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Savannah River Site Annual Meteorology Report for 2019

E.S. Bell

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REVIEWS AND APPROVALS

AUTHORS:

EVALEIGH BELL (Affiliate) Digitally signed by EVALEIGH BELL (Affiliate)
Date: 2021.03.11 06:10:13 -05'00'

Evaleigh S. Bell, Atmospheric Technologies Date

TECHNICAL REVIEW:

Stephen Weinbeck Digitally signed by Stephen Weinbeck
Date: 2021.03.11 09:11:28 -05'00'

Steve W. Weinbeck, Atmospheric Technologies Date

APPROVAL:

Steven R. Chiswell Digitally signed by Steven R. Chiswell
Date: 2021.03.15 09:32:59 -04'00'

Steven R. Chiswell, Manager Date
Nonproliferation Technology

EXECUTIVE SUMMARY

This report summarizes the general climate of the Savannah River Site (SRS), provides an updated overview of the SRS meteorological monitoring program, and includes a comparison of the 30-year averages of meteorological variables against 2019 observations. Additionally, this annual report will highlight significant weather events that impacted the SRS in 2019.

Overall, the site experienced a relatively normal year with temperature values near the 30-year average with the 2nd warmest May (of all May's on record), 3rd warmest September (of all September's on record), and 4th warmest October (of all October's on record). 2019 is the second year in a row that September ranked as the 3rd hottest September on record, and October had a record-breaking daily high of 98°F. In 2019, total rainfall amount was 3.79 inches below the mean 30-year value. February was ranked the 4th driest and July was ranked as the third driest July on record with 3.87 inches less than the 30-year average while December was the 5th wettest with 3.99 inches above average. Wind direction on site was frequently from the southwestern sectors, shifting to a prevalent northeast wind during the fall and northwest in the winter which agrees with the dominant synoptic patterns observed in the southeastern U.S.

The most significant weather event for the Southern U.S. was Hurricane Dorian. Although impacts of this system to the CSRA (Central Savannah River Area) were minimal, this tropical cyclone severely impacted the East coast of the United States in September 2019.

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LIST OF ABBREVIATIONS

AGL	Above Ground Level
ATG	Atmospheric Technologies Group
CDD	Cooling Degree Days
CLM	Central Climatology Tower
CSRA	Central Savannah River Area
HDD	Heating Degree Days
NLDN	National Lightning Detection Network
SRS	Savannah River Site
VVIS	Vertical Visibility
WBGT	Wet Bulb Globe Temperature
WRF	Weather Research and Forecasting model

1.0 Background

1.1 The General SRS Climate

The Savannah River Site (SRS) region has a humid subtropical climate characterized by relatively short, mild winters and long, warm, and humid summers (Oliver and Fairbridge, 1987). Summer-like conditions typically last from May through September, when the area is frequently under the influence of the western extension of the semi-permanent Atlantic subtropical anticyclone (i.e. the 'Bermuda' high). In summer, winds are light and cold fronts generally remain well north of the area. Daily high temperatures during the summer months on the average exceed 90°F on more than half of all days. Scattered afternoon and evening thunderstorms are common during this period.

The influence of the Bermuda high begins to diminish during the fall, and continental air masses become more prevalent, resulting in lower humidity and moderate temperatures. Rainfall totals during the fall are usually the least of the four seasons. Occasionally, the area is impacted by tropical systems moving in from the Atlantic during this season, mainly during the months of August and September (SRNS-IM-2013-00019, Rev. 2).

During the winter months, mid-latitude low pressure systems and associated fronts often migrate through the region. As a result, conditions frequently alternate between warm, moist, subtropical air from the Gulf of Mexico region and cool, dry polar air. The Appalachian Mountains to the north and northwest of the SRS help moderate the extremely cold temperatures that are associated with occasional outbreaks of Arctic air. Consequently, on average less than one-third of winter days have minimum temperatures below freezing, and days with temperatures below 20°F are rare. Measurable snowfall occurs on average once every 4 years.

Tornadoes over the region occur more frequently in the spring than in any other season of the year. Although spring weather is relatively windy, temperatures are usually mild, and humidity is relatively low compared to the rest of the year.

1.2 Overview of the Savannah River Site Meteorological Monitoring Program

Meteorological data is collected at SRS from a network of nine primary monitoring stations (Fig. 1). A more detailed description for each monitoring station can be found in the Meteorological monitoring Program (Weinbeck, 2020). Towers located adjacent to each of eight operations areas (A, C, D, F, H, K, L, and P areas) are equipped to measure wind direction, wind speed, temperature, and relative humidity at a height of 61 meters (m) above ground. A ninth tower near N-Area, known as the Central Climatology site (CLM), is instrumented with wind, temperature, and relative humidity sensors at four levels: 2- (4 m for wind), 18-, 36-, and 61-m Above Ground Level (AGL). The CLM site is also equipped with a tipping bucket rain gauge, a barometric pressure sensor, and a solar radiometer near the tower at ground level. Data acquisition units at each station record wind speed and direction from the sonic anemometers at a rate of 10 measurements per second. Measurements from the temperature and humidity sensors and the ground level instruments at CLM are recorded at 1-second intervals. Every 15 minutes, the instantaneous measurements (9000 or 900 data points, respectively) are processed to generate statistical summaries for each variable, including averages and instantaneous maxima, and the results are uploaded to a relational database for permanent archival. Additionally, a ceilometer located in B-area and gives information about cloud coverage as well as fog or smoke present in the lower atmosphere. All aspects of the

meteorological data collection program meet applicable regulatory criteria (SRNS-RP-2012-00202, Rev. 2).

Quality assurance of the data is conducted in two phases: an initial screening of recent data, followed by an in-depth review and final quality classification. The initial screening, generally performed twice daily by qualified instrument technicians, consists of a thorough examination of 15-minute data retrieved from the database, in conjunction with a summary of instrument diagnostics obtained from the local data acquisition units. Potential problems are noted in a daily check sheet and, as needed, data acquisition unit software is configured to assign a quality control tag to data collected from the questionable instruments. Quality flags are also set during periods of calibration and maintenance.

The second phase of the quality assurance process is conducted according to a formal procedure (SRNL, 2015). Daily check sheets generated during the initial screening, tower-specific logbook entries, initial quality flags, and time series plots of related data are reviewed to determine a final quality status for each record. All records permanently archived in the data base are identified as good, fatal, intermittent, biased, or uncalibrated.

1.3 Additional Measurements

Additional precipitation measurements are collected from a network of 7 plastic wedge rain gauges and 4 tipping bucket rain gauges across the SRS. The wedge gauges are read by security or operations personnel once per day around 6 am. The tipping bucket gauges are co-located with the D, F, P, and CLM towers and are uploaded to the WINDs database directly every 15-minutes. The daily data is reported to the SRNL Atmospheric Technologies Group, reviewed for any obvious flaws and manually entered into a permanent electronic database.

Measurements of temperature and relative humidity are also recorded from a weather station located in A-Area, adjacent to SRNL. This station consists of a standard National Weather Service ‘cotton region’ instrument shelter. Data from this station (daily high and low values of temperature and relative humidity) is obtained through a data logger and transferred into our system for archival in our electronic data base.

1.4 Data Sources for the 2019 Report

Summaries provided with this report are based on the following sources of data:

- Ground level (surface) measurements of *temperature (2m)*, *relative humidity (2m) wind speed (4m)*, *barometric pressure*, *rainfall* and *solar radiation* from CLM. Other meteorological quantities in this report are derived from this primary data (*dew point*, *wet bulb temperature*, *wet bulb globe temperature*, *cooling/heating degree days,* etc.*)*

- Wind speed and direction from measurements collected at each of the four levels of CLM and the 61-m level of the eight area towers.

- Precipitation from the network of wedge rain gauges.

- Fog from measurements made by the ceilometer in B-area.

- Lightning data from the National Lightning Detection Network (NLDN) operated by Vaisala Corp. and imported via ATG's NOAAPort data feed (Data currently unavailable).

Quality assurance of the data followed the formal procedure previously described and was completed with the aid of ATG's Fishnet software application. All data qualified as 'good' during this process was then imported into a CSV file which was evaluated using a custom code written in Python to generate the final summaries that are presented in this report. Plots provided in this document were generated using Microsoft Excel®.

Long-term climatological records are available for precipitation and temperature starting in 1964 and 1968, respectively. Statistics generated from these data are used for comparisons with the 2019 summaries. The period used for comparison was composed of the most recent 30 years: 1990-2019. From 1990 through 1995, the temperature values used were based on the average of daily maxima and minima recorded at the SRNL instrument shelter. Since 1995, temperature measurements are taken from the 2m level of CLM. Similarly, precipitation values reported before 1995 are based on daily observations from the SRNL rain gauge, then after 1995 precipitation data began to be continuously collected with the CLM tipping bucket rain gauge (with the exception of 2017, due to lightning damage to the sensor).

2.0 Climatology of SRS for 2019

2.1 Temperature

Daily mean temperatures, annual average temperature for 2019, and the 30-year average temperature are depicted in Figure 2. Overall, the 2019 annual average temperature was only slightly higher than the 30-year average - the annual average temperature for 2019, 65.6°F, was approximately 1.3°F above the 30-year climatological average of 64.3°F (Table 2 and Figure 4). However in terms of extreme temperature values, various events should be noted. Temperature values ranged from a minimum of 23.5°F on January 26th, to a maximum of 99.6°F on May 29th (Figure 3 and Table 1(a)). Daily highs did not exceed 100°F during the entire period, while a daily high temperature above 90°F was observed on a total of 90 days. Contrastingly, this year 23 days experienced daily lows below 32°F, of which no days reached minimum temperatures below 20°F (Table 1(a)).

Historically, July is the warmest month of the year with an average daily maximum temperature of 92.6°F and daily minimum of 71.0°F. In turn, January is the coldest month with an average daily maximum temperature of 57.7°F and an average minimum of 37.8°F. During the spring and fall months, temperatures are generally moderate. Monthly average temperatures in 2019 were generally near climatological average values through most of the year, but the month of May showed the greatest departure from the average value (Figure 5). May's monthly average temperature of 76.6°F was ranked as the 2nd warmest on record for the site with a departure of 4.7°F above the 30-year average (Table 1(a)). September and October were also ranked as the 3rd and 4th warmest respectively on record with departures of 3.7°F and 4.6°F from the 30-year average for that month. In addition, October had the warmest daily high on record for that month with a record-breaking 98°F. In contrast, average monthly temperature in November was cooler than average with a departure of 3.7°F.

Monthly and annual total heating and cooling degree days for 2019 (based on a reference temperature of 65°F) are summarized in Table 1(c). The total heating degree days was 2100, while

total cooling degree days was 2323. The daily maximum Heating Degree Day (HDD) was observed on January 21st with a total of 31 heating degrees, while the highest Cooling Degree Day (CDD) value was observed on July 17th and May 30th with a value of 21 cooling degrees.

2.2 Precipitation

Daily rainfall amounts during the year 2019 were generally less than 2 inches, with only a single exception observed at CLM (Fig. 6). The highest 24-hour rainfall amount recorded in 2019 was 2.24 inches in December 13th this event was associated with a heavy downpour from a passing severe thunderstorm. Hurricane Dorian (Fig. 7) caused significant damage moving along the Georgia and South Carolina coasts, however, no significant rainfall or damage was observed in the CSRA.

Total annual precipitation at the CLM was 42.82 inches, which is 3.79 inches below the 30-year average (Table 1(a) and Table 3). Comparing 2019 rainfall total to previous years shows that 2019 was a relatively 'dry' year (Fig. 8). During 2019, measurable precipitation (>0.01 inch) occurred on 107 days, rainfall greater than 0.1 inches was observed on 73 days, of which, 36 days exhibited rainfall amounts greater than 0.5 inches (Table 1(a)).

Monthly rainfall totals generally showed below average rainfall amounts for 2019 (Table 1(a) and Figure 9). Half of 2019 months were ranked drier than average with July ranking as the 3rd driest on record for that month with rainfall totaling 1.45 inches, and February ranking as the 4th driest at 1.13 inches for the month (Table 1(a)). In contrast, above average rainfall occurred during the late fall/early winter season, when the area climatologically experiences the least amount of rainfall. During the months of October and November, and at the start of December, the rainfall totals for each month were above the 30-year average. December 2019 was ranked as the 5th rainiest on record with 3.99 inches above the 30-year mean amount for that month (Table 1(a) and Figure 9).

Figure 10 and Table 4 display the spatial variability in rainfall amount totals on site using the rain gauge network. The highest rainfall totals were recorded at the Barricade 2 and F-Area wedge stations whereas the lowest annual totals were observed for Barricade 3 and K-Area gauges. The latter stations have values that are in close agreement to what was observed with the CLM.

2.3 Lightning

The 2019 lightning data is currently unavailable for calculation for this report. When the data becomes available, a revision to this document will be issued.

2.4 Atmospheric Moisture

Average relative humidity for 2019 was 71.9% with an average daily minimum value of 46.1% and an average daily maximum value of 94.2% (Table 1(b)). The lowest relative humidity observed in 2019 was measured on March 7th with a value of 15.3% (Fig. 14). Few days throughout the year reached relative humidity values below 20% or above 80% during the day, however overnight maximum relative humidity values commonly reached 90-100% (Table 1(b)).

Observed dew point temperatures ranged from a maximum of 77.7°F on July 10, to a minimum of 15.5°F on January 21st. The wet bulb temperature, which reached a maximum value of 86.1°F on July 17th.

2.5 Fog

Fog is detected at SRS using a ceilometer located in B-area. Ceilometer data has been collected since 2010. Fog is characterized by a report of vertical visibility (VVIS) associated with the lack of a discernible cloud base. The number of days where fog is reported is the number of fog days. On average, SRS has about 35 days of fog per year, which agrees with 2019 total of 40 days with fog. Figure 15 shows the monthly occurrence of fog in 2019 and the average monthly fog for the previous years (2010-2018). The highest number of fog day months is tied between January, February, May, and August with 5 fog days total. Historically, August and December have the highest amount of fog days while October usually has the fewest. 2019 had a comparatively high number of fog days with about twice the average number of fog days occurred in January, February, and May. Whereas December and March had averaged half of the expected fog days for each month.

2.6 Heat Stress

Restrictions on outdoor work due to excessive heat are based on values of the wet bulb globe temperature. Hunter and Minyard (2000) provide a description of WBGT and the method used at SRS to calculate WBGT from standard meteorological measurements at CLM. During 2017, the thresholds for Heat Stress Categories were updated and temperatures needed to reach each category were changed, particularly for Category 4 and 5 which now have lower threshold temperature values (SRS, 2017). Given that inter-annual variability is large, the number of days per category is not significantly affected by this change and is consistent with values from previous years.

Monthly and annual maximum WBGT and statistics on heat stress category days for 2019 is summarized in Table 1(b). The highest WBGT for 2019 was 94.8°F on August 11th. As can be seen on Table 1(b) and Fig. 16, a total of 179 days reached or exceeded Category 1 (WBGT > 77.0 °F) in 2019. Category 2 (WBGT > 83 °F) was reached on 135 days. Category 3 (WBGT > 84°F) and Category 4 (WBGT > 86°F) were reached on 123 and 112 days, respectively. Lastly, heat stress Category 5 (WBGT > 88 °F) was reached on 74 days during 2019. Most of the Heat Stress days are observed during the summer and early fall, but in 2019 several Cat. 4 and 5 days were observed during the month of October (Table 1(b)).

2.7 Wind

Daily average wind speed at the 4-meter level of the CLM tower during 2019 was 3.4 mph (Fig. 17). Table 1(c) shows that monthly average wind speeds were higher during the spring months, then decreasing during the summer. The highest *monthly* average wind speed was observed in April and March with a value of 3.8 mph. The highest *15-minute* wind speed mean value recorded was 17.0 mph on February 12th. Additionally, instruments at CLM allow for measurement of an instantaneous maximum wind gust speed over each 15-min period in a day. The highest instantaneous wind gust speed recorded was of 46.3 mph on June 9th and February 12th.

An annual wind rose for the 61-m level at CLM shows that wind directions were most frequently from the southwesterly sectors, with a secondary component from the East-Northeast sector (Figure 18). Wind speeds were most frequently in the 2-4 m/s (4-9 mph) and 4-6 m/s (9 -13 mph) wind speed categories. Seasonal wind rose plots for CLM from the 61-m level show typical wind directions throughout the year (Fig. 19). During the winter (Jan–Feb 2019) westerly winds were predominant, as well as winds from the east during this period with wind speeds above 6 m/s (12 mph). In the spring (March-May) winds were most frequently southerly and westerly with speeds more frequently between 4-6 m/s (9-13 mph), and higher speeds for the westerly components. Summer (June–August) shows mainly from south or west wind direction sectors with speeds generally less than 4 m/s (9 mph) observed more frequently. During the fall (September-November) a northeasterly flow is predominant with speeds generally less than 6 m/s (13 mph, Figure 19). Note that December 2019 was not included in these calculations due to the nature of the data input of the wind rose plot generation system. These patterns agree with the climatology of winds for the region. (For a complete description of the seasonal distribution of wind directions and climatology of winds at SRS refer to Weber et. al, 2003).

An overall look at winds over the different area towers on site is presented on Fig. 20 (a-d). Towers around the site exhibit good agreement on the predominant wind directions and speed, with the exception of the D-area tower. The wind rose plot for D-area shows higher frequencies of winds from the SSE and NW than the other area towers. Additionally, winds at this area tower have a higher frequency of lower wind speeds. These discrepancies in wind characteristics result from the tower location within the river valley. Drainage flow occurs often (mainly overnight) and creates a different wind pattern over this region compared to observations for the rest of the site which is at a higher elevation.

2.8 Barometric Pressure

Average barometric (station) pressure at the site is of 1006.2 millibar (mb) (Table 1(c) and Figure 21). The lowest daily average pressure in 2019 was 992.1 mb on April 19th. The highest daily average pressured was 1022.6 mb and occurred on January 22nd.

