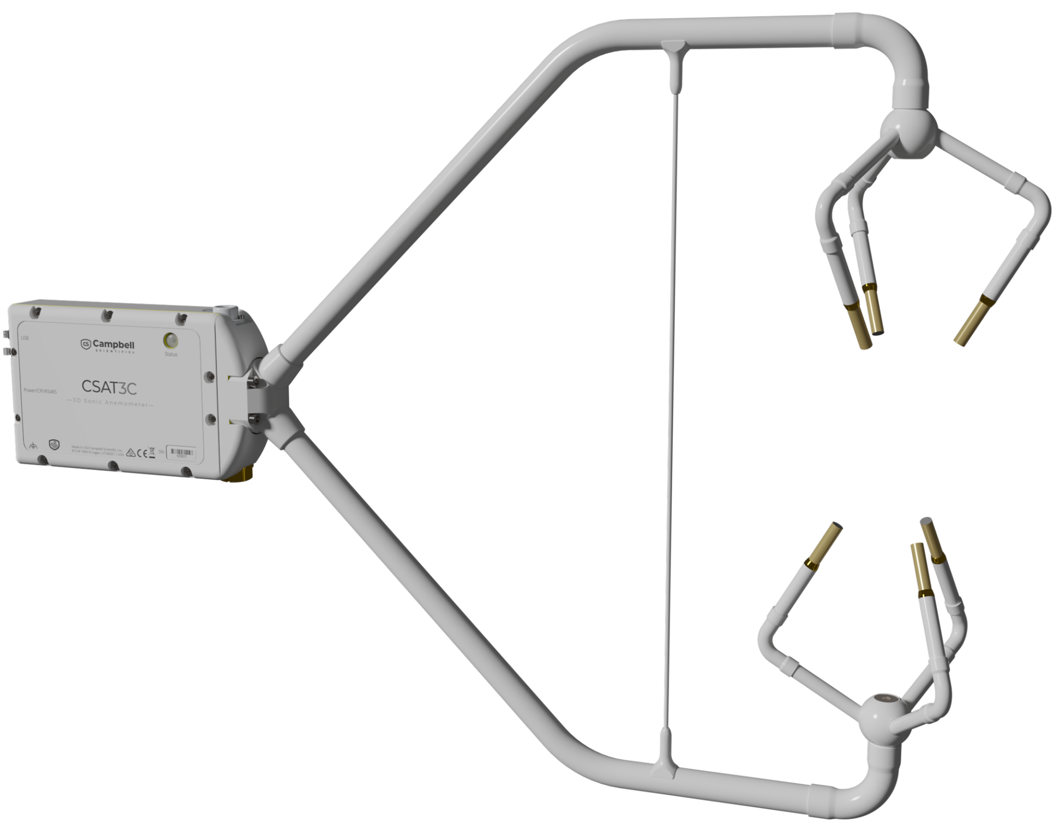
PRODUCT MANUAL

Sensor

CSAT3C

3-D Sonic Anemometer
for Demanding Flux Research



06/2026

RELIABLE MONITORING SINCE 1974

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Please read first

About this manual

Please note that this manual was produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this. In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to Europe, Middle East, and Africa (EMEA) or Asia Pacific (APAC) users. Differences include the U.S. standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for EMEA or APAC use. Please note, however, *that when a power supply adapter is ordered from Campbell Scientific it will be suitable for use in your country*.

Reference to some radio transmitters, digital cell phones and aerials (antennas) may also not be applicable according to your locality. Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the EMEA or APAC market; in some cases alternatives are offered.

Recycling information for countries subject to WEEE regulations 2012/19/EU

At the end of this product's life it should not be put in commercial or domestic refuse but sent for recycling. Any batteries contained within the product or used during the product's life should be removed from the product and also be sent to an appropriate recycling facility, per The Waste Electrical and Electronic Equipment (WEEE) Regulations 2012/19/EU. Campbell Scientific can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories. For further support, please contact Campbell Scientific, or your local agent.

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1. Introduction

> **NOTE:**
> An online version of this manual is available at help.campbellsci.com/csat3c.

The CSAT3C measures the three orthogonal wind velocity components (Ux, Uy, Uz) and sonic temperature (Ts), and can output average horizontal wind speed and direction or turbulent fluctuations of horizontal and vertical wind. From these measurements, momentum flux and sensible heat flux can be calculated directly. Latent heat flux and gas fluxes, including carbon dioxide, water vapor, and other trace gases, can be determined by computing the covariance between the vertical wind velocity measured by the CSAT3C and scalar quantities measured by other co-located fast-response sensors.

Before attempting to use or install the CSAT3C, please review:

- Precautions (p. 1)
- Initial inspection (p. 2)

2. Precautions

- READ AND UNDERSTAND the Safety section at the back of this manual.
- CAUTION
    - Voltage input must be within a range of 10.5 to 32 VDC. Operating outside this range may damage the instrument.
    - The CSAT3C head should be handled by holding the block at the back of the sensor. Handling it by the arms or transducers could cause geometric deformation, which directly degrades measurement accuracy.
    - The transducer faces are fragile. Avoid scratching or rubbing the surface of the transducer. Do not touch the transducer faces or allow contact with tools, cables, or other objects during handling or installation.

- Grounding the CSAT3C is critical. Proper grounding to earth will ensure maximum electrostatic discharge (ESD) and lightning protection and improve measurement accuracy.
- During winter, remove wicks from the transducers to prevent ice from melting and collecting on the wicks, which could lead to re-freezing and ice buildup on or near the transducers.

- IMPORTANT
    - Install USB drivers and ***Device Configuration Utility*** before attaching the sensor to a computer. ***Device Configuration Utility*** is required for initial configuration, operating system updates, and real-time diagnostics via USB.

3. Initial inspection

Upon receipt of the CSAT3C, inspect the packaging and contents for damage. File any damage claims with the shipping company. Contact Campbell Scientific to facilitate repair or replacement.

Immediately check package contents against shipping documentation. Thoroughly check all packaging material for product that may be trapped inside. Contact Campbell Scientific about any discrepancies. Model numbers are found on each product. On cables, the model number is often found at the connection end of the cable.

The CSAT3C ships with:

- Connector cap with lanyard (pn 44640).
- USB Type-C data cable, 4 m (pn 42103). Used for initial configuration and OS updates via ***Device Configuration Utility***. Not intended for long-term data collection in field deployments.
- CM250 leveling mounting kit (pn 26559).
- Replacement desiccant (pn 44579). A new canister should appear blue or orange; a pink-hued or green-hued canister indicates moisture absorption and should not be used. Store unused canisters in a cool, dry location; shelf life is approximately 2 years.
- Pelican IM2950 carrying case, yellow with foam insert (pn 44599), OR cardboard shipping box, 29 x 18 x 11 in (pn 39840) with foam insert (pn 29191).

Cables for the CSAT3C are specified at the time of order and are shipped with the CSAT3C. Verify that cable model, length, and termination option match the order before proceeding with installation:

- The CPIPCBL2 is a non-armored CPI + power cable featuring an 8-pin UTSX socket connector on one end and either an 8-pin UTSX pin connector or an RJ45 connector with two-conductor 14 AWG power leads on the other end. The CPIPCBL1 is the armored version of the same cable.

> NOTE:
> Part numbers may change over time and can vary by region. Please contact your local Campbell Scientific office to confirm the part numbers applicable to your area.

4. Overview

The CSAT3C is a three-dimensional ultrasonic anemometer that measures the three orthogonal wind velocity components (Ux, Uy, Uz) and sonic temperature (Ts) at output rates from 1 to 100 Hz. It is designed primarily for turbulence research and eddy covariance flux measurements, where fast-response, high-fidelity wind and temperature data are essential. These measurements capture the turbulent fluctuations of wind and temperature at the timescales relevant to atmospheric exchange processes, providing the inputs needed for flux calculations.

From the turbulent wind fluctuations measured by the CSAT3C, momentum flux can be calculated directly. The covariance of vertical wind velocity and sonic temperature yields sonic sensible heat flux. By combining the CSAT3C with other fast-response sensors, such as fine-wire thermocouples or open-path gas analyzers, other turbulent fluxes can be derived: sensible and latent heat, carbon dioxide, nitrous oxide, methane, and other trace gases.

The CSAT3C retains the proven CSAT3 measurement geometry, transducer configuration, and Version 5 signal processing algorithm - the same platform documented in hundreds of peer-reviewed publications. Users transitioning from the CSAT3B will find no change to measurement output format, data quality, or required post-processing workflows.

The CSAT3C supports USB, RS-485, and CPI (CAN Peripheral Interface) communications. For eddy covariance and other applications requiring tight synchronization between multiple fast-response sensors, Campbell Scientific recommends CPI communications with a compatible CR-series data logger. CPI uses the data logger as a hardware master clock to trigger all connected sensors simultaneously, eliminating inter-sensor synchronicity error, a critical advantage when precise temporal alignment between wind and scalar quantities such as CO_2 or water vapor is required. CPI also supports flexible multi-sensor network topologies (star, daisy-chain, and hybrid configurations) over a single standardized cable, simplifying installation and reducing wiring complexity in multi-instrument deployments. For integration into non-Campbell Scientific data acquisition systems, RS-485 ASCII mode provides unprompted output at up to 100 Hz with selectable bandwidth filters.

4.1 Features

The CSAT3C offers the following key features:

- **High-frequency wind and temperature measurements from 1 to 100 Hz**, with selectable bandwidth filters at 5, 10, or 25 Hz. The full 100 Hz output rate supports high-resolution turbulence studies; lower rates with bandwidth filtering reduce aliasing and data volume for standard eddy covariance applications.
- **Minimal flow distortion through the measurement volume**, achieved through a low transducer-diameter-to-path-length ratio and non-orthogonal transducer geometry. This design characteristic, established in the original CSAT3, is retained unchanged in the CSAT3C and supports accurate flux measurements without requiring custom flow-distortion corrections.
- **Version 5 signal processing algorithm**, combining high signal sensitivity with robust measurement continuity during precipitation events and very high wind conditions. The algorithm is peer-reviewed and has been validated across CSAT3 series instruments in field intercomparison studies.
- **Online crosswind correction** for speed of sound and sonic temperature, applied in real time by the instrument. No post-processing correction is required for standard deployments.
- **Optional Kaimal transducer shadow correction**, specific to CSAT3 series transducer diameter and sonic path length. This correction can be applied internally when enabled, addressing systematic underestimation associated with transducer shadowing of the measurement volume.
- **Single-cable architecture** via CPIPCBL1 (armored) or CPIPCBL2 (non-armored) cable, carrying both power and CPI/RS-485 communications in one cable. This replaces the two-cable setup of the CSAT3B (CSAT3BCBL2 + CSAT3BCBL3) and eliminates the CSAT3BCBL1 power/SDM cable entirely. The CPIPCBL cable and UTSX connector system are standardized across Campbell Scientific micrometeorology products, including the TGA300 series and future sensors.

- **CPI mode** for seamless integration into Campbell Scientific's data logger ecosystem. CPI provides hardware-level synchronization of all sensor measurements across complex network topologies (star, daisy-chain, and hybrid) without requiring time-stamping corrections in post-processing.
- **RS-485 ASCII mode** for direct integration into any third-party data acquisition system, with unprompted output at up to 100 Hz and selectable bandwidth filters. Differential signaling provides high noise immunity on long cable runs.
- **Waterproof sealed connectors**, maintaining IP67-rated ingress protection with a quarter-turn locking mechanism. IP67 protection applies whether the connector is mated or unmated.
- **Internal inclinometer** operating at 10 Hz, providing continuous pitch and roll output. This allows users to detect and log sensor tilt changes caused by crossarm sag or tower movement over multi-year deployments.
- **Internal temperature and humidity monitoring** with a field-replaceable desiccant canister. If monitoring shows internal relative humidity rising above 50%, the desiccant canister should be replaced. The canister can be replaced in the field without returning the instrument for service. Campbell Scientific recommends replacing the desiccant every 12–24 months even if internal humidity has not exceeded 50%, given the desiccant capsule shelf life of 2 years.
- **Advanced transducer coating** protects the transducer from degradation in harsh environments such as sulfur-rich agricultural fields, wetlands, and coastal sites.

4.2 Sensor components

The CSAT3C consists of several components. Standard components are included with every CSAT3C. Common and Other Accessories must be ordered separately.

4.2.1 Standard components

Standard components are items that are included or shipped with the CSAT3C. The following sections describe these items.

4.2.1.1 CM250 leveling mounting kit

The CM250 leveling mounting kit is shipped with every CSAT3C and comes with an adapter (Figure 4-1 [p. 6]) for mounting the CSAT3C at the end of a 3.33 cm (1.31 in) OD crossarm or pipe. The kit includes a captive 3/8-in bolt that screws into the bottom of the CSAT3C block to secure the sensor to the adapter, and a 3/16-in Allen wrench to tighten the adapter on the crossarm. Leveling instructions are provided in Installation (p. 14).

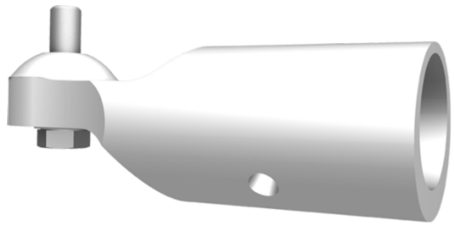

Figure 4-1. CM250 Leveling Mounting Kit

4.2.1.2 USB data cable

The USB data cable is a 4 m (13.1 ft) USB Type-C to Type-C cable shipped with the CSAT3C. The connector that attaches to the CSAT3C is rated IP67. This cable is used for sensor configuration, OS updates, and real-time data viewing via ***Device Configuration Utility*** and for unprompted USB data collection with a computer. It is not intended for long-term field data collection. Communications (p. 33) provides additional information.

4.2.1.3 Sonic carrying case

A large, hard plastic Pelican™ carrying case is available for the CSAT3C. The case is watertight, highly durable, and recommended for transporting and storing the CSAT3C. It includes a set of foam inserts that hold the CSAT3C in a protected position while providing space for additional components.

If the sonic carrying case option is not selected, the CSAT3C will be shipped in a large cardboard box. The same set of foam inserts used in the sonic carrying case is used in the cardboard box to securely hold the CSAT3C.

> NOTE:
> With the cardboard box shipment option, keeping the foam inserts and box is highly recommended. When returning a CSAT3C for factory recalibration or repair, it is important to ship the unit with the foam inserts provided from the factory.

4.2.1.4 Communications and power cable

A CPIPCBL cable is required to operate the CSAT3C and must be ordered with the sensor. The CPIPCBL carries both communications (CPI and RS-485) and power between the CSAT3C and the data acquisition system in a single cable.

Two versions are available:

- **CPIPCBL2** – non-armored CPI+ power cable with an 8-pin female UTSX connector on the sensor end. Available in standard lengths or custom user-defined lengths available as CPIPCBL2- U.
- **CPIPCBL1** – armored version of the same cable, for installations requiring additional mechanical protection. Available in the same standard lengths or custom user-defined lengths available as CPIPCBL1-U.

Two termination options are available for both cable types:

- **-RC** – RJ45 connector with 2-conductor 14 AWG power leads, for connection to a data logger CPI port and power supply.
- **-CU** – 8-pin UTSX pin connector, for daisy-chaining CPI devices or for connection to a CPI breakout board.
- **-PF** – Ferrules on wires for power and RS-485 communications for connection to a 3rd party data acquisition system.

For maximum cable lengths, refer to Communications (p. 12).

Figure 4-2. CPIPCBL2 CPI Non-Armored Communications & Power Cable w/UTSX 8-Pin Female Connector. With UTSX 8-Pin Male Connector (Left). With RJ45 w/2-Conductor 14AWG for Power (Right).

4.2.2 Common accessories

Common accessories for the CSAT3C are additional equipment to make sensible heat flux measurements. A fine-wire thermocouple is an example of an additional sensor often used with a CSAT3C. Descriptions of common accessories are provided in the following sections.

4.2.2.1 FW05 thermocouple

The FW05 is a Type E thermocouple with a 0.0127 mm (0.0005 in) diameter (Figure 4-3 [p. 8]). The thermocouple measures atmospheric temperature fluctuations and may be used with the CSAT3C to directly calculate sensible heat flux. Larger size fine-wire thermocouples, such as the FW1 and FW3, which are more robust but have slower response times, may also be used with the CSAT3C.

Figure 4-3. FW05 Type E Fine-Wire Thermocouple with 0.0005 in. Diameter

4.2.2.2 FWC-L cable

The FWC-L is a cable with connector that is compatible with the connector on a FW05, FW1, or FW3 fine-wire thermocouple. The other end of the cable has pigtail wires to wire to a pair of differential voltage terminals on a data logger. The -L denotes the length of cable in feet, which can be designated at the time of ordering.

4.2.2.3 Thermocouple cover

The thermocouple (TC) cover (pn 10080) is a white, metal thermocouple cover that is placed over the connectors of the FW05 and the FWC-L cable. (See Exploded view of fine-wire thermocouple (TC) with CSAT3C [p. 30].) It is used to mount the connectors to the side of the CSAT3C block. It also minimizes temperature gradients across the connectors.

Figure 4-4. Thermocouple cover for CSAT3C, CSAT3B, or IRGASON

4.2.2.4 Thermocouple cover backplate

The CSAT3C fine-wire thermocouple cover backplate (pn 31423) attaches to the CSAT3C block and is used to cover the back side of the TC cover.

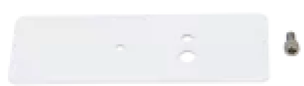

Figure 4-5. Fine-Wire Thermocouple Cover Backplate

4.2.3 Other accessories

The other accessories available for the CSAT3C are used when combining multiple CSAT3C units into a network of sensors, the data from which is collected by a single data logger. Networks of CSAT3Cs using CPI communications may be configured in one of three different configurations:

- In a series using a daisy-chain topology
- In parallel using a star topology
- In a combination of daisy-chain and star topologies

When designing a CPI network, careful attention should be given to not exceed a total network cable length that will excessively attenuate the sensor signals. The exact total length will depend on factors such as sample rate and topology, but in general the maximum cable lengths (given in Communications [p. 12]) should be followed.

Because CPI communications can support longer network cable lengths, it is generally recommended as the communication method for sensor networks. For more detailed information on network topologies and limits on cable lengths for CPI networks, see the white paper titled *Designing Physical Network Layouts for the CPI Bus*, available at www.campbellsci.com.

4.2.3.1 HUB-CPI

The 8-channel RJ45 HUB-CPI allows up to eight CPI devices to be connected in parallel. Up to seven CSAT3Cs, or CSAT3C daisy chains using CPIPCBL cables, may be connected in parallel to the HUB-CPI. The remaining port may be used with a CAT5e or CAT6 Ethernet cable to connect the HUB-CPI to the CPI port on a data logger such as the Granite 9.

The HUB-CPI (shown in Figure 4-6 [p. 10]) is not weatherproof and should be housed in an enclosure, typically alongside the data logger.

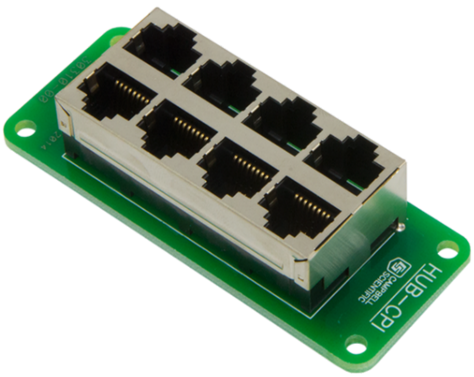

Figure 4-6. HUB-CPI 8-Channel RJ45 Hub for CPI Peripherals

5. Specifications

The CSAT3C measures wind speed and the speed of sound along the three non-orthogonal sonic axes. Wind speeds are transformed into the orthogonal wind components Ux, Uy, and Uz, referenced to the anemometer head. Sonic temperature (T_S) is reported as the average of temperatures computed for the three non-orthogonal sonic axes.

