TreeTalker®Cyber

User Manual

Nature 4.0

Inspired to invent change

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Nature 4.0

Introduction

At Nature 4.0, we are committed to providing high-quality sensing solutions for environmental monitoring. Since 2018, our flagship system, TTCyber, has been carefully developed and fine-tuned to deliver highly granular time series data. This system is focused on fundamental approaches to plant ecophysiological monitoring, allowing us to capture intricate details about plant health and environmental interactions. TTCyber empowers researchers and environmentalists with precise, real-time insights, helping to drive sustainable practices and enhance our understanding of ecosystem dynamics.

Understanding scientific approach

Our scientific approach at Nature 4.0 is rooted in rigorous research, driven by the expertise of Professor Riccardo Valentini and our dedicated PhD research team. We emphasize a holistic understanding of ecosystem dynamics, combining cutting-edge sensor technologies with deep knowledge of plant ecophysiology. Under Professor Valentini's guidance, we integrate innovative methodologies with traditional scientific principles, enabling us to address complex environmental challenges and deliver impactful, data-driven solutions for sustainable environmental management.

What's the reason

In today's world, the importance of understanding and monitoring ecosystem dynamics has never been greater. With the accelerating impacts of climate change, biodiversity loss, and environmental degradation, having precise and real-time data on plant health and ecological processes is crucial for making informed decisions. Systems like TTCyber, developed with expertise from leading scientists like Professor Riccardo Valentini and our PhD research team, provide the detailed insights needed to mitigate these global challenges. By applying advanced monitoring technologies, we can better understand how ecosystems are responding to stressors, ultimately fostering more sustainable land management, climate resilience, and conservation efforts.

"By understanding plant physiology and information analytics, we can provide state of the art sensing solutions for fine scaled real time plant monitoring"

TreeTalker®Cyber

Overview

The TreeTalkerCyber is an advanced device designed to monitor forest ecosystems by providing real-time, high-resolution data on tree physiology, environmental conditions, and forest health. A cybernetic evolution of the TreeTalker series, it is equipped with sophisticated sensors that collect information on tree growth, sap flow, water transport and carbon sequestration. This device integrates state-of-the-art Internet of Things (IoT) technology, enabling it to wirelessly transmit data to a centralized platform for analysis.

One of TreeTalkerCyber's key features is its ability to measure tree vitality and stress levels by monitoring fluctuations in sap flow, moisture, temperature, and internal water movement. In addition, it can detect environmental variables such as light intensity and weather conditions through on-board temperature and humidity sensors, creating a comprehensive ecological profile. Its sensors are also designed to track long-term changes in biomass through a dedicated radial dendrometer, allowing researchers to assess how trees respond to climate change, drought and other environmental stressors.

TreeTalkerCyber is particularly valued for its autonomous data collection capabilities, making it an indispensable tool for forest researchers. Its integration with cloud-based analytics enables remote monitoring and predictive modeling, offering insights into forest dynamics, biodiversity, and carbon cycles at an unprecedented scale. This it a critical tool for climate research and sustainable forest management globally.

Sensors

1. **Spectrometer**
   TTCyber spectrometer (TetraSpec) offers 28-channel spectral analysis, covering the visible to near-infrared range (410 nm to 1000 nm). Powered by AS7265x and AS7341 sensors, it offers accurate and versatile spectral sensing for a wide range of applications.

2. **Sap flow Probe**
   TTCyber offre due tipi di sonde per il flusso linfatico a tre aghi: la “TT-Cyber Probe Forest” (28 mm di lunghezza) e la “TT-Cyber W” (6 mm di lunghezza), entrambe progettate per misurare la velocità della linfa con metodi HPV (heat pulse velocity) personalizzabili.

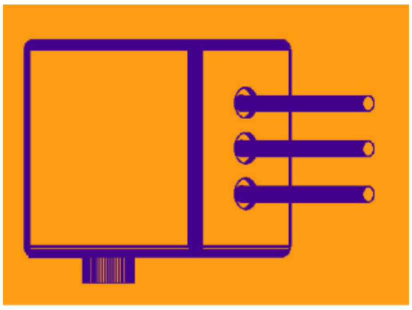
3. **Radial dendrometer**
   The TTCyber supports a high-precision magnetic radial dendrometer with a measurement resolution of <1 micron, providing a near real-time view of stem increment.

4. **Temperature and humidity**
   Temperature and humidity sensors are integrated into the main system hardware and provide accurate and precise measurements of temperature and humidity flows.