2.9 Solar Radiation

The average daily solar radiation ranged from a minimum daily total of 23.4 Langley's per day (ly/day) in January 4th, to a maximum daily value of 726.6 ly/day on 14th of June (Fig. 22 and Table 1(c)). Monthly fraction of observed average solar radiation relative to theoretical clear sky values was calculated. Theoretical clear sky maxima values were estimated from tables published by Budyko (1974). Monthly fractions of solar radiation suggest that 2019 was a typical year with all months recording on average solar radiation values that were about 60-70% of the theoretical maximum solar radiation for the majority of the year (Fig. 23). The highest fraction of theoretical maximum in 2019 was obtained in May with 77.4% of theoretical max while the lowest fraction (55.3%) was observed in February 2019 (Table 1(c)). These results agree with the typical seasonality of solar radiation, as well as with the synoptic frequently observed during these months. Generally, by the start of the spring, high pressure systems dominate over the region with more frequent clear days while during winter we tend to experience more cloudiness as well as much shorter days, which makes for lower values of solar radiation on this time of year.

3.0 Conclusions

The results of this report show that 2019 was an average year compared to the most recent 30-year temperature mean for SRS. However, May 2019 was ranked as having the 2nd warmest average temperature for that month since 1968, while September was the 3rd warmest September and October was the 4th warmest October for the same record setting a record daily high temperature of 98°F. Total rainfall for 2019 was 42.82 inches, which is 3.79 inches below the annual average for the last 30 years, with July being the 3rd driest July in record from 1968. The last trimester of the year was significantly wet compared to 30-year averages, with December departing from the 30-year average by 3.99 inches. Mean wind speed was near average values and wind direction patterns observed this year are also in agreement with previous reports, showing a predominant southwesterly and westerly flow through most of the year, and a northeasterly wind more frequent during the fall.

The most significant weather event for the Southern U.S. was Hurricane Dorian. Although impacts of this system to the CSRA were minimal, this tropical cyclone severely impacted the East coast of the United States in September 2019.

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Table 1(a): Means and Extremes of SRS Meteorological Data for 2019: Temperature and Precipitation

Month	Temperatures (°F)													Precipitation (in)							
	Average					Extremes				Number of Days									No. of Days		
	Avg. Daily High	Avg. Daily Low	Month Avg.	*Departure from 30yr avg*	Rank (1968-2019)	Highest	Highest Date	Lowest	Lowest Date	High Above 90 °F	High Above 100 °F	Low Below 32 °F	Low Below 20 °F	Total	*Departure from 30yr avg*	Rank (1964-2019)	Greatest in 24 Hrs	Date of 24hr max	Greater Than 0.01 in.	Greater Than 0.1 in.	Greater Than 0.5 in.
Jan	57.7	37.8	**47.5**	***0.6***	**18**	72.9	1-Jan	23.5	26-Jan	0	0	11	0	**4.19**	***0.15***	**21**	1.63	24-Jan	10	7	3
Feb	66.3	44.0	**54.5**	***4.2***	**6**	81.0	7-Feb	27.8	1-Feb	0	0	2	0	**1.13**	***-2.70***	**4**	0.27	16-Feb	13	3	0
Mar	68.3	44.1	**56.2**	***-0.4***	**22**	81.5	15-Mar	26.4	6-Mar	0	0	2	0	**2.25**	***-1.80***	**8**	1.18	3-Mar	6	4	2
Apr	76.2	53.1	**64.8**	***0.6***	**22**	87.3	29-Apr	35.5	3-Apr	0	0	0	0	**4.04**	***0.89***	**21**	0.98	2-Apr	10	7	4
May	88.7	65.0	**76.6**	***4.7***	**2**	99.6	29-May	50.9	14-May	14	0	0	0	**1.68**	***-1.31***	**12**	0.67	12-May	6	3	2
Jun	87.2	67.5	**76.7**	***-1.3***	**15**	92.5	2-Jun	56.2	14-Jun	10	0	0	0	**7.05**	***2.18***	**8**	0.98	8-Jun	12	11	8
Jul	92.6	71.0	**80.9**	***0.4***	**25**	97.6	31-Jul	63.9	28-Jul	24	0	0	0	**1.45**	***-3.87***	**3**	0.60	15-Jul	8	3	1
Aug	91.0	71.0	**79.6**	***0.2***	**22**	98.0	10-Aug	59.5	30-Aug	19	0	0	0	**3.21**	***-1.14***	**16**	1.24	23-Aug	7	6	2
Sep	91.2	68.2	**78.6**	***3.7***	**3**	96.6	9-Sep	57.7	20-Sep	20	0	0	0	**1.65**	***-2.20***	**13**	0.98	1-Sep	4	3	1
Oct	80.6	58.8	**69.6**	***4.6***	**4**	98.0	4-Oct	43.8	23-Oct	3	0	0	0	**4.68**	***1.58***	**9**	1.11	19-Oct	11	8	4
Nov	62.7	41.0	**51.2**	***-3.7***	**5**	77.5	5-Nov	27.4	13-Nov	0	0	3	0	**3.30**	***0.44***	**18**	1.40	15-Nov	7	6	2
Dec	61.0	41.8	**51.1**	***2.2***	**16**	78.3	10-Dec	26.9	20-Dec	0	0	5	0	**8.19**	***3.99***	**5**	2.24	13-Dec	13	12	7
Year	76.9	55.3	**65.6**	***1.3***	**11**	99.6	29-May	23.5	26-Jan	90	0	23	0	**42.82**	***-3.79***	**14**	2.24	13-Dec	107	73	36

Rank by coolest Rank by warmest Rank by wettest Rank by dryest

Table 1(b): Means and Extremes of SRS Meteorological Data for 2019: Dew Point, Wet Blub, Relative Humidity, WBGT

Month	Dew Point Temperature (°F)					Wet Bulb Temperature (°F)					Relative Humidity (%)					Wet Bulb Globe Temperature (°F)						
																		Number of Days				
	Average	Highest	Highest Date	Lowest	Lowest Date	Average	Highest	Highest Date	Lowest	Lowest Date	Avg. Daily Maximum	Avg. Daily Minimum	Monthly Avg.	Lowest	Lowest Date	Highest	Highest Date	Cat 1 and Above	Cat 2 and Above	Cat 3 and Above	Cat 4 and Above	Cat 5
Jan	**37.3**	66.1	1-Jan	15.5	21-Jan	**47.5**	68.0	1-Jan	34.2	21-Jan	**92.5**	**49.1**	73.8	18.9	26-Jan	76.2	1-Jan	0	0	0	0	0
Feb	**44.5**	61.1	21-Feb	18.6	9-Feb	**54.5**	67.7	7-Feb	44.1	1-Feb	**92.2**	**47.9**	73.8	15.4	25-Feb	77.5	21-Feb	1	0	0	0	0
Mar	**42.0**	60.4	10-Mar	17.2	6-Mar	**56.4**	68.6	15-Mar	38.5	6-Mar	**90.6**	**37.9**	64.0	15.3	7-Mar	77.4	15-Mar	1	0	0	0	0
Apr	**53.4**	68.9	13-Apr	23.7	1-Apr	**64.8**	73.5	13-Apr	44.9	2-Apr	**91.9**	**42.9**	70.6	21.8	27-Apr	84.2	13-Apr	14	3	1	0	0
May	**64.1**	71.9	4-May	49.4	15-May	**77.0**	85.8	30-May	63.6	14-May	**94.0**	**40.6**	67.4	24.2	30-May	92.7	4-May	28	26	21	17	8
Jun	**67.3**	73.2	19-Jun	51.2	14-Jun	**76.6**	81.2	17-Jun	67.6	12-Jun	**95.5**	**50.4**	75.3	25.8	1-Jun	89.8	23-Jun	28	22	22	20	12
Jul	**69.6**	77.7	10-Jul	58.0	25-Jul	**80.9**	86.1	17-Jul	76.3	24-Jul	**95.5**	**43.6**	70.8	22.3	29-Jul	93.6	4-Jul	31	30	26	26	24
Aug	**70.7**	75.5	11-Aug	59.6	30-Aug	**80.0**	85.4	13-Aug	75.2	26-Aug	**97.5**	**48.5**	74.1	22.0	9-Aug	94.8	11-Aug	29	26	26	24	19
Sep	**66.1**	73.5	9-Sep	49.4	19-Sep	**78.7**	83.1	9-Sep	71.2	20-Sep	**95.1**	**39.9**	67.7	23.0	19-Sep	93.4	9-Sep	28	24	23	21	8
Oct	**59.9**	71.6	30-Oct	43.2	18-Oct	**69.5**	82.9	4-Oct	56.0	17-Oct	**96.4**	**49.9**	73.9	28.0	23-Oct	90.2	3-Oct	17	4	4	4	3
Nov	**43.4**	60.2	7-Nov	19.6	13-Nov	**51.1**	64.4	7-Nov	35.2	13-Nov	**95.6**	**49.5**	75.8	31.4	28-Nov	77.3	5-Nov	2	0	0	0	0
Dec	**40.1**	63.8	28-Dec	25.3	20-Dec	**50.6**	67.2	10-Dec	37.3	19-Dec	**94.1**	**53.0**	75.2	23.1	5-Dec	76.2	10-Dec	0	0	0	0	0
Year	**54.9**	77.7	10-Jul	15.5	21-Jan	**65.6**	86.1	17-Jul	34.2	21-Jan	**94.2**	**46.1**	71.9	15.3	7-Mar	94.8	11-Aug	179	135	123	112	74

Table 1(c): Means and Extremes of SRS Meteorological Data for 2019: Wind, Pressure, Solar Radiation, Degree Days

	Wind Speed (mph)					Barometric Pressure (mb)					Solar Radiation (ly/day)						Degree Days					
Month	Monthly Average	Max 15-min Average	Date Max 15-min Average	Max Instantaneous Gust	Date Max Gust	Average	Lowest	Lowest Date	Highest	Highest Date	Daily average	% of Theoretical Max	Minumum Daily Value	Date	Maximum Daily Value	Date	Heating Degree Days	Daily maximum	Date	Cooling Degree Days	Daily Maximum	Date
Jan	3.6	14.3	24-Jan	37.1	24-Jan	1008.6	997.4	20-Jan	1022.6	22-Jan	235	65.2	23.4	4-Jan	377.6	31-Jan	545	31	21-Jan	3	3	1-Jan
Feb	3.4	17.0	12-Feb	46.3	12-Feb	1009.3	997.0	16-Feb	1022.2	9-Feb	249	55.3	60.4	17-Feb	480.1	25-Feb	297	21	1-Feb	3	3	7-Feb
Mar	3.8	11.4	22-Mar	29.8	25-Mar	1008.7	999.6	3-Mar	1015.6	28-Mar	404	70.8	113.4	1-Mar	595.6	27-Mar	278	27	6-Mar	9	4	15-Mar
Apr	3.8	14.8	26-Apr	38.3	26-Apr	1005.2	992.1	19-Apr	1014.8	3-Apr	476	70.1	149.5	14-Apr	669.1	27-Apr	98	20	2-Apr	92	9	13-Apr
May	3.6	14.8	11-May	45.0	11-May	1004.2	996.6	5-May	1012.4	1-May	581	77.4	192.0	12-May	704.2	14-May	1	1	14-May	362	21	30-May
Jun	3.4	14.5	20-Jun	46.3	9-Jun	1003.9	998.0	7-Jun	1010.0	28-Jun	526	66.6	109.3	12-Jun	726.6	14-Jun	0	0		324	16	17-Jun
Jul	3.1	15.7	23-Jul	33.1	23-Jul	1005.2	999.7	8-Jul	1011.8	27-Jul	556	72.2	381.7	10-Jul	671.1	1-Jul	0	0		494	21	17-Jul
Aug	3.1	12.1	2-Aug	35.3	17-Aug	1003.6	1000.4	8-Aug	1007.8	31-Aug	469	66.1	252.7	4-Aug	618.4	9-Aug	0	0		453	20	13-Aug
Sep	3.1	12.5	5-Sep	37.1	13-Sep	1005.9	996.4	5-Sep	1012.8	21-Sep	465	76.2	168.6	18-Sep	569.7	7-Sep	0	0		409	18	9-Sep
Oct	3.4	11.6	22-Oct	32.0	31-Oct	1005.3	997.4	16-Oct	1011.9	24-Oct	310	62.1	74.8	19-Oct	474.5	11-Oct	30	9	17-Oct	171	18	4-Oct
Nov	2.9	11.9	12-Nov	28.9	24-Nov	1007.4	998.1	18-Nov	1014.9	13-Nov	271	67.7	44.9	12-Nov	415.6	1-Nov	415	30	13-Nov	0	0	
Dec	3.6	13.2	1-Dec	31.3	1-Dec	1007.5	994.2	1-Dec	1020.7	20-Dec	211	64.1	26.5	17-Dec	318.4	4-Dec	435	28	19-Dec	4	2	10-Dec
Year	3.4	17.0	12-Feb	46.3	9-Jun/12-Feb	1006.2	992.1	19-Apr	1022.6	22-Jan	396	67.8	23.4	4-Jan	726.6	14-Jun	2100	31	21-Jan	2323	21	17-Jul

Table 2: Monthly, Annual, and Extreme Temperatures, 1990-2019

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1990	54.9	57.5	60.0	64.0	72.9	80.5	83.7	83.8	79.0	69.4	59.9	54.6	68.4
1991	47.9	54.1	60.3	69.2	76.9	79.5	83.6	81.2	77.4	68.1	55.4	54.0	67.3
1992	49.5	54.1	57.2	65.0	71.2	78.9	83.7	80.7	76.9	65.0	57.1	48.0	65.6
1993	51.7	47.8	53.2	58.9	69.7	78.2	83.6	80.0	75.2	62.8	55.2	43.6	63.3
1994	41.5	50.1	60.2	68.0	71.2	82.3	81.8	81.2	77.4	67.2	62.3	53.3	66.4
1995	45.5	49.9	58.6	65.9	73.5	75.0	79.9	79.0	71.8	65.9	50.8	43.8	63.3
1996	44.6	50.1	50.6	61.6	72.9	76.5	79.3	76.0	72.7	62.1	51.6	48.8	62.2
1997	48.2	52.9	63.3	61.2	68.5	74.0	80.2	79.0	75.0	64.1	51.6	47.0	63.8
1998	49.7	51.1	53.6	62.7	74.6	82.1	82.6	80.3	75.8	66.9	60.5	53.6	66.1
1999	51.9	51.6	53.4	67.2	69.7	76.6	80.7	82.9	73.8	64.3	58.1	48.6	64.9
2000	44.4	50.2	58.5	60.7	75.1	78.0	79.9	77.6	71.7	62.5	53.1	38.2	62.5
2001	43.8	52.4	53.0	63.9	71.3	75.3	77.7	78.8	71.2	62.2	60.0	52.4	63.5
2002	47.3	48.0	57.6	68.1	70.2	77.5	80.5	78.4	75.4	66.7	51.7	44.5	63.8
2003	42.0	47.5	57.6	61.6	70.6	75.2	77.3	77.7	71.9	63.7	58.2	42.9	62.2
2004	43.7	45.2	58.5	63.4	74.0	77.7	80.1	77.3	73.2	66.2	56.1	45.8	63.4
2005	47.9	49.0	53.1	60.9	68.0	75.4	79.4	78.8	77.0	64.7	56.1	44.3	62.9
2006	50.8	47.3	55.3	66.3	70.1	76.2	80.3	80.5	72.9	62.4	53.6	50.6	63.8
2007	48.6	46.4	58.4	61.8	70.2	76.5	77.4	81.9	75.2	68.7	54.0	52.3	64.3
2008	43.8	51.1	55.3	61.8	70.2	80.1	78.7	77.9	73.7	61.1	50.0	52.1	63.0
2009	44.9	47.4	55.2	62.3	70.7	79.2	78.6	78.2	74.1	62.7	54.6	45.5	62.8
2010	40.8	41.4	51.9	64.6	73.7	80.0	81.0	80.0	76.2	64.0	54.0	39.2	62.2
2011	41.3	50.9	56.8	66.8	72.0	81.4	81.9	81.3	74.1	60.8	55.6	51.0	64.5
2012	49.6	52.5	63.7	65.7	72.6	74.8	80.6	76.0	72.8	64.3	51.5	51.2	64.6
2013	52.1	46.8	49.7	62.6	68.5	76.2	76.9	76.3	73.7	64.6	52.6	50.9	62.6
2014		48.6	51.9	64.2	72.2	78.3	79.2	78.8	74.0	65.7	50.2	49.7	64.8
2015	44.5	43.0	58.6	66.6	73.0	79.1	81.7	78.9	74.1	63.7	58.8	59.5	65.1
2016	45.0	50.9	63.3	65.6	72.3	81.7	85.2	83.6	78.4	68.2	56.9	51.4	66.9
2017	53.6	57.1	57.5	68.0	72.1	76.9	79.6	78.9	74.4	66.4	55.1	49.0	65.7
2018	42.9	59.6	54.2	61.3	73.4	78.9	79.1	78.6	78.6	67.0	52.4	49.6	64.6
2019	47.5	54.5	56.2	64.8	76.6	76.7	80.9	79.6	78.6	69.6	51.2	51.1	65.6

30-yr Avg	46.9	50.3	56.6	64.2	71.9	78.0	80.5	79.4	74.9	65.0	54.9	48.9	64.3
Rec Monthly Lowest	35.3	41.3	49.5	58.9	66.8	74.0	76.9	74.5	70.5	60.1	48.7	38.2	62.2
Yr Lowest	1977	1978	1971	1993	1983	1997	2013	1973	1973	1976	1976	2000	2003/2010
Rec Monthly Highest	59.6	59.6	63.7	69.2	76.9	82.7	86.9	83.9	79.2	73.4	65.5	61.5	68.4
Yr Highest	1974	2018	2012	1991	1991	1986	1986	1983	1980	1984	1985	2015	1990
Rec Daily High	86	86	90	99	102	105	107	107	104	98	89	82	107
Yr Rec	1975	1989	1974	1986	1963	1985	1986	1983	1990	2019	1987	1984	1986
Rec Daily Low	-3	10	11	26	38	48	56	56	41	28	18	5	-3
Yr Rec	1985	1996	1980	2007	1989	1984	1963	1986	1967	1976	1970	1962	1985

*October 2019 had a record-breaking daily high of 98°F
*Extreme values (bottom table) are based on the full record of temperature data (1968-2019).