Crosswind components, the portion of wind normal to each sonic axis, introduce a measurement error that is corrected online by the CSAT3C before transformation into orthogonal coordinates. This correction eliminates the need for the post-processing speed-of-sound correction described by Liu, Peters, and Foken (2001; see References [p. 75]).

The CSAT3C supports several operating modes. It can be configured to make a single measurement per CPI data logger trigger, or it can operate in a self-triggered mode where measurements are made continuously at 100 Hz, with an optional user-selectable bandwidth filter applied, and the latest output provided upon receiving an output prompt. Prompts may come from the data logger or, in unprompted modes, from the CSAT3C itself.

The default operating mode is CPI-triggered, single measurement per trigger, with no bandwidth filter applied. See Communications (p. 33) for default settings, and see Operating modes (p. 44) for full mode descriptions.

5.1 Measurements

Ingress protection:	IP67
Operating temperature	
Standard:	–40 to 50 °C
Wind accuracy (–40 to 50 °C, wind speed < 30 m·s^{-1}, azimuth angles between ± 170°)	
Offset error	
Ux:	± 8 cm·s^{-1} max
Uy:	± 8 cm·s^{-1} max
Uz:	± 4 cm·s^{-1} max
Gain error	
Wind vector ± 5° of horizontal:	± 2% of reading max
Wind vector ± 10° of horizontal:	± 3% of reading max
Wind vector ± 20° of horizontal:	± 6% of reading max
Wind resolution	
Ux:	1.0 mm·s^{-1} RMS
Uy:	1.0 mm·s^{-1} RMS
Uz:	0.5 mm·s^{-1} RMS
Wind full scale range:	± 65 m·s^{-1}
Sonic temperature resolution:	± 0.002 °C RMS at 25 °C
Sonic temperature reporting range:	–40 to 50 °C
Measurement rates	
Data logger triggered:	1 to 100 Hz
Unprompted output (to computer):	1, 10, 20, 50, or 100 Hz
Internal self-trigger rate:	100 Hz

Measurement delay

Data logger triggered (no filter):	1 trigger period (1 scan interval)
Unprompted output (no filter):	10 ms
Filtered output (data logger prompted or unprompted to computer):	795 ms with 5 Hz bandwidth filter 395 ms with 10 Hz bandwidth filter 155 ms with 25 Hz bandwidth filter

Filter bandwidths: 5, 10, or 25 Hz

Internal monitor measurements

Inclinometer update rate:	10 Hz
Inclinometer accuracy:	± 1°
Board temperature and relative humidity update rate:	1 Hz
Relative humidity accuracy:	± 7% over 0 to 10% range ± 3% over 10 to 90% range ± 7% over 90 to 100% range
Board temperature accuracy:	± 2 °C

5.2 Communications

CPI (data logger-based data acquisition[1/])

Baud rate:	50 kbps to 1 Mbps
Cable length:	15 m (50 ft) max @ 1 Mbps 122 m (400 ft) max @ 250 kbps 853 m (2800 ft) max @ 50 kbps
Address range:	1 to 120 (Default: 30)
Bus clocks per sample:	~300

RS-485 (anemometer configuration or computer-based data acquisition)

Baud rate:	1200 bps to 230.4 kbps
Cable length:	305 m (1000 ft) max @ 115.2 kbps 610 m (2000 ft) max @ 9.6 kbps
Bus clocks per sample:	~500 (ASCII formatted)

USB: (anemometer configuration or computer-based data acquisition)

Connection speed:	USB 2.0 full speed 12 Mbps
Cable length:	5 m max

1/ For additional details, refer to Campbell Scientific whitepaper "Designing Physical Network Layouts for the CPI Bus".

5.3 Power requirements

Anemometer voltage requirement: 10.5 to 32 VDC

Current requirement (10 Hz measurement rate)

Current @ 12 VDC:	110 mA
Current @ 24 VDC:	65 mA

Current requirement (100 Hz measurement rate)

Current @ 12 VDC:	145 mA
Current @ 24 VDC:	80 mA

5.4 Physical description

Overall:	63.1 cm (24.8 in) length 43.3 cm (17.0 in) height 12.3 cm (4.9 in) width
Measurement path:	10.0 cm (3.9 in) vertical 5.8 cm (2.3 in) horizontal
Transducer angle:	60 degrees from horizontal
Transducer diameter:	0.64 cm (0.25 in)
Transducer mounting diameter:	0.84 cm (0.33 in)
Support arm diameter:	1.59 cm (0.63 in)
Packaging—cardboard box with foam	
Box dimensions:	73.7 x 45.7 x 25.4 cm (29 x 18 x 10 in)
Weight—head only:	1.9 kg (4.2 lb)
Weight—including cardboard box:	5.7 kg (12.6 lb)
Shipping weight:	9.1 kg (20.0 lb)

Shipping dimensions:	91 x 51 x 41 cm (36 x 20 x 16 in)
Packaging—Pelican carrying case with foam:	79.5 x 51.8 x 31 cm (31.3 x 20.4 x 12.2 in)
Weight—head only:	1.9 kg (4.2 lb)
Weight—including carrying case:	13.8 kg (30.5 lb)
Shipping weight:	16.3 (36.0 lb)
Shipping dimensions:	81 x 66 x 43 cm (32 x 26 x 17 in)

6. Installation

6.1 Introduction

Campbell Scientific recommends setting up the CSAT3C and data acquisition system in a laboratory before field installation. This provides an opportunity to verify settings and confirm system operation in a controlled environment before the sensor is deployed. Prior to setup, the user should be familiar with the desired sensor settings and the procedures for orienting, mounting, and leveling the CSAT3C, which are covered in the following sections.

6.2 Site considerations

If the CSAT3C is to be deployed in a marine environment or in an environment with exposure to corrosive chemicals - for example, sulfur-containing compounds in viticulture or wetland environments - mount the CSAT3C in a way that minimizes direct exposure of the sonic transducers to saltwater or corrosive aerosols. The advanced transducer coating on the CSAT3C provides improved resistance to these conditions compared to the CSAT3B, but transducers in marine or corrosive environments are still expected to age more quickly than those in inland, chemical-free deployments and will require replacement sooner.

6.3 Settings

Prior to installation, the CSAT3C settings should be verified in a lab setting to make sure all parts are accounted for and the system is functioning properly.

6.3.1 Verify CSAT3C settings

Verify the CSAT3C settings through the following steps:

1. Connect a CPIPCBL cable to the **Power/CPI/RS-485** port on the back of the CSAT3C block by engaging the UTSX connector with a quarter-turn until it locks. Connect the other end to a 10.5 to 32 VDC power source. The power leads are red (positive) and black (ground); refer to the cable wiring table in Communications (p. 33).
2. Connect the USB Type-C cable included with the CSAT3C to the **USB** port on the back of the CSAT3C block. Connect the other end of the cable to a USB port on a computer.
3. Launch ***Device Configuration Utility*** from ***LoggerNet*** or download from www.campbellsci.com/devconfig.

4. From the left side of the main screen, select the CSAT3C among the list of sensors. Select the appropriate communication port and click **Connect** at the bottom left of the window.

> **NOTE:**
> If this is the first time the computer has connected to a CSAT3C, and depending on the computer settings, the USB driver may need to be manually installed. To do this, make sure the computer is connected to the internet and click **install the USB driver** link as shown in Figure 6-1 [p. 16]). Once the driver has been installed, click **Connect** at the bottom left of the window.

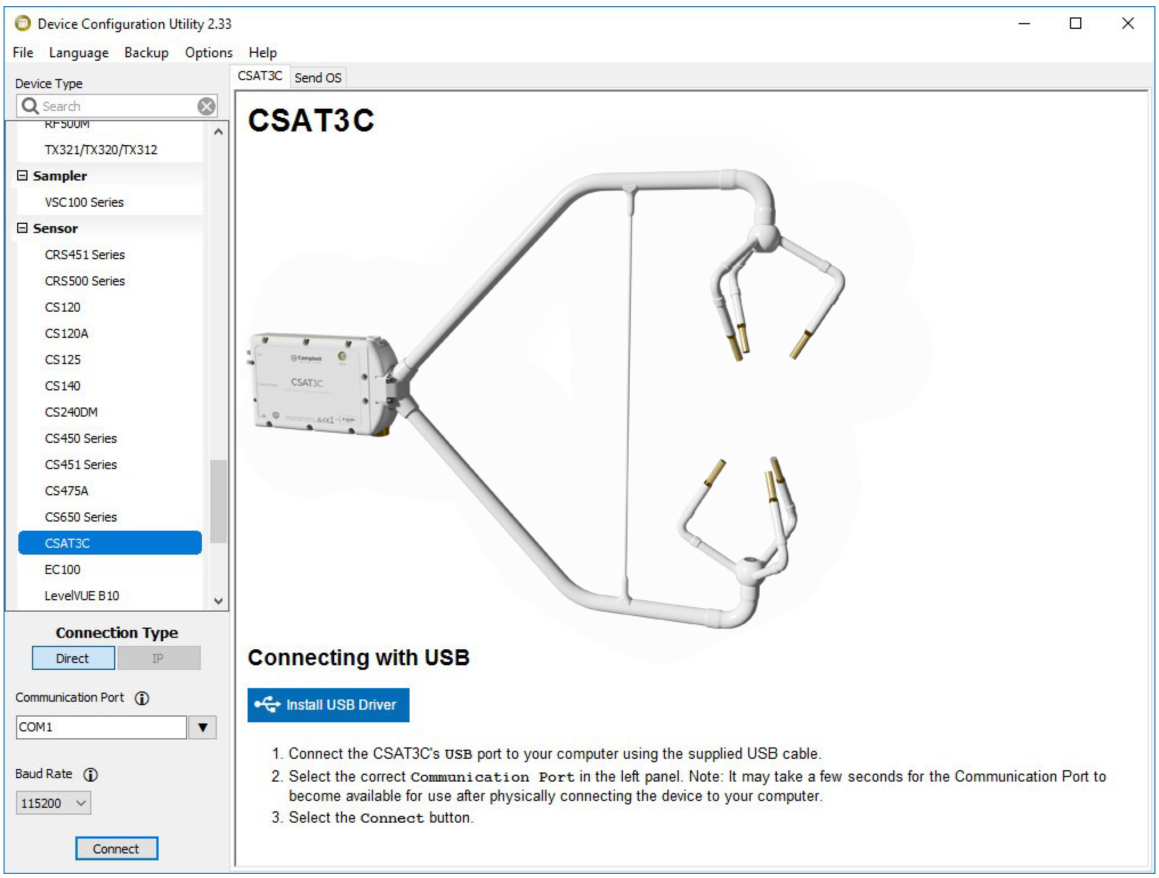

Figure 6-1. Connecting CSAT3C using ***Device Configuration Utility***

5. Once connected, the main screen will have a section with tabs to view the following four subscreens: **Real-Time Data**, **Communication Settings**, **Measurement Settings**, and **Instrument ID**. Table 6-1 (p. 18) describes each of the settings and its factory defaults. Verify communication protocol settings match the intended deployment configuration before proceeding.

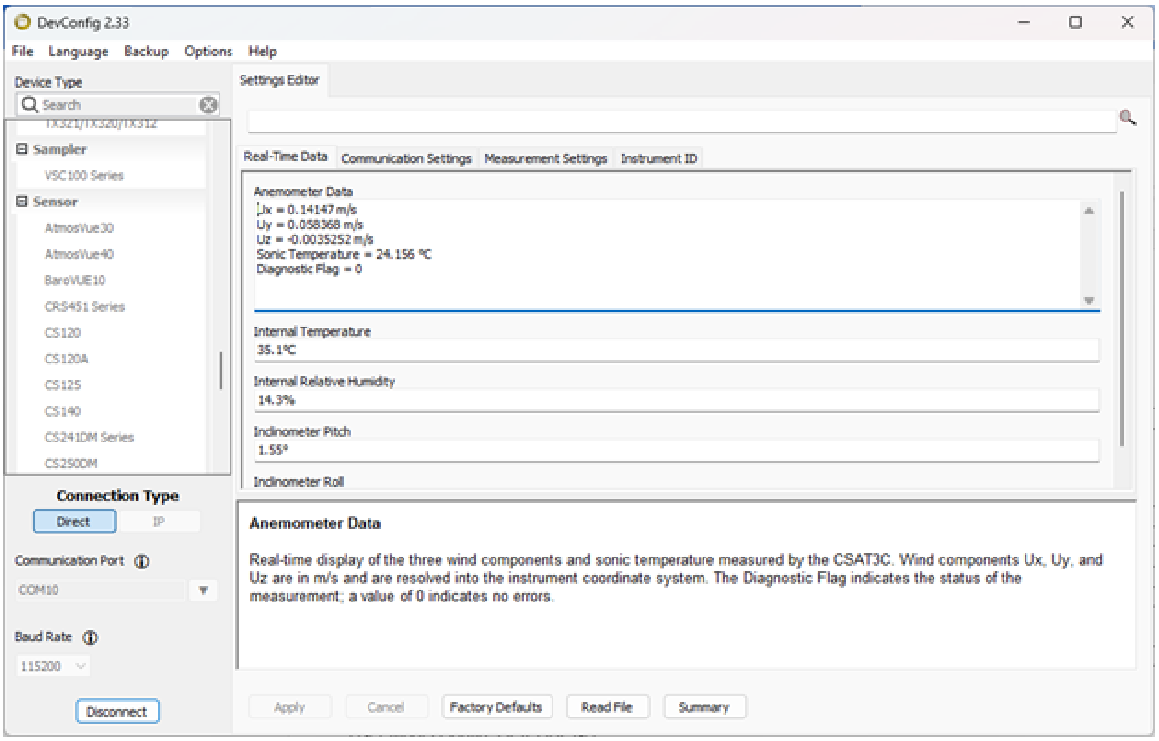

Figure 6-2. Connected to CSAT3C in ***Device Configuration Utility***

In the **Real-Time Data** subscreen, the **Anemometer Data** values (Ux, Uy, Uz, **Sonic Temperature**, and **Diagnostic Flag**) update once per second when the CSAT3C is in the default Operating Mode 0 (Logger-Triggered/ No Filter/ Logger-Prompted CPI Output). This confirms the sensor is powered and actively measuring. In **Mode 0**, the CSAT3C outputs data only when triggered by a connected data logger. If no data logger is connected and running a program that sends CPI triggers, the **Status** LED on the CSAT3C block will flash red. This is expected behavior during lab setup and does not indicate a fault. Once a data logger is connected, powered, and running a program that sends CPI measurement triggers, the **Status** LED will turn green, confirming measurements are being made and transmitted without diagnostic errors. If the **Status** LED does not turn green after connecting a data logger, refer to Troubleshooting (p. 65).

NOTE:
Factory defaults for all settings may be restored by clicking **Factory Defaults** at the bottom of the ***Device Configuration Utility*** screen.

Table 6-1: CSAT3C settings and status values in *Device Configuration Utility*

Subscreen	Setting or status value	Options	Description
Real-Time Data	Anemometer Data	-	Real-time display of the three wind components and sonic temperature. Ux, Uy, and Uz are in m/s and resolved into the instrument coordinate system. The Diagnostic Flag indicates the status of the measurement; a value of 0 indicates no errors.
	Ux, Uy, Uz	-	Wind velocity components resolved into the instrument coordinate system.
	Sonic Temperature	-	Sonic temperature (Ts)
	Diagnostic Flag	-	See Diagnostic word (p. 55).
	Internal Temperature	-	Temperature inside CSAT3C block
	Internal Relative Humidity	-	Relative humidity inside CSAT3C block. Change desiccant if greater than 50% (see Desiccant [p. 60]).
	Inclinometer Pitch	-	Pitch angle of CSAT3C head (see Leveling [p. 28])
	Inclinometer Roll	-	Roll angle of CSAT3C head (see Leveling [p. 28])

Table 6-1: CSAT3C settings and status values in *Device Configuration Utility*			
Subscreen	Setting or status value	Options	Description
Communication Settings	Communication Port Protocol	Disable Both CPI Enabled[1] RS-485 Enabled	Selects whether the combined port operates in CPI or RS-485 mode, or is disabled. Only one protocol may be active at a time. **CPI Enabled** requires Logger-Prompted CPI Output in the Measurement Setting, Operating Mode. **RS-485 Enabled** requires Operating Mode to be set to an Unprompted Output mode and Unprompted Output Port set to RS-485 port. Use **Disable Both** when streaming data via USB only.
	CPI Address	1 through 120 30[1]	Unique address for this CSAT3C on the CPI bus. Each CSAT3C must have a unique address. Only active when Communications Port Protocol is set to CPI Enabled.
	CPI Baud Rate	Auto[1] 1000 kbps 500 kbps 250 kbps 125 kbps 50 kbps	Sets the baud rate for CPI bus communications. **Auto** is recommended for most installations and allows the CSAT3C to auto-detect the baud rate from the datalogger. For installations with long cable runs, selecting a lower fixed baud rate may improve reliability. Only active when Communication Port Protocol is set to CPI Enabled.

Table 6-1: CSAT3C settings and status values in *Device Configuration Utility*			
Subscreen	Setting or status value	Options	Description
	RS-485 Baud Rate	1200 2400 4800 9600 19200 38400 57600 115200[1] 230400	Sets the baud rate for RS-485 serial communication. Must be sufficient to support the selected Unprompted Output Rate (see Baud rate and unprompted output rate compatibility [p. 24]). ***Device Configuration Utility*** will restrict selection of an unprompted output rate that is incompatible with the configured RS-485 baud rate; set the baud rate to at least the minimum required before selecting the output rate. The baud rate at the receiving device must match this value. Only active when Communication Port Protocol is set to RS-485 Enabled.
	Unprompted Output Port	Disabled[1] USB Port RS-485 Port	Must be set to **RS-485 Port** when RS-485 Enabled is selected for Communication Port Protocol. This setting is grayed out until Operating Mode is set to Mode 2 or Mode 3.

Table 6-1: CSAT3C settings and status values in *Device Configuration Utility*			
Subscreen	**Setting or status value**	**Options**	**Description**
	Unprompted Output Rate	1 Hz 10 Hz[1] 20 Hz 50 Hz 100 Hz	Sets the output rate for unprompted data. Ensure the RS-485 Baud Rate is sufficient to support the selected rate (see Baud rate and unprompted output rate compatibility [p. 24]). Over USB, the connection baud rate is negotiated at connection time; if the negotiated baud rate is insufficient for the configured output rate, the CSAT3C temporarily throttles output to the maximum rate the current USB connection supports, and resumes the configured rate automatically on the next sufficient connection. No permanent settings change occurs during throttling. This setting is grayed out until Operating Mode is set to Mode 2 or Mode 3.

Table 6-1: CSAT3C settings and status values in *Device Configuration Utility*			
Subscreen	**Setting or status value**	**Options**	**Description**
Measurement Settings	Operating Mode	**Mode 0**: Data logger triggered | No Filter | Data logger prompted CPI output[1] **Mode 1**: Self triggered | Filtered | Data logger prompted CPI output **Mode 2**: Self triggered | No filter | Unprompted output to USB or RS-485 **Mode 3**: Self triggered | Filtered | Unprompted output to USB or RS-485	Configures three aspects of CSAT3C operation: trigger source, filter mode, and output method. **Data Logger Triggered**: the data logger triggers each measurement via CPI; this is the recommended mode for CPI-connected Campbell Scientific data loggers to ensure synchronized eddy covariance data collection. **Self Triggered**: the CSAT3C triggers measurements autonomously at the Unprompted Output Rate; used for RS-485 or USB output to non-Campbell Scientific systems. **No Filter**: raw (unfiltered) wind and temperature data are output. **Filtered**: a low-pass filter is applied; set Filter Bandwidth as desired. **Data Logger Prompted CPI Output**: data is transmitted over CPI when requested by the data logger. **Unprompted Output to USB or RS-485**: data streams continuously out the selected port at the configured rate. **NOTE:** Operating Mode must be set to an Unprompted Output mode when RS-485 Enabled is selected for the Communication Port Protocol.

