A Multiscale Study of the Coupling Between Flow, Fire and Vegetation – Influence of Vegetation Distribution and Flow on Fire Behavior and Plume Development for Risk Mitigation in Prescribed Burns-Static Field Experiment – User Guide

Proposal Number: RC20-1362

https://serdp-estcp.mil/projects/details/64e6167e-49cb-44d5-b654-fc632591a160/rc20-1362-project-overview

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Abstract
The United States Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP) funded project: A Multiscale Study of the Coupling Between Flow, Fire and Vegetation – Influence of Vegetation Distribution and Flow on Fire Behavior and Plume Development for Risk Mitigation in Prescribed Burns (RC20-C3-1362) conducted static field experiment focusing on the plume dynamics under different updraft core configurations and fuel loading. These experiments along with small-scale laboratory work will help characterize the way structure and heterogeneity of fuel elements change the drag and convective heat transfer. The experiments will couple the effects of vegetation elements and vertical flow, as well as the effects of surface fuel heterogeneity on smoke plume development and dynamics. The static field experiment includes data conducted at the Tall Timbers Research Station and Land Conservancy on 10/18/2022, and multiple campaigns at the Savannah River Site 1.) 05/23/2023 – 05/26/2023, 2.) 10/18/2023 - 10/22/2023, 3.) 06/03/2024 – 06/06/2024, 4.) 06/09/2025 – 06/12/2025.

This document describes the data collected during static field experiments including the purpose, site descriptions, data collected including sensor and senor specifications. This document is to provide an overview of all the data collected during the static field experiment providing references to each dataset.

Purpose
When conducting prescribed burns, managers often face difficult choices that may have dire consequences (Hidalgo 2017). Having access to cutting-edge knowledge and tools to support their decisions would help greatly mitigate risks. One of the main aspects of managing prescribed burns is to control production of and public exposure to emissions and smoke (Ryan et al. 2013). Smoke trajectories 1 and downwind exposure are intimately coupled with the development of the fire plume in the vicinity of the fire front as well as the smoke production dynamics. In turn, the development of smoke plumes is strongly coupled with fire behavior and the flow environment near the fire at fine scales. Small perturbations in the flow environment near the combustion zone can have significant impacts on the combustion efficiency (and hence the energy release and products of combustion), which affects the local fire behavior and feeds back on the flow environment itself. At a larger scale, the flow can affect the fire spread processes by altering the dominance of heat transfer mechanisms (flame shape, flame contact, wind penetration through heterogeneous fuels). Finally, at the largest scale the interactions between the buoyant force generated by the hot combustion products and the ambient wind will determine the updraft core development, plume dynamics and the long-range transport phenomena (smoke and firebrands).

The ability to model and predict flow patterns in scenarios relevant to wildland fire spread remains a significant need, particularly in the vicinity of the fire front. This is compounded by the challenges associated with measuring flow and fire properties; obtaining a realistic representation of the flow necessitates field measurements, and generally, it is only feasible to make a finite number of point measurements in the field. Therefore, models are essential to interpolate, provide context, and extend the value of flow field data. The ability of models to do so, however, is hampered by a deficiency in understanding of the interaction of flow with vegetation, which is dynamically modified by the fire itself. Litters, shrubs and trees affect the flow both at the size of their fine structures and at the size of individual vegetation elements. The compounded effects will drive how the flow is behaving inside of a vegetation stand at a scale relevant to prescribed burns. To advance modeling, it is necessary to improve the descriptions of wind/fire/fuel feedback at those fine scales of vegetation and hence to increase the ability to accurately predict fire dynamics, plume development, and transport of firebrands and emissions. The project will address the following fundamental questions:

1. How does the variability in vegetation structure and vegetation distribution at multiple scales influence fire and plume dynamics regarding heat transfer and drag?
2. How do fuel structure, distribution, age and seasonality influence fire dynamics and plume development in the field for different burn intensities?
3. What physical processes are most relevant at different scales (thermal transfer, flow through vegetation, fire spread in heterogeneous fuels, near-field plume development, etc.)?

Addressing these fundamental wildland fire questions will establish the scientific basis for advancing decision support tools for helping managers to decide when and how they can conduct their prescribed burns to better reach their objectives, mitigate risks, and manage emissions to the benefit of the DoD mission, ecosystems and the public.

Site Descriptions

Field experiments were conducted in the south eastern United States at Tall Timbers Research Station and Land Conservancy (TT) located in Tallahassee Florida (30.655277° N, 84.22583° W) and the Savannah River Site (SRS) located in Aiken South Carolina (33.267817 N, 81.621249 W) shown in **Error! Reference source not found.**.

Tall Timbers Research Station

Seven static field experiments were conducted on October 18, 2022, at Tall Timbers Research Station and Land Conservancy located north of Tallahassee Florida in Leon County. Tall Timbers encompasses 13,000 acres in North Florida with a long-leaf pine-wiregrass woodland as the primary forest type. Research includes fire ecology, resource management, forestry, game bird management, and vertebrate ecology.

The experimental area used at the Tall Timbers Research Station was approximately a 0.5-ha clearing that had all vegetation removed and had been recently plowed (Figure 2).

Figure 1. Tall Timbers Research Station and Savannah River Site field site locations.

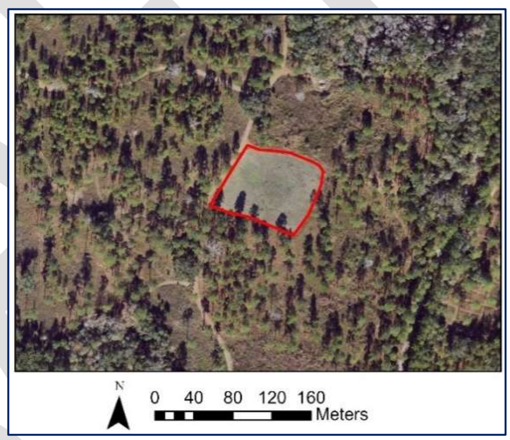


Figure 2. Tall Timbers Research Station 0.5-ha study area.

Savannah River Site

Eighty five static field experiments were conducted in 4 campaigns, 1.) 05/23 – 05/26/2023, 2.) 10/18 – 10/22/2023, 3.) 06/03 – 06/06/2024, 4.) 06/09 – 06/12/2025 - at the Savannah River Site located in Aiken, South Carolina (Figure 3). The Savannah River Site (SRS) is a Department of Energy (DoE) facility that encompasses 310 square miles (198,046 acres) located in the sand-hills region of South Carolina. The Savannah River and Georgia border the site on the west and includes portions of Aiken, Barnwell and Allendale counties. The experimental area used at the Savannah River Site was approximately 1.25-ha loblolly pine plantation where the understory vegetation was

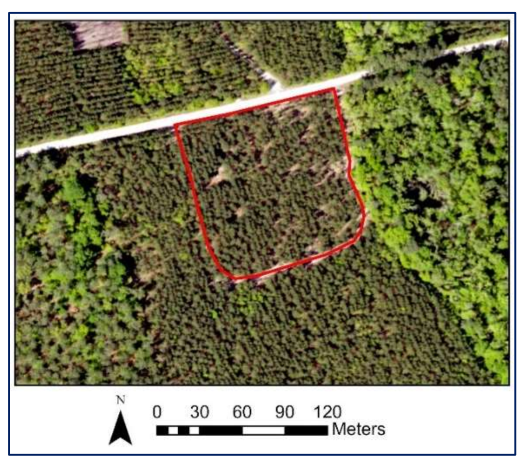


Figure 3. Savannah River Site 1.25-ha loblolly pine plantation pre thinning.

masticated prior to any field experiments and thinned between campaigns 2 and 3.

Experimental Design

Spatial and temporal measurements of fire and plume dynamics in the field are extremely challenging to obtain. Further, it is extremely difficult to simultaneously measure the dynamics of fire spread and the associated plume behavior. Therefore, liquid pool fires were chosen as a source for the plumes. Pool fires provided a simple route for testing the different ignition patterns followed during prescribed burns. By changing the geometric arrangements of pools and utilizing a sooty fuel mixture of diesel and canola oil (1:1 by volume), we were able to manipulate the spatial distribution of heat release rate (fire intensity) and control the volume of plume generation. The pool fires were characterized by point measurements of temperature, velocity, air-entrainment, and heat flux. The mass loss rate of fuel was measured to allow for the calculation of the heat release rate (intensity). Rectangular arrangements of pool fires were used to allow comparison to existing fire behavior data (and for the relative ease of setting up numerical simulations with FDS and FIRETEC which can handle only rectangular grids); however, line fires were also tested to simulate flaming fronts representative of prescribed fires and wildfires. Through this the effect of the fire line width to depth ratio was explored. Lab-scale experiments were undertaken in the fire protection engineering laboratory at Worcester Polytechnic Institute (WPI) to determine the combustion efficiency in open sites and the effect of ambient wind on the burning rates of pool fires [1]. The calibration was used to engineer the macro-scale surface area density of the pools so that the average heat release rate over the pool size is like that of wildland fuels. A unique advantage of using pool fires is that it will allow multiple experiments to be completed with the same vegetation structures in a short time frame. This will allow the effects of wind and fuel structures to be included as an independent variable. Sensor arrays for monitoring heat transfer and plume dynamics in the fire environment will remain in place as infrastructure from experiment to experiment, thus dramatically reducing experimental setup time, while facilitating direct comparison of data between burns. The plume measurements associated with this will permit matrices of plume temperature and flow characteristics [2].

Tall Timbers Research Station

Vegetation Configuration

A single vegetation configuration (VEG_CONFIG = 0) was used at Tall Timbers where all vegetation was removed in the 0.5-ha experiment area (Figure 4).

Tower Configuration

Within the 0.5-ha experiment area, a network of 10 towers were constructed to mount sonic anemometers. The tower configurations were as follows:

- Tower arrays (A, B and C) each had three towers downwind from the pans that increased in height as distance from the pans increased. Heights were 6, 10 and 30-ft (1.8, 3 and 9.1-m) respectively.
- A single 5-ft (1.8-m) control tower was upwind from the pans.

Tower configuration and locations for each burn are identified in the Burn Layout and Documentation section.

Sonic Anemometers

Ten sonic anemometers (RM 81000V, R. M. Young, Inc., Traverse City, MI) were used at Tall Timbers to record fine-scale patterns of three-dimensional flow, plume turbulence, and the gas-phase temperature. A single sonic anemometer was mounted at top of each tower. See Table 1 for heights.

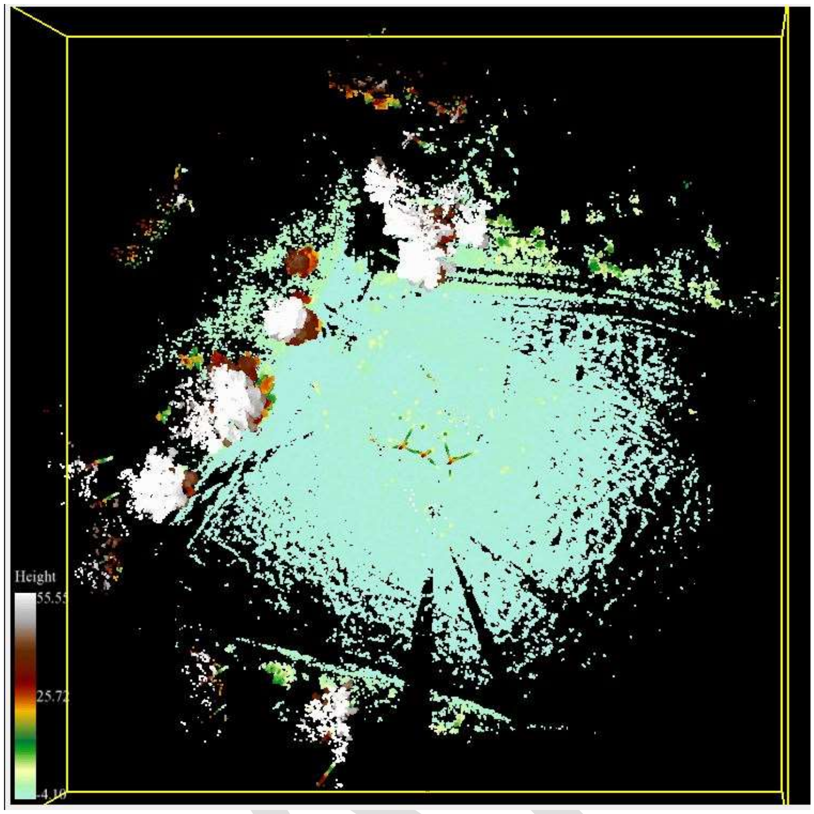


Figure 4. TLS view of Tall Timbers vegetation configuration 0 (TT_TLS_Veg0_Final.laz).

Table 1. Sonic anemometer height on the A, B and C tower arrays

Tower	Height above ground (ft/m)
A_06	6/1.8
A_10	10/3
A_30	30/9.1
B_06	6/1.8
B_10	10/3
B_30	30/9.1
C_06	6/1.8
C_10	10/3
C_30	30/9.1
Control_06	6/1.8

Thermocouples

No thermocouple data were collected at Tall Timbers.

Video Configuration

Video recorders were set up at Tall Timbers to document plume development, and transport from the source. The following recorders were used:

- Three Panasonic (HC-WXF991) video recorders mounted on tripods surrounding the pans (focusing on the pans).
- A single Vuze (Humaneyes VR Camera) camera mounted on a tripod near sonic B10 (Figure 5) was used to record a 360 spherical video in stereoscopic 3D of the experiment area.

Video configuration and camera locations for each burn are shown in the Burn Layout and Documentation section.

Master Configuration

- The master configuration identifies a unique combination of vegetation, platform center, tower, and video configurations. For Tall Timbers there is a single master configuration.
- Vegetation, tower, and video locations were collected using A BLK360 Terrestrial Laser Scanner.

