BNL-103733-2014-IR
Informal Report

METEOROLOGICAL SERVICES

ANNUAL DATA REPORT FOR 2013

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January 2014

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DISCLAIMER

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Purpose

This document presents the meteorological data collected at Brookhaven National Laboratory (BNL) by Meteorological Services (Met Services) for the calendar year 2013. The purpose is to publicize the data sets available to emergency personnel, researchers and facility operations. Met services has been collecting data at BNL since 1949. Data from 1994 to the present is available in digital format. Data is presented in monthly plots of one-minute data. This allows the reader the ability to peruse the data for trends or anomalies that may be of interest to them. Full data sets are available to BNL personnel and to a limited degree outside researchers based on the level of time and resources required. The full data sets allow plotting the data on expanded time scales to obtain greater details (e.g., daily solar variability, inversions, etc.).

Background

Meteorological Services (Met Services) is responsible for the maintenance, calibration, data collection and data archiving for the weather instrumentation network at Brookhaven National Laboratory. Measurements include wind speed, wind direction, temperature, rainfall, barometric pressure and relative humidity. Wind speed, wind direction and temperature are measured at 85 meters, 50 meters and at 10 meters. Rainfall, relative humidity, temperature and barometric pressure are taken at the 2 meter height. This critical data set is used for NEPA calculations, for emergency planning and operations (i.e., chemical spill or accidental release) and general research. In addition to the weather sensors, Met Services maintains a solar resource base station which measures solar radiation at BNL. Instruments include Solys-2, sun tracker equipped with a pyrheliometer (direct normal incidence radiation), a ventilated, shaded pyrgeometer (downwards long-wave, infrared radiation), a ventilated, shaded, research grade pyranometer (diffuse solar radiation) and a ventilated, unshaded, research grade pyranometer (global solar radiation). The base station also has a Total Sky Imager for cloud imaging and two SP-Lite2 pyranometers that replicate the research array sensors at the Long Island Solar Farm (LISF).

Meteorological data is also presented in real time via a webserver at http://wx1.bnl.gov. Current weather parameters are posted here. Using buttons and pull-down menus the user has a method to graph the data from several hours to several days for the past 12 months (http://wx1.bnl.gov/graph.html) and stability class (http://wx1.bnl.gov/stability.php). Graphing includes barometric pressure, temperature (@ all locations), wind speed, wind direction, wind gust, humidity, precipitation and solar radiation.

Site

Weather conditions at the BNL site have been recorded since August 1948. BNL is broadly influenced by continental and maritime weather systems. Locally, the major weather systems are modified by the Long Island Sound, the Atlantic Ocean and associated bays, which influence wind directions and humidity, and provide a moderating influence on extreme summer and winter temperatures.

BNL is a well-ventilated site, with an annual distribution of wind direction reflecting a predominance of westerly components. Prevailing winds are from the southwest during the summer, from the northwest during the winter, and about equally from these two directions during the spring and fall.

Instrument Towers

85-meter Tower

The 85-meter (280-ft.) meteorological tower was placed in operation in May 1981 to replace the former and original "Ace Tower" used in the first 30 operational years at BNL. The tower (Fig. 1) is located in an open field west of the majority of the Brookhaven building complex at latitude 40°52'14.84"N and longitude 72°53'20.05"W and its base is 24 m (80 ft.) above sea level and is referred to as "Tower Ten". In this document, the primary, tall tower will be called, the main or 85-meter tower to avoid confusion with the smaller, secondary 10-meter tower also in operation at the Met field.

The main tower is made of galvanized steel, is triangular in shape with 3 ft. sides and has 3 sets of 8 guy wires to keep it upright. It has an inside ladder for climbing, and two working levels with small platforms. It is difficult to mount booms and equipment or to work on this tower. Special safety belts and harnesses are required when climbing, maintaining or calibrating equipment on this tower. Sensor location names designate the approximate height of the sensors above the ground. At each location there are fully redundant sensor sets. Each set is independent of the other with unique data loggers and sensors. At locations M85 and M50 instrumentation includes; R.M. Young model 5106 Marine grade wind monitors for wind speed and direction and R.M. Young model 41342VC temperature probes. The temperature probes are protected by naturally aspirated radiation shields. Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

10-meter Tower

A foldable-mast, ten-meter tower is located approximately at the center of the Meteorological field. Again, fully redundant sensor sets are present. Instrumentation includes R.M. Young model 5106 Marine grade wind monitors for wind speed and direction and R.M. Young model 41342VC temperature probes. The temperature probes are protected by naturally aspirated radiation shields. Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

2-meter pole

At two meters (located near the 10-meter tower) sensors include; R.M. Young model 41372VC temperature and relative humidity probes and R.M. Young model 61302V barometric pressure sensors. The T/RH probes have actively aspirated (powered fan) shields. Data collection is via

Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

Two tipping-bucket rain gauges (Novalynx model 260-2501) are maintained on the roof of building 490D. This location was chosen for available 115VAC for the heaters in the gauges required for winter use. Data collection is via Campbell CR1000 data loggers with direct network connections.

Solar Base Station

Met Services maintains a platform on the roof of building 490D. This platform is used for testing of sensors and also houses the LISF research projects base station for solar irradiance measurements. Instrumentation at this location includes; a Kipp and Zonen model Solys-2 suntracker equipped with a shaded Kipp and Zonen model CGR-4 pyrgeometer for long-wave, far infrared radiation, a Kipp and Zonen model CHP-1 pyrheliometer to measure direct normal indicent radiation and two Kipp and Zonen CMP-22 research grade pyranometers, one shaded and one unshaded, to record diffuse and global radiation. BNL is also home to the Long Island Solar Farm (LISF) where we maintain a research array of sensors including pyranometers. As a reference for the LISF sensor array, two Kipp and Zonen model SP-lite2 pyranometers are maintained, one in-plane (aka tilted global radiation) at the 27° angle of inclination for the panels at the LISF and one horizontal (global radiation). Data collection is via a Campbell CR3000 data loggers directly connected to the network. Additionally a Total Sky Imager (TSI) is mounted on the platform and is directly connected to the network. Images from the TSI are available to BNL users.

Calibrations

All sensors are calibrated annually in accordance to the BNL Meteorological Instrument Network Calibration Plan (Heiser 2012). Where an instrument is sent off site for calibration a duplicate calibrated unit is available for replacement.

The calibration and maintenance frequency is based on the following hierarchy:

1. Manufacturer's recommendation as stated in the instruments Operation Manual or Owner’s Instruction Manual.

2. Manufacturer's recommendation as stated in other communications such as a memorandum, email, or documented phone conversation.

3. Other engineering or scientific standards specifically referring to a particular type of instrument (e.g., American Nuclear Society, American National Standards Institute).

4. Met Services determination of calibration needs based on experience with the equipment or recommendations from other sources.

Calibration certificates are required from the companies performing calibrations and these certificates are compiled in the Instrument Calibration Notebook. For sensors that are calibrated

on site or in-situ by BNL personnel, the data taken is recorded on instrument specific data sheets and the sheets are compiled into the Instrument Calibration Notebook. The original notebook is maintained by the head of Met Services. Additionally, an electronic master list of equipment and the current status of each instruments calibration along with calibration coefficients is maintained on the Met Services master computer with copies available from the Head of Met Services and the Operations Officer.