Table 3: Monthly, Annual, and Extreme Rainfall, 1990-2019

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1990	3.1	2.4	2.4	1.2	3.0	0.9	7.3	8.1	0.6	19.6	1.4	1.6	51.5
1991	7.0	1.8	7.9	4.7	3.1	2.2	7.9	9.3	4.4	1.0	1.6	3.3	54.1
1992	4.5	3.9	3.0	2.4	1.3	6.3	3.7	4.8	6.4	3.1	7.8	2.9	50.0
1993	7.5	3.6	8.4	1.7	1.4	3.3	3.1	2.2	7.3	1.0	1.9	1.8	43.2
1994	4.8	3.9	6.4	1.1	1.5	5.1	7.5	3.5	1.0	10.0	3.1	4.6	52.3
1995	7.0	8.0	0.9	1.3	1.8	8.2	5.7	6.9	5.8	2.6	2.4	4.5	54.9
1996	3.7	2.4	6.6	2.4	3.0	3.0	5.6	6.9	3.7	2.2	2.3	3.2	45.0
1997	4.2	5.5	2.7	4.4	2.4	6.9	7.1	2.0	4.9	4.1	5.5	9.1	58.7
1998	7.7	8.9	6.7	7.4	4.1	4.7	5.3	2.9	4.8	0.8	0.8	1.8	55.7
1999	5.3	2.3	3.4	2.0	1.3	7.5	4.9	3.1	4.5	2.6	1.5	1.2	39.6
2000	5.8	0.7	4.0	1.3	1.4	4.7	2.5	4.5	7.7	0.0	3.5	1.5	37.6
2001	3.1	2.7	7.2	1.3	3.9	6.5	4.8	3.6	3.3	0.5	1.0	0.5	38.4
2002	2.9	2.1	3.9	2.6	1.7	2.3	6.0	5.5	3.5	3.2	4.0	3.6	41.1
2003	1.7	5.0	7.1	8.4	5.6	11.0	8.9	4.6	2.7	3.0	1.2	1.9	61.2
2004	2.9	6.7	0.8	1.3	3.5	6.4	1.2	3.0	10.3	1.0	3.2	2.7	42.9
2005	2.1	3.9	6.1	1.7	2.9	8.2	5.8	4.1	0.2	3.6	2.7	6.2	47.4
2006	3.4	2.9	1.8	2.4	1.8	6.9	5.2	2.2	2.5	1.7	3.0	4.6	38.3
2007	3.3	3.6	2.0	3.0	1.2	4.8	4.6	2.7	1.0	1.4	0.6	8.8	36.8
2008	3.7	5.4	3.0	2.4	1.8	1.4	5.4	5.4	0.9	4.1	5.1	2.9	41.6
2009	2.0	1.7	3.7	4.6	5.2	2.7	2.6	3.1	3.7	3.0	5.5	10.2	48.0
2010	4.8	2.4	3.0	1.5	2.6	5.7	2.7	5.2	2.9	0.3	1.3	1.3	33.7
2011	2.2	4.9	5.5	1.8	1.1	1.5	4.0	3.0	4.3	2.1	1.1	1.7	33.2
2012	1.8	1.5	3.6	1.8	8.9	2.4	6.0	6.4	2.6	0.3	1.3	4.8	41.2
2013	0.8	10.1	3.3	5.0	2.4	9.6	12.9	5.6	1.1	1.4	1.7	4.6	58.6
2014	3.0	5.1	3.1	4.1	3.9	1.9	7.4	3.2	3.8	0.8	4.0	4.7	45.0
2015	4.1	4.7	4.2	5.2	0.9	4.5	3.0	1.2	5.1	5.0	6.3	5.5	49.5
2016	3.0	3.8	3.2	4.6	5.7	3.1	3.1	3.2	6.9	3.7	0.8	5.7	46.7
2017	9.8	2.4	2.0	5.8	4.5	3.0	7.1	5.8	6.3	0.9	1.3	5.6	54.4
2018	2.1	1.7	3.5	3.3	6.5	4.4	7.1	5.6	1.9	5.1	6.8	7.0	54.9
2019	4.19	1.13	2.25	4.04	1.68	7.05	1.45	3.21	1.65	4.68	3.30	8.19	42.82

30-yr Avg	4.04	3.83	4.05	3.15	2.99	4.87	5.32	4.35	3.85	3.10	2.86	4.20	46.61
Record Lowest	0.8	0.7	0.8	0.6	0.9	0.9	0.9	1.2	0.2	0.0	0.4	0.5	33.2
Yr Lowest	2013	2000	2004	1972	2015	1990	1980	2015	2005	2000	1969	2001	2011
Record Highest	10.0	10.1	11.0	8.4	10.9	13.0	13.7	12.3	10.3	19.6	7.8	10.2	73.1
Yr Highest	1978	2013	1980	2003	1976	1973	1971	1964	2004	1990	1992	2009	1964

*Extreme values (bottom table) are based on the full rainfall record (1964-2019)

Table 4: SRS Rainfall (inches) for 2019, Manual Gauges

Month	700-A	BARR2	BARR3	100-C	400-D	200-H	200-F	100-K	100-L	100-P	SRNL
January	5.6	5.5	4.2	5.0	5.0	5.0	4.4	4.6	4.4	4.8	5.4
February	1.5	3.3	1.3	1.2	1.1	1.0	1.7	0.8	1.1	1.2	0.5
March	2.9	3.5	2.8	2.4	2.7	2.1	2.5	3.6	2.3	2.4	2.7
April	4.3	3.9	3.2	3.7	4.1	4.5	5.1	4.4	4.2	4.0	4.0
May	1.9	3.1	1.7	2.6	1.8	2.6	2.6	1.9	2.2	2.0	2.1
June	7.4	8.8	12.6	7.5	7.8	8.3	7.7	7.8	8.6	6.4	7.9
July	1.1	2.7	2.8	1.6	1.2	3.3	3.9	0.8	1.1	2.9	1.1
August	11.5	8.8	2.1	4.8	1.9	7.4	6.6	4.8	3.7	4.9	7.4
September	1.0	0.7	0.4	1.2	1.8	1.2	0.4	1.2	1.1	1.1	1.0
October	3.7	5.9	6.3	3.7	4.4	3.6	3.8	3.5	4.6	4.4	3.7
November	3.1	3.5	1.8	3.5	4.4	3.4	4.3	3.8	3.1	3.4	3.4
December	7.8	10.0	4.8	8.4	8.7	8.3	9.4	6.8	8.0	9.2	8.8
Annual	**51.7**	**59.4**	**43.8**	**45.6**	**44.8**	**50.5**	**52.4**	**44.0**	**44.3**	**46.7**	**47.7**