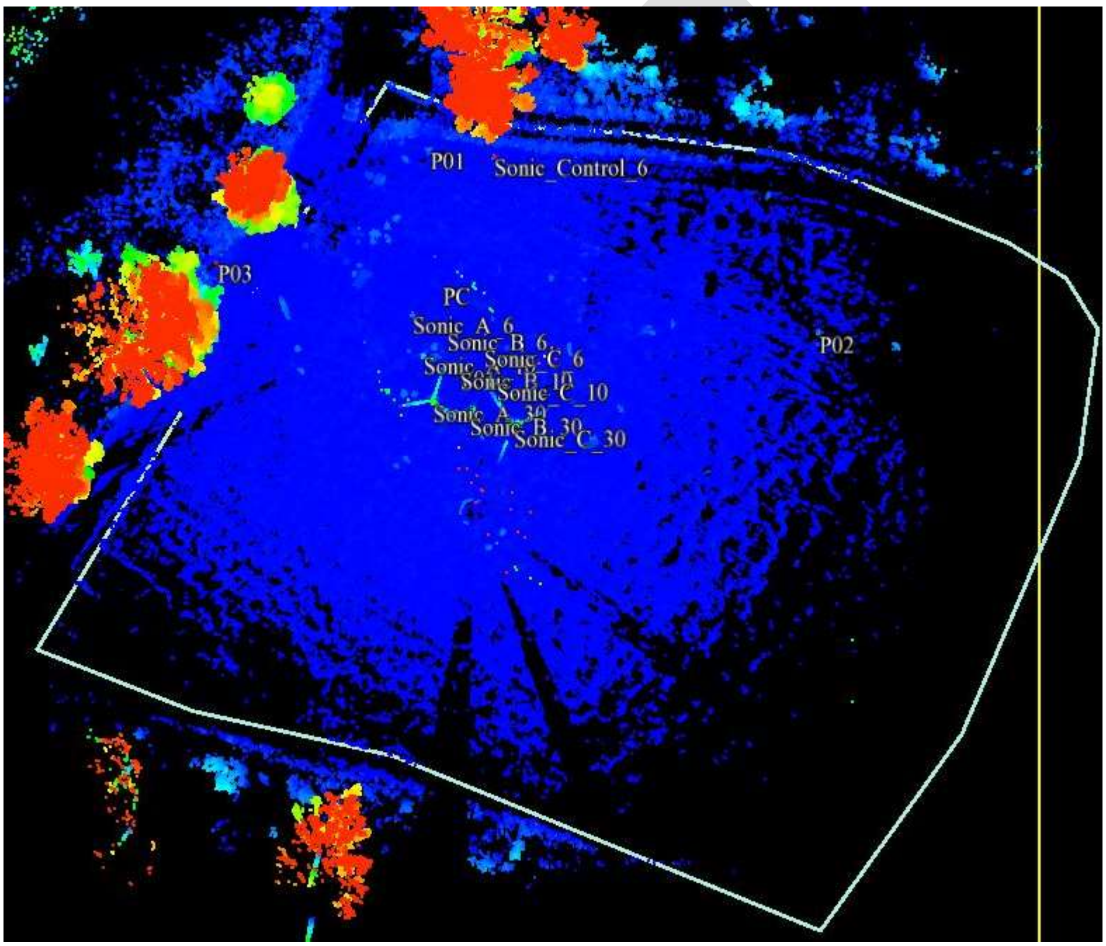


Figure 5. Tall Timbers master configuration 00.

Pan Configuration

The stainless-steel pans used at Tall Timbers had a cross section of 0.63 m × 0.68 m and a depth of 6.5 cm. The pans were set directly on the ground. For each burn 2-gallons of diesel fuel were added to the specified pan configuration and ignited. The pan configurations (PAN_CONFIG) used at Tall Timbers listed in the Burn Date table in the Burn Layout and Documentation section are as follows:

1. Line (15) – Single line of 15 pans (Figure 6).
2. Line (2) – Single line of 2 pans (Figure 7).
3. Single (1) – Single pan (Figure 8).
4. Square (4) – Double line with 2 pans each or 4 pans in a square (Figure 9).

Figure 6. Line (15) – Single line of 15 pans (Burn 1).

Figure 7. Line (2) – Single line of 2 pans (Burns 2-3).

Figure 8. Single (1) – Single pan (Burns 4-5).

Figure 9. Square (4) – Double line with 2 pans each or 4 pans in a square (Burns 6-7).

Savannah River Site

Vegetation Configuration

The Savannah River Site burns were conducted within a 1.25-ha loblolly and long leaf pine plantation with a row spacing of approximately 2.5-m. The trees in the plantation had an average height of 13.03-m and an average DBH of 21-cm. The vegetation configurations (VEG_CONFIG) listed in the Burn Date table in the Burn Layout and Documentation section were as follows:

1. VEG_CONFIG (1) – Understory vegetation was removed (Burns 1-43) (Figure 10).
2. VEG_CONFIG (2) – Understory vegetation was removed and tree density reduced by two thirds, removing every third row in both the east/west and north/south direction (Burns 44 – 67) (Figure 11Figure 11).
3. VEG_CONFIG (3) – Increased understory vegetation and Hurricane Helene damage occurred in the fall of 2024. (Burns 68 – 85) (Figure 12).

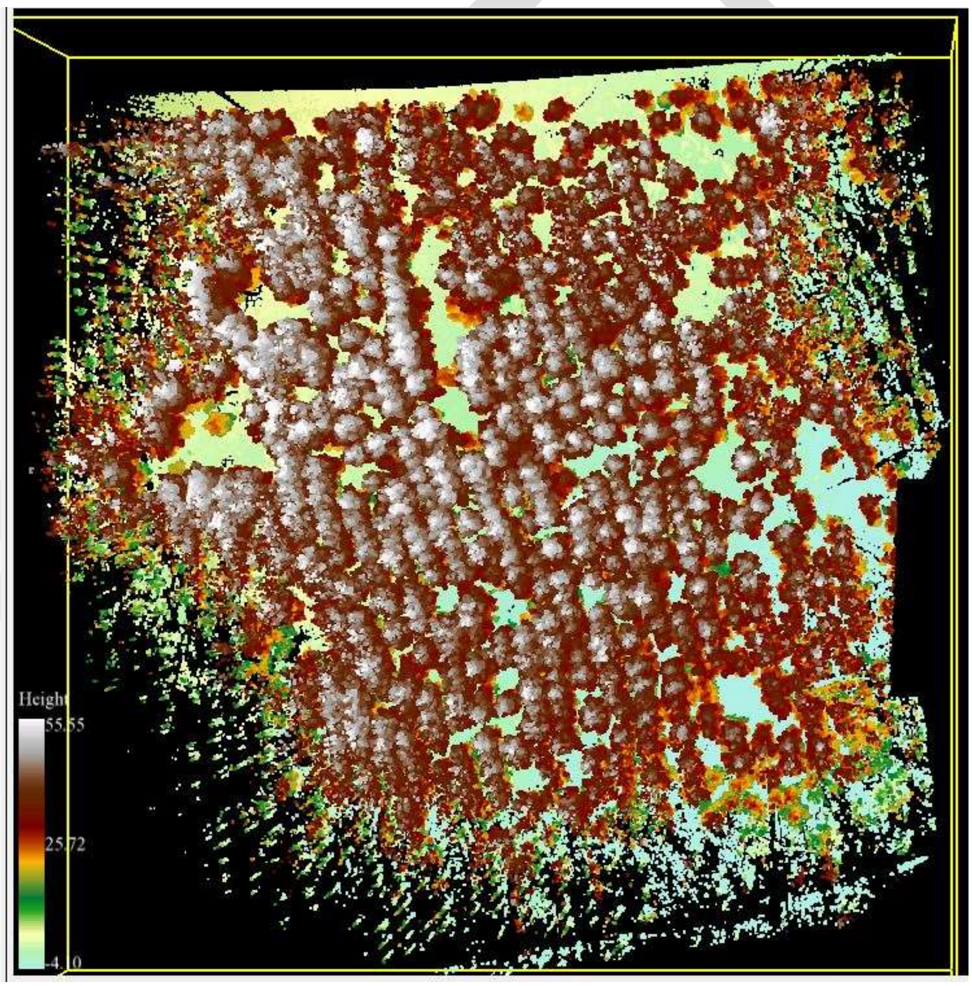


Figure 10. TLS view of vegetation configuration 1 (Burns 1-43).

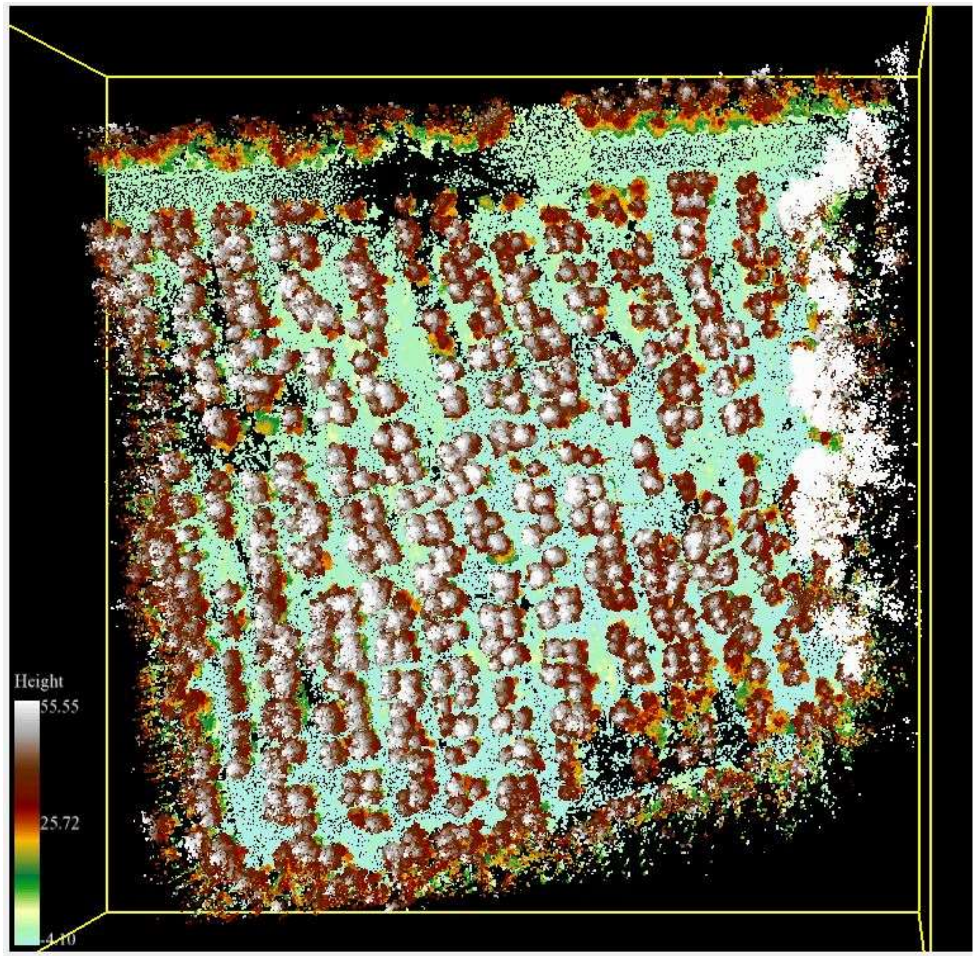


Figure 11. TLS view of vegetation configuration 2 identifying individual tree crowns. Tree density was reduced by two thirds, removing every 3rd row of trees in both the east/west/west and north/south direction (Burns 44-67).

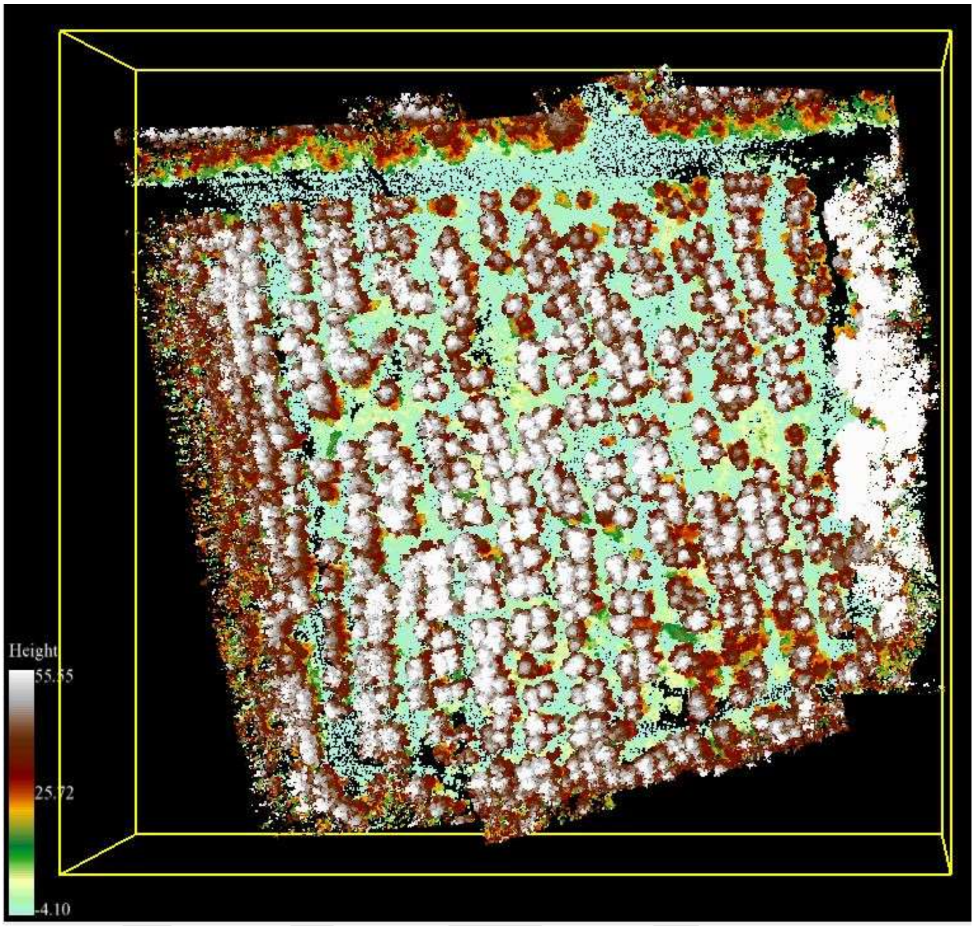


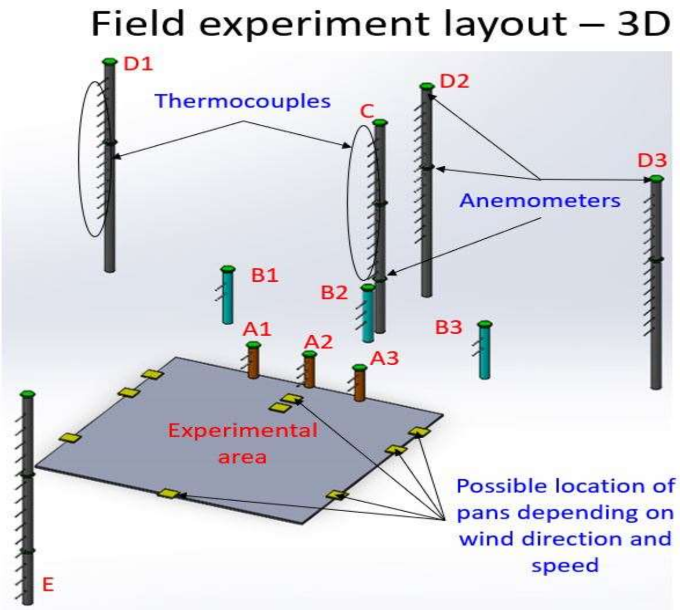
Figure 12. TLS view of vegetation configuration 3 after hurricane Helene damage (Burns 68-85).