Table 6-1: CSAT3C settings and status values in *Device Configuration Utility*			
Subscreen	Setting or status value	Options	Description
	Filter Bandwidth	5 Hz[1] 10 Hz 25 Hz	The cut-off frequency of the low-pass filter. Only applicable if in Operating Mode 1 or 3. **5 Hz**: typical minimum for flux measurement applications. **10 Hz**: higher bandwidth for faster response. **25 Hz**: maximum filtered bandwidth; preserves more high-frequency content. To avoid aliasing, the data logger scan rate or Unprompted Output Rate should be set to at least twice the selected filter bandwidth (e.g., scan at 10 Hz or faster when using the 5 Hz filter).
	Sonic Transducer Shadow Correction	Disabled[1] Enabled	Applies an optional Kaimal transducer shadow correction for ultrasonic wind measurements. Transducer shadowing occurs when the transducers partially block airflow, causing a slight underestimation of wind speed. See Sonic transducer shadow correction (p. 43).

Table 6-1: CSAT3C settings and status values in *Device Configuration Utility*			
Subscreen	Setting or status value	Options	Description
Instrument ID	Anemometer Serial Number	Serial Number[1]	The serial number of the CSAT3C
	User ID String	Blank[1]	A unique identifier (in addition to the serial number) that the user may assign
	Factory ID String	Blank[1]	A unique identifier (in addition to the serial number) that the factory may assign
	OS Version	-	The version number of the CSAT3C operating system
	OS Date	-	The date the loaded operating system was built
[1] Denotes a factory default setting			

NOTE:
Factory defaults for all settings may be restored by clicking the **Factory Defaults** button at the bottom of the screen in the ***Device Configuration Utility***.

Table 6-2: Baud rate and unprompted output rate compatibility	
Unprompted output rate	Minimum baud rate required
1 Hz	1200 bps
10 Hz	9600 bps
20 Hz	19200 bps
50 Hz	57600 bps
100 Hz	115200 bps

6.4 Mount the CSAT3C

The CSAT3C is supplied with mounting hardware to attach it to the end of a horizontal pipe with an outer diameter of 3.33 cm (1.31 in), such as the Campbell Scientific CM202, CM204, or CM206 crossarm (referred to generically as a CM20X crossarm). The following steps describe a general mounting procedure

1. Secure the chosen crossarm to a tripod or other vertical structure using a CM210 crossarm-to-pole mounting kit as shown in Figure 6-3 (p. 25).

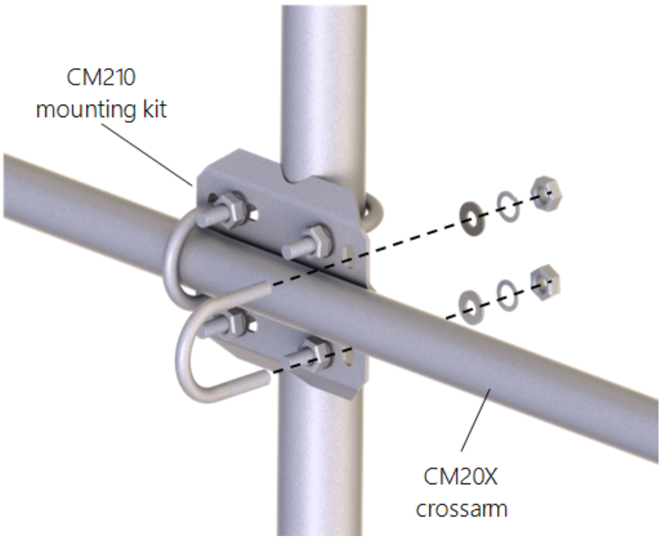

Figure 6-3. CM210 mounting kit with CM20X crossarm

2. Point the horizontal arm into the direction of the prevailing wind (for example, if the primary wind blows from the south, point the sensor to be facing south) and tighten the nuts and bolts of the mounting hardware.
3. Attach the CM250 leveling mount (included with the CSAT3C) to the crossarm by tightening the set screws on the boom adapter with a 3/16-in hex socket head wrench. Refer to Figure 6-4 (p. 26).
4. Attach the CSAT3C to the leveling mount by inserting the bolt on the mount into the threaded hole on the bottom of the CSAT3C block as shown in Figure 6-4 (p. 26). The orientation of the CSAT3C should be level and pointing in the direction of the prevailing wind.
5. Lightly tighten the bolt so that final leveling can be performed once all instrumentation is fully mounted to the structure.

> **CAUTION:**
> Do not carry the CSAT3C by the arms or the strut between the arms. Always hold the CSAT3C by the block, where the upper and lower arms connect.

> **CAUTION:**
> Over-tightening bolts will damage the screw threads in the CSAT3C block.

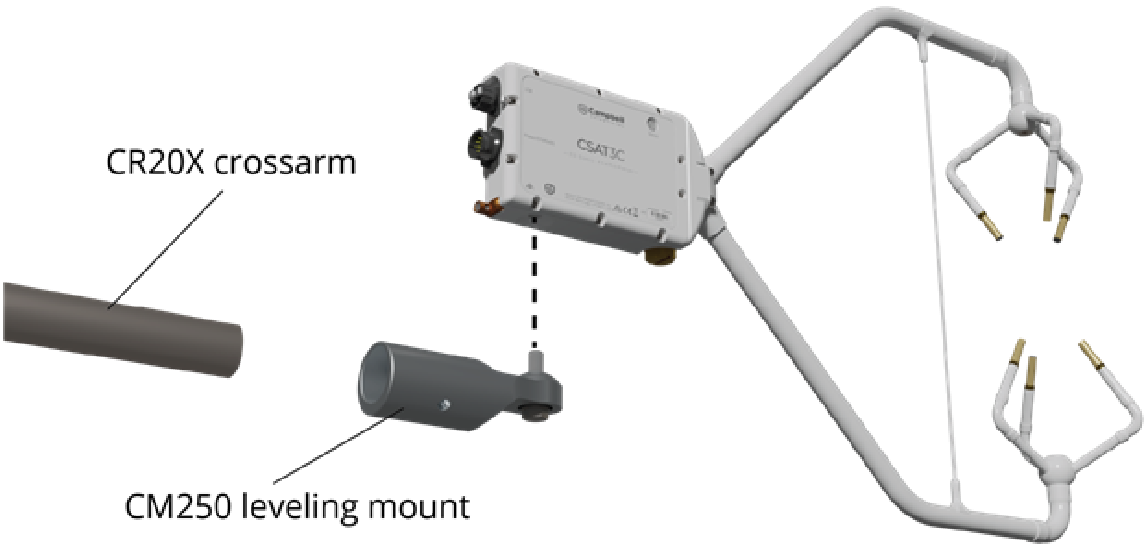

Figure 6-4. CSAT3C mounting

6.5 Orientation

The three components of wind are defined by a right-handed orthogonal coordinate system. The CSAT3C points into the negative x direction (see Figure 6-7 [p. 29]). If the anemometer is pointing into the wind, it will report a positive u_x wind.

In general, the anemometer should be pointed into the prevailing wind to minimize interference from support structures such as the tower or tripod. Typically, the anemometer should be mounted level to the ground as described in Leveling (p. 28).

6.5.1 Sonic azimuth

The example programs report the wind direction in both the sonic coordinate system (a right-handed coordinate system; Figure 6-5 [p. 27]) and in the compass coordinate system (a left-handed coordinate system; Figure 6-6 [p. 28]). The sonic coordinate system is relative to the sonic itself and does not depend on the sonic orientation (azimuth of the negative x-axis). The compass coordinate system is fixed to Earth. For the program to compute the correct compass wind direction, the azimuth of the sonic negative x-axis must be entered into the program. The program default value for the variable `CSAT_AZIMUTH` is `0`. This assumes that the prevailing wind is from the north (e.g., the sonic is mounted such that the negative x-axis points to the north). To change this to the appropriate azimuth, open the CRBasic program, navigate to `Const CSAT_AZIMUTH`, input the correct azimuth, and send this updated program to the data logger.

NOTE:
Remember to account for the magnetic declination at the site; see CSAT3C orientation (p. 69) for details. If using an app on a cellular phone, magnetic declination is most likely already taken into consideration.

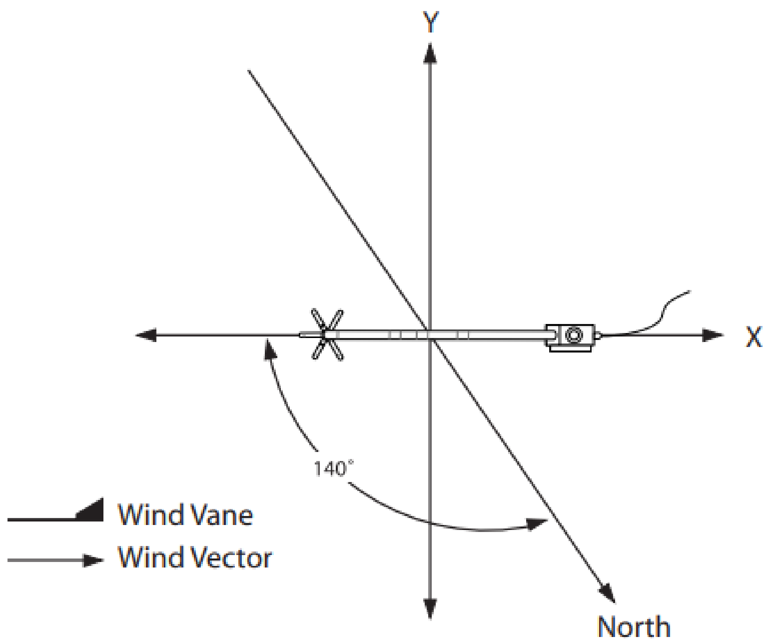

Figure 6-5. Right-hand coordinate system, horizontal wind vector angle is 0 degrees

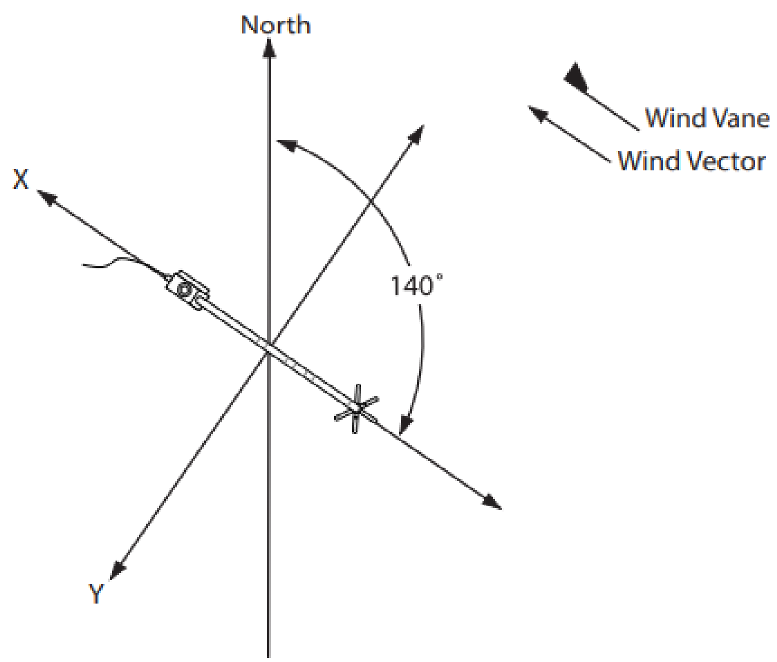

Figure 6-6. Compass coordinate system, compass wind direction is 140 degrees

6.6 Leveling

Leveling the CSAT3C within a couple degrees is usually sufficient. The user commonly applies coordinate rotations to time series data to report the three-dimensional wind in a coordinate system where the x- and y-axes lie along the streamwise wind plane.

Adjust the anemometer head so that the bubble within the level on top of the CSAT3C block is in the bullseye. Firmly grasp the sonic anemometer block, loosen the bolt underneath the block, and adjust the head accordingly. Finally, tighten the bolt with a 9/16-in wrench.

If an application requires greater accuracy in inclination of the CSAT3C, or if an application requires a measurement that shows if, and when, the inclination of the CSAT3C changes over time (for example, a sagging crossarm or tower tilt), an integrated inclinometer in the CSAT3C can give pitch and roll measurements.

Pitch is the angle between the gravitationally horizontal plane and the CSAT3C x-axis. A positive pitch angle corresponds to a clockwise rotation about the y-axis when looking down on the y-axis (see Figure 6-7 [p. 29]). In other words, a positive pitch angle occurs when the transducer end of the CSAT3C is pointed downwards, while a negative pitch angle occurs when CSAT3C is pointed upwards.

Roll is the angle between the gravitationally horizontal plane and the CSAT3C y-axis. A positive roll angle corresponds to a counter-clockwise rotation about the x-axis when looking down the x-axis (see Figure 6-7 [p. 29]).

The inclinometer is sampled at a rate of 10 Hz and is not necessarily synchronized with the wind and sonic temperature data outputs. For applications that require correction for a moving measurement platform (on a buoy or ship, for example), a separate fast-response inclinometer, gyrometer, and accelerometer sensor should be used and sampled at the same rate as the CSAT3C wind measurements.

The outputs of the CSAT3C integrated inclinometer can be viewed by connecting the USB data cable to the CSAT3C and a computer running Campbell Scientific ***Device Configuration Utility***. It can also be output using the CRBasic instruction `CSAT3CMonitor()`. See CSAT3CMonitor() (p. 54) for more information about setting this instruction.

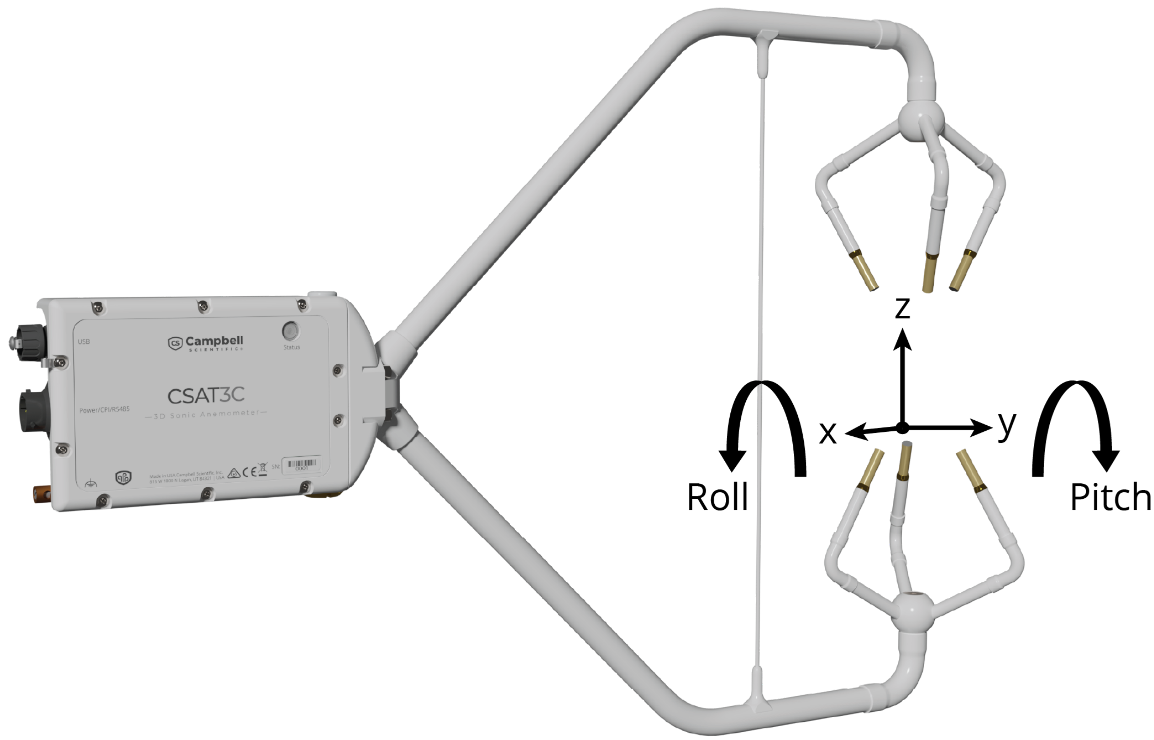

Figure 6-7. CSAT3Cshown with coordinate system, with arrows representing positive x-, y-, and z-axes; curved arrows indicate positive rotations of pitch and roll angles

6.7 Installing additional fast-response sensors

6.7.1 Fine-wire thermocouple

A fine-wire thermocouple (TC; model FW05 with a FWC-L cable, TC cover, and TC cover backplate) can be mounted to the side of the anemometer block to measure temperature fluctuations.

First, attach the TC cover backplate to the CSAT3C with the screw that was included. Next, attach the socket connector from the FWC-L to the side of the anemometer with the short screw (#2-56 x 0.437 in) that was provided with the white thermocouple cover. Insert the pin connector of the FW05 into the socket connector of the FWC-L. Finally, attach the thermocouple cover to the anemometer block using the thumb screw so the FW05 and FWC-L connectors are both covered. See Figure 6-8 (p. 30) for positioning and Figure 6-9 (p. 31) with the FW05 fully installed.

