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Meteorological Monitoring Program at the Savannah River Site

December 2020

SRNL-STI-2020-00197, Revision 0

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Printed in the United States of America

Prepared for
U.S. Department of Energy

SRNL-TR-2020-00197
Revision 0

Keywords: *ATG, Meteorological, Weather*

Retention: *Permanent*

Meteorological Monitoring Program

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December 2020

Prepared for the U.S. Department of Energy under contract number DE-AC09-08SR22470.

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ACKNOWLEDGEMENTS

The authors would like to thank the following people for making this document possible. Chuck Hunter who started the preparation of the document and much of the editing, Steven Ashe for much of the photography, Evaleigh Bell for general document formatting and figure preparations, John Hamilton and Norman Smith for detailed working of instrumentation, calibration and general knowledge, Cory Herbst, Andrew Kail, and David Skeen for the inner workings of the IT side of the network and datalogger programing.

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LIST OF ABBREVIATIONS

ABL	Atmospheric Boundary Layer
ASOS	Automated Surface Observation System
ATG	Atmospheric Technologies Group
BCF	Backup Computing Facility
CCF	Central Computing Facility
DOE	Department of Energy
DSA	Design Safety Analysis
EIS	Environmental Impact Statements
EPHA	Emergency Preparedness Hazards Assessments
ETS	Environmental Technology Section
GUI	Graphical User Interface
HPDFS	High Performance Computing File Server
LIDAR	Light Detection And Ranging
MAA	Mutual Aid Agreement
MATS	Mesoscale Atmospheric Transport Studies
MSL	Mean Sea Level
MTI	Multispectral Thermal Imager
NIST	National Institute for Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
PDU	Power Data Unit
QA	Quality Assurance
QC	Quality Control
RAM	Random-Access Memory
RH	Relative Humidity
RPM	Revolutions Per Minute
RTD	Resistance Temperature Detectors
SCT	South Carolina Tower
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SRSL	Savannah River Standards Lab
SRSOC	SRS Operations Center
STABLE	STAble Boundary Layer Experiment
WDFM	WINDS Data Flow Monitor
WINDs	Weather Information and Display System

Chapter 1 - Overview

Introduction

The purpose of this report is to provide a comprehensive, detailed overview of the meteorological monitoring program at the Savannah River Site (SRS) near Aiken, South Carolina (Figure 1-1). The information which has been compiled for the report is the most current and accurate documentation available. This report is an update to a previous report by Parker and Addis (1993).

Historical Perspective

To better understand the current meteorological monitoring program, a description of the program's rationale and historical development is provided in the following sections. Most of the information prior to 1980 was provided by Todd V. Crawford who pioneered the first comprehensive meteorological monitoring program at the SRS.

Rationale

The meteorological monitoring program at the SRS is owned and managed by the Atmospheric Technologies Group (ATG) which is part of the Savannah River National Laboratory's (SRNL) National Security Directorate. A primary function of this program is to provide accurate, real-time meteorological data as input for calculating the transport and diffusion of routine or unplanned releases of airborne contaminates. For this reason, this program is an integral part of an emergency response capability at the SRS called the Weather Information and Display (WIND) System. There are, however, many other uses for meteorological data at the SRS. Data archived over long periods is used to characterize local climate. Climatological data bases characterizing transport and dispersion, temperature, and precipitation for example, are used to perform chronic dosimetric and air quality calculations for routine emissions, to support engineering analyses for facility design and operation, and to prepare the site environmental characterizations required for Design Safety Analysis Reports (DSA), Environmental Impact Statements (EIS) and Emergency Preparedness Hazards Assessments (EPHA). The current meteorological monitoring program meets or exceeds guidance criteria provided in the American National Standard for Determining Meteorological Information at Nuclear Facilities, ANSI/ANS - 3.11 (ANS, 2015) and the DOE Handbook HDBK-1216-2015, Environmental Radiological Effluent Monitoring and Environmental Surveillance (DOE, 2015).

To accomplish the multiple goals of the SRS meteorological monitoring program, a network of observation towers has been erected onsite. A 61-m tower is located in each of the following operations areas of the Site: A, C, D, F, H, K, L, and P. The siting of the Area towers and placement of instrumentation was chosen using the following industry standard requirements:

- Located within 0.5 – 1.0 miles of the primary production facility in the area
- Situated above relatively undisturbed forest canopy, as the SRS landscape is primarily covered by forest
- Tower base at similar mean sea level elevation to the nearby production facility
- Ensure representative characterization of dispersion for releases from the primary production facility stack.

Although many of the major production facilities have been shut down, the 61-m measurements continue to provide representative data for characterizing the dispersion above the generally forested landscape for any SRS release transported to the Site boundary and beyond.

To provide data for ATG research programs and long-term climate characterizations, another 61-m tower (Central Climatology), located near N-area, was erected in a clearing so vertical profiles of wind, temperature, and atmospheric moisture could be measured. Instrumentation is set up at 4-, 18-, 36- and 61-m above ground. In addition, measurements of solar radiation, precipitation, evaporation, soil temperature, barometric pressure are made near the tower at ground level.

Additional measurements at SRS include a cloud height sensor (ceilometer) in B-area, Windcube at Central Climatology and visibility sensors B, C, H and L-Area towers. An instrument shelter in A-area provides additional measurements of temperature, relative humidity and rainfall, and a network of tipping bucket rain gauges across SRS also provides daily rainfall measurements.

Meteorological instrumentation mounted on the WJBF/WAGT-TV transmission tower near Beech Island, South Carolina provides wind, temperature, and humidity data at three different levels up to 330 m. ATG's Forest Flux Tower located north of the ATTA Range near Highway 278 provides additional data for ATG research with high frequency measurements of wind, turbulence, temperature, relative humidity and carbon dioxide (CO_2) collected from four levels within the forest canopy.

In 1996, a mutual aid agreement was set up between SRS and Augusta/Richmond County, GA which resulted in the establishment of 4 meteorological towers in the county near hazardous materials corridors. These data were archived in the database and made available in real time for use by emergency responders. Data collection from these sites was terminated when the initiative ended in 2018.

History of Savannah River Site Instrumentation

Meteorological instrumentation used at the SRS has varied considerably throughout the history of the program (Figure 1-2). Many of the early climatological surveys (Falk, 1953) were conducted over short periods with instruments that are now considered obsolete. During the 1950s, primary meteorological information was provided to the SRS by the Augusta office of the Weather Bureau (now the National Weather Service in Columbia, SC). Eventually, anemometers and wind vanes were installed on short towers on top of each major production facility. Strip charts were used to record data, and bandwidth (standard deviations of wind azimuth) estimates were used in conjunction with nomographs to make downwind dose estimates. This system remained in place from the 1950s through the early 1970s.

In the mid-1960s, the first instruments were installed on the WJBF-TV tower. In 1966, a study was performed to determine the meteorological monitoring required for a proposed 850-ft reactor stack (Cooper and Rusche, 1968). For this study, instruments were installed on the tower up to 1,200 ft. Additional instrumentation was installed on the 110-ft Casells Fire Tower. Data acquisition was accomplished through the use of paper "punch tape".

In the early 1970's, the need for a much more comprehensive meteorological monitoring system became evident. New national environmental laws to manage air pollution were becoming increasingly stringent. Specifically, the TV tower data at SRS demonstrated the need for more accurate measurements of turbulence, as well as measurements more representative of production facility stack heights. In addition, due to the common occurrence of light winds, the need for more sensitive meteorological sensors

was recognized. As a result of these emerging requirements, a comprehensive SRS meteorological monitoring program was created in 1973. The new system incorporated a totally automated data acquisition system, data archival and storage, and "menu" access to atmospheric models used for emergency response. Sixty-one-meter towers were erected at A, C, D, F, H, K and P areas (L-area was erected later). Each of these 'Area' towers was placed in the forest within one-half mile of the primary operational facility to obtain representative turbulence measurements above the surrounding, predominantly forested site. State-of-the-art turbulence grade instruments for that time were installed on each tower. Data acquisition was accomplished by running signal cables to the nearest heated building where phone line access was available. Signals were then transmitted via phone line to a central computer in the Savannah River Laboratory in 773-12A (now the Atmospheric Technology Center in 773-A). This automated system was the beginning (Kern, 1975) of the Weather INformation and Display (WIND) System that continues in use today for emergency response consequence assessment.

Also in 1973, the monitoring system at the TV tower was modified with improved meteorological instruments and computerized digitization equipment. In November 1983, the TV tower was rewired, and uniform instrumentation was installed at all of the measurement levels. A 10 m tower which had been erected near the TV tower in the early 1970's was replaced with an 18-m tower. All levels were instrumented with a bivane, cup anemometer, and temperature probe except at two meters where only a temperature probe was present. At the time, data was collected at 18-, 36-, 91-, 137-, 182-, 243- and 304-m.

All of the Area towers underwent modification during the 1980s. In 1985, a 61-m tower was added at L-area to coincide with the restart of the L Reactor and the Central Climatology facility was established near N-Area for collecting data to support local climatological and special measurement studies. The 61-m tower at Central Climatology was erected in an open field and instrumented at 4-, 18-, 36- and 61 m with anemometers, bivanes and temperature probes to obtain profiles of boundary layer structure (Note: the temperature probe for the lowest measurement level is at 2-m). Instrumentation for measuring solar radiation, evaporation, precipitation, soil temperature and atmospheric pressure were installed nearby at ground level.

In 1987, new and more stable Area towers were installed to replace the original towers which had suffered degradation (except H and L which had already been upgraded). Lightning protection and grounding also were added to the towers; as a result, post-1987 data collection experienced far fewer outages due to lightning induced surges. Central Climatology received this same upgrade in 1991. Major improvements to Area tower data acquisition and archival was implemented in 1998 as part of a general re-engineering of the WIND System. New, more capable data loggers were installed which for the first time performed local processing of the instantaneous measurements collected over the standard 15-minute reporting period. The data loggers also had the capability to store several days of data locally for later retrieval in case of a temporary loss of communications. In addition, the DEC VAX 8550 minicomputer that had been used for data archival was replaced with a Unix workstation and all incoming data were stored in a relational database. Also, in 1998, new technology was developed in which the Area tower anchor rods could be assessed for corrosion using ultrasonic testing. This technique was later patented and commercialized as SoundAnchor™.

A mutual aid agreement (MAA) was established in 1995 to provide technical assistance for the emergency management agencies of five counties surrounding SRS – Aiken, Barnwell, and Allendale counties in South Carolina and Richmond and Columbia counties in Georgia. The MAA with Richmond County led to establishing meteorological monitoring stations in three industrial clusters. All equipment was installed and maintained by ATG and configured as part of the WIND System for real-time data collection and dissemination. This program expired and data collection from all of the Richmond county sites ceased in 2018.

Data collection from the TV tower was terminated in 1998 and all instrumentation was removed when the tower was replaced by a new tower equipped with high definition transmitters. A project to re-establish data collection from the new tower was later approved and a new monitoring system with equipment at three levels (33, 68, and 328m) became operational in 2004. Each level was equipped with state of the science equipment, including 10hz measurements of wind and temperature using sonic anemometers and fast-response measurements of water vapor and carbon dioxide. In 2008, ATG partnered with NOAA's Global Monitoring Division to establish the TV tower as one of eight tall towers nationwide contributing measurements to NOAA's Carbon Tracker system. Sampling and analysis at the tower provide real-time data on CO_2 and CO concentration at the three levels of the tower, as well as periodic collection of air samples that are shipped to NOAA for analysis of more than 50 trace greenhouse gases.

As part of Office of Science funded research, ATG established a fully instrumented carbon flux monitoring site within a forested region of SRS in 2009. This 110-foot scaffold tower is equipped at four levels with sonic anemometers, and fast-response water vapor and CO_2 sensors. Data from this tower support ATG research and are reported to an international greenhouse gas database known as the Aiken Ameriflux tower.

To support SRS security force aviation activities, ATG partnered with the SRS security contractor to establish cloud base measurements from a ceilometer located at a site near the contractor's helipad in B-Area. This project also included the addition of visibility sensors on the C, H, and K area towers

A complete replacement of instrumentation and data acquisition systems for the Area Towers occurred over the years 2012-14. R. M. Young sonic anemometers replaced the bivanes and cup anemometers and R. M. Young fast-response temperature and relative humidity probes replaced the existing temperature and dew point sensors. New, more powerful data loggers were installed, and redundant network-based communication of data was established to transmit data simultaneously to a primary data base server in the A-Area computer facility and to a secondary data base server in the backup computer facility in C Area. To enhance cyber security, sub-networks to the primary SRS network infrastructure were established for the Area towers to prohibit unauthorized access to these networked data acquisition systems. In addition, the data base was re-configured to archive the 10hz data from the sonic anemometers as well as several boundary layer parameters derived from the flux measurements.

Today, the eight Area towers, Central Climatology, the TV tower, the Forest Flux tower and the ceilometer site, comprise the core network of facilities comprising this comprehensive meteorological monitoring program (see Figure 1-3). The redundant design of, and operational protocols used for the current system configuration (i.e., instruments, hardware and software for data acquisition, transmission,

and archival, and system maintenance) provides unprecedented resiliency and reliability of data collection. Real-time availability of quality data for use in emergency response is well in excess of 90%.

In addition to the standard instrumentation and data collection systems summarized above, other instruments are available for use in intensive field studies. Several tracer gas experiments have been organized and executed by ATG to evaluate and improve atmospheric dispersion models. The Mesoscale Atmospheric Transport Studies (MATS) (Weber, 1992) utilized fixed and mobile atmospheric samplers as well as rawinsondes and airsondes for detailed boundary layer measurements. In 1988, the Project STAble Boundary Layer Experiments (STABLE) (Weber and Kurzeja, 1991) was conducted to investigate the behavior of traces gas releases during nighttime conditions. In addition to the data collected during MATS, the STABLE experiment utilized a tethersonde and two Sodars. A second series of nighttime releases was conducted in 2009 through DOE Office of Science funding. A variety of tracer species was released from locations at varying distances upwind of the TV tower. The data was subsequently examined to characterize turbulence processes that drive the vertical flux of airborne contaminants (Kurzeja, 2020).

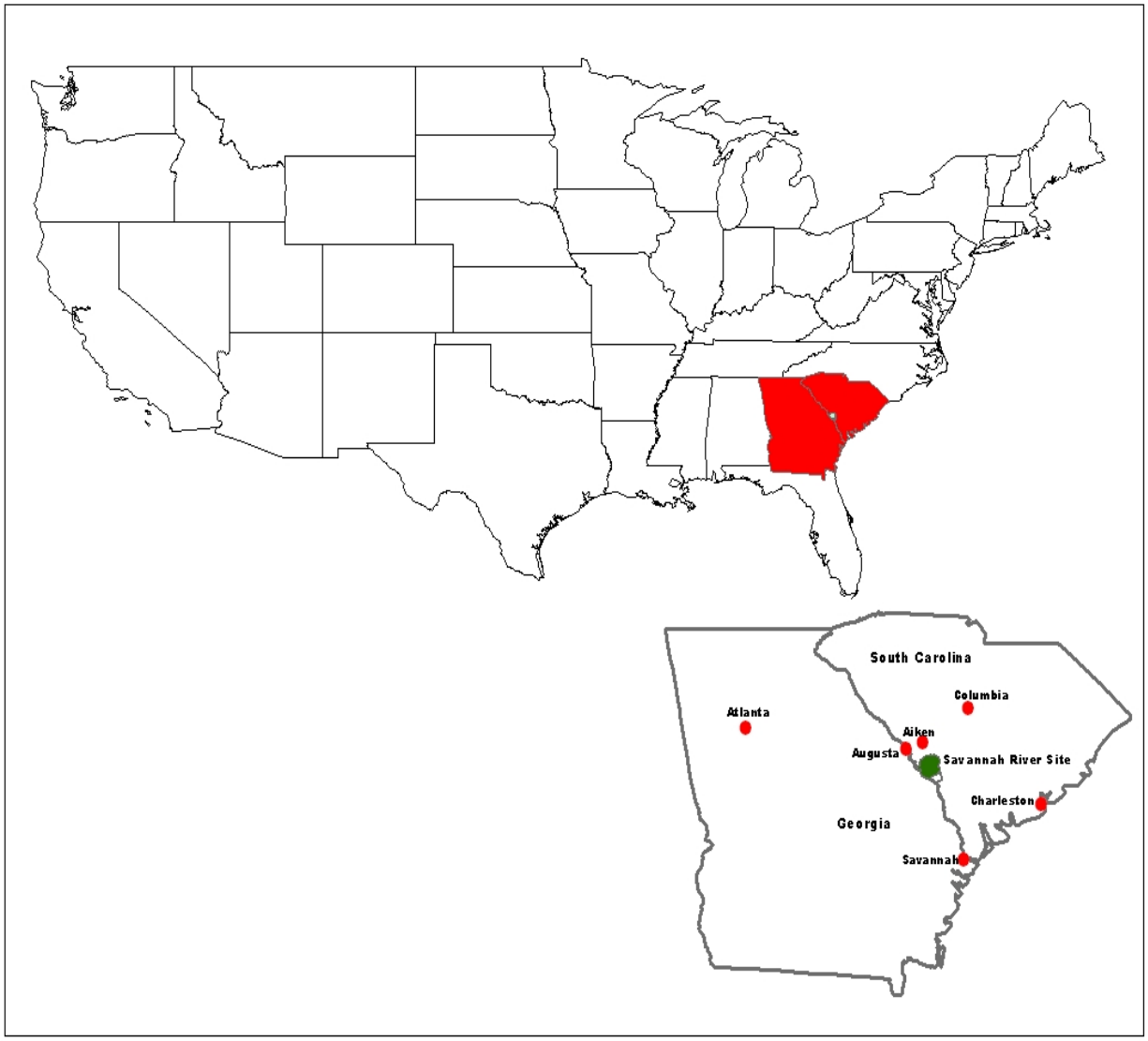
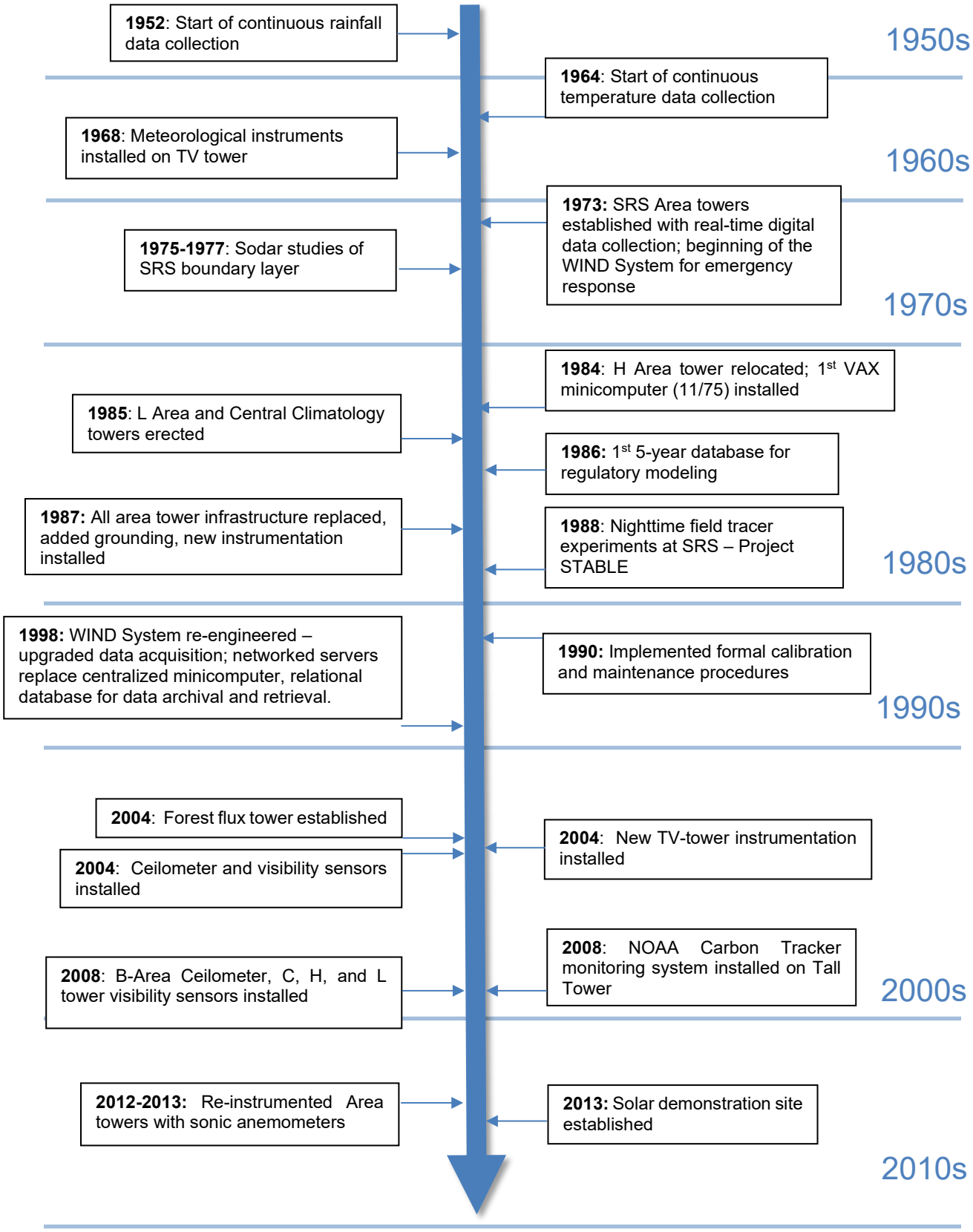


Figure 1-1. Location of the Savannah River Site with Surrounding Cities

Figure 1-2. A summary of major milestones in the history of meteorological monitoring at SRS



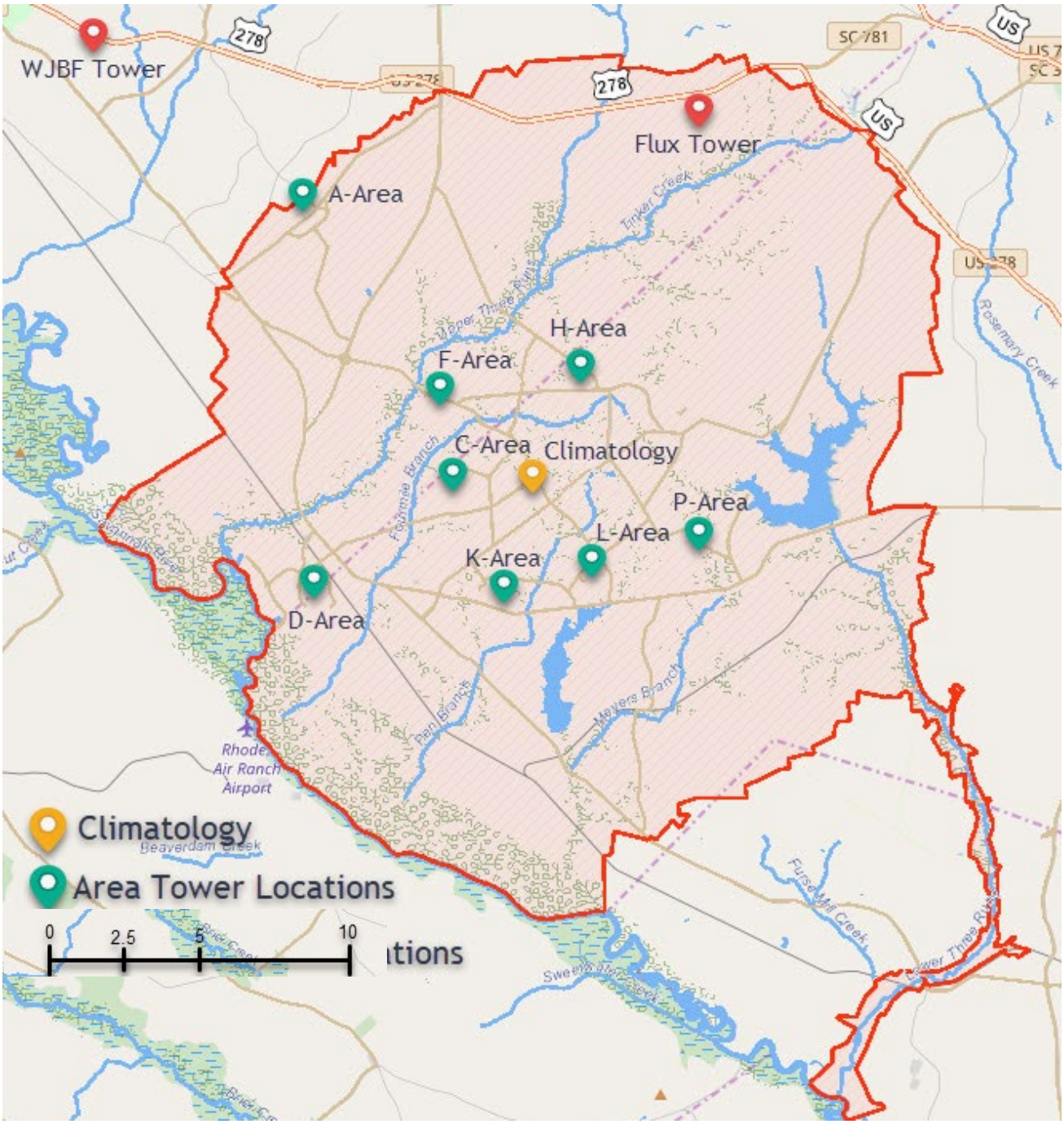


Figure 1-3. Location of the Area Towers, Research Towers, and Central Climatology at the SRS

Major roads, lakes, streams, and Site areas are also included in this map

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Chapter 2 - Climate of the Savannah River Site

This chapter provides a brief description of the prevailing climate at the SRS. The information provided is general and intended to characterize the types of meteorological conditions that the instrumentation of the meteorological monitoring program must sample. More detailed climate summaries are available on a monthly and annual basis. The annual summaries have been issued nearly every year since 1997. The most recent annual summary for 2018 is provided in Rivera-Giboyeaux (2019).

Terrain and Predominant Weather Patterns

The SRS is located on the Atlantic Coastal Plain of southern South Carolina about 20 miles southeast of Augusta, Georgia (see Figure 1-1). The site encompasses about 300 square miles and is a secure area with public access limited to US Highway 278, SRS Road 1, through traffic on SC Highway 125 (SRS Road A) and the CSX railroad. The topography of the SRS is characterized by gently rolling, forested hills with an adjacent flood plain near the river. The flood plain is thickly forested with 15 to 18 meter (m) tall deciduous trees. The higher terrain exhibits a mix of tall pine and deciduous trees with heights of 20 to 25 m. Areas not covered by forest consist of scattered open fields, buildings, parking lots, roads and two cooling lakes. The local SRS terrain elevations generally decrease gradually toward the Savannah River that runs along the southwestern boundary of the site. Site elevations range from 30 to 128 m above mean sea level.

The climate of the SRS area is classified as humid subtropical and is characterized as having relatively short, mild winters and long, warm, humid summers. Summer usually lasts from May through September, when the area is under the influence of the western extension of a semi-permanent Atlantic sub-tropical high pressure (commonly known as the Bermuda high). As a result, winds are generally light and weather associated with low-pressure systems and fronts usually remain well to the north of the area. The Bermuda high is a persistent feature resulting in few breaks in the summer heat. Daytime temperatures are frequently above 90°F and temperatures of 100°F or greater occur once per year on average. The relatively high heat and humidity often results in the development of scattered afternoon and evening thunderstorms.
During the fall, the influence of the Bermuda high begins to diminish, resulting in drier weather with more moderate temperatures. Average rainfall for the fall months is lower on average than for the other months of the year. Frequently, fall days are characterized by cool, clear mornings and warm, sunny afternoons.

During the winter, migratory low-pressure systems and associated fronts influence the weather of the SRS. Conditions frequently alternate between warm, moist subtropical air from the Gulf of Mexico and cool, dry polar air. Occasionally, an outbreak of Arctic air will influence the area. However, the Appalachian Mountains to the northwest of the SRS moderate the extremely cold temperatures associated with the Arctic air masses. Consequently, less than one-third of all winter days have minimum temperatures below freezing and temperatures below 20°F are infrequent. Frozen precipitation occurs less than once per year on the average.

Spring is characterized by a higher frequency of tornadoes and severe thunderstorms than the other seasons of the year. This weather is often associated with the passage of cold fronts. Although weather during the spring is changeable and relatively windy, temperatures are usually mild.

Wind

Figure 2-1 shows a wind rose from the 61-m level at the Central Climatology tower for the 2015 through 2019 period. Higher frequencies of wind

occur from the northeasterly and southwesterly to west sectors. Higher frequencies of westerly wind occur in the winter although this season is the most variable for wind direction due to the frequent passage of cold front and low-pressure systems. During the spring the flow shifts to predominantly southerly and then mainly southwesterly flow during the summer months. The frequency of northeasterly wind increases in the fall.

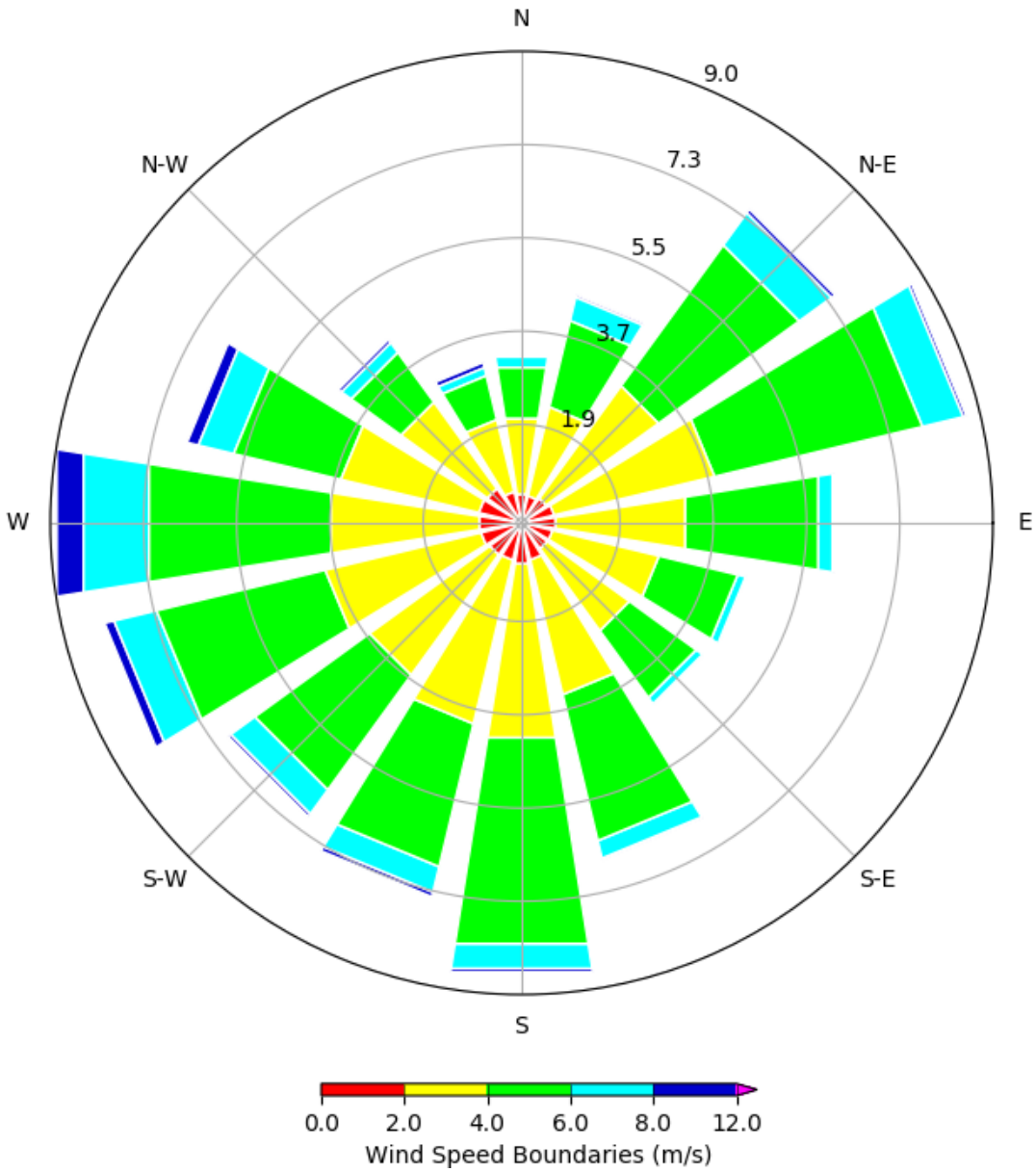

Figure 2-1. Central Climatology Wind Rose

This wind rose was created from 61-m level at Central Climatology for the period 2015 through 2019.

Extreme or straight-line winds which are not associated with tornadoes occur during tropical weather, thunderstorms or strong winter storms. Since 1997, the highest instantaneous surface level gust to occur at Central Climatology was 63.2 mph on August 18, 2000 (Note: Central Climatology measures wind at 4-m compared to the standard NWS 10-m height).

Temperature

Monthly and annual average temperatures for SRS (period of record, 1996-2018) are given in Table 2-1. At SRS, the annual average temperature is 63.6°F. July is the warmest month with an average maximum temperature of 90.3°F. January is the coldest month with an average minimum temperature of 37.0°F. Observed temperature extremes for SRS range from a high of 107 °F to a low of -3 °F.

Precipitation

The annual average precipitation for SRS between 1996 and 2018 was 45.63 inches. Monthly average and extreme precipitation amounts are shown in Table 2-2. Precipitation is fairly well distributed throughout the year, although average precipitation totals for the fall months (September, October, November) account for only about 18 percent of the average annual rainfall. July has the highest average precipitation with 5.35 inches and November has the lowest average at 2.80 inches. Extremes in annual precipitation range from 28.82 inches in 1954 to 73.06 inches in 1964.

Table 2-1. Maximum, Minimum and Monthly Average and Extreme Temperature for SRS

	Averages by Month			Daily Extremes by Month	
Month	**Maximum**	**Minimum**	**Monthly**	**Maximum**	**Minimum**
January	57.4	37.0	46.3	86	-3
February	61.1	39.6	54.5	86	10
March	68.3	45.5	56.2	90	11
April	75.7	52.4	63.8	99	26
May	81.7	62.0	71.4	102	38
June	88.0	68.1	77.3	105	48
July	90.4	71.1	79.7	107	56
August	89.3	70.7	78.8	107	56
September	84.7	65.7	78.8	104	41
October	75.7	54.9	74.2	98	28
November	66.1	44.4	64.5	89	18
December	59.0	39.2	54.3	82	5
Year	**74.9**	**54.2**	**63.7**	**107**	**-3**

Note: Units are in °F. The period of record for the Daily extremes is for the full record of the site from 1963 to 2019. The period of record for the Averages by Month is for 1996 to 2019 from the Central Climatology Tower excluding 2014

Table 2-2. Maximum, Minimum and Monthly Average Rainfall at SRS

Month	Average	Maximum	Year	Minimum	Year
January	3.62	10.02	1978	0.77	2013
February	3.92	10.11	2013	0.73	2000
March	3.92	10.96	1980	0.81	2004
April	3.40	8.43	2003	0.60	1972
May	3.31	10.90	1976	0.87	2015
June	4.92	12.97	1973	0.89	1990
July	5.35	13.71	1971	0.90	1980
August	4.03	12.34	1964	1.22	2015
September	3.85	10.26	2004	0.19	2005
October	2.21	19.62	1990	0.02	2000
November	2.80	7.78	1992	0.40	1969
December	4.31	10.24	2009	0.54	2001
Year	**45.63**	**73.06**	**1964**	**33.24**	**2011**

Note: Units are in inches. The period of record for rainfall averages is 1996 through 2019 using Central Climatology. The period of record for the rainfall maximums and minimums is 1964 through 2019 taken from the annual report (Rivera-Giboyeaux 2019)

Long Term Climate Trends

Two recent studies (Weinbeck 2016, and Werth 2016) suggest statistically significant increases in temperature at SRS. From 1964 through 2016, average nighttime lows have increased by 3.1°F while daytime highs have only increased by 1.4°F. During that 50-year period there has been an increase in cooling degree days (CDD) during the summer months, accompanied by a decrease in heating degree days (HDD) during the winter months, which is consistent with the projection of generally warmer conditions for SRS. Weinbeck (2016) also found a statistically significant increase in the relative humidity at SRS during the summer and fall over the last 50 years, which suggests the persistence of hot and humid days during these seasons. Extreme temperature values have also been observed to change with time and a trend of increased very hot days (>95°F) paired with a decreasing number of freezing days (<32°F) is observed in the data. Lastly, there is a wide range of precipitation projections for the site. A decreasing trend was observed in seasonal and annual precipitation totals over the last 50-years in Weinbeck (2016). Werth (2016) obtained inconclusive results for precipitation projections into the 2040s for the site using statistical downscaling of Global Climate Model (GCM) data, however, a trend towards more intense rainfall but less frequent rainfall events was observed.