Tower Configuration

Within the 1.25-ha experiment area, a network of 11 towers were constructed to mount sonic anemometers and thermocouples. The towers were setup as follows:

- The A towers included three 6-ft (1.8-m) towers (A1, A2, A3).
- The B towers included three 10-ft (3-m) towers (B1, B2, B3).
- The C tower included one 40-ft (12.2-m) tower (C).
- The D tower included three 40-ft (12.2-m) tower (D1, D2, D3).
- The E tower included one 40-ft (12.2-m) tower (E).

The optimum field setup with the location of pans and tower configurations is shown in Figure 13. However, due to changing wind direction and operational feasibility, multiple tower configurations were used at SRS. Tower sensor heights remained constant, only the tower locations from platform center changed. Towers C and E were fixed and did not move. Tower configurations and locations for each burn are identified in the Burn Layout and Documentation section.



Tower	Thermocouples	Anemometers
A1	2	1
A2	3	1
A3	2	1
B1	2	1
B2	3	1
B3	2	1
C	14	3
D1	14	2
D2	14	3
D3	14	2
E	14	3
Total	84	19

Figure 13. SRS 3D view of optimal field experiment layout.

Sonic Anemometers

Nineteen sonic anemometers (RM 81000V, R. M. Young, Inc., Traverse City, MI) were used at the Savanah River Site to record fine-scale patterns of three-dimensional flow, plume turbulence in the plume, and the gas-phase temperature. Sonics were mounted on the 6, 10 and 40-ft towers.

- A single sonic anemometer was mounted at top of the A (6-ft) and B (10-ft) towers. See Table 2 for heights.
- Towers D1 and D3 had two sonic anemometers and towers C, D2, and E had three sonic anemometers. See Table 3 for heights.

Table 2. Sonic anemometer heights on the A (6-ft) and B (10-ft) towers.

Tower	Height above ground (ft/m)
A1	6/1.8
A2	6/1.8
A3	6/1.8
B1	10/3.0
B2	10/3.0
B3	10/3.0

Table 3. Sonic anemometer heights on the C, D and E (40-ft) towers.

	C	D1	D2	D3	E
Height above ground (ft/m)	10/3.0	-	10/3.0	-	10/3.0
	25/7.6	25/7.6	25/7.6	25/7.6	25/7.6
	40/12.2	40/12.2	40/12.2	40/12.2	40/12.2

Thermocouples

Eighty-four Omega K-type thermocouples (KMTXL-IOM25G-150, Omega Engineering Inc., Norwalk, CT) were used at the Savannah River Site to measure convective heat transfer. Thermocouples were mounted on the 6, 10 and 40-ft towers.

- Towers A1, A3, B1, and B3 had 2 thermocouples per tower. See Table 4 for heights.
- Towers A2 and B2 had three thermocouples per tower. See Table 4 for heights.
- Each forty-foot tower (C, D1, D2, D3, E) had fourteen thermocouples. See Table 5 for heights.

Table 4. Thermocouple heights above ground on A (6-ft) and B (10-ft) towers.

Height of Thermocouples on A (6-ft) and B (10-ft) Towers						
	A1	**A2**	**A3**	**B1**	**B2**	**B3**
Height above ground (ft/m)	-	1.6/0.5	-	-	3.9/1.2	-
	3.3/1	3.3/1	3.3/1	5.9/1.8	5.9/1.8	5.9/1.8
	4.9/1.5	4.9/1.5	4.9/1.5	7.9/2.4	7.9/2.4	7.9/2.4

Table 5. Thermocouple heights above ground on the C, D and E 40-ft towers.

	C, D1, D2, D3	**E**
Heights above ground (ft/m)	11.8/3.6	2.6/0.8
	13.8/4.2	5.2/1.6
	15.7/4.8	7.9/2.4
	17.7/5.4	10.5/3.2
	19.7/6	13.1/4.0
	21.7/6.6	15.7/4.8
	23.6/7.2	18.4/5.6
	25.6/7.8	21/6.4
	27.6/8.4	23.6/7.2
	29.5/9	26.2/8
	31.5/9.6	28.9/8.8
	33.5/10.2	31.5/9.6
	35.4/10.8	34.1/10.4
	37.4/11.4	36.7/11.2

Video Configuration

Multiple video cameras were used at the Savannah River Site to document plume development, transport and the interaction of flow with vegetation (tree canopy). The following recorders were used:

- GoPro (GoPro HERO8 Black) cameras mounted on posts surrounding the pans with the focus towards the pans or elevated above the canopy on a boom lift capturing the plume leaving the canopy.
- GoPro Max 360 cameras mounted on towers to record a 360 spherical video in stereoscopic 3D of the experiment area.
- Panasonic (HC-WXF991) video recorders mounted on tripods surrounding the pans at a distance to monitor plume transport through the canopy.
- Vuze (Humaneyes VR Camera) camera mounted on a tripod near the pans to record a 360 spherical video in stereoscopic 3D of the experiment area.

Video configurations and camera locations for each burn are identified in the Burn Layout and Documentation section.

Master Configuration

The master configuration identifies a unique combination of vegetation, platform center, tower, and video configurations.

- For Savanah River Site there are seven master configurations (Figs. 16 - 22).
- Vegetation, tower, and video locations were collected using A BLK360 Terrestrial Laser Scanner and Field Measurements.

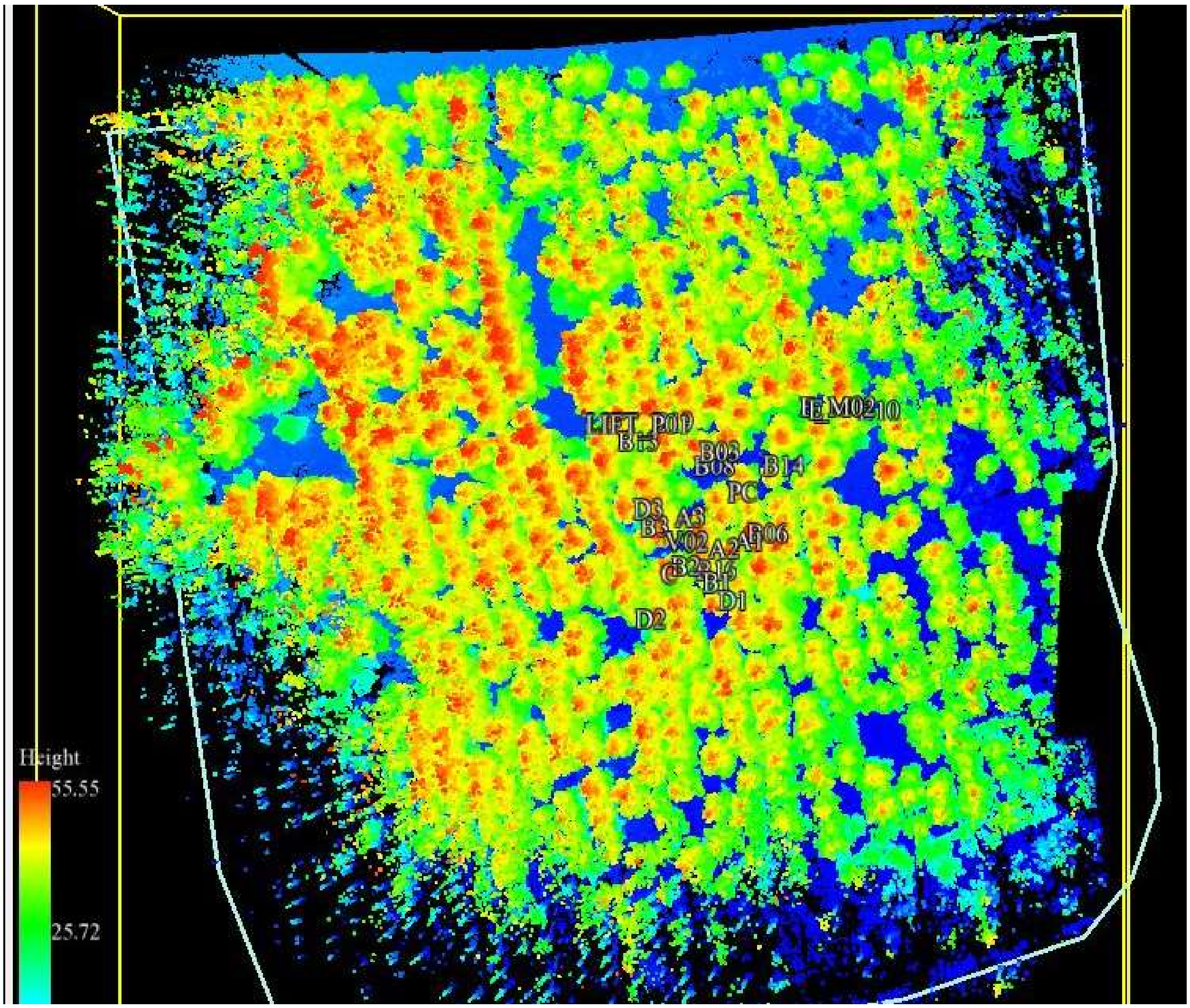


Figure 14. Terrestrial laser scan master configuration 1 (SRS_M_Config01_Layout_UTM).

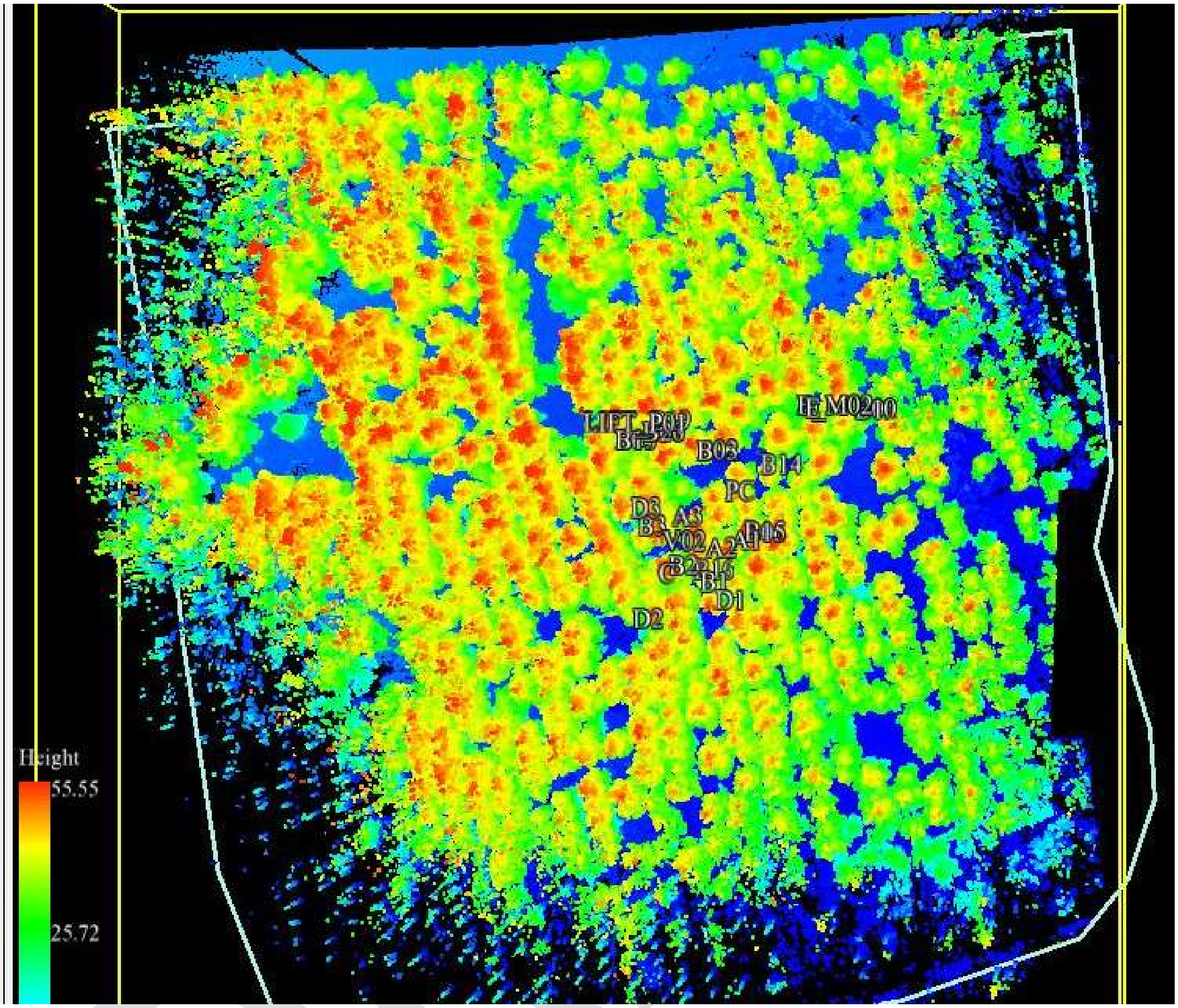


Figure 15. Terrestrial laser scan master configuration 2 (SRS_M_Config02_Layout_UTM).