5. **Accelerometer**
   The device also includes an accelerometer to determine the inclination and corresponding standard deviations of a tree in different directions, xyz, contributing to the understanding of its stability.

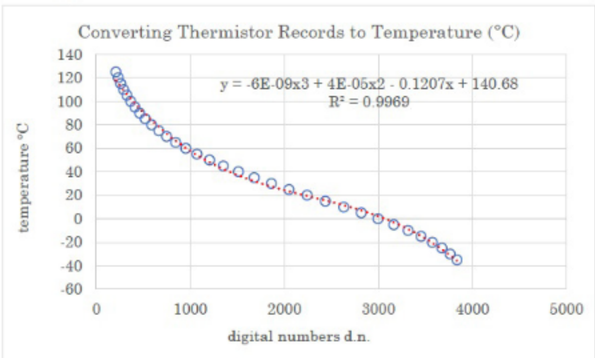
Sap Flow

TTCyber offers two variations of its three-probe configuration sap flow probes: the "TT-Cyber Probe Forest," equipped with 28 mm long and 2 mm diameter needles, and the "TT-Cyber W," featuring 6 mm long and 2 mm diameter needles. Both types of probes have needles positioned 7.5 mm apart and are equipped with three thermistors, positioned in series across each needle.



The default method employed for measuring sap velocity is the heat pulse velocity family (HPV) methods with 6 sec duration of heat pulse in hourly interval measurements. The energy input is approximately 780 (J m-1). Temperature readings from the thermistors in the TTCyber's sap flow probe consists of three measurements: the downstream probe (TD), the heater (TM), and the upstream probe (TU). These temperature readings are captured approximately every 13 seconds, covering maximum measurement points, and are recorded as sensor digital numbers. The sensor digital numbers are inverted into Temperature Degrees Celsius by way of a calibration function as described below.

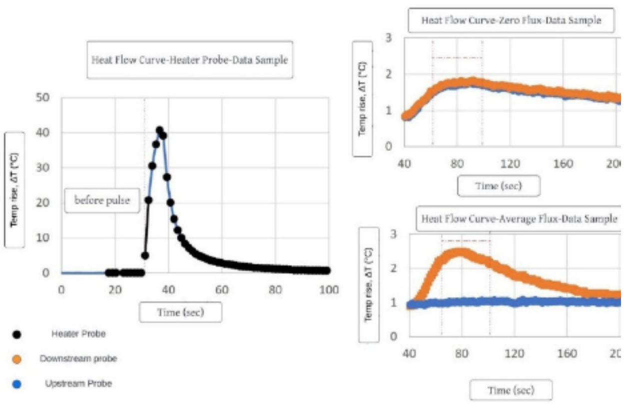
T (°C) = -6E-09x³ + 4E-05x² - 0.1207x + 140.68, where x is the d.n.



Applying the HRM (Heat Ratio Method) temperature changes both upstream and downstream of a heater probe after a heat pulse is emitted. We analyze the ratio of these temperature changes at equidistant points to estimate sap flow velocity.

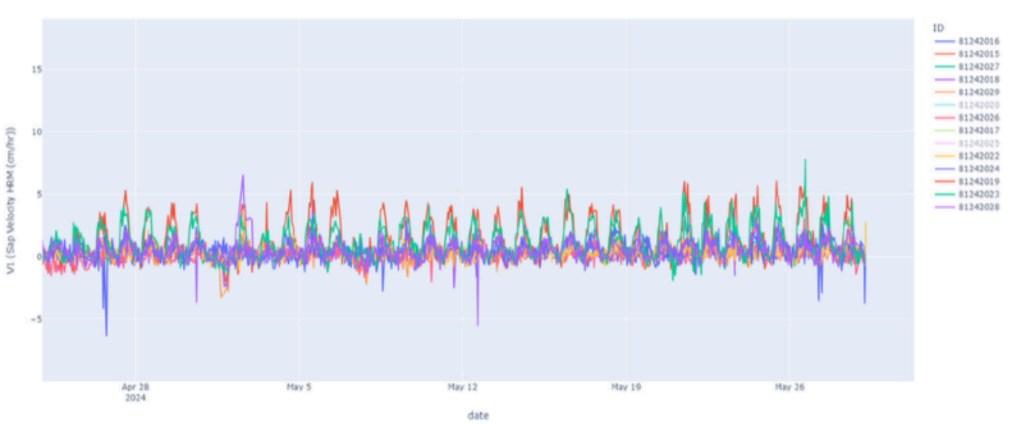
$$V = \frac{D}{X}\ln\left(\frac{\Delta T_D}{\Delta T_U}\right)$$

