from Kelvin to Celsius (temperature in C equals temperature in K minus 273.15) before m and b are plotted versus T_D.

To make measurements of target temperatures, Eq. (1) is rearranged to solve for T_T [C], measured values of S_D and T_D are input, and predicted values of m and b are input:

$$T_T = \left(T_D{}^4 + m \cdot S_D + b\right)^{\frac{1}{4}} - 273.15 \qquad (4)$$

Emissivity Correction

Appropriate correction for surface emissivity is required for accurate surface temperature measurements. The simple (and commonly made) emissivity correction, dividing measured temperature by surface emissivity, is incorrect because it does not account for reflected infrared radiation.

The radiation detected by an infrared radiometer includes two components: 1. radiation directly emitted by the target surface, and 2. reflected radiation from the background. The second component is often neglected. The magnitude of the two components in the total radiation detected by the radiometer is estimated using the emissivity (ε) and reflectivity (1 - ε) of the target surface:

$$\mathrm{E_{Sensor}} = \varepsilon \cdot \mathrm{E_{Target}} + (1 - \varepsilon) \cdot \mathrm{E_{Background}} \qquad (1)$$

where E_{Sensor} is radiance [W m^{-2} sr^{-1}] detected by the radiometer, E_{Target} is radiance [W m^{-2} sr^{-1}] emitted by the target surface, $E_{Background}$ is radiance [W m^{-2} sr^{-1}] emitted by the background (when the target surface is outdoors the background is generally the sky), and ε is the ratio of non-blackbody radiation emission (actual radiation emission) to blackbody radiation emission at the same temperature (theoretical maximum for radiation emission). Unless the target surface is a blackbody (ε = 1; emits and absorbs the theoretical maximum amount of energy based on temperature), E_{Sensor} will include a fraction (1 – ε) of reflected radiation from the background.

Since temperature, rather than energy, is the desired quantity, Eq. (1) can be written in terms of temperature using the Stefan-Boltzmann Law, $E = \sigma T^4$ (relates energy being emitted by an object to the fourth power of its absolute temperature):

$$\sigma \cdot T_{Sensor}^{\ 4} = \varepsilon \cdot \sigma \cdot T_{Target}^{\ 4} + (1-\varepsilon) \cdot \sigma \cdot T_{Background}^{\ 4} \qquad (2)$$

where T_{Sensor} [K] is temperature measured by the infrared radiometer (brightness temperature), T_{Target} [K] is actual temperature of the target surface, $T_{Background}$ [K] is brightness temperature of the background (usually the sky), and σ is the Stefan-Boltzmann constant (5.67×10^{-8} W m^{-2} K^{-4}). The power of 4 on the temperatures in Eq. (2) is valid for the entire blackbody spectrum.

Rearrangement of Eq. (2) to solve for T_{Target} yields the equation used to calculate the actual target surface temperature (i.e., measured brightness temperature corrected for emissivity effects):

$$T_{Target} = \sqrt[4]{\frac{T_{Sensor}^{\ 4} - (1-\varepsilon) \cdot T_{Background}^{\ 4}}{\varepsilon}} \,. \qquad (3)$$

Equations (1)-(3) assume an infinite waveband for radiation emission and constant ε at all wavelengths. These assumptions are not valid because infrared radiometers do not have infinite wavebands, as most correspond to the atmospheric window of 8-14 µm, and ε varies with wavelength. Despite the violated assumptions, the errors for emissivity correction with Eq. (3) in environmental applications are typically negligible because a large proportion of the radiation emitted by terrestrial objects is in the 8-14 µm waveband (the power of 4 in Eqs. (2) and (3) is a reasonable approximation), ε for most terrestrial objects does not vary significantly in the 8-14 µm waveband, and the background radiation is a small fraction $(1 - \varepsilon)$ of the measured radiation because most terrestrial surfaces have high emissivity (often between 0.9 and 1.0). To apply Eq. (3), the brightness temperature of the background ($T_{Background}$) must be measured or estimated with reasonable accuracy. If a radiometer is used to measure background temperature, the waveband it measures should be the same as the radiometer used to measure surface brightness temperature. Although the ε of a fully closed plant canopy can be 0.98-0.99, the lower ε of soils and other surfaces can result in substantial errors if ε effects are not accounted for.

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 radiation detector in Apogee SI-100 series infrared radiometers is a self-powered device that outputs a voltage signal proportional to the radiation balance between the detector and target surface. A quick and easy check of detector functionality can be accomplished using a voltmeter with microvolt (μV) resolution. Connect the positive lead of the voltmeter to the white wire from the sensor and the negative lead (or common) to the black wire from the sensor. Direct the sensor toward a surface with a temperature significantly different than the detector. The μV signal will be negative if the surface is colder than the detector and positive if the surface is warmer than the detector. Placing a piece of tinfoil in front of the sensor should force the sensor μV signal to zero.

The thermistor inside Apogee SI-100 series radiometers yields a resistance proportional to temperature. A quick and easy check of thermistor functionality can be accomplished with an ohmmeter. Connect the lead wires of the ohmmeter to the red and green wires from the sensor. The resistance should read 10 kΩ at 25 C. If the sensor temperature is less than 25 C, the resistance will be higher. If the sensor temperature is greater than 25 C, the resistance will be lower. Connect the lead wires of the ohmmeter to the green and blue wires from the sensor. The resistance should read 24.9 kΩ, and should not vary. Connect the lead wires of the ohmmeter to the red and blue wires from the sensor. The resistance should be the sum of the resistances measured across the green and white wires, and green and blue wires (e.g., 10 kΩ plus 24.9 kΩ at 25 C).

Compatible Measurement Devices (Dataloggers/Controllers/Meters)

SI-100 series radiometers have sensitivities in the microvolt range, approximately 20 to 60 μV per C difference between target and detector (depending on specific model). Thus, a compatible measurement device (e.g., datalogger or controller) should have resolution of at least 3 μV (0.003 mV), in order to produce temperature resolution of 0.05 C.

Measurement of detector temperature from the internal thermistor requires an input excitation voltage, where 2500 mV is recommended. A compatible measurement device should have the capability to supply the necessary voltage.

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

Modifying 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 measurement device is 10 MΩ or higher, there is negligible effect on the radiometer calibration, even after adding up to 50 m of cable. Apogee model SI series infrared radiometers use shielded, twisted pair cable, which minimizes electromagnetic interference. This is particularly important for long lead lengths in electromagnetically noisy environments. 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

Due to the small voltage signals from the detector, care should be taken to provide appropriate grounding for the sensor and cable shield wire, in order to minimize the influence of electromagnetic interference (EMI). In instances where SI-100 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.