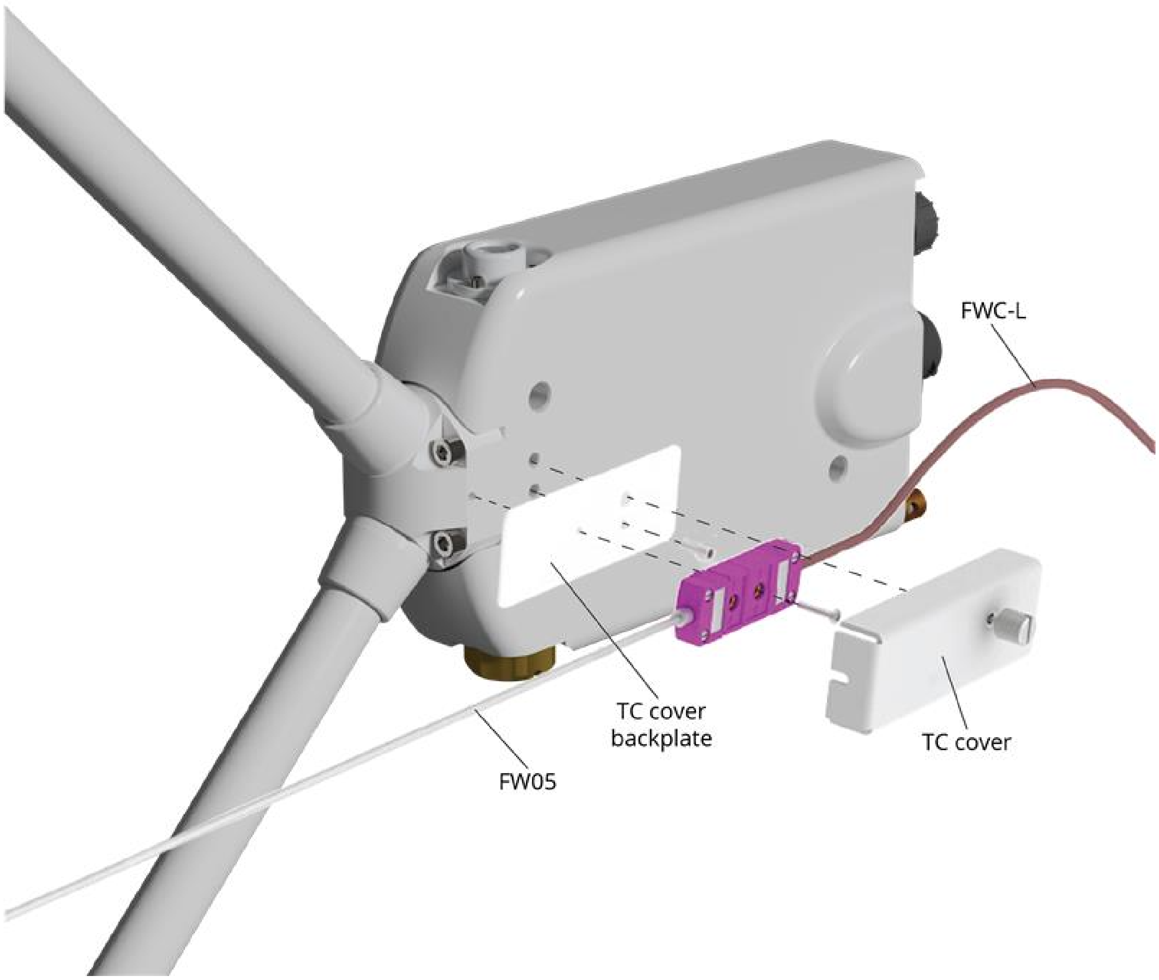

Figure 6-8. Exploded view of fine-wire thermocouple (TC) with CSAT3C

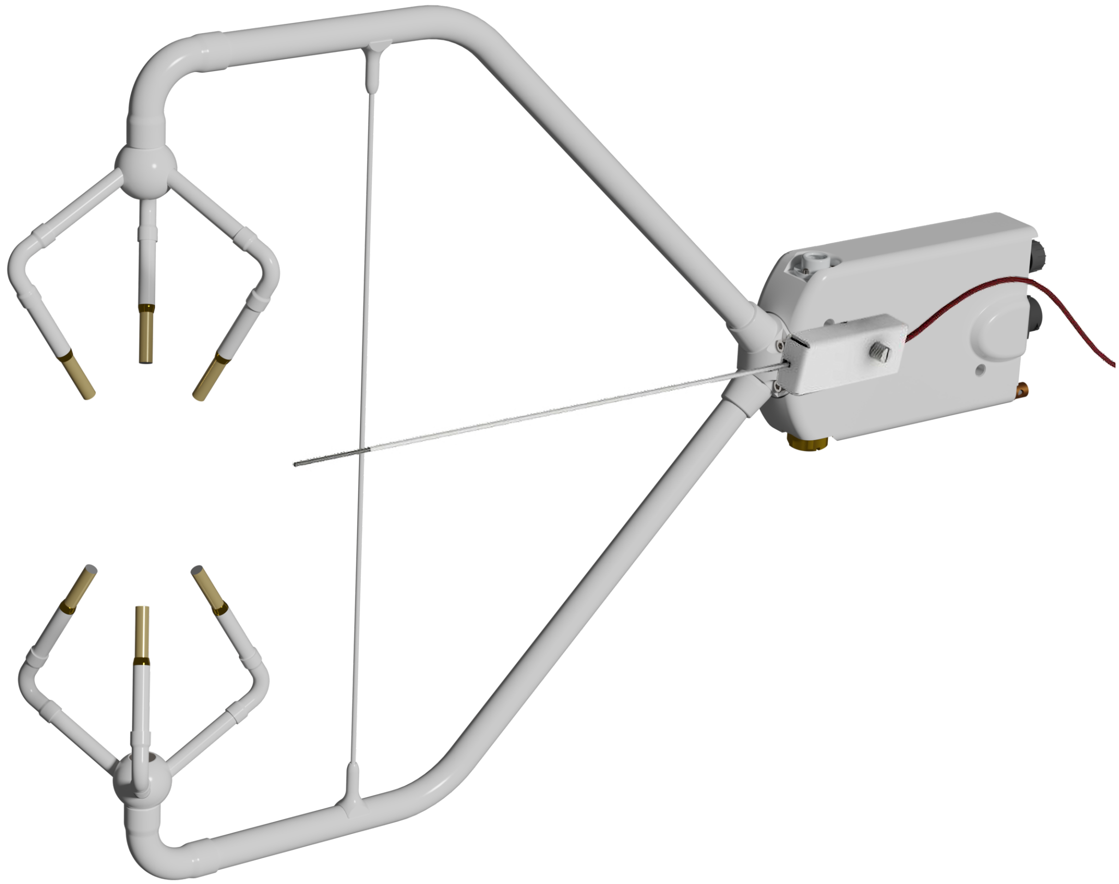

Figure 6-9. CSAT3C with fine-wire thermocouple mounted

6.7.2 Other gas analyzers

If a fast-response gas analyzer is being used with the CSAT3C, care should be taken to mount the analyzer (open-path) or the analyzer intake (closed-path) as close as possible to the sonic sampling volume in order to obtain good spatial and temporal synchronicity between vertical wind and gas concentration fluctuations while also retaining adequate spatial separation. This will avoid excessive wind distortion. In general, mount the analyzer or its intake downwind of the sonic sampling volume.

6.8 Grounding to earth

The CSAT3C and data logger enclosure must be earth grounded to the same grounding rod. They should be grounded from their grounding lugs (shown in Figure 6-10 [p. 32]) as described generally in the following steps.

CAUTION:
Grounding the CSAT3C is critical. Proper grounding to earth will ensure maximum electrostatic discharge (ESD) and lightning protection and improve measurement accuracy. The data logger and CSAT3C electronics should all be grounded to the same grounding rod.

On the back of the CSAT3C block is a copper grounding lug (refer to Figure 6-10 [p. 32]). Use a standard flat-head screwdriver to pinch a wire (from 8 to 14 AWG) between the lug and the lug screw. Campbell Scientific offers a 10 AWG copper wire that is suitable for grounding sensors. Connect the other end of the wire to the tripod or tower, which should be grounded to earth with a grounding rod. A 5-ft copper-clad grounding rod ships with Campbell Scientific tripods, or it can be purchased separately.

The CSAT3C has two ports at the rear of the block: **Power/CPI/RS-485** and **USB**, as shown in Figure 6-10 (p. 32). Unless a port is in use and connected to a cable, they should be securely covered by one of the caps that are captive to the CSAT3C.

1. Ground the CSAT3C and data logger to the tower by attaching a user-supplied, heavy-gauge wire from the copper grounding lug on the back of the CSAT3C block (see Figure 6-10 [p. 32]).
2. Earth (chassis) ground the other ends of the wires to the CSAT3C mounting structure or to a grounding rod. Proper grounding lends stability and protection to a data acquisition system. It is the easiest and least expensive insurance against data loss—and often the most neglected. The following terminals are provided for the CSAT3Cgrounding.

Figure 6-10. CSAT3C Ground Lug

NOTE:
If connecting multiple CSAT3Cs together either in a daisy chain series or star topology, each CSAT3C must be separately grounded to either the mounting structure or a grounding rod.

6.9 Communications

If the CSAT3C is going to be operated using CPI communications in Mode 0 (data logger triggered, no filter), the default settings are appropriate and do not require modification. If, however, the CSAT3C will be operated in another mode that either requires data filters or uses RS-485 communications, the settings must be modified as described in Settings (p. 14).

Table 6-3: CPIPCBL cable wire assignments

Wire color	Signal
Brown	SyncA
Brown/White	SyncB
Blue	DataA
Blue/White	DataB
Green	RGND
Black	GND
Red	Power (10.5 to 32 VDC)
Drain	Shield

Table 6-4: RJ45 termination w/2-conductor 14 AWG for power (-RC)	
Pin	**Wire color**
1	No connect
2	No connect
3	No connect
4	Blue
5	Blue/White
6	Green
7	Brown/White
8	Brown

Table 6-5: UTSX 8-pin male connector termination (-CU) pinout	
Pin	**Wire color**
A	Drain
B	Brown
C	Brown/White
D	Red
E	Blue
F	Blue/White
G	Green
H	Black

Table 6-6: Ferrules on wires for power & RS-485 communications (-PF)	
Wire Color	**Signal**
Blue	DataA/(Tx-)
Blue/White	DataB/(Tx+)
Green	Signal GND
Red	Power (+)
Black	Power GND
Clear	Drain

6.9.1 CPI communications

Connect a CPIPCBL cable to the **Power/CPI/RS-485** port on the CSAT3C block by engaging the UTSX connector with a quarter-turn until it locks. For a single CSAT3C, use a CPIPCBL-RC cable (RJ45 termination): plug the RJ45 connector into the CPI port of the data logger, and connect the power leads to a 10.5 to 32 VDC source.

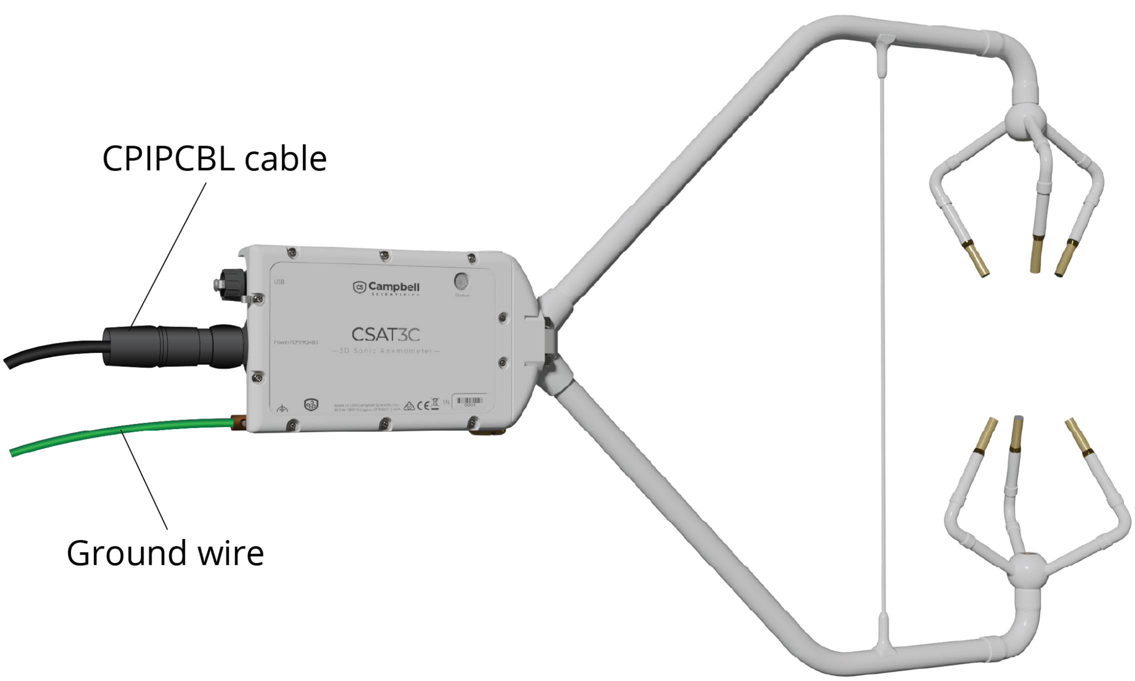

Figure 6-11. Power and CPI cable connections

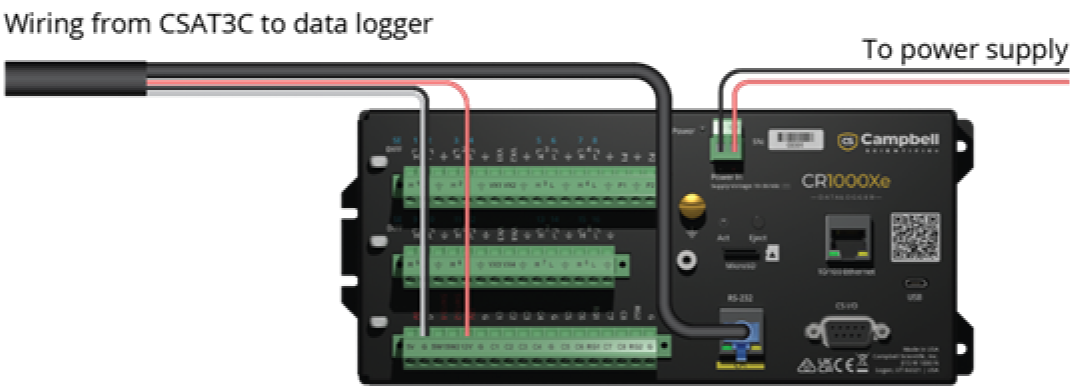

Figure 6-12. CPI connection to a CR1000Xe data logger

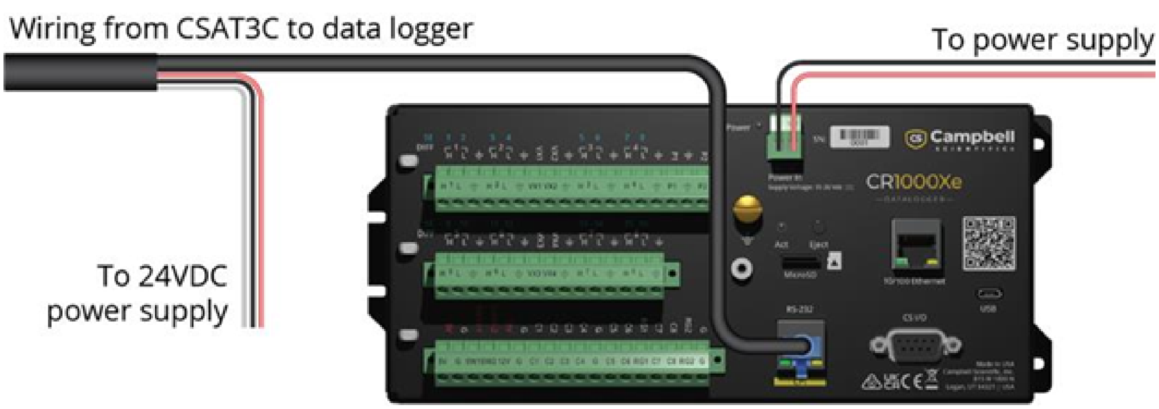

Figure 6-13. CPI connection to a CR1000Xe data logger with power connected to 24Vdc power supply

CPI star topology

If several CSAT3Cs using CPI communications are being connected in parallel or with a star topology, connect a CPIPCBL cable to each CSAT3C, and plug each RJ45 connector into a port on the HUB-CPI. Then, use a CAT5e or CAT6 Ethernet cable to connect the HUB-CPI to the CPI port of a data logger. Refer to Figure 6-14 (p. 37) for these connections.

> **NOTE:**
> The sockets or ports on the HUB-CPI are all the same. Any socket may be used to connect to the data logger or to other CSAT3Cs.

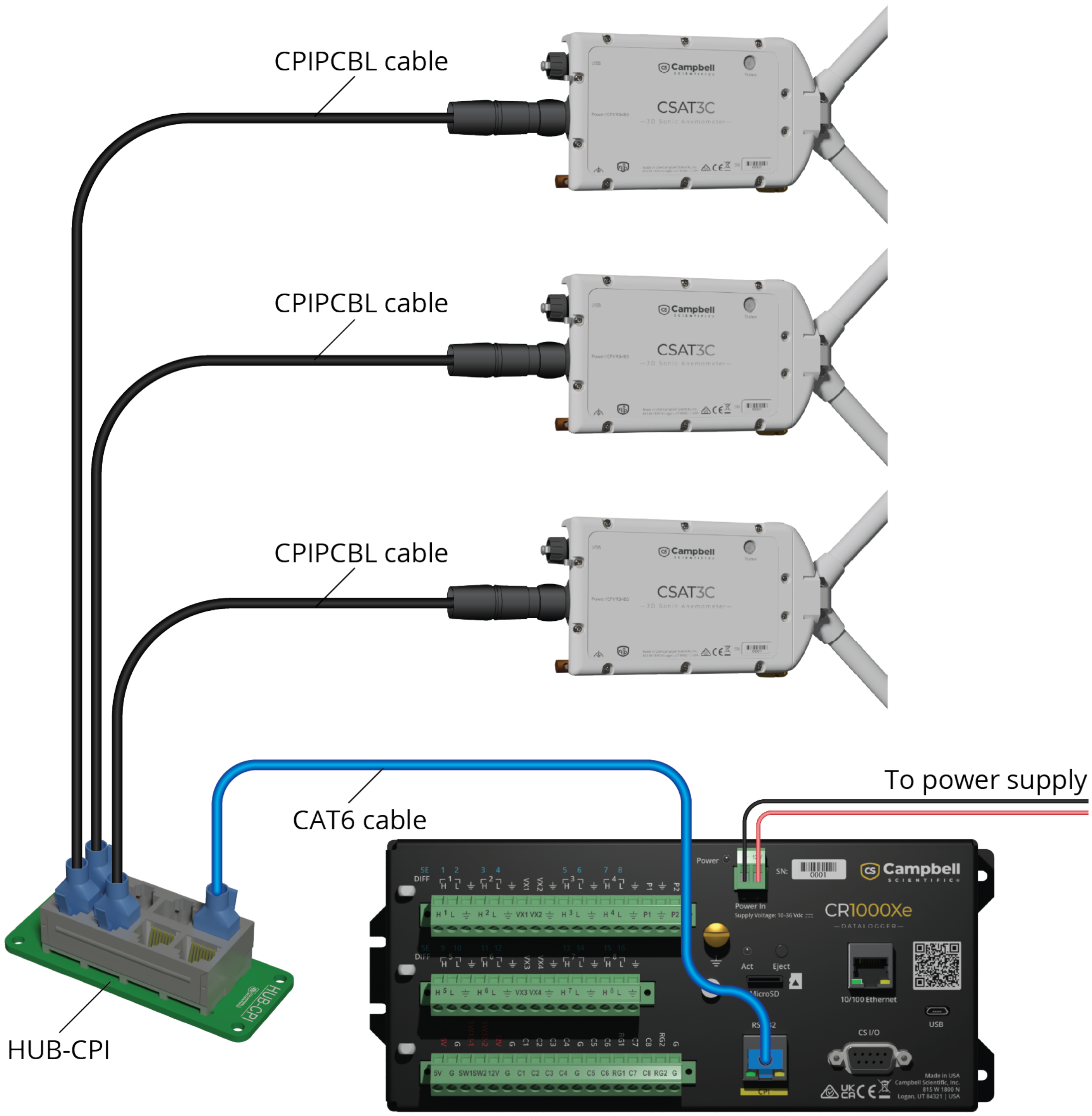

Figure 6-14. CPI star topology (CSAT3C sensor arms, grounding cables, and power leads from CPIPCBL2 not shown)

6.9.2 RS-485 communications

If data collection from the anemometer is to be accomplished by a computer, for example, using RS-485, first connect the CSAT3C as described in Settings (p. 14) to confirm the following settings:

Operating Mode (choose one of the following):

- Mode 2: Self-triggered | No filter | Unprompted Output to USB or RS-485
- Mode 3: Self-triggered | Filtered | Unprompted Output to USB or RS-485 (if Mode 3, select filter bandwidth)

CPI/RS-485 Communication Port Protocol: RS-485 Enabled

RS-485 Baud Rate: 115200 or other appropriate value

Unprompted Output Port: RS-485 port

Unprompted Output Rate: 1, 10, 20, 50, or 100 Hz

NOTE:
In ***Device Configuration Utility***, the settings for **Unprompted Output Port** and **Unprompted Output Rate** will be grayed-out until the operating mode has been set to Mode 2 or Mode 3.