References:

Rivera-Giboyeaux, A.M., 2019: *Savannah River Site Annual Meteorology Report for 2018,* SRNL-RP-2019-00371, Savannah River National Laboratory, Aiken, SC.

Weinbeck, S. W., 2016: *Trends in Atmospheric Climate Parameters Measured at SRS 1964-2013, SRNS-STI-2016-00241*, Savannah River National Laboratory, Aiken, SC.

Werth, D. W., 2018: *Climate Change Projection for the Department of Energy's Savannah River Site*, SRNL-STI-2016-00207, Savannah River National Laboratory, Aiken, SC.

Chapter 3 - Area Tower Monitoring System

The Area Towers are 61 m (200 ft) meteorological observation towers that are located near each of the eight primary production facilities at SRS (A, C, D, F, H, K, L, and P Areas). Although operations at C, D and P areas have been permanently shut down, meteorological data continue to be collected at these locations to ensure that dispersion conditions throughout the Site can be adequately characterized (DOE, 2015).

To meet the DOE Order 151.1D specification that DOE emergency response programs have near continuous availability of meteorological data, the Area Tower network is designed to be a highly resilient system capable of surviving a reasonably expected range of natural hazards (i.e., lightning, high wind, ice storms) and technological hazards (i.e., computer or communications system failures). The following sections describe the Area Towers design and instrumentation. Additional information concerning instrument specific maintenance is also provided.

Historical Perspective

In the early 1970's emerging environmental regulations required that a comprehensive meteorological monitoring program be established at SRS. The Area Tower network became the primary source of accurate and timely measurements of wind speed, wind direction and atmospheric turbulence for use in assessing the effects of unplanned and routine effluent releases at SRS. Sites for the Area Towers were chosen in 1972 (L-area in 1985). The basic requirements used in the selection of each tower site was:

- Located within 0.5 – 1.0 mile of each operational production facility
- Situated above relatively undisturbed forest
- Raised at similar mean sea level (MSL) elevations to the nearby facility
- Measurements taken at the major facility stack height of 200 ft (61 m) above the ground surface to ensure representative dispersion calculations.

Near the end of 1987, new, more stable Area Towers were installed to replace the original towers (Left side of Figure 3-1). These towers were erected within 10 ft of the original towers. During this renovation, MRI Vector Vanes were replaced with Teledyne Geotech bivanes and cup anemometers to measure wind speed, direction and atmospheric turbulence. Instruments to measure temperature and dew point temperature were also installed. In 2012 and 2013, the bivanes and cup anemometers were replaced with R.M. Young sonic anemometers (Table 3-3) and the temperature and dewpoint sensors replaced with R. M. Young temperature and relative humidity probes (Table 3-4). By January 2014, all the Area Towers were equipped with sonic anemometers for measuring wind speed, direction and turbulence.

Table 3-1. Area Tower Installation Dates for Sonic Anemometers and Temperature/ Relative Humidity Sensors (Scott, 2014)

Tower	Date of Upgrade
A	August 2012
C	November 2013
D	June 2013
F	March 2013
H	June 2013
K	March 2013
L	July 2013
P	December 2013
CLM	March 2014

In addition to providing real-time data for emergency response, meteorological data collected from the Area Towers are used to create

Figure 3-1. Left, Old Area Tower with Dissipative Array on Top of Tower for Lightning Protection. Right – Current Area Tower Configuration; Lightning Protection Provided by Concentric Underground Cables

five-year, quality assured meteorological data bases of wind speed, direction, turbulence, and temperature. These data bases are used to perform dose calculations supporting the safety basis of SRS nuclear facilities, the Site annual environmental report, and environmental impact analyses for non-radiological effluent. The most recent 5-yr data base of Area Tower measurements covers the period 2007-2011 (Viner, 2013).

Facility Layout

The facility layout at each of the eight Area Towers is nearly identical. A Rohn 55 triangular lattice tower is anchored in a 125 ft^3 concrete pad. The tower structure is supported by 3 sets of guy wires separated by 120° (see Figure 3-12). This tower meets the design standards for a Class III communications tower as defined by American National Standards Institute (ANSI) Standard TIA-222-Rev G and, therefore, rated for a wind speed of up to 130 mph. Anchor rods are primarily Rohn model GAC 57-55 with a length of 14 feet and diameter of 1.45 inches. Two towers (H and CLM) have GAC 55-56 anchors 10 feet in length and a diameter of 1.25 inches. The towers are also equipped with a strobe light at the top of the tower to meet a Federal Aviation Administration commitment. A "data building" is located 30-40 ft from the base of the tower. This building (see Figure 3-2) is approximately 10 ft by 10 ft and is used to house the cabling, datalogger, data transmission and electrical-power-supply equipment required by the tower and instrumentation system. The data building is heavily insulated, and a nearly constant temperature is maintained through use of heating and air conditioning. Extra space and a small table inside the building provide a work area for instrument maintenance.

Figure 3-2. Data Building for C-Area Tower

To maintain the characteristics of the forest canopies surrounding each Area Tower, guidelines have been defined (SU-91-22-O, see attachment A-3) that restrict land uses for zones having radii of 250 ft and 2000 ft from the base of each tower. No activity or construction is permitted with 250 ft of the tower. Any site activity or construction which is proposed within 2,000 ft of the tower must be approved by ATG. The US Forest Service-Savannah River has implemented a specialized plan to maintain the health and prevailing height of the forest canopy through selective thinning and reseeding practices. In general, only small-scale construction is permitted within 2,000 ft of each tower.

Instrumentation

Area tower instrumentation is located at a height of 61 m above ground level (AGL). Direct measurement of the u, v, and w components of the wind are collected at 10 Hz with an R. M. Young model 81000 sonic anemometer and used to determine values of horizontal and vertical wind speed, the horizontal (azimuth) and vertical wind direction (elevation), and atmospheric turbulence expressed as the standard deviation of the azimuth (σ_A) and vertical (σ_E) wind.

Air temperature is measured using the R.M. Young model 41382VF Temperature and Relative Humidity (RH) probe. This probe contains a high accuracy capacitive humidity sensor and a precision platinum resistance temperature detector (RTD). These data are collected at 1 Hz.

Table 3-2. Instrument Orientation

Tower	Nominal Boom Arm Orientation*
A-Area	211
C-Area	278
D-Area	195
F-Area	260
H-Area	256
K-Area	258
L-Area	191
P-Area	276
Climatology	138

* Units are in degrees

In D-area, an additional level of instruments is located at 36 m to detect atmospheric flows induced by the terrain in the Savannah River valley (drainage flows).

Instruments are mounted on a 1 meter supporting cross arm at the end of 2 m boom (see Fig 3-3). The instrument boom can be raised to the 61 m measurement level or lowered to ground for maintenance and calibration using a wench system manufactured by Tower System, Inc (see Figure 3-4). The temperature and RH probe is housed in an aspirated shield that extends below the cross arm.

Table 3-2 summarizes for each tower the azimuth direction angle from the center of the boom arm to the center of the tower. The tower structure will generate a relatively minor disturbance on airflow which may affect measurements when the upwind direction is within +/- 15° of the nominal boom orientation.

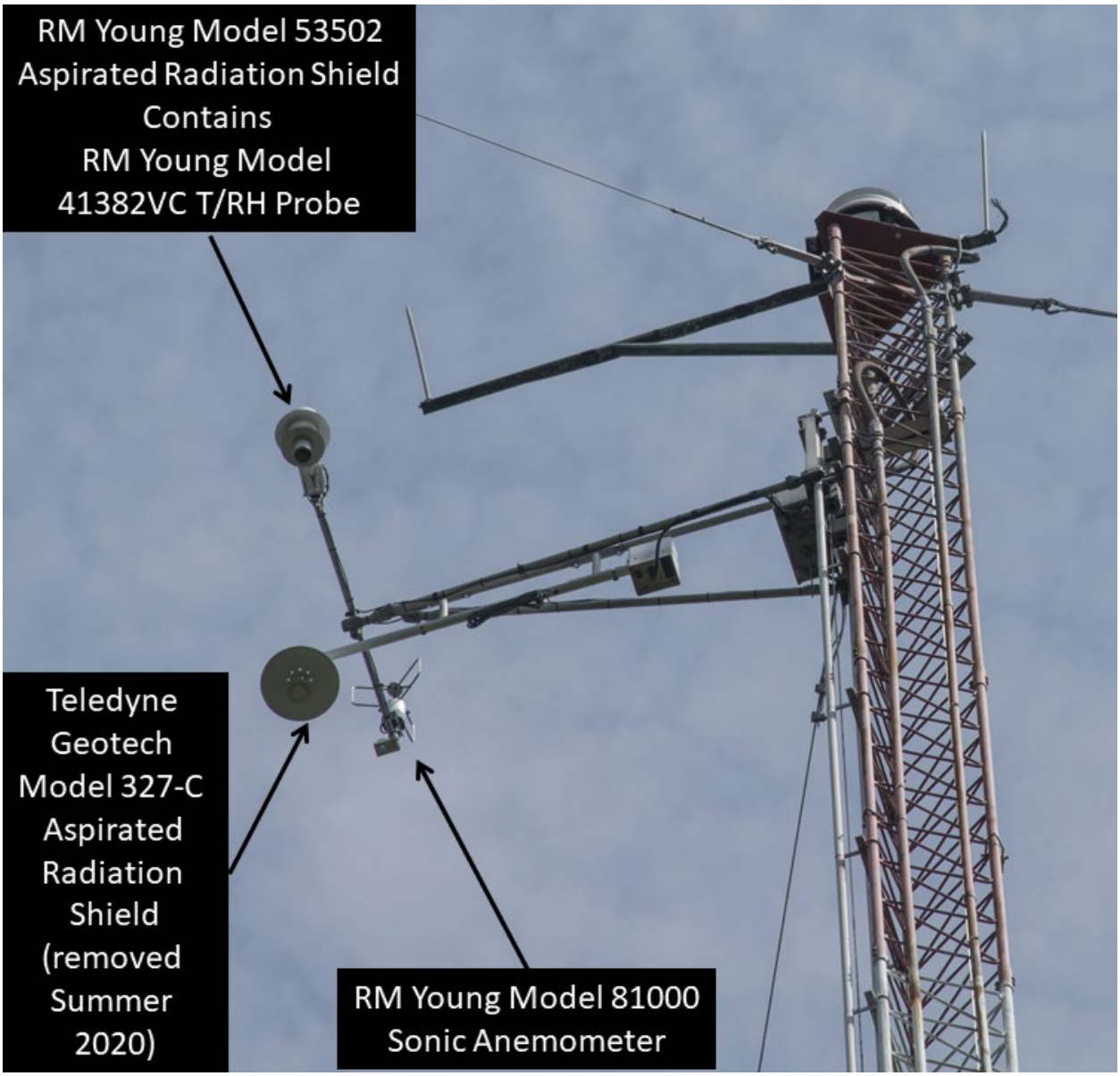

Figure 3-3. Area Tower Boom Arm and Cross Arm

Figure 3-4. Winch Assembly for an Area Tower

Silver rails guide the boom arm up and down, when being raised or lowered by the winch. Note the old Area Tower pad to the upper left of the current pad.

A description of each of the instruments used on the Area Towers, as well as instrument specifications follows.

R. M. Young Model 81000 Sonic Anemometer
The most important instrument on the SRS Area towers for calculating atmospheric dispersion is the R. M. Young sonic anemometer. This instrument determines three components of the wind (u, v, and w), as well as a sonic temperature, by measuring the transmission time of sound waves between the three pairs (6 total) of transducers in the head of the sensor. The wind components are then used to calculate wind speed, wind direction, wind elevation (angle) and turbulence (σ_A and σ_E). In addition to the meteorological signals calculated by the instrument, the instrument also outputs a checksum (communication diagnostic) and instrument validity, which are also part of the digital signal sent to the datalogger.

The tower data logger(s) polls the sonic anemometer at the rate of 10 Hz and parses the measured values in the datalogger program's data table. The datalogger uses the stored values to calculate the horizontal wind speed, the horizontal wind direction (azimuth), vertical wind direction (elevation), sonic temperatures (degree C), and atmospheric turbulence expressed as the standard deviation of the azimuth (σ_A) and vertical (σ_E) wind direction. An example of the Model 81000 is shown in Figure 3-5. Operational specifications for the instrument are summarized in Table 3-3.

Figure 3-5. R. M. Young Model 81000 Sonic Anemometer

R.M. Young Model 41382VC Relative Humidity and Platinum Resistance Temperature Sensor
The RM Young Model 41382VC (Figure 3-6) combines a high capacitive type humidity sensor with a precision platinum resistance temperature detector (RTD) in the same probe. This arrangement is advantageous since it eliminates potential errors in calculating dew point temperatures using temperature and humidity measurements that are not coincident with one another.

Table 3-3. R. M. Young Model 81000 Sonic Anemometer Specifications

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:	0.01 m/s
Accuracy:	±0.1% rms ±0.05 m/s (0 to 30 m/s)
Sonic Temperature	
Range:	-50 to +50 ºC
Resolution:	0.01 ºC
Accuracy:	± 2 ºC (0 to 30 m/s wind)
General	
Air sample clmn:	10 cm high X 10 cm
Air sample path:	15 cm
Output rate:	4 to 32 Hz (10 Hz)
Output formats:	Serial data (selectable) RS-232 and RS-485 Baud
Rates:	1200 to 38400
Power Supply:	12 to 24 VDC, 110 mA
Dimensions:	Height 56 cm Arm radius 17cm Mounting 34mm (1.34 in) diameter (standard 1-inch pipe)
Weight:	Sensor weight 1.7 kg (3.8 lb)

The humidity portion of the probe is a small thin-film capacitive type of humidity sensor that responds to changes in the relative humidity (as opposed to absolute humidity changes) in the ambient air. A humidity absorbing polymer is sandwiched between two porous electrodes. Water vapor penetrates the porous layer and is absorbed by the polymer. The resulting change in the capacitance is measured as the relative humidity changes. To protect the thin film capacitive layer, moist air must first pass through a filter. The sensor output measures a range of 0 to 100%.

Figure 3-6. R.M. Young Model 41382VC Relative Humidity and Platinum Resistance Temperature Sensor

The temperature portion of the probe consists of a platinum resistance element. The conductivity of the metal changes with temperature. The lead wires are heavily insulated to ensure that only the conductivity of the platinum portion of the circuit is measured (instead of the entire circuit, including the copper wires in and out of the circuit). Platinum is used for these measurements, since it gives very stable and accurate readings over a wide range of temperatures. The temperature output for the sensors in in degrees Celsius.

The probe consists of three separate circuits. An incoming power supply, the temperature RTD measurements leads, and the leads from the RH thin film capacitor. The instrument measurements are made by the dataloggers as an analog differential voltage measurement (relative to a voltage difference across the instrument circuit, rather than to a common ground). The voltage output ranges for the measured RH and temperature is configured to a 0 to 5-volt (0-5000 mV) range, to allow the greatest possible precision in reading the values from the instrument. Specifications for the Model 41382VC temperature and relative humidity sensors are summarized in Table 3-4.

Table 3-4. RM Young Model 41382VC Temperature and Relative Humidity Sensor Specifications

Relative Humidity	
Measuring range:	0-100% RH
Accuracy at 23°C:	±1%
Stability:	Better than ±1%RH per year
Response Time:	10 seconds (Without Filter)
Sensor type:	Rotronic Hygrometer
Temperature	
Measuring Range:	-50 to +50°C
Accuracy at 23°C:	±0.3°C
Response Time:	10 seconds (Without Filter)
Sensor type:	Platinum RTDW
Output signal:	0-1 or 0-5 VDC (jumper option)
Power Required:	8-30 VDC at 7 mA
Recommended Cable:	5 conductors shielded, Young 18446

Figure 3-7. Model 43502 Aspirated Radiation Shield (for RH and Temperature Sensor)

Compact Aspirated Radiation shield (for RH and Temperature Sensor)

The RM Young Model 41382 VC Temperature/RH probe is mounted in an R.M Young Model 43502 compact, aspirated radiation shield (Figure 3-7). This is done to isolate the probe from solar radiation and precipitation to minimize any radiation biases, convective heating and evaporative cooling caused by rainfall. The shield mounts to the end of the cross arm at the 61-m level. The shield and blower housing are made of plastic materials that provide high reflectivity, low conductivity, and maximum weatherability. The shield employs a triple-walled intake tube and multiple shades to isolate the sensor from precipitation and solar radiation. A continuous duty blower draws ambient air up through the intake tubes/baffles and across the sensor, minimizing radiation errors by keeping a supply of ambient air blowing past the sensor probes, removing any excess heat before it heats the instruments. The shield reduces the amount of radiation absorption, by providing a reflective surface, and providing standoff distance between the location of the absorption and the instrument. The shape of the shield and baffles, forces air to be constantly drawn past the instrument, preventing heating and keeping water from condensing and pooling in the air intake baffles. The aspirated fan has the revolutions per minute (RPM) measured by an onboard circuit that is recorded by the datalogger pulse channel, in the main datalogger memory.

Table 3-5. RM Young Model 43502 Aspirated Radiation Shield Specifications

Specifications	
Sensor Types:	Accommodates temperature and humidity sensors up to 24mm (0.9 in) diameter
Ambient Temp:	<0.2°C (0.4°F) RMS (@1000 W/m² intensity)
Aspiration Rate:	5 to 11 m/s (16-36 fps) depending on sensor size
Power Requirement:	12-14 VDC@500 mA for blower
Operating Temperature Range	-50° to +60° C. (-58° to +140° F.)
Dimensions	
Overall Height:	33 cm (13 in)
Overall Diameter:	20 cm (8 in)
Shield:	7 cm (2.7 in) dia. x 12 cm (4.7 in)
Blower Housing:	17 cm (6.7 in) dia. x 11 cm (4.3 in)
Mounting:	V-Block and U-Bolt for vertical post or tower member 25-50 mm (1.0-2.0 in) dia.

RH and Temperature Sensor Maintenance

Cleaning the aspirated radiation shield is performed as part of the twice-yearly calibration to remove debris (dirt, pollen and dead bugs) that accumulates in the baffles, fan and fan exhaust vents. In addition, buildup of debris is monitored by checking the data reported on the fan RPM as an indication of the air flow being blocked. Occasionally, extensive debris accumulates, and the entire enclosure will need to be removed and soaked to remove the debris. In addition to the cleaning of the enclosure, filters at the end of the probe are periodically removed and replaced.

Figure 3-8. Campbell Scientific Model CR1000 Datalogger Used for Data Collection and Control

Dataloggers

Data acquisition for each Area Tower is controlled by a Campbell Scientific CR-1000 (Figure 3-8) or 1000X (Figure 3-10) Datalogger, which is mounted in an instrument rack in the data building. The CR1000/1000X is a microprocessor-controlled system consisting of measurement and control electronics, communication ports, 16-character keyboard, LED display, and power supply. The datalogger interprets a custom written program that controls the operation of the tower instruments, datalogging, computations and communications. Measurement instructions allow users to control basic pulse/frequency counting and analog to digital conversions, as well as specify instrument voltage ranges, bridge configurations, thermocouples, and other basic processing functions.

Table 3-6. CR1000 Datalogger Specifications

Specification	Description
Operating Temperature Range	-25° to +50°C (standard), -55° to +85°C (extended) Non-condensing environment
Analog Inputs	16 single-ended or 8 differential (individually configured) channels
Pulse Counters	2
Voltage Excitation Terminals	3 (VX1 to VX3)
Communications Ports	Parallel peripheral, RS-232, CS I/O
Switched 12 Volt	1 terminal
Digital I/O	8 I/Os or 4 RS-232 COM I/O ports can be paired as transmit and receive for measuring smart serial sensors. Certain digital ports can be used to count switch closures.
Input Limits	±5 Vdc
Analog Voltage Accuracy	±(0.06% of reading + offset) at 0° to 40°C
ADC	13-bit
Power Requirements	9.6 to 16 Vdc
Real-Time Clock Accuracy	±3 min. per year (Correction via GPS optional.)
Battery-backed SRAM for CPU Usage & Final Storage	4 MB
Idle Current Drain, Average	< 1mA (@ 12 Vdc)
Dimensions	23.8 x 10.1 x 5.4 cm (9.4 x 4.0 x 2.1 in.) 25.2 x 10.2 x 7.1 cm (9.9 x 4.0 x 2.8 in.) with CFM100 or NL116 attached
Weight	1.0 kg (2.1 lb)

The on-board operating system includes instructions that allow the user to control the measurement, processing, and output of the instrument by programming the datalogger. The programming language, CRBasic, uses a BASIC-like syntax. Processing instructions support algebraic, statistical (such as averaging), and transcendental functions for on-site processing. The program execution stops when primary (input) power drops below 9.6 V, to minimize the chances of inaccurate readings. An on-board battery continues to retain internal memory to store data should main power be lost. Specifications for the CR1000/1000x are given in Tables 3-6 and 3-7, respectively.

In addition, a Campbell Scientific NL 115 Ethernet/Compact Flash module (Figure 3-9) is used to provide Ethernet connectivity between the Campbell Scientific CR1000 Dataloggers and the central data base servers. Specifications for the NL 115 Ethernet/Compact Flash module is summarized in Table 3-8.

Table 3-7. CR1000X Datalogger Specifications

Specifications	Dimensions
Operating Temperature Range	-55° to +85°C (extended), -40° to +70°C (standard) Non-condensing environment
Analog Inputs	16 single-ended or 8 differential (individually configured) channels
Pulse Counters	10 (P1 to P2 and C1 to C8)
Voltage Excitation Terminals	4 (VX1 to VX4)
Communications Ports	Ethernet, CPI, RS-485, RS-232, CS I/O, USB Micro B
Data Storage Ports	microSD
Switched 12 Volt	2 terminals
Input Limits	±5 V
Analog Voltage Accuracy	Accuracy specifications do not include sensor or measurement noise. • ±(0.06% of measurement + offset) at -40° to +70°C • ±(0.04% of measurement + offset) at 0° to 40°C • ±(0.08% of measurement + offset) at -55° to +85°C (extended temperature range)
ADC	24-bit
Power Requirements	10 to 18 Vdc for charger input (CHG)
Battery-backed SRAM for CPU Usage & Final Storage	4 MB
Data Storage	4 MB SRAM + 72 MB flash (Storage expansion of up to 16 GB with removable microSD flash memory card.)
Active Current Drain, Average	55 mA (20 Hz scan @ 12 Vdc) 1 mA (1 Hz scan @ 12 Vdc)
Dimensions	23.8 x 10.1 x 6.2 cm (9.4 x 4.0 x 2.4 in.) Additional clearance required for cables and leads.
Weight	0.86 kg (1.9 lb)

Figure 3-9. Campbell Scientific Ethernet/Compact Flash Module Model DL 115 Used for Networking CR1000 to WINDs Network

Table 3-8. NL 115 Ethernet/Compact Flash Module for Campbell CR1000 Ethernet Communications

Specifications	Dimensions
Power Requirements	12 V supplied through the data logger's peripheral port
Ethernet Speed	10Base-T (10 Mbps), half-duplex
Typical Access Speed	200 to 400 kbits s^{-1}
Memory Configuration	User selectable; ring (default) or fill-and-stop
CF Card Requirements	Industrial-grade
Data Logger Operating System (OS)	The CR1000 OS must be OS 9 or later. Both the CR1000 and CR3000 need OS 25 or later to read cards with more than 2 GB of storage.
Dimensions	10.2 x 8.9 x 6.4 cm (4.0 x 3.5 x 2.5 in.)
Weight	154 g (5.4 oz)

Figure 3-10. Campbell Scientific Model CR1000X Datalogger Used for Data Collection

The CR1000X does not use the NL 115 ethernet interface and compact flash module, since it has an ethernet connection and microSD storage card interface built into the logger.

For both datalogger models, the program that controls data collection has two parts. The primary program execution occurs at 10 Hz, and samples a digital signal from the sonic anemometer, as well as the pulse channel. The program reads the digital signal from the anemometer at a rate of 10 Hz, and parses the data coming back. The data that is returned is in the form of u, v, w components of the wind, 2-dimensional wind speed, 3-dimensional wind speed, elevation angle (calculated by the anemometer from the uvw components of the wind), sonic temperature (measured directly by the anemometer), as well as a checksum and a sonic diagnostics channel. This digital signal is parsed into the individual components of the string and placed into memory. Values that fail the checksum or sonic validity check are flagged as bad, and not used for averaging. The pulse channel returns a pulse count from the fan from the RM Young Model 53502 Aspirated Radiation Shield.

The second part of the datalogger program samples at the slower rate of 1 Hz. This channel measures relative humidity, the RTD (temperature), as well as alarm measurements for both the RTD temperatures, the data cabinet/rack alarm, the datalogger battery voltage, the strobe light alarm, and the main power alarm. These quantities are all measured as an analog differential (voltage).

Once a 15-minute sampling period ends, the datalogger computes average values, standard deviations, and validity values for each meteorological quantity. Maximum values for the 2-dimenisonal and 3-dimensional wind speeds are determined. The data logger performs vector averaging of the horizontal wind speed and direction, while all other channels perform scalar averaging (scalar wind speed and direction), elevation angle, sonic temperature, relative humidity, RTD temperature and validity measurements.

The computed 15-minute quantities along with all the 10 Hz (raw) data are transmitted using an ethernet connection (via the NL 115 module mounted to each CR1000 and via a peripheral connection and built in to every CR1000X) to a rack mounted switch. The rack mounted switch connects to the SRS network, which has redundant destinations. Data is sent automatically to the Central Computing Facility (CCF) in A-Area and to the Backup Computing Facility (BCF) in C-Area, to maintain redundancy and ensure reliability. Data is collected at the CCF/BCF and then automatically uploaded to a PostgreSQL database. The database server in the CCF contains a complete archive of SRS meteorological data; the server in the BCF only contains data for the past year to ensure real-time support of site operations and emergency response can continue in the event the CCF server is unavailable. Automated scripts also calculate additional boundary layer parameters from the raw wind files, such as the friction velocity, u_*, heat flux, and Obukhov length, L, that are not needed immediately for emergency response.

A PDU (Power Data Unit) at each tower allows the components in the equipment rack that enable network communications to be cycled remotely, so the towers can be restarted without having to send personnel to the tower. Area Tower dataloggers lie on a specialized network enclave that is separated from the rest of the SRS network. This network segment physically extends to every meteorological tower and is dedicated to ATG devices. It is independent of the rest of the SRS Network and is configured such that general SRS users cannot access this network or the devices on it. This helps separate normal SRS network traffic from Area Tower communications and ensures the reliability, timeliness, and availability of the data.

If the network connection to an Area Tower is lost, the dataloggers continue to collect data, which is written into a circular buffer. Once the connection is restored the dataloggers will automatically back poll, filling in the missing periods in the PostgresSQL database.

System Monitoring

A custom utility, known as the WINDS Data Flow Monitor (WDFM), has been configured to allow ATG and SRNL Scientific Computing personnel to monitor and troubleshoot Area Tower data collection in real time. Computer scripts monitor the activity as the data passes through the various system components, from initial data collection through to the status of the database servers, archival of data in the relational database, and processing files and generating products used in emergency response consequence modeling, data displays supporting SRS operations through the Atmospheric Technologies web page and external users such as DOE's National Atmospheric and Release Advisory Capability (NARAC). Results of the WDFM system checks are plotted graphically in the form of a color code to indicate the system status (see Figure 3-11). A more detailed text summary is provided to the right of the plot (not shown) or can be displayed by hovering the mouse above the component in the image.

Typically, this is done when the system state changes from green to purple or red. For the Towers block, voltage for the Area Tower datalogger internal battery is displayed, along with the 61-m radiation shield aspirator fan RPM, the RTD aspirator, power, strobe light and cabinet temperature alarm status.

For other blocks, data products (files) or ping status are displayed to allow staff to quickly determine the nature of the problem, and to return the status to green.

The WDFM display graphic is updated approximately every 15-minutes (to match the nominal data period for the data collection) and the summary image is posted to High Performance Computing File Sever (HPCFS) image directory. Images stored in this directory can be displayed via a web browser or via downloading and using image display software. The instrument status is also displayed continuously via 2 large TV monitors in 735-7A, along with other troubleshooting displays for inspection by field engineering specialists.

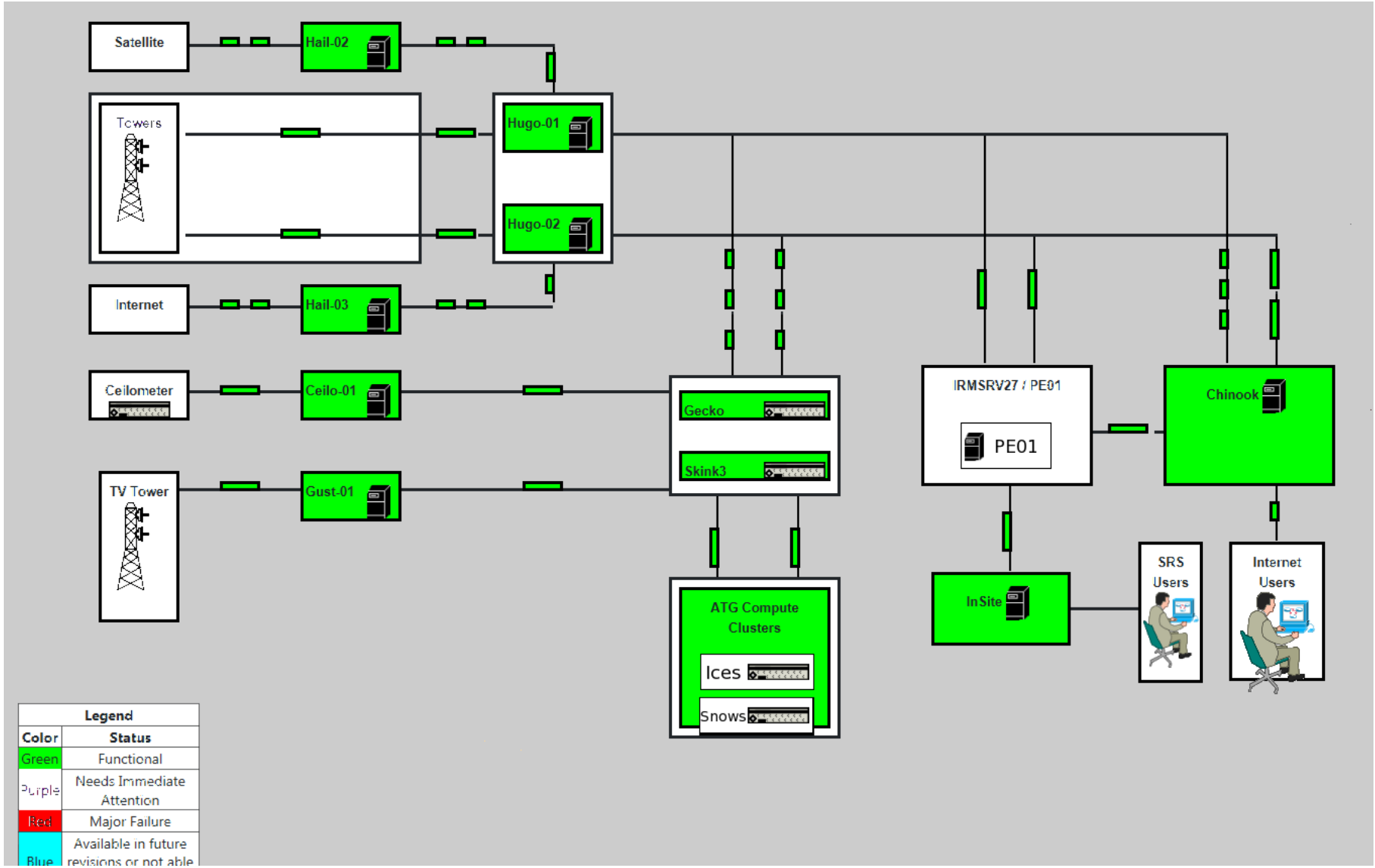

Figure 3-11. WINDS Data Flow Monitor (WDFM)

Tower Lightning Suppression

The location of the SRS in the thunderstorm prone southeastern U.S. makes a quality lightning protection system extremely important because meteorological instrument failures can be caused by lightning induced currents or direct strikes. Lightning related instrument and data collection system failures were prevalent in the early 1970s. However, the present grounding system at each tower greatly minimizes lightning related damages. A network of grounding cables and rods have been installed at each tower to inhibit lightning related damages (see Figure 3-12).

At the top of each tower, two 4-ft lightning rods comprise the pinnacle of the lightning protection system. Three 2/0-stranded ground cables are connected to the two lightning rods and each wire descends via a separate tower support post. Each wire is connected to the top guy wire and then terminates at the second highest guy wire. The middle sections of each tower are grounded directly to each guy wire. A ground wire is connected to each tower support post and then to the nearest guy wire.