Data Sets and Data Availability

Meteorological sensors are checked daily and duplicate sensors inter-compared. On a monthly basis the data goes through a QA/QC process to help eliminate bad records and correct or remove any erroneous values. The post processing of the data involves visually analyzing the data in eight day increments looking for bad data points. MatLab, data analysis software, is used for this purpose. Using a series of scripts it is relatively easy to remove single or multiple data points. Once the bad data is removed the operator can chose to fill in the missing points by interpolation or leave the data as "missing". The data is then saved to a file. This data is then backed up along with the raw unedited data. In addition to this we also do a comparative analysis on the "A" and "B" datasets to insure precision between the two independent systems. Data reported is generally taken from the "A" side sensors with "B" side sensors serving as backups. If data checks show the A sensors to be out of service, out of spec or questionable the data is replaced by B sensor data until the A sensor is replaced/repaired.

After the editing is complete, daily and hourly averages and sums are calculated and saved to files to be disseminated upon request. The averages are then added to a spreadsheet that includes all the past data collected here at BNL, going back as far as 1949. See; http://www.bnl.gov/weather/MonthlyClimatology.asp

Currently data is available as monthly, daily, hourly and one minute averages. Subsets of the main data set are also available. Most requests are for a small, specific time frame, which can usually be produced in one to two days.

Meteorological Data Recovery for 2013

For the year, Met Services had a 100 percent record retrieval rate, collecting all of the 525,600 records. During the course of the year there was a single instrument failure event that resulted in a loss of data. This event began at 2000 hrs on December 10th and ended on December 11th at 0738 hrs. There was very little solar insolence on the 4 previous days. Due to the lack of sunlight the battery voltage dropped below 11.4 volts DC. The solar charger, that controls the battery charging from the solar panels, has a built in low voltage disconnect that disconnects the load from the batteries when the battery voltage drops below 11.4 volts. This outage accounted for 4968 data points or 61.7% of the lost data for the year. The remaining 38.3% of missing data points is attributed to erroneous data, bad data points during instrument exchanges and the short term instrument reporting failures. These short term reporting failures are generally less than an hour in duration.

Of the 8,935,200 data points available for collection the system failed to record 8057 points. This equates to a loss of just 0.09% of the total amount of data available for recording or 99.91% data recovery for the year.

2013 was the second full year that the Solar Base Station (SBS), that supports the LISF, was in operation. There was one major failure to the tracker that required that it be returned to the factory for repair. We were able to secure a loaner from the manufacturer to use during the repair period. Therefore, the CHP and the diffused measurements were not taken from December 26, 2013 to the end of the calendar year (and continued until) January 18, 2014.

For the second year of operation of the solar base station, we collected 99.90% of all possible records (525,079 of 525,600). Of the collected data we expected to see 3,675,533 fields of good data. We had 123,490 fields with bad data. That is 3.36% of the fields contained bad data. So, of the 99.90% data we recovered 96.64% was considered good data.

21.4% of the CHP data was unallowable because the instrument was participating in a World Wide Cavity Radiometer comparison study in addition to lost data when the tracker failed in December. This accounted for 90.8% of the bad data points. The remaining 9.2% of bad data is from diffused instrument data that was removed when the tracker stopped working, instrument replacements and the occasional erroneous data points.

2013 Meteorological Data

Table 1. 2013 Extremes and Totals[a]

Highest Temperature	35.0 C° July 10th
Lowest Temperature	-17.8 C° January 24th
Average Yearly Temperature	11.0 C°
Annual Precipitation	43.23"
Maximum Monthly Precipitation	8.37" in June
Minimum Monthly Precipitation	0.26” in October
Maximum Daily Precipitation	4.12” on May 30th
Maximum Hourly Rainfall	0.9” on July 23rd from 1800hrs to 1900hrs
Maximum Wind Speed (85 meters)	23.3 m/s (51.9 mph) January 31st
Maximum Wind Gust (85 meters)	32.7 m/s (73.2 mph) January 31st
Maximum Wind Speed (10 meters)	10.5 m/s (23.5 mph) January 31st
Maximum Wind Gust (10 meters)	19.7 m/s (44.1 mph) January 31st
Maximum Barometric Pressure	1039.2 mbar November 30th
Lowest Barometric Pressure	982.5 mbar January 31st
Lowest Relative Humidity	14.6% April 6th
Heating Degree Days	5612.3
Cooling Degree Days	763.5
Average Daily Irradiance	168.1 W/m^2

a = Measurements taken at the 2 meter height unless otherwise noted.

Air Temperature

Temperature is measured at 2-meters, 10-meters, 50-meters and 85-meters at the locations described above. The probes are calibrated internally by BNL staff. A high quality constant temperature bath along with a reference platinum resistance thermometer (PRT) are used to perform a comparison calibration curve. The PRT is calibrated off-site to NIST standards. Air temperature sensors are maintained to ±0.1°C, which is the requirement for determining stability class by temperature differential.

Met Services uses a characterization calibration using four points (temperatures T=-10°C, 5°C, 20°C and 35°C). For platinum resistance probes and modest accuracy applications the resistance-temperature relationship can be approximated by the Callendar-Van Dusen equation as:

$R(t) = R(0)[1 + At + Bt2 + C(t-100)t3]$

Where:
t = temperature (°C),
R(t) = resistance at temperature t,
R(0) = resistance at 0°C,
and using ASTM 1137 and IEC 60751 coefficient values for a standard 100 ohm sensor having an alpha value of 0.00385;
A = 3.9083 x 10-3 (°C-1),
B = -5.775 x 10-7(°C-2) and
C = -4.183 x 10-12 (°C-4) [for temperatures above 0°C, C = 0]

Within the temperature range of BNL's minimum observed temperature (-31°C) and maximum observed temperature (38°C), the B and C coefficients can be ignored and approximated as zero and;

$R(t) = R(0) + R(0) \bullet At$

Met Services uses the comparison method of calibrating temperature sensors. The thermometer is calibrated by comparison with a reference or standard thermometer in a thermally stabilized bath. The procedure uses a four point calibration consisting of -10°C, 5°C, 20°C and 35°C. ANSI/ANS-3.11-2005 lists the air temperature minimum accuracy of 0.5°C and a minimum resolution of 0.1°C (see Appendix H). For stability class determinations using vertical temperature differences the requirements are; a minimum accuracy of 0.1°C and a minimum resolution of 0.01°C. Meteorological data (data from the met field towers) is held to the latter (LISF data to the former).

Daily average temperature for the year is presented in Figure 1. Daily minimums and maximums for the year are shown in Figure 2. Table 2 summarizes the 2 meter monthly average daily temperatures, average daily minimum and maximum temperatures and monthly extreme highs and lows. Figure 3 depicts the 2012 monthly temperature means and compares them to historic means. Table 3, 4 and 5 lists the historic monthly average, average monthly maximum and average monthly minimum temperatures from 1949 to 2012. Monthly data plots of 1-minute data at the four met field measurement locations are presented in Figures 4 through 15.