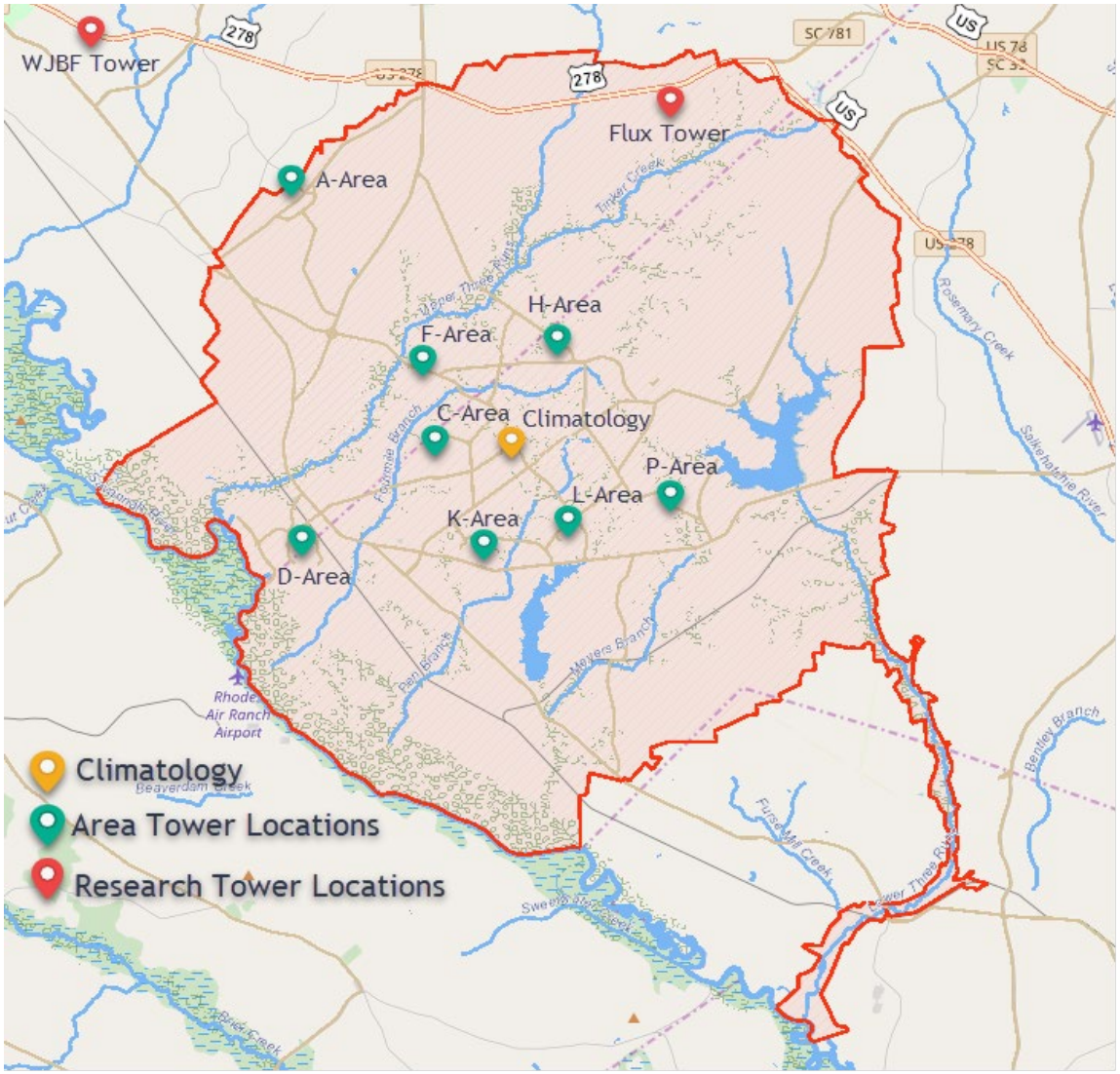

Figure 1: SRS Meteorological Towers

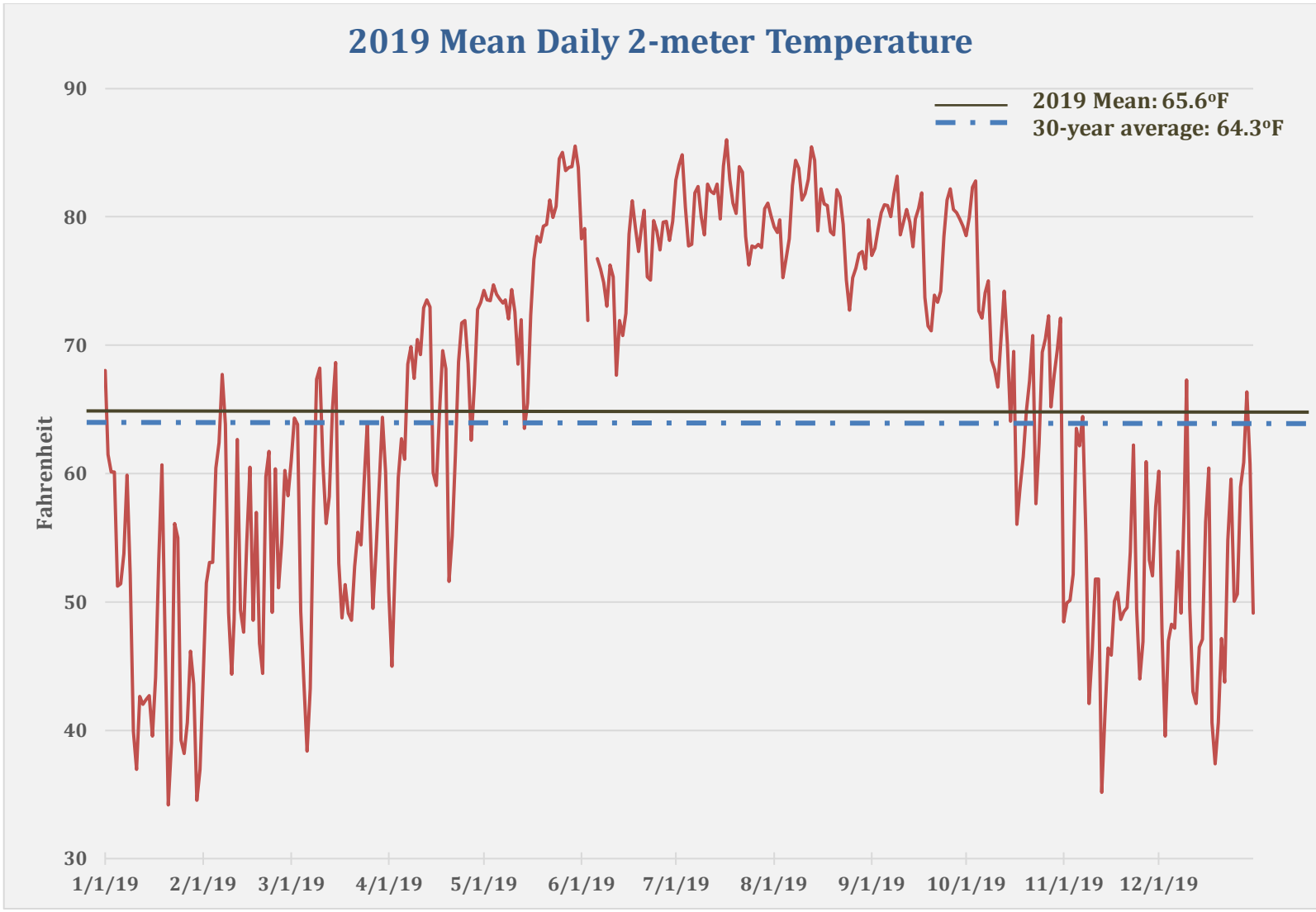

Figure 2: 2019 Mean Daily 2-meter Temperature

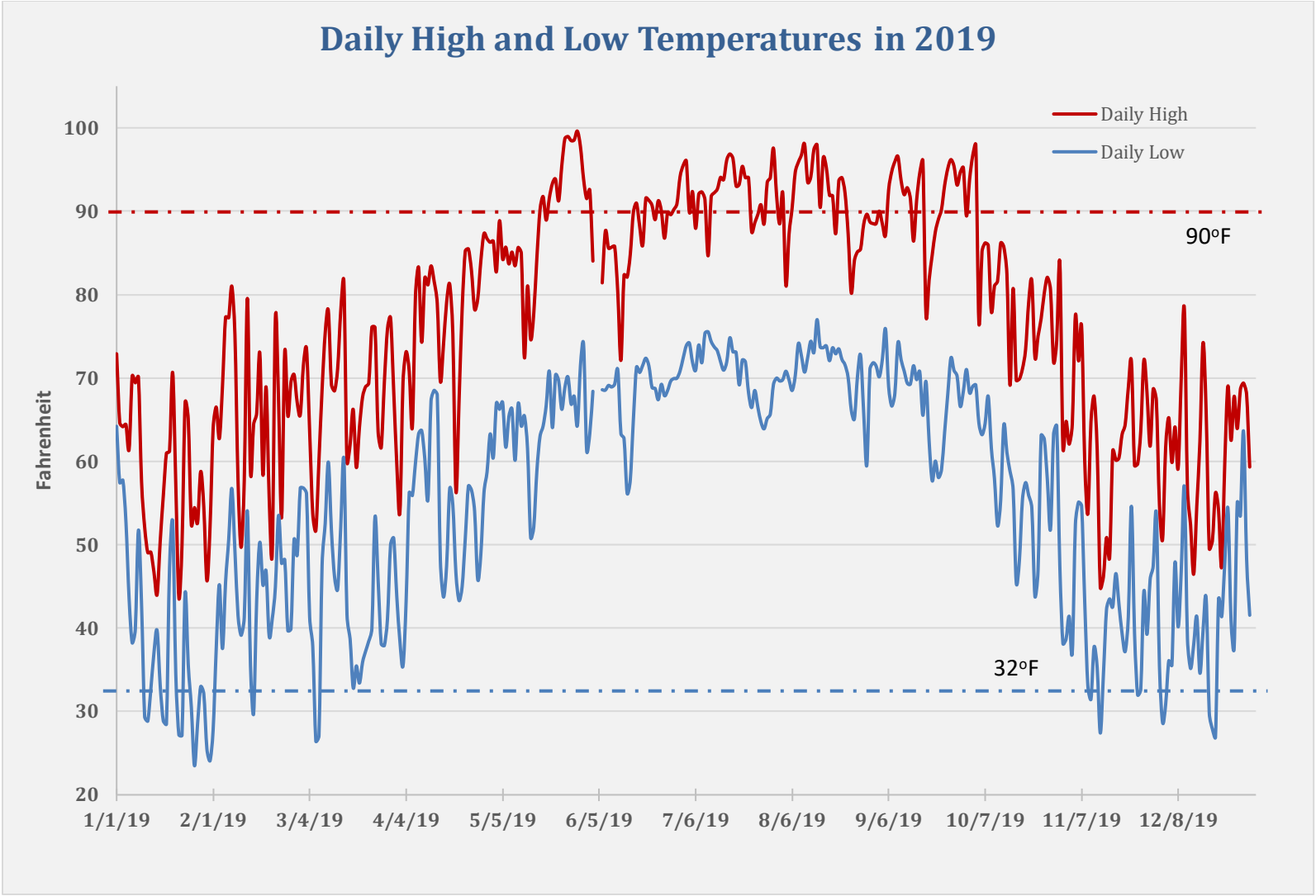

Figure 3: Daily High and Low Temperatures in 2019

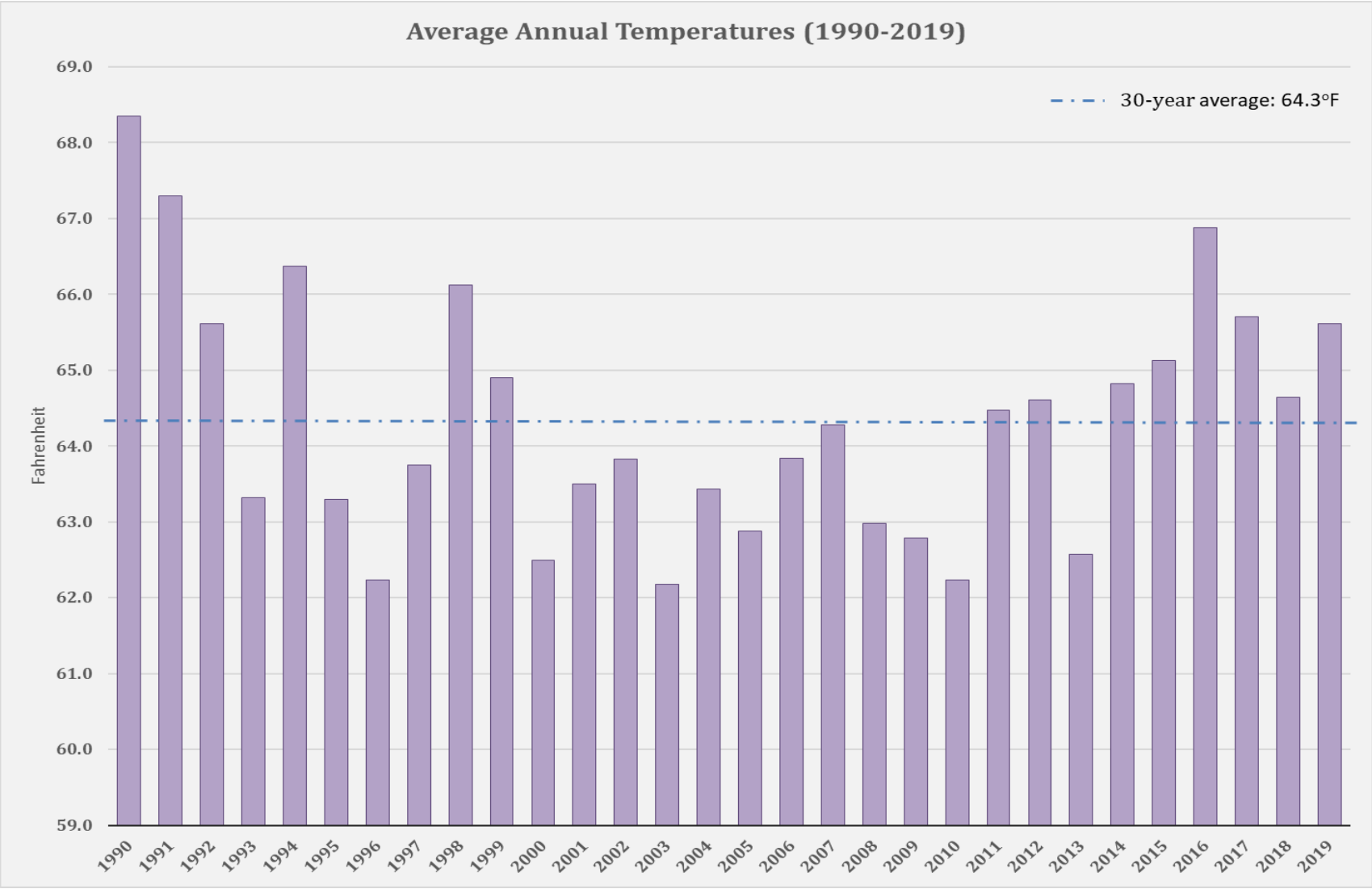

Figure 4: Average Annual Temperatures (1990-2019)

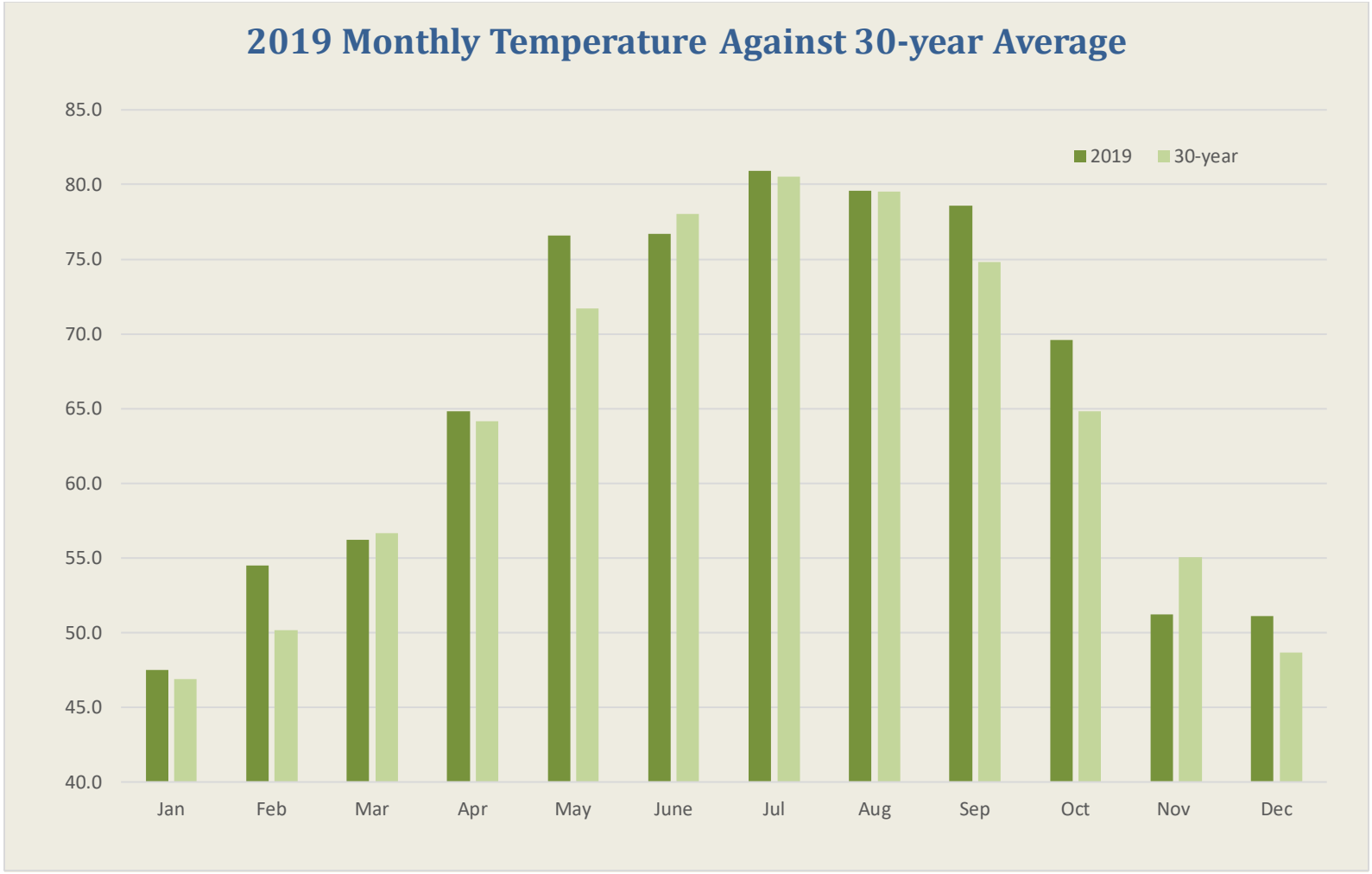

Figure 5: 2019 Monthly Temperatures and 30-year Average

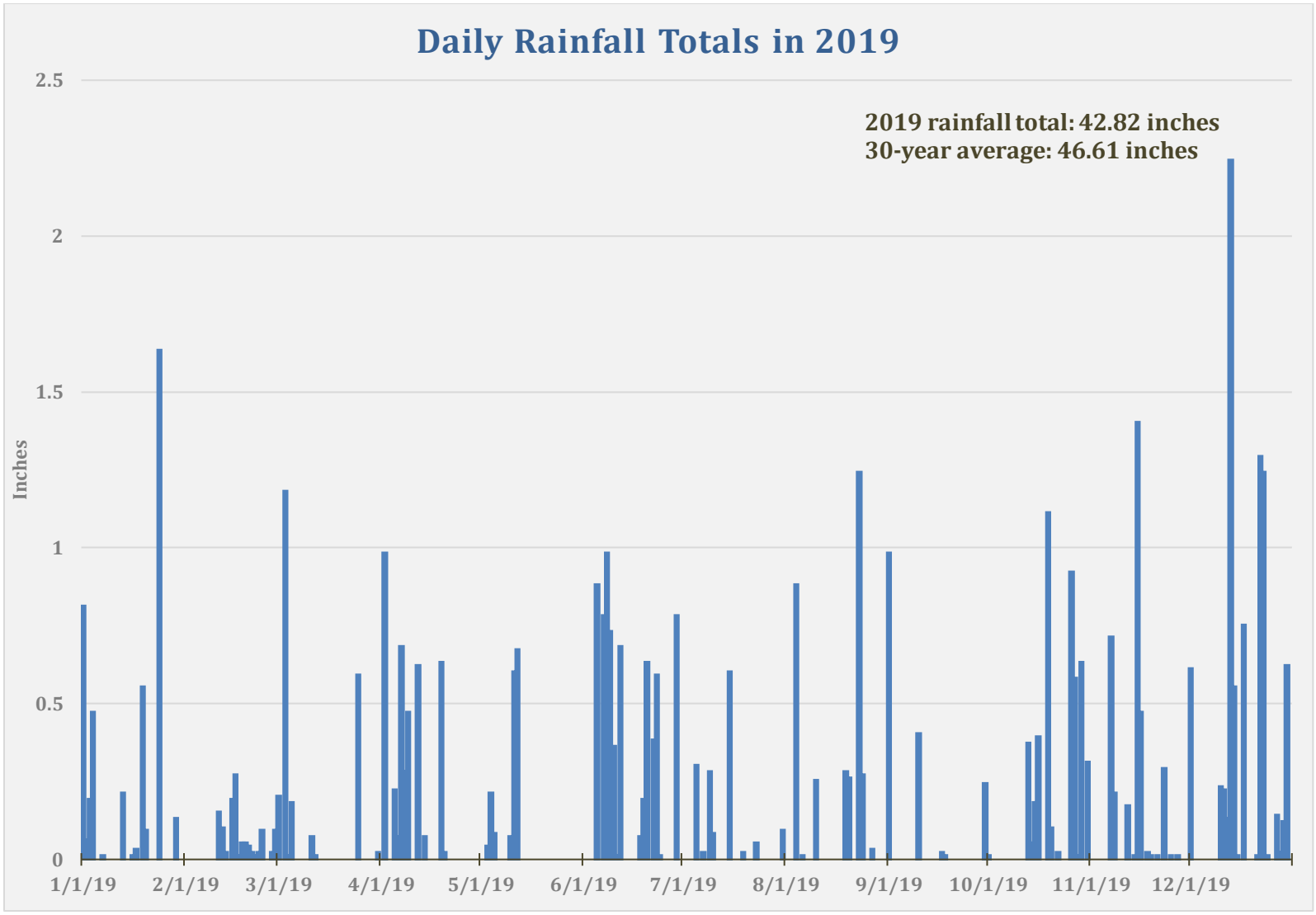

Figure 6: Daily Rainfall Totals in 2019

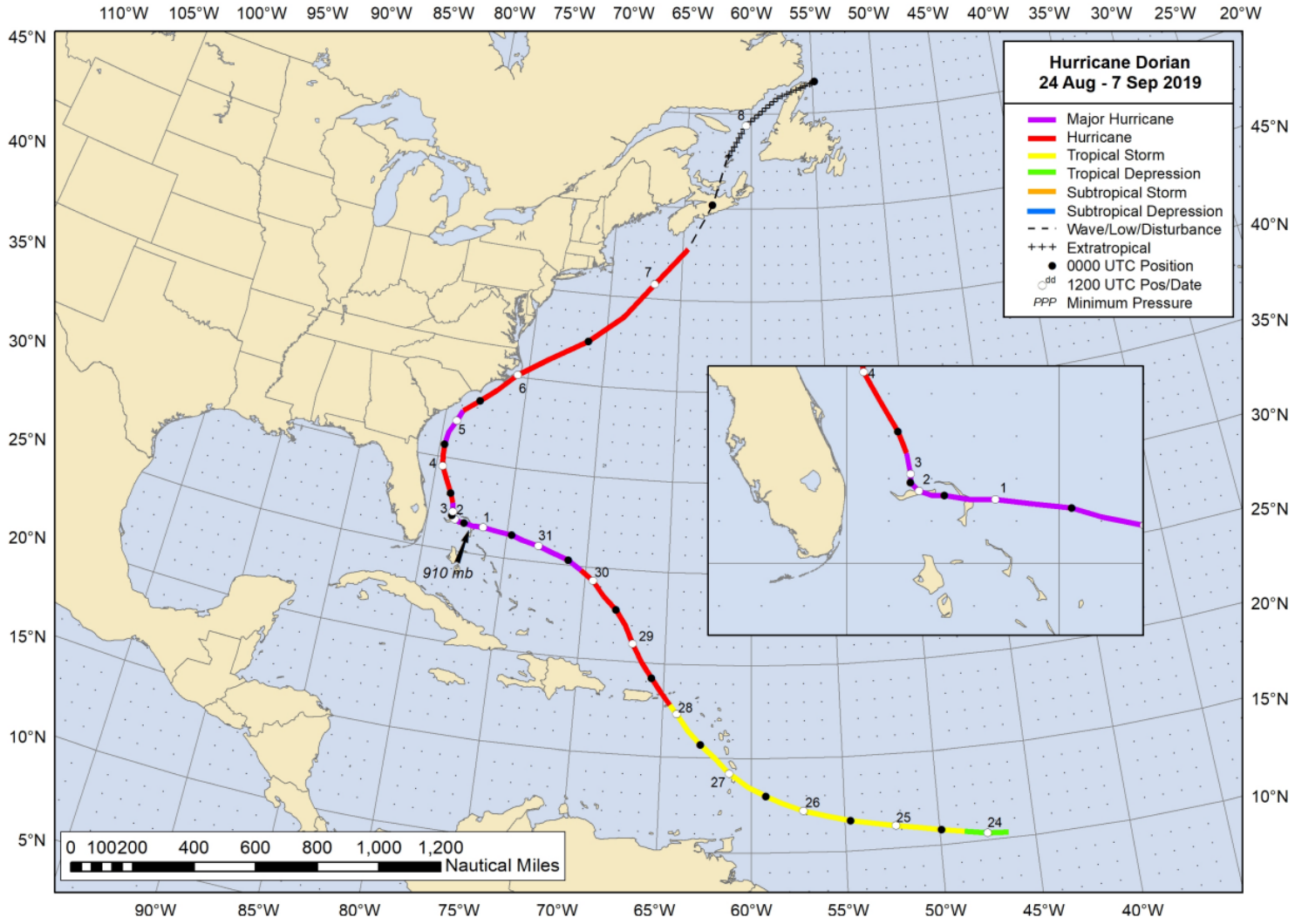

Figure 7: Hurricane Dorian Track over the SE U.S. (NHC, 2020)