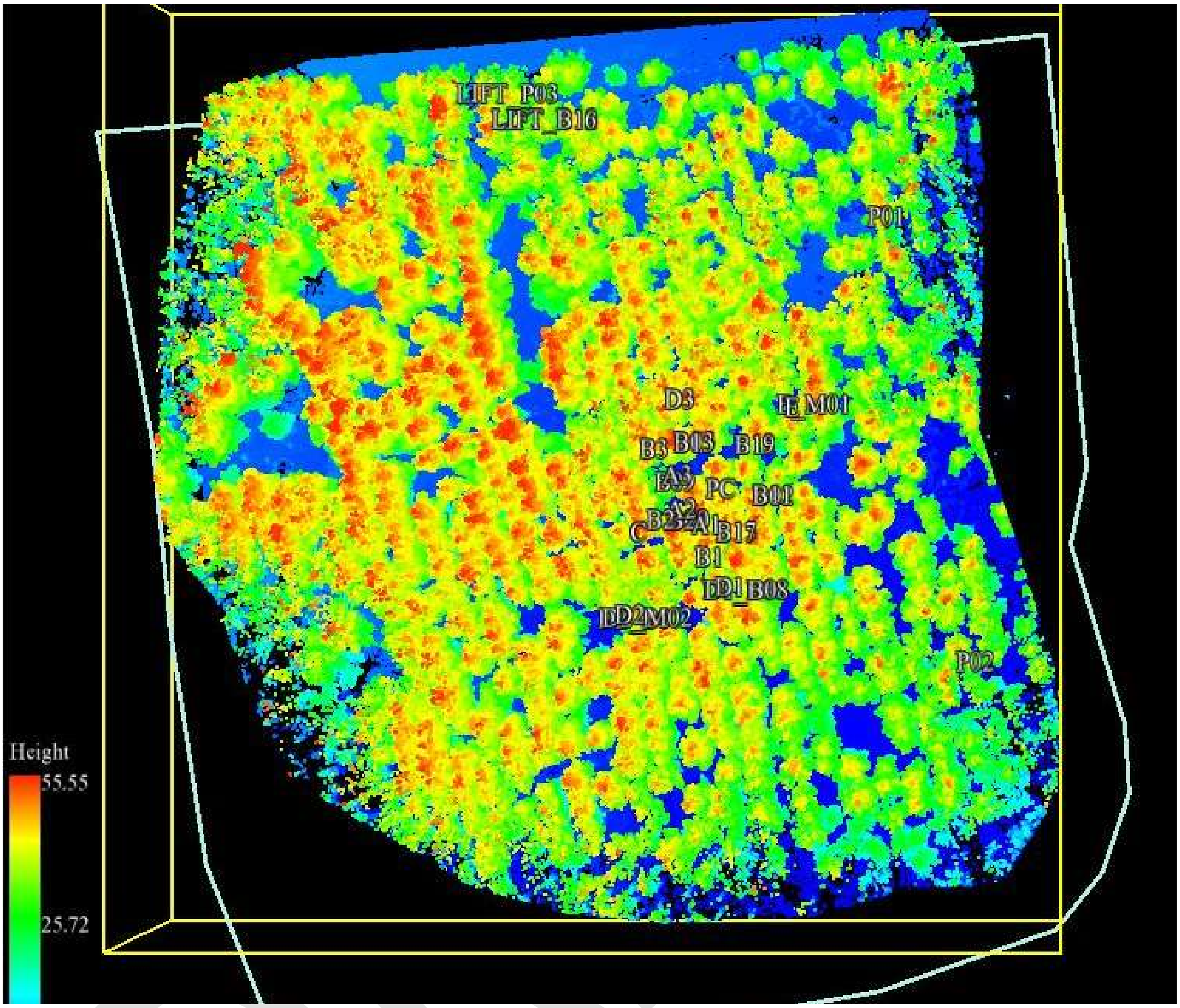


Figure 16. Terrestrial laser scan master configuration 3 (SRS_M_Config03_Layout_UTM).

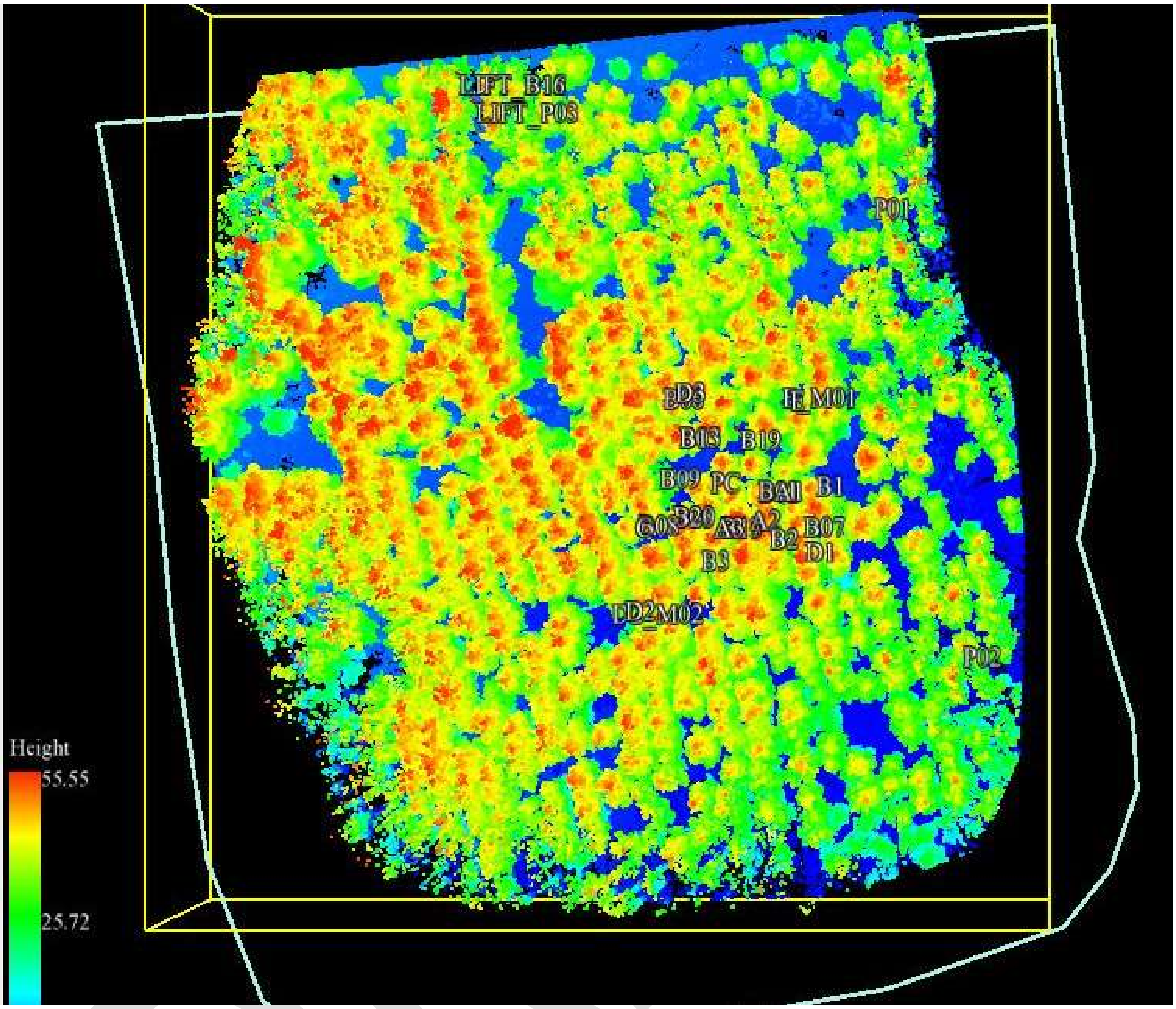


Figure 17. Terrestrial laser scan master configuration 4 (SRS_M_Config04_Layout_UTM).

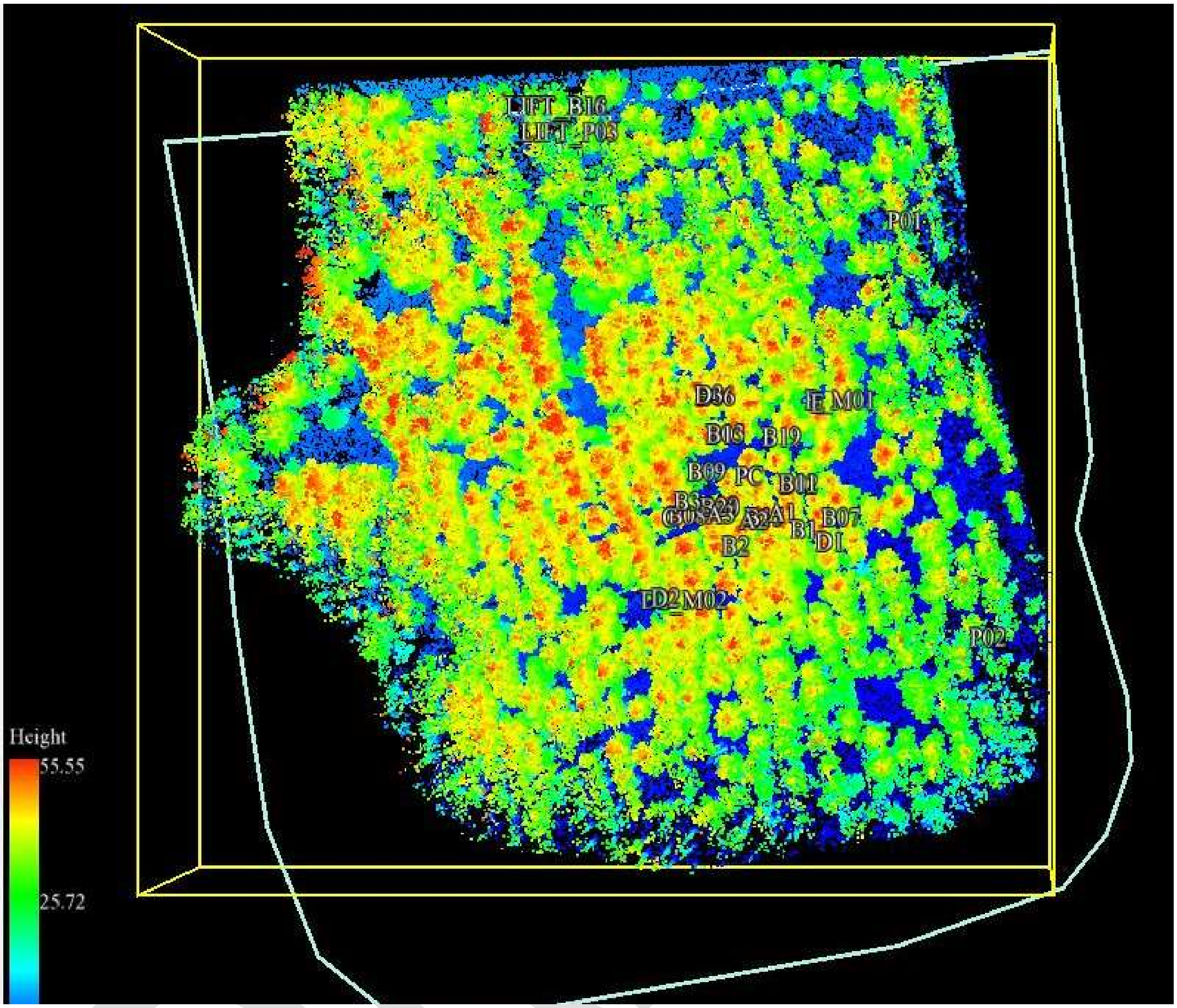


Figure 18. Terrestrial laser scan master configuration 5 (SRS_M_Config05_Layout_UTM).

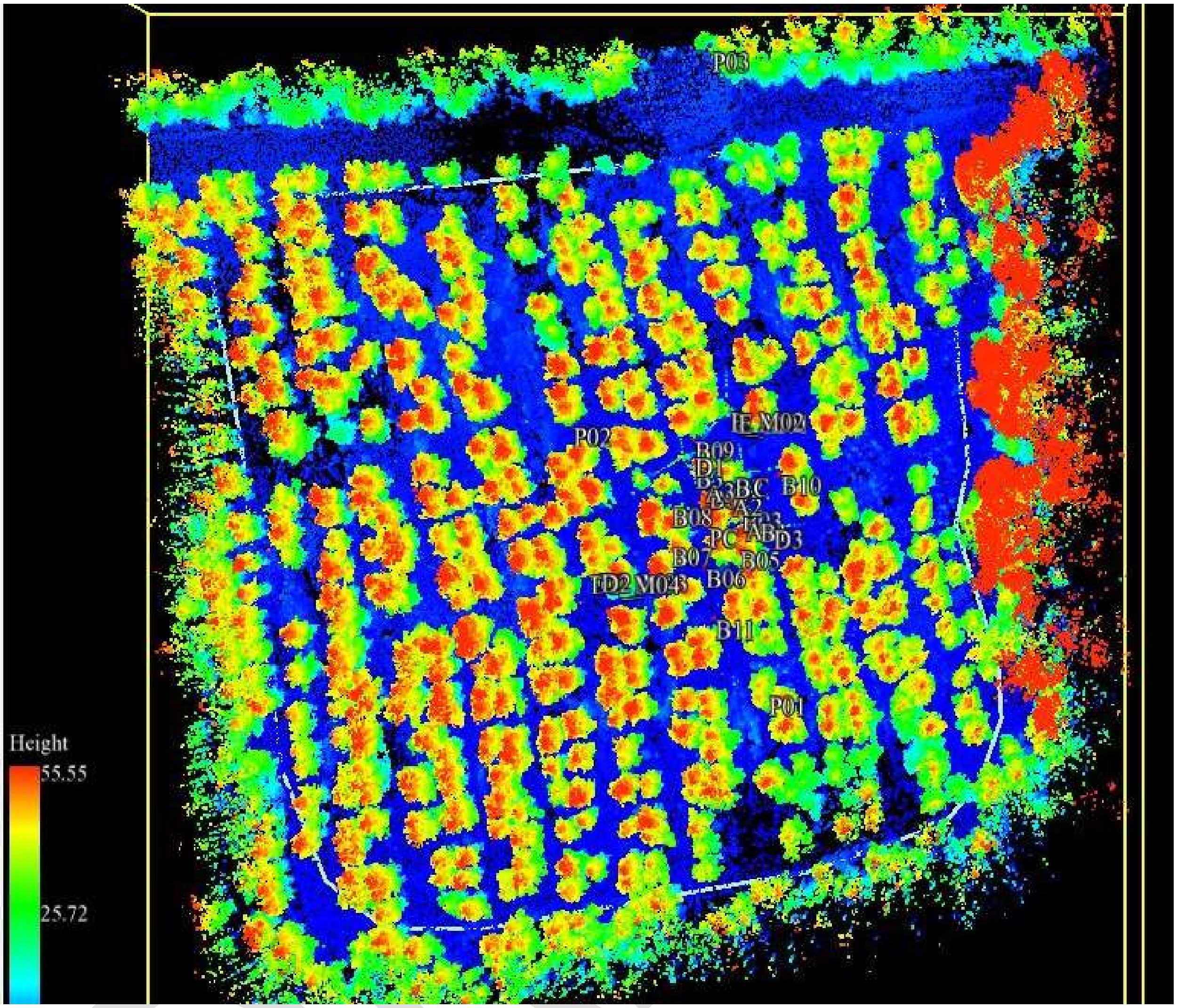


Figure 19. Terrestrial laser scan master configuration 6 (SRS_M_Config06_Layout_UTM).