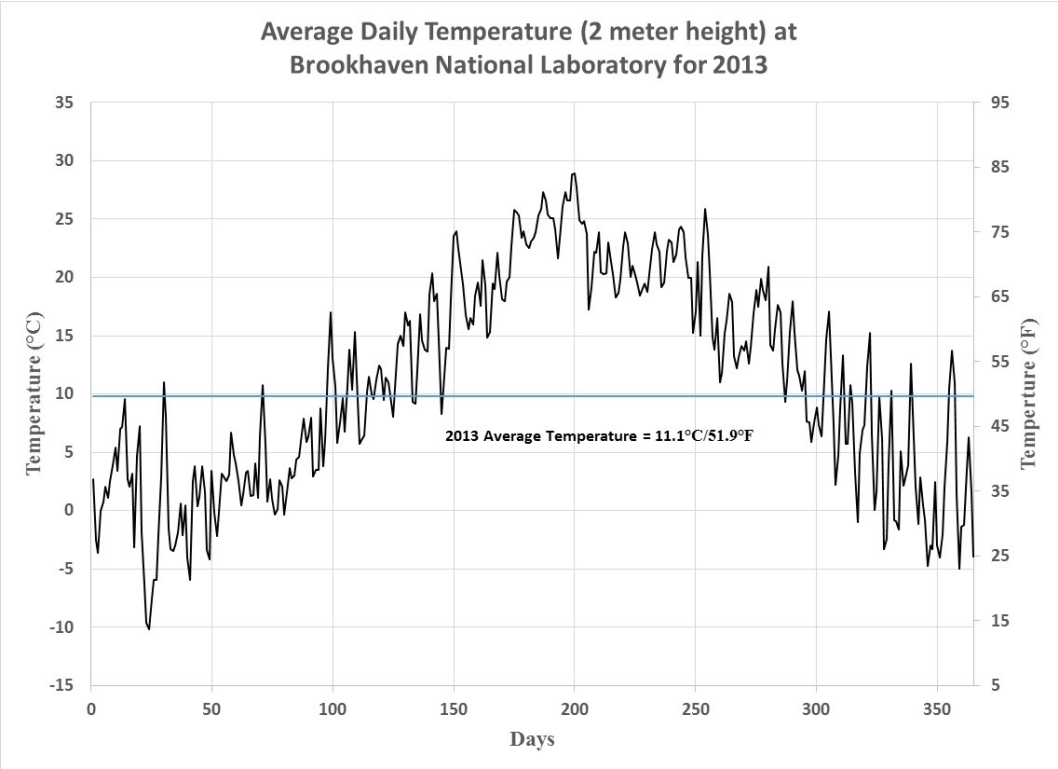

Figure 1. Average Daily Temperature taken at the 2 meter height at BNL for 2013

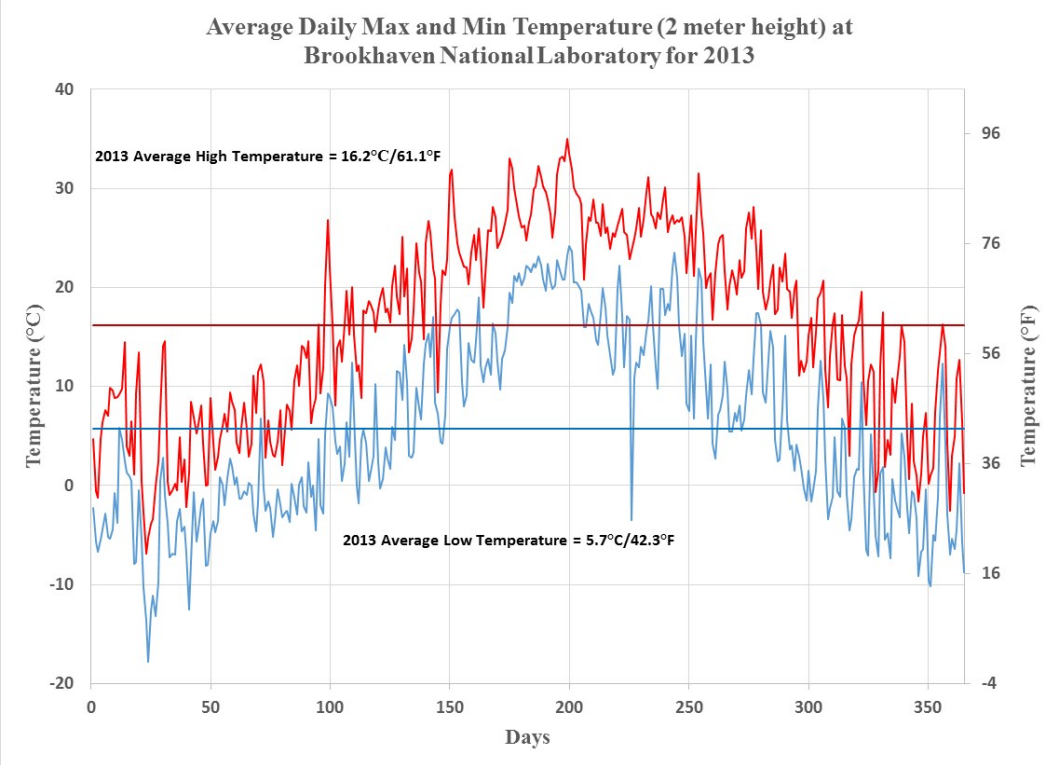

Figure 2. Daily Minimums and Maximums in Temperature taken at the 2 meter height at BNL for 2013

Table 2. Monthly Temperature Summary

Month	2013 Temperatures (°C) @ 2 meters						
	Average			Extremes			
	Daily Mean	Daily High	Daily Low	High	Date	Low	Date
Jan	33.7	40.9	23.9	58.3	Jan 31	0.0	Jan 24
Feb	32.4	38.4	25.0	48.9	Feb 27	9.5	Feb 10
Mar	37.8	45.3	29.5	57.4	Mar 29	22.6	Mar 17
Apr	48.6	59.1	38.1	80.2	Apr 9	23.9	Apr 4
May	57.9	69.1	47.0	89.4	May 31	31.5	May 1
Jun	68.1	77.6	59.0	91.4	Jun 24	46.4	Jun 5
Jul	75.9	84.2	68.6	95.0	Jul 18	57.6	Jul 31
Aug	70.0	79.8	60.7	88.0	Aug 21	49.6	Aug 25
Sep	62.8	73.9	51.5	88.7	Sep 11	36.9	Sep 18
Oct	55.9	66.8	44.6	82.6	Oct 4	29.1	Oct 28
Nov	42.6	52.5	32.2	69.3	Nov 2	18.7	Nov 30
Dec	35.8	44.0	27.4	61.3	Dec 22	13.6	Dec 17