NOTE:
Device Configuration Utility will restrict selection of an **Unprompted Output Rate** that is incompatible with the configured **RS-485 Baud Rate**. Set the **RS-485 Baud Rate** to at least the minimum required for the desired output rate (see Table 6-2 [p. 24]) before selecting the output rate.

Connect a CPIPCBL cable to the **Power/CPI/RS-485** port. Connect the power leads (red and black) to a 10.5 to 32 VDC supply. Connect the RS-485 signal wires (DataA/DataB, Blue/Blue-White) to the RS-485 interface of the receiving system. GND (Green) should be connected to the reference ground of the RS-485 interface.

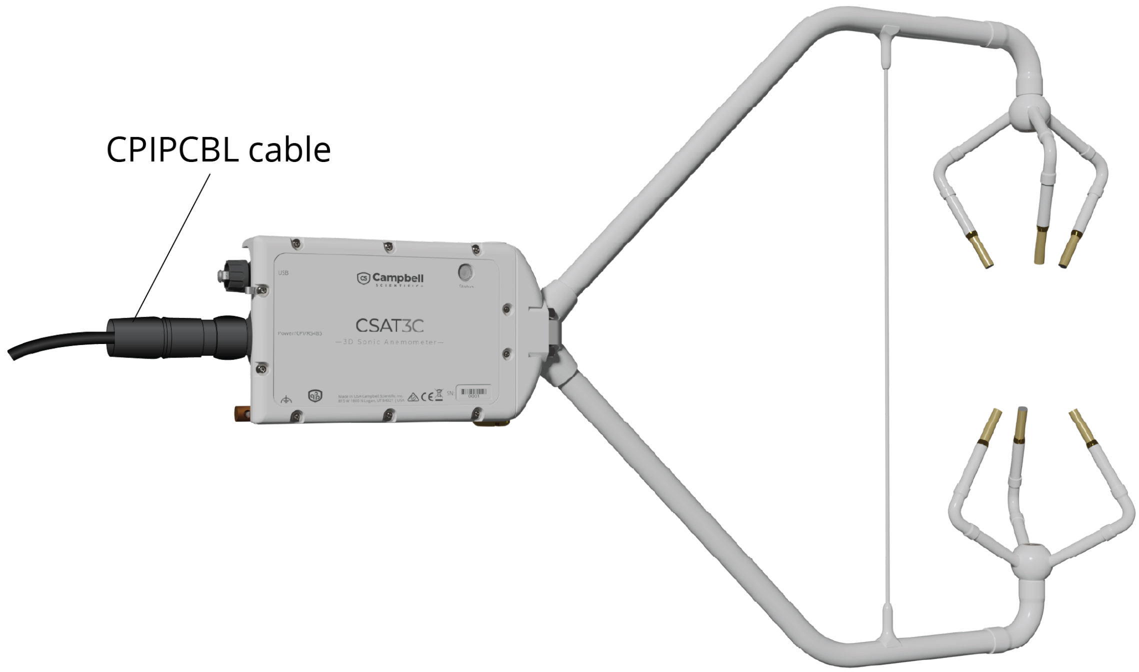

Figure 6-15. RS-485 cable connections

6.9.3 USB

For computer-based data collection in unprompted USB mode, connect the 4 m (13.1 ft) USB Type-C to Type-C cable with IP67 connector rating, included with the CSAT3C, to the **USB** port on the CSAT3C and to a **USB** port on the computer. The CPIPCBL cable should have pigtail wires, which may be connected to a 10.5 to 32 VDC power supply. In ***Device Configuration Utility***, set **Unprompted Output Port** to **USB** and configure the **Operating Mode** and **Unprompted Output Rate**. Maximum USB cable length is 5 m.

Operating Mode (choose one of the following):

- Mode 2: Self-triggered | No filter | Unprompted Output to USB or RS-485
- Mode 3: Self-triggered | Filtered | Unprompted Output to USB or RS-485 (if Mode 3, select filter bandwidth)

Unprompted Output Port: USB port

Unprompted Output Rate: 1, 10, 20, 50, or 100 Hz

NOTE:
Unlike RS-485, the USB connection baud rate is negotiated at connect time and may vary. If the CSAT3Cconnects over USB at a baud rate insufficient to support the configured **Unprompted Output Rate**, the CSAT3C temporarily throttles output to the maximum rate supported by the current USB connection. Normal output at the configured rate resumes automatically when the device is next connected at a sufficient baud rate. No permanent settings change occurs during throttling.

NOTE:
In ***Device Configuration Utility***, the settings for **Unprompted Output Port** and **Unprompted Output Rate** will be grayed-out until the operating mode has been set to Mode 2 or Mode 3.

6.10 Power connections

The CSAT3C uses CPIPCBL cables that combine both power and CPI communication in a single cable. The CPI port on Campbell Scientific dataloggers provides communication only - sensor power must be supplied through the data logger's 12V power terminals or from an external power supply.

NOTE:
Campbell Scientific data loggers have thermally-limited 12V power outputs. For installations with multiple CSAT3C sensors or long cable runs, an external 12 to 32 VDC power supply is recommended to ensure adequate power delivery and prevent voltage drop below the CSAT3C's minimum 10.5 VDC requirement.

6.10.1 Data logger power connections

For single CSAT3C installations, power can be supplied directly from the data logger's **12V** terminal. Connect the CPIPCBL-RJ cable power leads (red and black) to the appropriate data logger terminals and plug the RJ45 connector into the **CPI** port.

Refer to Figure 6-12 (p. 36) and Figure 6-13 (p. 36).

6.10.2 External power supply connections

When using an external power supply, connect the CPIPCBL cable power leads to the power supply terminals and connect the RJ45 to the data logger's **CPI** port for communication only.

Table 6-7: CSAT3C external power supply connections		
Power supply terminal	CPIPCBL wire color	Signal
Positive (+)	Red	Power (10.5 to 32 VDC)
Negative (-)	Black	Ground

Connect the RJ45 connector from the CPIPCBL cable to the **CPI** port on the data logger. In this configuration, the data logger provides only CPI communication while the external power supply provides sensor power.

> **NOTE:**
> When using an external power supply, ensure the power supply ground and the data logger ground are connected to the same earth ground point to maintain proper system grounding.

> **NOTE:**
> For long cable runs (>400 ft/122 m), Campbell Scientific recommends using a 24 VDC power supply to compensate for voltage drop and ensure the CSAT3C receives adequate voltage at the sensor input.

7. Operation

7.1 Theory of operation for wind and sonic temperature measurements

The CSAT3C uses three pairs of non-orthogonally oriented transducers that transmit and receive ultrasonic signals. The time of flight of a sonic signal between a pair of transducers is directly related to the wind vector component that is parallel to the sonic axis. The CSAT3C calculates the wind vector components along each sonic axis using the time difference between an outgoing and return sonic signal, along with the distance between sonic transducers. Trigonometric relationships are used to calculate the wind speed in an orthogonal x-y-z coordinate system.

The time of flight measurement is also related to the speed of sound in air, which is a function of the air density (temperature and humidity). Through these relationships, the CSAT3C outputs a measurement of sonic air temperature from which actual air temperature may be calculated if humidity is known.

For more complete details on the theory of operation of the CSAT3C, refer to CSAT3C measurement theory (p. 72).

7.1.1 Algorithm Version 5

Since the release of the original CSAT3 in 1996, various improvements have been made to the algorithms used for signal processing and measurement output. Each time a significant change has been made to these algorithms, a new version number has been issued. The CSAT3C uses algorithm Version 5. Version 5 maintains many of the advantages of signal recognition and diagnostic sensitivity that were made possible by Version 3, while also adding the advantages of performance during precipitation events made possible by Version 4. It also resolves Version 4 issues of speed-of-sound measurement errors in very high wind conditions as reported by Burns et al. (2012; see References [p. 67]).

7.1.2 Effects of crosswind on the speed of sound

When sound travels between a pair of transducers, the measured speed of sound is influenced by both the wind component parallel to the sonic path and the component perpendicular to it (the crosswind). The parallel component cancels in the round-trip time-of-flight calculation (see Eq. 6 [p. 73]), but the perpendicular component does not — it introduces a systematic positive bias in the measured speed of sound and therefore in the derived sonic temperature. Left uncorrected, this bias propagates into temperature variance and sensible heat flux calculations.

The theoretical framework for correcting this bias was established by Schotanus, Nieuwstadt, and de Bruin (1983) for single-path sonic anemometers. Liu, Peters, and Foken (2001) extended this framework to three-path instruments, such as the CSAT3C, that compute sonic temperature as the average of measurements along three non-orthogonal axes. Their corrected equations include terms for humidity–temperature correlation, horizontal heat flux, and momentum flux that can be significant under typical field conditions; omitting the crosswind correction can bias sensible heat flux by up to 20 W m^{-2} and inflate sonic temperature variance by approximately 10% in unstable conditions. The quality of this correction further depends on accurate knowledge of the sonic path geometry embedded in the instrument (Zhou et al., 2018).

The CSAT3C eliminates the need for any post-processing crosswind correction by applying it automatically and online, before outputting wind and temperature data. The crosswind component normal to each sonic axis is computed from the real-time three-axis wind vector and removed from the speed-of-sound measurement prior to transformation into orthogonal coordinates. This approach is consistent with the broader eddy covariance community's recognition that firmware-level correction is the standard practice; eddy covariance post-processing software widely used across flux networks explicitly identifies the CSAT3 family as instruments where the crosswind correction is applied internally, and warns that applying it again in software results in double accounting. Recent work using CSAT3B instruments confirms that once the crosswind correction is properly handled at the firmware level, residual temperature flux errors are attributable to other sources such as mounting arm vibrations rather than the crosswind bias itself (Gao et al., 2024).

> **NOTE:**
> Because the CSAT3C applies the crosswind correction internally during each measurement cycle, **do not apply any additional offline crosswind correction**, including the method described by Liu, Peters, and Foken (2001), to CSAT3C output data. Double-correcting will introduce errors in computed temperature variance and sensible heat flux.

7.1.3 Sonic transducer shadow correction

The CSAT3C suffers minimal wind distortion compared to many other sonic anemometer designs because of a very low ratio of transducer diameter to sonic path length, and since the non-orthogonal geometry keeps the sonic paths at angles closer to perpendicular with respect to a mean horizontal wind flow. However, there are cases, such as when oncoming wind has high angles of attack (for example, low frequency eddies on a tall tower), that will lead to more shadowing. Accordingly, an **optional** wind shadow correction specific to the CSAT3C transducer diameter and sonic path length can be enabled.

This shadow correction, known as the Kaimal correction (Kaimal 1979; Horst et al., 2015), is applied according to:

$$U_{i_{measured}} = U_i(0.84 + 0.16\,(\sin\theta))$$ **Eq. 1**

Where:

U_i = the magnitude of the wind vector parallel to the sonic path without shadowing errors

i = a placeholder index for a, b, or c, representing the three sonic paths

θ_i = the angle between the three-dimensional wind vector and the wind vector component along the i-th sonic path (see Figure 7-1 [p. 44])

The CSAT3C embedded code improves the estimates of θ_i — and therefore the accuracy of the correction — by iteratively applying the preceding correction three times for each measurement of each sonic path. Since there continues to be debate on the appropriateness of this and other shadow corrections in turbulent versus laminar flows (Horst et al., 2015; Frank et al., 2016), the default of this setting is **Disabled**.

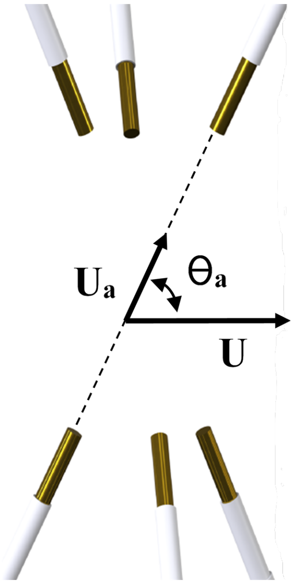

*Figure 7-1. Angle θ_a is defined as the angle between the vector of oncoming wind (**U**) and the wind component along the a-sonic path, (**U_a**).*

7.2 Operating modes

The CSAT3C has different operating modes that are selected based on the desired measurement trigger source, presence of a data filter, and type of data output. Specifically, the following four modes are available:

- **Mode 0**: Logger-Triggered | No filter | Logger-Prompted CPI Output
- **Mode 1**: Self triggered | Filtered | Logger-Prompted CPI Output
- **Mode 2**: Self triggered | No filter | Unprompted Output to USB or RS-485
- **Mode 3**: Self triggered | Filtered | Unprompted Output to USB or RS-485

The mode is selected using the ***Device Configuration Utility*** under the **Measurement Settings** tab (see Settings (p. 14) for details on viewing and selecting settings). Table 7-1 (p. 45) gives a summary of the CSAT3C operating modes. The following sections give more information on the measurement trigger, data filters, and data output as a guide to selecting the appropriate mode. Mode 0 is the default operating mode for the CSAT3C and is recommended when fluxes are the primary interest.

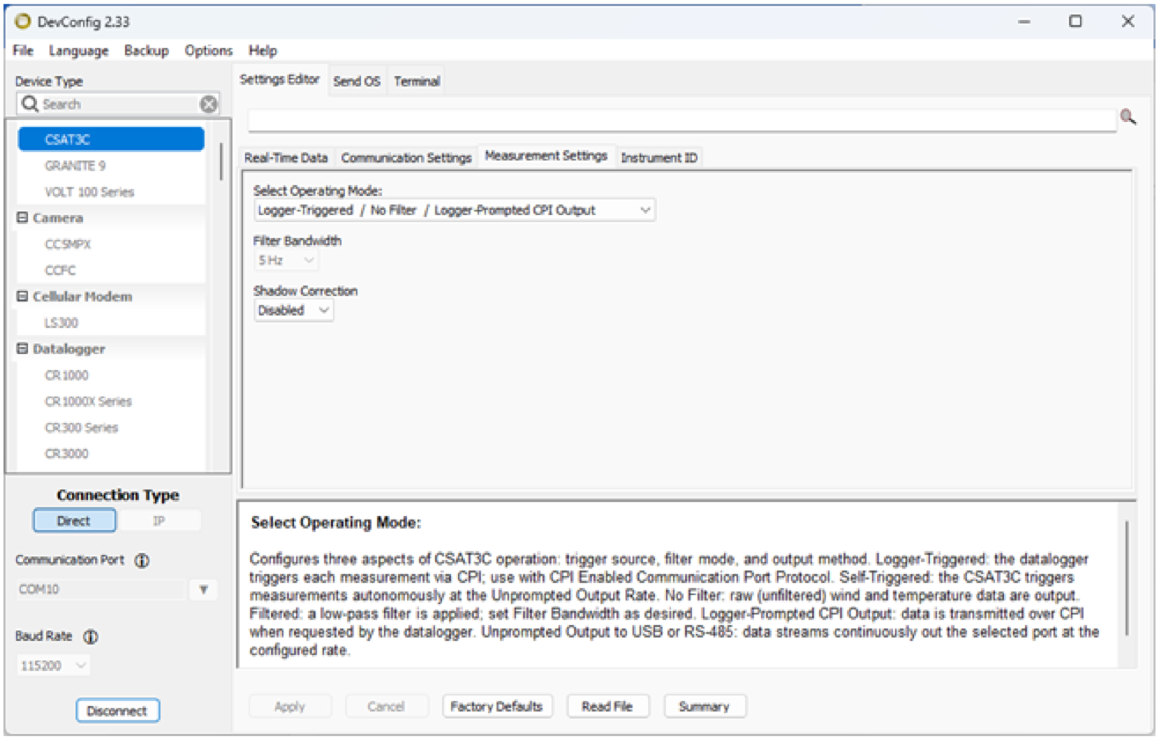

*Figure 7-2. Measurement settings in **Device Configuration Utility***

Table 7-1: Overview of CSAT3C operating modes

Mode	Measurement Trigger		Filters		Output Prompt	
	Source	Rate	Enabled	Bandwidth (Hz)	Source	Rate
0	Data logger	1 to 100 Hz1/	No	-	Data logger	1 to 100 Hz1/
1	CSAT3C	100 Hz	Yes	5, 10, 25	Data logger	1 to 100 Hz1/
2	CSAT3C	100 Hz	No	-	CSAT3C	1, 10, 20, 50, 100 Hz
3	CSAT3C	100 Hz	Yes	5, 10, 25	CSAT3C	1, 10, 20, 50, 100 Hz

1/ The exact rate is determined by the scan interval set in the CRBasic program of the data logger.

> **NOTE:**
> Data logger prompted output using Mode 0 and Mode 1 requires use of CPI communications. The options for unprompted output to a data acquisition system (DAQ) or computer require use of RS-485 or USB communications.

7.2.1 Measurement trigger

A measurement trigger is the actual command to initiate a sonic measurement and can be driven by either a data logger or the CSAT3C internal clock. If the trigger is given by a data logger as in Mode 0, then no data filtering is done (bandwidth is wide open) since each trigger will initiate a single new measurement (single-measurement regime). The data logger can trigger measurements at rates from 1 to 100 Hz. If the trigger is given by the internal CSAT3C timer as in Modes 1 through 3, the measurements will be self-triggered at a rate of 100 Hz. This results in an oversampled measurement regime where the 100 Hz samples may be optionally processed through a filter before being down sampled or decimated and output.

> **NOTE:**
> If a data logger fails to provide a trigger and the CSAT3C has not been configured for unprompted output, the CSAT3C will enter into a lost-trigger state where it will output measurements at 1 Hz based on its internal timer. If the CSAT3C is in a lost-trigger state while connected with ***Device Configuration Utility***, real-time anemometer data will flash on the screen at one-second intervals, and the LED **Status** LED on the CSAT3C head will flash red. This is an indication that the settings should be checked. In this particular instance, it does not indicate a problem with the CSAT3C hardware. Once a trigger is received by the CSAT3C, or once unprompted output is enabled, normal operation will ensue.

7.2.2 Data filter

The optional data filter (Modes 1 and 3) takes the 100 Hz sample points that were self-triggered by the CSAT3C and runs them through a low-pass (high-cut) filter, resulting in a new filtered output at the same 100 Hz rate. The degree to which the data is filtered is determined by the user-selected filter bandwidth. This is selected from the ***Device Configuration Utility*** in the **Measurement Settings** tab.

The benefit of applying a filter is to reduce aliasing when measurements are subsequently down-sampled by the data logger or computer. The trade-off is that the filter introduces a group delay-the amount of time it takes a signal to pass through the filter. Table 7-4 (p. 52) shows the group delay associated with each filter bandwidth.

This aliasing does not compromise the variances and covariances (and therefore fluxes) computed from aliased data. The variance and covariance calculations are not frequency dependent, they simply measure total variation from one signal or total covariation from two signals, respectively. Aliasing redistributes energy across frequency bins, distorting the shape of the power spectrum. However, because variance is the integral over all frequencies, total variance, and therefore flux, is conserved. The filter is thus essential for spectral characterization but optional for flux measurements. Given this, under circumstances where measuring fluxes are the primary interest, it is recommended to operate without a filter and, if possible, have the data logger provide the trigger.

Table 7-2: Time delays by mode and filter

Mode	Delay between measurement and output		
0	1 data logger scan interval		
2	10 ms		
1 and 3	Bandwidth	5 Hz	795 ms
		10 Hz	395 ms
		25 Hz	155 ms

7.2.3 CSAT3C sonic data output

After a measurement is triggered and optionally run through a filter, it is stored in the CSAT3C data buffer until it is output to either a data logger or a computer.