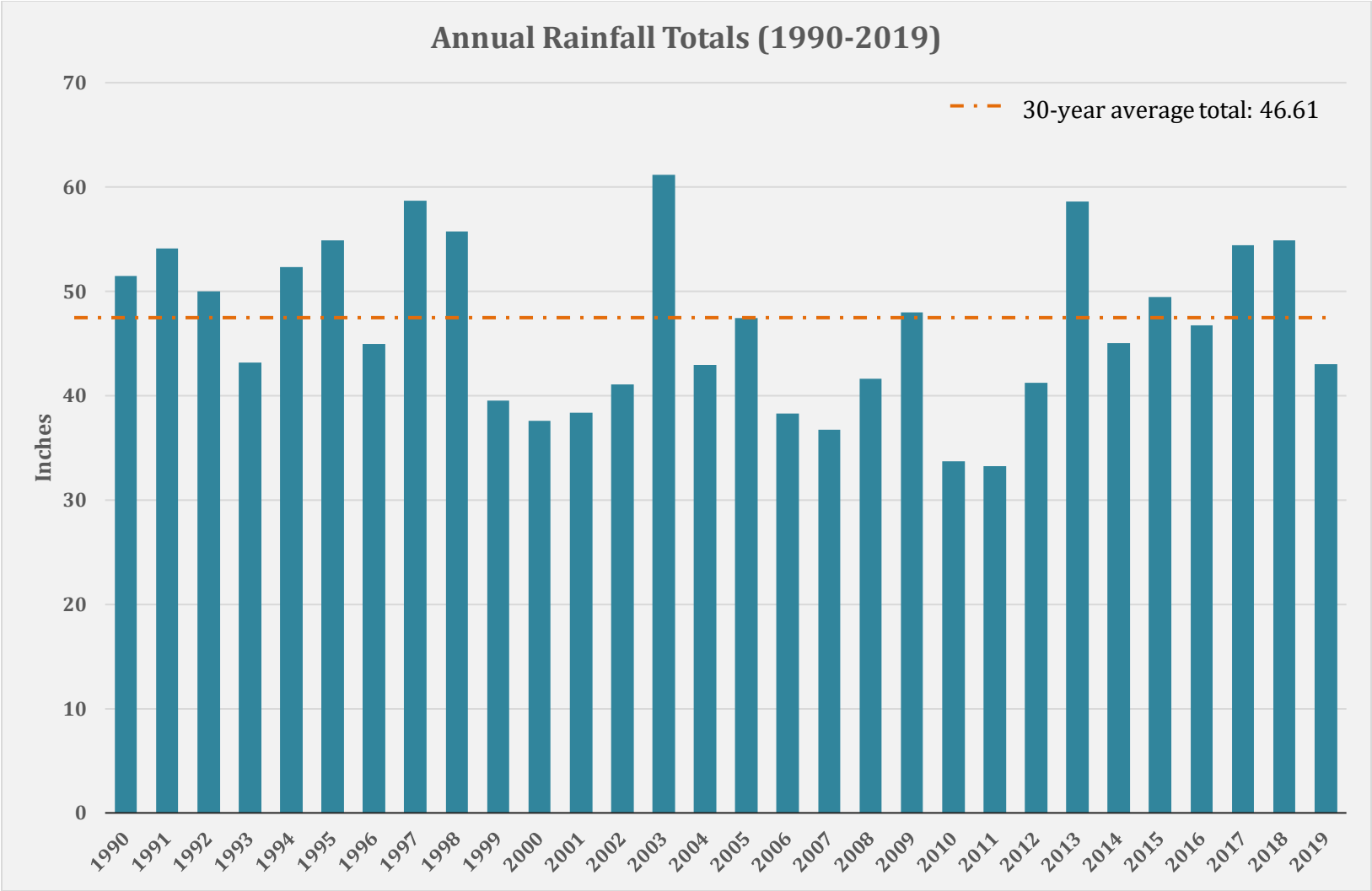

Figure 8: Annual Rainfall Totals (1990-2019)

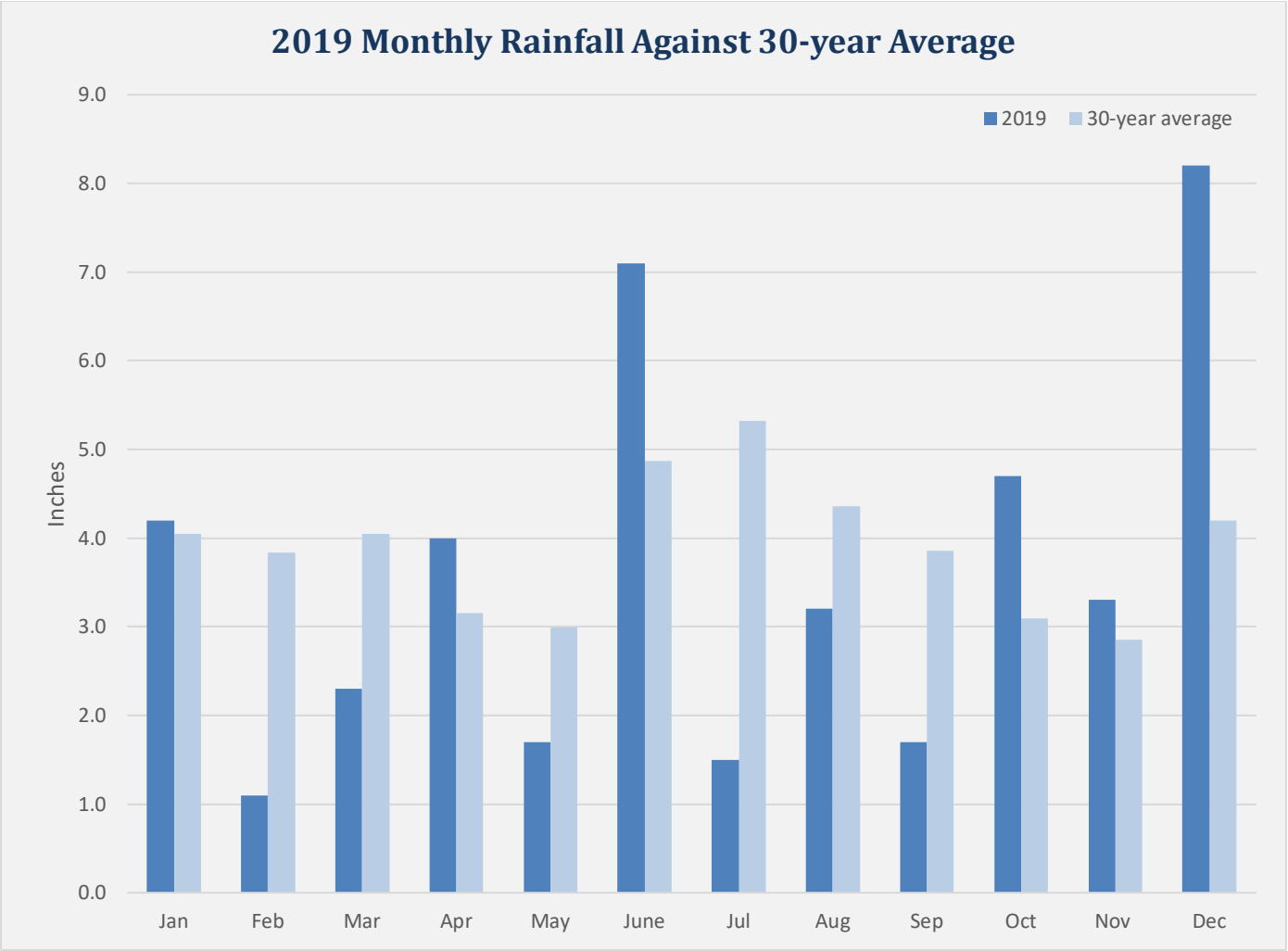

Figure 9: 2019 Monthly Rainfall Total and 30-year Averages

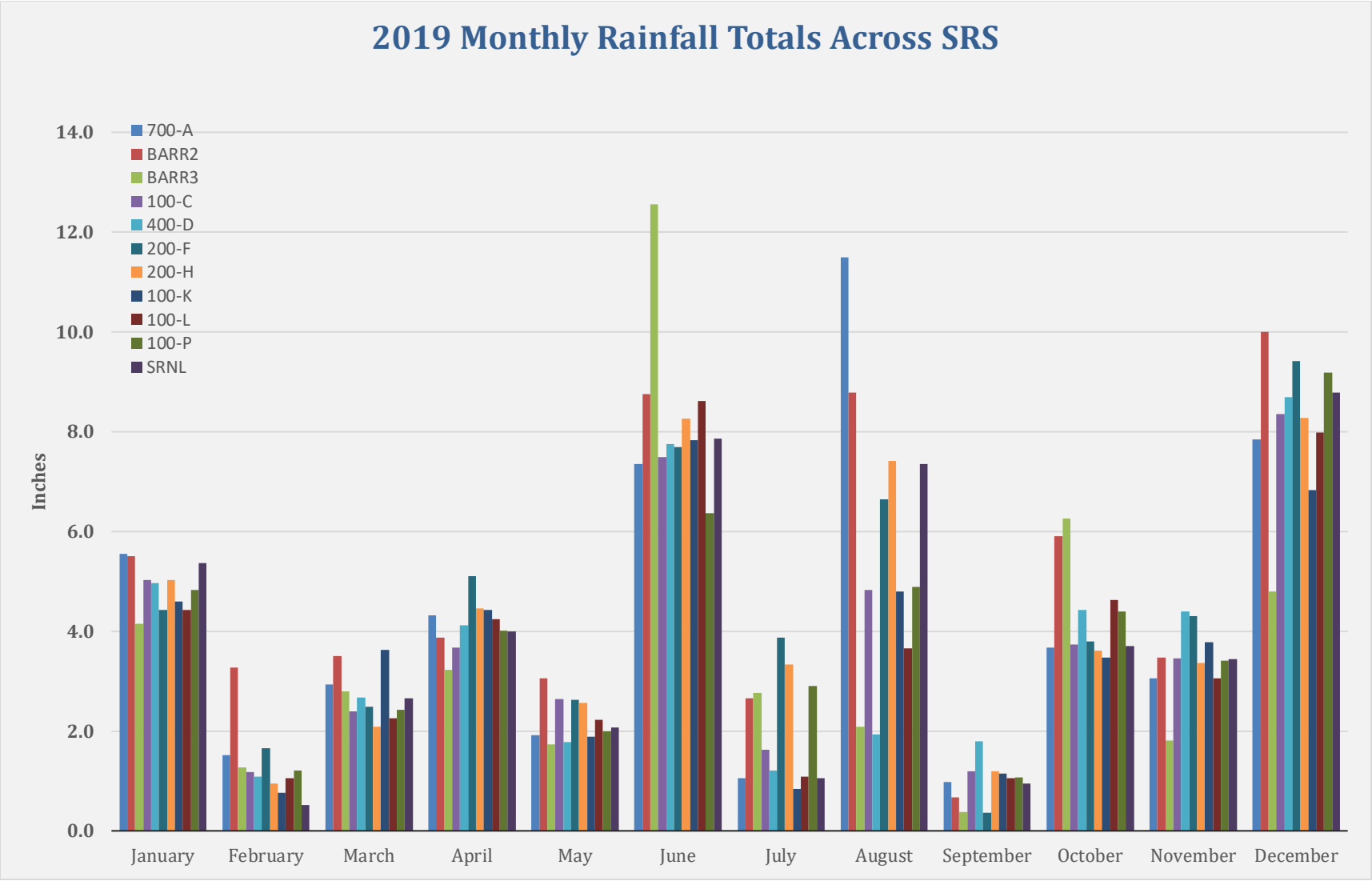

Figure 10: 2019 Monthly Rainfall Totals Across SRS

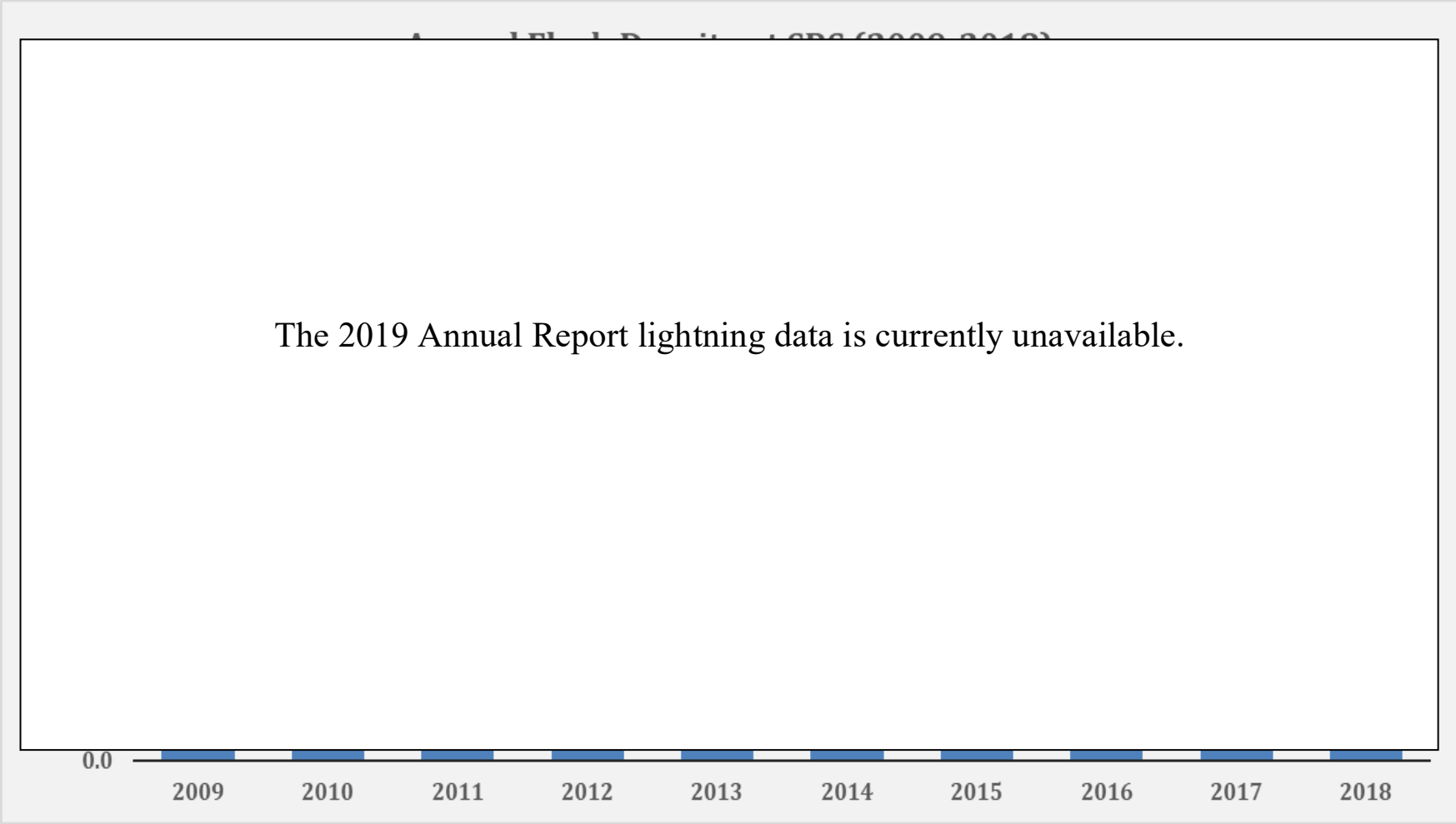

Figure 11: Annual Flash Density at SRS (2009-2019)