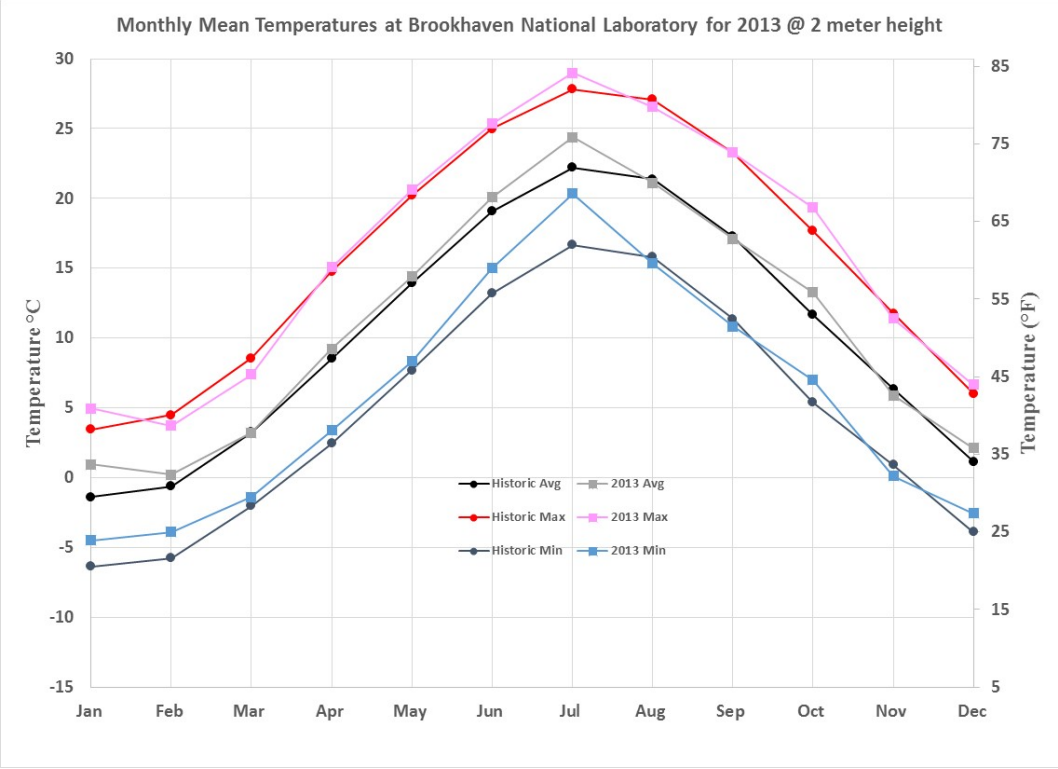

Figure 3. Monthly Mean Temperatures (°C) at Brookhaven National Laboratory for 2013