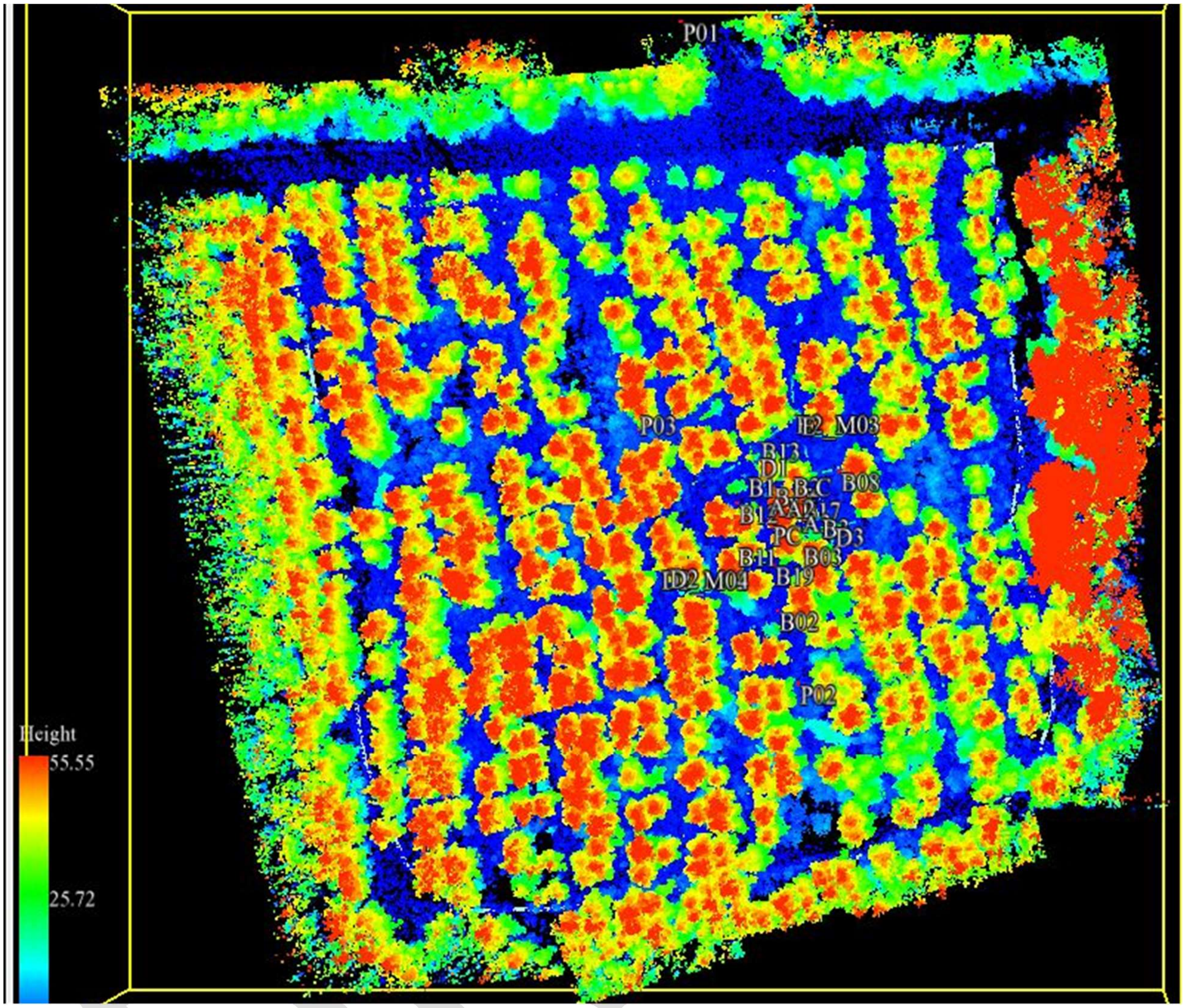


Figure 20. Terrestrial laser scan master configuration 7 (SRS_M_Config07_Layout_UTM).

Pan Configuration

The pans used at the Savannah River Site had a cross section of 0.63 m × 0.68 m and were 6.5-cm deep. It was constructed of 3/16-gauge steel with reinforced base to reduce warping. The pans were set on a platform of concrete blocks that were 8-in tall. The concrete blocks were rearranged as needed to fit the different pan configurations. For each burn the pans were filled with equal portions of diesel fuel and canola oil (1-gallon each). The pan configurations (PAN_CONFIG) listed in the Burn Date table in the Burn Layout and Documentation section were as follows:

1. Single (1) – Single pan (Figure 21).
2. Line (2) – Single line of 2 pans (Figure 22).
3. Line single space (1-1) – Single line of 2 pans with 1-pan spacing between them (Figure 23).
4. Two rows single space (2&2) – Double line with 2 pans in each line and 1 pan spacing between lines (Figure 24).
5. Line single space (2-2) A single line of 4 pans with a 1-pan spacing between the sets (**Error! Reference source not found.**).
6. Line (4) – Single line of 4 (Figure 26).
7. Square (4) – Double line with 2 pans each or 4 pans in a square (Figure 27).

8. Two rows single space (4&2) – Double line with 4 pans in one and 2 in the other with a 1-pan spacing between lines (Figure 28).
9. Two rows double space (4&2) – Double line with 4 pans in one and 2 in the other with a 2-pan spacing between lines (Figure 29).
10. Two rows double-double space (4&1-1) – Double line with 4 pans in one and 2 pans in the other with 2-pan spacing between lines and between 2 pan line (Figure 30).
11. Two rows double space (4&4) – Double line with 4 pans in each with a 2-pan spacing between lines (Figure 31).
12. Two rows double-double space (2-2&2-2) – Double line with 4 pans per line with 2-pan spacing between lines and pan sets within each line (**Error! Reference source not found.**).
13. Two square double space (4&4) – Two squares of 4 pans with a 2-pan spacing between squares (Figure 33).

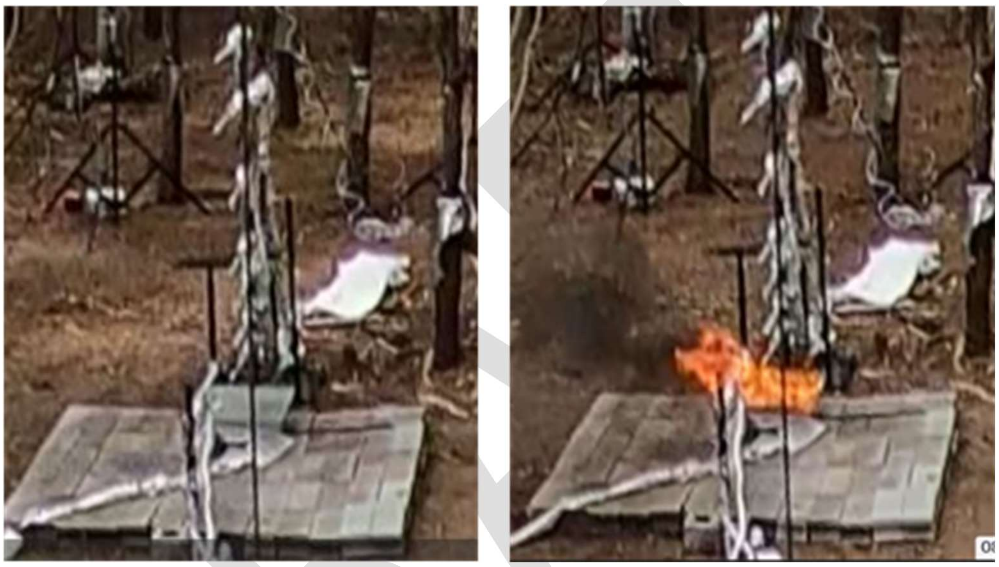


Figure 21. Single (1) – Single pan (Burns 1-4, 20-21, 30-31, 44-45, 68-69 and 75).

Figure 22. Line (2) – Single line of 2 pans (Burn 5-7, 22-23, 46-47, 70-71 and 74).

Figure 23, Line single space (1-1) – Single line of 2 pans with 1-pan spacing between them (Burn 28-29, 48-49 and 72-73).

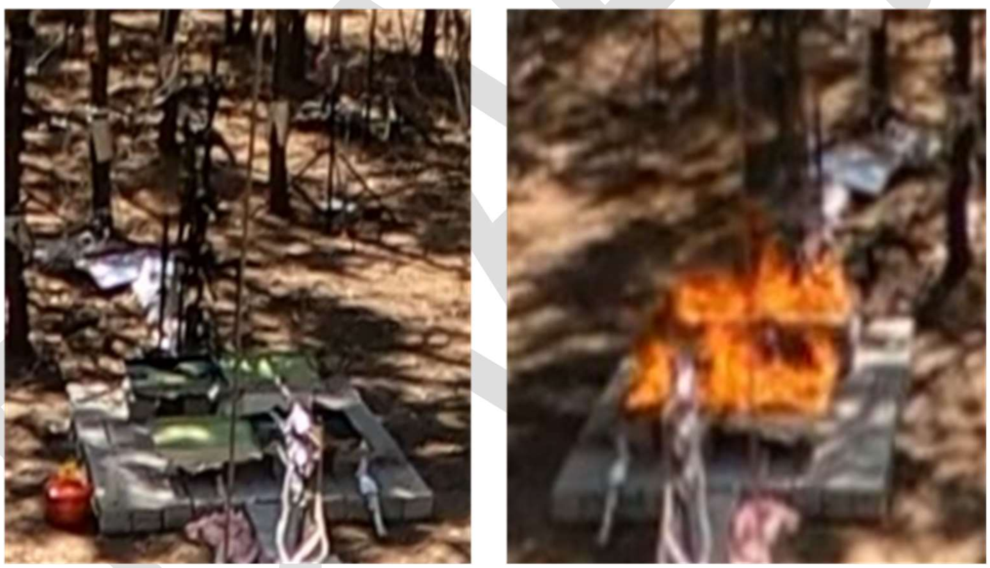


Figure 24. Two rows single space (2&2) – Double line with 2 pans in each line and 1 pan spacing between lines (Burn 8-10).

Figure 25. Line single space (2&2) A single line of 4 pans with a 1-pan spacing between the 2 sets (Burns 11-13 and 54-55).

Figure 26. Line (4) – Single line of 4 pans (Burns 14-16, 26-27, 50-51 and 80-81).

Figure 27. Square (4) – Double line with 2 pans each or 4 pans in a square (Burn 17-19, 24-25, 52-53 and 84-85).

Figure 28. Two rows single space (4&2) – Double line with 4 pans in one and 2 in the other with a 1-pan spacing between lines (Burns 32-33, and 56-57).

Figure 29.Two rows double space (4&2) Double line with 4 pans in one and 2 in the other with a 2-pan spacing between lines (34-35, 58-59 and 78-79).

Figure 30. Two rows double-double space (4&1-1) – Double line with 4 pans in one and 2 pans in the other with 2-pan spacing between lines and between 2 pan line (Burns 38-39, and 62-63).

Figure 31. Two rows double space (4&4) – Double line with 4 pans in each with a 2-pan spacing between lines (Burns 36-37, 60-61 and 81-82).

Figure 32. Two square double space (4&4) – Two squares of 4 pans with a 2-pan spacing between squares (Burns 42-43, and 66-67).

Figure 33. Two rows double-double space (2-2&2-2) – Double line with 4 pans per line with 2-pan spacing between lines and pan sets within each line (Burns 40-41 and 64-65).

General Data Description

- **Data structure** – data was broken out by site (TT, SRS), sensor type, burn number and location within the burn unit. For specific sensor locations within a burn refer to the burn layout section.
- **Burn times** – data was archived based on the archive start (AT_START) and end (AT_END) times where available.
  - Archive start – the ignition time (AT_START) of the burn. The archive start was determined from notes taken the day of the burn.
  - Archive end – Was noted in the field (AT_END).
- **Data formats:**
  - CSV – Comma-separated values.
  - HTML – Hyper Text Markup Language.
  - JPG – Compressed digital image format.
  - LAZ – Compressed LiDAR file.
  - MP4 – Digital multimedia container format.
  - TXT – Standard text document that contains plain text.
- **Missing data** – null or missing data are represented by NaN (not a number).
- **Graphs** – HTML format graphs were created using Plotly in Python to visualize the data.
  - Instruments can be turned off or on by selecting an instrument in the legend.
  - Data tools in upper left of file can further enhance viewing.

Burn Layout and Documentation

This section provides a general summary of each burn including site, burn data and time, number of pans used and pan and sensor configurations. Table 6 provides a general overview of the data collected during each field campaign including units, sample rate and instruments used. See instrument sections for instrument specific details.

Table 6. Data collection summary table.

DATATYPE	Mapping	Meteorological			Video		360 Video	
PARAMETER	Structure & Topography	3D wind speed	Virtual temperature	Temperature	Fire and plume dynamics	Fire and plume dynamics	Fire and plume dynamics	Fire and plume dynamics
UNITS		m/s	°C	°C				
SAMPLE_RATE	Per unique veg and tower config	10 Hz	10 Hz	10 Hz	23.976 fps	2160 mp4	30 fps	29.97 fps
INSTRUMENT	Terrestrial laser scanner (TLS)	Sonic	Sonic	Thermocouple	GoPro Black	Panasonic Video Recorder	VR 3d 360 VR camera	GoPro Max
MODEL	BLK 360	RM 81000V	RM 81000V	Type K	GoPro HERO8 Black	HC-WXF991	3D 360° 4K VR Camera	GoPro Max360
MANUFACTURER	LEICA Geosystems	R. M. Young	R. M. Young	Omega	GoPro	Panasonic	Vuze	GoPro
FIELD CAMPAIGN	**DATA COLLECTED**							
TT burns 1-7	X	X	X			X	X	
SRS burns 1-19	X	X	X	X	X	X	X	X
SRS burns 20-43	X	X	X	X	X	X		X
SRS burns 44-67	X	X	X	X	X	X		X
SRS burns 67-85	X	X	X	X	X	X		X

Burn Date

A single CSV (BurnDate.csv) for all burns described in Table 7. Prior to ignition the plot was abandoned by all staff so the instruments could collect data to be used in calibration. At minimum, 5 minutes of no interactions within the plot were collected (AT_START).

Table 7. "Burn Date" Table Description.

COLUMN	UNITS	DESCRIPTION
LOC		Site location where the burn was conducted (TT=Tall Timbers, SRS= Savannah River Site).
BURN		Burn number. A unique number starting with 1 for each location. A numeric value identifying an individual burn at a location.
DATE	Date	Burn date (YYYY-MM-DD).
CAL_START	Time	Calibration start time (HH:MM:SS) in local (EST) time adjusted for daylight savings. Start of 5 minutes of no interactions within the plot.
BURN_START	Time	Burn start time (HH:MM:SS) in local (EST) time adjusted for daylight savings. The burn start time was noted in field.
BURN_END	Time	Burn end time (HH:MM:SS) in local (EST) time adjusted for daylight savings. The burn end time was noted in field.
AT_START	Time	Archive start time (HH:MM:SS) in local (EST) time adjusted for daylight savings. The suggested start time of the data archive.
AT_END	Time	Archive end time (HH:MM:SS) in local (EST) time adjusted for daylight savings. The suggested end time of the data archive.
PANS		Pan count. A numeric value used to identify the number of pans ignited.
PAN_CONFIG		Pan configuration. Text describing the configuration pans ignited.
TOW_CONFIG		Tower configuration. A numeric value used to identify a unique tower configuration.