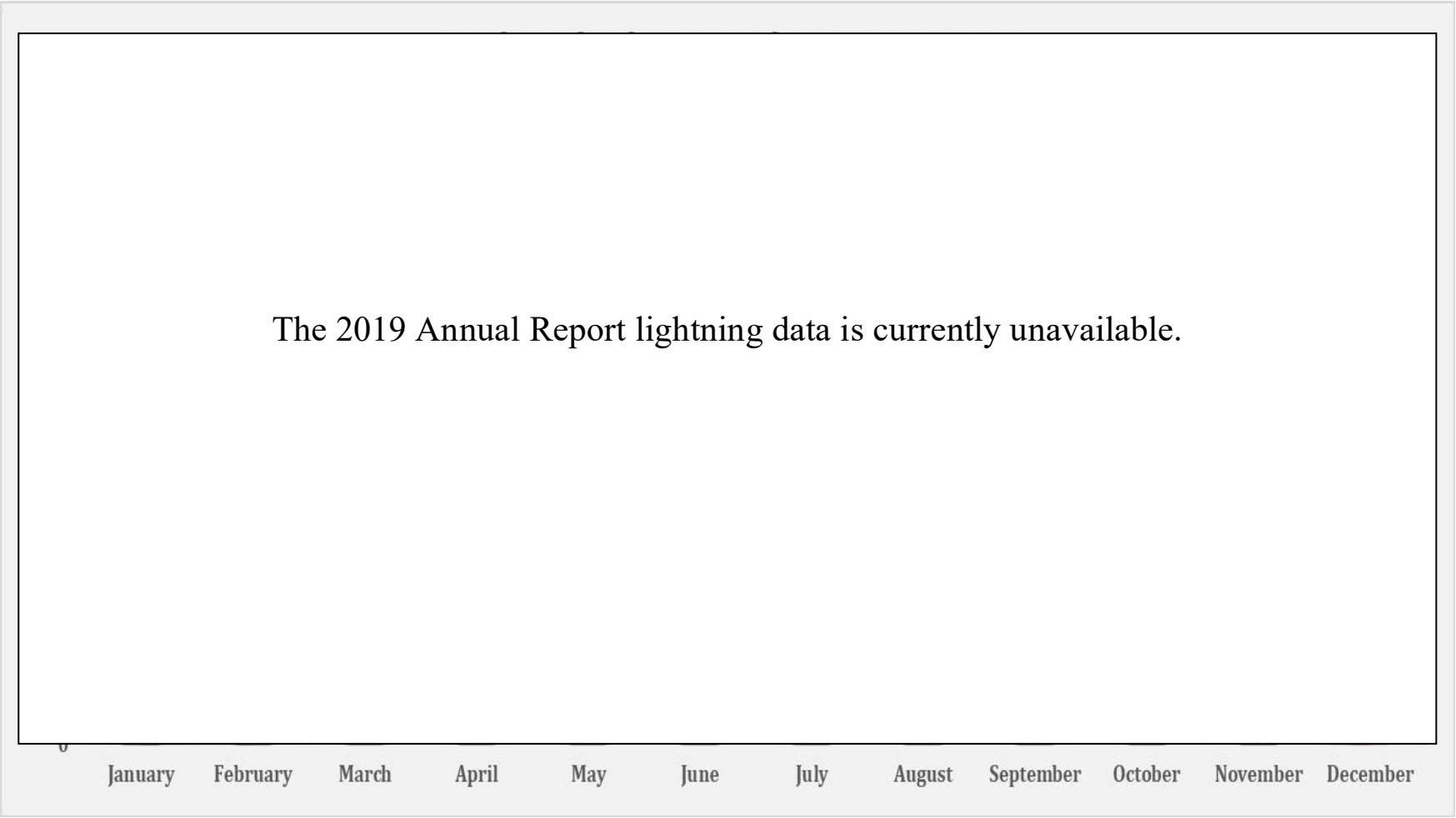

Figure 12: Number of Lightning Strikes at SRS in 2019

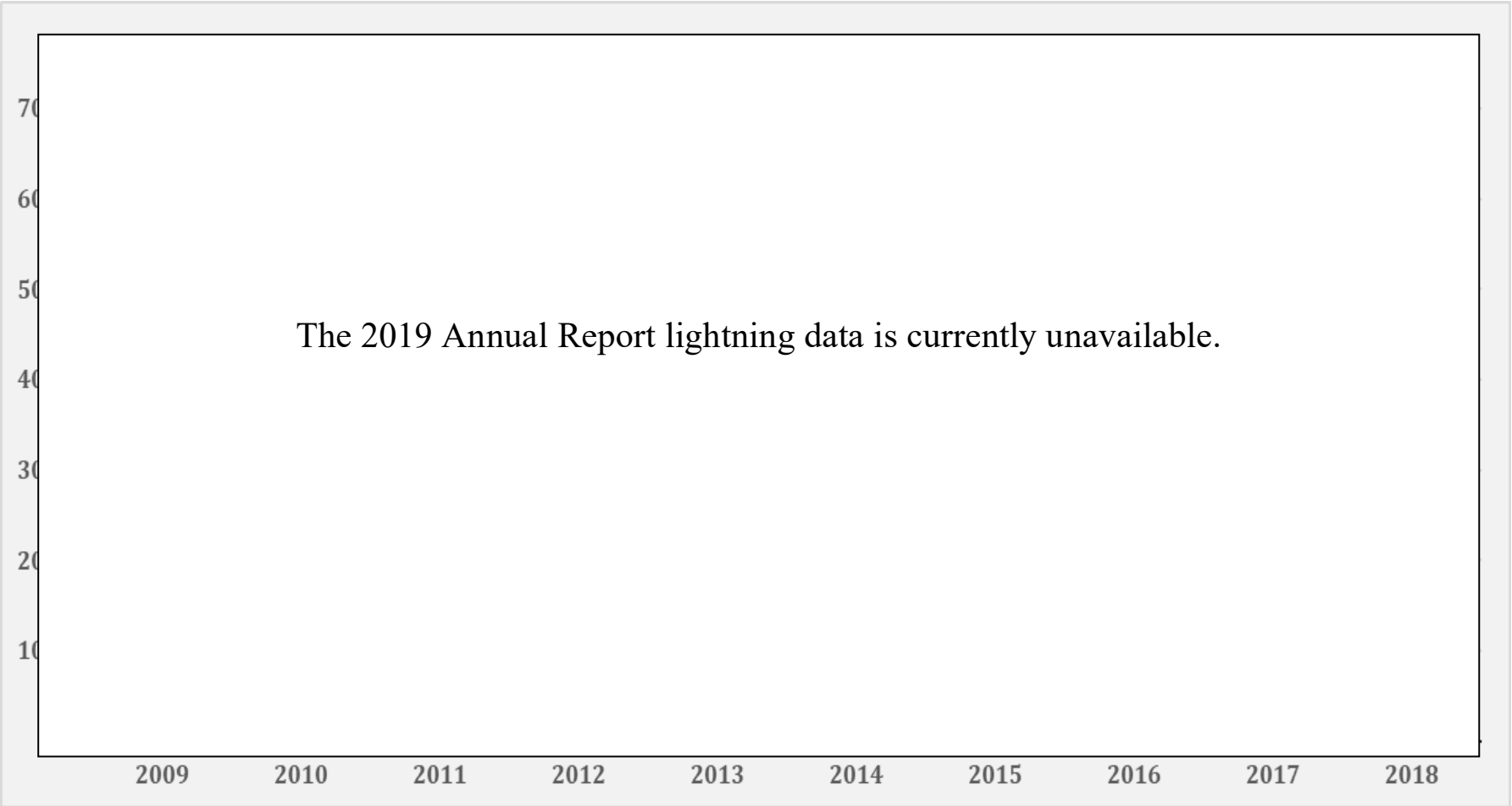

Figure 13: Total Number of Strikes at SRS from 2009-2019

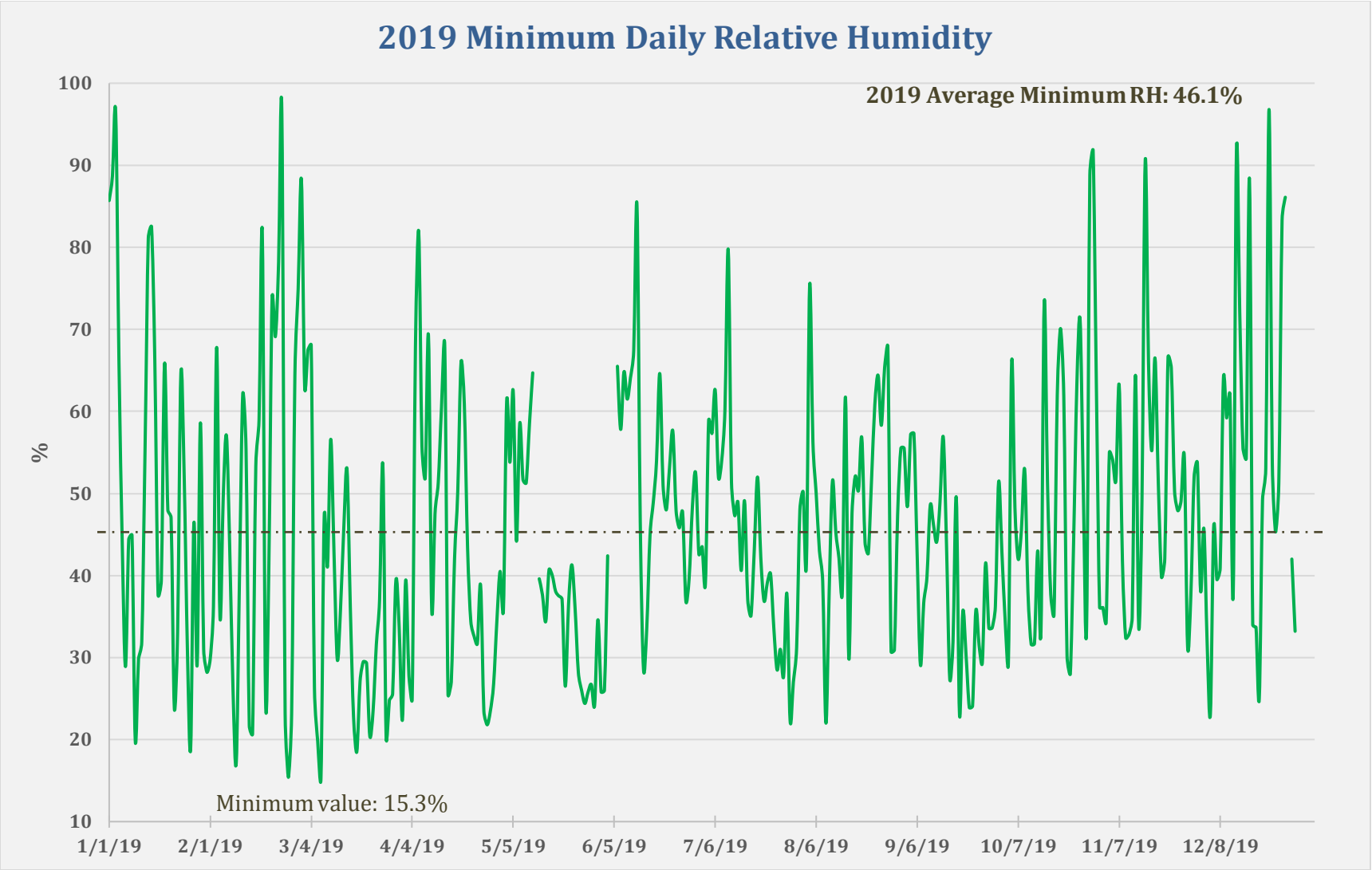

Figure 14: 2019 Minimum Daily Relative Humidity

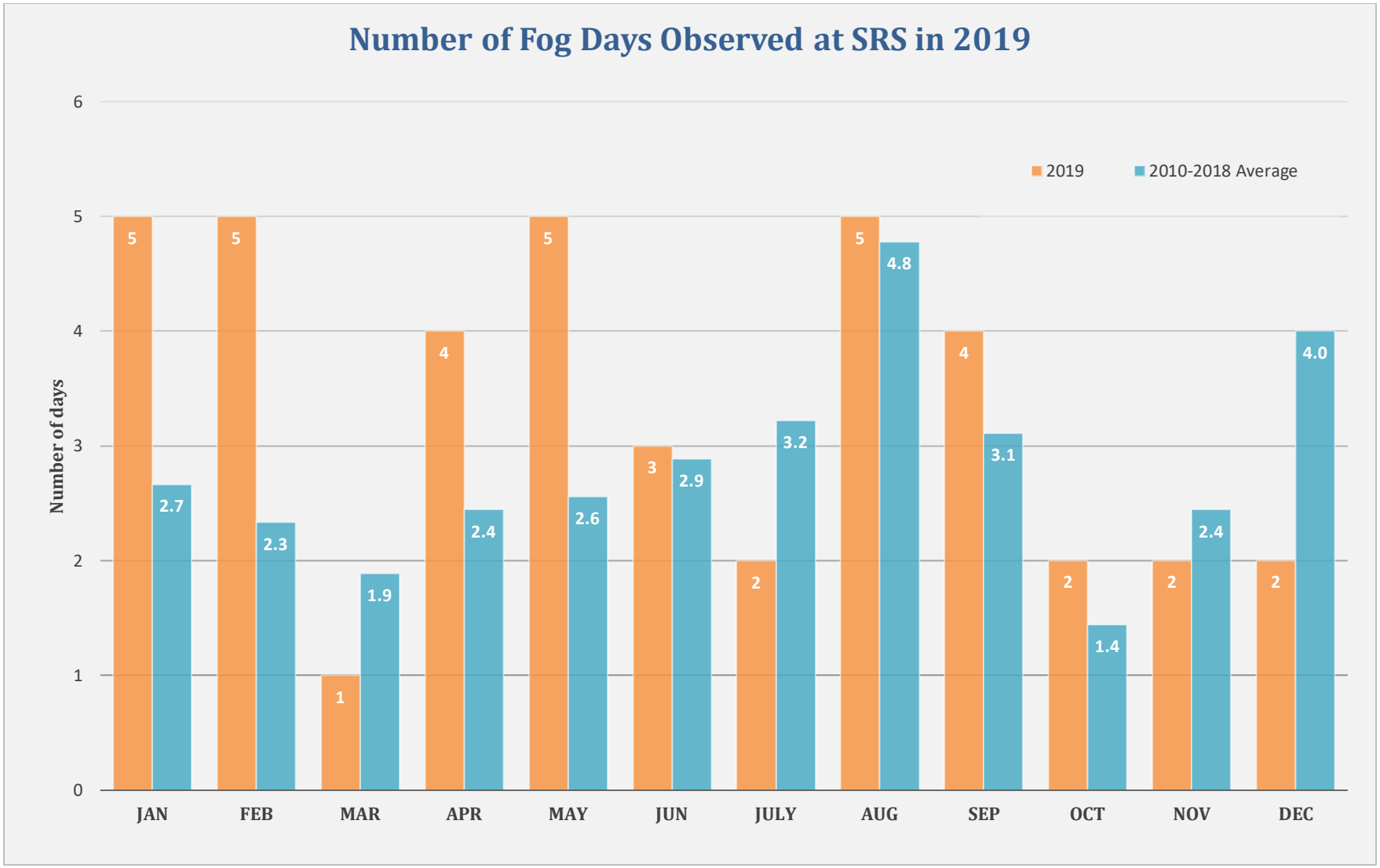

Figure 15: Number of Fog Days Observed in 2019