Where:
V= Heat pulse velocity
D= is the thermal diffusivity ΔTD dand ΔTU = are the temperature increases in downstream and upstream probes.
X=is the distance between the heater and the temperature probes.



$$\Delta T = \frac{H}{4\pi K t}\exp\left(-\frac{pc((x - Vt)^2 + y^2}{4Kt}\right)$$

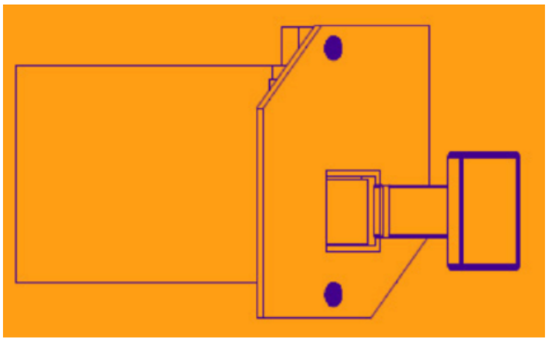
where:
ΔT is the temperature difference at a point (x, y) from the heater, V is the heat velocity, K is thermal conductivity, and (x,y) is volumetric heat capacity (Marshall, 1958; Vandegehuchte & Steppe, 2012).



Dendrometer

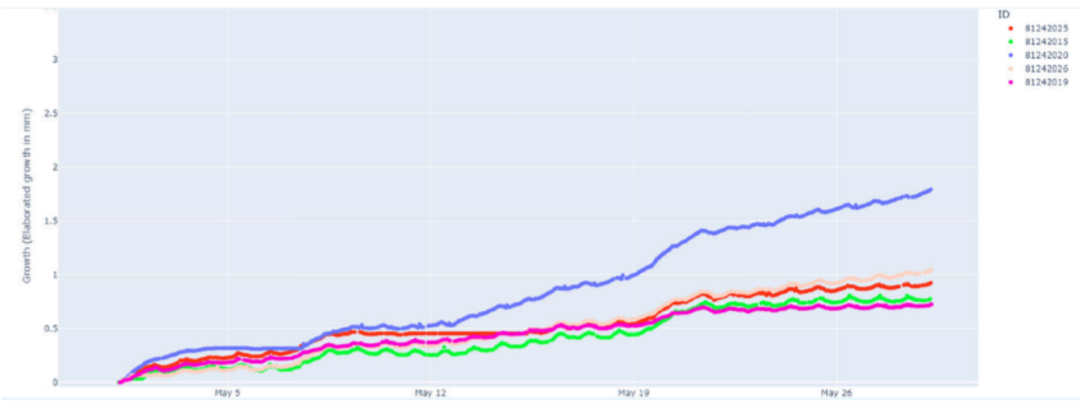
The TTCyber includes a high resolution radial dendrometer to detect fine scaled changes in stem growth increment and diel stem dynamics.

The dendrometer is suitable for trees with a diameter at breast height (dbh) of 7cm or more. This criterion is set because of the installation process, which includes drilling two 3mm diameter holes at a depth of 18mm. This method may pose a risk of harming the plant tissue, particularly in smaller trees.



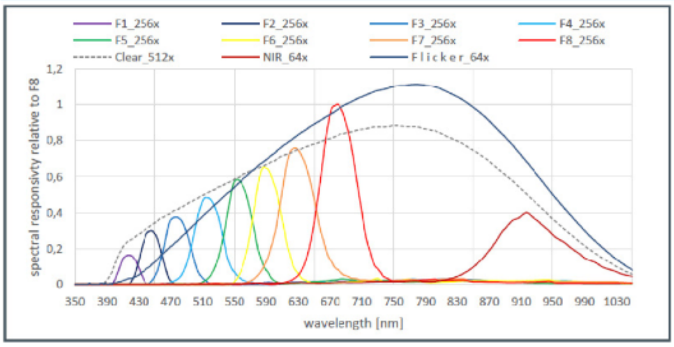
The dendrometer is designed for trees with a diameter at breast height (dbh) of 7cm or more. This requirement is based on the installation process, which involves drilling two 3mm diameter holes at a depth of 18mm. This approach could potentially harm the plant tissue, especially in smaller trees. The system operates based on hall mechanics and utilizes an incremental linear magnetic encoder (LME) at its core. Furthermore, it is built to withstand diverse weather conditions and features a durable measurement system for multi-year monitoring.