Mode 0

In the case where a data logger provides the measurement trigger (Mode 0), the trigger is issued each time the data logger goes through a scan of the program and executes the `CSAT3C()` CRBasic instruction. See CSAT3C() (p. 53) for details on the instruction. When the trigger is executed, it will also prompt the CSAT3C to output the most recent measurement in the buffer. This means that the data collected in the data logger will be delayed by exactly one scan interval or timestamp.

The program code can correct for this delay before storing the data to a data table, or the raw time series data can be saved and aligned with other data during post-processing of the data. Once the one scan delay is accounted for, this method of triggering and prompting the CSAT3C with a data logger is the best way to achieve optimum synchronicity with other fast-response sensors. Because the measurement was triggered according to the data logger clock, the timing is known exactly. If the data logger makes measurements of other fast-response sensors via analog measurement or CPI, then the measurements from the CSAT3C and other sensors can be synchronized precisely.

> **NOTE:**
> Mode 0 (no filter and data logger prompted sampling) is only compatible with CPI communications.

Mode 1

In the case where the CSAT3C is self-triggered and filtered, the output data can still be collected by a data logger (Mode 1) using CPI communications. In this case, the data logger will prompt the CSAT3C for an output each time it executes the `CSAT3C()` CRBasic instruction in the program scan. When the data logger prompt is received by the CSAT3C, it will output the most recent 100 Hz filtered sample in its buffer to the data logger. This filtered data is delayed by a certain time interval (given in Table 7-2 [p. 47]) and should be taken into account when aligning with other fast-response sensors. There are additional synchronicity considerations. Because the measurement was not triggered by the data logger according to its own clock, the sample received by the data logger may have a small synchronicity error between –5 and +5 milliseconds with respect to the data logger timestamp. The actual error depends on the operational mode and the output rate, as shown in Table 7-3 (p. 51).

> **NOTE:**
> Mode 1 (bandwidth filter and data logger prompted sampling) is only compatible with CPI communications.

Modes 2 and 3

If the CSAT3C measurements are to be self-triggered and output to a computer, as in Modes 2 and 3, an unprompted output operating mode should be selected. Available output rates for the CSAT3C are 1, 10, 20, 50, or 100 Hz. In unprompted mode, the CSAT3C will downsample or decimate the 100 Hz buffer data (unfiltered or filtered, depending on whether the user has selected Mode 2 or Mode 3, respectively) to output at the appropriate rate. The unprompted output record is an ASCII string of comma-delimited data terminated by a carriage return and contains the following seven data fields:

1) Ux — x-axis wind speed in meters per second ($m \cdot s^{-1}$)

2) Uy — y-axis wind speed in meters per second ($m \cdot s^{-1}$)

3) Uz — z-axis wind speed in meters per second ($m \cdot s^{-1}$)

4) T_s — Sonic temperature in degrees Celsius (°C)

5) Diagnostic word

6) Record counter

7) Signature

The record counter is a decimal value that is incremented each record until reaching a maximum value of 255, at which point it starts back over at zero. The counter may be used to ensure each record is not a duplicate of the last and that a record has not been omitted.

The final data field in each record is the signature, a four-character hexadecimal value that is a function of the specific sequence and number of bytes in the output array. The computer may calculate its own signature using each transmitted byte until reaching the signature data field. The computed signature and the transmitted signature are compared. If they match, the data was received without error. This is very similar to a Cyclic-Redundancy-Check (CRC).

> **NOTE:**
> Signature checking is done automatically by a data logger when using CPI communications and does not require extra programming by the user.

In most situations, a computer computes the signature by reading in the ASCII data and extracting the last four ASCII characters, casting them as Long data type. The signature is then calculated on the data sent from the CSAT3C, starting with u_x and ending with the counter. All the characters after the counter are not part of the signature. Once the signature is computed using the algorithm below, it is compared to the transmitted signature. If signatures do not match, the data should be disregarded.

The following block of code is an example implementation of the Campbell Scientific signature algorithm in the programming language C. To generate the signature of an output array of bytes, the “seed” needs to be initialized to 0xaaaa and a pointer passed to the first byte of the output array. The number of bytes in the output array should be entered in as the “swath”. The returned value is the computed signature.

```
// signature(), signature algorithm.
// Standard signature is initialized with a seed of 0xaaaa.
// Returns signature.
unsigned short signature( unsigned char* buf, int swath, unsigned short seed ) {
unsigned char msb, lsb;
unsigned char b;
int i;
msb = seed >> 8;
lsb = seed;
for( i = 0; i < swath; i++ ) {
  b = (lsb << 1) + msb + *buf++;
  if( lsb & 0x80 ) b++;
  msb = lsb;
  lsb = b;
  }
return (unsigned short)((msb << 8) + lsb);
}
```

Figure 7-3 (p. 50) shows an example of unprompted output (RS-485 or USB) to a computer. A timestamp for the incoming data record may be assigned by the computer, where the interval between records is 1/unprompted output rate. The data in each unprompted output record will be delayed according to Table 7-3 (p. 51). Even after accounting for the sample delay, a synchronicity error between the computer and the CSAT3C may still exist, since they each have their own clocks. Table 7-3 (p. 51) shows the possible synchronicity errors for each output rate.

```
|
0.08945,0.06552,0.05726,19.69336,0,5,c3a6
0.10103,0.06517,0.05312,19.70499,0,6,3927
0.09045,0.04732,0.04198,19.71161,0,7,d7e5
0.08199,0.03341,0.03421,19.73416,0,8,4ad9
0.08867,0.03522,0.03378,19.75360,0,9,e314
0.08675,0.02142,0.03289,19.76858,0,10,9b60
0.09035,0.01987,0.03667,19.78433,0,11,931a
0.09960,0.02615,0.04330,19.79236,0,12,14a1
0.09489,0.02513,0.05120,19.79083,0,13,0c0d
0.09513,0.02403,0.05648,19.79037,0,14,c30d
0.10715,0.02723,0.05739,19.78729,0,15,a14c
0.11630,0.03674,0.05579,19.78812,0,16,5cd7
```

Figure 7-3. Example of unprompted RS-485 or USB output to computer

<table>
<tr><th colspan="4">Table 7-3: CSAT3C synchronicity errors</th></tr>
<tr><th>Mode</th><th colspan="3">Synchronicity error</th></tr>
<tr><td>0</td><td colspan="3">0 ms</td></tr>
<tr><td>1</td><td colspan="3">–5 to +5 ms</td></tr>
<tr><td rowspan="5">2 and 3</td><td rowspan="5">Output rate</td><td>1 Hz</td><td>0 to 1000 ms</td></tr>
<tr><td>10 Hz</td><td>0 to 100 ms</td></tr>
<tr><td>20 Hz</td><td>0 to 50 ms</td></tr>
<tr><td>50 Hz</td><td>0 to 20 ms</td></tr>
<tr><td>100 Hz</td><td>0 to 10 ms</td></tr>
</table>

7.2.4 Operating mode recommendations

Due to the advantages in making synchronous measurements, Campbell Scientific recommends using a data logger that supports CPI communications to collect data from the CSAT3C. If flux measurements are the primary interest, Campbell Scientific further recommends that the CSAT3C be operated in Mode 0 where the data logger triggers the measurements, no filters are applied, and the data is collected by the data logger. If unaliased spectra are desired for characterization of the system and site, Mode 1 is recommended in which the measurements are self triggered, a filter is applied with a bandwidth that is half the data logger scan rate, and the data is down-sampled by the data logger. This satisfies the Nyquist criterion: sampling at twice the filter bandwidth ensures the filtered signal is fully resolved without aliasing. If flux measurements and spectral characterizations are of interest, Campbell Scientific recommends operating in Mode 1 with a sample rate sufficient to capture the high-frequency variations that contribute to fluxes, and a filter bandwidth set to half the output rate to ensure spectrally unaliased data.

7.3 Synchronization with other sensors

As a delay exists between the CSAT3C measurement and output to a data logger or computer (see Table 7-2 [p. 47]), the CSAT3C data will be slightly older than the record timestamp (recall that the timestamp is assigned to the record by the data logger or computer). This delay is not important when calculating covariances between variables from the CSAT3C since the variables are already synchronized and aligned with one another. However, when covariances are being calculated between CSAT3C data and data from other fast-response sensors, the time difference must be accounted for. As an example, suppose a data logger is making 10 Hz (100 ms) measurements of a CSAT3C and an analog sensor such as a fine-wire thermocouple. In the raw data table of the data logger, the timestamp for the thermocouple data will be when the measurement actually took place, whereas the CSAT3C data will be delayed by 100 ms. Before covariances are calculated, the fine-wire thermocouple data should be lagged by one scan interval (100 ms) so that all data is aligned in time. This lagging of the data can be done online with the data logger, or it is often done offline using computer software.

Table 7-4 (p. 52) shows the measurement lags that should be applied to analog measurements or measurements with no delay in order to align them with CSAT3C data. The lags shown for Modes 1 and 3 indicate the number of output scans that the analog measurements should be delayed.

For example, in Mode 1 where data is being filtered and then output is prompted by a data logger, if the data logger has a 10 Hz scan rate and the CSAT3C has been set to use a 5 Hz bandwidth filter, the analog measurements should be delayed by eight data logger scans (eight 100 ms/scan = 800 ms). Table 7-4 (p. 52) also indicates the preferred settings for flux measurements and spectral analysis. As discussed previously, for spectral analysis, the bandwidth should be selected as half the output rate. For flux applications, the output rate or sampling frequency need not be greater than 10 or 20 Hz in order to reduce unwieldy data sets, and the bandwidth may be left fairly wide open (for example, 25 Hz) to ensure high frequency fluxes are retained in the signal.

Table 7-4: Measurement lags (N_{lag}) for analog measurements or measurements with no delay

<table>
<tr><th>Mode</th><th colspan="7">Measurement lag (N_{lag})</th></tr>
<tr><td>0[1]</td><td colspan="7">1 data logger scan</td></tr>
<tr><td>2</td><td colspan="7">Unprompted output rate/100 (lag in seconds)</td></tr>
<tr><td rowspan="5">1 and 3</td><td colspan="2" rowspan="2">Lag is in output samples</td><td colspan="5">Output rate (f_{scan})</td></tr>
<tr><td>1 Hz</td><td>10 Hz</td><td>20 Hz</td><td>50 Hz</td><td>100 Hz</td></tr>
<tr><td rowspan="3">Bandwidth</td><td>5 Hz</td><td>-</td><td>8[2]</td><td>16</td><td>40</td><td>80</td></tr>
<tr><td>10 Hz</td><td>-</td><td>4</td><td>8[2]</td><td>20</td><td>40</td></tr>
<tr><td>25 Hz[1]</td><td>-</td><td>-</td><td>-</td><td>8[2]</td><td>16</td></tr>
</table>

[1] Wide bandwidth, good for flux applications

[2] Anti-aliased frequency response, good for spectral analyses

NOTE:
For Modes 1 and 3, N_lag = floor(f_scan / f_bw) x 4. A filter bandwidth greater than the output rate is not meaningful; those cells are shown as dashes.

7.4 Data logger programming using CPI

The following CSAT3C CRBasic instructions control and retrieve data from the CSAT3C. These instructions are available on the CR6, CR1000X/e, and GRANITE 9/10 data loggers.

The following sections give specifics about CRBasic instructions.

7.4.1 CSAT3C()

The CSAT3C() instruction is used to set up and retrieve data from a CSAT3C sonic anemometer. This instruction sets the operating mode of the anemometer and retrieves the wind, sonic temperature, and diagnostic information from the CSAT3C. The CSAT3C() instruction should appear in the main scan of the CRBasic program operating in pipeline mode.

Syntax: CSAT3C(Dest, Address, Mode)

Parameters

Destination (Destination variable)

A variable array that will store the values returned by the anemometer. The destination variable must be declared as a float (default) with at least five elements. The CSAT3C returns the following data in response to a measurement trigger:

- **Dest(1)**: Ux — x-axis wind speed in meters per second ($m{\cdot}s^{-1}$)
- **Dest(2)**: Uy — y-axis wind speed in meters per second ($m{\cdot}s^{-1}$)
- **Dest(3)**: Uz — z-axis wind speed in meters per second ($m{\cdot}s^{-1}$)
- **Dest(4)**: T_s — Sonic temperature in degrees Celsius (°C)
- **Dest(5)**: Diagnostic word (refer to Table 7-6 [p. 55])

Address (CPI address of CSAT3C)

Identifies the unique address of the CSAT3C on the CPI bus. Valid addresses are 1 through 120. This parameter must be a constant. Default CSAT3C CPI address is 30.

> NOTE:
> If programming Granite 9, the CPI port must also be identified in the address constant as either CPI_BUSA or CPI_BUSB, e.g., Const CPI_ADDR = 30 + CPI_BUSB.

Mode (Trigger source and filter)

Defines the trigger source and application of filters to the anemometer data. This parameter must be a constant and may have one of the following values: 0, 5, 10, or 25. Table 7-5 (p. 54) lists the meaning of each of these values. Default CSAT3C mode is 0.

Table 7-5: CSAT3C modes (trigger source and filter)	
Code	Description
0	Data logger triggered/no filter/data logger prompted output
5	Self triggered/5 Hz bandwidth filter/data logger prompted output
10	Self triggered/10 Hz bandwidth filter/data logger prompted output
25	Self triggered/25 Hz bandwidth filter/data logger prompted output

7.4.2 CSAT3CMonitor()

The CSAT3CMonitor() instruction provides auxiliary information pertaining to the physical condition of the anemometer. This retrieves the internal temperature and relative humidity of the electronics enclosure and also the inclination of the anemometer. The CSAT3CMonitor() instruction should appear in a slow sequence of the CRBasic program operating in pipeline mode.

Syntax: CSAT3CMonitor(Dest, Address)

Parameters

Destination (Destination variable)

A variable array that will store the values returned by the anemometer. The destination variable must be declared as a float (default) with at least four elements. The CSAT3C returns the following data in response to the instruction:

- **Dest(1)**: Electronics temperature in degrees Celsius (°C)
- **Dest(2)**: Electronics relative humidity as a percentage (%)
- **Dest(3)**: Inclinometer pitch in degrees (°)
- **Dest(4)**: Inclinometer roll in degrees (°)

Address (CPI address of CSAT3C)

Identifies the unique address of the CSAT3C on the CPI bus. Valid addresses are 1 through 120. This parameter must be a constant. Default CSAT3C CPI address is 30.

> **NOTE:**
> If programming Granite 9, the CPI port must also be identified in the address constant as either CPI_BUSA or CPI_BUSB, e.g., Const CPI_ADDR = 30 + CPI_BUSB.

7.4.3 Diagnostic word

The fifth output from the CSAT3C is the diagnostic word. The diagnostic word describes the status of the anemometer and is useful in filtering data. For example, when the anemometer is locking in on the ultrasonic signals after receiving the acquire signals command, the **NAN** it sends to the data logger for the science data can be filtered out of the statistics based on the diagnostic word.

The diagnostic word is formatted as a simple 32-bit binary word. Each bit in the diagnostic word represents a different warning flag related to the operation of the CSAT3C. The data logger will display the diagnostic word as a base-10 integer. Viewed in this manner, each of the 32 bits has a different magnitude as a decimal number. The resultant decimal number will be the sum of the decimal magnitudes of each of the bits that are set. Table 7-6 (p. 55) summarizes the CSAT3C diagnostic word flags.

Table 7-6: Diagnostic word flags

Bit #	Hex value	Decimal value	Flag name	Description	Troubleshooting
0	0x0001	1	Low Amplitude	Ultrasonic signal is too small	Check for an obstruction in the anemometer path or on the transducer face
1	0x0002	2	High Amplitude	Ultrasonic signal is too large	Check if an obstruction, in the anemometer path or on the transducer face, was removed
2	0x0004	4	Tracking	The signal lock is poor	Check for an obstruction in the anemometer path or on the transducer face

Table 7-6: Diagnostic word flags					
Bit #	Hex value	Decimal value	Flag name	Description	Troubleshooting
3	0x0008	8	High Delta C	Difference in the speed of sound between the three non-orthogonal axes is greater than 2.360 $m \cdot s^{-1}$ (~4 °C @ 25 °C)	Check if the anemometer path length was altered, or if the anemometer head is structurally damaged
4	0x0010	16	Acquiring	Indicates that the anemometer is trying to acquire the sonic signal	Check for an obstruction in the anemometer path or on the transducer face, or if a transducer has failed
5	0x0020	32	Low Voltage	The supply voltage to the anemometer is below 10.5 VDC	Check the power supply or investigate whether cable lengths are excessive
6	0x0040	64	Trigger Error	A measurement trigger has not been received for at least 1 sec, or the time interval between triggers is varying by greater than 5%[1]	Check wiring to the data logger, and check the data logger program for the expected trigger rate

Table 7-6: Diagnostic word flags					
Bit #	Hex value	Decimal value	Flag name	Description	Troubleshooting
7	0x0080	128	Memory Error	There is a signature mismatch from the calibration file or another section of memory	Resend an OS and/or cal file to the CSAT3C; contact Campbell Scientific for details.
8	0x0100	256	ADC Skip	There is a mismatch in the number of expected versus actual samples transferred between the ADC and memory	Check sufficient power is supplied to the CSAT3C; contact Campbell Scientific for details.

[1] When using ***Device Configuration Utility***, the CSAT3C will not receive trigger events and the Trigger Error flag will be set. This is expected behavior during configuration and does not indicate a hardware fault. Normal operation resumes once a CRBasic program is running and providing triggers, or once unprompted output is enabled. See also the lost-trigger behavior described in Measurement trigger (p. 46).

7.5 Programming

Programming the CSAT3C is accomplished by accessing the program for either the CR6, CR1000X/e, or GRANITE 9/10 data logger at the downloads section of the CSAT3C web page www.campbellsci.com/csat3c.

7.5.1 Programming best practices

CPI address selection

- Default address: 30
- Valid range: 1-120
- Avoid conflicts with other CPI devices on the same bus

Scan rate recommendations

- Flux measurements: 10-20 Hz minimum (SCAN_INTERVAL = 50-100 ms)
- Spectral analysis: Match filter bandwidth (e.g., 10 Hz filter -> 20 Hz scan minimum)

- Battery conservation: Lower rates for remote installations

Pipeline mode requirement

- Always use PipeLineMode for sonic anemometer applications
- Ensures proper timing and synchronization with other sensors
- Required for eddy covariance flux measurements

SlowSequence usage

- Always use SlowSequence for CSAT3CMonitor() calls
- Recommended interval: 5 seconds for monitor data
- Purpose: reduces power consumption and CPI bus traffic

Data quality control

- Process diagnostic flags to identify data quality issues
- Use NAN filtering to exclude invalid measurements from statistics
- Implement disable flags for statistical processing based on diagnostic status

8. Maintenance and troubleshooting

8.1 General maintenance

With no moving parts, maintenance of the CSAT3C is minimal and limited to the following:

- Replacing the desiccant canister
- Monitoring diagnostics and measurement offsets to determine when factory recalibration is needed
- Monitoring diagnostics to ensure power supply voltage remains above 10.5 VDC

The following sections address these maintenance activities.

CAUTION:
The cover plate to the CSAT3C electronics should only be removed by qualified technicians at the factory. When covered, the electronics are well protected against transient voltages during handling and operation. Once uncovered, however, they are highly sensitive to electrostatic discharge. There are no user-serviceable components beneath the cover plate. Opening this will void the warranty on the anemometer.

8.2 Sonic wicks

Ultrasonic anemometers are unable to measure wind when water droplets completely obscure the face of the transducers. Campbell Scientific algorithm Version 5 along with sonic wicks (shown in Figure 8-1 [p. 60]) improve transducer performance in rainy conditions. Under certain conditions, the wicking properties of the sonic wicks may not be adequate. In these circumstances, a sonic anemometer may report diagnostic error conditions or erroneous data until the water droplets evaporate or are manually removed. Droplets can be removed by dabbing a cotton swab or tissue on the face of the transducer.

