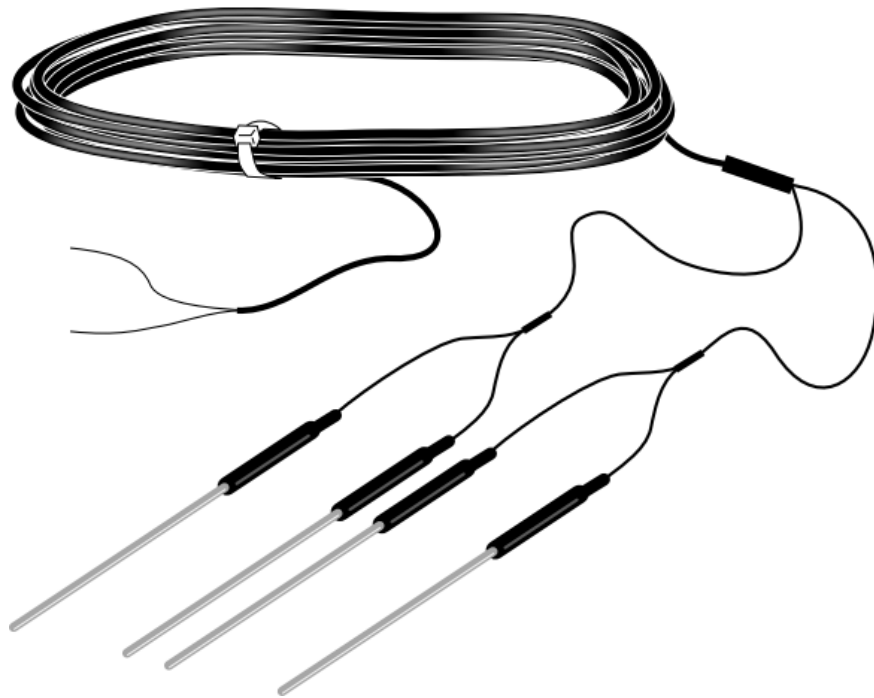


# TCAV

## Averaging Soil Thermocouple Probe



# **Limited Warranty**

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“Products manufactured by CSI are warranted by CSI to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified in the corresponding product manual. (Product manuals are available for review online at [www.campbellsci.com](http://www.campbellsci.com).) Products not manufactured by CSI, but that are resold by CSI, are warranted only to the limits extended by the original manufacturer. Batteries, fine-wire thermocouples, desiccant, and other consumables have no warranty. CSI’s obligation under this warranty is limited to repairing or replacing (at CSI’s option) defective Products, which shall be the sole and exclusive remedy under this warranty. The Customer assumes all costs of removing, reinstalling, and shipping defective Products to CSI. CSI will return such Products by surface carrier prepaid within the continental United States of America. To all other locations, CSI will return such Products best way CIP (port of entry) per Incoterms ® 2010. This warranty shall not apply to any Products which have been subjected to modification, misuse, neglect, improper service, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied. The warranty for installation services performed by CSI such as programming to customer specifications, electrical connections to Products manufactured by CSI, and Product specific training, is part of CSI’s product warranty. **CSI EXPRESSLY DISCLAIMS AND EXCLUDES ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. CSI hereby disclaims, to the fullest extent allowed by applicable law, any and all warranties and conditions with respect to the Products, whether express, implied or statutory, other than those expressly provided herein.”**

# Assistance

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Products may not be returned without prior authorization. The following contact information is for US and international customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit [www.campbellsci.com](http://www.campbellsci.com) to determine which Campbell Scientific company serves your country.

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RMA# \_\_\_\_\_  
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Logan, Utah 84321-1784

For all returns, the customer must fill out a "Statement of Product Cleanliness and Decontamination" form and comply with the requirements specified in it. The form is available from our website at [www.campbellsci.com/repair](http://www.campbellsci.com/repair). A completed form must be either emailed to [repair@campbellsci.com](mailto:repair@campbellsci.com) or faxed to (435) 227-9106. Campbell Scientific is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

# Safety

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**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](http://www.campbellsci.com) or by telephoning (435) 227-9000 (USA). 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

- 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, 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.