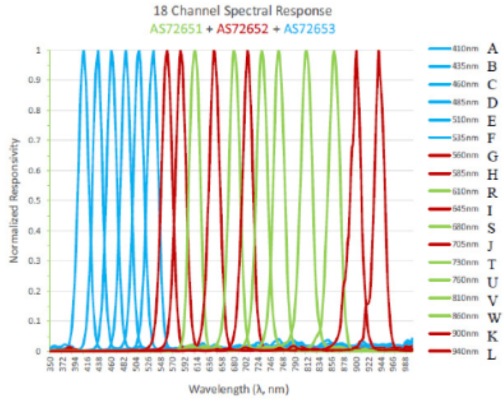
Sensor Features	
Supply Voltage	3.3V
Measurement range	0 — 35cm
Digital number range	0 — 4096 over 2mm dipole
Operating temperature	-40°C — + 80°C
Measurement resolution	0.488 µm (12bit / 2mm pole pair)
Temeprature sensitivity	0.13 µm change per 1°C



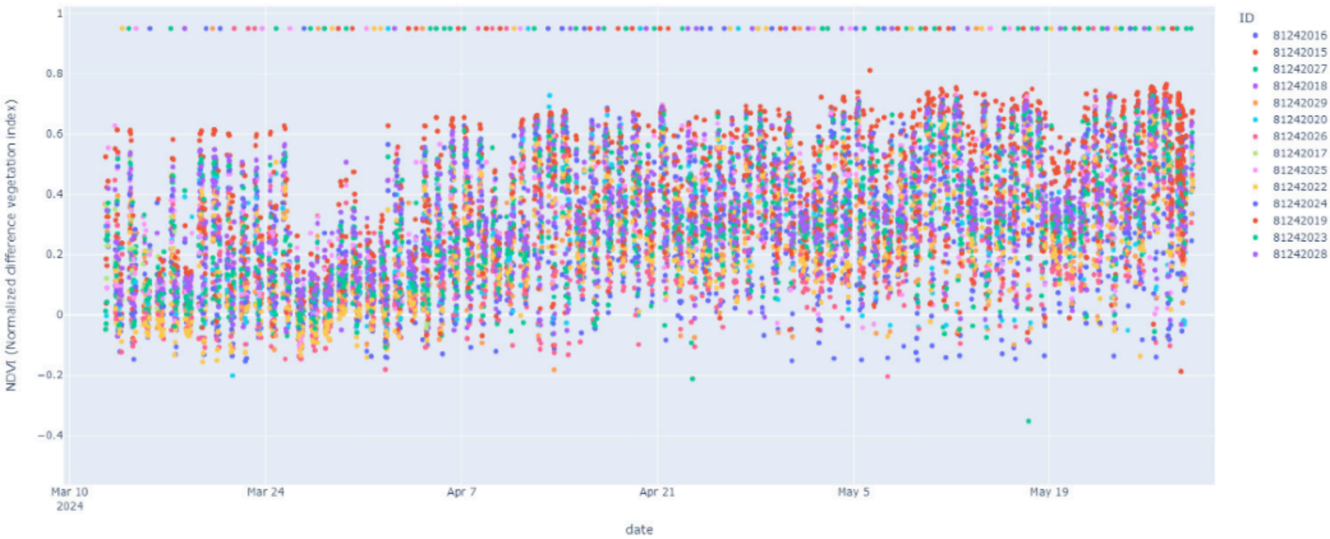
Spectrometer

The TTCyber Spectrometer, also known as TetraSpec and illustrated in Figure 6, is composed of a fusion of four chipsets that integrate AS7265x and AS7341 spectral devices. AS7265x, an 18-channel multispectral sensor, comprises AS72651, AS72652, and AS72653, and operates within a wavelength range of 410 nm to 940 nm, with a full width at half maximum (FWHM) of 20 nm. Among the AS7265x family, AS72651 (610 nm to 860 nm) acts as the primary unit, working in conjunction with AS72652 (560 nm to 940 nm) and AS72653 (410 nm to 535 nm) as detailed in Figure 8. The fourth sensor, AS7341, is a 10-channel spectrometer with an approximate FWHM of 30 nm, functioning within the spectrum of 415 nm to 1000 nm. This includes 8 channels in the visible (VIS) region, one channel in the near-infrared (NIR) region, and one clear channel. These multi-spectral sensors are flexible instruments for spectral analysis, with the ability to distinguish different attributes within the visible and near-infrared (NIR) range. Hereafter, you will encounter an extensive depiction of the varied spectral and optical traits demonstrated by these sensors.