COLUMN	UNITS	DESCRIPTION
VID_CONFIG		Video configuration. A numeric value used to identify a unique cameras configuration.
PC_CONFIG		Platform center configuration. A numeric value used to identify a unique platform center location.
VEG_CONFIG		Vegetation configuration. A numeric value used to identify a unique vegetation configuration.

Burn Layout

A single CSV for each burn describes the location of instruments and towers in relation to the platform center. Sensors were only included if data were collected during the burn. The azimuth and distance from platform center (0, 0) and the height above ground were measured in the field. Then were used to calculate the X, Y and Z (HAG) coordinates (Table 8). The coordinates are in a local projection. Burn layout data are separated by site location and burn.

- File name – Loc_Burn#_Layout.ext
    - Where:
        - Loc – location of the study (TT = Tall-Timbers SRS = Savannah River Site)
        - # – burn number.
        - ext – file extension (CSV or HTML).

Table 8. "Burn Layout" Table Description.

COLUMN	UNITS	DESCRIPTION
LABEL		Label name. If mounted on a tower or other structure with multiple sensors the structure name is also included (D1_B06 = camera B06 mounted on tower D1).
ITEM		Item type.
AZIMUTH	deg	Degree from platform center to item (declination = 0).
DIST	m	Distance (meters) from platform center to item.
X	m	X coordinate (meters).
Y	m	Y coordinate (meters).
HAG	m	Height Above Ground (meters).
NOTES		General Notes

Master Configuration Layout UTM

A single CSV and shapefile for each master configuration (M_CONFIG) describing the unique configuration of vegetation, video, instrument and tower locations in NAD 1983 UTM Zone 17N coordinates (Table 9). UTM coordinates were calculated by applying a shift from the local platform center (Burn Layout) to the platform center GPS coordinate. Master configuration data are separated by site location and burn.

- File name – Loc_M_Config#_Layout_UTM.ext
    - Where:
        - Loc – location of the study (TT = Tall-Timbers SRS = Savannah River Site)
        - # – master configuration number.
        - Ext – file extension (CSV or SHP).

Table 9. "M Config Layout UTM" Table Description.

COLUMN	UNITS	DESCRIPTION
LABEL		Label name. If mounted on a tower or other structure with multiple sensors the structure name is also included (D1_B06 = camera B06 mounted on tower D1). Note cameras are tied to a specific location for each configuration and were switched out based on battery and memory. Some locations may have multiple cameras listed, only one camera per location was used at a time. Check the file directory to identify which was used.
ITEM		Item type.
AZIMUTH	deg	Degree from platform center to item (declination = 0).
DIST	m	Distance (meters) from platform center to item.
UTM_X	m	X coordinate (NAD1983 UTM Zone 17N (ESPG = 26917)).
UTM_Y	m	Y coordinate (NAD1983 UTM Zone 17N (ESPG = 26917)).
HAG	m	Height Above Ground (meters).
NOTES		General Notes

Sonic Anemometer Data

Sonic anemometers (RM 81000V, R. M. Young, Inc., Traverse City, MI) were logged at 10-Hz to CR3000 and CR1000x dataloggers (Campbell Scientific, Inc., Logan, UT, USA). Sonic data can be found in "A multiscale study of the coupling between flow, fire and vegetation static field experiments: three-dimensional wind and temperature from 2022-2025".

Sonic Anemometer Sensor Specifications

The RM Young sonic specifications (Table 10) are to guide the user. All data collected were archived and it is the user's responsibility to determine which data are valid for their application.

Table 10. RM Young sonic anemometer 8100V specifications.

RM YOUNG ULTRASONIC ANEMOMETER 81000V	
Wind Speed	
Range:	0 to 40 m/s (0 to 90 mph)
Resolution:	0.01 m/s
Threshold:	0.01 m/s
Accuracy:	±1% rms ±0.05 m/s (0 to 30 m/s) ±3% rms (30 to 40 m/s)
Wind Direction	
Azimuth Range:	0.0 to 359.9 degrees
Elevation Range:	±60.0 degrees
Resolution:	0.1 degree
Accuracy:	±2° (1 to 30 m/s) ±5° (30 to 40 m/s)
Speed of Sound	
Range:	300 to 360 m/s
Resolution:	.01 m/s
Accuracy:	±0.1% rms ±0.05 m/s (0 to 30 m/s wind)
Sonic Temperature	
Range:	-50 to +50 ºC
Resolution:	0.01 ºC
Accuracy:	± 2 °C (0 to 30 m/s wind)

Sonic Anemometer Data Description

A single CSV per sonic per burn as described in Table 11 and a HTML visualization (Figure 36). Sonic data are separated by site location and burn.

- File name – Loc_Burn#_Sonic_@_*.ext
  - Where:
    - Loc – location of the study (TT = Tall-Timbers SRS = Savannah River Site)
    - # – burn number.
    - @ – tower sonic is mounted on.
    - * – sonic height above ground (feet).
    - ext – file extension (CSV or HTML).
    - Collection rate – 10 Hz.
- Missing data – TIMESTAMP and RECORD were added to align sensors, variables with missing timestamps were set to NaN.
- All data collected within the AT_START and AT_END times are included. Suspect data are noted with a DIAG code.
- DIAG = 0 – valid, all else suspect. Refer to manual for specific DIAG codes greater than 0.
- Values outside of sensor specs are included and identified in DIAG code. Use at own risk or remove.
- HTML graphs only include data with DIAG code = 0.

Table 11. "Sonic Anemometer Data" Table Description.

COLUMN	UNITS	DESCRIPTION
TIMESTAMP	Datetime	Datetime in yyyy-MM-dd hh:mm:ss.0, where yyyy = year, MM = month, dd = day, hh = hour, mm = minutes, and ss.0 = seconds. Local (EST) time adjusted for daylight savings. Note in Excel, set the specified format (yyyy-MM-dd hh:mm:ss.0) using the custom category to view the data correctly.
RECORD		Unique record identifier.
Ux	m/s	Sampled horizontal wind direction (x; east/west) in meters per second. Positive values of x (+) indicate wind from the east, negative values (-) indicate wind from the west.
Uy	m/s	Sampled horizontal wind direction (y; north/south) in meters per second. Positive values of y (+) indicate wind from the north, negative values (-) indicate wind from the south.
Uz	m/s	Sampled vertical wind direction (z) in meters per second. Positive values of z (+) indicate upward wind direction, negative values (-) indicate downward wind direction.
T	°C	Sampled sonic temperature, calculated from speed of sound measurements in degrees Celsius (±2 °C).
DIAG	Coded	Sonic diagnostic code (0 – valid, non-zero code – invalid measurement) as described in the manual.
NOTES	Text	Notes on sonic (Sonic Orientation)

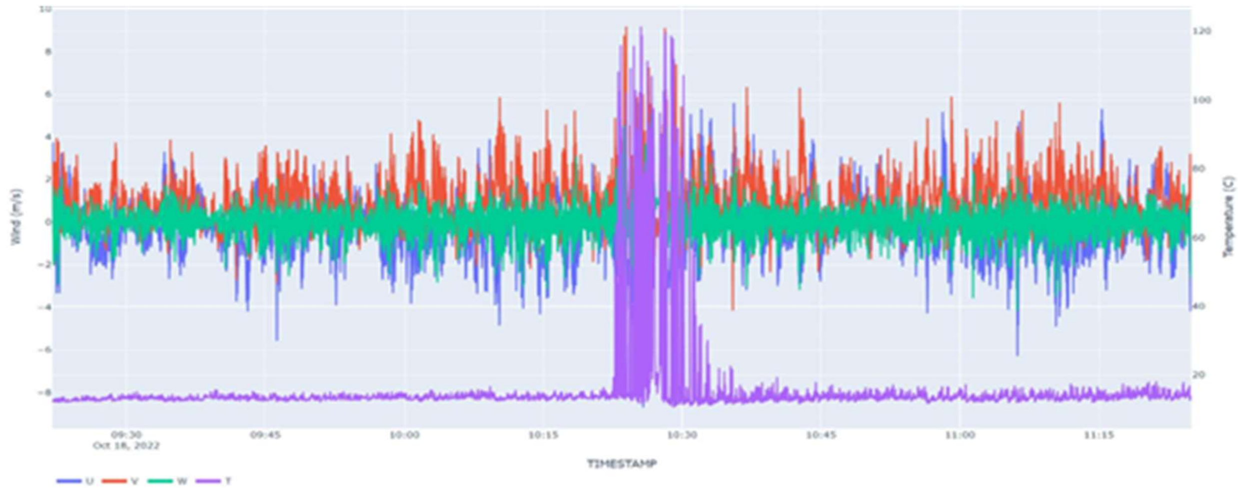


Figure 34. Example sonic data graph sonic data including Ux, Uy, Uz wind directions (m/s) and Temperature (deg C).

Sonic Anemometer Error

A single CSV per site that identifies the percentage of missing data (NaN) and data with suspect diagnostic codes (Table 12).

Table 12. "Sonic Anemometer Error" Table Description.

COLUMN	UNITS	DESCRIPTION
BURN		Burn – numeric value identifying an individual burn.
LOC		Sensor location (Tower) matching sonic file name.
HGT		Sensor height in feet to match sonic file name.
MISS_AT_START	s	Missing time (seconds) from the archive start time (defined in the Burn Summary section). Identifies missing data at the beginning of the file (e.g., the sensor was not on at archive start time).
MISS_BT_START	s	Missing time (seconds) from the burn start time (defined in the Burn Summary section). Identifies missing data at the time the fire is considered burning (e.g., the sensor was not on at burn start time).
MISS_AT_END	s	Missing time (seconds) from the end of data collection (defined in the Burn Summary section). Identifies missing data at the end of the file (e.g., the sensor cut out before the end archive time was reached).
Ux_ERROR	%	Horizontal wind direction (Ux) error (percent). The percent of NaN values during data collection.
Uy_ERROR	%	Horizontal wind direction (Uy) error (percent). The percent of NaN values during data collection.
Uz_ERROR	%	Vertical wind direction (UZ) error (percent). The percent of NaN values during data collection.
Ts_ERROR	%	Temperature error (percent) for each data column. The percent of the data with NAN values where data were collected.
DIAG_ERROR	%	Diagnostic error (percent). The percent of data where DIAG code was not equal to zero.

Thermocouple (TC) Data

Omega K-type thermocouples (KMTXL-IOM25G-150, Omega Engineering Inc., Norwalk, CT) were logged at 10-HZ to CR3000 and CR1000x dataloggers (Campbell Scientific, Inc., Logan, UT, USA). Thermocouple data were only collected at the Savannah River Site.

Thermocouple Sensor Specifications

Thermocouple sensor specifications (Table 13) are to guide the data user. All data collected has been archived and it is the user's responsibility to determine what data valid for their application.

Table 13. OMEGA KMTXL-IOM25G-150 K thermocouple specifications.

OMEGA KMTXL-IOM25G-150 K	
Calibration:	K
Temperature Range:	-200 to 1250 °C (-328 to 2282 °F)
Standard Limits of Error:	Greater of 2.2 °C or 75%
Special Limits:	Greater of 1.1 °C or 0.4%

Thermocouple Data Description

A single CSV per TC per vertical profile per burn as described in Table 14 and a HTML visualization (Figure 35). Thermocouple data are separated by site location and burn.

- File name – SRS_Burn#_TC_@_*.ext
  - Where:
    - # – burn number.
    - @ – tower sonic is mounted on.
    - * – sonic height above ground (feet).
    - file extension (CSV or HTML).
- Collection rate – 10 Hz.
- Missing data – TIMESTAMP and RECORD were added to align sensors, variables with missing timestamp were set to NaN.
- Missing data – TIMESTAMP and RECORD were added to align with other sensors, variables for missing timestamp were set to NaN.
- Simple visual diagnostic check was performed.
  - DIAG = 0 – valid, 1 – suspect.
  - Suspect values are included and identified in DIAG code. Use at own risk or remove.
- All data collected within the AT_START and AT_END times are included. Suspect data are noted in DIAG code.
- HTML graphs only include data with DIAG code = 0.

Table 14. "Thermocouple Data" Table Description.

COLUMN	**UNITS**	**DESCRIPTION**
TIMESTAMP	Datetime	Datetime in yyyy-MM-dd hh:mm:ss.0, where yyyy = year, MM = month, dd = day, hh = hour, mm = minutes, and ss.0 = seconds. Local (EST) time adjusted for daylight savings.
RECORD		Record number. Unique record identifier specific to the file it is in.
T**	°C	Thermocouple temperature (°C) at specified height (**) in feet.
T**_DIAG	Coded	T** diagnostic code (0 – valid, all else suspect) at specified height (**) in feet.

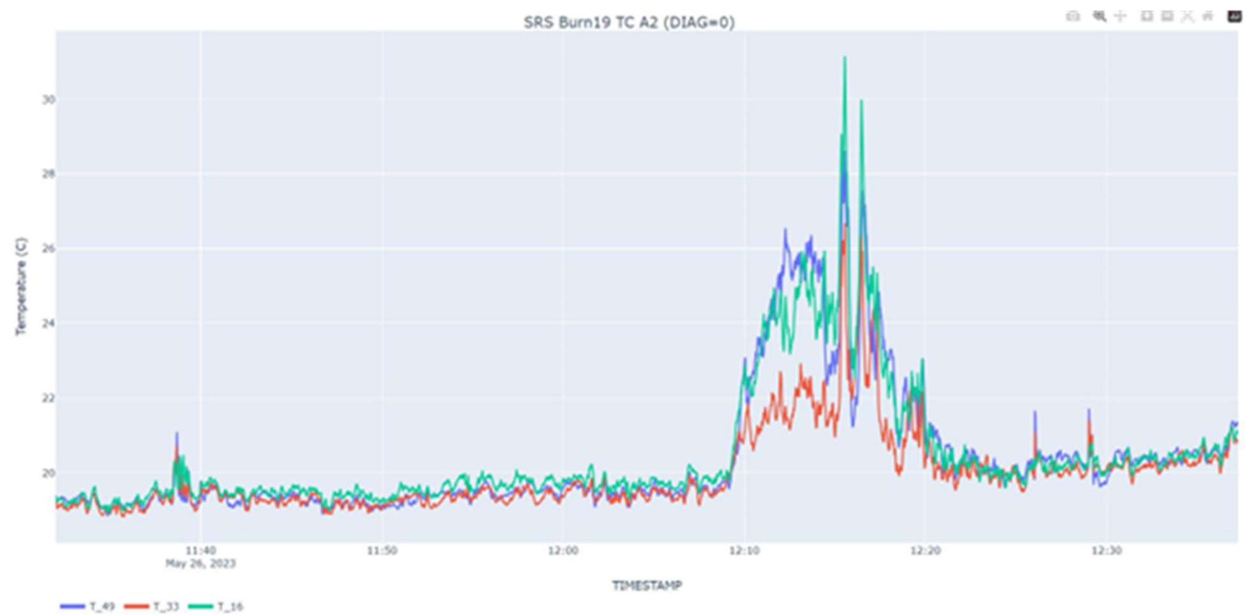


Figure 35. Example thermocouple temperature (deg C) vertical profile.