## 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.

## 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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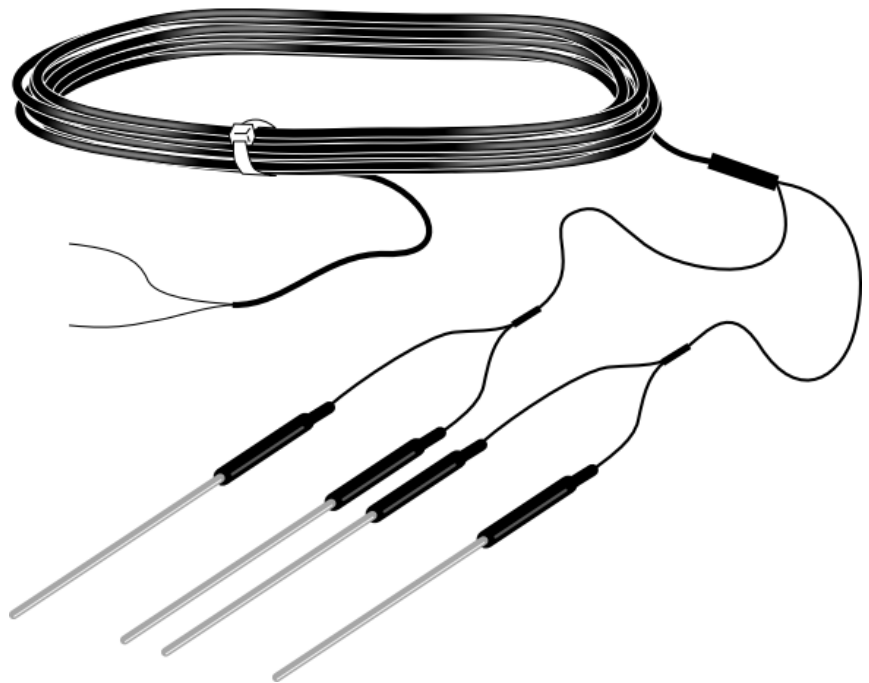
# ***TCAV – Averaging Soil Thermocouple Probe***

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## **1. Description**

The TCAV is a temperature probe which parallels four thermocouple junctions into one. One channel is required to measure the output voltage which represents the average temperature of the four junctions. The TCAV is most often used to obtain the average temperature of a soil layer for use in calculating stored energy.

The probe is constructed with type E thermocouple wire (chromel-constantan) and can be measured with one of the datalogger thermocouple measurement instructions, **TCSe()** or **TCDiff()**. **TCDiff()** is recommended because it reduces noise and ground loop problems.



*FIGURE 1-1. TCAV Thermocouple Probe*

## **2. Using the TCAV with Soil Heat Flux Plates**

The TCAV is used in conjunction with soil heat flux plates to calculate the heat flux at the surface of the soil. The plates are buried at a fixed depth of between 5 and 8 cm to reduce errors due to vapor transport of heat.

## 2.1 Installation

The TCAV and two heat flux plates are typically installed as in FIGURE 2-1. The TCAV is constructed so two thermocouples can be used to obtain the average temperature of the soil layer above one heat flux plate and the other two above the second plate. One datalogger channel is required to measure the output voltage which represents the average temperature of the four junctions. The thermocouple pairs may be up to one meter apart.