If site conditions are such that the wicks are unnecessary, gently remove the wicks from the transducers, taking care not to damage or peel the matching layer (rubber tips) from the brass housing of the transducers. Remove the wicks during the winter, as the wicks will accumulate snow or freezing rain to the point where the transducer face will be obscured.

The Spare Sonic Wicks Kit consists of three top wicks, three bottom wicks, and an installation tool (see Figure 8-2 [p. 60]). The installation tool is used by placing a wick over the angled end of the tool, placing the straight end of the tool gently against the transducer face, and sliding the wick down the tool onto the transducer.

CAUTION:
Lightly dab the face of the transducer to remove water droplets. Applying excessive force on the face of the transducer may damage the matching layer. Do not attempt to remove ice or frost without melting it first by gently warming the anemometer.

If the wicks are to be permanently installed at the site, ensure that the wicks are located in the proper position. Figure 8-1 (p. 60) shows the proper orientation of the transducer wicks. The top wick must be flush with the transducer face, with the wick tail located at the lowest point of the transducer (Figure 8-1 [p. 60], left). The end of the bottom transducer wick must extend above the transducer face by between one-half and one mesh lines (Figure 8-1 [p. 60], right). The wicks will stay in place; it is not necessary to use an adhesive.

Replacement top wicks and bottom wicks can be purchased from Campbell Scientific. A complete set of wicks for one sonic anemometer consists of three top wicks and three bottom wicks.

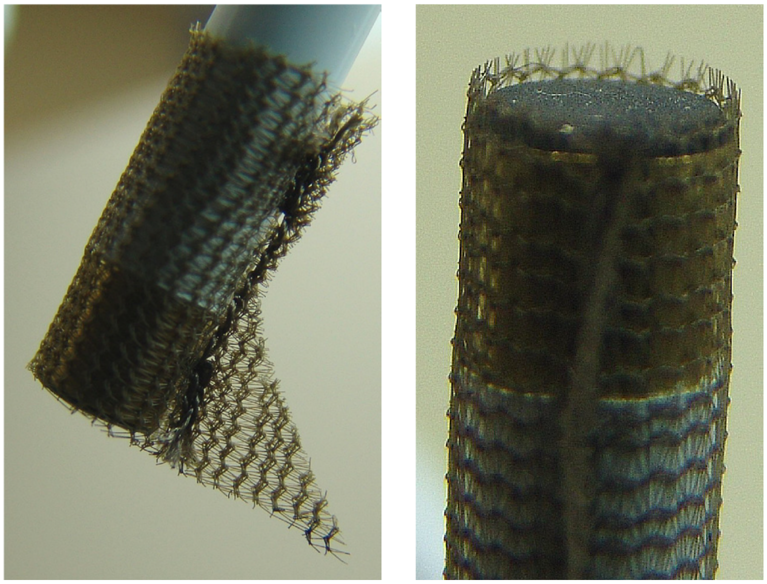

Figure 8-1. Proper location of the sonic top wick (left) and bottom wick (right)

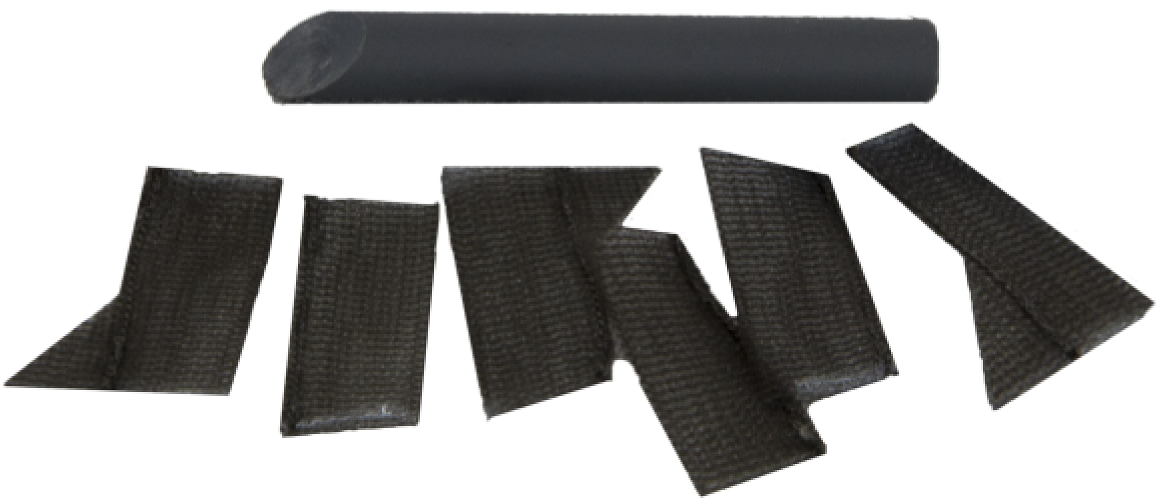

Figure 8-2. Spare Sonic Wicks Kit contents

8.3 Desiccant

To prevent liquid water from coming in contact with any electronics, the internal humidity must be maintained at non-condensing levels. The CSAT3C has an on-board relative humidity sensor that continuously monitors the humidity inside the enclosure. This humidity ranges between 0 and 100%. As temperature decreases, the capacity of air to hold water also decreases, and the relative humidity will increase even if no additional water has been introduced into the closed system. As the relative humidity approaches 100%, condensation will begin to form on the internal surfaces.

The CSAT3C has a cavity to hold a replaceable desiccant canister that removes water from the air (see Figure 8-3 [p. 62]). Water molecules will unavoidably ingress into the electronics over time, so the internal humidity of the CSAT3C head should periodically be checked. This can be done automatically with a data logger if the data logger program uses the `CSAT3CMonitor()` instruction in ***CRBasic Editor***, or manually by connecting a CSAT3C to a computer using the USB cable and then launching the ***Device Configuration Utility***. Under the **Settings Editor** tab of the utility, there is secondary tab for **Real-Time Data**, where the internal humidity measurement will be displayed along with various other measurements.

If monitoring shows the internal humidity of the CSAT3C rising above 50%, including during nighttime cooling cycles, the desiccant should be replaced with canisters that can be purchased from Campbell Scientific. The small canister holds desiccant and is installed on the underside of the anemometer block inside the brass screw cap (see Figure 8-3 [p. 62]). Use a large flat-headed screwdriver to unscrew the cap and remove the canister. Replace the old canister with an unused one.

The new canister should appear blue or orange in color. A pink-hued or green-hued canister indicates that moisture has been absorbed, and the canister should be discarded and replaced with a new one. When replacing the brass screw cap, ensure the cap is tightened until the head of the screw is flush with the housing and the o-ring cannot be seen.

> **NOTE:**
> Replacement desiccant canisters are shipped in a vacuum-sealed bag. The bag should not be opened until the canisters are to be inserted into the anemometer block.

Figure 8-3. Exploded view of CSAT3C desiccant canister

8.4 Calibration

The CSAT3C is calibrated at the factory over the temperature range of –40 to 50 °C, as sonic transducer response is a function of temperature. Any measurements taken at temperatures outside of this range will be suspect.

The CSAT3C does not require field calibration; however, it may require a factory recalibration every few years. An indication that the CSAT3C is due to be returned to the factory for recalibration is when diagnostic flags are persistent under dry conditions with little to no wind and with no obstruction in the ultrasonic paths. A wind offset greater than the specifications found in Specifications (p. 10) is another indication that a recalibration is due. To check for wind offset, refer to Test for wind offset (p. 63).

8.4.1 Test for wind offset

Testing wind offset on a CSAT3C requires creating an environment where wind is absent. Because it is difficult to do this in the field, wind offset data from the CSAT3C should be collected in a field office or the lab. A zero-wind environment can be created with a kitchen waste bin liner. The following steps should be taken to test the CSAT3C for wind offset.

1. Mount the head using the horizontal mount boom (as described in Mount the CSAT3C [p. 24]), or hang the head from the block that supports the CSAT3C upper and lower arms. Do not lay the CSAT3C head on its side or balance it on the transducers, as this will affect its measurements.
2. Cover the CSAT3C head with a medium (13-gallon) kitchen waste bin liner. Close the opening of the liner by folding, taping, or tying, to prevent air from moving in and out of the liner. Temporarily disable the HVAC system in the room, or cover air vents that may cause air drafts to pass by the CSAT3C. Ensure that the liner does not obstruct any of the three CSAT3C sonic paths.
3. Connect the CSAT3C power and communications cable to the data logger referring to Communications (p. 33). Connect to the data logger with ***LoggerNet***.
4. Use the real-time monitoring graph display to create two graphs.
    a. On the first graph, add the Ux and Uy wind components and set the y limits from –0.08 to 0.08 as shown in Figure 8-4 (p. 64).
    b. On the second graph, add the Uz wind component and set the y limits from –0.04 to 0.04 as shown in Figure 8-5 (p. 65).
    c. For both graphs, set **Graph Width** to 1 minute and **Update Interval** to 1 second.

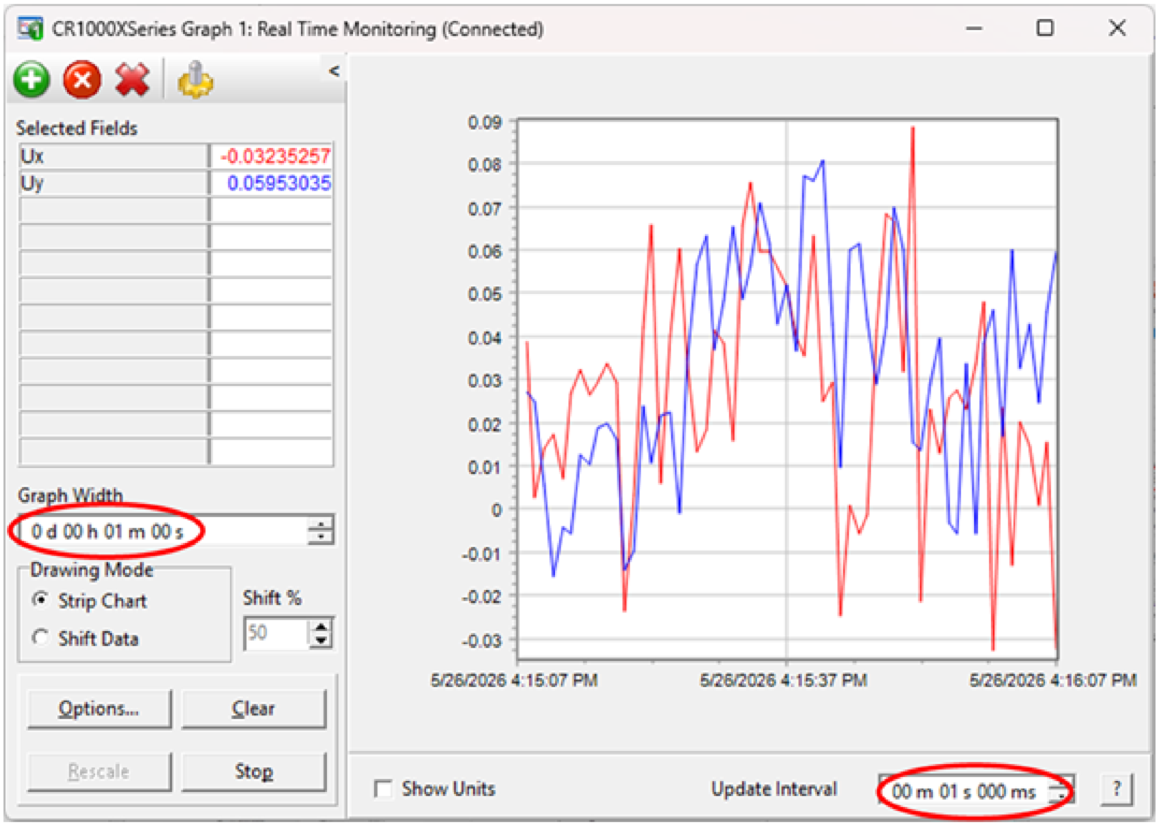

Figure 8-4. CSAT3C real-time data with 1 sec update and Ux and Uy wind components graphed

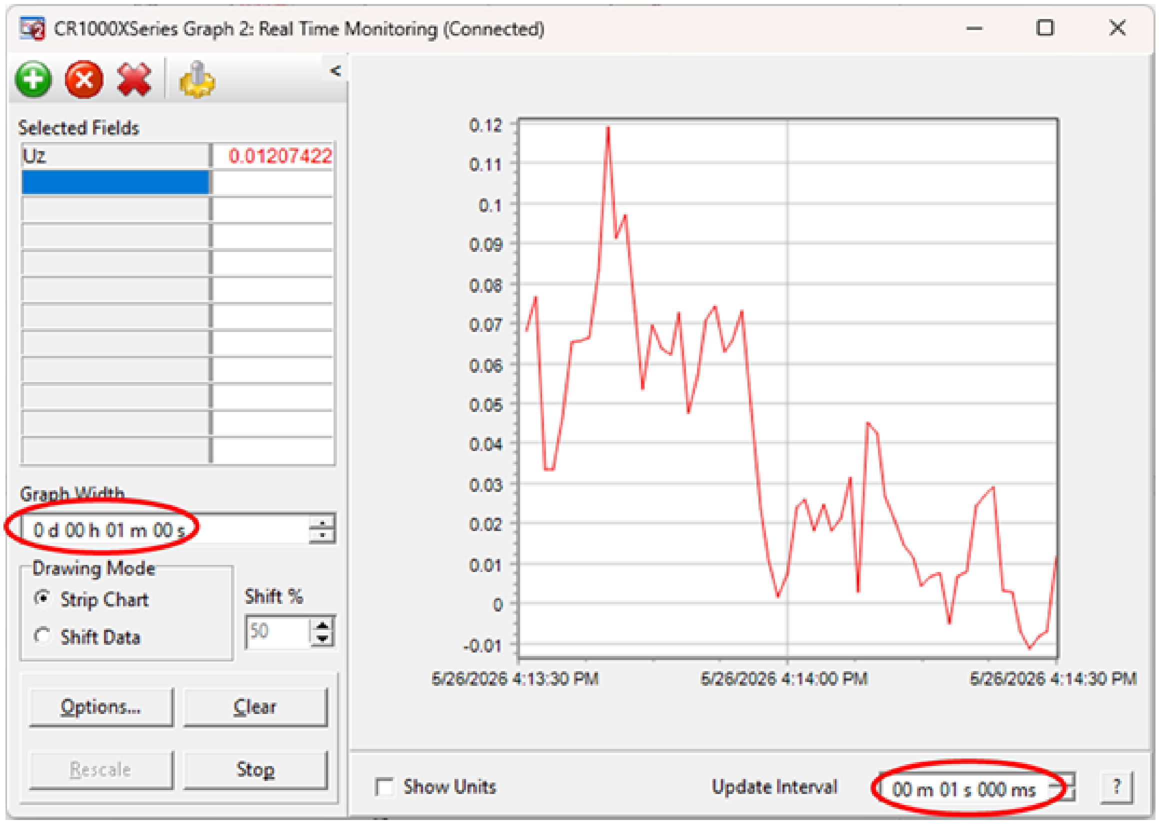

Figure 8-5. CSAT3C real-time data with 1 sec update and Uz wind component graphed

5. Graph 1 minute of wind data from the CSAT3C while it is in the zero-wind environment. The wind offset should be less than ±8 cm·s^{-1} (0.08 m·s^{-1}) for u_x and u_y, and less than ±4 cm·s^{-1} (0.04 m·s^{-1}) for u_z. If the CSAT3C wind offset is greater than these specifications, contact Campbell Scientific for an RMA number to recalibrate the CSAT3C.

> **NOTE:**
> When returning a CSAT3C for factory recalibration or repair, it is important to ship the unit with the foam inserts (see Sonic carrying case [p. 6]) provided from the factory.

8.5 Troubleshooting

Most problems that occur with the CSAT3C will generate a flag in the diagnostic word that are set high (see Diagnostic word [p. 55] and Table 7-6 [p. 55]). It is normal to see occasional sonic flags being set due to precipitation, insects, spider webs, birds, etc., that pass through one or more of the sonic paths and obstruct the signal. If diagnostic flags are persistently high, however, this could indicate a more serious problem. In the case that diagnostic flags are persistent, troubleshoot with the following steps:

1. Perform a visual inspection of the CSAT3C. Make sure it is clear from anything that might obstruct the sonic signal. Check for signs that the geometry of the arms has changed in any way, possibly from an impact from another object.
2. Check all wiring connections between the CSAT3C and data logger.
3. Check to see if the diagnostic flags are still high.
4. If diagnostic flags persist, remove the CSAT3C from the site and perform a zero-wind offset as described in Test for wind offset (p. 63). Check to see if the diagnostic flags are any different once inside the laboratory.
5. In case the diagnostic flags are related to a bug or corruption of the OS, send a new OS following the instructions in Sending an OS to the CSAT3C (p. 66).

If the problems are still unresolved, contact Campbell Scientific. If possible, be prepared to send a file of CSAT3C output data, including the diagnostic word, to Campbell Scientific. If it is determined that the unit must be returned to the factory for recalibration and/or repair, an RMA will be required (see Returning the CSAT3C [p. 67]).

8.5.1 Sending an OS to the CSAT3C

To send an OS to the CSAT3C, follow these steps:

1. Go to the downloads section of the CSAT3C web page (www.campbellsci.com/csat3c) to download the latest version of the CSAT3C OS to your computer.
2. Connect to the CSAT3C via USB and launch the ***Device Configuration Utility*** as described in Settings (p. 14).
3. After connecting to the CSAT3C, click the **Send OS** tab at the top of the ***Device Configuration Utility*** main screen. Click the **Start** button at the bottom of the page, select the .obj file that you downloaded from the CSAT3C website, and click **Open**. The OS will then be sent, followed by a confirmation message that it was loaded properly.

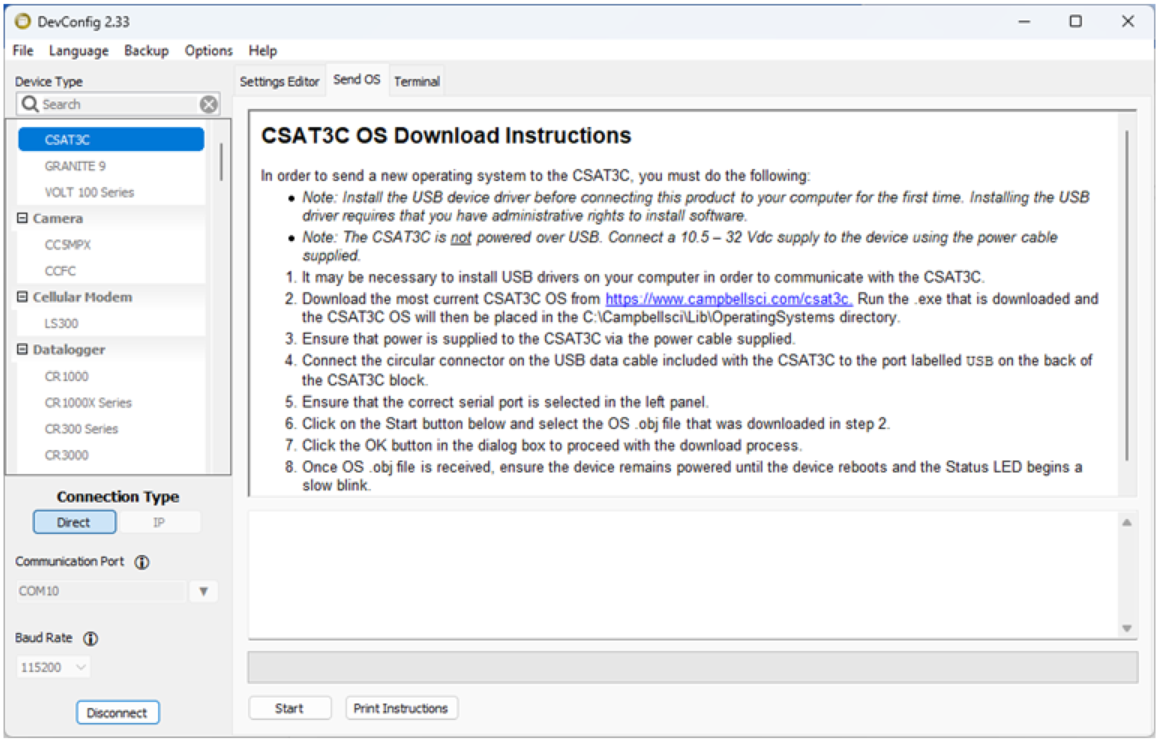

*Figure 8-6. The Send OS screen in the **Device Configuration Utility***

8.6 Returning the CSAT3C

If returning the CSAT3C either for calibration or repair is necessary, please follow the detailed instructions provided in the Assistance section at the end of this manual, which gives instructions for generating an RMA number. If additional help is needed, please contact Campbell Scientific. When preparing the CSAT3C for shipment, be sure to package it in the same foam in which it was sent. If the foam cannot be found, new foam should be ordered from Campbell Scientific before returning the unit.