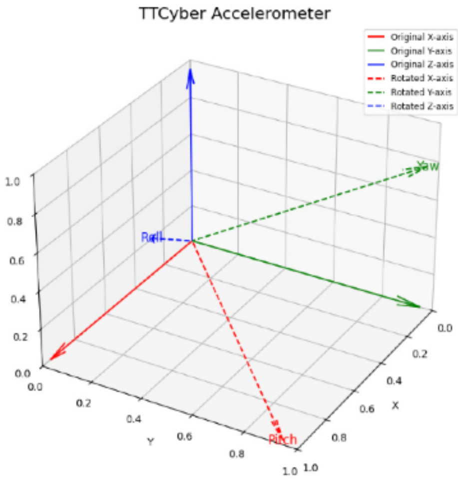
The TetraSpec system generates two types of digital number records, "6" and "7," within a range of 0 to 65,000. Calibration was performed using the Ocean Optics E65000 spectrometer and the HL-3 plus calibrated halogen light source, which provides precise measurements across the 400–1000 nm spectral range with a resolution of 0.8 nm. The calibration used a 16X gain setting and a 100 ms integration time to ensure accuracy.
The calibration process significantly improves data reliability, with average calibration coefficients (MEAN [count/μW/cm2/nm]) calculated for each band. While the TetraSpec's autogain feature, along with a light diffuser, reduces light saturation, saturation is still observed in midday conditions for the CLEAR and NIR bands. Calibration coefficients for these bands are currently unavailable but will be updated in the next version of the system.

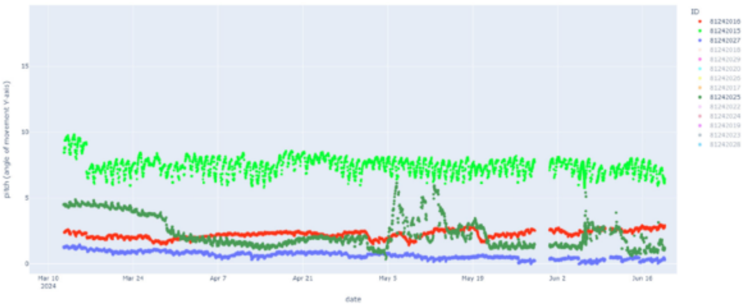


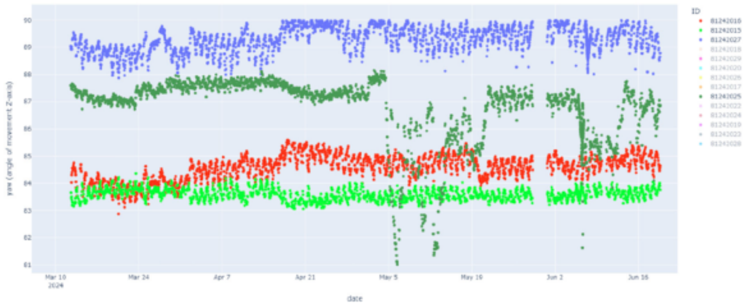
Accelerometer

The TTCyber integrates an accelerometer enabling the assessment of tree stability in response to external forces like wind, soil conditions, and physical disturbances. Every device monitors tree movement by measuring oscillations and swaying, in hourly sequence delievring quasi real time data individual trees. By analyzing resonance frequencies, accelerometers can indicate structural integrity.

Additionally, these devices detect damage through unusual movement patterns that may suggest root failure or trunk damage. Establishing movement thresholds allows researchers to identify when trees are at risk of falling. Integrating accelerometer data with other sensors, such as moisture and temperature sensors, provides a comprehensive understanding of tree health. Advanced data analytics and machine learning can further predict potential failures, aiding forest management and urban planning.