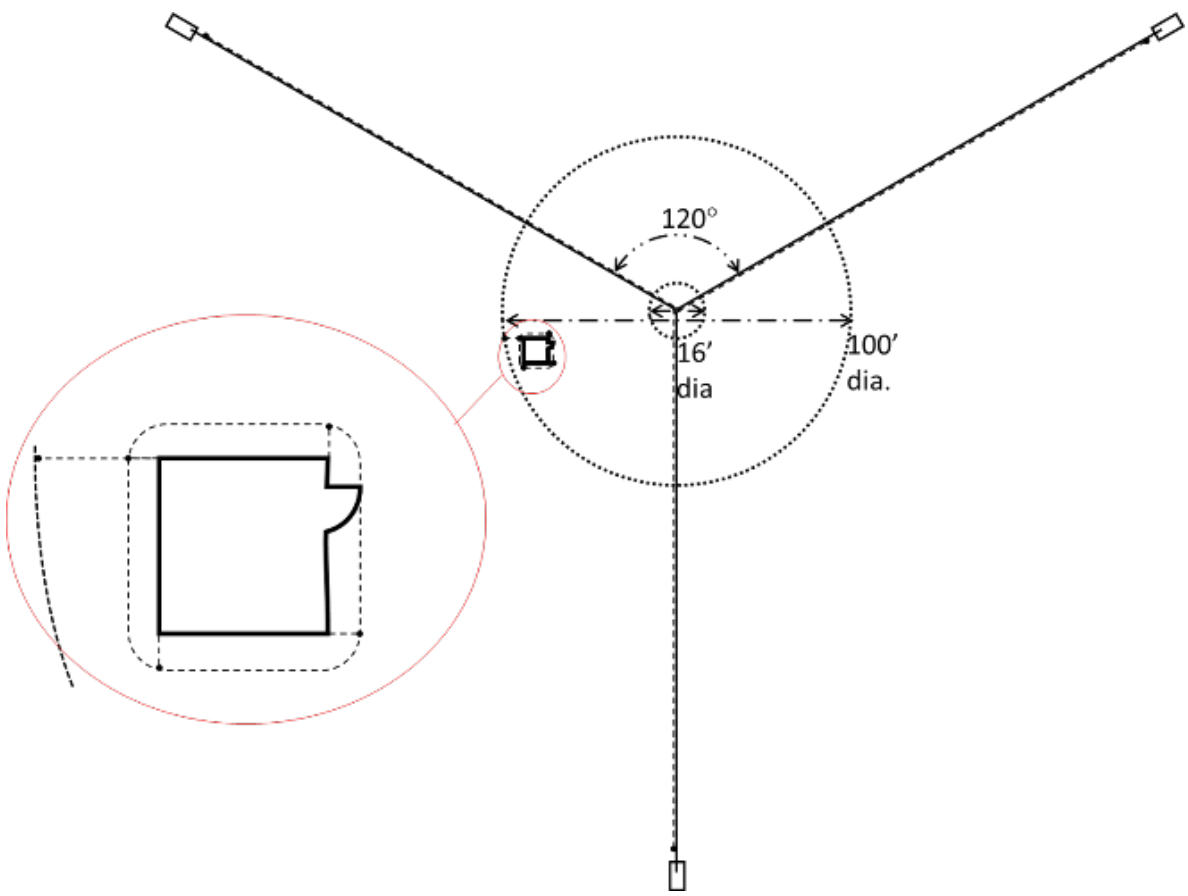

Figure 3-12. Tower Lightning and Grounding Proctor

At the base of the tower structure, a copper 2/0 stranded ground cable is connected to each of three tower supports. These cables pass underground, parallel to the support guy wires, beyond the base of the tower to ground cables in concentric circles of 8 ft and 50 ft radii buried 2.5 ft below the ground surface. The termination point for each tower support cable is at the ground level base of the guy wires that are also ground points for all the guy wires. Ground rods, made primarily of copper, are located at every intersection of two ground cables and at the base of the guy wires. Each ground rod extends 20-30 ft below the ground surface.

The data building is also grounded. Four ground rods are located at each corner and four more are located at the corners of a square that extends 3 ft beyond the outside of the building. All of these rods are connected by ground cable. The data building ground system is also tied to the 8 and 50 ft radii ground cables of the tower. When possible the grounding network for each tower has been tied to the existing grounding network of the tower that had been previously erected at the site.

The grounding network is supplemented by additional lightning suppression circuitry (Figure 3-13a). Surge suppressors are used to protect against damaging power 'spikes' caused by lightning inducted electrical current. These surge suppressors work by redirecting current through a ground wire when potential differences (voltages) become too great. Residual current that escapes the grounding pathway is channeled to a Zener diode that further protects the instrument circuitry. Surge suppressors are located at three strategic points between each instrument and its respective signal processor card. The first location is at the junction box attached to the tower at 200 ft. These surge suppressors inhibit surges that flow from the tower structure toward the instrument. The other two locations at the tower base junction box and the instrument cabinet inside the data building have surge suppressors that inhibit flow from the tower toward the signal processor cards.

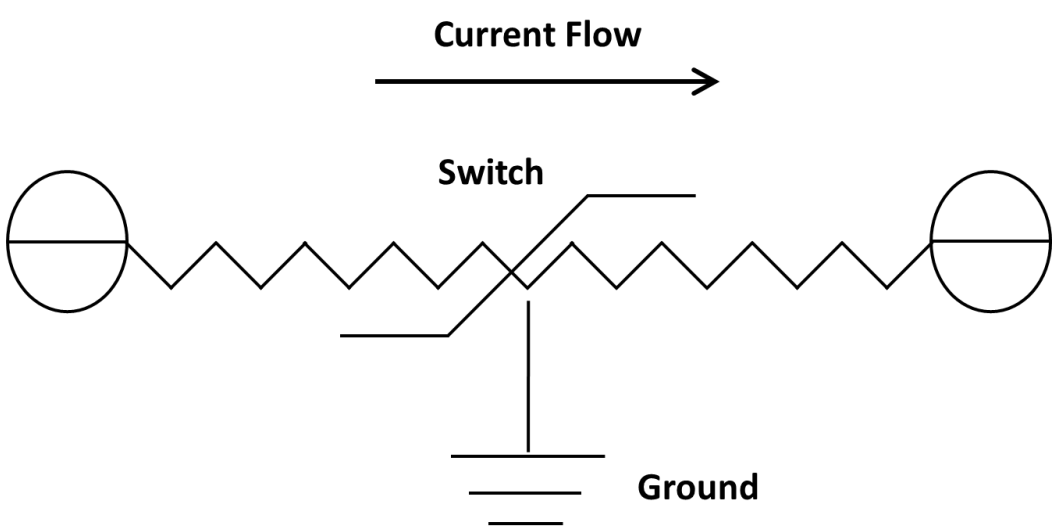

Figure 3-13a. Basic Description of a Surge Suppresser

Current flow under normal condition. Switch is not activated.

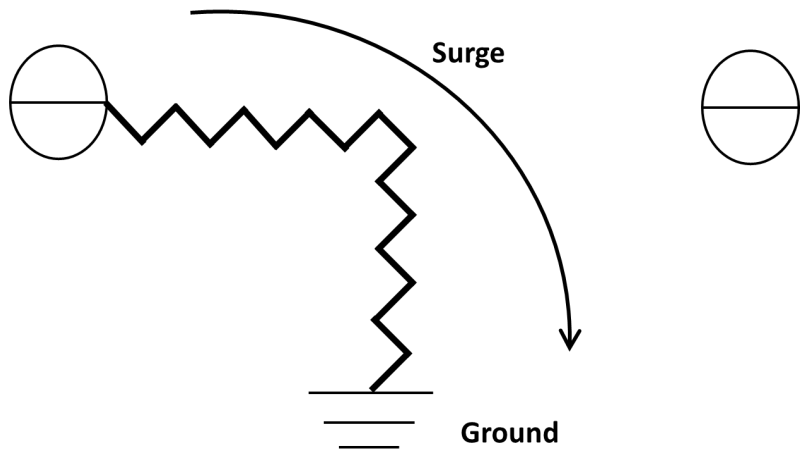

Figure 3-13b. Basic Description of a Surge Suppresser

A lightning induced power surge activates the switch which redirects the current harmlessly to ground. If the surge is too great, the circuit may become damaged despite the effort to redirect the surge**.**

Surge protector power strips are connected to electrical outlets to prevent surges for coming from an AC power source. Surge protectors are also used to protect various phone lines in the data building.

Electrical Power Supply

Electrical power is supplied to each tower via the SRS grid. Onsite power is supplied primarily by Dominion Energy. In the event of a power outage, the SRS Utilities Department will set-up portable diesel or gas-powered generators to supply electricity to an individual tower.

All meteorological instrumentation and signal processing equipment installed at the area towers are powered by 12-VDC. Transformers convert 110-VAC power to 12-VDC to provide the appropriate current for each instrument.

Routine Facility Maintenance

Each tower facility undergoes several types of annual maintenance. Annual inspections are made of the electric winch and winch system cables of each tower by the SRS Rigging group. A more complete annual inspection of towers is made by an off-site vendor who inspects the tower for irregularities or "kinks" that, if necessary, can be corrected by adjusting tension on the appropriate guy wires. The tower and winch cable are checked for wear or rust, and the condition of the lightning rods is also documented. Guy wire tension measurements are made at the end of an inspection and adjusted as needed. Grounds keeping involve routine grass cutting and/or forest canopy culling or trimming. The entire maintenance process is coordinated by SRNL ATG.

Nominally, every 5 years, a contractor is brought onsite to check the integrity of the guy wires and guy wire anchor rods, to ensure that corrosion has not weakened the system. If the anchor rod begins to degrade significantly, monitoring will occur more frequently. The testing utilizes a noninvasive, ultrasound technique that is based on the patented SoundAnchor technology developed by SRNL.

Area Specific Descriptions

Characteristics of each specific area are described in the following sections. Elevation is given with respect to height above mean sea level (MSL). All latitude and longitudes given in NAD83 datum.

A-Area

The A-area tower facility is located at 33° 18' 51'' N, 81° 28' 56'' W (Plant coordinates N 107,578.5, E 50,951.8) at an elevation of 109m ASL in the vicinity of the SRNL. The SRS Operations Center (SRSOC), Emergency Operations Center, and badge office are also located in A-area. The potential for harmful atmospheric releases in this area is minimal and is limited mainly to waste disposal failure (i.e. exhaust hoods, low level drains and tanks, drums, etc.). The A-area tower is located the farthest north of any Area Tower and represents an important data point when creating spatially averaged means of meteorological variables. The physical layout of the A-Area tower is shown in Figure 3-14. Data acquisition is performed with the CR1000 data logger coupled with a DL 115 Compact Flash Module to enable network communications.

The surface features within 2000 ft of the A-area tower varies (see Figure 3-15). The building/parking lot complex is located to the southeast of the tower. Generally, all other quadrants are forested. The forest buffer between the tower and building/parking lot complex is approximately 300-500 ft. There is no pronounced terrain slope. Instrumentation is directed west.

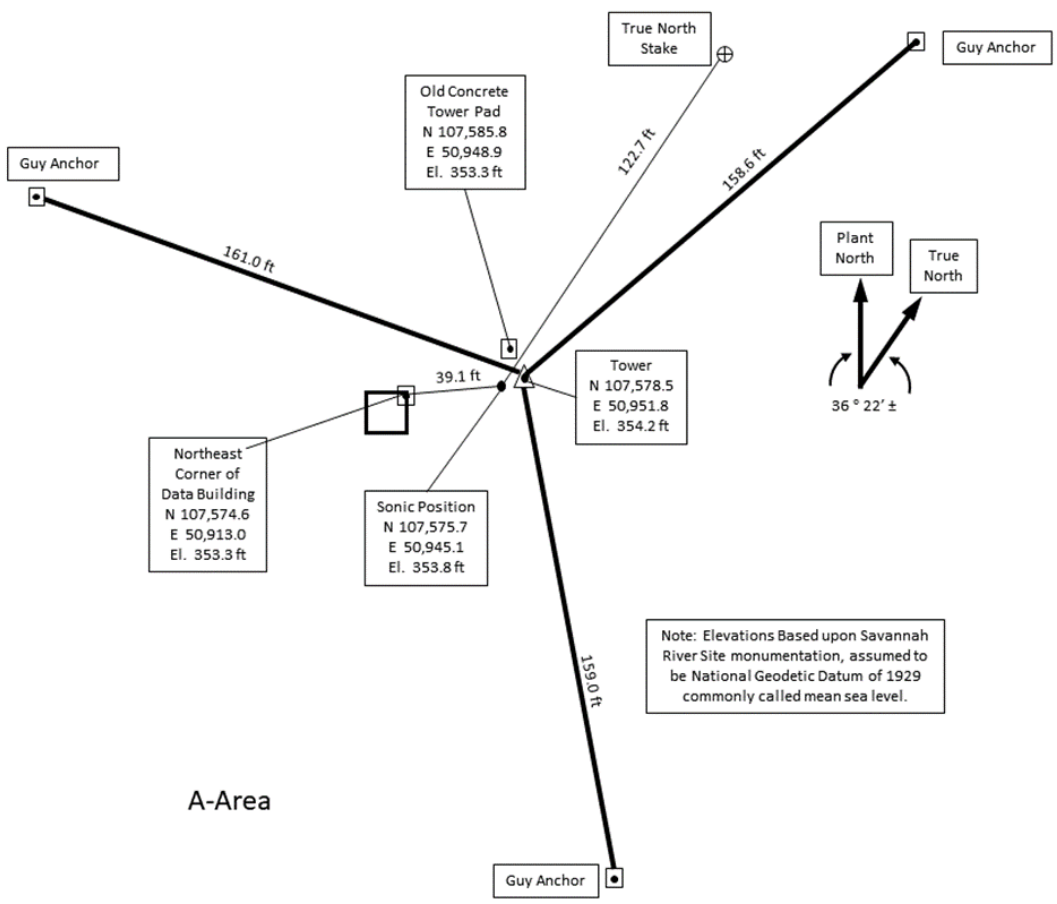

Figure 3-14. A-Area Tower Facility Diagram

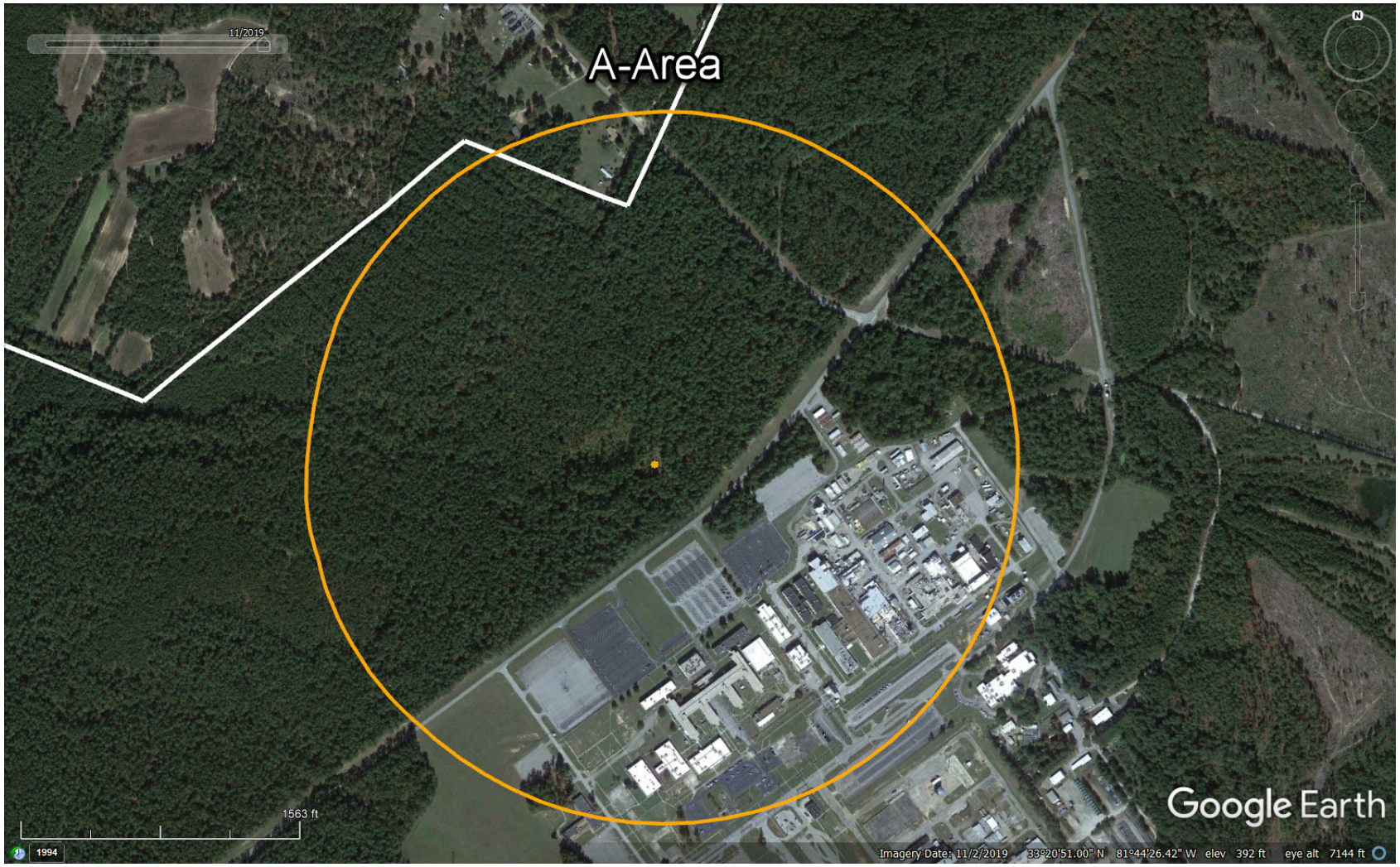

Figure 3-15. Google Earth Image from 11/1/2017 of A-Area Tower and Surrounding Area

C-Area

The C-area tower facility is located at 33° 14' 23'' N, 81° 35' 08''W (Plant coordinates N 66,159.7, E 47,898.5) at an elevation of 92 m ASL near the C Reactor. The C Reactor was shut down in 1985 and is now occasionally used for Department of Defense training. The potential for a harmful atmospheric release is virtually non-existent. The location of C-area toward the center of SRS provides a centrally located measurement point for spatial averaging. The C-area tower is located about 1 mile away from the Central Climatology Tower and provides a measurement of comparison at 61 m. The physical layout of the C-Area tower is shown in Figure 3-16.

The forest canopy within 2000 ft is full to the north, northeast, south and southeast of the tower (see Figure 3-17). The C-area building complex dominates the terrain to the west of the tower. The N-area (Central Shops) building complex is located to the east of the C-area facility, but a half-mile wide forest buffer helps to protect the tower from building wake effects. The terrain slope near the tower is negligible and the ground is composed primarily of sand as opposed to red clay at the other towers. Instrumentation is directed west.

The C-Area Tower also is equipped with a visibility sensor mounted on the tower. The CR1000 data logger at the C-Area tower was replaced with a CR1000x in the spring of 2019 to eliminate the need to utilize a custom external voltage bridge for performing visibility sensor calibrations. The visibility sensor is described in Chapter 5.

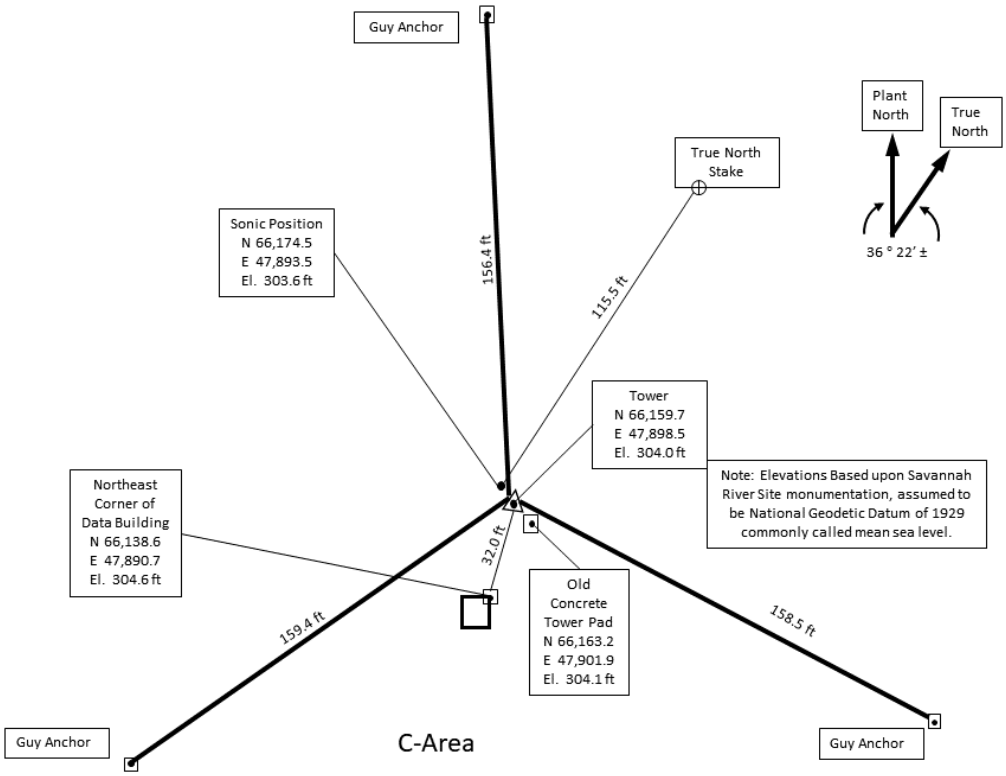

Figure 3-16. C-Area Tower Facility Diagram

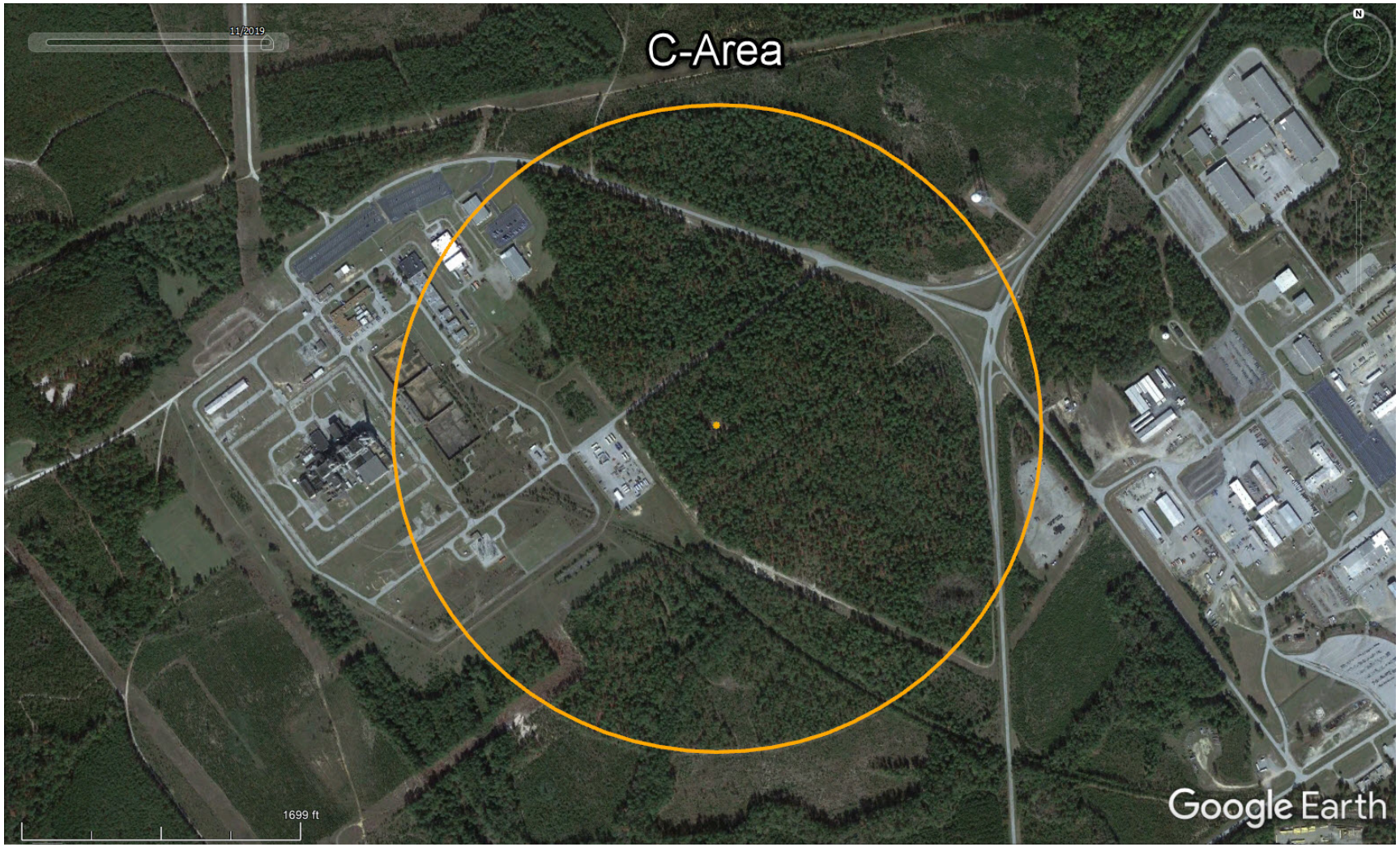

Figure 3-17. Google Earth Image from 11/1/2017 of C-Area Tower and Surrounding Area

D-Area

The D-area Tower facility is located at 33° 10' 52'' N, 81° 32' 02'' W (Plant coordinates N 67,175.7, E 21,331.3) at an elevation of 43 m ASL and differs slightly from other Area Towers. D-area is in the flood plain of the Savannah River in the western portion of SRS. D-area was originally the location for heavy water production for the SRS reactors, and for a coal fired boiler that provided onsite electrical power and steam production. D-area has since been shut down; however, the D-area tower remains important due to its location near the Savannah River and Georgia Power's Vogtle Nuclear Plant. The physical layout of the D-Area tower is shown in Figure 3-18. Terrain driven flows play an important role in the river valley, and an extra level of instrumentation, identical to the 61-m level (with no T or RH probes), has been installed at 36 m to measure drainage related phenomena. Consequently, the increased storage requirements due to the extra level of instrumentation mean that the data logger only can store five days of data as opposed to 14 days at the other Area Towers. In 2016, a tipping bucket rain gauge was installed near the tower at ground level (see Ch. 7 for details). To handle the demand of a 2nd level of instrumentation and the rain gauge, two CR1000 data loggers are used for data acquisition.

The forest canopy within 2000 ft of the D-area tower is generally full, except for power line path clearings, to the southwest, west, north, and northeast (see Figure 3-19). The canopy is virtually non-existent to the south and east. The terrain slopes slightly from northwest to southeast. The canopy is predominantly composed of hard-wood trees as opposed to pine trees at the other Area Towers. Instrumentation is directed south.

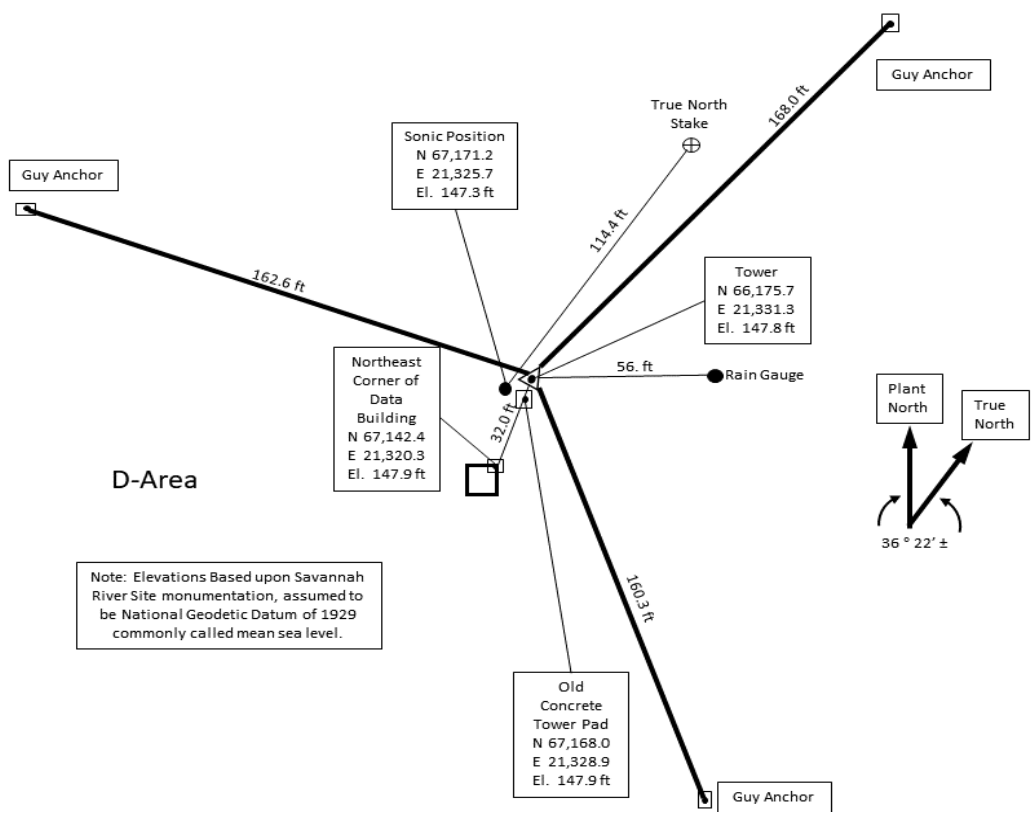

Figure 3-18. D-Area Tower Facility Diagram

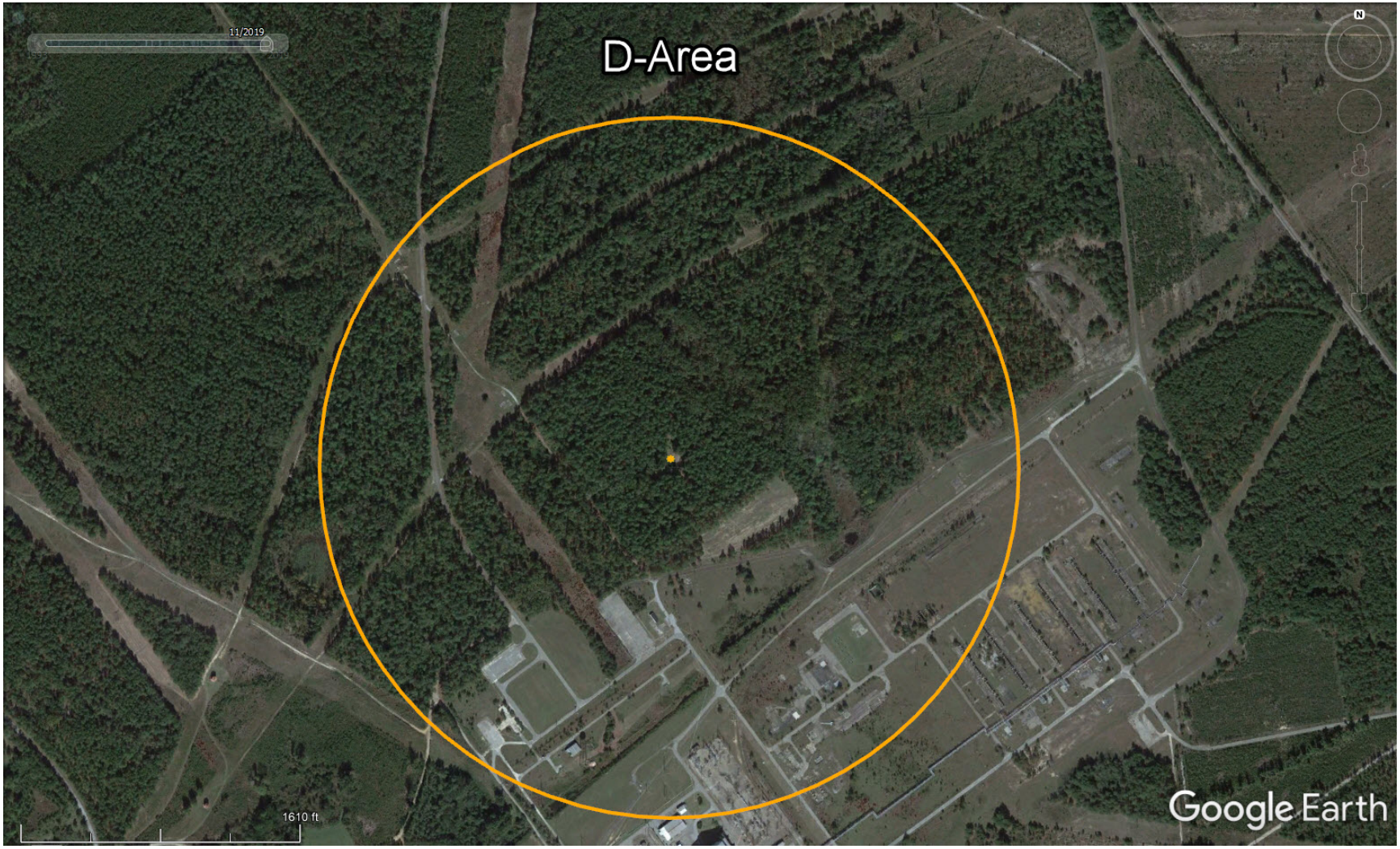

Figure 3-19. Google Earth Image from 11/1/2017 of D-Area Tower and Surrounding Area

F-Area

Since separations activities conducted in F-Canyon and FB-Line have been discontinued, the primary source of hazardous materials in F Area is the F Tank Farm. In addition, a new plutonium pit manufacturing facility is planned for F-Area. The F-area tower facility is located to the southwest of the old canyon building complex at 33° 15' 49" N, 81° 33' 48" W (Plant coordinates N 76,769.0, E 50,792.4) at an elevation of 88 m ASL. The proximity of the SRS burial grounds (E-area) also increases the importance of the F-area tower. In 2016, F-area had a tipping bucket rain gauge added to an area adjacent to the tower at ground level (see Ch. 7 for details). As a result, a second CR1000 data logger is used at the F-Area tower for data acquisition. The physical layout of the F-Area tower is shown in Figure 3-20.

The forest canopy within 2000 ft of the F-area tower contains breaks due to roads and buildings (see Figure 3-21). These breaks are evenly distributed in all quadrants. The terrain slopes gently from northwest to southeast. Instrumentation is directed to the west.