Thermocouple Error

CSV files were created to identify the percentage of missing data and data with suspect diagnostic codes including error file or all TC data collected and individual error files for tower group (A, B, C, D and E) as described in **Error! Reference source not found.**.

- File name
  - SRS_TC_Error.csv
  - SRS_TC_*_Error.csv
    - Where: * - is the tower group
- NaN indicates there is no data available for the specified HAG code.

Table 15. "Thermocouple Error" Table Description.

COLUMN	UNITS	DESCRIPTION
BURN		Burn – numeric value identifying an individual burn.
LOC		Sensor location.
MISS_AT_START	s	Missing time (seconds) from the archive start time (defined in the Burn Summary section). Identifies missing data at the beginning of the file (e.g., the sensor was not on at archive start time).
MISS_BT_START	s	Missing time (seconds) from the burn start time (defined in the Burn Summary section). Identifies missing data at the time the fire is considered burning (e.g., the sensor was not on at burn start time).
MISS_AT_END	s	Missing time (seconds) from the end of data collection (defined in the Burn Summary section). Identifies missing data at the end of the file (e.g., the sensor cut out before the end archive time was reached).
T**_ERROR	%	T** error (percent) at specified height above ground (**) in feet. The percent of NaN values during data collection. If no data were collected at the specified height, the value was set to NaN.
T**_DIAG_ERROR	%	T**_DIAG error (percent) at specified height above ground (**) in feet. The percent of data where DIAG code was not equal to zero. If no data were collected at the specified height, the value was set to NaN.

Video Data

Video data were collected using multiple recorders.

- GoPro (GoPro HERO8 Black)
- GoPro Max 360
- Panasonic (HC-WXF991)
- Vuze (Humaneyes VR Camera)

Camera Specifications

GoPro Hero8 Black Specifications

GoPro Hero8 specifications (

Table 16) are to guide the user. All data collected were archived and it is the user's responsibility to determine which data is valid for their application.

Table 16. GoPro Hero8 video specifications.

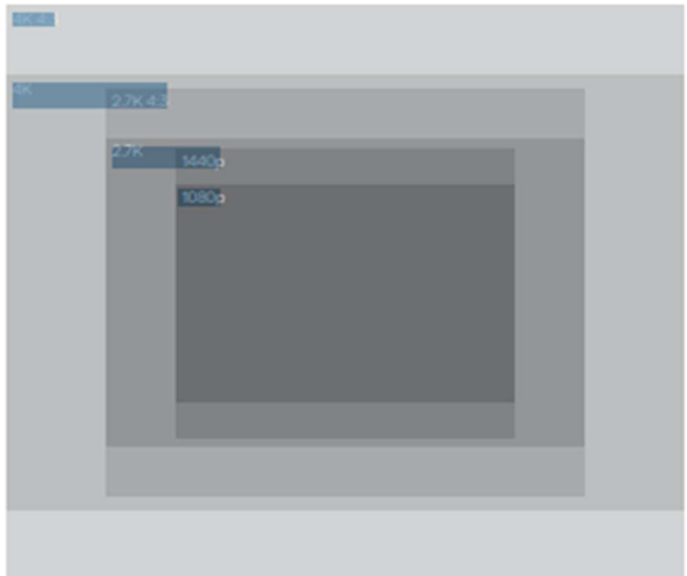
GOPRO HERO8 SPECIFICATIONS

VIDEO RESOLUTION (RES)

Video resolution refers to the number of horizontal lines used in each frame of video. A 1080p video is made up of 1080 horizontal lines, each with a width of 1920 pixels. A 4K video is made up of 3840 horizontal lines, each with a width of 2160 pixels. Since more lines equals greater resolution, 4K will deliver a more detailed picture than 1080p.

Video Resolution	***Description***
4K	Our highest resolution video. Great for tripod and fixed-position shots. Can be used to grab 8MP stills from your video.
4K 4:3	Our highest resolution video. The tall 4:3 aspect ratio captures more of the scene than 16:9 shots. Great for point-of-view footage.
2.7K	High resolution 16:9 video that provides stunning, cinema-quality results for professional productions.
2.7K 4:3	Great for high-resolution point-of-view body and gear-mounted shots with fluid slo-mo playback.
1440p	Tall 4:3 aspect ratio fits more into the frame than 1080p. Great for capturing fast action and point of view shots and for sharing to social media.
1080p	Standard HDTV resolution that's great for all shots and sharing to social media. High 240 fps and 120 fps options enable super slo-mo during editing.

This chart compares the frame size of each resolution:



PRO TIP: Be sure that your phone, computer, or TV can support the setting you choose, especially if you're using a high resolution and frame rate.

FRAMES PER SECOND (FPS)

Frames per second refers to the number of frames captured in each second of video. Higher fps values (60, 120, or 240) are better at capturing fast-action shots. You can also use high fps footage for slo-mo playback.

Resolution + FPS

Higher video resolutions capture more detail and clarity, but they're generally available at lower fps values. Lower video resolutions capture less detail and clarity, but they can be shot at higher fps values.
When choosing a resolution on the RES | FPS screen, all of the available frame rates for the resolution you selected are shown in white. Unavailable frame rates are in gray

ASPECT RATIO

Aspect ratio refers to the width and height of an image. HERO8 Black captures videos and photos in two aspect ratios.

- 4:3 — The tall 4:3 format captures more of the scene than the 16:9 widescreen format. It's great for selfies and point-of-view footage. The 4:3 resolutions are listed in the top row of the RES | FPS screen.
- 16:9 — This is the standard format used for HDTV and editing programs. The widescreen format is ideal for capturing dramatic cinematic footage. The 16:9 resolutions are listed below the 4:3 resolutions on the RES | FPS screen.

Heads Up: Black bars will appear on both sides of the screen when playing back 4:3 footage on an HDTV.

DIGITAL LENSES (VIDEO)

Digital lenses let you choose how much of the scene is captured by your camera. The different lenses also affect the zoom level and the fisheye effect in your shot. For Video mode, Super View captures the largest field of view while Narrow captures the smallest.

Digital Lens	***Description***
Super View (16mm)	Widest and tallest field of view, served up as 16:9 video.

Wide (16–34mm)	Wide field of view that captures as much as possible within the frame.
Linear (19–39mm)	Wide field of view without the fisheye effect of Super View and Wide.
Narrow (27mm)	Narrow field of view without the fisheye effect of Super View and Wide.

Heads Up: Only the lenses that are compatible with the resolution and frame rate you selected will be available.

HERO8 Black VIDEO SETTINGS

Here's a rundown of your camera's video resolutions along with available fps, lenses, and aspect ratio for each.

Video Resolution (RES)	***FPS (60Hz/ 50Hz)***	***Digital Lenses***	***Screen Resolution***	***Aspect Ratio***
4K	60/50	Wide, Linear	3840x2160	16:9
4K	30/25 24/24	Super View, Wide, Linear	3840x2160	16:9
4K 4:3	30/25 24/24	Wide, Linear	4096x3072	4:3
2.7K	120/100	Wide	2704x1520	16:9
2.7K	60/50 30/25 24/24	Super View, Wide, Linear, Narrow	2704x1520	16:9
2.7K 4:3	60/50	Wide	2704x2028	4:3
2.7K 4:3	30/25 24/24	Wide, Linear, Narrow	2704x2028	4:3
1440p	120/100	Wide	1920x1440	4:3
1440p	60/50 30/25 24/24	Wide, Linear, Narrow	1920x1440	4:3
1080p	240/200	Wide	1920x1080	16:9
1080p	120/100 60/50 30/25 24/24	Super View, Wide, Linear, Narrow	1920x1080	16:9

*60Hz (NTSC) and 50Hz (PAL) refer to the video format, which depends on your region. To learn more, see Anti-Flicker (page 87).

High Resolutions/High Frame Rates Shooting

High Resolutions/High Frame Rates Shooting high-resolution or high-fps video when it's warm out can cause your camera to heat up and use more power. Lack of airflow and connecting to the GoPro app can cause your camera to warm up even more, use even more power, and shorten recording time. If heat's a problem, try recording shorter videos. Also limit use of features that take a lot of power, such as the GoPro app. The GoPro Smart Remote (sold separately) can control your GoPro while using less energy.

HYPERSMOOTH 2.0 VIDEO STABILIZATION

Hyper Smooth 2.0 delivers ultra smooth professional footage by correcting for camera shake. It crops your videos while recording, which lets it buffer the footage to eliminate bumps and jitters. This makes it perfect for biking, skating, skiing, handheld shots, and more. HERO8 Black has four Hyper Smooth settings:

Setting	***Description***
Boost	Maximum video stabilization with tight cropping.
High	Stronger video stabilization with minimal cropping (Wide lens is cropped by 10%).
On	Stabilized video with minimal cropping (Wide lens is cropped by 10%).
Off	Records without video stabilization or cropping.

Heads Up: Hyper Smooth is unavailable when recording 4K60 video with the Linear digital lens. It will use standard video stabilization in its place.

GOPRO HERO8 SPECIFICATIONS

PRO TIP: You can smooth out your footage even more by using Touch Zoom to crop your shots before you start recording. This will give your camera an even bigger buffer to use when stabilizing your video.

AUTO LOW LIGHT

HERO8 Black can tell if there isn't enough light for your shot and will automatically lower the frame rate to improve video quality. This is especially helpful when you're moving in and out of low-light conditions. Auto Low Light is set to on by default. It works with all resolutions when shooting at 50 or 60 fps. Turning Off Auto Low Light 1. From the Video screen, tap the settings. 2. Tap Low Light.

LOOPING INTERVAL

You can set your GoPro to record 5 (default), 20, 60, or 120 minute loops. It can also be set to Max, which will record until your SD card is full before looping back to record over the start of the video

Panasonic Specifications

The Panasonic HC-WXF991 specifications (Table 17) are to guide the user. All data collected were archived and it is the user's responsibility to determine which data are valid for their application.

Table 17. Panasonic HC-WXF991 specifications.

PANASONIC SPECIFICATIONS	
SENSOR SECTION	
SENSOR FOR MAIN CAMERA	
Image Sensor	½.3- inch BSI MOS Sensor
Total Pixels	18.91 M
Effective Pixels [Motion Image]	4K: 8.29M [16:9], Full HD: 6.10M [16:9} (Level Shot Function off or Normal)
Effective Pixels [Still Image]	7.00M [3:2] 8.29M 16:9] 6.22M [4:3]
SENSOR FOR SUB CAMERA	
Image Sensor	¼-inch MOS Sensor
Total Pixels	5.27M
LENS SECTION	
LENS FOR MAIN CAMERA	
F Value	F1.8 (WIDE) / F3.6 (TELE)
Optical Zoom	20x
Focal Length	4.08 – 81.6 mm
35 mm Film Camera Equivalent [Motion Image (16:9)]	4k: 30.8 – 626 mm (Level Shot Function OFF), Full HD: 37.0 – 752 mm (Level Shot Function OFF or Normal)
35 mm Film Camera Equivalent [Still Image]	34.5 – 690.3 mm [3:2] 30.8 – 626 mm [16:9] 37.6 – 752.8 mm [4:3]
Filter Diameter	49 mm
Lens Brand	LEICA Dicomar Lens

PANASONIC SPECIFICATIONS	
LENS FOR SUB CAMERA	
F Value	F2.2
Focal Length	3.54 mm
35 mm Film Camera Equivalent [Motion Image]	37.2 mm (Motion picture recording mode)
CAMERA SECTION	
Standard Illumination	1400 Ix
Minimum Illumination	2 Ix (Scene Mode Low Light 1/30), 1 Ix (Night Mode (Color), 0 Ix (Night Mode (IR)
Focus	Auto / Manual
Zoom	
Intelligent Zoom Off	20x
Intelligent Zoom On	4K: 25x, Full HD: 40x
Digital Zoom	60x /1500x (maximum value of zoom magnification)
White Balance	Auto / White Set / Sunny / Cloudy / indoor1 / Indoor2
Shutter Speed	
Motion Image	Auto Slow Shutter ON: 1/30 – 1/8000 [(60p / 60i / 30p), 1/24m -1/8000 (24p)] Auto Slow Shutter OFF: [1/60 – 1/8000 (60p / 60i / 30p), 1/48 – 1/8000 (24p)]
Still Image	½ 1/2000
Iris	Auto / Manual
Image Stabilizer	HYBRID O.I.S.+ WITH Active Mode, O.I.S. Lock, Level shot Function (Strong mode: 2k only)
HDR Movie (Except 4K Mode)	Yes
Image Stabilizer	HYBRID O.I.S.+ WITH Active Mode, O.I.S. Lock, Level shot Function (Strong mode: 2k only)
HDR Movie (Except 4K Mode)	Yes
Creative Control (Except 4K Mode)	Miniature Effect, Silent Movie, 8mm Movie, Time Lapse Rec
RECORDING SECTION	
Recording Media	SD / SDHC / SDXC Memory Card
Recording Format	[AVCHD] AVCHD Progressive [iFrame / MP4] MP4
Compression Method	MPEG-4 AVC/H.264
Recording / Playback Mode	
AVCHD	1080/60pv (28Mbs / VBR), (1920 x 1080/60p) PH (24Mbps /VBR), (1920 x 1080/60i) HA (17Mbs / VBR), (1920 x 1080/60i) HG (13Mbs / VBR), (1920 x 1080/60i)

PANASONIC SPECIFICATIONS	
	HE (5Mbps / VBR), (1920 x 1080/60i)
MP4	2160p/30p (72M) (72Mbs / VBR), (3840 x 2160) 2160p/24p (72M) (72Mbs / VBR), (3840 x 2160) 1080p/60p (50M) (50Mbs / VBR), (1920 x 1080) 1080p/60p (28M) (28Mbs / VBR), (1920 x 1080) 1080p/24p (50M) (50Mbs / VBR), (1920 x 1080) 720p/30p (9M) (9Mbs / VBR), (1280 x 720)
iFrame	960 x 540/30p (28Mbps / VBR)
Actual Recordable Time with Supplied Battery	Approx. 45 min (4K MP4) Approx. 50 min (60p mode) Approx. 50 min (PH mode) Approx. 50 min (HA mode) Approx. 50 min (HG mode) Approx. 50 min (HE mode) Approx. 50 min (2160p/24p) Approx. 60 min (1080p/24p) Approx. 50 min (MP4 50M) Approx. 50 min (MP4 28M) Approx. 60 min (MP4 720p) Approx. 60 min (iFrame) *Twin Camera OFF
Thumbnail Display	20 thumbnails/page, 9 thumbnails/page, 1 thumbnails/page,
Audio Recording System	AVCHD: Dolby Digital (5.1ch / 2ch) iFrame, MP4: AAC (2ch)
Microphone	5.1ch Surround, Zoom, Focus and Stereo Microphone
Speaker	Dynamic type

GoPro Max 360

GoPro Max 360 specifications (Table 188) are to guide the user. All data collected were archived and it is the user's responsibility to determine which data are valid for their application.