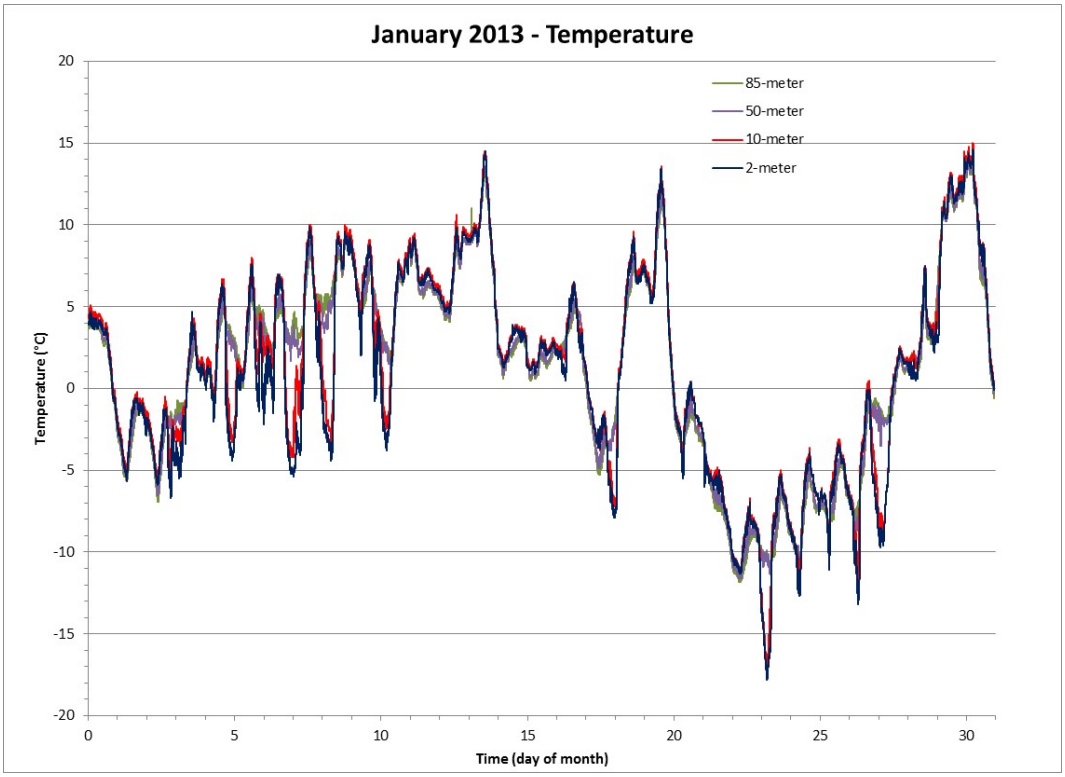

Figure 4. Air Temperature for the Month of January 2013

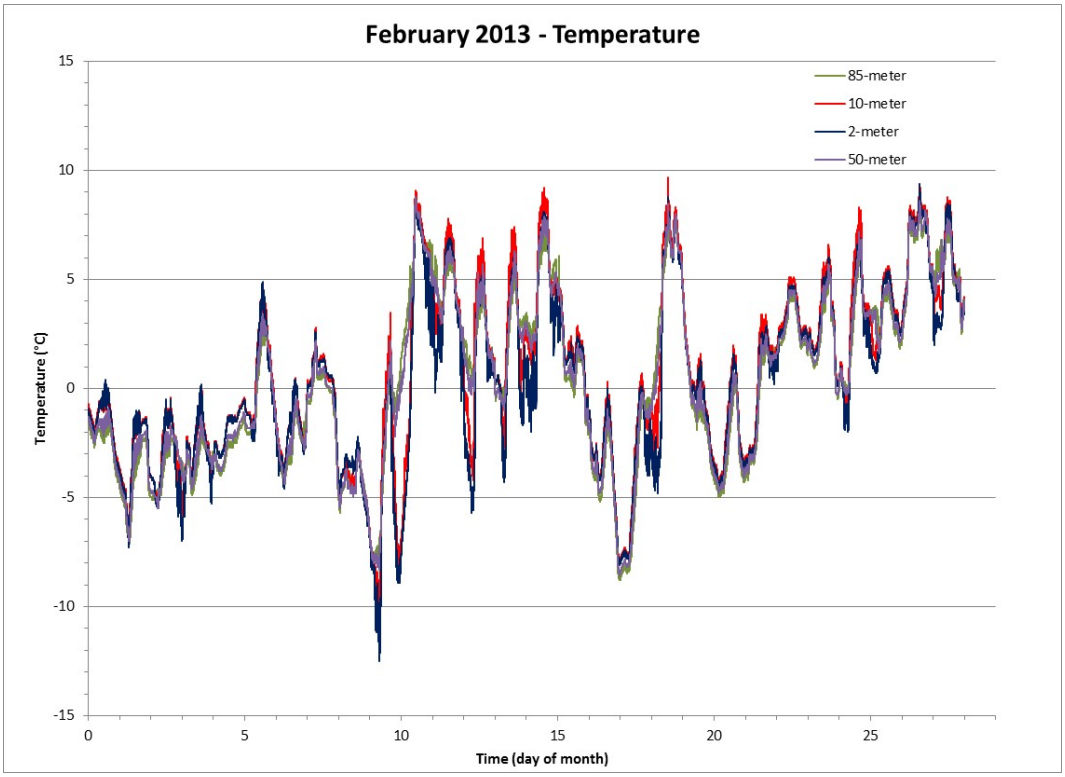

Figure 5. Air Temperature for the Month of February 2013

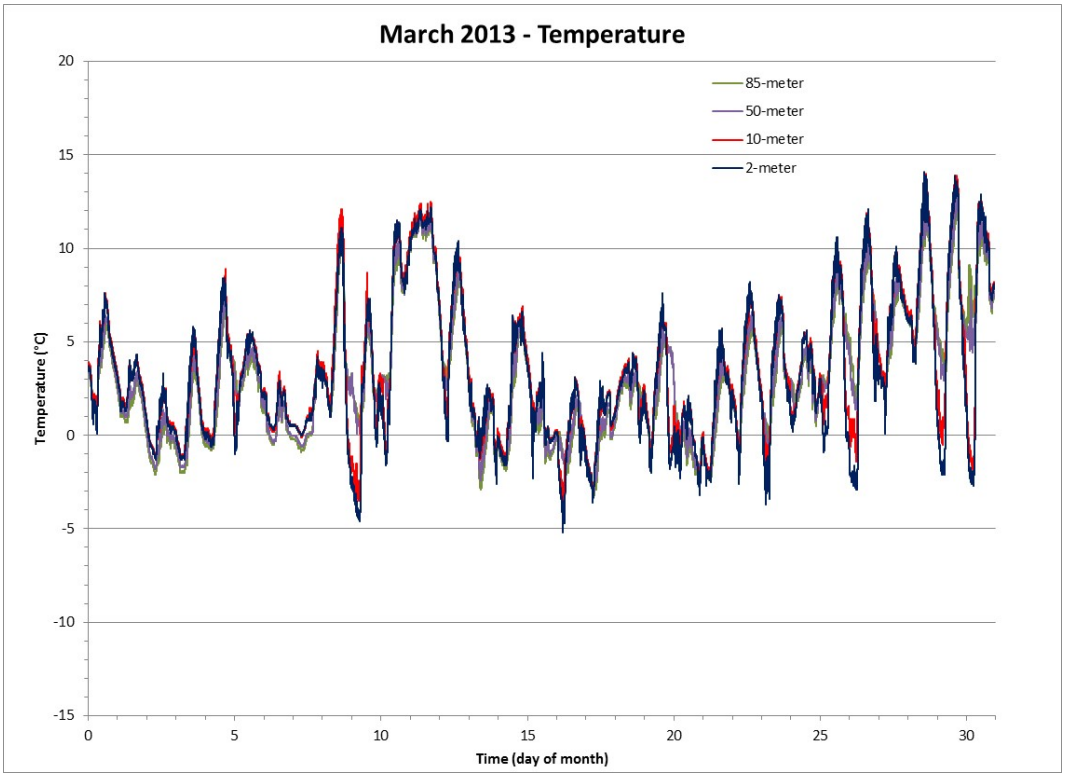

Figure 6. Air Temperature for the Month of March 2013

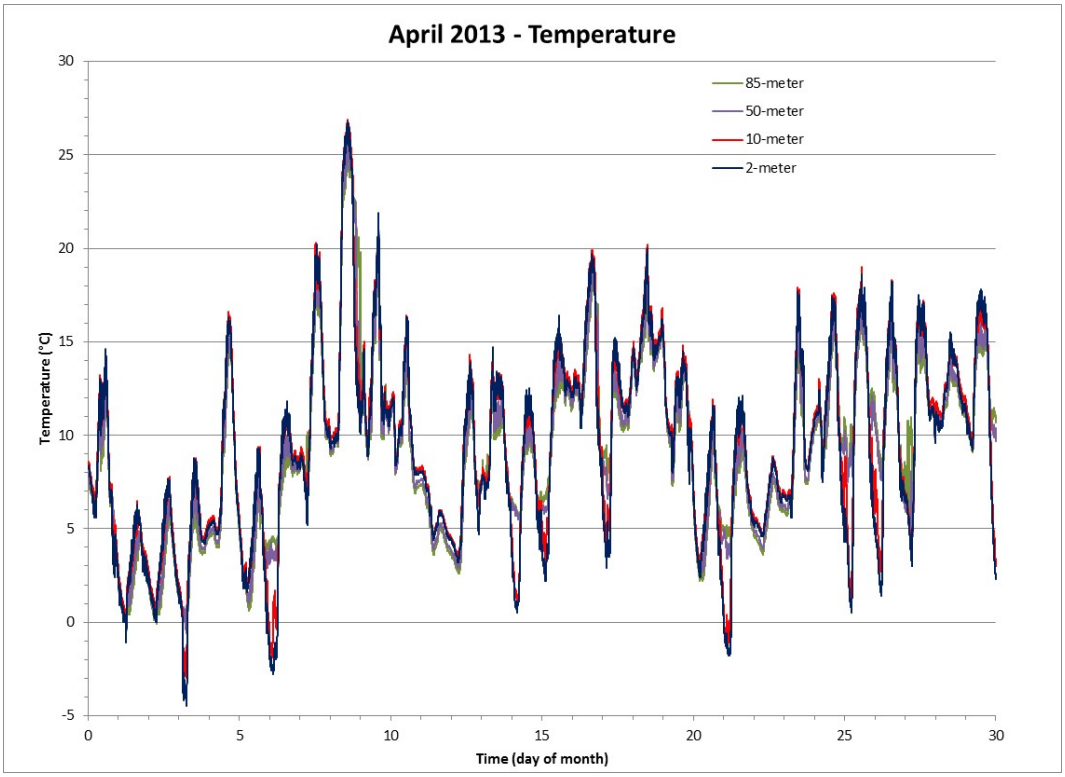

Figure 7. Air Temperature for the Month of April 2013