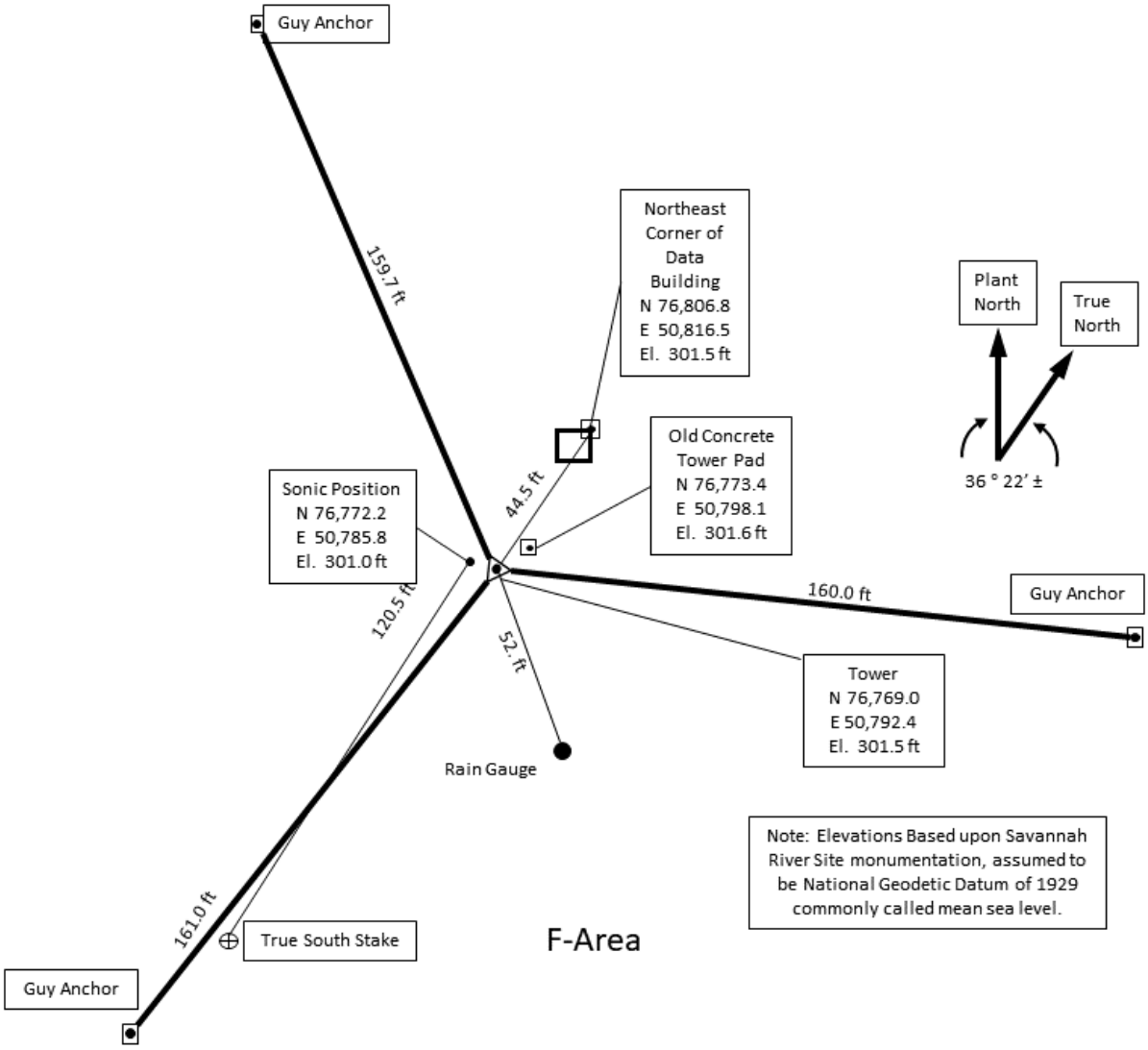

Figure 3-20. F-Area Tower Facility Diagram

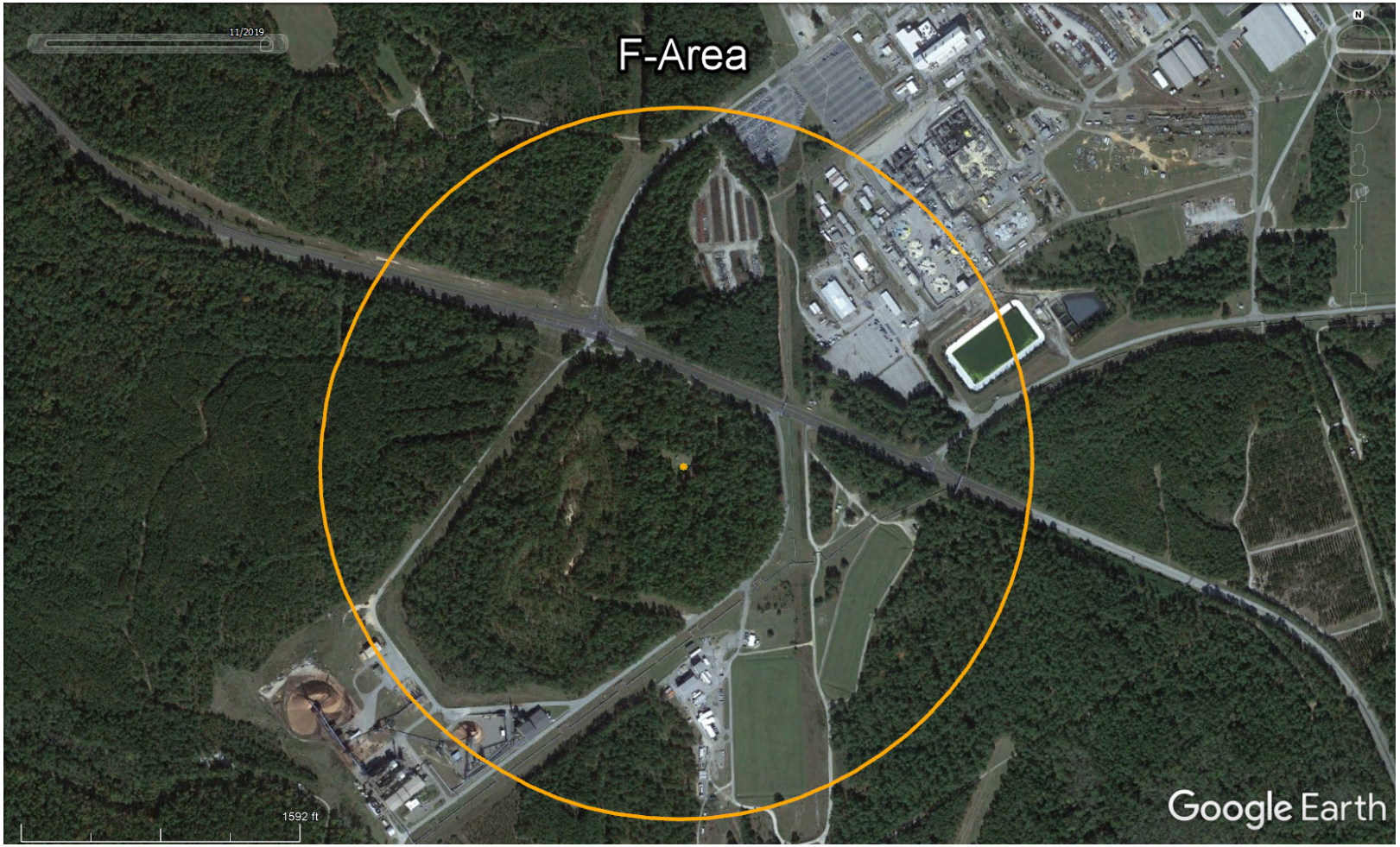

Figure 3-21. Google Earth Image from 11/1/2017 of F-Area Tower and Surrounding Area

H-Area

H-area is the site for processing tritium in the Tritium Facilities and spent nuclear fuel in H-Canyon. Potential tritium releases are a major concern for this area. The H-area tower facility is located at 33° 17' 09" N, 81° 36' 54" W (Plant coordinates N 68,835.9, E 66,775.6) at an elevation of 91 m ASL to the east of the main building complex. The H-area tower also provides a representative data for the H-Area Tank Farm, S-Area (DWPF), Z-Area (Saltstone facility and storage vaults), and the Salt Waste Processing Facility (J Area). This tower was previously located to the west of the present site but was moved in 1984 because of construction and forest removal. The physical layout of the H-Area tower is shown in Figure 3-22. The H-Area tower also is equipped with a visibility sensor mounted on the tower. The CR1000 data logger at the H-Area tower was replaced with a CR1000x in the spring of 2019 to eliminate the need to utilize a custom external voltage bridge for performing visibility sensor calibrations.

The forest canopy within 2000 ft of the tower is nearly completely intact except for a small area to the extreme southwest of the tower (see Figure 3-23). Meteorologically, this tower provides the most representative data for flow over the forest canopy regardless of wind direction due to the completeness of the canopy. The terrain slope is negligible. Instrumentation is directed west.

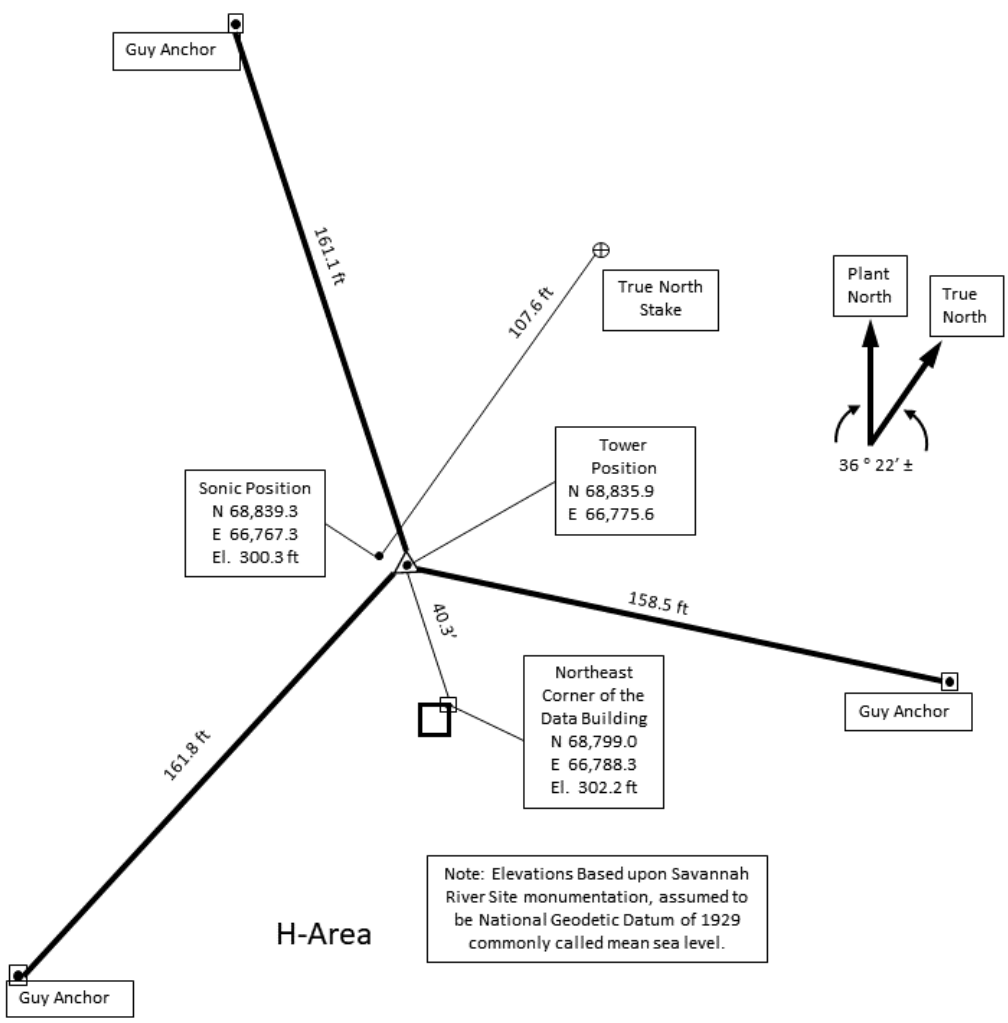

Figure 3-22. H-Area Tower Facility Diagram

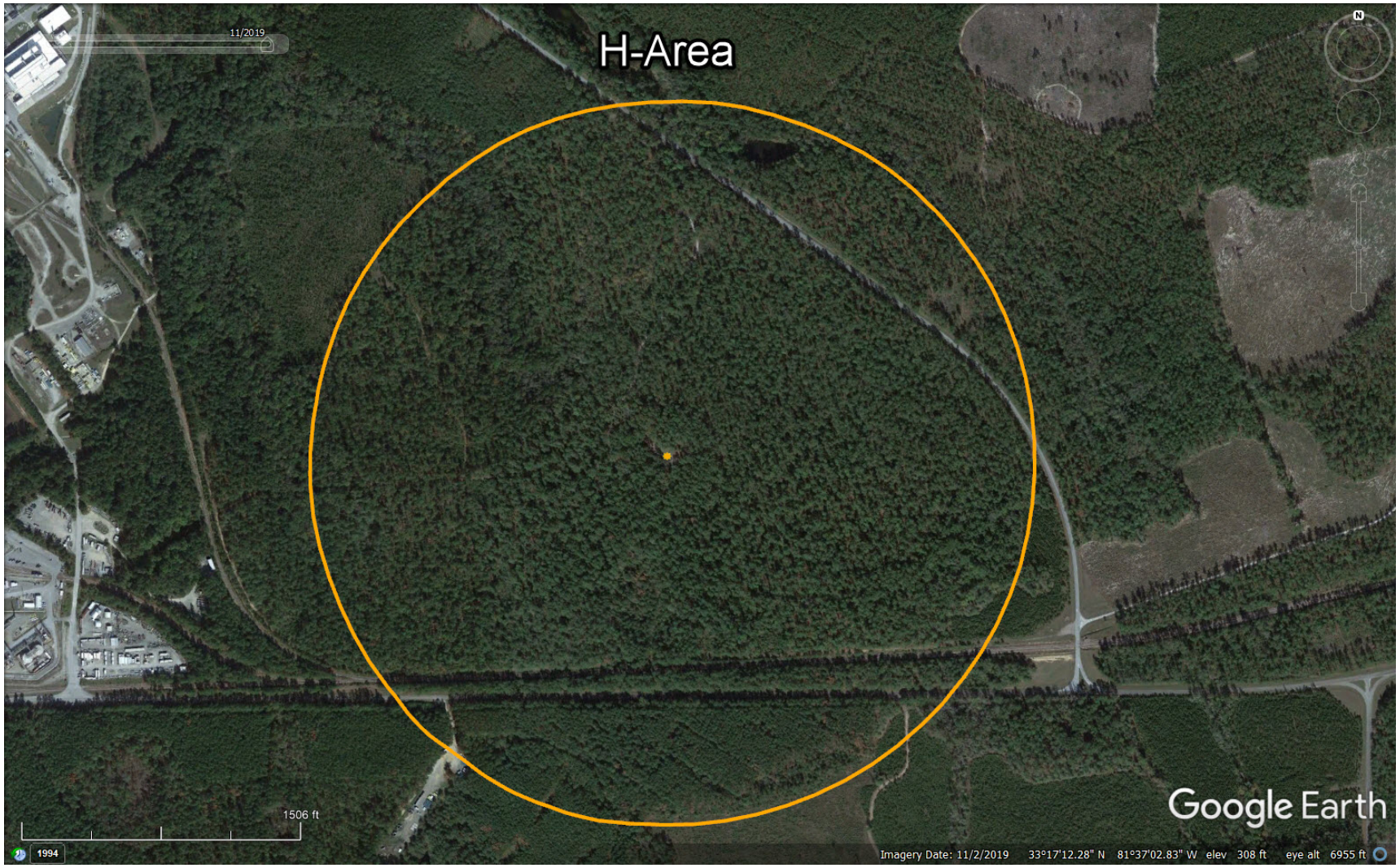

Figure 3-23. Google Earth Image from 11/1/2017 of H-Area Tower and Surrounding Area

K-Area

K-area was previously the site of the K production reactor at SRS and meteorological monitoring at this site characterized dispersion for potential releases from the reactor stack or filters. The K reactor was shut down permanently in 1996; however, in 2000 the building was converted for long-term storage of spent nuclear fuel. The K-area tower facility is located at 33° 12' 14" N, 81° 36' 46" W (Plant coordinates N 51,712.39, E 41,285.51) at an elevation of 81 m ASL to the south of the complex. The physical layout of the K-Area tower is shown in Figure 3-24. Data acquisition is performed with the CR1000 data logger.

The forest canopy within 2000 ft of the K-area tower is generally full in all directions except to the north where a considerable portion of the radius zone falls into the building complex (see Figure 3-25). The terrain slope is negligible. Instrumentation is directed west.

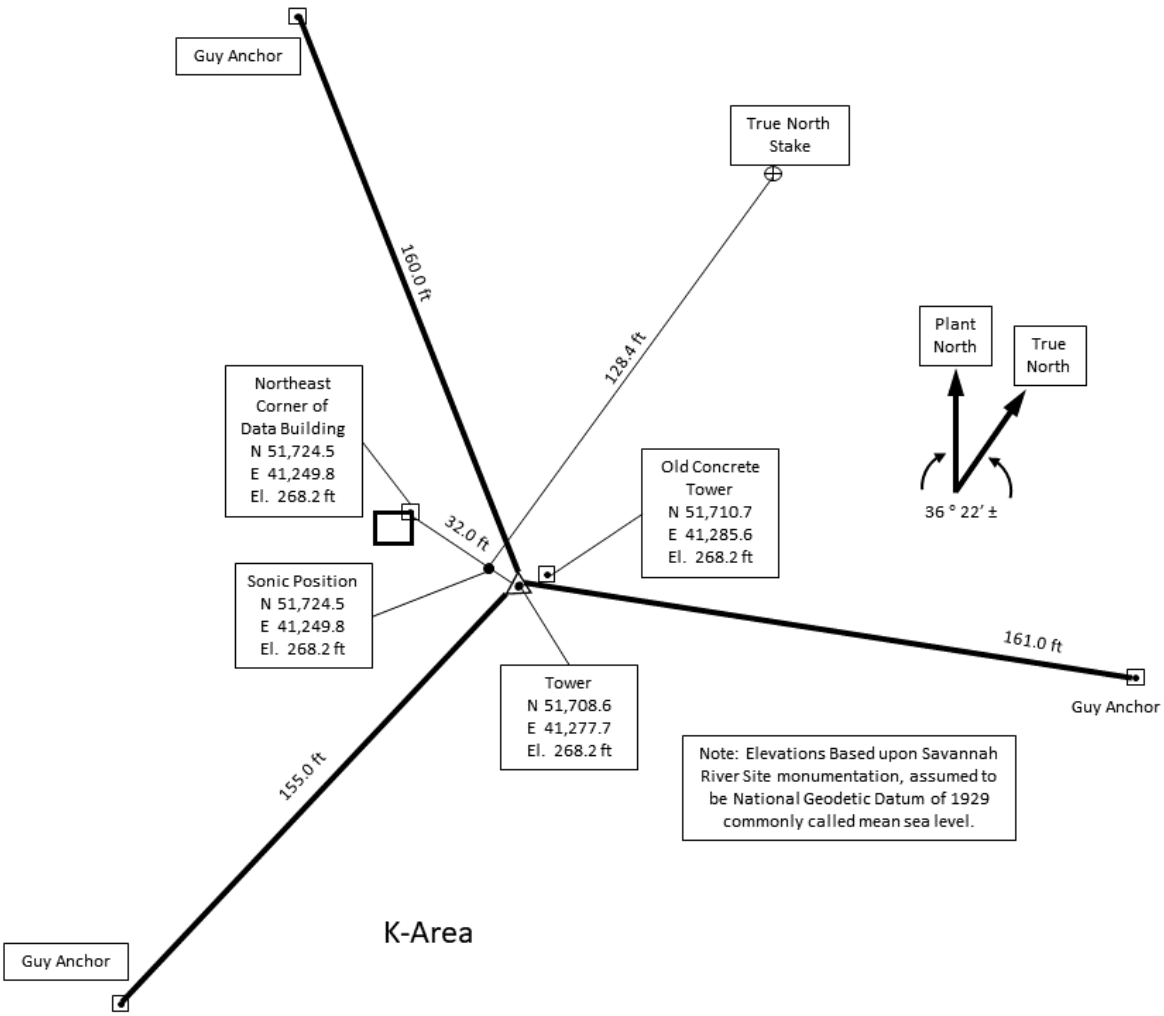

Figure 3-24. K-Area Tower Facility Diagram

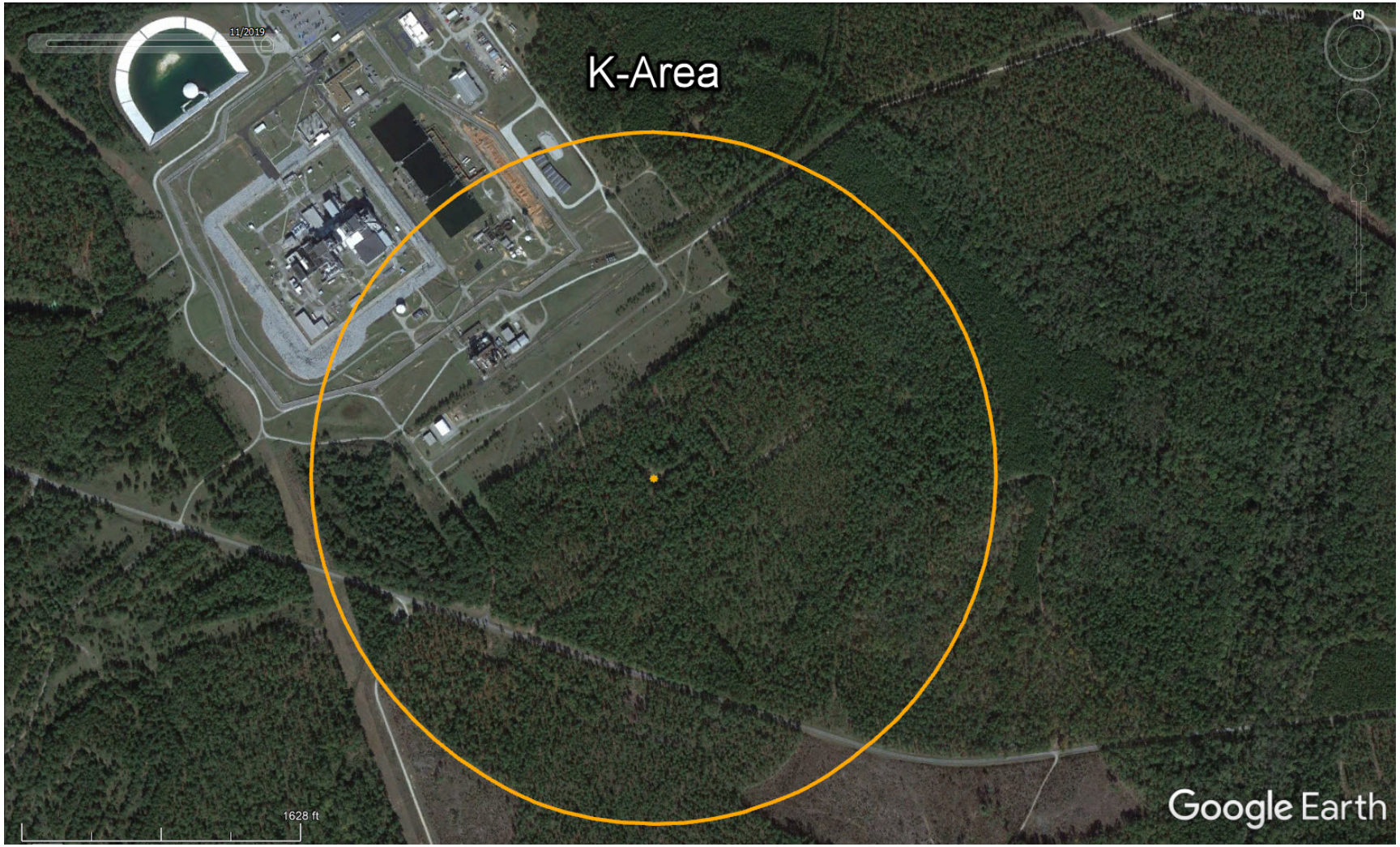

Figure 3-25. Google Earth Image from 11/1/2017 of K-Area Tower and Surrounding Area

L-Area

L-area was previously the site of the L production reactor at SRS and meteorological monitoring at this site characterized dispersion of potential releases from the reactor stack or filters. The L reactor was shut down permanently in 1991; however, like K reactor, the building was converted for spent nuclear fuel storage.

The L-area tower facility is located at 33° 13' 11" N, 81° 38' 50" W (Plant coordinates N 46,654.0, E 53,193.9) at an elevation of 85 m ASL to the east of the L-area complex. A 1000-acre cooling retention reservoir, L Lake, is located to the south-southwest of the L-area Tower. Under certain conditions, turbulence measurements may be lower compared to other towers due to a more laminar flow over L Lake. Normally, this phenomenon is only observed when a strong wind from the south-southwest arc is observed. The physical layout of the L-Area tower is shown in Figure 3-26. The L-Area tower also is equipped with a visibility sensor mounted on the tower. The CR1000 data logger at the C-Area tower was replaced with a CR1000x in the spring of 2019 to eliminate the need to utilize a custom external voltage bridge for performing visibility sensor calibrations.

The forest canopy within the 2000 ft radius zone of L-area tower is generally intact except for the area adjacent to the building complex (see Figure 3-27). The slope of the terrain is gentle from northwest to southeast. Instrumentation is directed to the south.

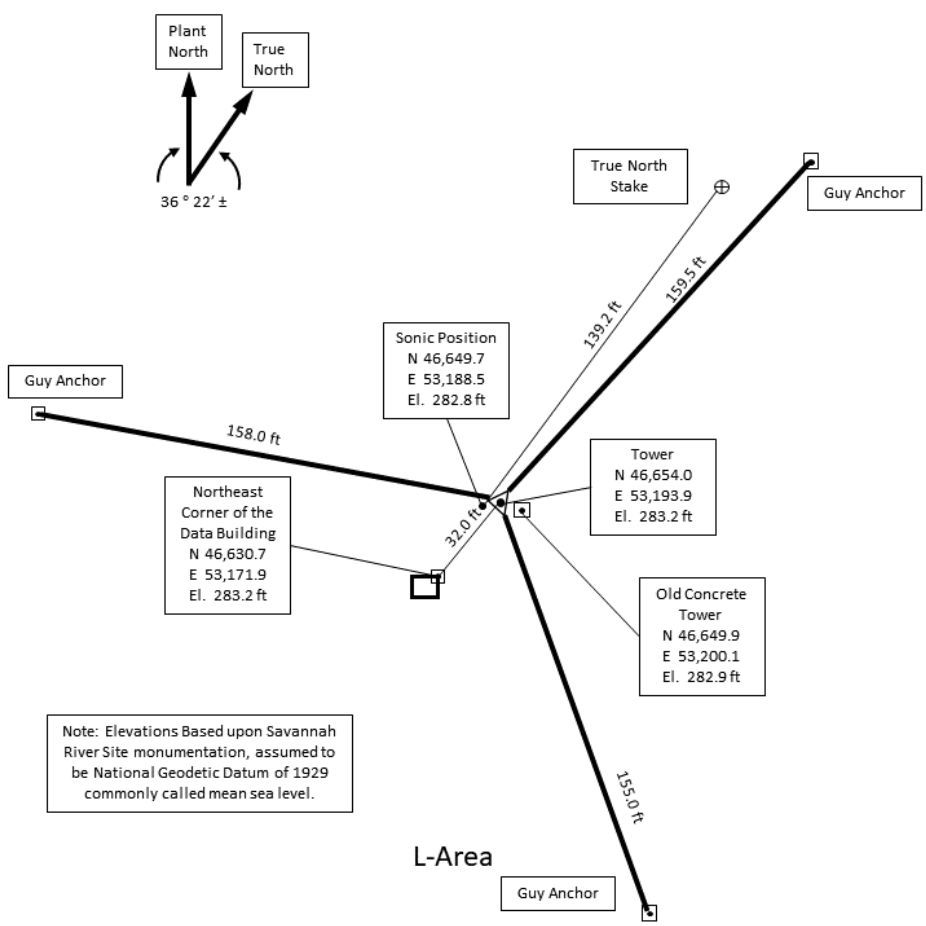

Figure 3-26. L-Area Tower Facility Diagram

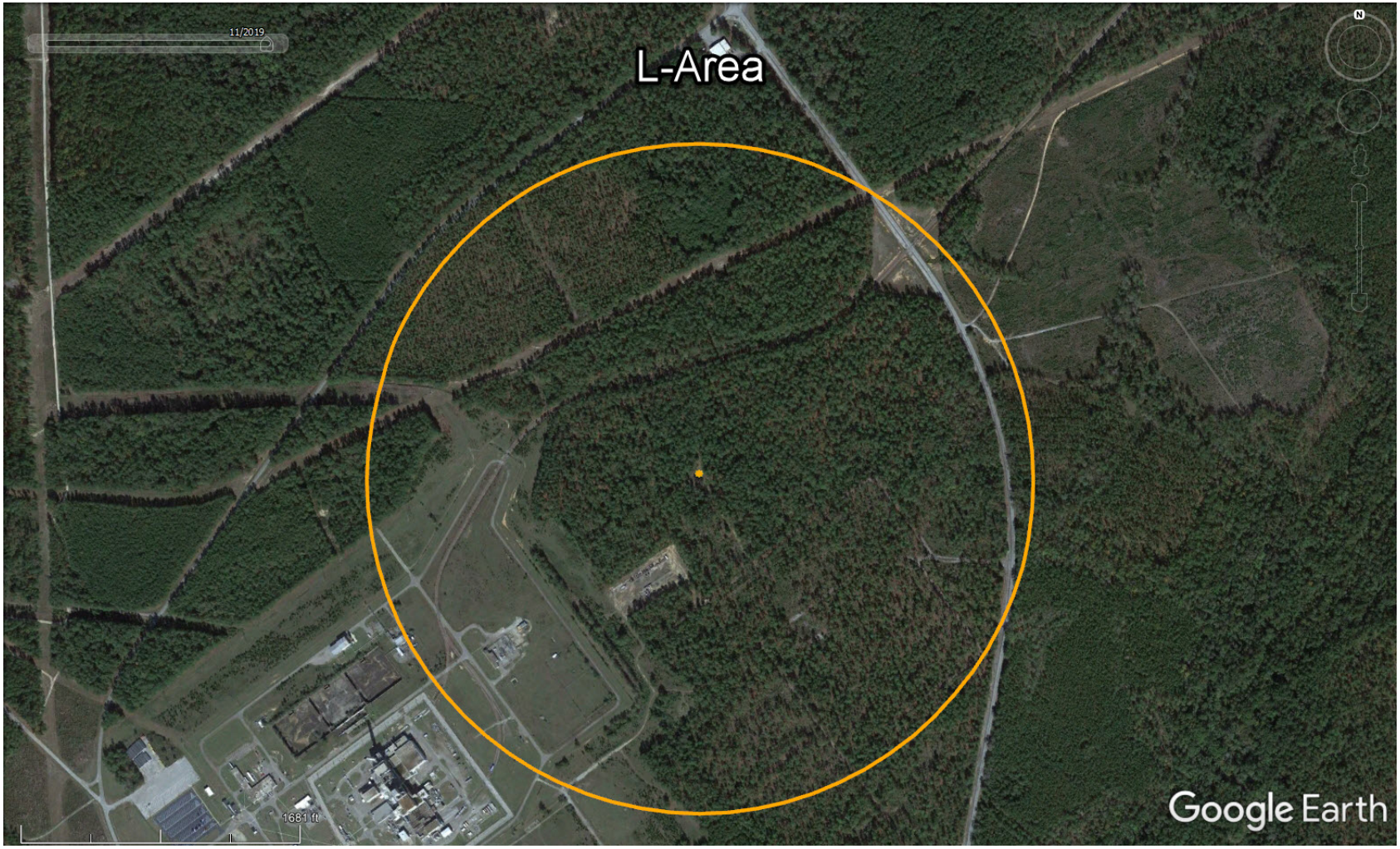

Figure 3-27. Google Earth Image from 11/1/2017 of L-Area Tower and Surrounding Area

P-Area

P-area, like K and L areas, was previously the site of a production reactor at the SRS. Meteorological monitoring at this site was originally done for potential releases from the reactor stack or filters. The P reactor was shut down in 1988 and since then P-area has been grouted and closed. The P-area tower facility is located at 33° 14' 25" N, 81° 41' 11" W (Plant coordinates N 41,448.8, E 66,330.3) at an elevation of 93 m ASL to the southeast of the P-area building complex. The physical layout of the P-Area tower is shown in Figure 3-28. Similar to L, turbulence measured at P-area can be lower due to the proximity of Par Pond, a cooling retention reservoir. This phenomenon normally occurs only with a strong northeast wind and is not likely to be as pronounced as L-area since the lake is farther from P-area tower. The P-area tower is located the farthest east of any Area Tower and represents an important data point when creating spatially averaged means of meteorological variables. Data acquisition at the P-Area tower is performed with a CR1000 data logger.

The forest canopy within 2000 ft of the P-area tower is generally full to the east and south (see Figure 3-29). The canopy is more broken to the north and west with the P-area building complex to the northwest. The terrain slope is gentle from northwest to southeast. Instrumentation is directed west.

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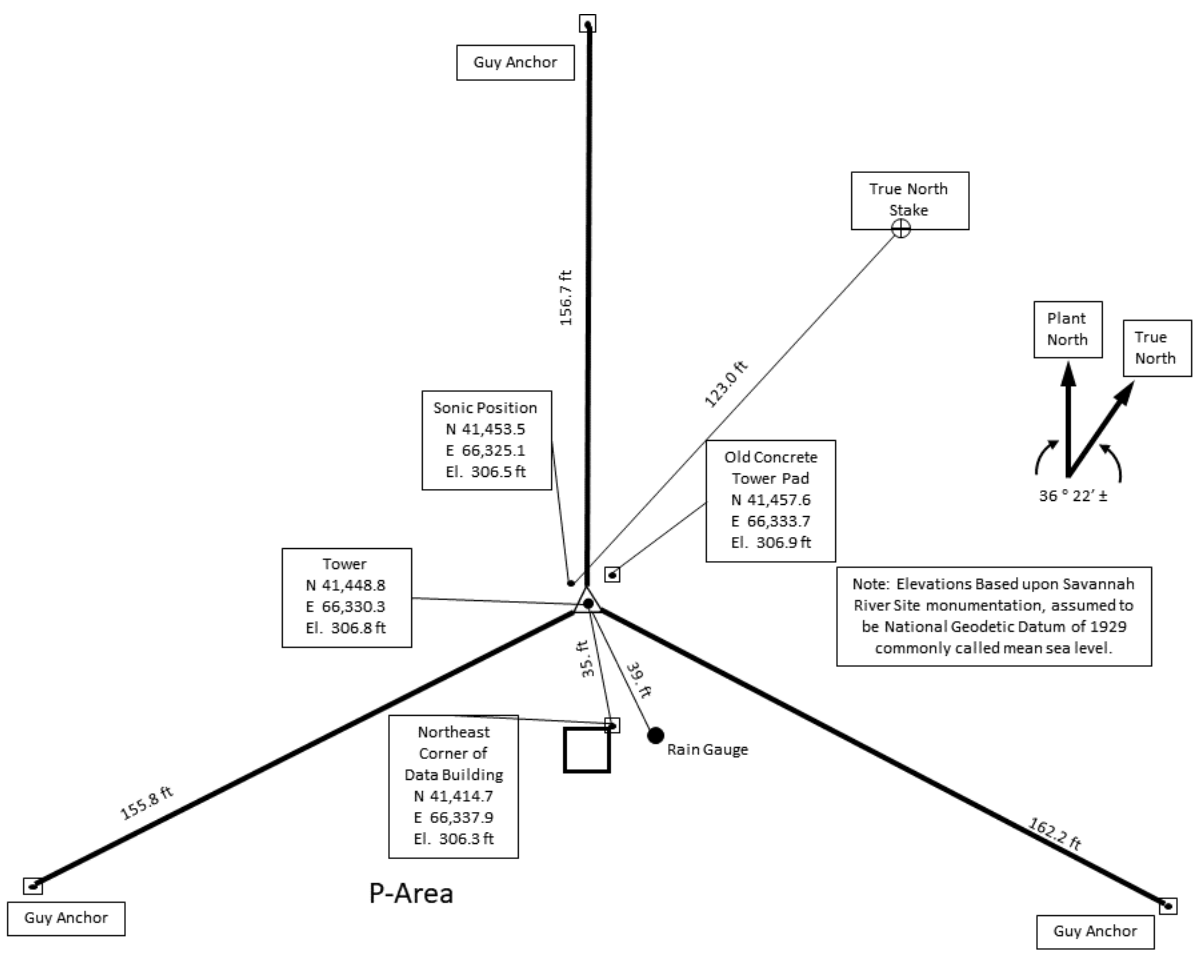

Figure 3-28. P-Area Tower Facility Diagram

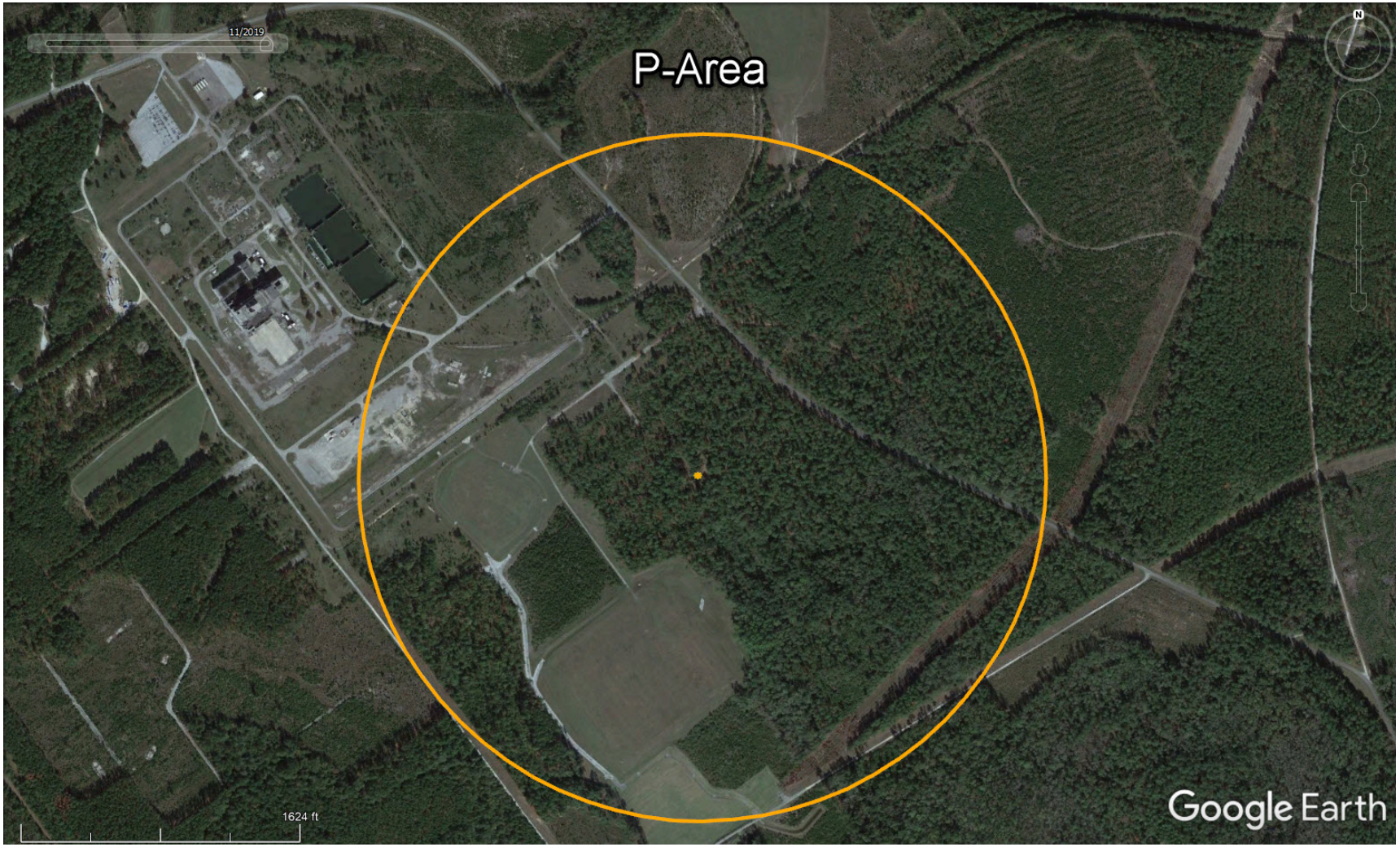

Figure 3-29. Google Earth Image from 11/1/2017 of P-Area Tower and Surrounding Area

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Chapter 4 - Tall Tower Monitoring System

Introduction

The tall tower monitoring system, residing on the WJBF/WAGT television transmitter tower in Beech Island, SC (Figure 4-1), is a multi-purpose observational resource that supports boundary layer research, SRS applied meteorology programs, and emergency response. The unique nature of this facility has fostered development of partnerships including the University of Georgia and the National Oceanic and Atmospheric Administration (NOAA). With instruments located up to 328m above ground, tower measurements capture evolving boundary layer processes, particularly during nocturnal and transitional periods near sunrise and sunset. The measurements also provide a temperature profile of the atmosphere which can play an important role in describing and predicting winter weather hazards such as freezing rain.