Table 18. GoPro Max 360 video specifications.

GOPRO MAX SPECFICATIONS

RESOLUTION (VIDEO, TIMEWARP, TIME LAPSE)

Video resolution refers to the number of horizontal lines used in each frame of video. MAX features a choice of two resolutions in both HERO mode and 360 modes.

HERO Mode Resolution	***Description***
1080p	The standard resolution and aspect ratio (16:9) for HDTV. Use 1080p if you want full-screen playback on your TV or phone.
1440p	The tall 4:3 aspect ratio fits more into the frame than 1080p. Great for selfies, point-of-view shots, and sharing to social media. Heads Up: Black bars will appear on both sides of the screen when playing back 1440p footage on an HDTV

GOPRO MAX SPECFICATIONS

360 Mode Resolution	***Description***
6K Source, 5.6K Stitched	High resolution 360 video that captures everything around you in stunning detail. Let's you create amazing 1080p30 traditional videos using Reframe in the GoPro app.
3K Source/Stitched	Records video at 60 frames per second (fps) that can be slowed down to 2x normal speed during playback. Let's you create 720p60 traditional videos using Reframe in the GoPro app.

PRO TIP: Be sure that your phone, computer, or TV can support 5.6K video before recording.

FRAMES PER SECOND (VIDEO)

Frames per second (fps) refers to the number of frames captured in each second of video. A higher fps value (60 fps) is better at capturing fast action shots. You can also use high fps footage for slow-motion playback. High Resolutions/High Frame Rates Shooting high-resolution or high-fps video when it's warm out can cause your camera to heat up and use more power. Lack of airflow and connecting to the GoPro app can cause your camera to warm up even more, use even more power, and shorten recording time. If heat's a problem, try recording shorter videos. Also limit use of features that take a lot of power, like the GoPro app. Your camera will tell you if it needs to shut down and cool off. To learn more, see Important Messages (page 75

DIGITAL LENSES (HERO MODE–VIDEO)

Digital lenses let you choose how much of the scene is captured by your camera. The different lenses also affect the zoom level and the fisheye effect in your shot. For Video mode, Max Super View captures the largest field of view while Narrow captures the smallest.

Setting	***Description***
Max Super View (13mm)	Widest, most immersive field of view ever on a GoPro.
Wide (16mm)	Wide field of view with less fisheye effect than Max Super View.
Linear (19mm)	Wide field of view without the fisheye effect.
Narrow (27mm)	Narrow field of view without the fisheye effect.

MAX HYPERSMOOTH VIDEO STABILIZATION (HERO MODE)

Max Hyper Smooth gives you unbreakable stabilization by using a 180° field of view as the ultimate video buffer. It lets your camera eliminate almost all bumps and shakes while you're recording. This makes it perfect for biking, skating, handheld shots, and more.

PRO TIP: Watch your 360 footage on the GoPro app to see your Video and Time Warp shots with full stabilization.

HORIZON LOCK (HERO MODE)

Horizon Lock keeps your footage smooth and level even if your camera gets flipped upside down while recording. With Horizon Lock on, your footage and the live view on the touch screen will be locked into the orientation your camera was in when you pressed the Shutter button. If your camera was in a portrait orientation, your footage will stay in a level portrait orientation no matter how much your camera rotates. With Horizon Lock off, your footage and the live view on the touch screen will roll with the rotation of your camera. PRO TIP: To capture all the twists of barrel rolls, banked turns, and other activities, make sure that Horizon Lock is off when you're shooting extreme POV action.

Vuze - 3D 360 VR Camera

Humaneyes 3D 360 VR Camera – specifications (Table 199) are to guide the user. All data collected were archived and it is the user's responsibility to determine which data are valid for their application.

Table 19. Vuze (3D 360 VR Camera) specifications.

VUZE SPECIFICATIONS	
Optics	
Sensors	8 Sony FHD image sensors imx408
Media FOV	360ºx180º (Full Spherical)
ISO	100-1600
Operation	
Processors	Two Ambarella A9 video processors
Controls	One button operation, remote-control mobile application
Indications	Colorful LED indications
IP rating	IP64 (Dust tight, splash proof)
Operating temperature	0 - 40ºC
Operating Humidity	Under 95% RH
Battery type	Li-ion 3,700 mAh (3.8V)
Battery life	About 2 hours operation
Motion tracking	Inertial measurement units (IMU): Accelerometer, Gyroscope, Compass
Wi-Fi	IEEE 802.11b/g/n 2.4 GHZ
USB port	USB 2 (for charging and data connection)
Memory	Replaceable Micro SD card, compatible with UHS 1 and above.
Video/Image	
Spherical Resolution	4K (per eye)
Frame rate	30 fps Bit rate 15 MB/sec or 10MB/sec (configurable by app)
360 Video Format	mp4
Video Compression	H.264
360 Photo Format	JPEG
Audio	
Microphones	Four MEMS 48Hz microphones
Format	Four ACC audio tracks
General	
Camera weight	~ 450 g
Camera dimensions	~ 120x120x30 mm
Package dimensions	240x160x60 mm
Camera colors	Black, Yellow, Red, Blue
Camera model	HETVZ-1-xxx
Included Accessories	Hardshell case, Mini-handle, Mini glasses, USB cable, Power adaptor (model KSA29B0500200D5), Lens cleaning cloth

Video Data Description

Video files are in MP4 or 360 format depending on the camera used. GoPro and Panasonic files are broken into ~2-GB chapters to reduce file size. GoPro and Panasonic videos include a single TXT file per video of metadata. Files are broken out by site location, camera and burn. Each camera burn directory (not including Vuze) has a summary file describing basing information about the video in the directory described in Table 20.

- File name – Loc_Burn#_@@_*.ext
    - Where:
        - # – burn number.
        - @@ – camera type and number
            - B – GoPro Hero8 Black
            - M – GoPro Max 360
            - P – Panasonic
            - V - Vuze
        - * – chapter
        - ext – mp4 or 360 (GoPro Max 360 only)

Table 20. Video directory summary.

COLUMN	UNITS	DESCRIPTION
LOC		Location- text identifying location of burn (TT=Tall Timbers, SRS= Savannah River Site
SLOC		Sub Location – text identifying location within the site location. SLOC will vary from the camera name only if mounted by itself otherwise it will be the name of the item it is mounted on.
BURN		Burn – numeric value identifying an individual burn.
CAMERA		Camera– text identifying an individual camera.
CHAPTER		Chapter- numeric value identifying chapter
SERIAL_NUMBER		Serial Number – a unique string of letters and numbers Identifying camera
FILE_NAME		File Name - the video file name the metadata represents.
FTYP		File Type- the file type the meta data represents
DATE	Date	Burn date (mm-dd-yyyy). The burn date was noted in field.
BURN_START	Time	Burn start time (hh:mm:ss) in local (EST) time adjusted for daylight savings. The burn start time was noted in field.
BURN_END	Time	Burn end time (hh:mm:ss) in local (EST) time adjusted for daylight savings. The burn end time was noted in field.
F_DUR	Sec	Fire duration – the seconds the fire lasted based on burn start and burn end.
V_START	Time	video start time (hh:mm:ss) in local (EST) time adjusted for daylight savings.
V_END	Time	Video end time (hh:mm:ss) in local (EST) time adjusted for daylight savings.
FPS		Frames per second.
V_DUR	Sec	Video duration (seconds)
FCNT		Frame count.

Terrestrial Laser Scan (TLS) Data

A Leica BLK360 Gen 1 terrestrial laser scanner was used to create 3D point clouds of vegetation and instrument locations (configurations) to map the relationship of vegetation to fine-scale patterns of vertical and horizontal flow, turbulence above flame fronts, sensible (convective) heat fluxes, and momentum fluxes.

- Tall Timbers
    - 2022 - 4 scans were taken to represent both vegetation and tower configurations.

- Savannah River Site
    - 2023 – 29 scans were taken pre instruments to create vegetation configuration 1.
    - 2024 – 57 scans were taken to create vegetation configuration 2.
    - 2025 – 136 scans were taken to create vegetation configuration 3.
    - Additional scans were taken each time there was a new tower or video configuration.

BLK 360 Gen 1 Terrestrial Laser Specifications

The BLK 360 Terrestrial Laser specifications (Table 21) are to guide the user. All data collected were archived and it is the user's responsibility to determine which data are valid for their application.

- Scanner Settings:
    - Scan Density – Medium
    - Image – HDR
    - IR EV – 0
    - IR Emissivity – 0.95
    - IR Gain – High

Table 21. BLK 360 Gen 1 Specification.

LEICA BLK360 – IMAGING LASER SCANNER	
Imaging scanner	3D scanner with integrated high-speed HDR spherical imaging system and Visual Inertial System (VIS) for real-time pre-registration
DESIGN & PHYSICAL	
Housing	Black anodized aluminum
Dimensions	Height: 155 mm Diameter: 80 mm
Weight	0.75 kg (0.85 kg incl. battery)
Transport cover	GVP739 transportation cover
Mounting mechanism	Button-press quick release
OPERATION	
Standalone operation	One-button operation
Mobile devices	BLK Live app for iOS and Android smartphones
	Leica Cyclone FIELD 360 app for iOS and Android tablet computers and smartphones
Wireless communication	Integrated wireless LAN (802.11 b/g/n)
GENERAL	
Internal memory	Storage for up to 1500 setups
Instrument orientation	Upright and upside down
POWER	
Battery type	Internal, rechargeable Li-Ion battery (Leica GEB825)
Capacity	Up to 70 setups per battery
SCANNING	
Distance measurement system	High speed time of flight enhanced by Waveform Digitizing (WFD) technology
Laser class	1 (in accordance with IEC 60825-1:2014)
Wavelength	830 nm
Field-of-view	360° (horizontal) / 270° (vertical)
Range*	Minimum 0.5 m - up to 45 m
Point measurement rate	Up to 680,000 pts/sec
Measurement modes	4 user selectable resolution settings (6/12/25/50 mm @ 10 m)
IMAGING	

LEICA BLK360 – IMAGING LASER SCANNER	
Camera system	13 Mpixel 4-camera system captures 104 Mpx raw data for calibrated 360° x 270° spherical image
Speed	< 8 sec. for full spherical LDR image in any light conditions < 20 sec. for full spherical 5-brackets HDR image in any light conditions
Image modes	• Auto-exposed LDR • 5-brackets HDR • Off - scanning only
PERFORMANCE	
Data acquisition	< 20 sec. for complete full dome scan and spherical LDR image at 50 mm @ 10 m resolution with automatic tilt measurements
3D point accuracy*	4 mm @ 10 m
Real-time pre-registration	Automatic point cloud alignment based on real-time tracking of scanner movement between setups based on Visual Inertial System (VIS) by video-enhanced inertial measurement unit
ENVIRONMENTAL	
Robustness	Designed for indoor and outdoor use
Operating temperature	0° C to + 40° C
Dust/Humidity	Solid particle/liquid ingress protection IP54 (IEC 60529)
DATA PROCESSING	
Data transfer	Wireless and USB 3.0
Desktop software	Leica Cyclone REGISTER 360 and Cyclone REGISTER 360 (BLK Edition)
Cloud software	HxDR Digital Reality: cloud-based digital reality platform

Terrestrial Laser Scan Data Description

TLS Raw

The raw TLS were converted from the BLK proprietary format to LAZ using Leica Cyclone Register 360 for further analysis. Multiple LAZ files per location were collected based on canopy manipulation, tower position and video Locations. Scans are separated by location and year collected.

- File name – Scanner_Loc#_Date.laz
  - Where:
    - Scanner – Make and model (BLK360-G1 = BLK360 generation 1).
    - Loc – Location (TT = Tall-Timbers SRS = Savannah River Site).
    - # – scan number uniquely identifying a scan collected during a collection cycle.
    - Date – year month day (YYYYMMDD).

TLS Products

Scans from each setup were registered manually in CloudCompare v. 2.13 (GPL software). 2024. Retrieved from http://www.cloudcompare.org/. Instrumentation and burn platform points were segmented away from the combined point cloud in each of the alternate setups and set aside.

Synoptic registered point clouds were then tiled using the catalog_retile function in lidR in the R statistical computing environment. Individual point clouds were tiled to the 20-m scale with 5-m buffering. These tiles were then processed using the srsseg.R script in which the ground was classified, the point clouds were normalized, and voxelized to 2-cm scale and stem finding algorithms using the TreeLS [3] package were run to classify stem points. Utilizing the fastPointMetrics functionality in TreeLS, thresholds of verticality, and linearity were used to classify branch and leaf/surface vegetation.

Once all points are classified as ground, stem, branch or fine vegetation, bulk density values are assigned to each point. The synoptic forest point clouds are combined in CloudCompare and linked with appropriate instrumentation point clouds. The point clouds are then shifted to a standard 10-cm grid and output as a CSV file for input into fire models. The grid voxelization scripts are also included in the srsseg.R script.

Each point cloud was shifted and rotated to NAD 1983 UTM Zone 17N coordinates. UTM coordinates were calculated by applying a shift from the local coordinate platform center to the platform center GPS coordinate and then rotated to match each Master Configuration Layout UTM file using CloudCompare transformation tool.

A single CSV of 10-cm grid voxel data was created for each master configuration (M_CONFIG) in NAD 1983 UTM Zone 17N coordinates (Table 22).

- File name – Loc_M_Config#_TLS_Voxel.csv
  - Where:
    - Loc – location of the study (TT = Tall Timbers SRS = Savannah River Site).
    - # – master configuration number.

Table 22. "Terrestrial laser scan 10-cm voxel data" Table Description.

COLUMN	UNITS	DESCRIPTION
ID		Grid cell ID.
X	m	X coordinate (NAD1983 UTM Zone 17N (ESPG = 26917)).
Y	m	Y coordinate (NAD1983 UTM Zone 17N (ESPG = 26917)).
Z	m	Height Above Ground (meters).
BulkDensity	Kg/m3	Grid cell bulk density (kilograms/cubic meter).

Literature Citations

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[3] De Conto, T., Olofsson, Kenneth, Gorgens, E.B., Rodriguez, L.C.E. (2017). Performance of stem denoising and stem modelling algorithms on single tree point clouds from terrestrial laser scanning. Computers and Electronics in Agriculture, 143:165-176. doi.org/10.1016/j.compag.2017.10.019