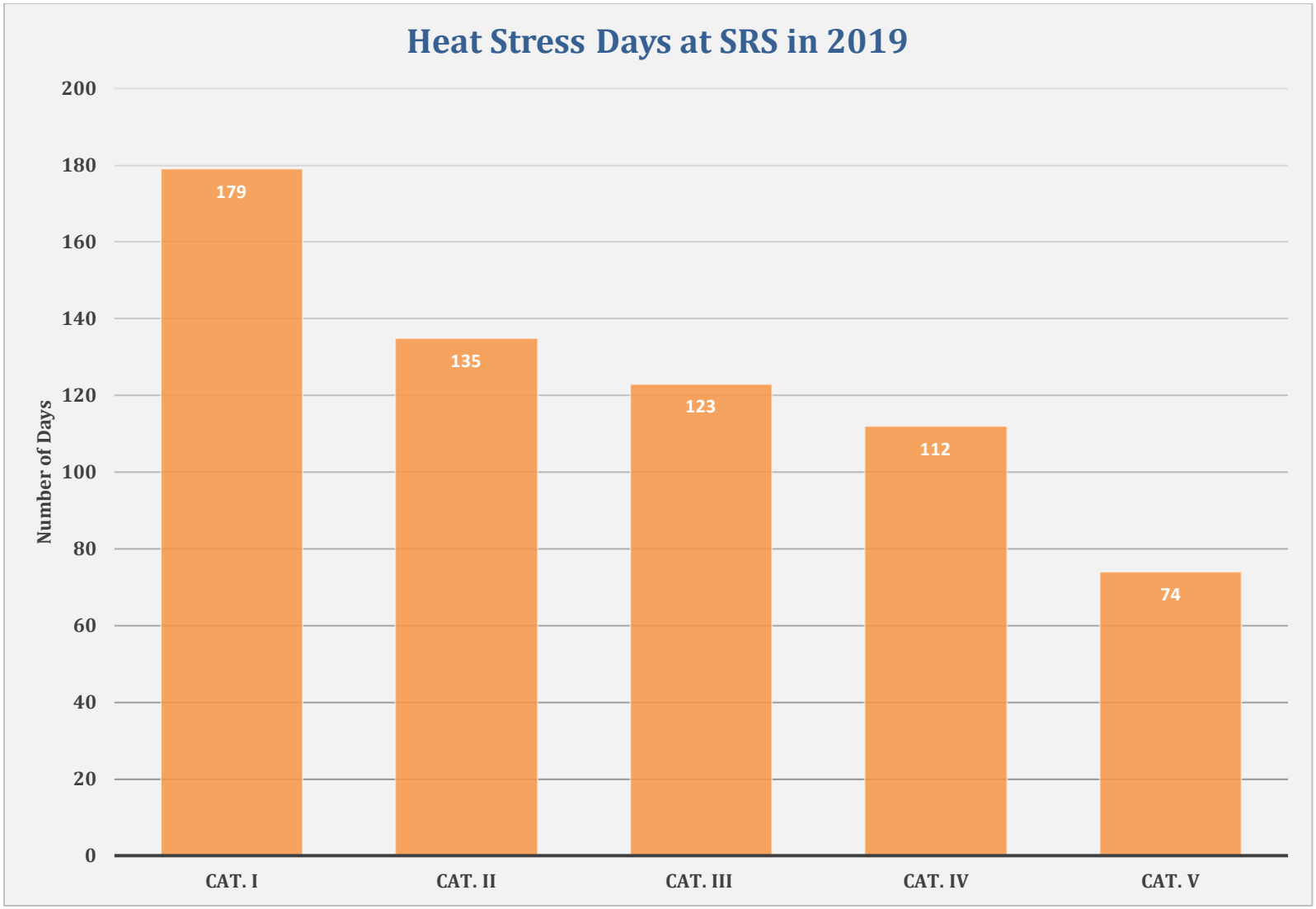

Figure 16: Heat Stress Days at SRS in 2019

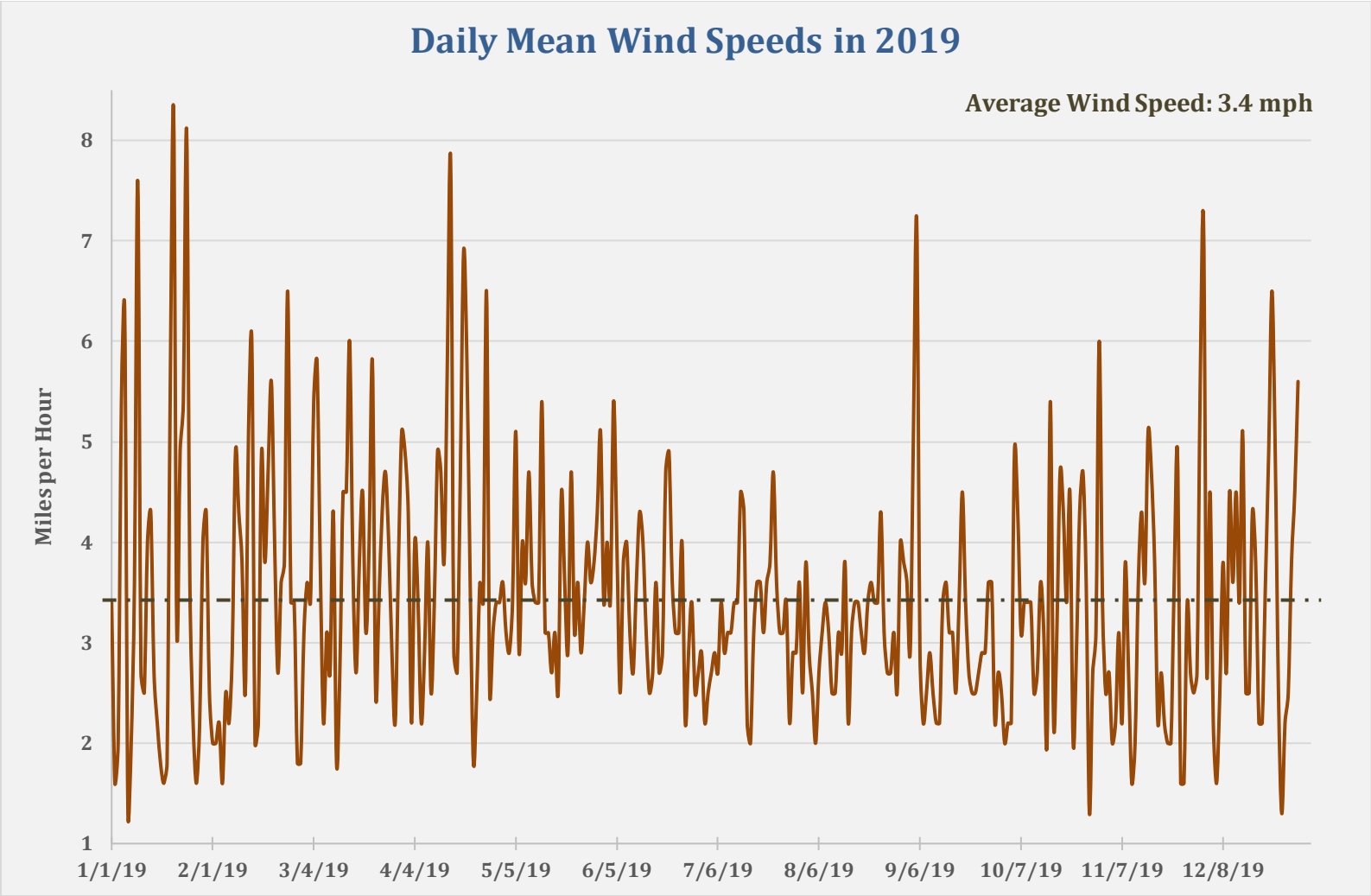

Figure 17: Daily Mean Wind Speeds in 2019

Climatology Tower

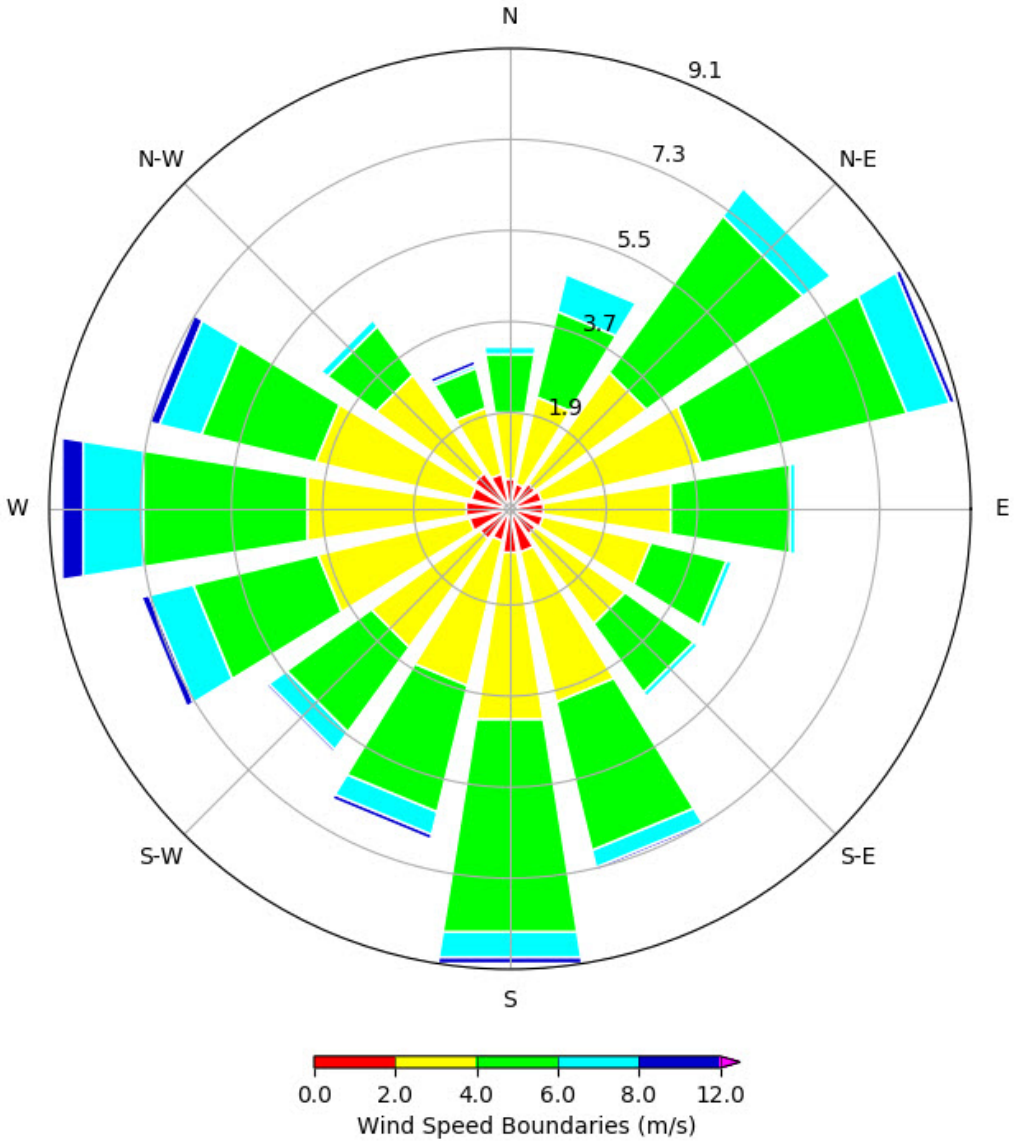

Figure 18: 2019 Annual Wind Rose for the Climatology (CLM) Tower (61 meters)

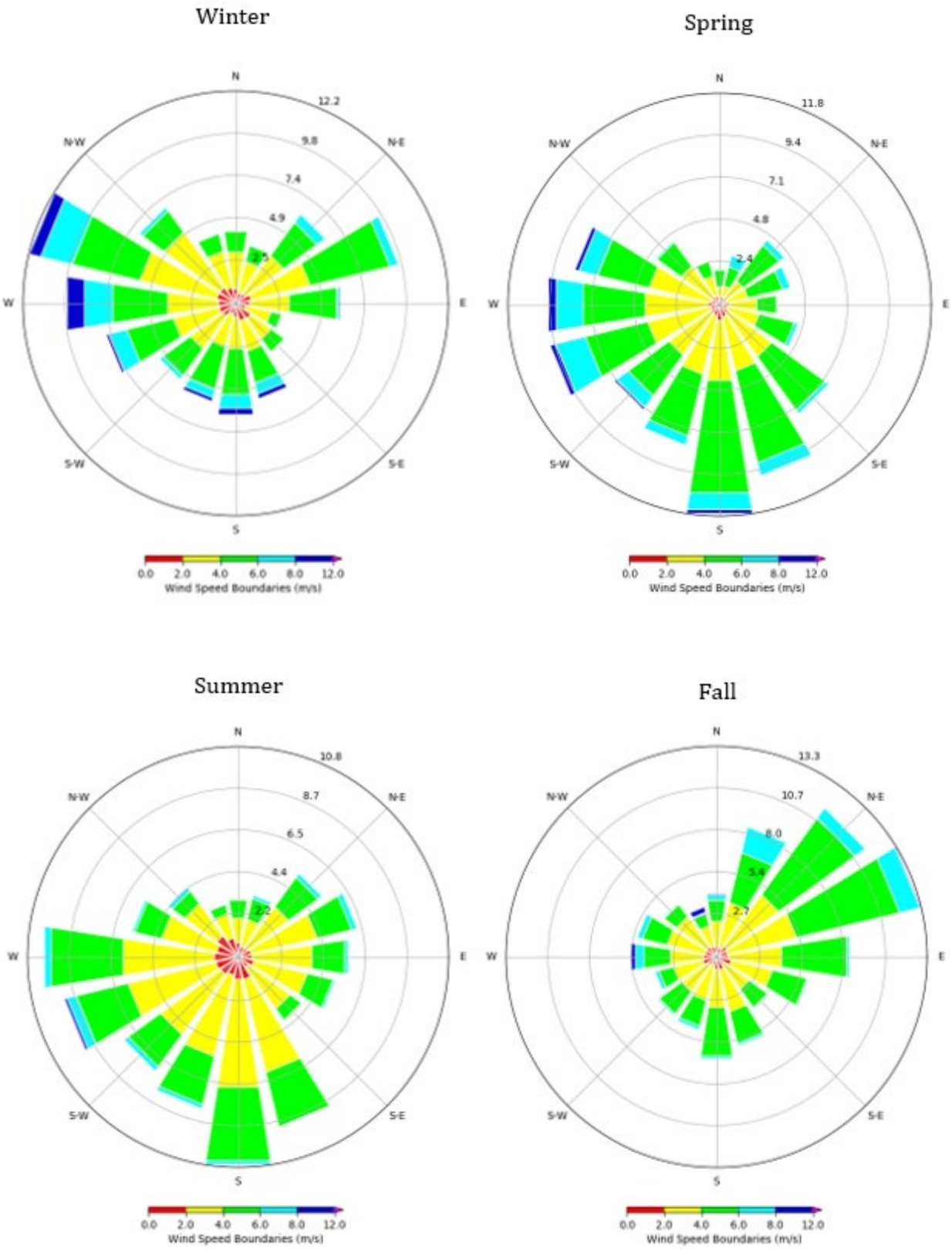

Figure 19: 2019 Seasonal Wind Roses for the CLM Tower (61 meters)