Temperature and RH

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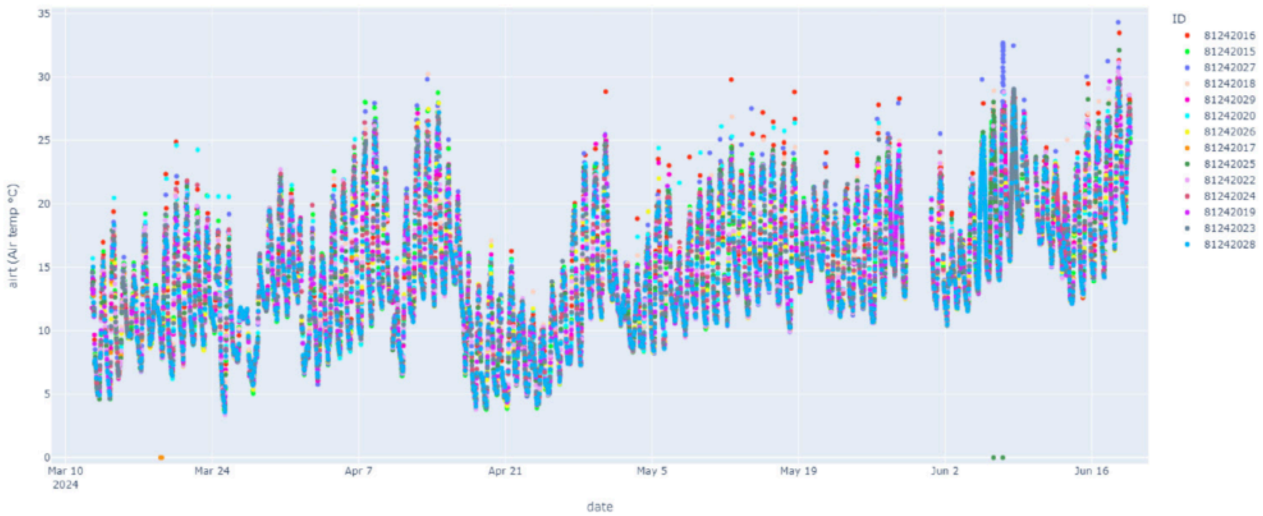


Data string 4 & 5

Every hour, TTcyber performs consecutive scans on its internal sensors, capturing and storing data locally and on a server. It provides raw, uncalibrated data as separate strings for each sensor.

Sap Velocity			
String type 4		String type 5	
03.07.24 20:11:1	date & time	03.07.24 20:11:11	date & time
81234007	ID	81234007	ID
4	string type	5	string type
199448	timestamp	201601	timestamp
0	t1	42	t6
1902	TD-1	1878	TD-6
1897	TM-1	1790	TM-6
1887	TU-1	1877	TU-6
6	t2	54	t7
1902	TD-2	1875	TD-7
595	TM-2	1819	TM-7
1885	TU-2	1876	TU-7
6	t3	66	t8
1902	TD-3	1874	TD-8
598	TM-3	1837	TM-8
1885	TU-3	1876	TU-8
18	t4	78	t9
1897	TD-4	1875	TD-9
1549	TM-4	1848	TM-9
1885	TU-4	1876	TU-9
30	t5	90	t10
1886	TD-5	1876	TD-10
1729	TM-5	1857	TM-10
1880	TU-5	1876	TU-10

Legend			
t	TD	TM	TU
time (sec)	Temp of downstream probe	Temp of heater probe	Temp of upstream probe

- The temperature records of thermistors from the TTCyber's sap flow probe are specified as string 4 and string 5. Data represents the downstream probe TD, heater TM, and upstream probe TU. The records are presented in digital format.

- Data sample:

  23.08.23 15:03:17,81234007,4,199448,0,1902,1897,1887,6,1902,595,1885,6,1902,598,1885,18,1897,1549,1885,30,1886,1729,1880

  23.08.23 15:03:18,81234007,5,201601,42,1878,1790,1877,54,1875,1819,1876,66,1874,1837,1876,78,1875,1848,1876,90,1876,1857,18 76

Data string 6 & 7

Every hour, TTcyber performs consecutive scans on its internal sensors, capturing and storing data locally and on a server. It provides raw, uncalibrated data as separate strings for each sensor.

TTCyber Spectrometer Strings 6 & 7					
Raw data	label	MEAN (count/µW/cm^2/nm)	Raw data	label	MEAN (count/µW/cm^2/nm)
16:15:21	date & time		29.08.23 16:15:23	date & time	
81234007	ID		81234007	ID	
6	string type		7	string type	
200699	timestamp		202511	timestamp	
3	Gain		10	Gain	
117	A (410nm)	216.1	4570	F1 (415 nm)	437.27
138	B (435 nm)	140.9	5965	F2 (445nm)	362.29
190	C (460 nm)	143.7	7851	F3 (480nm)	281.41
149	D (485 nm)	68.74	9715	F4 (515 nm)	270.15
139	E (510 nm)	63.2	10719	F5 (555 nm)	219.8
130	F (535 nm)	51.89	11276	F6 (590nm)	271.58
108	G (560nm)	37.75	13308	F7 630nm)	287.04
124	H (585 nm)	46.52	15125	F8 (680nm)	349.52
82	I (645 nm)	25.75	61391	CLEAR No Calib	No calibration
88	J (705 nm)	30.91	53401	NIR No Calib	No calibration
120	K (900 nm)	26.91			
56	L (940 nm)	26.53			
186	R (610 nm)	47.8			
167	S (680 nm)	58.12			
260	T (730 nm)	56.67			
311	U (760 nm)	58.44			
364	V (810 nm)	58.91			
409	W (860 nm)	59.76			