ATG maintains instrumentation at three levels: 33m, 68m, and 328m AGL, (Figure 4-2). Observations from these instruments are important in identifying key near-surface phenomena such as the development of the atmospheric boundary layer through convection following sunrise and the formation of low-level inversions and jets following sunset. Tall tower measurements began in the mid-1960s when the original WJBF tower was equipped with meteorological instrumentation as part of a reactor safety study related to tall-stack-effluent monitoring. These measurements were formally incorporated into ATG's meteorological monitoring program in the early 1970s to support emergency response, operational atmospheric modeling, and research and development. The instrumentation was removed from the original tower in 1998 when the tower was abandoned by WJBF for a replacement tower adjacent to the original. ATG later received funding to install instrumentation on the new tower which was completed in 2004 (Parker 2003). The tower instrumentation configuration is being updated at the time of this writing (2020) in order to replace failing equipment.

Historical Perspective

Meteorological instrumentation was first installed on the WJBF-TV tower in October 1965 with measurements taken at several levels up to 366 m above ground to study the behavior of effluent from a proposed 260 m reactor facility stack at SRS. (Cooper and Rusche, 1968). Continuous data were collected between 1966 and 1968 and then intermittently through 1972 (Pendergast, 1975). Data were recorded on 'punch tape' until a Datacom digital acquisition system was purchased and installed in 1973. This system was updated in 1983, when new equipment was installed with identical instruments at six levels up to 304 m. Data collection continued until 1998 when WJBF replaced this tower with a new taller tower equipped with high definition TV transmitters. In the early 2000s, ATG was funded to begin development of a meteorological monitoring system for the new tower. The new system became operational in 2004 with state-of-the-science instrumentation, providing data of interest to the regional and national community. In 2008, ATG partnered with NOAA's Global Monitoring Division to establish the "South Carolina Tower" (SCT) site for measuring trace greenhouse gasses. This is the only such 'tall tower' site in the Southeastern US, a critical region for carbon flux studies, as carbon uptake by the prevalent pine forests are a major factor in North American carbon budgets.

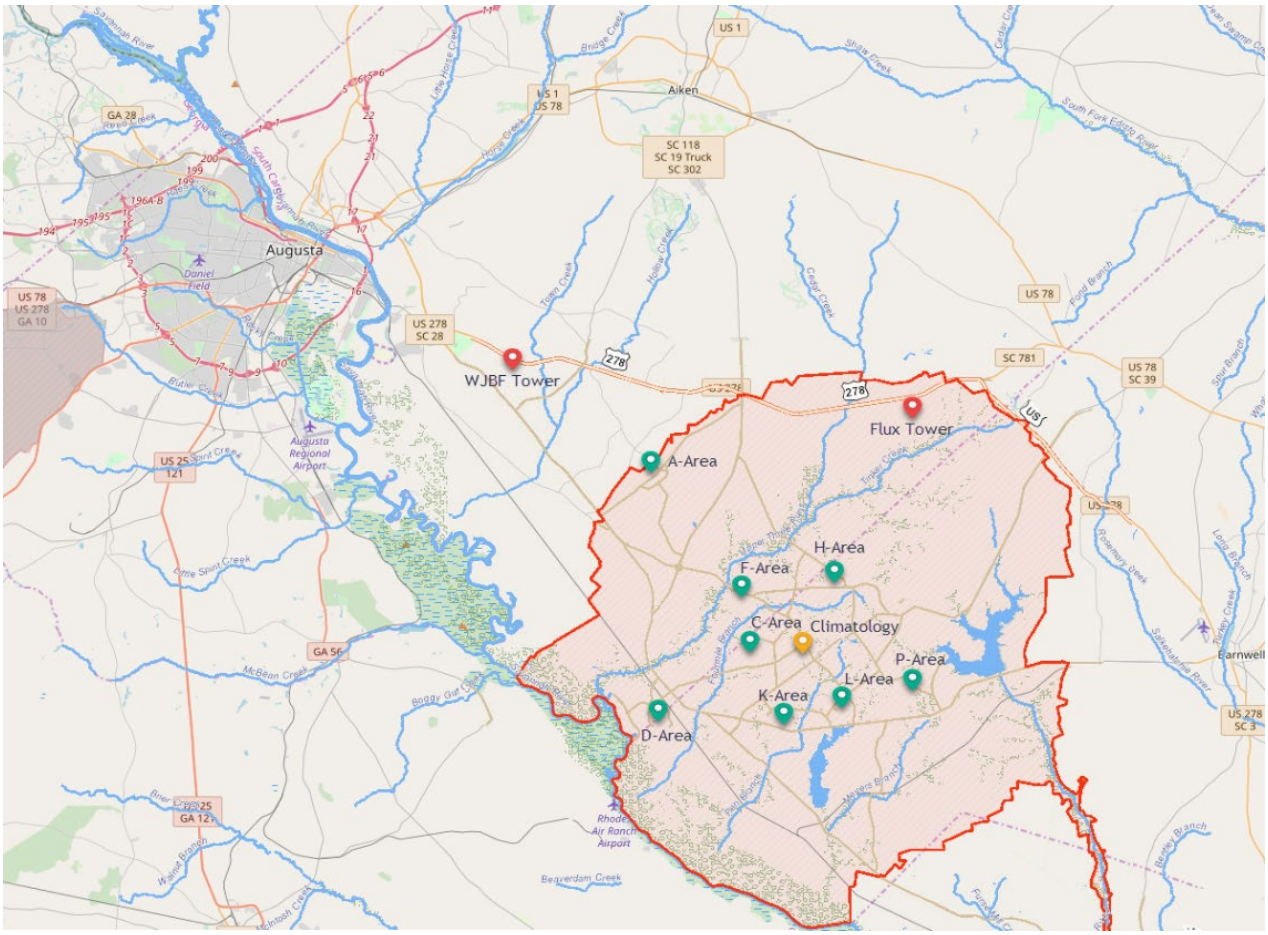

Figure 4-1. Map Showing the Location of the Tall (WJBF) Tower

The original TV tower monitoring system consisted of Climet cup anemometers, vanes, and bivanes along with Rosemont temperature probes. Most recently, sonic anemometers were deployed on the new tower for capturing wind speed, wind direction, and associated turbulence measurements, as well as CO_2/H_2O Infrared Gas Analyzers to provide data related to moisture and carbon fluxes. A history of measurements at the Tall Tower is summarized in Table 4-1.

Tower Description and Facility Layout

The Tall Tower facility is located near Beech Island, SC, approximately 10 km northwest of SRNL at 33.4058°N, 81.8336°W. The facility consists of the tower, a walk-up metal lattice for accessing the tower, two buildings that house the operational capabilities of the TV stations which utilize the tower, and a small data trailer located under the latticework which houses the instrumentation and computers supporting NOAA's Carbon Tracker program. The new TV tower is equipped with an elevator system that is utilized by professional tower climbers to perform maintenance.

Access to the tower is restricted and a limited number of keys have been provided from the site property owners for access to the grounds. Any work that is required to be performed on the tower requires notification of the site's operations personnel to ensure they are aware of ongoing work.

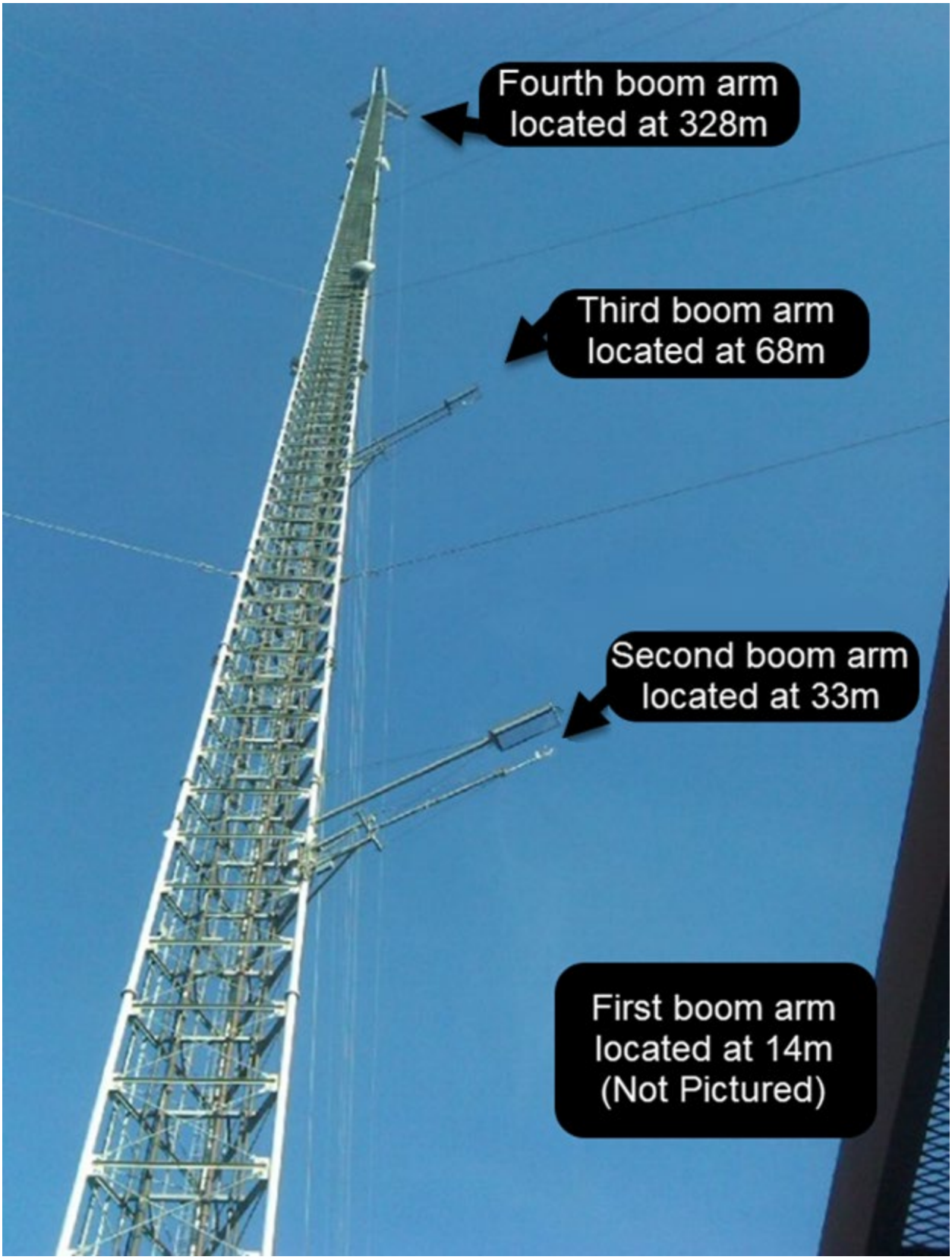

Figure 4-2. Tall Tower Instrumentation and Boom Arm Orientation

Table 4-1. Historical Summary of TV Tower Instrumentation

	1965 - 1973	1973 - 1983	1983 - 1998	2004 - 2020	2020 - Present
Wind Speed	37, 91, 137, 183, 244, 304	33+, 37, 91, 137, 183, 244, 304	18#, 37, 91, 137, 183, 244, 304	33, 68, 328	14, 33, 68, 328
Wind Direction	37*, 91, 137, 183*, 244, 304	33+, 37, 91, 137, 183, 244, 304	18#, 37, 91, 137, 183, 244, 304	33, 68, 328	14, 33, 68, 328
Temperature	3, 37, 91, 137, 183, 244, 304, 335, 366	33+, 37, 91, 137, 183, 244, 304, 335	2#, 18#, 37, 91, 137, 183, 244, 304	33, 68, 328	14, 33, 68, 328
Relative Humidity	N/A	N/A	N/A	33, 68, 328	14, 33, 68, 328
Water Vapor	N/A	N/A	N/A	33, 68, 328	14, 33, 68, 328
Carbon Dioxide	N/A	N/A	N/A	33, 68, 328	14, 33, 68, 328

* Measured by a standard wind vane, all other measurement performed by bivane.
+ Measurements taken from a 10m tower located approximately 250 ft from the TV tower base
# Measurements taken from a separate Rohn lattice tower located approximately 20 ft from the TV tower base.

Figure 4-3 shows the tower is located in a heterogenous landscape with a mix of pine forest and small farms and isolated subdivisions. More significant urbanization associated with Augusta, GA is approximately 10 km west of the tower.

Instrumentation

Instrumentation to Support SRNL's Applied Meteorology Program

Instrumentation is located on booms extending 24 feet from the tower and oriented at 209° azimuth with sampling levels of 33, 68, and 328 m above ground. An additional set of instrumentation is located at 14 m on top of the Rohn lattice platform, approximately 20 ft from the TV tower base. The instrument boom was constructed by Kline Iron and Steel Company in Columbia, SC. An ice shield is located above the meteorological instruments at each boom level to protect the instruments from ice which may fall upon from the upper portions of the tower (Figure 4-2).

The tower is instrumented to collect wind, temperature, barometric pressure, relative humidity, water vapor and CO_2. Fast response sonic anemometers are used to measure winds, turbulence and temperature. Also utilized are fast-response water vapor, barometric pressure sensors, slow response temperature and relative humidity sensors.

Instrumentation to Support NOAA's GMD Program

The trace gas sampling system (Andrews et al. 2014) operated in partnership with by NOAA's Global Monitoring Division for the Carbon Tracker program, consists of Teflon sample lines extending from each of the three instrumented levels on the tower (33, 68, and 328 m) into gas analyzers located within the data trailer located near the base of the tower (Figure 4-4). Samples are taken approximately every-other day at 1930 UTC. A Picarro analyzer owned by SRNL is also used to collect CO, CO_2, and CH_4 measurements which are transmitted to NOAA in real time. These measurements are taken every 30 minutes and are available upon request to the current NOAA program coordinator or through the Earth System Research Laboratory, Global Monitoring Division website.

Figure 4-3. A Depiction of Land Use in the Vicinity of the Tower

Summary of Instrumentation

Data Collection and Transmission

A Campbell Scientific CR-3000 Datalogger is placed at each level to collect 10 Hz data from each instrument at that level (Figure 4-5). The data is sent back to SRNL through wireless modems operating on a 4G network using Campbell Scientific CELL210 modems to send and receive the data. Data is stored in ATG's meteorological data base.

The CR3000 is a microprocessor controlled "Micrologger" consisting of measurement and control electronics, communication ports, 16-character keyboard, display, power supply, and carrying handle. The on-board operating system includes instructions that allow the user to monitor the incoming data and modify the program if necessary. The programming language, CRBasic, uses a BASIC-like syntax.

The data logger's settings not only allow users to control basic pulse/frequency counting and analog to digital conversions but control the

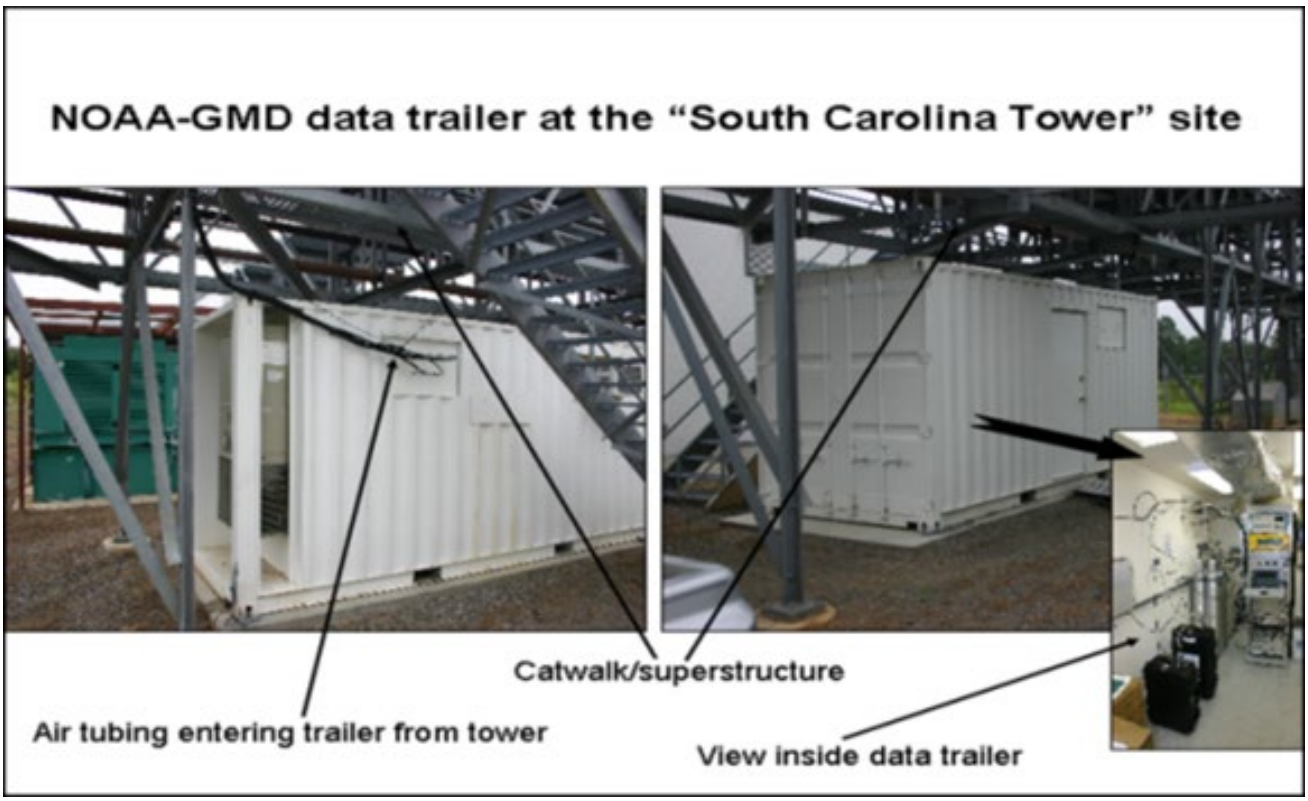

Figure 4-4. The Data Trailer Located at the Base of the Tall Tower

The trailer houses instrumentation used by NOAA-GMD to collect gas samples from the same levels as the meteorological instrumentation.

Figure 4-5. Campbell Scientific CR3000 Datalogger

specific voltage ranges, bridge configurations, thermocouples, and other basic signal processing

Processing instructions support algebraic, statistical (such as averaging), and transcendental functions for on-site processing. It suspends execution when primary power drops below 9.6V, reducing the possibility of inaccurate measurements. An internal, on board battery will continue to retain internal memory to store data should main power be lost. For more information on specifications, circuitry, or maintenance, please refer to Campbell Scientific CR3000 Operator's Manual and the CR3000 Specifications Sheet (Table 4-2 and Figure 4-6).

Measurements from the TV Tower include the 10 Hz data and 15-minute averages of three-dimensional winds and temperature from Campbell Scientific's CSAT3B Sonic Anemometer as well as CO_2 and H_2O measurements from the Li-Cor 7500 infrared gas analyzer. The raw data is used to calculate other values of interest, including standard deviations of wind speed and direction, friction velocity, and fluxes of heat, CO_2, and H_2O.

Table 4-2. Description of the Parameters Used by the Campbell Scientific CR 3000 Datalogger

Specification	Description
Operating Temperature Range	-25° to +50°C (standard) -40° to +85°C (extended)
Analog Inputs	28 single-ended or 14 differential (individually configured)
Pulse Counters	4
Voltage Excitation Terminals	4 (VX1 to VX4)
Communications Ports	CS I/O RS-232 Parallel peripheral
Switched 12 Volt	2 terminals
Digital I/O	Certain digital ports can be used to count switch closures. 3 SDM and 8 I/Os or 4 RS-232 COM I/O ports can be paired as transmit and receive for measuring smart serial sensors.
Input Limits	± 5 Vdc
Analog Voltage Accuracy	± (0.04% of reading + offset) at 0° to 40°C
ADC	16-bit
Power Requirements	10 to 16 Vdc
Idle Current Drain, Average	2 mA (@ 12 Vdc)
Active Current Drain, Average	3 mA (1 Hz sample rate @ 12 Vdc without RS-232 communication) 10 mA (100 Hz sample rate @ 12 Vdc without RS-232 communication) 38 mA (100 Hz sample rate @ 12 Vdc with RS-232 communication)
Dimensions	24.1 x 17.8 x 7.6 cm (9.5 x 7.0 x 3.0 in.) with low-profile base
Weight	1.6 kg (3.6 lb) with low-profile base 3.8 kg (8.3 lb) with alkaline battery base 4.8 kg (10.7 lb) with rechargeable battery base

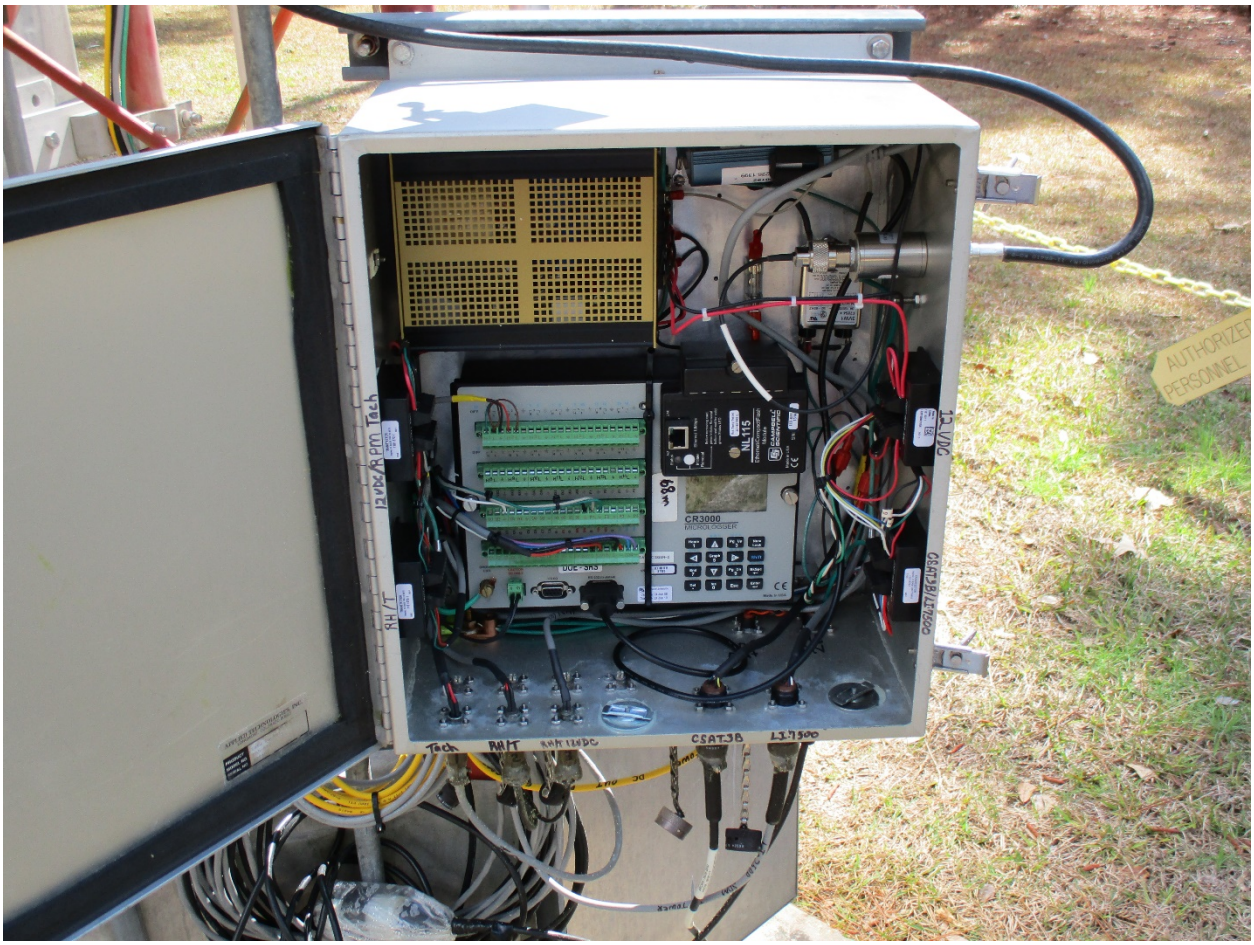

Figure 4-6. TV Tower Datalogger for New Configuration

Sonic Anemometers

Campbell Scientific Inc.'s CSAT-3B 3-D sonic anemometers (Figure 4-8) are operated at each level of the Tall Tower. Data from the anemometers are used to provide three-dimensional winds, standard deviations of the wind in each direction, sonic virtual temperatures, and fluxes of momentum and heat in each direction.

The CSAT-3B has a 10-cm vertical measurement path and operates in a pulsed acoustic mode. Three orthogonal wind components (u_x, u_y, u_z) and the sonic virtual temperature (T_s) are measured and output at a maximum rate of 100 Hz. The CSAT3B mounting box contains the electronic components allowing for easy installation and flexibility in instrument placement, while minimizing the aerodynamic wake from the instrument in the measurement path. Measurements are triggered by commands from the datalogger via the SDM communication between the sensor and the datalogger. An integrated inclinometer allows for the alignment of the instrument during installation and calibration, as well as to determine if the boom arm and instrument are being excited by high winds. Instrument specifications are summarized in Table 4-3.

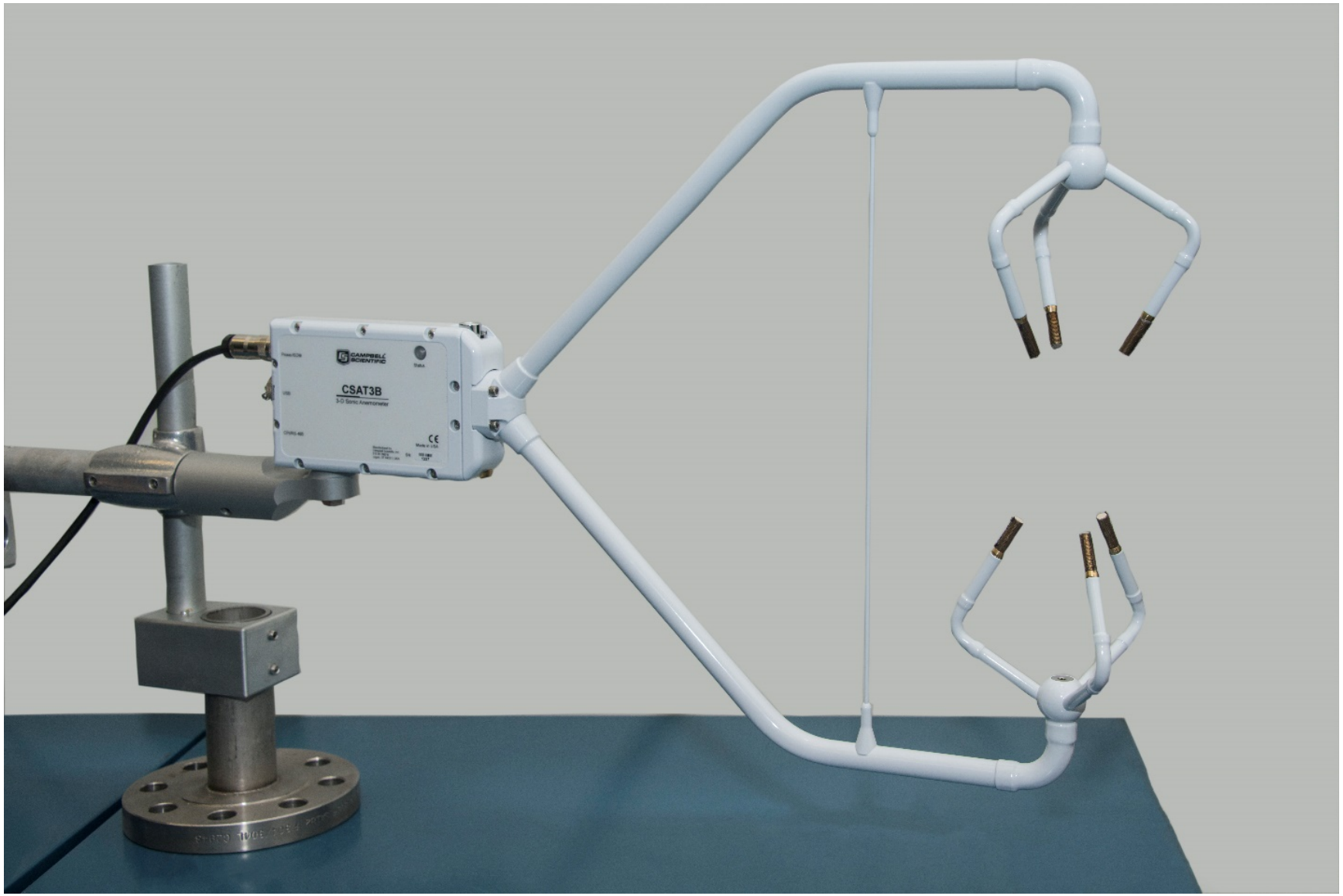

Figure 4-7. Campbell Scientific's CSAT3B Sonic Anemometer

Table 4-3. Specifications for CSAT3B Sonic Anemometer

Specification	Description
Path Angle from Horizontal	60°
Operating Temperature Range	-30° to +50°C
Voltage Supply	10 to 16 Vdc
Current	200 mA (60 Hz) 100 mA (20 Hz)
Digital SDM Output Signal	CSI 33.3 k baud serial interface for data logger/sensor communication. (Data type is 2-byte integer per output plus 2-byte diagnostic.)
Anemometer Head Dimensions	47.3 x 42.4 cm (18.6 x 16.7 in.)
Anemometer Head Weight	1.7 kg (3.7 lb)
Electronics Box Dimensions	26 x 16 x 9 cm (10.24 x 6.3 x 3.54 in.)
Outputs	ux, uy, uz, c
Measurement Rate	Programmable from 1 to 60 Hz, instantaneous measurements. Two over-sampled modes are block averaged to either 20 Hz or 10 Hz.
Wind Direction Accuracy	±0.7° at 1 m/s (for horizontal wind)
Baud Rate	9600, 19200 bps
Data Type	2-byte integer per output plus 2-byte diagnostic
Number of Outputs	4
Voltage Range	±5 V
Full-Scale Wind	±65.535 m/s autoranging between four ranges (Least significant bit is 0.25 to 2 mm/s.)
Speed of Sound	300 to 366 m/s (-50° to +60°C) Least significant bit is 1 mm/s (0.002°C).
ux, uy, uz, c	(±30 m s-1, ±60 m s-1), (±30 m s-1, ±60 m s-1), (±8 m s-1), (300- 366 m s-1)

Tidbits

Tidbit temperature sensors (Figure 4-8) have been installed at 10 levels on the Tall Tower for special field projects in 2011/2012 and 2018/2019. Tidbit is a trademark name of a temperature/data logger made by the Onset Corporation. The sensors are 3 cm in diameter and 2 cm thick and weigh 20 gm. They are sealed and accessed with a PC via an optical link. The sensor is programmable to collect up to 42,000 12-bit thermistor temperature samples in time intervals of 1 sec to 18 hours (~ 10 months of 15-min averages). Accuracy is 0.2C with resolution of 0.02 to 0.15C, depending on the release version. A sealed battery provides ~5 years of operation before disposal. Its response time is 5 minutes in water and 12 minutes in moving air. ATG has used these sensors on the Tall Tower and for field data collections in water and open air.

Figure 4-8 Onset TidBit V2 Temp Logger

Water Vapor and CO_2

Water vapor and CO_2 measurements are made with an open path analyzer, the LI-7500DS. The fast-response water vapor sensor (Figure 4-9) is manufactured by Li-Cor, Inc. of Lincoln NE and uses non-dispersive infrared spectroscopy to measure CO_2 fluctuations and water vapor densities in air. Infrared radiation is transmitted through temperature-controlled optical filters, then through the open sample path to a thermally regulated lead selenide detector. Some of the infrared radiation is absorbed by CO_2 and water vapor in the sample path.