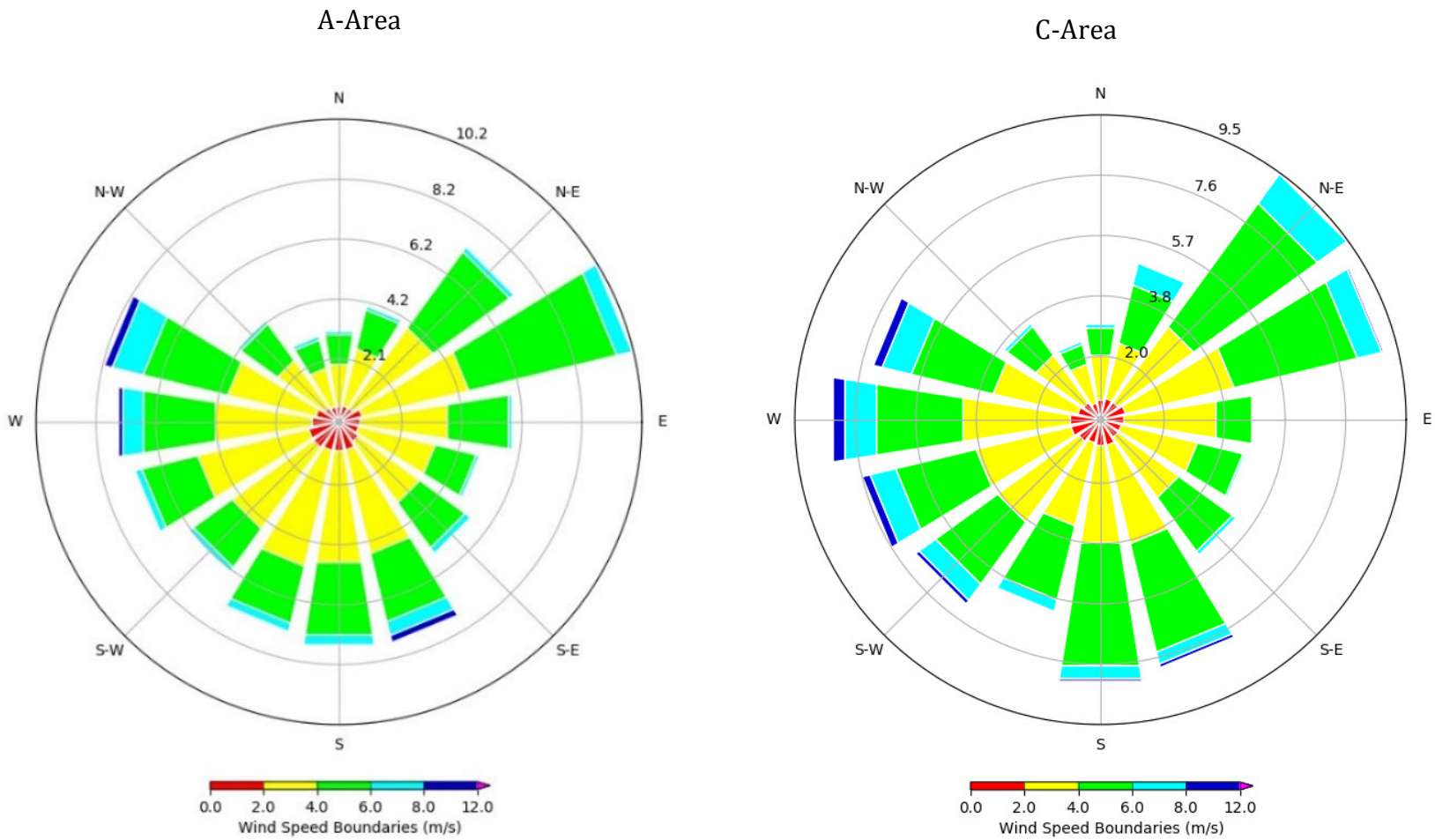

Figure 20 (a): 2019 Wind Roses for Area Towers A and C

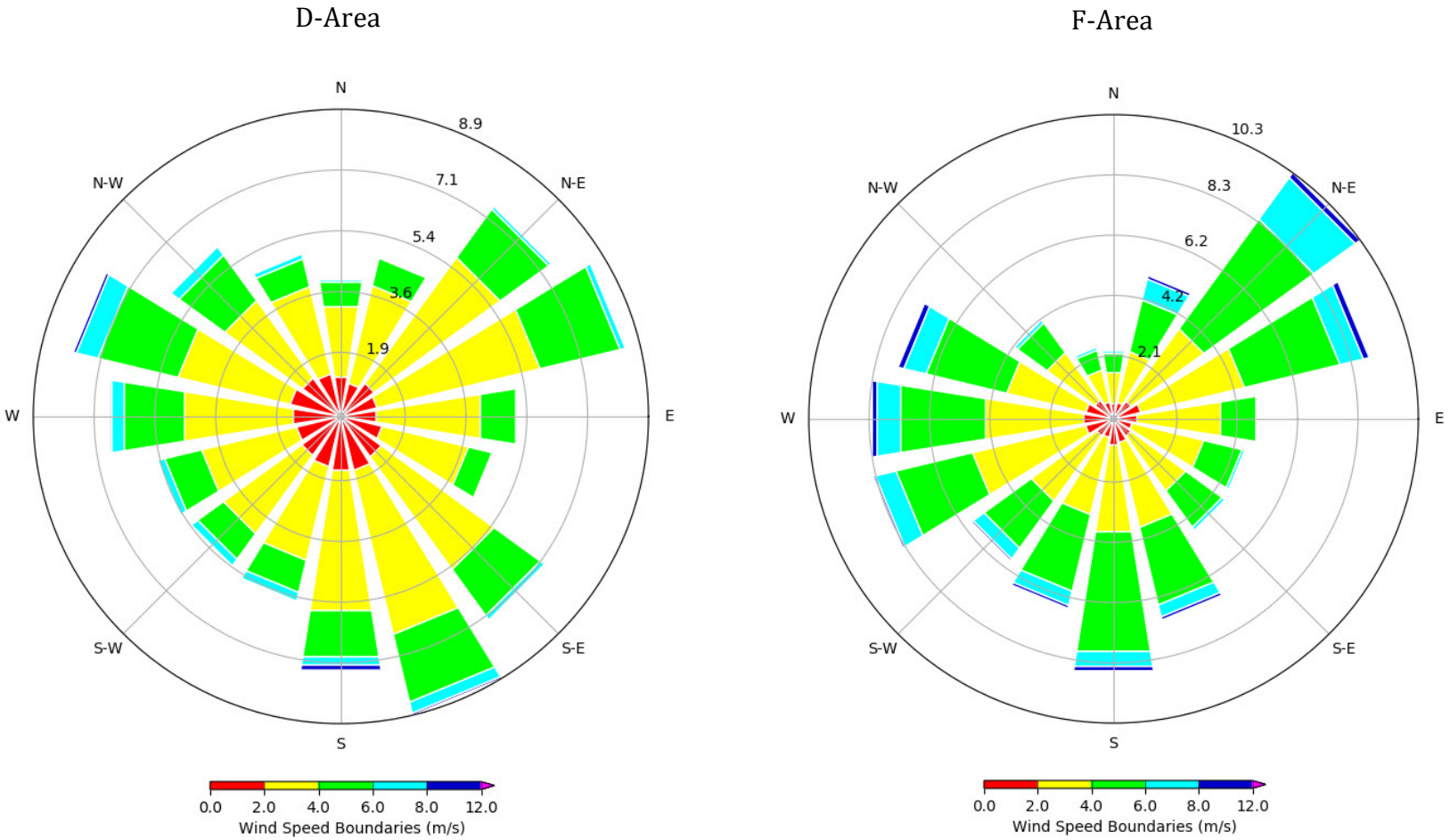

Figure 20 (b): 2019 Wind Roses for Area Towers D and F

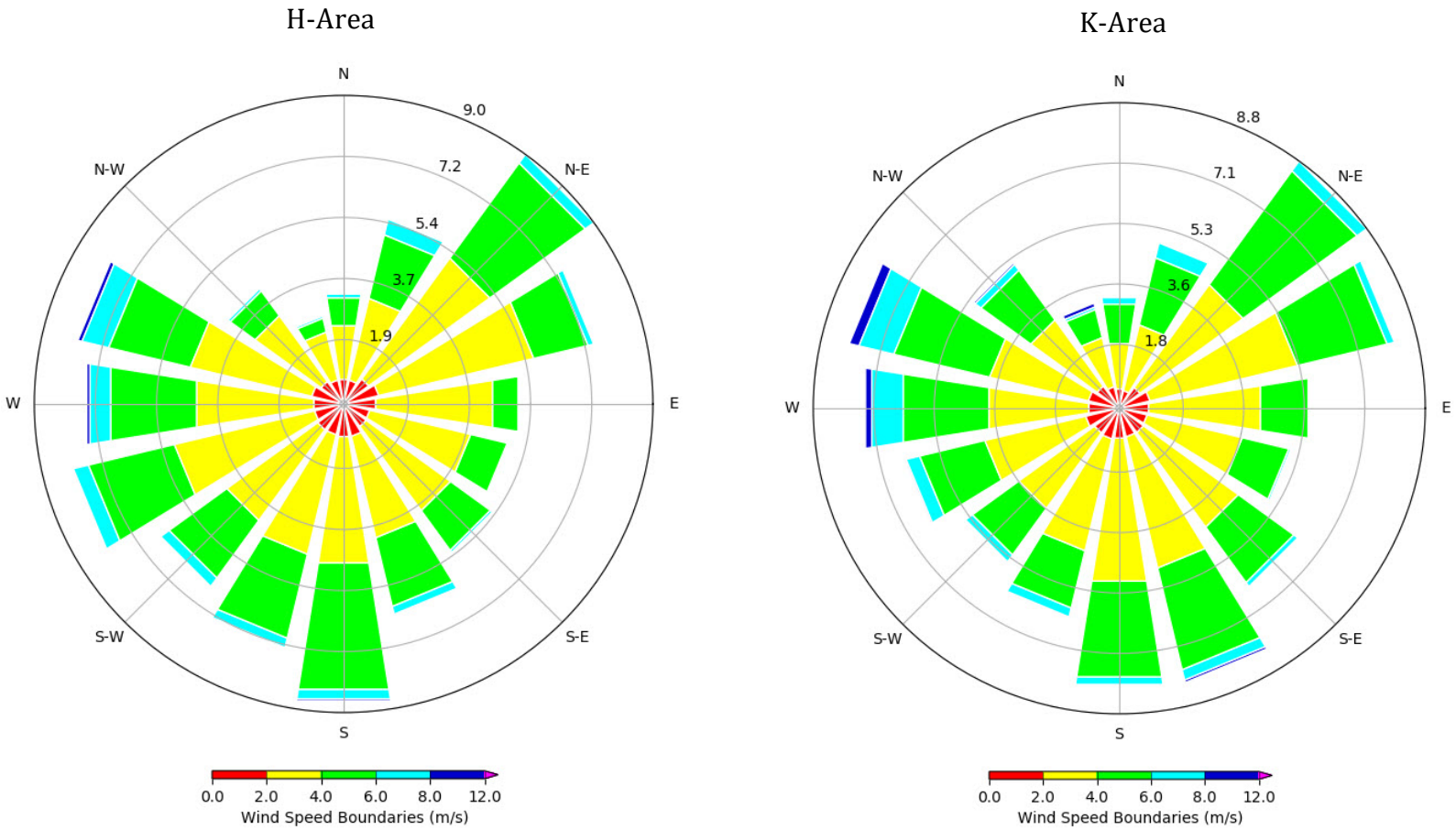

Figure 20 (c): 2019 Wind Roses for Area Towers H and K

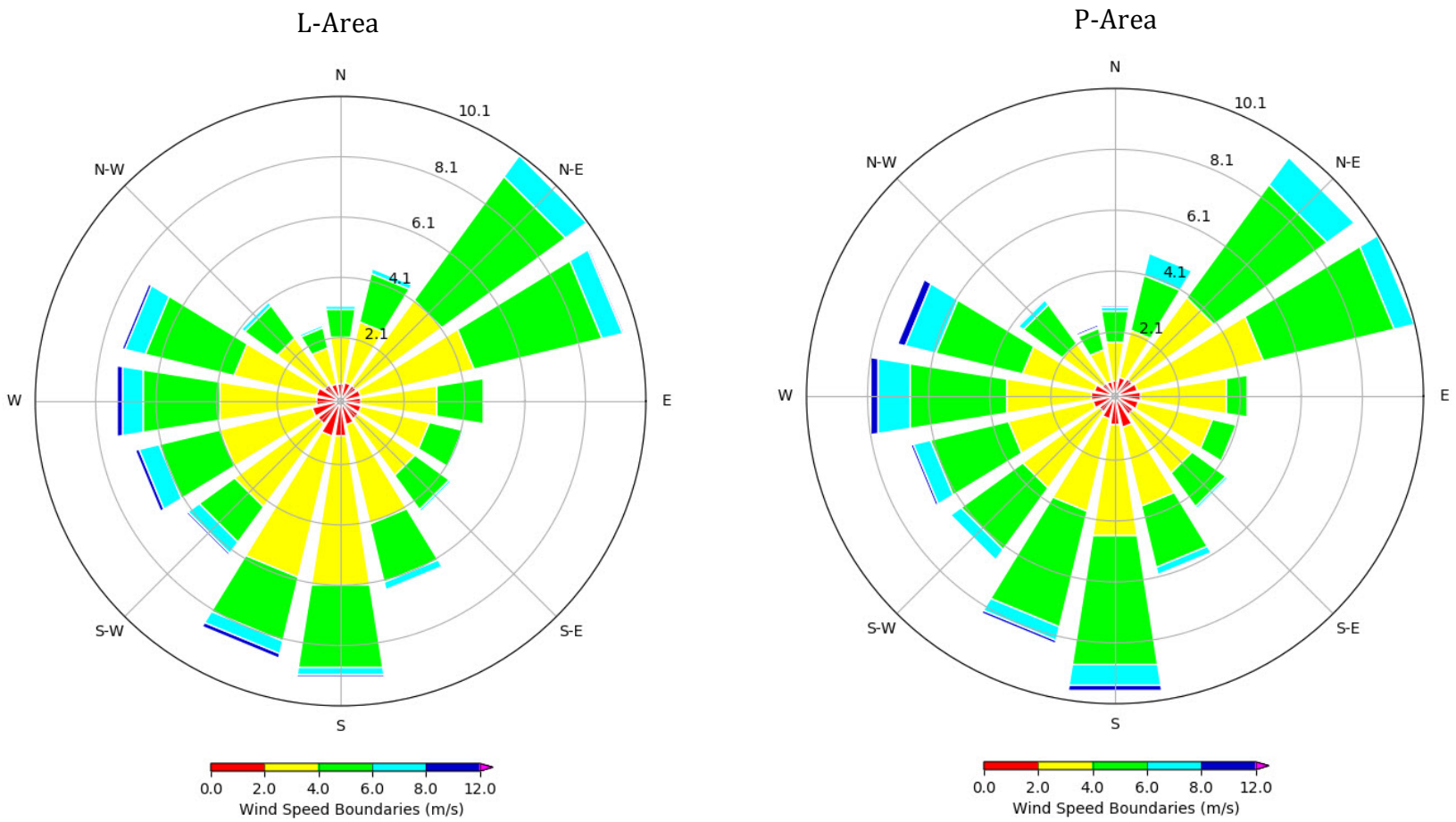

Figure 20 (d): 2019 Wind Roses for Area Towers L and P

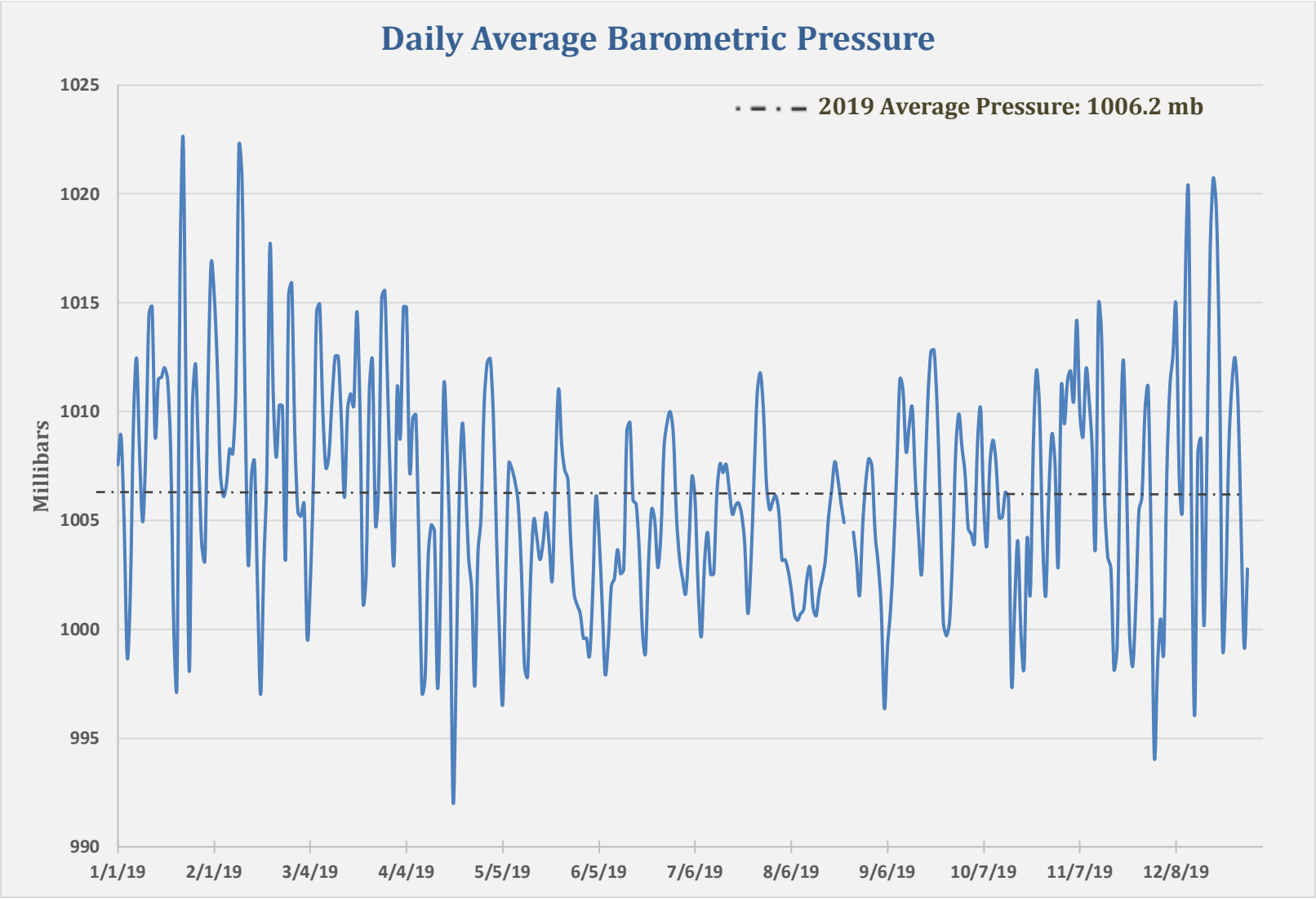

Figure 21: 2019 Daily Average Barometric Pressure

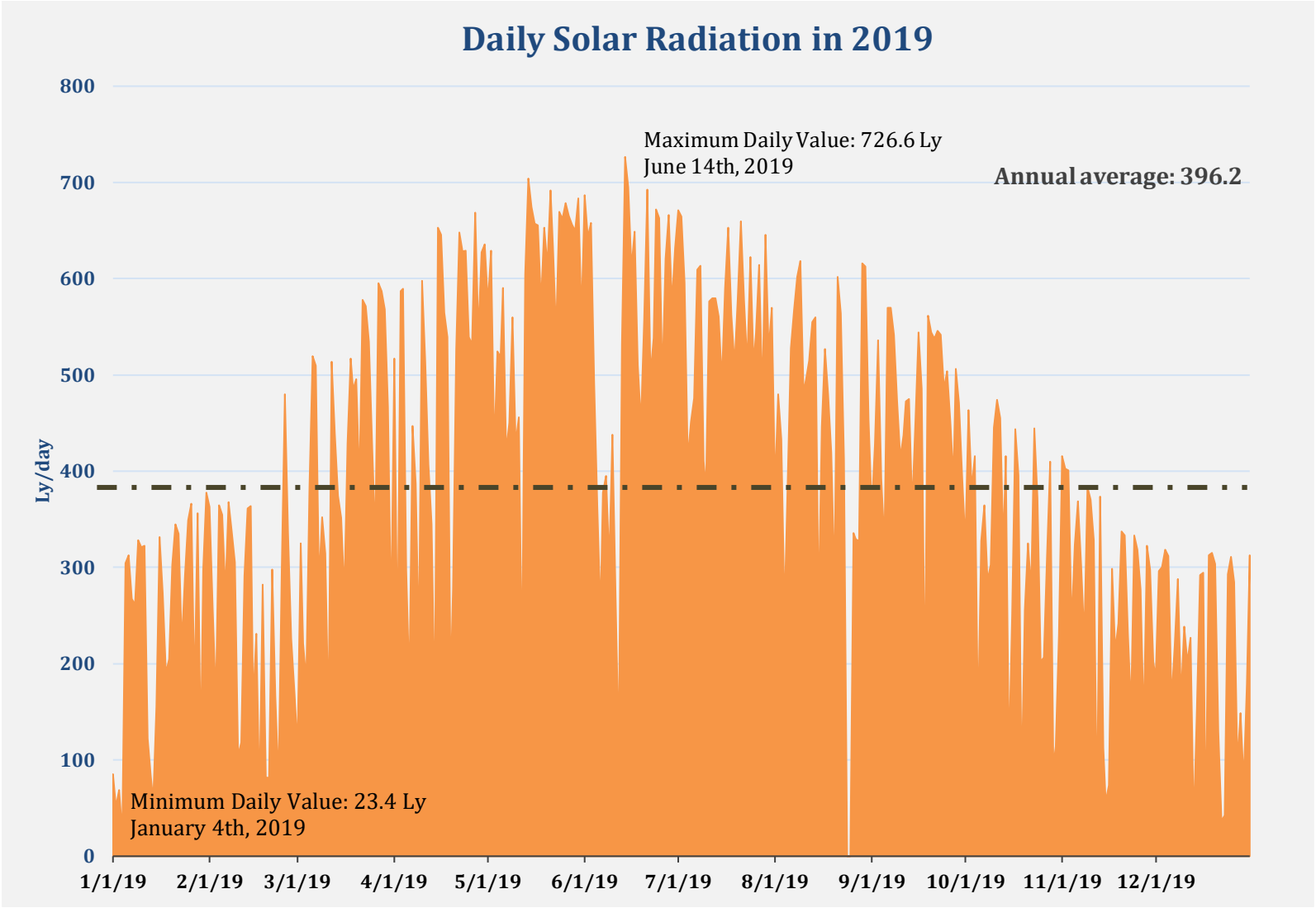

Figure 22: Daily Solar Radiation in 2019

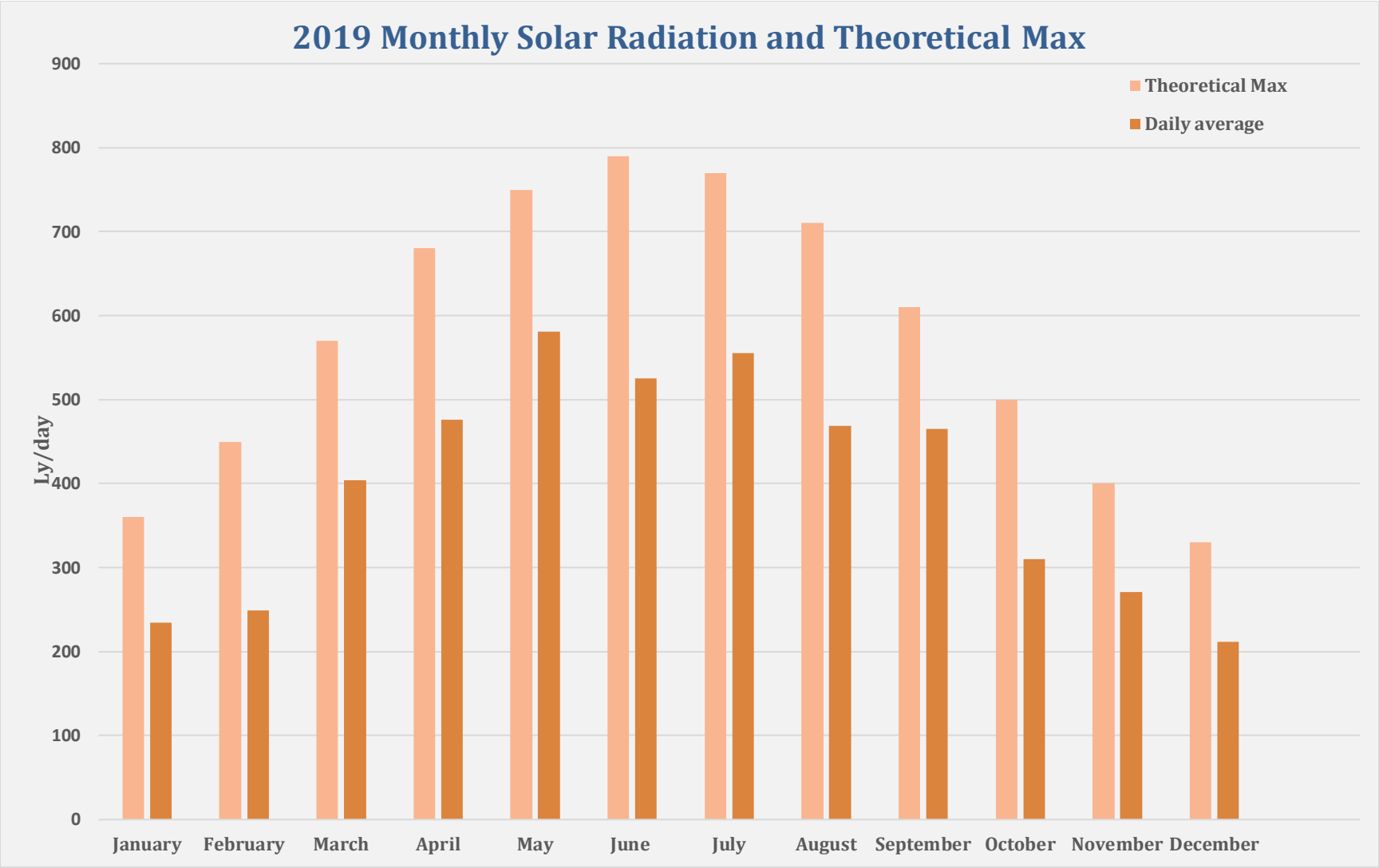

Figure 23: 2019 Monthly Solar Radiation and Theoretical Max