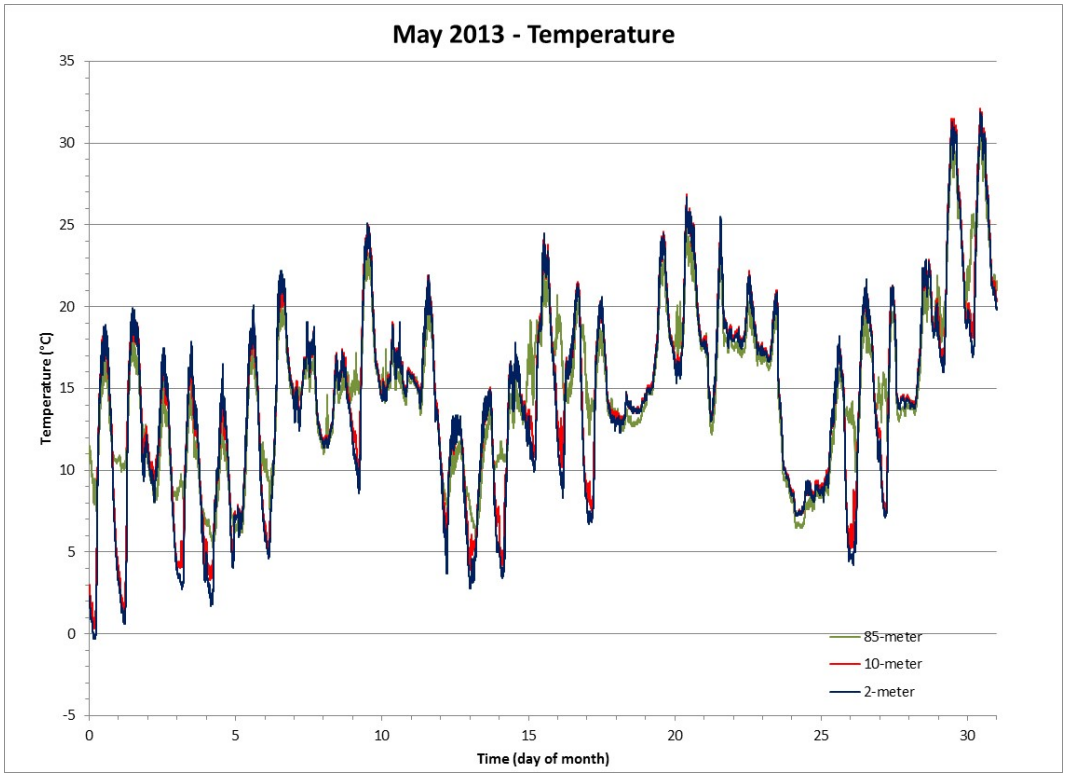

Figure 8. Air Temperature for the Month of May 2013

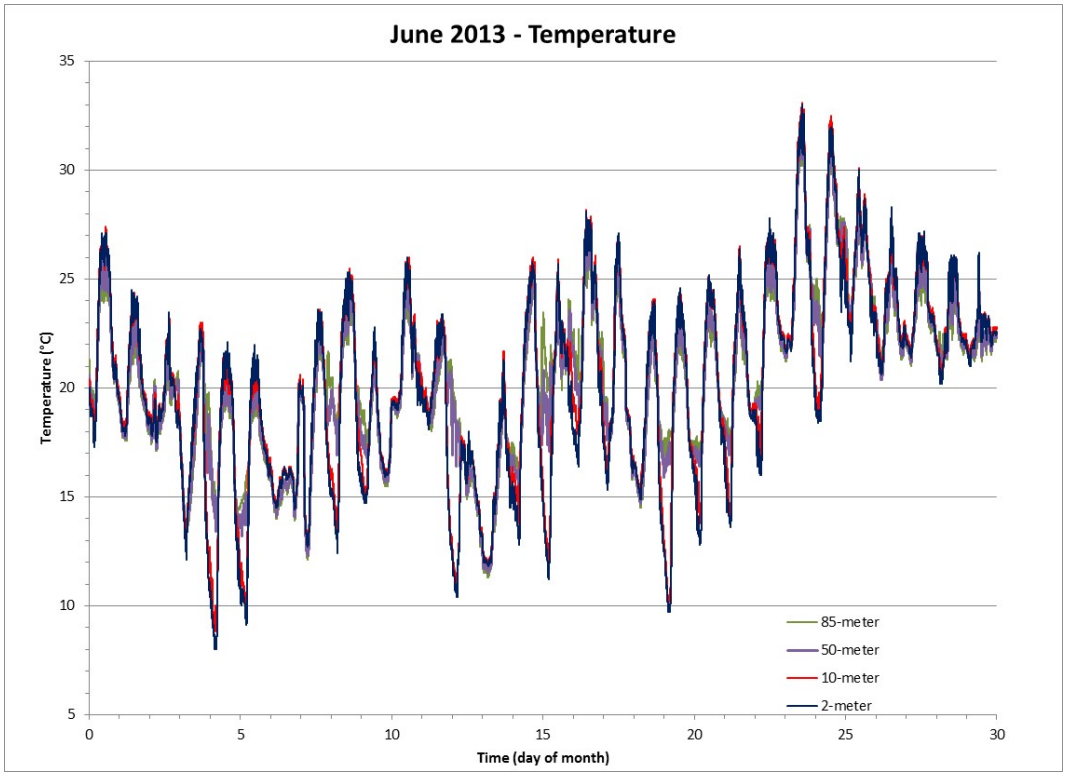

Figure 9. Air Temperature for the Month of June 2013

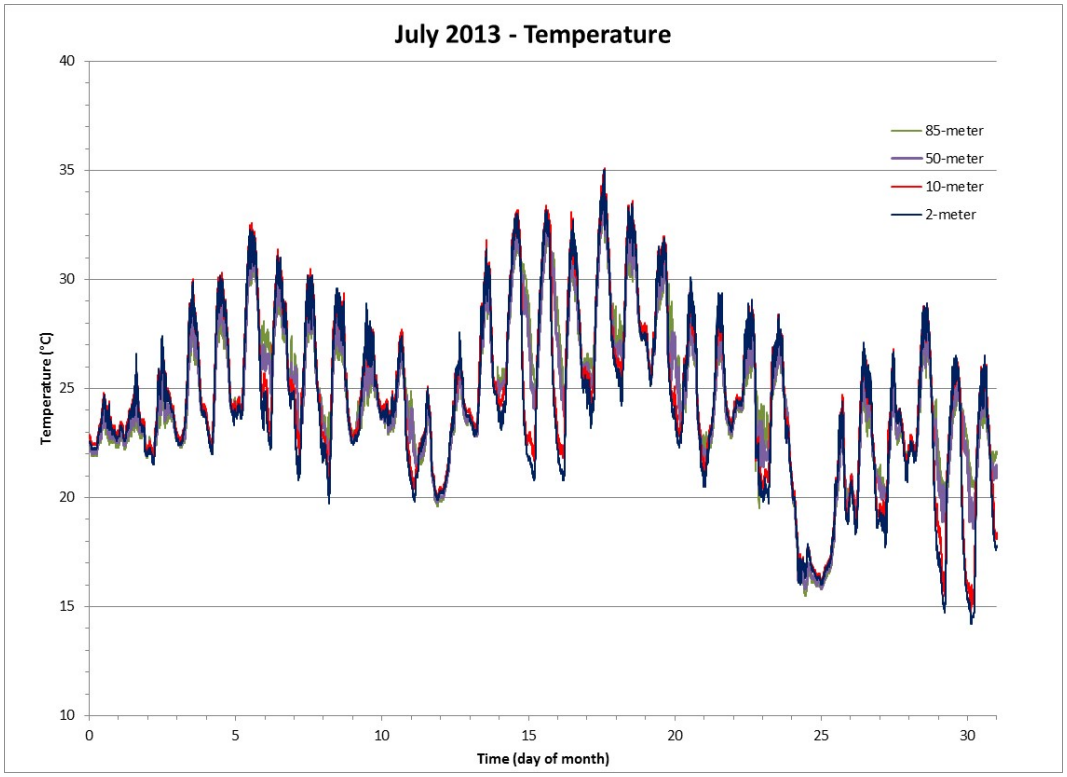

Figure 10. Air Temperature for the Month of July 2013

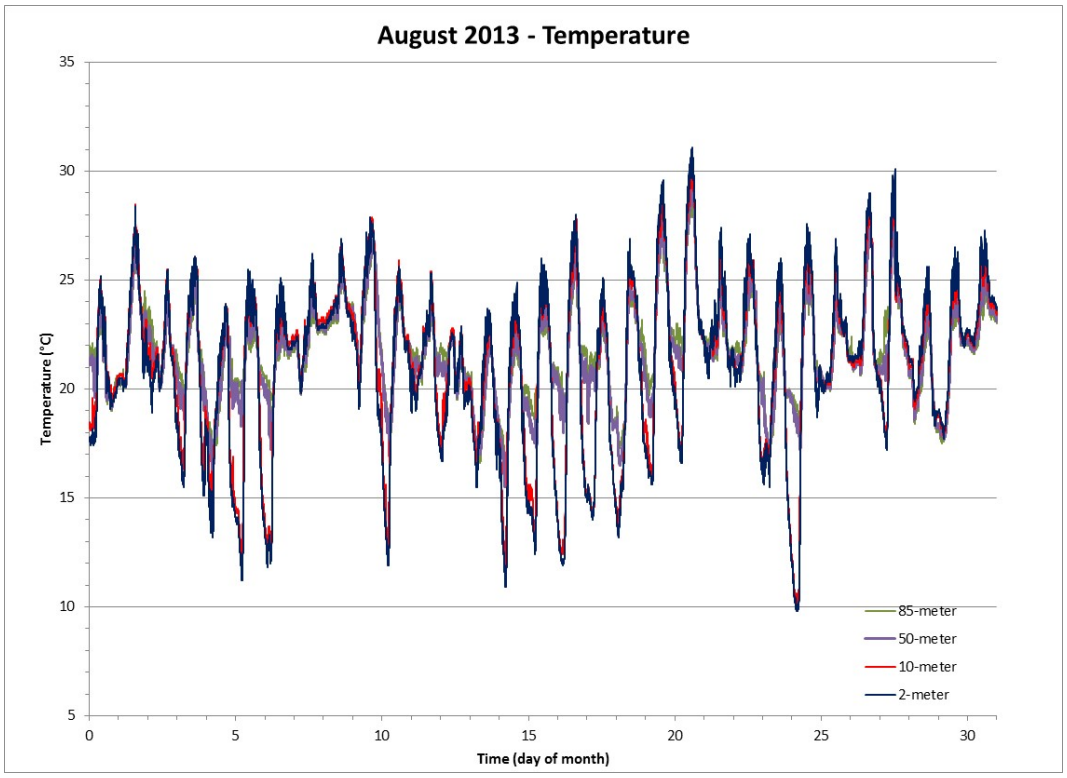

Figure 11. Air Temperature for the Month of August 2013