Figure 4-9. LiCor LI-7500DS with Optical Sensor

Table 4-4. LI-7500DS LiCor Specifications

CO_2 Measurements	
Calibration range	0 to 3000 µmol mol-1
Accuracy	Within 1% of reading
Zero drift (per °C)	±0.1 ppm typical ±0.3 ppm maximum
RMS noise	@10 Hz: 0.11 ppm
Gain drift (% of reading per °C @ 370 ppm)	±0.02% typical ±0.1% maximum
Direct sensitivity to H2O (mol CO2 mol-1 H2O)	±2.00E-05 typical ±4.00E-05 maximum
H2O Measurements	
Calibration range	0 to 60 mmol mol-1
Accuracy	Within 1% of reading
Zero drift (per °C)	±0.03 mmol mol-1 typical ±0.05 mmol mol-1 maximum
Noise (typical @ 10 mmol mol-1 H2O)	@10 Hz: 0.0047 mmol mol-1
Gain drift (% of reading per °C @ 20 mmol mol-1)	±0.15% typical ±0.30% maximum
Direct sensitivity to CO2 (mol H2O/mol CO2)	±0.02 typical ±0.05 maximum
General	
Fundamental Gas Sampling Rate: 150 Hz Bandwidth	5, 10, or 20 Hz; software selectable Type: Absolute, open-path, non-dispersive spectroscopy
Detector	Thermoelectrically cooled lead selenide Path Length: 12.5 cm (4.92")
Air Temperature Thermistor: 10K Ohm @ 25 °C Thermistor	
Measurement Range	-40 to 70 °C
Sensor Accuracy	±0.25 °C from -20 to 70 °C
Resolution	0.003 °C @ 25 °C
Pressure Sensor	
Measurement Range	20 to 110 kPa
Sensor Accuracy	±0.4 kPa from 50 to 110 kPa
Resolution	0.006 kPa
Outputs	Ethernet
Operating Temperature Range	-25 to 50 °C (-40 to 50 °C verification on request)
Relative Humidity Range	0-95% (non-condensing) Weatherproof Rating: Tested to IEC IP65 standard User Interface: Windows® PC software
Power Requirements	10.5 to 30 VDC
Head	
Size	Diameter 6.5 cm, Length 30 cm.
Weight	0.67 kg; 1.3 kg with mounting post. Head Cable Length: 200 cm
DSI Box	
Size	13.24 × 14.64 × 6.24 cm (H × W × D)
Weight	0.93 kg

Routine Facility Maintenance

The instruments on the TV tower are to be removed and tested by ATG specialists once each year. While the sonic anemometers can likely remain for longer periods of time without any significant drift, the chemical pack used by the Li-Cor sensors should be swapped out once a year to ensure accurate measurements of CO_2 and water vapor. Since the Li-Cor must be removed and serviced annually, and access to the tower is limited, standard practice is to remove and check the sonic anemometers as well. The tidbit temperature sensors are also swapped out once per year to prevent data loss since their data storage is limited to a little over one year.

The tower instrumentation can only be accessed by professional climbers, so any maintenance work must be coordinated with a contracted climbing company approved by the tower owner. This includes installation and removal of instruments on the tower, and any associated wiring and testing of the instruments and dataloggers.

Tall Tower Measurement Studies

Data from the tall tower has supported multiple research projects. In particular, the data is collected in partnership with NOAA is aggregated into a database with other tall tower sites from around the United States which is available for download. In 2018, over two hundred download requests that included data from the Aiken Tall Tower were made.

In May 2009, a comparison of tracer gas concentrations measured at the Tall Tower on weakly-stable and moderately stable nights was conducted to assess whether vertical transport of tracer gas was sufficient on either night for surface CO_2 emissions to be detected at the top of the tower (Werth et al. 2017). Changing stability was found to affect the rate of vertical transport, but vertical transport was observed on both nights over distances of up to 24 km. This study was funded by DOE's Office of Science. Additional analysis of tower measurements and model simulations performed by Kurzeja (2020) showed that nocturnal turbulence above the surface layer was more vigorous and variable than previously thought which explains the enhanced vertical transport of the tracer gas.

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Chapter 5 - Central Climatology Monitoring Facility

Introduction

The Central Climatology facility (CLM) was established in 1985 to provide data for developing a comprehensive description of the local climate, identifying conditions significant to worker and facility safety, and supporting ATG's applied research programs. The 61m tower at Central Climatology is equipped to measure wind, temperature and humidity at four levels of the tower (4-, 18-, 36- and 61-m), rather than the single level (61-m) at the Area Towers. In addition, CLM is equipped to measure solar radiation, atmospheric pressure, rainfall, evaporation wind profiles (via Windcube) and soil temperature nearby at ground level.

Facility Layout, Location, and Description

Central Climatology is located near the geometric center of the Site 33° 14' 43" N, 81° 39' 0" W (Plant coordinates N 61,307.5, E 51,477.1) with a base elevation of 155 m ASL (above sea level). The physical characteristics of CLM (tower type, anchors, grounding, winch system, and strobe) are nearly identical to the Area Towers (see description in Ch. 3). The tower stands in a flat, open, grass-covered field that is clear of any obstacles to distances of roughly 200 feet. Further out are scattered equipment and material lay-down areas (obstacle heights generally <6 ft), a few low structures, and finally pine tree stands at distances of about 600 ft hundred feet from the tower (Figure 5-2).

A small concrete pad located about 25 ft from the base of the tower is used as a level mount for a tipping-bucket rain gauge. An evaporation gauge and several radiometers are mounted within 20-30 ft of the concrete pad. A data building and adjacent storage shed are located 75 ft from the base of the tower. The data building is approximately 10 ft by 20 ft and houses signal processing and communication equipment as well as ample workspace. The storage building is used for spare parts and equipment.

Instrumentation

Configuration

Instrumentation is mounted on the end of a 2-m boom that extends toward the southeast, at elevations of 2 (temp/RH only), 4 (wind only), 18, 36 and 61-m above ground (wind and temp/RH) (Figure 5-1). The instruments installed at each of the 4 levels are the same as the Area Towers: A R.M. Young Model 81000 Sonic Anemometer and a R.M. Young Model 41382VC Temperature /RH Probe mounted in a R.M. Young Model 43502 aspirator. The specifications for these instruments are discussed in Chapter 3.

The instrumentation and mounting configuration of the 18-, 36- and 61-m levels of Central Climatology is on boom arms and crossarms that are identical to that at the 61 m level of the Area Towers. The lowest of the T/RH probes is mounted to a downward extension from the boom arm at 2-m. The sonic anemometer extends above the 2-m boom arm by an additional 2-m, making the actual measurement height 4-m (Figures 5-3 and 5-4).

The datalogger configuration at CLM is significantly different than at the Area Towers. To accommodate the volume of data collected by the sonic anemometers at four levels, there are 3 dataloggers. Two (2) of the dataloggers are the Campbell model CR3000, which is a more powerful version model of the CR1000/1000X. Each CR3000 controls and stores data from sonic anemometers and Temperature/RH probes at two levels. Levels 4- and 18-m are on one datalogger; levels 36- and 61-m are on the other datalogger. The third datalogger is a CR1000, which controls the slower response instruments at ground level. Specifications for the CR1000 and CR3000 dataloggers are summarized in Chapters 3 and 4, respectively.

Figure 5-1. Google Earth Image from 11/1/2017 of N-Area (Central Climatology) Tower and Surrounding Area

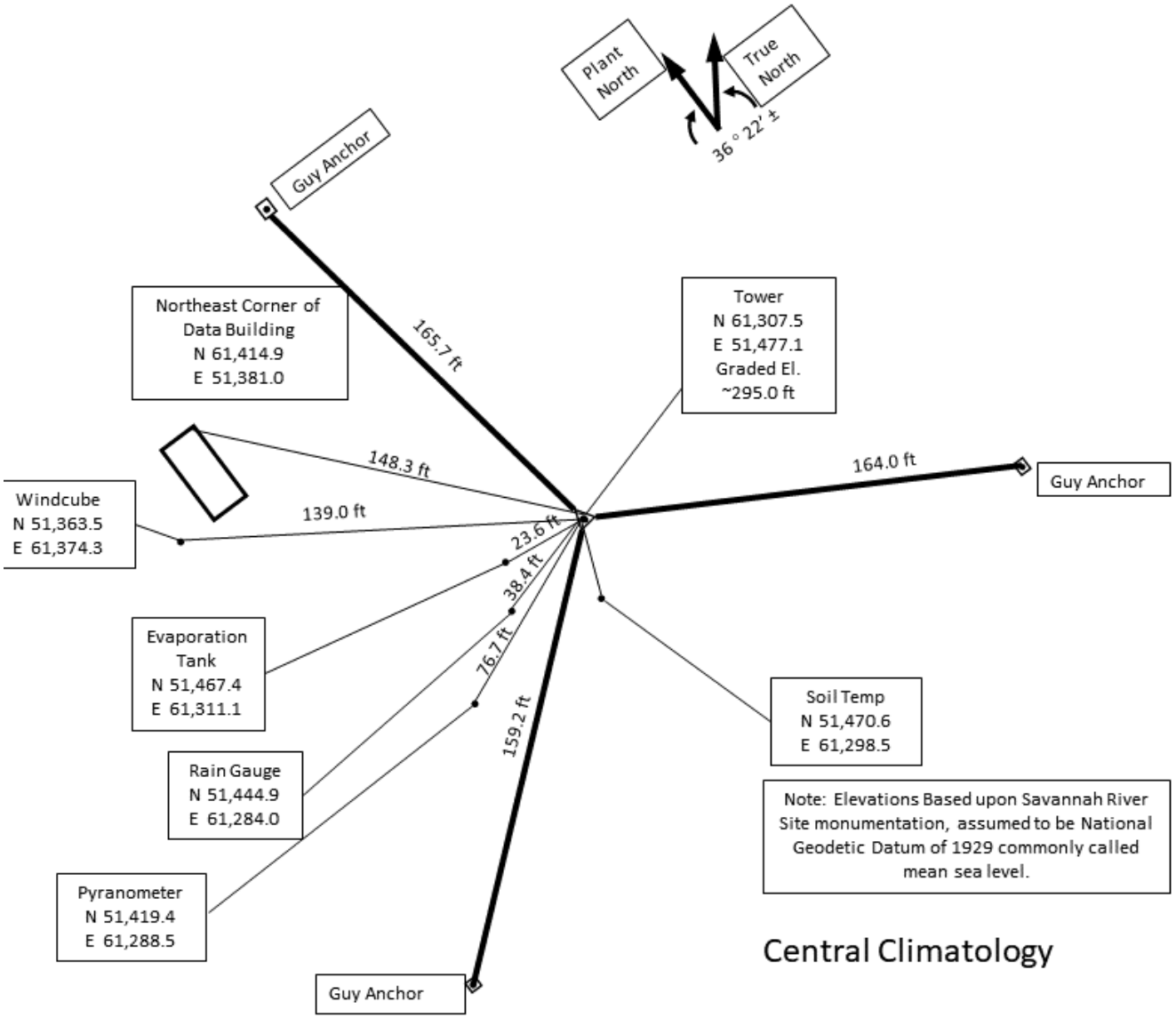

Figure 5-2. Central Climatology Tower Facility Diagram

Figure 5-3. Top Two (Left) and Bottom Two Levels (Right) at Central Climatology Looking West

The top 3 boom arms and cross arms are attached to carriages, like the Area towers. The lowest level can be manually retracted

Figure 5-4. Close View of the 2-m R.M. Young Temperature/RH Probe in Radiation Shield with Aspirator and 4-m R.M. Young Sonic Anemometer Model 81000 (looking Northeast).

Sensors Unique to the Central Climatology Facility

Solar and Long Wave Radiation Sensors

The total short-wave radiation from the sun is measured by an Eppley Black and White Pyranometer Model 8-48 (Figure 5-5). Its detector is a differential thermopile with the hot-junction receivers blackened and the cold-junction receivers whitened. The element is of radial wire-wound plated construction with the black segments coated with 3M black and the white segment with barium sulfate. Built-in temperature compensation with thermistor circuitry is incorporated to free the instrument from ambient temperature effects. It also has a precision ground optical glass hemisphere of Schott glass that uniformly transmits energy from 295 to 2800 nm. This hemispherical envelope seals the instrument from the weather but is readily removable for instrument repair. Specifications for the Model 8-48 are listed in Table 5-1.

For more information concerning the specifications, circuitry, or maintenance refer to *Instrumentation for the Measurement of the Components of Solar and Terrestrial Radiation* by the Eppley Laboratory, Inc.

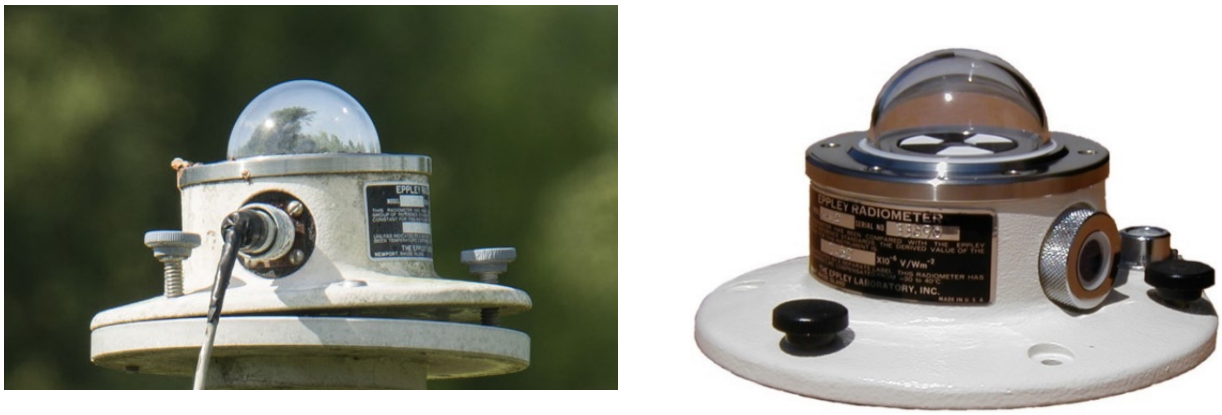

Figure 5-5. Eppley Black and White Pyranometer Model 8-48

Table 5-1. Eppley Black and White Pyranometer Model 8-48

Specifications	
Traceability	World Radiation Reference
Spectral Range	295-2800 nm
Output	0-10 mV analog
Sensitivity	approx. 8 µV / Wm^{-2}
Impedance	approx. 350 Ω
95% Response Time	30 s
Zero Offset a)	1 Wm^{-2}
Zero Offset b)	2 Wm^{-2}
Non-Stability	1%
Non-Linearity	1%
Directional Response	30 Wm^{-2}
Spectral Selectivity	2%
Operating Temperature	-50°C to +80°C
Temperature Response	1.5% (-30°C to +50°C)
Tilt Response	3%
Calibration Uncertainty	< 2%
Measurement Uncertainty	
Single Point	< 10 Wm^{-2}
Hourly Average	approx. 2%
Daily Average	approx. 1%

Barometric Pressure Sensor

Barometric (static) pressure is measured in data building 623-27N along, with the datalogging and site networking equipment. The barometer is a Vaisala Model PTB-100A analog barometer (Figure 5-6). The sensor uses a silicon capacitive pressure sensor that measures changes in electrical capacitance when parallel conducting plates, separated by a gap, are displaced by changes in the force (per unit area) exerted by the barometric pressure, changing the resonance frequency of the circuit. The barometer receives an excitation of electrical energy from the datalogger, so that the parallel capacitive films both have an initial charge. Since the resonance frequency is proportional to the separation of the film layers, the measurement given is in terms of absolute (station) pressure. Specifications for the Model 8PTB-100A are listed in Table 5-2.

Figure 5-6. Vaisala PTB-100A Barometric Pressure Sensor

Table 5-2. Vaisala PTB-100A Barometric Pressure Sensor

Operating range (1hPa=1mbar)	
Pressure range	800 to 1060 hPa
Temperature range	-40 to +60 °C (-40 to +140 °F)
Humidity range	non-condensing
Accuracy	
Linearity	* ±0.25 hPa
Hysteresis	* ±0.03 hPa
Repeatability	* ±0.03 hPa
Calibration uncertainty	** ±0.15 hPa
Accuracy at +20 °C (+68 °F)	*** ±0.3 hPa
Total Accuracy	
+20 °C (+68 °F)	±0.3 hPa
0...+40 °C (+32…104 °F)	±1.0 hPa
-20...+45 °C (-4…113 °F)	±1.5 hPa
-40...+60 °C (-40…140 °F)	±2.5 hPa
Long-term stability	±0.1 hPa/year
Effect of thermal or mechanical shocks	< ±0.2 hPa
General	
Supply voltage	10 to 30 VDC
Supply voltage control	with TTL level trigger when enabled with an internal jumper, barometer can be triggered on/off using external TTL level trigger
Supply voltage sensitivity	less than 0.1 hPa
Settling time at power-up	1 s
Response time (100% response)	300 ms
Warm-up shift	less than 0.1 hPa
Acceleration	sensitivity negligible
Pressure connector	M5 (10-32) internal thread
Pressure fitting	barbed fitting for 1/8" I.D. tubing
Maximum pressure limit	2000 hPa abs.
Electrical connector	a removable connector for five wires (AWG 28...16)
Housing material aluminum	Weight 85 g
Current Consumption	
Operation mode	less than 4 mA
Shutdown mode	less than 1 µA
Output voltage	0..2.5 VDC
Resolution	0.1 hPa
Load resistance	10 kohm minimum
Load capacitance	47 nF maximum

* Defined as ±2 standard deviation limits of end point non-linearity, hysteresis error or repeatability error
** Defined as ±2 standard deviation limits of inaccuracy of the working standard at 1000 hPa including traceability to NIST
***Defined as the root sum of the squares (RSS) of end-point non-linearity, hysteresis error, repeatability error and calibration uncertainty at room temperature

Soil Temperature Sensors

Soil temperature is measured at one, six, and twelve inches at the base of the Central Climatology Tower. The probes that are used are Teledyne Geotech Model T-200 platinum resistance temperature probes that are identical to the ones formerly used on the Area Towers (see Teledyne Geotech model T-200 Temperature Sensor in Section 3, Attachment A-1). Each probe is protected by an outer covering of heat-treated plastic.

Tipping Bucket Precipitation Gauge

Precipitation is measured with a Belfort Instrument Company No. 5-405HAX-l heated tipping bucket rain gauge (Figure 5-7). Rain enters through the upper funnel into one compartment of the bucket until approximately 0.21 mm of rainfall has accumulated. The weight of this amount of rain unbalances the bucket, causing the unit to tip on its pivots, dumping the accumulated rainwater and moving the other compartment directly under the funnel.

The tipping motion of the bucket actuates a mercury switch on the casting, triggering an electrical impulse to the datalogger. An event counter on the datalogger provides a measure of the total accumulation of "tips" during the 15-minute time period. The water discharged by the bucket is not accumulated in the gauge but passes out of the gauge through a hole in the lower funnel. This tipping-bucket gauge is equipped with two heaters. An upper heater is wrapped around the underside of the collector to melt snow or hail in the collector. A thermostat senses the temperature of the collector and maintains the temperature above 40° ±5°F. A lower heater, controlled by its own thermostat, prevents ice from forming in the lower housing and maintains the bucket mechanism above freezing temperature.

The gauge is surrounded by a metal curtain to lessen the effect of wind on the measured precipitation (Figure. 5-7).

Figure 5-7. Belfort 405HAX-1 Heated Tipping Bucket Rain Gauge with Wind Screen

For information concerning circuitry, specifications, or maintenance, refer to *Instruction Book for the Heated Tipping- Bucket Rain Gauge*, catalog No. 5-405 HA (inches), catalog No. 5-405 HA-a (millimeters) by Belfort.

Evaporation Tank

Evaporation is measured by a Qualimetrics Analog Output Evaporation gauge model 6844-A (figure 5-8). Measurements are based on the change in level of the free water surface in an above-ground analog output evaporation gauge. The level of floats in this gauge follow the level of the liquid in the pan. The floats are attached to a recording system that provides a continuous

record of the fluid level changes. A wind baffle has been installed around the gauge to minimize the effects of wind on the amount of precipitation collected. This unit measures water levels to a ±0.015 in. accuracy. For more information concerning the circuitry. specifications, or maintenance, refer to the *Manual for Analog Output Evaporation Gauge Model 6844-A*.

Windcube

The wind profile is measured by Vaisala (formerly Leosphere) Windcube. The sensor is a five (5) beam, doppler Lidar. Four beams measure along a diagonally pointed eye-friendly laser (two oriented roughly east-west, two north-south) at 28 degrees from vertical. The fifth beam is oriented vertically, so that the vertical velocity can be resolved directly and the vector decomposition of the horizontal wind can be performed. The sampling is set up to provide vertical wind and turbulence measurements averaged to 5 minutes, and selected at 40-, 60-, 80-, 100-, 120-, 150-, 180-, 200-, 230-, 260- and 290-m above ground. This sampling strategy provides an overlap with the Central Climatology tower measurements at 36- and 61-m. The addition of wind profile measurements provides above surface measurements that provide continuity in wind measurements between the 61-m observation height at the Area Towers, and the 328-m level at Central Climatology.

Data Collection and Transmission

Data collection and transmission at the Central Climatology facility is similar to the Area Towers with additional instruments being processed. The collection and transmission hardware is configured to accommodate four levels of instrumentation and the additional ground-level instruments.

Lighting Suppression

The grounding network at Central Climatology was improved in the fall of 1990 due to the susceptibility of this particular site to lightning strikes. New cable was laid in the same general pattern as the Area Towers (See Ch. 3). Lightning suppression circuitry, in the form of surge protectors, has been installed in much the same manner as the Area Towers. These surge protectors utilize resistors or Zener diodes or combinations of the two. In contrast to the Area Towers, surge suppression circuitry can be disconnected form the system if necessary due to damage or for repair purposes.

Electrical Power Supply

Electrical power is supplied to Central Climatology via the SRS grid. In the event of power outage, a portable diesel or gasoline generator is used to supply the tower electricity. Normal 110-VAC is converted to usable 12-VDC by transformers.

Routine Facility Maintenance

Facility maintenance of the Central Climatology facility follows the same plan as the Area Towers (see Section 3).

Figure 5-8. Qualimetrics Analog Output Evaporation Gauge Model 6844-A

Chapter 6- Specialized Monitoring Systems

The ATG operates additional monitoring systems and instrumentation to support a variety of specialized needs. A network of manually read plastic wedge rain gauges has provided a near continuous record of precipitation data for SRS since 1952. These data have been used extensively for a variety of operational and research requirements, such as determining when to sample stormwater discharge for compliance with National Pollution Discharge Elimination System regulations or to determine recurrence frequencies for extreme rainfall events to support facility design. The wedge gauge network has transitioned to a more contemporary system of automated tipping bucket gauges supplemented with high resolution National Weather Service radar derived precipitation. Over the last few years, tipping bucket gauges have been established adjacent to the F, P and D Area towers and at the forest flux tower (see Ch. 7).

To support helicopter flight operations of the SRS security force contractor, ATG installed in 2005 a ceilometer for real-time measurement of cloud ceiling height and a network of sensors for observations of near surface level visibility. The visibility sensors operate on the C-, H-, and L-Area meteorological towers at a height of 45 m above ground and on a 2-m mast in B-Area near the helicopter pad. The ceilometer, also located in B-Area, detects backscatter from a vertically directed LIDAR (light detection and ranging) pulse to detect cloud base heights up to 8,000-m above ground. Backscatter data collected by the ceilometer is also processed to determine atmospheric aerosol density profiles, which can be used to determine the height of the atmospheric boundary layer.

Rain Gauge Network

Operational Measurements

Precipitation data has been collected manually using plastic wedge rain gauges since 1952. Daily rainfall data are available for most of this period from gauges in A, C, D, F, H, K, L and P Areas as well as Barricades 2, 3, and 5 (see Figure 6-1). Location coordinates for the wedge gauges are summarized in Table 6-1. Shorter periods of data were collected at R Area, the TNX facilities near D Area, the U.S Forest Service Savannah River Station headquarters, and the now re-purposed Mixed Oxide (MOX) facility in F-Area. Data collection was performed by local facility operations or SRS security force personnel. The wedge gauge used for these measurements is depicted in Figure 6-2. Data collection for the F-Area and Barricade 5 gauges was terminated in 2013; however, automated rain gauges were installed adjacent to the F Area and D Area meteorological towers in 2016.

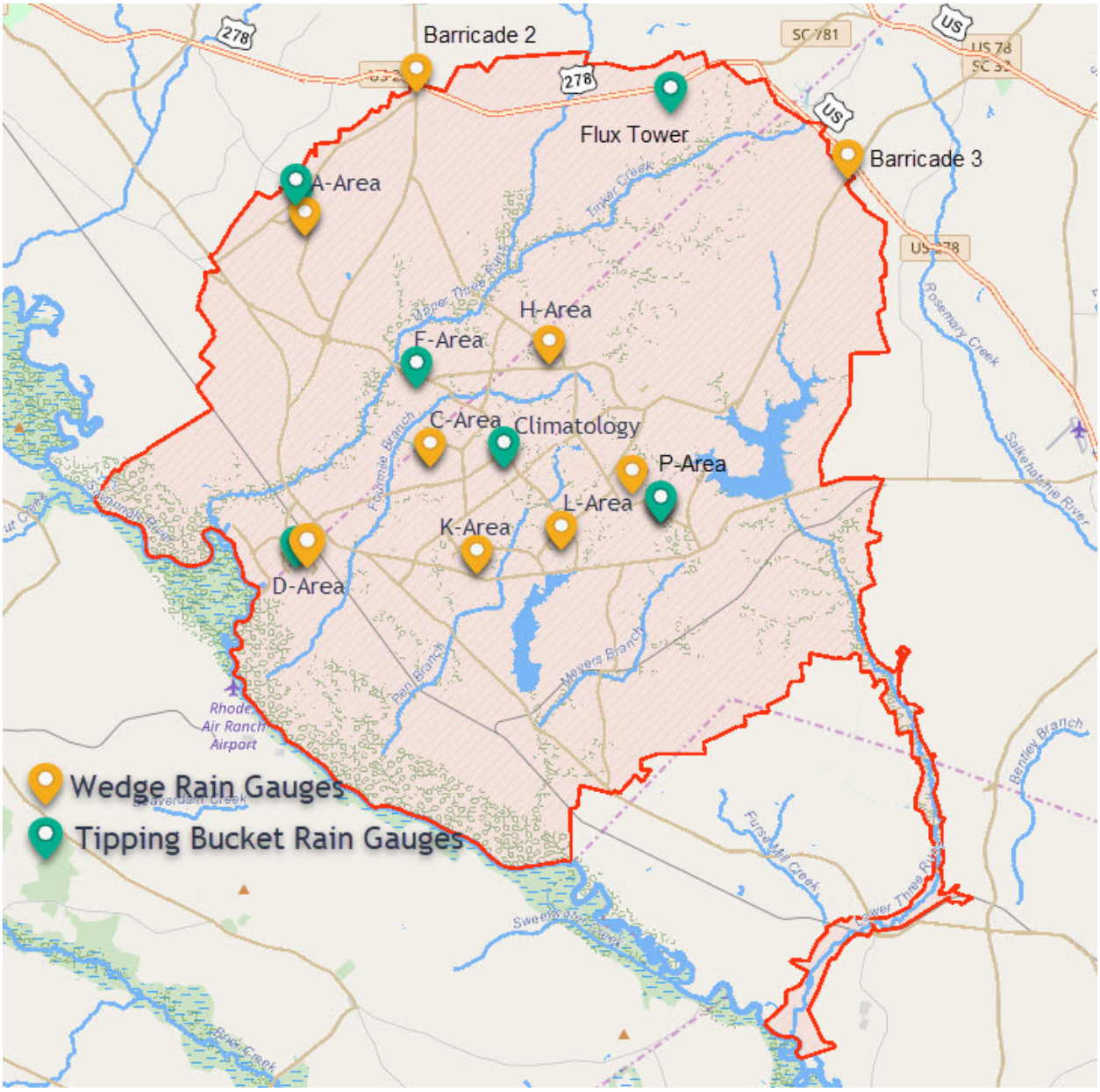

Figure 6-1. Historical Wedge Rain Gauge Locations at SRS

Note that not all rain gauges are necessarily operating in the same time period

Table 6-1. Historical Wedge Rain Gauge Locations

Rain Gauges	Location	Lat (deg)	Lon (deg)
773-A (SRTC)*	weather center	33.3479	-81.7388
700-A	beside the, 700-A Fire station	33.3361	-81.7338
200-F	beside the F-area Fire station		
200-H	at the H-area main barricade beside the guardhouse	33.2881	-81.6426
100-C	beside the abandoned guardhouse at the main entrance	33.2525	-81.6772
400-D	located behind building 483-D		
100-P	beside the abandoned guardhouse at the main entrance	33.2313	-81.5818
100-K	beside the manned guardhouse in the automated gate area	33.2124	-81.6657
100-L	beside the abandoned guardhouse at the main entrance	33.2083	-81.6250
Barr 2	at Aiken barricade beside the guardhouse	33.3802	-81.6851
Barr 3	at Williston barricade beside the guardhouse	33.3570	-81.4876
Barr 5	at Allendale Barricade beside the guardhouse	33.1233	-81.5963
MOX		33.2916	-81.6779

* 773-A (SRTC) rain gauge is a tipping bucket, but data available from ATG web Site is available only as a daily total.

Table 6-2. Tipping Bucket Rain Gauge Locations

Tipping Bucket Rain Gauges*	Lat (deg)	Lon (deg)
Climatology	33.2455	-81.6502
D-Area	33.2095	-81.7408
F-Area	33.2786	-81.6820
P-Area	33.2257	-81.5724

* data from tipping bucket rain gauges at Area towers and Central Climatology are available as 15-minute totals.

Figure 6-2. Wedge Rain Gauge

Name is derived from distinctive wedge shape, with wedge cross-section getting larger towards the top. Graduated lines are used to read rainfall amounts.

Costs required to support the daily readings, instrument maintenance problems that affected data accuracy such as pollen and dirt collecting in the funnel, and the potential for error in communicating the readings from the observer to the SRSOC to ATG for data entry led to a decision to eliminate all of the wedge gauges (end of February 2020). To maintain historical continuity, some tipping bucket rain gauges were added to nearby area towers to allow in-situ rain gauge measurements to continue.

To date, automated tipping bucket gauges are installed at SRNL and the D, F, and P Area tower sites which collect data every 15 minutes. The measurements are made with a Met One Model tipping bucket rain gauge (Figure 6-3). Location coordinates for these gauges are listed in Table 6-2.

Rain enters through the upper 12” funnel into one compartment of the bucket until 0.01 in of rainfall has accumulated. The weight of this amount of rain unbalances the bucket, causing the unit to tip on its pivots, dumping the accumulated rainwater. The tipping motion of the bucket actuates a mercury switch on the casting. Each time 0.1 mm of rainfall is measured, an electrical impulse is transmitted to the datalogger. The impulses drive an event counter to provide a measure of the total accumulation during the 15-minute time period. The water discharged by the bucket is not accumulated in the gauge but passes out of the gauge through a hole in the lower funnel.

For information concerning circuitry, or maintenance, refer to the *Instruction Manual for the Met One Rain Gauge Models 380 and 385 Revision 2/08*.

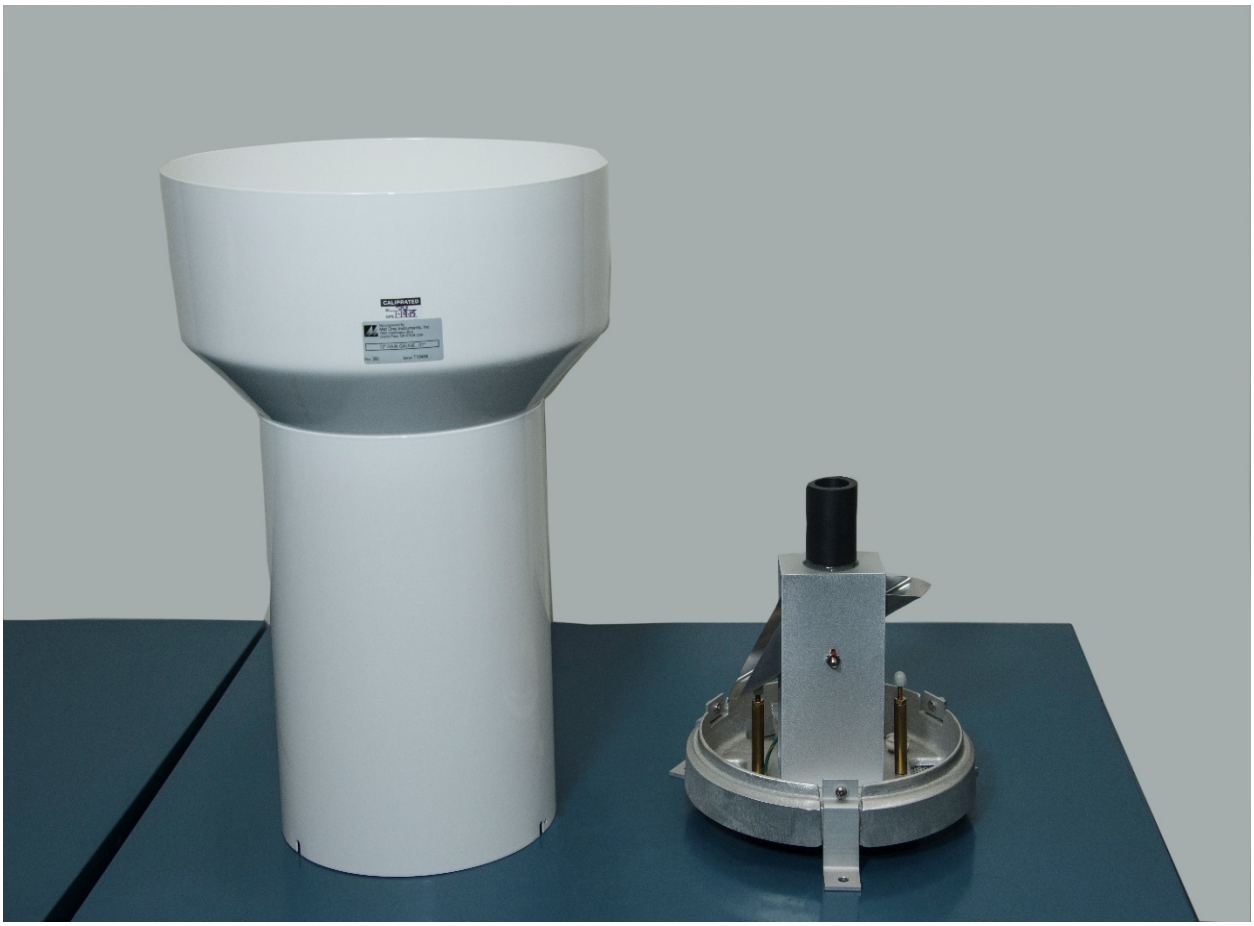

Figure 6-3. Met One Rain Gauge

Rivera-Giboyeaux (2020) compared wedge and tipping bucket measurements to radar-derived rainfall amounts obtained from ATG's NOAAPort feed of National Weather Service Level III radar data. Two data sets of radar-derived data were evaluated, one based on the unmodified radar reflectivity to rainfall (Z-to-R) relationship and the second based on a multi-radar multi-sensor (MRMS) methodology which adjusts the Z to R precipitation estimates according to ground measurements taken from a national network of rain gauges.

Although it takes longer to be available than the Z-to-R data, the MRMS data was found to provide better agreement with the in-situ observations in point to point comparisons. As of March 1, 2020, the manual rainfall data collection was terminated and the MRMS data are used to maintain the rainfall data sets for all of the traditional wedge gauge monitoring locations.

In addition to the use of MRMS data for maintaining the SRS rainfall climatology and supporting NPDES sampling decisions, these data are used to adjust stream flows for each of the primary SRS streams simulated by the WIND System's Stream II emergency response contaminant transport model. The color regions depicted on Figure 6-4 indicate drainage areas for each of these primary streams, as well as the points for which the MRMS data is available.