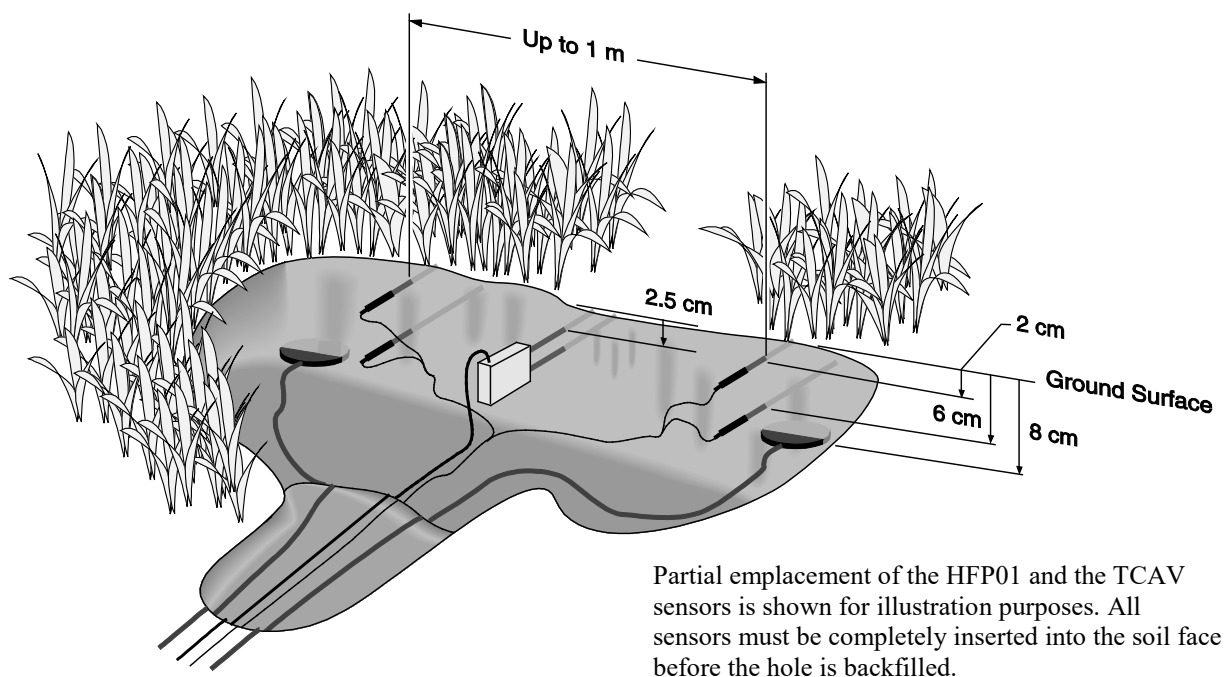


FIGURE 2-1. Placement of Thermocouples and Heat Flux Plates

The location of the two heat flux plates/thermocouples should be chosen to be representative of the area under study. If the ground cover is extremely varied, it could be necessary to have additional sensors to provide a valid average.

Use a shovel to cut a vertical slice in the soil and remove the soil to one side of the cut. Try to keep the soil that is removed intact so that it can be replaced with as little disruption as possible.

The sensors are installed in the undisturbed face. The depths are measured from the top of the soil. A horizontal cut is made with a knife to install a heat flux plate. The stainless steel tubes encasing the thermocouple junctions are pressed into the soil, keeping the tubes horizontal. (When removing the thermocouples, grip the tubing, not the thermocouple wire.)

To minimize thermal conduction down the sensor lead wires, wrap them around the edge of the hole keeping the leads at the same level as the sensor for as long as possible. Replace the soil in the same position as it was. Do not run the leads directly to the surface.

## 2.2 Calculating Soil Heat Flux

The soil heat flux at the surface is calculated by adding the measured flux at a fixed depth (in this case 8 cm) to the energy stored in the layer above the heat flux plates. The heat capacity of the soil and the change in temperature over the output interval are required to calculate the average stored energy,  $S$  ( $W\ m^{-2}$ ):

$$S = (T_i - T_{i-1}) \cdot D \cdot C_s / t$$

Where:

$T_i$  is the current temperature ( $^{\circ}C$ ),  
 $T_{i-1}$  is previous temperature ( $^{\circ}C$ ),  
 $D$  is depth to heat flux plate (m),  
 $C_s$  is the soil heat capacity ( $J\ m^{-3}\ ^{\circ}C^{-1}$ ), and  
 $T$  is the time interval (s).

One method of calculating  $C_s$  is to add the specific heat of the dry mineral soil,  $C_{sd}$ , to that of the soil water,  $C_w$  ( $4190\ J\ kg^{-1}\ ^{\circ}C^{-1}$ ). The values used for  $C_{sd}$  and  $C_w$  are on a mass basis ( $J\ kg^{-1}\ ^{\circ}C^{-1}$ ).  $C_s$ , the heat capacity of the moist soil on a volume basis ( $J\ m^{-3}\ ^{\circ}C^{-1}$ ) is:

$$C_s = BD \cdot (C_{sd} + W \cdot C_w)$$

This calculation requires site specific inputs for bulk density ( $BD$ ,  $kg\ m^{-3}$ ), mass basis water content ( $W$ ,  $kg\ water/kg\ soil$ ), and  $C_{sd}$ , the specific heat of the dry soil.  $840\ J\ kg^{-1}\ ^{\circ}C^{-1}$  is a reasonable value for  $C_{sd}$  for most mineral soils (Hanks and Ashcroft, Applied Soil Physics, Published by Springer-Verlag, New York, 1980).



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