- The transmitted light under the canopy records from the TTCyber's spectrometer are specified as string 6 and string 7. Data represents

- Data sample

  23.08.23
  15:03:17,81234007,4,199448,0,1902,1897,1887,6,1902,595,1885,6,1902,5 98,1885,18,1897,1549,1885,30,1886,1729,1880

  23.08.23
  15:03:18,81234007,5,201601,42,1878,1790,1877,54,1875,1819,1876,66,18 74,1837,1876,78,1875,1848,1876,90,1876,1857,1876

Data string 8

Every hour, TTcyber performs consecutive scans on its internal sensors, capturing and storing data locally and on a server. It provides raw, uncalibrated data as separate strings for each sensor.

Environmental data/tree stability/growth/battery level		
String type 8		
Raw data	label	Legend
29.08.23 3:11:20 PM	date & time	
81234007	ID	
8	string type	
205082	timestamp	
2864	x	Tree stability data
58	std-x	
-13312	y	
48	std-y	
-8520	z	
93	std-z	
4028	vbat	battery level in milivolts, threshold = 3750
6196	v-stepup	Heater probe power input
2426	airt	air temp, 2426/100=24.26° C
6025	RH	air RH, 6025/100=60.25 %
849	growth(d.n.)	TTCarbon record in d.n.

- The rest of the records of Temperature, humidity, dendrometer and accelerometer are from the TTCyber's subsequent sensors and specified as string 8. Data represents all measurements as digital numbers accordingly..

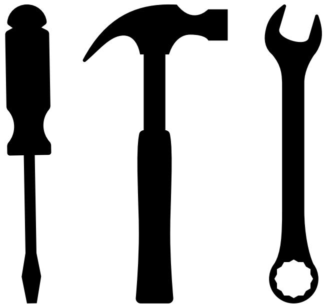
- Data sample
  29.08.23
  15:11:20,81234007,8,205082,2864,58, -13312,48, -8520,93,4028,6196,2426,6025,849

Training Manual

TreeTalker®Cyber installation

Guidelines & regulation

Tool list for Installation



1. Electric Drill
2. Drill bit-2.2/2.3mm and 3mm
3. Metal Chisel
4. Drill guide sensor template
5. Rubber hammer
6. Phillips head screwdriver
7. Spanners 10", 11" and 12"

Included:

1. Antennas
2. Tree Belts
3. Mounting plates
4. Nuts and Bolts
5. Mounting ball

Trunk installation

Here is the revised installation procedure in a step-by-step format:

1. Prepare the TreeTalker®Cyber Trunk Installation:
   - Begin by threading the support belt through the two support plates and adjusting them as needed.

2. Attach the Ball Support Mount:
   - Connect the ball support mount to the support plate without using Velcro.
   - Install the Cyber unit with the spectrometer facing upwards.
   - Secure the device by tightening a bolt over the exposed nut, adjusting the ball support to allow for easy installation.

3. Mount the Device on the Tree:
   - Wrap the belt around the tree with the device attached, ensuring the belt is threaded correctly through the belt clip.
   - Adjust the ball joint on the support plate to set the spectrometer's line of sight. Position it to maximize canopy coverage for the most comprehensive spectral readings.

4. Install the Antenna:
   - Attach the LoRa or NB-IoT antenna to the outside of the device.

5. Connect Sensors
   - Plug in the sap flow probe on the left side.
   - Connect the dendrometer on the right side.

6. Install the Battery:
   - Insert the battery into the device.

7. Activate the System:
   - Plug in the system. The device should automatically start communicating with the server or cloud.

Following these steps will ensure that the RemoteTree is installed and configured correctly for optimal data collection.

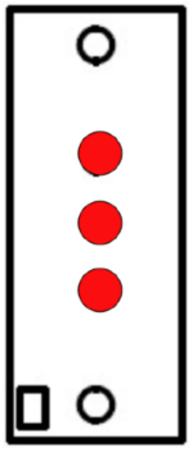
We have included a video tutorial for the installation of the entire device.