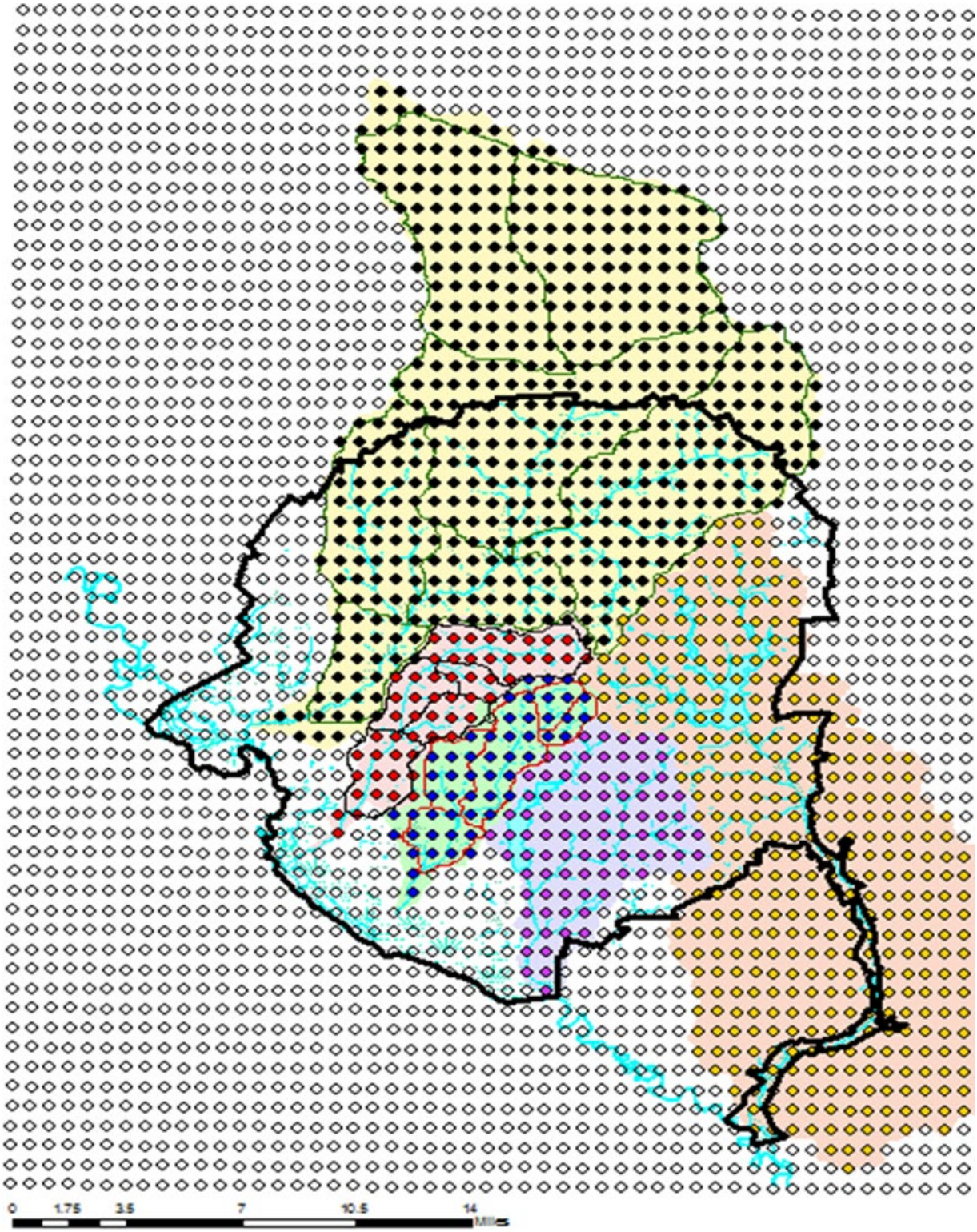

Figure 6-4. Virtual Rain Gauges for the Z to R and MRMS Radar Rainfall Datasets

Prepared by ATG, dots represent the center of each virtual rainfall measurement. Shaded colors represent the watersheds that extend over the SRS site. Blue are the various tributaries and the Savannah River.

Visibility Sensor Network

ATG operates four R.M. Young Sentry visibility sensors Model 73000 (purchased as Envirotech SVS-1) to support SRS security force helicopter operations. The sensor works by transmitting light from an optical transmitter across a scanning volume, that is being monitored by the field of view of a receiver. The angle between the transmitter and receiver is set at 42 degrees to ensure the performance over a wide range of hydrometeors and particulates (Figure 6-5). Visibility is reported from 30 meters to 16 km. Values beyond 10 miles (16 km) are reported as "10 miles +". One unit is deployed at the B-Area aviation facility and is located on a 2-meter mast. The other three (3) sensors are mounted on the C-, H- and L- Area towers at 45-meters above ground. Specifications for the Model 73000 are summarized in Table 6-3.

The sensors used at SRS are set to provide output in milliamps. This was done because the length of the sensor leads from the tower to the datalogger are so long that the use of a voltage signal could lead to signal degradation.

Figure 6-5. R.M Young Model 7300 Visibility Sensor at the C-Area Tower

Table 6-3. Specifications for the R.M. Young 73000 / Envirotech SVS-1 Visibility Sensor

Specification	Description
Visibility Range	30m - 16 km standard 10m - 10 km optional
Extinction Range	100 km^{-1} – 0.1863 km^{-1} standard 300 km^{-1} – 0.30 km^{-1} optional
Accuracy	± 10% RMSE
Time Constant	60 sec
Scatter Angle	42 deg nominal
Source	880 nm LED
Power	
AC Version (optional)	100-240 VAC, 24 VA Nominal; 75 VA w/ Hood Heaters
DC Version (standard)	10-36 VDC, 6 VA Nominal; 18 VA w/ Hood Heaters
Environmental Operating Temperature	-40 to 60 C
Operating Humidity	0-100%
Protection	IP66 (NEMA-4X)
Outputs	Serial RS-232 standard
Output Options	0-5 VDC analog
	4-20 ma single ended or isolated
	Relays - Control (up to 2),
	diagnostic, or latching
	0-10 VDC analog
	Wireless RF Modem
Weight	8 kg (18 lb)
Dimensions	889 mm W x 292 mm H x 305 mm D (35 in x 11.5 in x 12 in)
Mounting	Nominal 40 mm ISO pipe, 48 mm OD max (1-1/2” IPS pipe, 1.9-inch OD max) or Nominal 25 mm ISO pipe, 33 mm OD max (1” IPS pipe, 1.3-inch OD max)

Ceilometer System

ATG operates a Vaisala CL31 Ceilometer (Figure 6-6) in B-Area. Although the ceilometer was installed primarily to provide data on cloud height for SRS security force helicopter flight operations, this instrument also provides information from which to determine the height of the atmospheric boundary layer (ABL). The sensor is a ground based, single-lens pulsed laser (LIDAR) system. Pulses of laser energy are aimed nearly vertically and scattered back to the lens by atmospheric aerosols or fog/cloud droplets. The instrument measures the amount of

backscattered energy in small time intervals until the next pulse is transmitted. By measuring the delay between the transmission of the beam and the return time, the ceilometer can determine a profile of backscattered energy. The sampling is repeated every 33 or 67 ns, which provides a spatial resolution of 5 or 10 meters, respectively. Using this method, up to 3 separate cloud bases can be determined between the surface and 7700 m (about 25,000 ft. AGL).

Aerosol backscatter profiles are integrated over 30 seconds (user programmable duration). An automated algorithm searches for gradients in the backscatter profile (white lines in Figure 6-7). These gradients in the aerosol profiles are of interest since regions of uniform aerosol loading indicates regions of constant mechanical and/or thermal turbulence. The bright orange and yellow region on the right-hand side of Figure 6-7 shows a region where the surface layer is heated, destabilized and is growing under the presence of daytime heating. The extensive area of enhanced turbulent diffusion below the white line indicates that the region is well mixed. The blue regions, either above the gradients or below the gradients, indicate regions with substantially fewer aerosols, and associated with generally stable conditions.

Figure 6-6. Vaisala CL31 Ceilometer

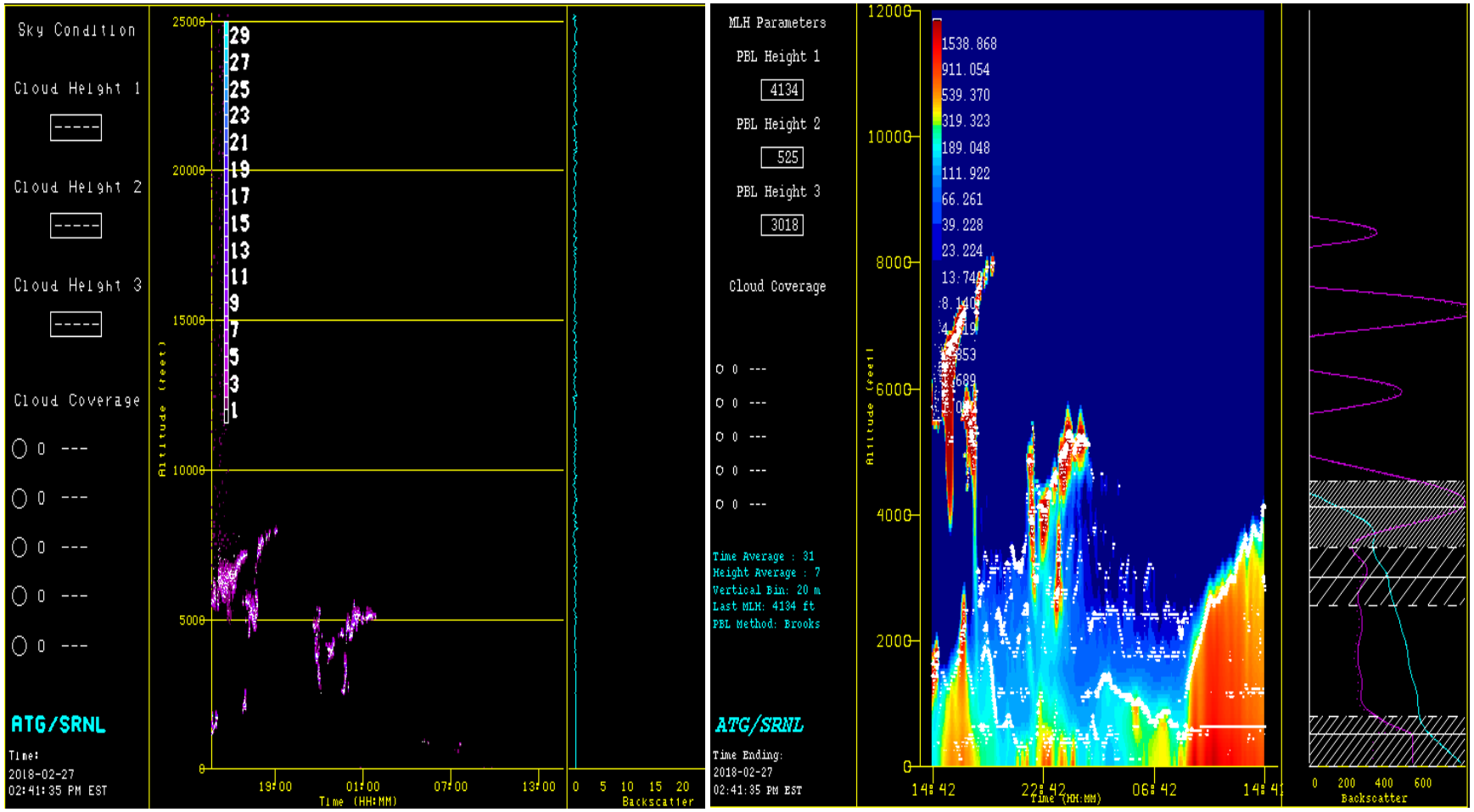

Figure 6-7. Sample Ceilometer Data Left side provides cloud height information and right side depicts the full backscatter profile for Feb 27th, 2018 at 14:42 LST. A region of strong vertical mixing can be seen in the bottom right side of the image depicted by warmer colors.

The data signal from the Ceilometer travels across an RS232 (serial cable) to a Lantronix serial to ethernet device server and PDU that send the data packets over the network to a dedicated server at the BCF. The header block of the data contains ascii parameters that describe the current operations of the ceilometer followed by hexadecimal data where each fixed block of characters describes the backscatter value for each bin. The BCF server then pushes the files via the network to the CCF where the data is added to the daily file that contains all the other profiles measured on a given day. The header block contains the information for both the cloud coverage and the cloud height. The algorithms used to calculate these parameters are stored on the ceilometer and are identical to the algorithms used by the NWS.

From mid-2009 to early 2019, the ceilometer collected data using 20m bin resolution and sampled every 30 seconds. This was done to maintain continuity with regional NWS ASOS and AWOS stations operating the same instrument. However, in February 2019, it was decided that the size of the bin should be decreased to 5m, to improve the low-level resolution. This required the instrument to be set to transmit at a faster sampling frequency, resulting in a decrease in the transmission time from every 30 seconds, to every 15 seconds.

Since the Vaisala CL31 has a maximum number of vertical bins that can be transmitted in each data message, adjusting the resolution potentially would lead to a decrease in the maximum height in which clouds could be measured.

Table 6-4. Specifications for the Vaisala CL31 Ceilometer Receiver System

Specifications	Description
Detector	Silicon Avalanche
Surface	0.5 mm (0.02 in.)
Receiver	3MHz (-3db) bandwidth
Interference Filter	Center wavelength 915nm
50% Pass Band	36 nm
Transmissivity	80 % typical
Field-of-View Div.	± 0.83 mrad
Optics Sys Focal	300 mm (11.8 in.)
Eff. Lens Diameter	96 mm (3.8 in.)
Lens Transmittance	96 % typical
Transmittance	97 % typical, clean
Measurement Range	0 -7.5 km (0-25,000 ft.)
Measurement Res.	10 m or 5 m
Reporting Resolution	5 m
Reporting Interval	2 - 120 s, selectable (30
Measurement Interval	2 s default (3s high-res)

Anecdotally, it had been observed that the SRS and regional NWS ceilometers would not measure very high cirrus clouds even at the higher operating resolution. Since the SRS site security and USFS helicopters operate at fairly low levels (well below 25,000 ft), it was decided that any loss of functionality would not be detrimental at SRS, and the higher resolution was implemented.

For more information on specifications, circuitry, or maintenance, please refer to Vaisala CL31 *Ceilometer Users Guide.*

Figure 6-8. Stevenson Screen

The Stevenson screen is used for Maximum/Minimum Temperature and Rainfall for SRNL Limited Area.

773-A Instrument Shelter

Precipitation measurements in A-Area have been collected at various locations since 1952. Data was collected from January 1952 until December 1974 at a location near 735-A. A second gauge located neat 773-41A was used to collect data during an overlapping period from April 1968 through December 1974.

The A-Area instrument shelter was established in 1964 (Figure 6-8) and instrumented with a hygrothermograph to collect data on minimum and maximum temperature and relative humidity. The A-Area rain gage was co-located with the instrument shelter in 1975. The instrument shelter was first located near 735-A, then relocated in front of 773-41A near the parking lot, and then moved to its current location near the 708-A security gate in 1991. Each of these locations are within a few hundred feet of each other.

Prior to 2013, a Belfort Model 594 Hydrothermograph was used to record daily values of maximum and minimum temperature and relative humidity on a strip chart. The charts were periodically read and data values recorded manually on a standard data sheet. Precipitation was read manually every morning from the wedge rain gauge with values also recorded on a data sheet. These data were then periodically entered into the database.

The shelter was refurbished in 2015 with new instrumentation and automated data acquisition.

Current instrumentation is summarized as follows:

Temperature/Relative Humidity

The Campbell Scientific CS-500 Temperature/ Relative humidity sensor has a minimum accuracy of ± 1ºC for temperature and ± 5% for relative humidity. The minimum accuracy is compared with an ATG portable standard once per year.

Sky Temperature

The Omega OS36K-50F Infrared thermocouple measures the non-contact temperature with an accuracy of ± 2% based on a response to energy in a spectral range between 6.5 – 14 microns (IR) over a 60-degree field of view. To provide sky temperature, the thermocouple is oriented 45 degrees from the vertical, facing north. The sky temperature is compared with the ambient temperature on days with low overcast or fog. Agreement is required to be within 1C°. Cleaning of the lens is carried out as needed.

Rainfall

Three instruments used to collect rainfall data.

- A Belfort tipping bucket rain gage provides automated measurements at a resolution of 0.01 inch of precipitation
- A cylindrical rain gage consisting of a 1-inch cylinder with overflow into a 4-inch cylinder (12-inch capacity) read manually
- Wedge rain gage with 5-inch capacity, read manually.

The tipping bucket gage is calibrated with ATG's drip pipet technique. A correction multiplier of 1.06 is applied to each 15-minute period. The wedge and cylinder gages are read every 1-2 weeks and the cumulative rainfall for the period compared with the equivalent value for the tipping bucket. Values are typically within 10%. (The cylindrical rain gage has an entry diameter of 2 cm and thus evaporation during the period is minimal.)

Automated data collection is performed with a Campbell Scientific CR1000 data logger. The logger records the temperature, relative humidity, sky temperature, and rainfall in 15-minute intervals, which are retained for later use. Maximum and minimum values are derived from an Excel program. Daily rainfall for each day is calculated for the 24-hr period between 7am (previous day) to 7am (day of record) for consistency with the SRS rain gage network.

Barometers

Figure 6-9. Aneroid Model BM70 Barometer

Aneroid Barometer (735-7A and 773-A)
A Weather Measure BM 70 (Figure 6-9) wall mount aneroid barometer is used in conjunction with the wind tunnel in the Meteorological Engineering Facility (735-7A) for pressure readings needed for air flow density measurements.
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References:

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Rivera-Giboyeaux, A. M., 2020: *Radar Derived Rainfall and Rain Gauge Measurements at SRS*, SRNL-STI-2019-00644, Savannah River National Laboratory, Aiken SC, 29801, https://weather.srs.gov/weather/static/pdf/SRNL-STI-2019-00644.pdf.

Vaisala User's Guide, 2009: *Vaisala Ceilometer CL31*, M210482EN-D, 142 p.

Chapter 7 - Instrumentation Supporting ATG Research

A variety of fixed location and portable instruments are available to support field studies of boundary layer turbulence, and contaminant transport and diffusion as well as ground truth measurements for remote sensing projects including atmospheric optical path and aerosol loading.

Historical Perspective

During the 1970s and 80s, the ATG in collaboration with partners in government, universities, and other National labs investigated problems in atmospheric dispersion utilizing releases of tracer gas. The first such study involved local measurements of 85Kr emission, a by-product of ongoing SRS nuclear operations at the time. A database of tracer and meteorological data was compiled for the March 1975 to August 1976 period (Pendergast et al., 1979). Similar data was gathered from 1982-1983 for the broader middle Atlantic coastal region (Schubert, et al., 1983). These data sets were used to validate WIND System codes and were made available for public distribution.

A series of experiments called the Mesoscale Atmospheric Transport Studies (MATS) (Weber, et al., 1992) were conducted from 1983 through 1986. The basic experiment was to monitor a release of Sulphur Hexaflouride (SF_6) tracer gas from a 200ft stack during daytime convective turbulence conditions. The first MATS samples were taken by up to 28 portable samplers which were placed at ground level in an arc 25km downwind of the release. Up to 10 grab samples, taken by each sampler, were made in sequence during times of the probable maximum concentration. Later MATS utilized a continuous trace gas analyzer on the mobile Tracking Radioactive Atmospheric Contamination (TRAC) vehicle for continuous SF_6 monitoring. TRAC made repeated passes through the plume which provided a better understanding of the plume's characteristics. During these sampling periods, computer simulations (models) of the SF_6 plumes were completed.

Another experiment, the Stable Boundary Layer Experiment (STABLE) (Weber and Kurzeja, 1991) was conducted to observe tracer releases in the stable nocturnal boundary layer. These experiments included measurements from the Area Towers and CLM as well as specialized equipment including portable air samplers, the TRAC vehicle, radiosondes, a tethered balloon and an ozone analyzer. Other documents describing these and other tracer studies at SRS are given by Bench et al. (1978), Flythe and Amlicke (1983), and Parker and Raman (1993).

In 2007, ATG partnered with the University of Georgia on a DOE Office of Science funded initiative to develop a carbon flux supersite at SRS and conduct research in processes that affect the exchange of CO_2 between the atmosphere and terrestrial ecosystems. This project led to the establishment of a carbon flux monitoring site in the relatively undisturbed pine forest in the northeast corner of SRS. In addition, ATG added carbon flux instrumentation to the Tall Tower and entered into a partnership with NOAA's Global Monitoring Division in 2008, which resulted in the installation of a trace gas sampling system as part of NOAAs national tall tower monitoring network supporting the Carbon Tracker system (see Chapter 4 for more details).

As part of the partnership with University of Georgia, along with Brookhaven National Laboratory, a nighttime field tracer study was conducted in 2009 to examine the vertical flux of the tracer gas during weakly and moderately stable nights. A unique set of perfluorocarbons were released from locations at various upwind distances from the Tall Tower and measured by the Tall Tower's sampling systems as well as additional mobile samplers at ground level. Kurzeja (2020) has examined the fine scale

structure of the boundary layer during the study nights.

During the early 2000's, ATG was involved in a partnership with Sandia National Laboratory and Los Alamos National Laboratory to validate the Multispectral Thermal Imager (MTI). The MTI was a satellite-based instrument designed to take images of government, industrial and natural sites in 15 spectral bands including the infrared and visible light spectrums (Decker et al. 2001). ATG deployed instrumentation to collect data needed to provide ground-truth to the satellite-based measurements.

Thermal targets with varying atmospheres from around the world were monitored with hand-held instruments and imaging from a helicopter including Crater Lake in the winter (cold), Kilauea lava flows in Hawaii (hot) and Nauru Island (tropical pacific). Instruments used in the study to measure surface conditions included thermal imagers, spectrophotometers and infrared thermometers while sun photometers, and balloon soundings measured atmospheric structure. Industrial targets for the MTI were thermal discharge from commercial nuclear power sites in Texas, Massachusetts and Florida. Benefits from the program included validation of models of cooling lake thermal structure and a technique to measure the sea surface skin temperature. The accuracy of the SRNL ground truth measurements exceeded the accuracy of the satellite design specifications by a factor of 2 to 10.

Forest Carbon Flux Site

ATG established a Forest Carbon Flux Site through an initiative funded by the Office of Science. The observational infrastructure is a flux tower based on the AmeriFlux protocols (https://ameriflux.lbl.gov/) with a trace gas monitoring system. The tower, shown in Figure 7-1, is a 29 m walk-up scaffold tower equipped to measure micrometeorological variables at 2, 12, 18 and 28 m. Each level of the tower is instrumented with a Campbell Scientific sonic anemometer (CSAT3) to measure three dimensional winds and virtual temperature along with a Li-Cor Biosciences open path CO_2/H_2O analyzer (LI-7500) to measure CO_2 and water vapor concentrations. All measurements occur at 10 Hz frequency. Specifications for these instruments are summarized in Ch. 4 (Tables 4-3 and 4-4)

This forest stand at the site is dominated by *c*. 50-year-old longleaf pine (*Pinus palustris*) with an average canopy height of 25 m. The stand also contains a small number of slash pine (*Pinus elliottii*) and white oak (*Quercus alba*). Power for the tower is provided by a set of solar panels located approximately 50 m from the tower in a small clearing and are connected to a suite of batteries located at the tower base.

Figure 7-1. Carbon Flux Tower Site

The Aiken AmeriFlux tower located in the pine forest at Savannah River Site (left); the solar panel array used to provide power to the tower (top right); and the batteries located at the base of the tower which receive and store power from the solar panels (bottom right).

The tower is accessible by a series of stairs and requires the use of a climbing harness attached to a cable running up the center of the tower. Data from the tower is stored on memory cards on two data loggers (one data logger handles data coming from the lower levels of the tower while the other handles the upper levels). The memory cards are swapped periodically, and the data is downloaded and processed by the Edire software (available from the University of Edinburgh School of Geosciences: www.geos.ed.ac.uk/homes/jbm/micromet/EdiRe) to produce half-hourly statistics of the data and a range of calculated variables including fluxes, energy balance quantities and data quality statistics. Projects using this data have included examination of carbon and energy balance during the USFS prescribed burn activities and determining the exchange of carbon and water into and out of the forest canopy (Viner, 2020) to support nuclear facility safety research on the fate of airborne tritium plumes.

Also located at the Forest Carbon Flux Site is an automated rain gauge which collects 15-minute rainfall totals (Figure 7-2). Other instrumentation operating at this site has included a COSMOS soil moisture probe operated by the University of Arizona and a variety of soil moisture (Figure 7-3), soil carbon, and soil temperature and surface pressure measurements from instruments operated by other university collaborators.

Figure 7-2. Rain Gauges for the Flux Tower

A manual and tipping bucket rain gauge located at the flux tower and their associated data logger and solar panel

Figure 7-3. Soil Moisture Probe for the Flux Tower The COSMOS soil moisture probe located adjacent to the rain gauge

Solar Research Site

This site (Figure 7-4) is located at the Savannah River Research Campus a few miles north of SRNL and was established to better understand the relationships between different type of incoming solar radiation measurements related to photovoltaic energy production. Equipment at the solar research site for measuring radiation plus the optical depth at wavelengths from 300 to 1100 nanometers consists of:

- A Yankee Environmental Multi-filter rotating shadowband radiometer (MFR-7) at 2-m to capture direct and indirect solar radiation as well as solar angle and global solar radiation;
- An Eppley Precision Infrared Radiometer to measure incoming and outgoing infrared radiative fluxes;
- An Eppley Black and White Pyranometer to measure incoming radiation in the UV, Vis, NIR and IR bands;
- An Omega sky temperature sensor

Additional equipment at the site capturing other variables of interest include temperature/relative humidity probes, a sonic anemometer, a barometric pressure sensor and a solar panel which records power, voltage and panel temperature. The data is captured by a single Campbell Scientific CR1000 datalogger which transmits in near real-time to ATG's (https://weather.srs.gov) meteorological database server.

Figure 7-4. Solar Research Site

Radiation sensors (Left) and solar panels (Right) which make up the solar research station located at the Savannah River Research Campus

Yankee Environmental MET-210 Precision Thermo-Hygrometer

This instrument measures the temperature with an aspirated platinum resistance sensor and dew point by optically detecting the dew or frost point temperature of a controlled-temperature mirror. Performance is given in Table 7-1 below. The instrument was in operation at the Climatology site from May 2006 to January of 2014.

Table 7-1. Yankee MET-210 Precision Thermo-Hygrometer

Temperature Performance	
Range	+/- 50°C
Accuracy	+/- 0.05°C
Analog Output	+/- 5.00 Vdc corresponding to +/- 50°C, (14-bit DAC yields > 0.01°C resolution)
Digital Output	RS-232, 9600 baud 8-N-1, ASCII (14-bit, 0.01°C res.)
Air Flow	Approx. 400 FPM
Dew Point	
Dew/frost	To -18°C at 22°C ambient temp
Dew/frost	Dew/Frost Point: +/- 0.2+/- 0.5° C
Sensitivity	+/- 0.01 °C
Repeatability	+/- 0.01°C
Hysteresis	None
Slew Rate	Typically 1.5°C per sec

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Chapter 8 – Data Quality

Introduction

The following sections describe the methods of meteorological instrumentation calibration and maintenance used by the ATG. The history, personnel requirements and procedures of meteorological instrumentation calibrations are covered in the following sections. Each individual procedure can be found in SRNL Procedure Manual L15.3 *Meteorological Monitoring Procedures*.

Historical Perspective

Before the mid 1980's, calibration of meteorological instruments was completed by the ATG in the wind tunnel located in Building 735-7A, but the instruments were installed in the field by SRS electronic technicians (DuPont, 1977). Maintenance between calibration periods also was performed by the electronic technicians; however, frequent schedule conflicts prevented adequate maintenance of the instruments in the field. Currently, the calibration, installation, and maintenance of meteorological instrumentation are performed in the field by ATG electrical engineering specialists. This has ensured that proper attention is given to optimizing instrumentation in-service time at each tower. The SRS meteorological monitoring program now achieves data recovery rates much greater than the 90% annual availability required by DOE and other regulatory agency standards.

Maintaining this network requires the use of a fully equipped pick-up truck for executing field work activities. The types of instrumentation located at these facilities are diverse. Measurements are made of very minute voltages that require sensitive electrical and mechanical measuring devices. Furthermore, maintenance, calibration and troubleshooting of these sensitive instruments require diligent attention to detailed procedures and a working knowledge of electrical test equipment (i.e. volt meters, oscilloscopes, etc).

Meteorological Monitoring Procedures

Procedures used for installation, calibration and maintenance of meteorological instruments and equipment, and the quality assurance of the data are contained in Procedure Manual L15.3 Meteorological Monitoring Procedures. Due the knowledge, training, and skill of the ATG specialists, these procedures are classified as technical reference procedures with calibration data captured on controlled forms.

Standard Installation Procedures for Meteorological Instrumentation (ETSP T-101)

This procedure describes the process for sighting true north, sensor leveling, and minimization of solar radiation errors. The procedure is written in a generic format so as to apply to the initial installation of any brand of instrument. The procedure is followed when initially installing an instrument; reinstallation of any instrument is covered in the field calibration procedures. Documentation of sensor orientation is made while performing the field calibration procedure.

Field Calibration Procedures for Meteorological Instrumentation (ETSP T-100A)

This procedure addresses the operational verification of the R.M. Young sonic anemometers and temperature/RH probe aspirators, and calibrations of the temperature and relative humidity probes on the Area and CLM towers. Verification data for the sonic anemometers and temperature/RH probe aspirators are recorded on form number L15.3-FORM-OP-2. Calibration data for the R. M. Young temperature/RH probe are recorded on form L.15.3-FORM-OP-4. This sensor is checked against traceable standards. Forms are managed as records and stored in fireproof cabinets in 735-7A and also scanned and archived electronically.

The procedure begins with documentation of the sensors' 'as-found' condition. Then, a thorough check of the entire system is made from sensor,

to communication hardware, to algorithms on the database server. If any adjustments are made, then the resulting as-left conditions are recorded. This process provides a starting and stopping point for each calibration period with a comprehensive check of the entire system. An additional measurement of the level of the instrument platform also is made. If possible, adjustments of a sensor are made in the field during calibration. However, irreparable instruments are sent back to R. M. Young for refurbishing.

Standard Maintenance Procedures for Meteorological instrumentation (ETSP T-102)
This procedure provides the methods used to maintain the integrity of the meteorological data archived in the WIND System data base. Records of data checks are accomplished through daily data evaluations and tower logbooks. Continuously updating time series plots of all measurements are displayed on large screen monitors in the Meteorological Engineering Facility, Building 735-7A, and reviewed every workday to assess any discrepancies in data quality. In addition, a 24-hr average of the previous day's data is created and evaluated according to specific criteria that considers variability among all Area Towers and the multiple levels of the Central Climatology tower. An evaluation of these data, in conjunction with a tower repair priority policy is made every working day to determine appropriate action as needed. Any visit to a tower facility to perform maintenance must be documented to the tower's logbook, including the reason for the visit and any actions taken.

Other Calibration Methods

Calibration of meteorological instrumentation is performed at SRS by ATG. However, in certain cases instrumentation and hardware may be sent off to be refurbished by the vendor to factory conditions. Measuring and test equipment used by ATG is calibrated by the Savannah River Standards Lab (SRSL). This equipment includes voltage meters and reference temperature probes, which are formally maintained by ATG, per procedural requirements, as measurement and test equipment (M&TE). Calibrations performed by SRSL are conducted once per year or as necessary. The SRSL calibrations provide the means of traceability of the National Institute of Standards and Testing (NIST).

Calibrations and Maintenance Facilities

The facilities described below are integral to ATG instrument calibration and maintenance activities.

Meteorological Engineering Facility
The ATG's Meteorological Engineering Facility is located in Building 735-7A (Figure 8-1). This facility is equipped to troubleshoot instruments and supporting components and to set up test prototype instrumentation system prior to deployment in the field. The facility also includes office space for ATG's engineering specialists and other ATG staff involved with the operational meteorological monitoring activity. Desktop computers and large screen displays of continuously updating time series plots of all meteorological monitoring system measurements and the system status flow sheet are available.

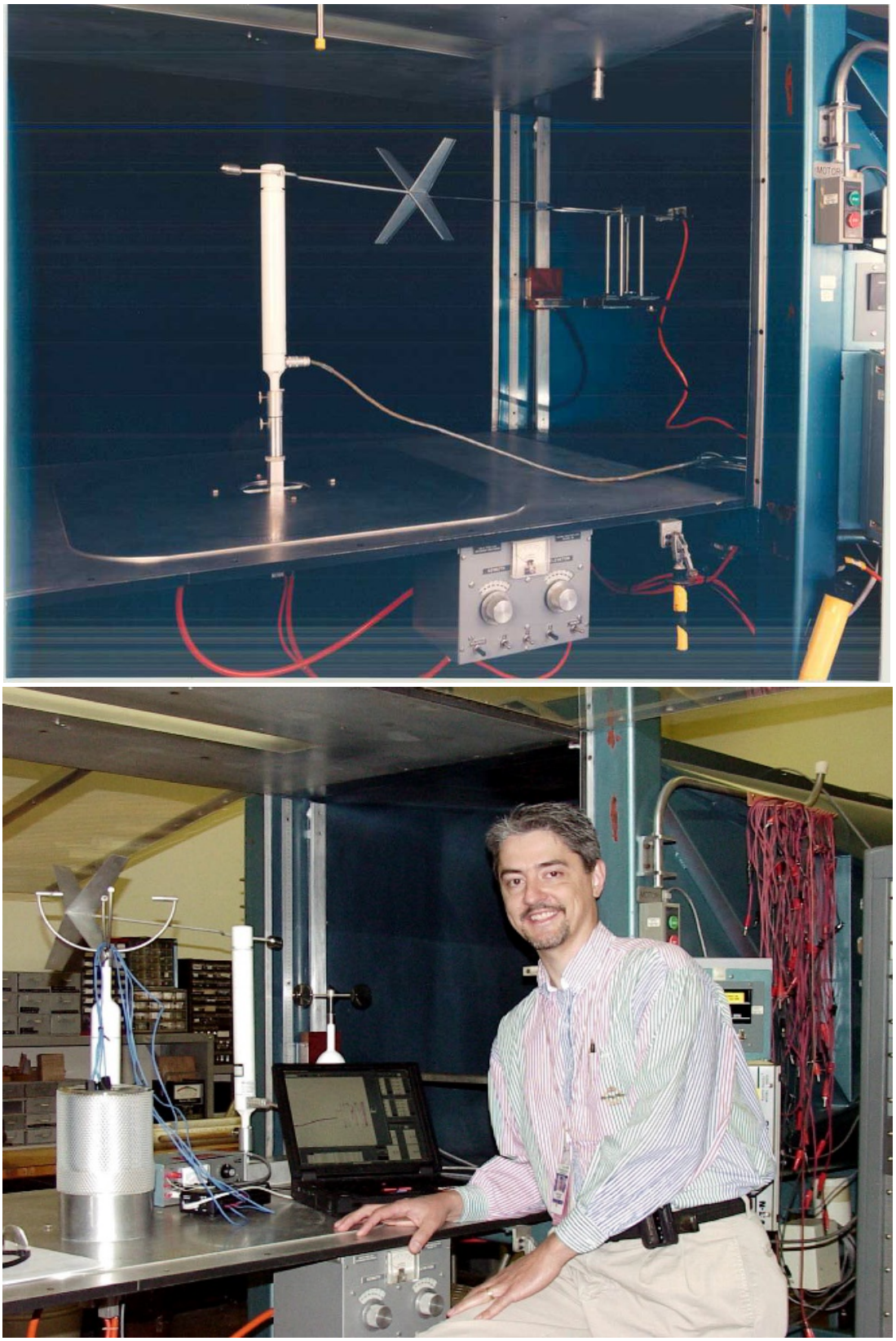

Figure 8-1. Instrument calibration being performed in the Wind Tunnel. A Bivane is in the section (top), while Matt Parker is shown evaluating a 2-dimensional sonic anemometer (bottom)

Available Equipment

The Meteorological Engineering Facility provides test equipment such as oscilloscopes, soldering irons, and special hand tools needed to perform diagnostics and repair of instruments, signal processor cards, etc. Manuals and schematics are stored and available for reference. An inventory of spare equipment and parts are also maintained in the facility. A drill press and grinder are also available for maintenance and fabrication work.