9. References

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Appendix A. CSAT3C orientation

A.1 Determining true north and sensor orientation

The orientation of the sonic anemometer negative x-axis is found by reading a magnetic compass and applying the site-specific correction for magnetic declination, where the magnetic declination is the number of degrees between true north and magnetic north. Magnetic declination for a specific site can be obtained from a USGS map, local airport, or through a NOAA web calculator (Online magnetic declination calculator [p. 70]). A general map showing magnetic declination for the contiguous United States in 2015 is shown in Figure A-1 (p. 69).

Declination angles east of true north are reported as positive values and are subtracted from 360 (0) degrees to get true north as shown in Figure A-2 (p. 70). Declination angles west of true north are reported as negative values and are subtracted from 0 (360) degrees to get true north as shown in Figure A-3 (p. 70). Note that when a negative number is subtracted from a positive number, the resulting arithmetic operation is addition.

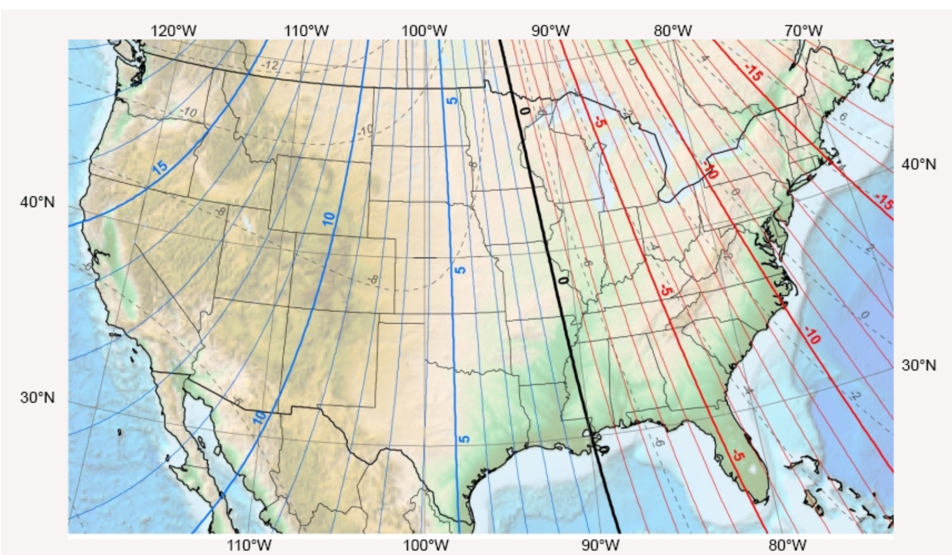

Figure A-1. Magnetic declination for the contiguous United States (2015)

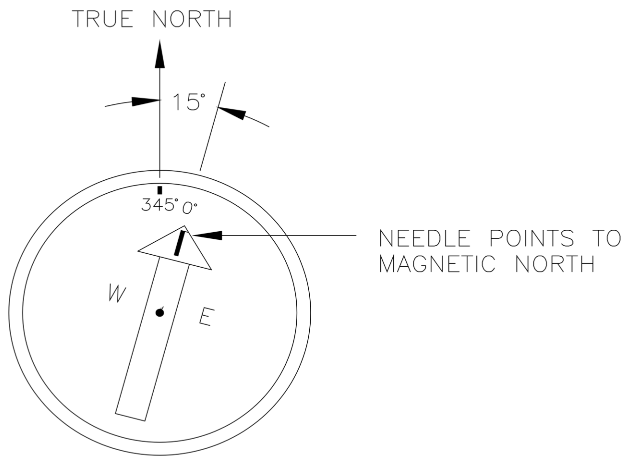

Figure A-2. Declination angles east of true north are subtracted from 360 to get true north

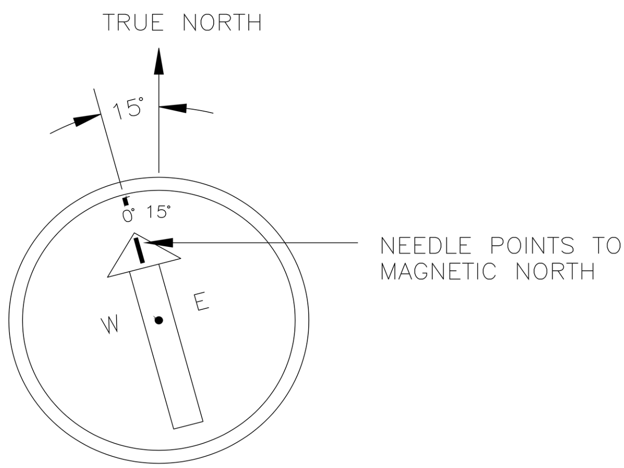

Figure A-3. Declination angles west of true north are subtracted from 0 to get true north

A.2 Online magnetic declination calculator

The magnetic declination web calculator published by the NOAA Geophysical Data Center is available at the following URL: https://www.ngdc.noaa.gov/geomag-web/#declination. Enter the latitude, longitude, date, and the format you wish to view the data. Once entered, click **Calculate** to determine the declination (Figure A-4 [p. 71]).

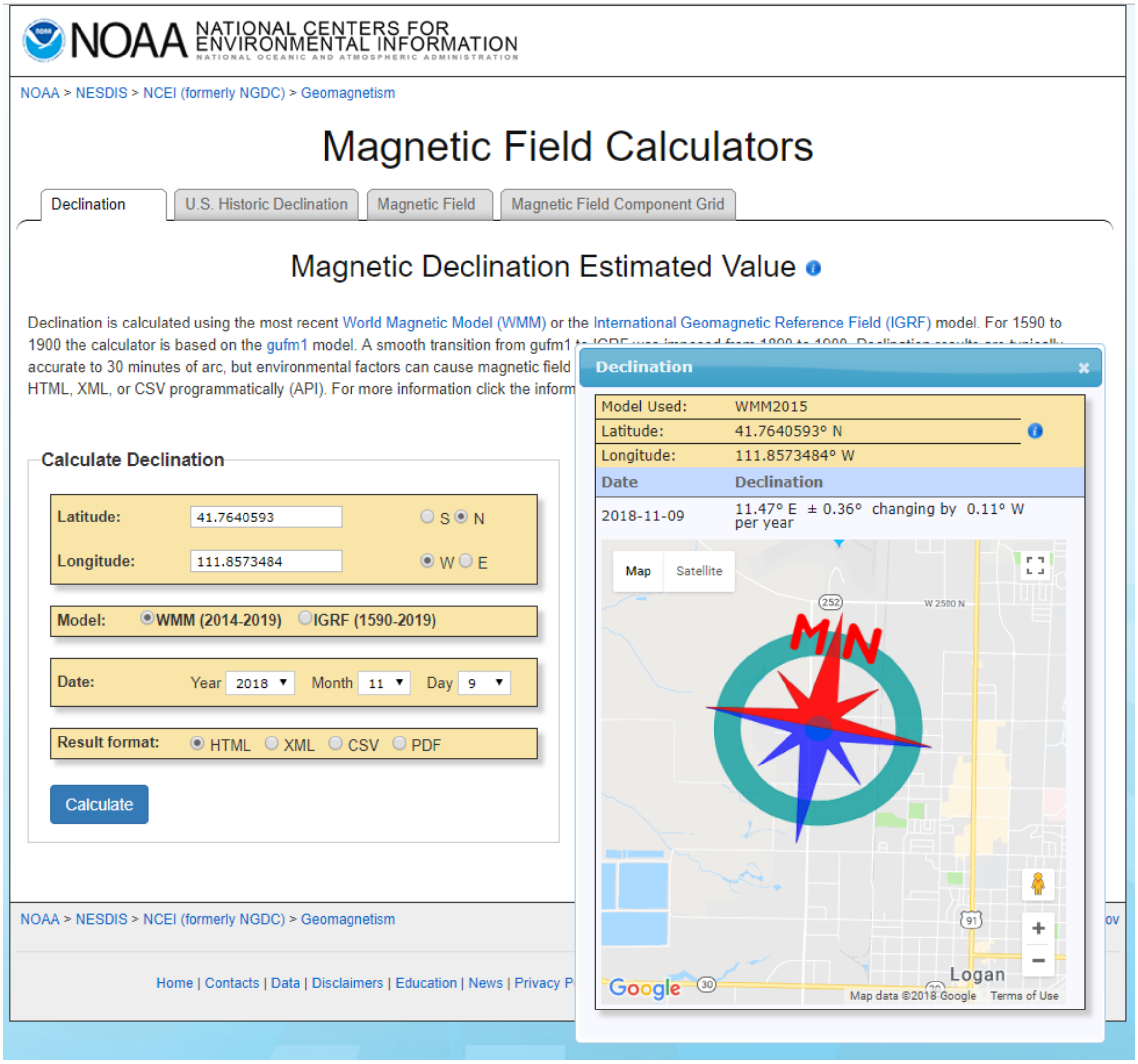

Figure A-4. Online magnetic declination calculator with inputs and output for Logan, UT, USA

The declination for Logan, UT, USA is 11.47° E. Therefore, true north is 360° – 11.47° = 348.53°. So when looking at a compass at this location, true north is located at 348.53°, not 360°. Declination results are typically accurate to 30 minutes of arc, but environmental factors can cause magnetic field disturbances.

Appendix B. CSAT3C measurement theory

B.1 Theory of operation

B.1.1 Wind speed

Each axis of the CSAT3C pulses two ultrasonic signals in opposite directions. The time of flight of the first signal (out) is given by:

$$t_o = \frac{d}{c + u_a} \qquad \text{Eq. 2}$$

and the time of flight of the second signal (back) is given by:

$$t_b = \frac{d}{c - u_a} \qquad \text{Eq. 3}$$

where:

t_o = time of flight out along the transducer axis

t_b = time of flight back, in the opposite direction

u_a = wind speed along the transducer axis

d = distance between the transducers

c = speed of sound

The wind speed (u_a) along any axis can be found by inverting the preceding relationships, then subtracting Eq. 3 (p. 72) from Eq. 2 (p. 72) and solving for u_a.

$$u_a = \frac{d}{2}\left[\frac{1}{t_o} - \frac{1}{t_b}\right] \qquad \text{Eq. 4}$$

The wind speed is measured on all three non-orthogonal axis to give u_a, u_b, and u_c, where the subscripts a, b, and c refer to the non-orthogonal sonic axes.

The non-orthogonal wind speed components are then transformed into orthogonal wind speed components (Ux, Uy, and Uz) with the following:

$$\begin{bmatrix} u_x \\ u_y \\ u_z \end{bmatrix} = A \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \quad \text{Eq. 5}$$

where:

A = a 3 x 3 coordinate transformation matrix that is unique for each CSAT3C and is stored in ROM memory

B.1.2 Temperature

The sonically determined speed of sound is given in Eq. 6 (p. 73) and was found from the sum of the inverses of Eq. 2 (p. 72) and Eq. 3 (p. 72). The CSAT3C corrects online for the effect of wind blowing perpendicular to the sonic path. No additional off-line corrections are required as suggested by Liu, Peter, and Foken (2001).

$$c = \frac{d}{2}\left[\frac{1}{t_o} + \frac{1}{t_b}\right] \quad \text{Eq. 6}$$

The speed of sound in moist air is a function of temperature and humidity and is given by:

$$c^2 = \gamma P/\rho = \gamma R_d T_v = \gamma R_d T(1 + 0.61q) \quad \text{Eq. 7}$$

where:

γ = ratio of specific heat of moist air at constant pressure to that at constant volume

P = pressure

ρ = air density

R_d = gas constant for dry air

T_v = virtual temperature

T = air temperature

q = specific humidity defined as the ratio of the mass of water vapor to the total mass of air (as in Kaimal and Gaynor 1991; Wallace and Hobbs 2006)

Note that γ is a function of specific humidity. It would be convenient if the effects of humidity could be consolidated into one term.

The specific heats for moist air at constant pressure and volume are given by:

$$C_p = qC_{pw} + (1 - q)C_{pd}$$
$$= C_{pd}(1 + 0.84q) \quad \text{Eq. 8}$$

$$C_v = qC_{vw} + (1 - q)C_{vd}$$
$$= C_{vd}(1 + 0.93q) \quad \text{Eq. 9}$$

where, at constant pressure and volume, respectively (Fleagle and Businger 1980):

C_p and C_v = specific heat of moist air

C_{pw} and C_{vw} = specific heat of water vapor

C_{pd} and C_{vd} = specific heat of dry air

Substitute Eq. 8 (p. 74) and Eq. 9 (p. 74) into Eq. 7 (p. 73) and ignore the higher order terms. This yields

$$c^2 = \gamma_d R_d T_s = \gamma_d R_d T(1 + 0.51q) \quad \text{Eq. 10}$$

where:

T_s = sonic temperature

γ_d = ratio of specific heat of dry air at constant pressure to that at constant volume (Fleagle and Businger 1980; Kaimal and Gaynor 1991; Kaimal and Businger 1963; Schotanus, Nieuwstadt, and de Bruin 1983)

With Eq. 10 (p. 74), the effect of humidity on the speed of sound is included in the sonic temperature.

The sonic virtual temperature, in degrees Celsius, is given by Eq. 11 (p. 74), where γ_d = 1.4 and R_d = 287.04 JK^{-1} kg^{-1}.

$$T_s = \frac{c^2}{\gamma_d R_d} - 273.15 \quad \text{Eq. 11}$$

B.2 References

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Kaimal, J.C. and J.A. Businger. 1963. "A continuous wave sonic anemometer-thermometer." *Journal of Applied Meteorology* 2: 156–164.

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Schotanus, P., F.T.M. Nieuwstadt, and H.A.R. de Bruin. 1983. "Temperature measurement with a sonic anemometer and its application to heat and moisture fluxes." *Boundary-Layer Meteorology* 26: 81–93.

Wallace, J.M. and P.V. Hobbs. 2006. *Atmospheric Science: An Introductory Survey*. New York: Academic Press.

Limited warranty

Covered equipment is warranted/guaranteed against defects in materials and workmanship under normal use and service for the period listed on your sales invoice or the product order information web page. The covered period begins on the date of shipment unless otherwise specified. For a repair to be covered under warranty, the following criteria must be met:

1. There must be a defect in materials or workmanship that affects form, fit, or function of the device.

2. The defect cannot be the result of misuse.

3. The defect must have occurred within a specified period of time; and

4. The determination must be made by a qualified technician at a Campbell Scientific Service Center/ repair facility.

The following is not covered:

1. Equipment which has been modified or altered in any way without the written permission of Campbell Scientific.

2. Batteries; and

3. Any equipment which has been subjected to misuse, neglect, acts of God or damage in transit.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country. For directions on how to return equipment, see Assistance.

Other manufacturer's products, that are resold by Campbell Scientific, are warranted only to the limits extended by the original manufacturer.

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In the event of any conflict or inconsistency between the provisions of this Warranty and the provisions of Campbell Scientific's Terms, the provisions of Campbell Scientific's Terms shall prevail. Furthermore, Campbell Scientific's Terms are hereby incorporated by reference into this Warranty. To view Terms and conditions that apply to Campbell Scientific, Logan, UT, USA, see Terms and Conditions. To view terms and conditions that apply to Campbell Scientific offices outside of the United States, contact the regional office that serves your country.

Assistance

Products may not be returned without prior authorization. Please inform us before returning equipment and obtain a **return material authorization (RMA) number** whether the repair is under warranty/guarantee or not. See Limited warranty for information on covered equipment.

Campbell Scientific regional offices handle repairs for customers within their territories. Please see the back page of the manual for a list of regional offices or visit www.campbellsci.com/contact to determine which Campbell Scientific office serves your country.

When returning equipment, a RMA number must be clearly marked on the outside of the package. Please state the faults as clearly as possible. Quotations for repairs can be given on request.

It is the policy of Campbell Scientific to protect the health of its employees and provide a safe working environment. In support of this policy, when equipment is returned to Campbell Scientific, Logan, UT, USA, it is mandatory that a "Declaration of Hazardous Material and Decontamination" form be received before the return can be processed. If the form is not received within 5 working days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. For details on decontamination standards specific to your country, please reach out to your regional Campbell Scientific office.

> NOTE:
> All goods that cross trade boundaries may be subject to some form of fee (customs clearance, duties or import tax). Also, some regional offices require a purchase order upfront if a product is out of the warranty period. Please contact your regional Campbell Scientific office for details.

Safety

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Protect from over-voltage.
- Protect electrical equipment from water.
- Protect from electrostatic discharge (ESD).
- Protect from lightning.
- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a hardhat and eye protection, and take other appropriate safety precautions while working on or around tripods and towers.
- Do not climb tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- You can be killed or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in contact with overhead or underground utility lines.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, whichever is greater, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.
- Only use power sources approved for use in the country of installation to power Campbell Scientific devices.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Internal Battery

- Be aware of fire, explosion, and severe-burn hazards.
- Misuse or improper installation of the internal lithium battery can cause severe injury.

- Do not recharge, disassemble, heat above 100 °C (212 °F), solder directly to the cell, incinerate, or expose contents to water. Dispose of spent batteries properly.

Use and disposal of batteries

- Where batteries need to be transported to the installation site, ensure they are packed to prevent the battery terminals shorting which could cause a fire or explosion. Especially in the case of lithium batteries, ensure they are packed and transported in a way that complies with local shipping regulations and the safety requirements of the carriers involved.
- When installing the batteries follow the installation instructions very carefully. This is to avoid risk of damage to the equipment caused by installing the wrong type of battery or reverse connections.
- When disposing of used batteries, it is still important to avoid the risk of shorting. Do not dispose of the batteries in a fire as there is risk of explosion and leakage of harmful chemicals into the environment. Batteries should be disposed of at registered recycling facilities.

Avoiding unnecessary exposure to radio transmitter radiation

- Where the equipment includes a radio transmitter, precautions should be taken to avoid unnecessary exposure to radiation from the antenna. The degree of caution required varies with the power of the transmitter, but as a rule it is best to avoid getting closer to the antenna than 20 cm (8 inches) when the antenna is active. In particular keep your head away from the antenna. For higher power radios (in excess of 1 W ERP) turn the radio off when servicing the system, unless the antenna is installed away from the station, e.g. it is mounted above the system on an arm or pole.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

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