Sap flow probe installation

1. You have been provided with a sensor guide template to install the sap flow sensor.

2. For Trees with thick bark you may have to remove the bark. Conifers and oaks. Smooth bark species such as some Eucalyptus and Fagus, for example, generally don't require bark removal.

3. Place the guide template flush with the stem and using a 2.1-2.3 mm drill bit, drill three holes into the stem using the central holes of the templat. Make sure they are clean and ready for the sensor placement.



4. Gentle push the sensor into the holes and use a rubber hammer to gently tap it into the stem so the sensor is flush with tree stem.

Dendrometer installation

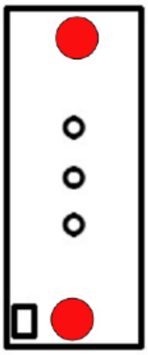
When installing a dendrometer:
- Conifers: Avoid the lower side of leaning branches or stems, where dense compression wood may distort readings.
- Broadleaves: Avoid the upper side, where flexible tension wood can impact measurements.
Positioning on unaffected wood improves data accuracy.

1. Clean the surface of the tree for installation. Remove any surface irregularities and try to place the guide template on a part of the tree that is a 90 degree face.

2. Using the guide template provided as part of the installation kit, place it vertically and flush against the stem.

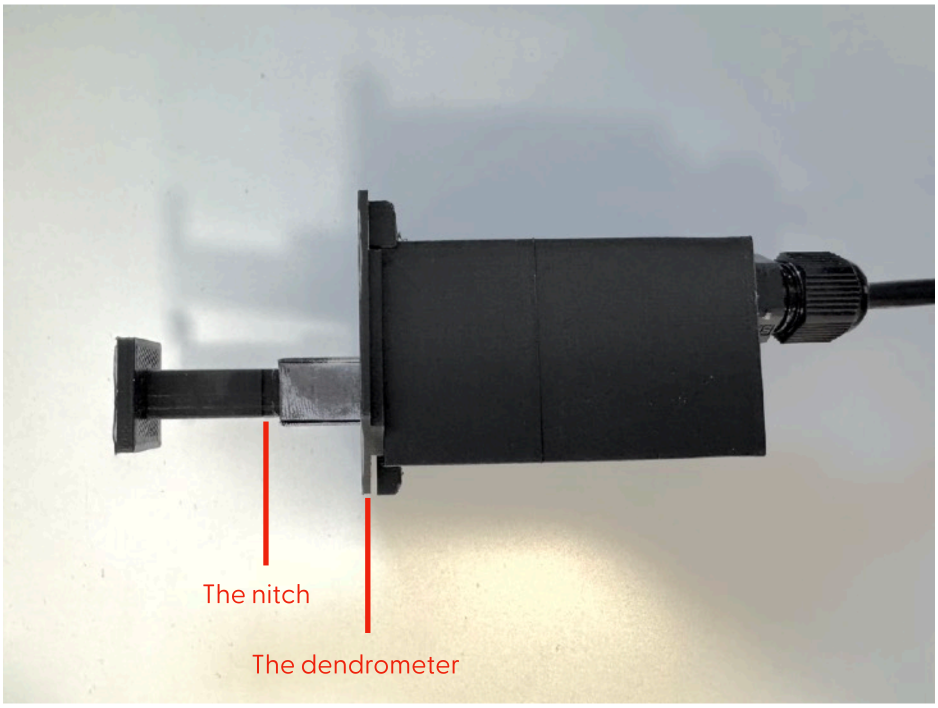
3. Using the two large holes at the top and bottom of the guide template drill into stem using a 3mm drill bit with a depth of approximately 2.5cm

4. Place some glue on the end of the carbon fibre rods and insert them into the stem.



5. Thread the dendrometer box and arm over the two carbon sticks and using some glue on the arm face firmly hold the face to the cleaned part of the stem until it holds.

6. Slowly move the dendrometer box into position inline with the nitch in the dendrometer arm



Cloud installation

1. Choose a location to install the solar panel whic is exposed to most sun.

2. Mount the Cloud and the Battery in horizontal positions NOT vertical.

3. Connect the Solar Panel to the Battery.

4. Connect the Battery to the Cloud.

5. Press the button on the Cloud to activate. Press it again to deactivate.

   Do Not Disconnect the Battery from the Cloud while the Battery is still connected to the Solar panel. Disconnect the battery from the solar panel and then the Cloud from the battery.