Wind Tunnel

The Meteorological Engineering Facility houses an Aerolab Subsonic Low Turbulence Wind Tunnel (Figure 8-2) for calibration and research on meteorological instrumentation. The tunnel is operated by utilizing a 15-horse-power constant-speed motor that turns a fan to draw air through a honeycomb grid. The air is drawn through the test section and exhausted beyond the fan blades. The test section is 36” x 36” x 60”. Airflow is regulated by a calibrated variable-tachometer control unit (Weber, 1990) and is traceable to the NIST. Airflow rate can be measured with a manometer or with a hot-wire anemometer.

Operating the wind tunnel is governed by instruction L15.3-I-NTS-110.

Figure 8-2. View of the Aerolab Subsonic Wind Tunnel in Building 735-7A Also visible is the instrument technician bench where instrument maintenance or configurations are tested

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Chapter 9 - Archival and Quality Assurance

Quality Assurance

The purpose of the ATG meteorological quality assurance program is to characterize and document the status of all data obtained from the meteorological towers for data users (mainly ATG meteorologists) and ATG engineering specialists. A multi-layer approach has been put in place to perform data quality assurance. First, data review takes place every workday by the engineering specialists so possible instrument problems can be resolved before they degrade instrument quality. Faulty instruments are changed quickly, so that more intermittent and difficult to detect problems are resolved earlier in the process.

The overarching theme of the data archival is that data is not eliminated, even if known to be bad. Instead of trying to modify the values of the data in the WIND System database, quality flags are used to indicate the status of every 15-minute value. Data are flagged when the sensor readings are not representative or are known to have errors, while anomalous weather is not flagged. For example, calm winds would not be flagged as bad, even though the readings may be below the instrument threshold. However, icing conditions, where the ice buildup is physically preventing the instrument from operating correctly would be flagged as bad data.

Archive Database

When the WIND System was first envisioned back in the early 1970's, the need for the real-time transmission and archival the data has been a key feature of the interface of the meteorological observations and the dispersion modeling being performed at SRS. Timeliness in managing the data collection was critical so that the data could be usefully employed to determine consequence analysis in case of an emergency, and then provide datasets for the technical planning basis of accidental analysis.

Today the database is still a central part of WIND System operations. The database is currently running on an enterprise scale PostgreSQL database. PostgreSQL is a commercial off the shelf, open source, object-relational database that runs on dedicated Linux servers in the Central Computing Facility (CCF) and Backup Computing Facility (BCF). Much of the needed functionality of the WIND System is built in as system calls, so that by using the SQL (sequential query language) the data can quickly be added to, or recalled from the database via the network, through automated scripts. The PostgreSQL database software system is managed by the SRNL Integrated Computing Group and controlled according to software quality assurance plan B-SQA_A-00064 (SRNL, 2019a).

The data that is collected and processed among the Area, CLM, and research towers are transmitted to the CCF/BCF via a user-controlled network and, using custom written scripts, automatically written to the PostgreSQL database. In the case of network communications being lost, local storage on the dataloggers allow for back-polling to fill in missing data. In the case of data that is lost for some other reason (power failure, for example), the data values are filled in with a (null value) so that there can be no confusion as to whether the data is legitimate or not.

Data Quality Control

There were three types of data quality flags associated with each 15-minute data value: a data logger flag, a data quality flag and a manual flag. With the switch to the new PostgreSQL database data quality and data logger flag types have been combined, since the Campbell scientific dataloggers do not automatically add logger flags, as was the case with the older ESC loggers.

Data logger flags

During periods of instrument calibration and maintenance, the data logger is set to maintenance mode and a "M" flag is written to the database for all the data periods associated

with that tower while the calibration or maintenance activity is being performed. A "D" flag is set at the datalogger for suspected malfunctions. These are usually determined by the engineering specialists or ATG meteorologists. The "P", "U" and "O" flags are set by the datalogger for power interruption, instrument under-voltage, and instrument over-voltage, respectively. These added flags are advisory in nature, since they may not capture the exact source of the error. Typically, since it would be impossible to determine whether data collected could be good, these data are to be excluded from use as being unrepresentative.

Table 9-1. Common Datalogger Quality Flags

Data Flag	Flag Type	Explanation
M	Logger	Tower Maintenance – set when tower maintenance is being performed
P	Logger	Power Interruption – Incoming AC power interrupted during time period
U	Logger	Under Voltage – Power coming in is continuous, but voltage is low, causing possible instrument malfunctions
O	Logger	Over Voltage – Power coming in is continuous, but voltage is high, causing possible instrument malfunctions
D	Logger	Instrument Malfunction – Set for a period when the instrument or system is not working
G	Quality	Good
F	Quality	Fatal
I	Quality	An interval where 50% or more is good and the rest is bad
B	Quality	Data is offset by a constant value
U	Quality	Uncalibrated. Infrequently used, but possible for newly installed instruments

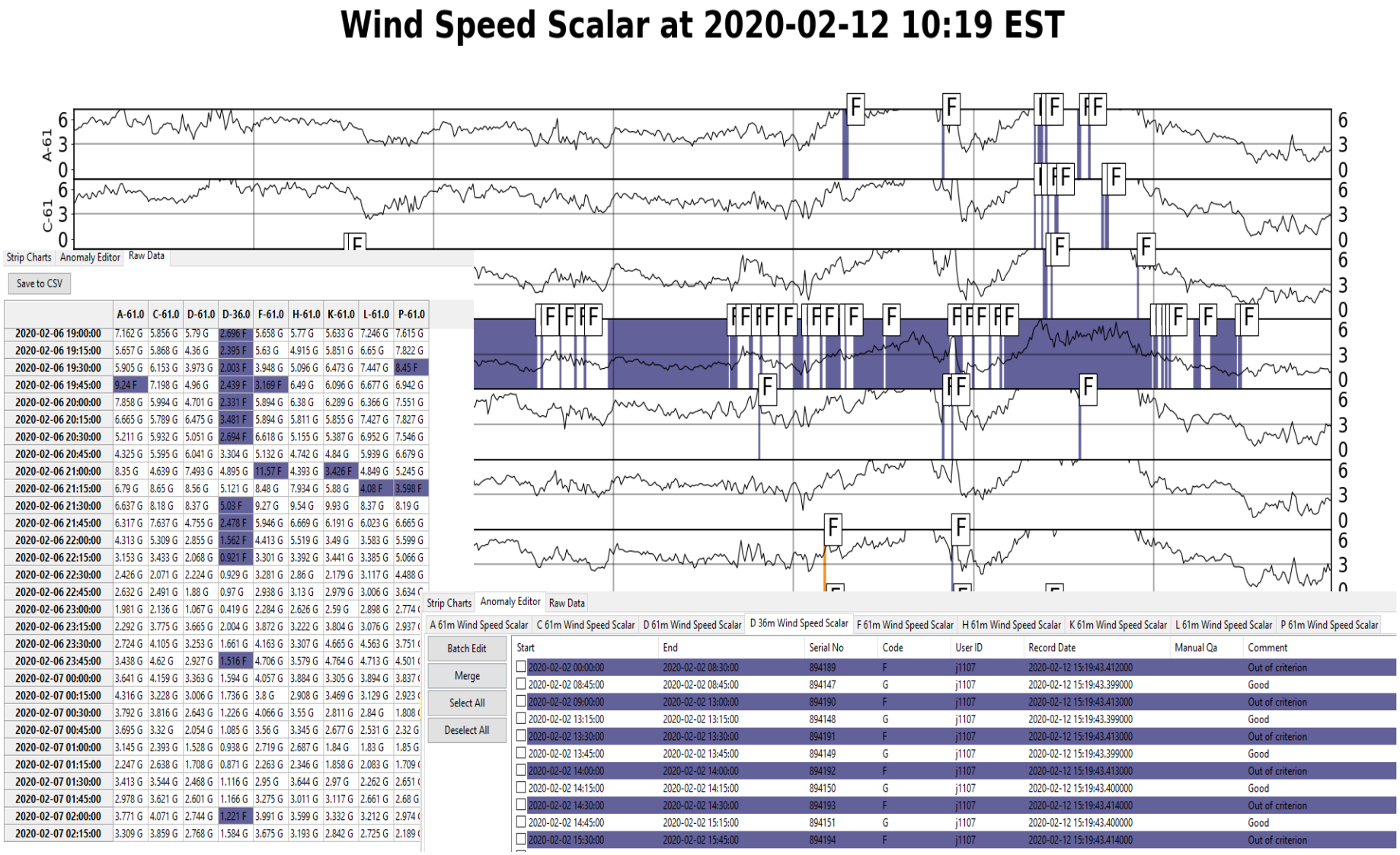
Data Quality Flags

The final quality status of the data is determined by a data review using the custom software application Fishnet. This software generates a time series plot of all 15-minute values of a selected variable for every Area tower or every level of the Climatology tower over a designated time period. A sample Fishnet plot is displayed in Figure 9-1. Since all the Area towers at SRS are relatively near each other, with similar exposures, terrain and elevation, they should all exhibit spatial continuity, i.e., generally measure similar atmospheric properties. Similarly, CLM is expected to also exhibit a degree of vertical continuity among the four (4) tower levels.

Manual Quality Flag

Periodically, ATG personnel log onto Fishnet and, using a GUI (Graphical User Interface), select a one-week time period to be examined (Sunday to Saturday). Once loaded, QA Groups, i.e., all area towers or all levels of CLM, can be viewed on the same monitor display. The simultaneous display allows the QA reviewer to see all the variations amongst towers or levels at the same time.

Fishnet also performs and displays a basic automated check on the data. For the Area towers, all measured values for a given 15-min period are used to calculate the Site Area Mean (SAM) of the variable being examined. If the instantaneous 15-min sigma value exceeds the SAM value by the amount given in the top half of Table 9-2, then



	A-61.0	C-61.0	D-61.0	D-36.0	F-61.0	H-61.0	K-61.0	L-61.0	P-61.0
2020-02-06 19:00:00	7.162 G	5.856 G	5.79 G	2.696 F	5.658 G	5.77 G	5.633 G	7.246 G	7.615 G
2020-02-06 19:15:00	5.657 G	5.868 G	4.36 G	2.395 F	5.63 G	4.915 G	5.851 G	6.65 G	7.822 G
2020-02-06 19:30:00	5.905 G	6.153 G	3.973 G	2.003 F	3.948 G	5.096 G	6.473 G	7.447 G	8.45 F
2020-02-06 19:45:00	9.24 F	7.198 G	4.96 G	2.439 F	3.169 F	6.49 G	6.096 G	6.677 G	6.942 G
2020-02-06 20:00:00	7.858 G	5.994 G	4.701 G	2.331 F	5.894 G	6.38 G	6.289 G	6.366 G	7.551 G
2020-02-06 20:15:00	6.665 G	5.789 G	6.475 G	3.481 F	5.894 G	5.811 G	5.855 G	7.427 G	7.827 G
2020-02-06 20:30:00	5.211 G	5.932 G	5.051 G	2.694 F	6.618 G	5.155 G	5.387 G	6.952 G	7.546 G
2020-02-06 20:45:00	4.325 G	5.595 G	6.041 G	3.304 G	5.132 G	4.742 G	4.84 G	5.939 G	6.679 G
2020-02-06 21:00:00	8.35 G	4.639 G	7.493 G	4.895 G	11.57 F	4.393 G	3.426 F	4.849 G	5.245 G
2020-02-06 21:15:00	6.79 G	8.65 G	8.56 G	5.121 G	8.48 G	7.934 G	5.88 G	4.08 F	3.598 F
2020-02-06 21:30:00	6.637 G	8.18 G	8.37 G	5.03 F	9.27 G	9.54 G	9.93 G	8.37 G	8.19 G
2020-02-06 21:45:00	6.317 G	7.637 G	4.755 G	2.478 F	5.946 G	6.669 G	6.191 G	6.023 G	6.665 G
2020-02-06 22:00:00	4.313 G	5.309 G	2.855 G	1.562 F	4.413 G	5.519 G	3.49 G	3.583 G	5.599 G
2020-02-06 22:15:00	3.153 G	3.433 G	2.068 G	0.921 F	3.301 G	3.392 G	3.441 G	3.385 G	5.066 G
2020-02-06 22:30:00	2.426 G	2.071 G	2.224 G	0.929 G	3.281 G	2.86 G	2.179 G	3.117 G	4.488 G
2020-02-06 22:45:00	2.632 G	2.491 G	1.88 G	0.97 G	2.938 G	3.13 G	2.979 G	3.006 G	3.634 G
2020-02-06 23:00:00	1.981 G	2.136 G	1.067 G	0.419 G	2.284 G	2.626 G	2.59 G	2.898 G	2.774 G
2020-02-06 23:15:00	2.292 G	3.775 G	3.665 G	2.004 G	3.872 G	3.222 G	3.804 G	3.076 G	2.937 G
2020-02-06 23:30:00	2.724 G	4.105 G	3.253 G	1.661 G	4.163 G	3.307 G	4.665 G	4.563 G	3.751 G
2020-02-06 23:45:00	3.438 G	4.62 G	2.927 G	1.516 F	4.706 G	3.579 G	4.764 G	4.713 G	4.501 G
2020-02-07 00:00:00	3.641 G	4.159 G	3.363 G	1.594 G	4.057 G	3.884 G	3.305 G	3.894 G	3.837 G
2020-02-07 00:15:00	4.316 G	3.228 G	3.006 G	1.736 G	3.8 G	2.908 G	3.469 G	3.129 G	2.923 G
2020-02-07 00:30:00	3.792 G	3.816 G	2.643 G	1.226 G	4.066 G	3.55 G	2.811 G	2.84 G	1.808 G
2020-02-07 00:45:00	3.695 G	3.32 G	2.054 G	1.085 G	3.56 G	3.345 G	2.677 G	2.531 G	2.32 G
2020-02-07 01:00:00	3.145 G	2.393 G	1.528 G	0.938 G	2.719 G	2.687 G	1.84 G	1.83 G	1.85 G
2020-02-07 01:15:00	2.247 G	2.638 G	1.708 G	0.871 G	2.263 G	2.346 G	1.858 G	2.083 G	1.709 G
2020-02-07 01:30:00	3.413 G	3.544 G	2.468 G	1.116 G	2.95 G	3.644 G	2.97 G	2.262 G	2.651 G
2020-02-07 01:45:00	2.978 G	3.621 G	2.601 G	1.166 G	3.275 G	3.011 G	3.117 G	2.661 G	2.68 G
2020-02-07 02:00:00	3.771 G	4.071 G	2.744 G	1.221 F	3.991 G	3.599 G	3.332 G	3.212 G	2.974 G
2020-02-07 02:15:00	3.309 G	3.859 G	2.768 G	1.584 G	3.675 G	3.193 G	2.842 G	2.725 G	2.189 G

Start	End	Serial No	Code	User ID	Record Date	Manual Qa	Comment
2020-02-02 00:00:00	2020-02-02 08:30:00	894189	F	j1107	2020-02-12 15:19:43.412000		Out of criterion
2020-02-02 08:45:00	2020-02-02 08:45:00	894147	G	j1107	2020-02-12 15:19:43.399000		Good
2020-02-02 09:00:00	2020-02-02 13:00:00	894190	F	j1107	2020-02-12 15:19:43.413000		Out of criterion
2020-02-02 13:15:00	2020-02-02 13:15:00	894148	G	j1107	2020-02-12 15:19:43.399000		Good
2020-02-02 13:30:00	2020-02-02 13:30:00	894191	F	j1107	2020-02-12 15:19:43.413000		Out of criterion
2020-02-02 13:45:00	2020-02-02 13:45:00	894149	G	j1107	2020-02-12 15:19:43.399000		Good
2020-02-02 14:00:00	2020-02-02 14:00:00	894192	F	j1107	2020-02-12 15:19:43.413000		Out of criterion
2020-02-02 14:15:00	2020-02-02 14:15:00	894150	G	j1107	2020-02-12 15:19:43.400000		Good
2020-02-02 14:30:00	2020-02-02 14:30:00	894193	F	j1107	2020-02-12 15:19:43.414000		Out of criterion
2020-02-02 14:45:00	2020-02-02 15:15:00	894151	G	j1107	2020-02-12 15:19:43.400000		Good
2020-02-02 15:30:00	2020-02-02 15:45:00	894194	F	j1107	2020-02-12 15:19:43.414000		Out of criterion

Figure 9-1. QA Group plot for the Area Towers QA, displaying the Scalar Wind Speed for the week 3/03/2019 to 03/29/2019 GMT. Notice there are three tabs, that correspond to the three windows that are used as part of Fishnet, Strip Charts, Anomaly Editor and Raw Data

the display is shaded in purple (i.e., "purpled"). Segments of the plot that are purpled, are not necessarily bad, but rather need further investigation. A similar process is used to visually identify suspect data for CLM (bottom half of Table 9-2) based on adjacent levels of the tower, rather than between towers (via the SAM).

Table 9-2. Screening QA Criteria for Meteorology Program Measurements

Area Towers	**15-minute averages and standard deviations of an individual tower should agree with the Site Area Mean (SAM) values within:**	
Sonic Anemometer	SPD (speed)	5 mph/2.2 m/s
	Instantaneous values from each individual tower should Agree within	
Thermometer	FT (61-m temp)	3.5 F/2.0 C
RH	RH (61-m)	5%
Central Climatology	**15-minute averages and standard deviations of an individual level should agree with an adjacent level within:**	
Sonic Anemometer	SPD (speed)	5 mph/2.2 m/s
Thermometer	T 2m (temperature) T other levels (delta temp)	3.5 F/2.0 C 3.5 F/2.0 C
RH	RH	5%
Soil Temperature	ST (soil temp)	3.5 F/2.0 C

Additional shading is used to indicate missing data (yellow), or data collected while the logger had been placed in maintenance mode (orange).

While the shaded areas of the Fishnet plots represent an initial screening for suspect data, the analyst performing the data QC will examine the full sequence of time series plots to identify additional suspicious areas based on inter-comparisons between each of the Area towers or each of the CLM levels. This includes additional examination of the regions that have been purpled. The only prior classification of data is for maintenance or missing data.

Three conditions can occur as part of the QC process. First, a period has been automatically highlighted using the ranges identified in Table 9-2 and a quality flag value has to be added for the period in question. Second, a period is highlighted (purpled) and the data is representative and needs to have the anomaly flag removed. Third, a region has data that is not highlighted, and period of data needs to have an anomaly flag added.

Fishnet also allows anomalies from "mother" variables (directly measured by the instrument) to be propagated down through the "daughter" variables (calculated values). For example, the 15-min products of relative humidity and temperature ("mothers") are used to calculate the "daughter" product dew point. If an anomaly is created for the "mother", Fishnet will create the corresponding anomaly in the "daughter".

In deciding what regions of data are "good" or "bad" the QC analysist may need to check tower maintenance and calibration logs. These logs contain technician notes and are stored in the ATG electronic document library. These documents mention not only periods when routine maintenance and calibration were being performed but notes as to the nature of instrument

issues that were noticed as part of the QC review at the beginning/end of the day. After that, other ATG and NWS data sources are used in addition to the data in Fishnet to determine if data is good or bad. For example, relative humidity is consistently high, radar data would be examined to determine if an extremely wet period took place. While most QC takes place soon after collection, problems with instruments may take time to become apparent. In those cases, it may be necessary, once identified, to go back some time, flagging large periods of time to where "unusual" performance may first appear. Typically, these problems are somewhat intermittent in nature. This is the norm with meteorological datasets: the database is a "living" database in the sense that status of any given period may only correspond to a snapshot in time. The QA process may originally determine a period as being good, only to discover later in time, when a problem has magnified over time, that the problem may have been intermittently present at earlier times. The data may need to have the data quality revised later. These issues typically occur with instrument wiring, where internment shorts may occur and only periodically cause any detectable bias (typically in the sigma values). The Fishnet software application is managed by the SRNL Integrated Computing Group and controlled through software quality assurance plan B-SQP-A-00086 (SRNL, 2018).

WAS

The WAS (WINDs Application Suite) was developed to offer user level access to the database. It is a series of applications, written in Python code, that were developed to allow access to elements of the WINDs database. The applications within WAS are under constant development. Some products provide extensive access to all variables in the WIND System database (Data Review and Archive Data) while others provide specialized output that simplifies computations. An example would be the WAS Heat Stress algorithm uses pre-programmed functions to implement the same computations as the system calls by the InSite Heat Stress libraries. Highly specific output formats that are used repetitively for the WAS Monthly Reports app are automated to ensure that human users will not inadvertently select the wrong data range. Many of the applications allow the user to generate simple visualizations (through the Matplotlib) to create plots of data. Data files can be exported as CSV (Comma Separated Values) files to allow more extensive examination using other applications. The functionality of WAS is under constant development, both to refine existing capabilities and to add new functionality.

While WAS and Fishnet are intended as very different products for different purposes, they are often used together to allow the QC process to proceed smoothly. Fishnet only allows the user to view Area Tower or Central Climatology data at one time. Through WAS, the data from one can be used to compare data from the other. Plots of various values can be overlaid on one another individually, as well as collectively to see if, for example, Central Climatology sigma values for temperature are within the range of the other Area towers for a given period. The WAS software application is managed by the SRNL Integrated Computing Group and controlled through software quality assurance plan B-SQP-A-00082 (SRNL, 2019b).

References:

L15.3-NTSP-T-113 rev. 3., 2015: *Quality Assurance of Meteorological Data (On and Off Site Towers)*.

B-SQP-A-00064 (Rev. 1), 2019a: *Software Quality Assurance Plan for the WINDS PostgreSQL Database Subsystem*, Savannah River National Laboratory, Aiken, SC.

B-SQP-A-00086 (Rev. 0), 2018: *Software Quality Assurance Plan for Fishnet*, Savannah River National Laboratory, Aiken, SC.

B-SQP-A-00082 (Rev. 0), 2019b: *Software Quality Assurance Plan for the WINDS Application Suite*, Savannah River National Laboratory, Aiken, SC.

Appendix A: Period of Record Tables

Variables from the ATG meteorological towers are summarized in this Appendix and have been organized and documented in this memo with special focus on the start date for each variable and the frequency of the measurement. This summary considers the current meteorological database and accessible historical data considering portions of data have been lost due to some magnetic tape storage malfunctions over time. "Accessible" for the purposes of this report is defined as data currently available through the WIND Application Suite v0.5.25 (WAS).

The towers included in this report are the SRNLTC A-Area Shelter, Central Climatology, and the Area Towers: A, B, C, D, F, H, K, L, and P. The CLM Tower and the Area Tower's variable lists include variables that are calculated from a primary measurement. These calculations include standard deviations, heat flux, friction velocity, and scalar/vector conversions and are denoted in Table A-1 and Table A-2 below with an *asterisk. The dew point is also listed as a calculation in the Tables below, however the dewpoint was initially a direct measurement before the upgrade to relative humidity (RH) sensors in 2012-2014. After this switch, the dew point values are calculated from the RH measurements and RH temperature sensor. The specific dates for each switch can be found using the start date of the RH sensor for the given tower.

A-Area Shelter

Precipitation measurements in A-Area have been collected at since 1952 starting as monthly totals. In 2004 the shelter was updated to include a Belfort tipping bucket rain gauge for additional 15-minute precipitation measurements. At this same time a Campbell Scientific CS-500 temperature/relative humidity datalogger was also installed. Even though the tipping bucket, and humidity/temperature is recorded in 15-minute increments, this data has continued to be presented in daily totals for use on the ATG webpage.

The SRNLTC A-Area shelter information can be found on Table A-2 below.

Central Climatology Tower

Though the tower was completed in 1985, the database for CLM starts on December 31st, 1988. This is due in part to a delay in instrument calibrations, and the data not being archived until January 1989 (Kurzeja 1993).

All of the data for this location is stored as 15-minute data points with the exception of the Vaisala Windcube which is a vertical wind profiler. The Windcube was installed December 2019 and is located next to building 623-27N. This instrument records data at 5-minute increments but is averaged to 15-minutes for data storage.

The Central Climatology Tower information can be found on Table A-1 below.

Area Towers

Some of the data for the Area Tower network has been lost over time due to magnetic tape storage malfunctions before the digital database conversion for historical data. This resulted in the current period of record for the ATG Area Towers only having accessible data as far back as June 7th, 1980.

For the Area Towers B, C, H, and L, and the B-Area helipad location ATG operates four R.M. Young Sentry visibility sensors. Installations for these instruments began in 2008 and each data point from these sensors are presented in 15-minute increments.

The Area Tower information can be found on Table A-2 below.

Miscellaneous Instruments

In B-Area ATG also operates a Vaisala CL31 Ceilometer. The ceilometer was installed to provide data on cloud height for SRS security force helicopter flight operations, and also provides information to determine the height of the atmospheric boundary layer (ABL). This data started with a measurement frequency of 2 seconds when installed in February in 2009. Later that year the measurement frequency was altered to 30 seconds and was changed again in February 2019 to 15 seconds.

The P-Area forest tipping bucket and forest soil moisture probes have been decommissioned as of August 2018. Similarly, the rainfall listed in Table A-2 refers to wedge rain gauges which require a daily manual check have also been decommissioned as of 02/29/2020. Daily rainfall estimates for the former wedge locations are instead derived from NOAA's Multi-Radar Multi-Sensor (Rivera 2020).

References:

Kurzeja, Robert. 1993: *The SRTC Climatology Site: Past, Present and Future,* Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, SC.

Parker, M.J. and Addis, R.P., 1993: *Meteorological Monitoring Program at the Savannah River Site*, WSRC-TR-93-0106, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, SC.

Rivera-Giboyeaux, A. M. 2020*: Radar Derived Rainfall and Rain Gauge Measurements at SRS*, SRNL-STI-2019-0064 rev 0. Savannah River National Laboratory, Aiken SC.

Table A-1: Central Climatology Tower Period of Record List

Variable Name	Start Date (2m)	Start Date (4m)	Start Date (18m)	Start Date (36m)	Start Date (61m)
Barometric Pressure	1989-03-20				
Barometric Pressure Sigma *	2014-03-18				
Dew Point [a]*	1988-12-31		1988-12-31	1988-12-31	1988-12-31
Dew Point Sigma *	2014-03-18		2014-03-18	1988-12-31	1988-12-31
Evaporation	1989-03-20				
Evaporation Linear Sigma *	2014-03-18				
Friction Velocity *		2014-04-18	2014-04-18	2014-04-18	2014-04-18
H. Wind Direction Scalar		1988-12-31	1988-12-31	1988-12-31	1988-12-31
H. Wind Direction Sigma *		1988-12-31	1988-12-31	1989-12-31	1988-12-31
H. Wind Direction Vector *		1988-12-31	1988-12-31	1988-12-31	1988-12-31
Heat Flux *			2016-04-26		2016-04-26
Max Wind Speed [b]		1988-12-31	1988-12-31	1988-12-31	1988-12-31
Max Wind Speed 2D		2014-03-17	2014-03-17	2014-03-17	2014-03-17
Max Wind Speed 3D *		2014-03-17	2014-03-17	2014-03-17	2014-03-17
Rainfall	1989-03-20				
Relative Humidity	2014-03-27		2014-03-18	2014-03-17	2014-03-17
Relative Humidity Sigma *	2014-03-27		2014-03-18	2014-03-17	2014-03-17
Solar Radiometer	1989-03-20				
Solar Radiometer Sigma *	2014-03-18				
Temperature[c]	1988-12-31		1988-12-31	1988-12-31	1988-12-31
Temperature from RH Probe	2014-03-27		2014-03-18	2014-03-17	2014-03-17
Temperature RH Probe Sigma *	2014-03-27		2014-03-18	2014-03-17	2014-03-17
Temperature from Sonic		2014-03-17	2014-03-17	2014-03-17	2014-03-17
Temperature from Sonic Sigma *		2014-03-17		2014-03-17	2014-03-17
Temperature Sigma *	1988-12-31				1988-12-31
V. Wind Direction Scalar		1988-12-31	1988-12-31	1988-12-31	1988-12-31
V. Wind Direction Sigma *		1988-12-31	1988-12-31	1988-12-31	1988-12-31
Water Temperature	1989-03-20				
Water Temperature Sigma *	2014-03-18				
Wind Cube LIDAR	2019-12-03				
Wind Linear Sigma *		1988-12-31	1988-12-31	1988-12-31	1988-12-31
Wind Speed Scalar		1988-12-31	1988-12-31	1988-12-31	1988-12-31
Wind Speed Vector *		1988-12-31	1988-12-31	1989-12-31	1988-12-31

Soil Temperature (-1 in)	1989-03-20
Soil temperature Sigma (-1 in) *	2014-03-20
Soil Temperature (-6 in)	1989-03-20
Soil temperature Sigma (-6 in) *	2014-03-20
Soil Temperature (-12 in)	1989-03-20
Soil temperature Sigma (-12 in)*	2014-03-20

* Delineates the variable listed as a calculated value

[a]/[b] The variable started as a measurement as listed in 1988. As RH/Sonic sensors were installed in 2014, dew point/max wind speed became a calculated value

[c] RTD Temperature probes decommissioned March 2014 with the installation of the RH sensors

Table A-2: Area Tower, and A-Area Shelter and B-Area Helipad Period of Record List

Variable Name	Height (m)	A-Area	B-Area	C-Area	D-Area	D-Area (Height 36m)	F-Area	H-Area	K-Area	L-Area	P-Area	A-Area Shelter
Dew Point [a]*	61	1988-12-31		1988-12-31	1988-12-31		1988-12-31	1988-12-31	1988-12-31	1988-12-31	1988-12-31	
Dew Point Sigma *	61	1988-12-31		1988-12-31	1988-12-31		1988-12-31	1988-12-31	1988-12-31	1988-12-31	1988-12-31	
Friction velocity *	61	2014-04-30		2013-11-21	2013-07-08	2013-07-08	2013-03-27	2013-07-01	2013-03-21	2013-08-07	2013-12-20	
H. Wind Direction Scalar	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
H. Wind Direction Sigma *	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
H. Wind Direction Vector	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
Heat flux *	61	2016-04-26		2016-04-26	2016-04-26	2016-04-26	2016-04-26	2016-04-26	2016-04-26	2016-04-26	2016-04-26	
Max Windspeed	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
Max Windspeed 2D	61	2012-09-18		2013-11-18	2013-06-21	2013-06-21	2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-12-17	
Max Windspeed 3D	61	2012-09-18		2013-11-18	2013-06-21	2013-06-21	2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-12-17	
Relative Humidity	61	2012-09-18		2013-10-29	2013-06-21		2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-12-17	
Relative Humidity Sigma *	61	2012-09-18		2013-10-29	2013-06-21		2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-12-17	
Temperature	61	1988-12-31		1988-12-31	1988-12-31		1988-12-31	1988-12-31	1988-12-31	1988-12-31	1988-12-31	
Temperature Sigma *	61	1988-12-31		1988-12-31	1988-12-31		1988-12-31	1988-12-31	1988-12-31	1988-12-31	1988-12-31	
Temperature from RH probe	61	2012-09-18		2013-11-03	2013-06-21		2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-08-26	
Temperature from RH Probe Sigma *	61	2012-09-18		2013-11-03	2013-06-21		2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-08-26	
Temperature from Sonic	61	2012-09-18		2013-11-18	2013-06-21	2013-06-21	2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-12-17	
Temperature from Sonic Sigma *	61	2012-09-18		2013-11-18	2013-06-21	2013-06-21	2013-03-25	2013-05-30	2013-03-14	2013-07-22	2013-12-17	
V. Wind Direction Scalar	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
V. Wind Direction Sigma *	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
Wind Speed Scalar	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
Wind Speed Sigma *	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
Wind Speed Vector	61	1980-06-07		1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1980-06-07	1984-02-17	1980-06-07	
Visibility	45			2008-09-18				2008-09-22		2008-09-22		
Visibility Sigma *	45			2013-11-18				2013-06-03				
Visibility	3		2008-07-11									
Visibility Sigma *	3		2014-06-03									
Humidity (High/Low Daily)												1964-01-01
Temperature	2	1988-12-31		1988-12-31	1988-12-31		1988-12-31	1988-12-31	1988-12-31	1988-12-31	1988-12-31	1964-01-01 [b]
Temperature Sigma *	2	1988-12-31		1988-12-31	1988-12-31		1988-12-31	1988-12-31	1988-12-31	1988-12-31	1988-12-31	
Rainfall	1	1961-01-13 [c]		1984-07-12 [c]	1973-01-01 [c]		1961-01-13 [c]	1984-07-11 [c]	1984-07-12 [c]	1961-01-13 [c]	1968-12-21 [c]	1952-01-31 [d]
Rainfall in Forest (Tipping Bucket)											1999-12-10 [e]	
Rainfall in Grass (Tipping Bucket)	1				2014-09-25		2017-09-23				1999-12-10	
Ceilometer	1		2009-02-09									
Soil Moisture in Forest	1										1999-12-10 [e]	
Soil Moisture in Grass	-2										1999-12-10	

Table A-2 Continued. Table A-2 Footnotes

* Delineates the variable listed as a calculated as described in the opening paragraph

[a]The dewpoint started as a measurement as listed in 1988, RH sensors were installed to each tower in 2012/2013 where the dew point became a calculated value

[b]Temperature data from SRTC Shelter is in daily high/ low format

[c] Rainfall wedge gauges are no longer used after 02/29/2020 refer to SRNL-STI-2019-00644 for details

[d] The SRTC rain data starts in a monthly format until 09/01/1964 where the data is updated to a daily format

[e] P-Area Forest Tipping bucket and soil moisture probe decommissioned 08/16/2018

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Appendix B: Forest Management Agreement with the U.S. Forest Service Savannah River around Meteorological Towers

Forest Management Agreement with the U.S. Forest Service Savannah River

February 22, 1991

To: SRTC Staff

From: John G. Irwin, Forest Manager, Savannah River Forest Station

Subject: Timber Management Policy For Wind Towers

In a meeting on February 11, 1991, with Roger Pitts, Bob Harllee, of the SRFS, and Matt Parker and Rob Addis of SRTC, there was agreed the policy or management guides to be followed when working around the swindle Towers. It is stated on Site Use SV-91-22-O that SRFS and SRTC will agree on this policy.

SRTC has not told us how to accomplish management in these areas, but the conditions they need maintained. This condition is that of a nearly unbroken canopy of trees of about the same height. They have said that this condition needs to be maintained for a 2,001-foot radius around each of the eight meteorological towers. The 609-foot radius around the Climatology Tower at Central Shops will be maintained in its existing cleared condition.

Management will be as follows:

- Salvage of insect, fire, or disease killed trees will be permitted. In cases where this involve more than 1 acre, SRTC should be contacted and advised and/or shown what needs to be done.

- Prescribed burning will be permitted to within 100 feet of the tower or any associated structure. This100 feet is only for the protection of the tower or it associated structures and has no climatological significance. Prescribed burning Site Uses will have to be coordinated specifically and personally with SRTC to be sure that the burning parameters in the Site Use are adequate. There will be no mechanical line plowing within 100 feet of the towers.

- Planned timber management with the 2000-foot radius of the towers will be emphasizing uneven-aged management, using different techniques to achieve this structure. Types of management will be different combination of group selection and also single tree selection. The size of the openings in group selection will be a maximum of 1/2 acre. Basal areas for thinning between the openings will be no less than 40 square feet/acre. Target basal areas for single tree selection areas will be 58 to 65 square feet/acre of pine species The Site Uses for all timber operations will be coordinated specifically and personally with SRTC.

If species conversion is prescribed to regeneration i.e., Slash-Pine to be converted to Longleaf Pine, there will still have to be 40 square feet of basal area per acre left of the existing species, or as stated above, openings not exceeding 1/2 acre may be created and the species to be converted to will have to be under planted, and the young trees cared for and released until they can take over the stand