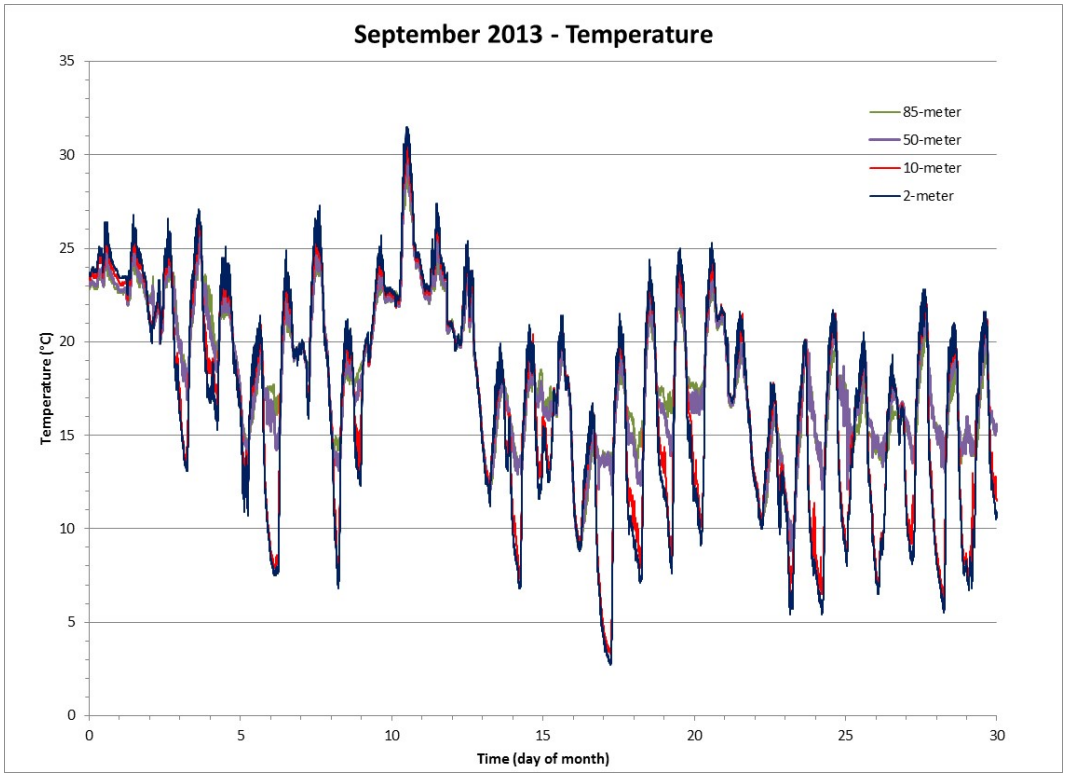

Figure 12. Air Temperature for the Month of September 2013

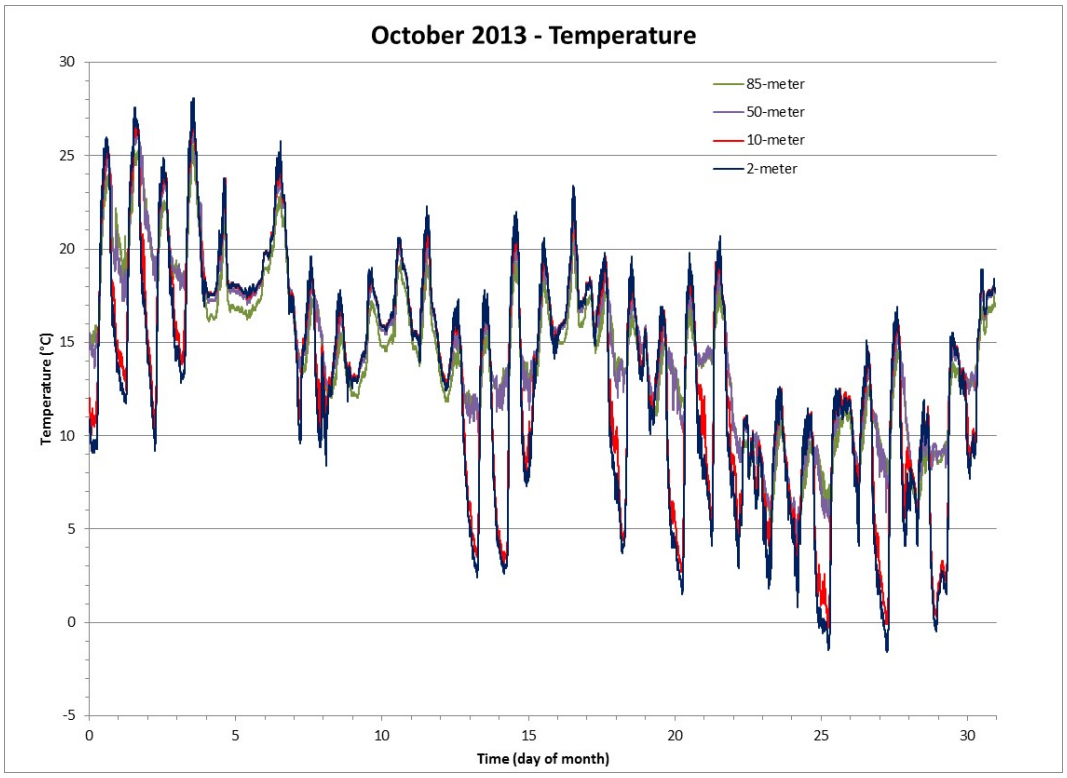

Figure 13. Air Temperature for the Month of October 2013

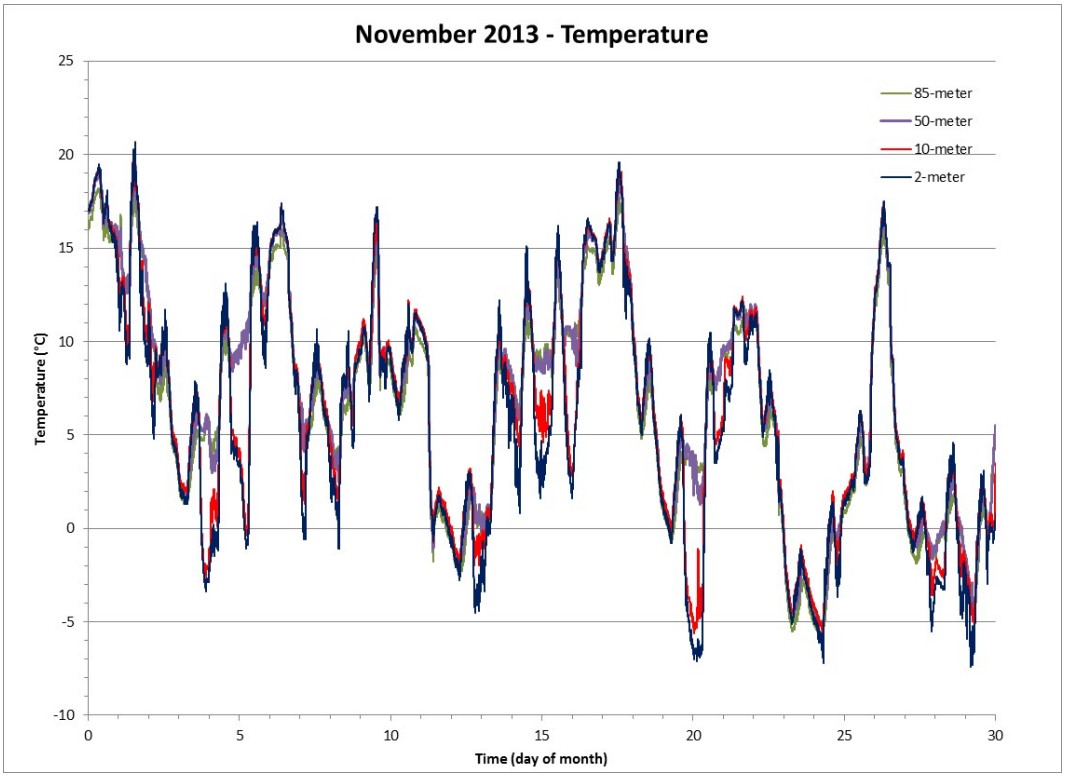

Figure 14. Air Temperature for the Month of November 2013

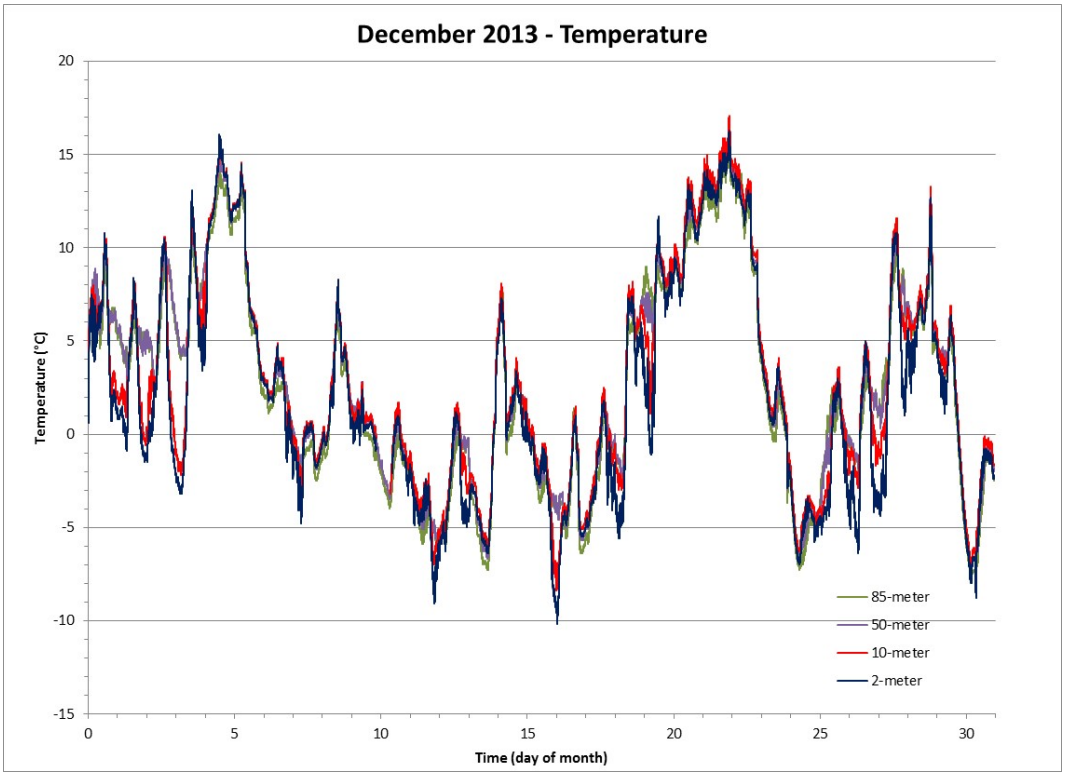

Figure 15. Air Temperature for the Month of December 2013

Table 3. Historic Monthly Mean Temperatures (°C) for Brookhaven National Laboratory from 1949 to 2013 (@ 2 meters)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	2.3	2.0	3.6	9.5	14.3	20.1	23.3	21.9	16.2	14.1	5.6	1.2	11.2
1950	**3.3**	-1.7	0.6	6.3	11.9	17.9	21.1	19.7	15.4	12.1	6.3	0.0	9.4
1951	0.1	-0.1	3.2	8.6	13.9	17.6	21.5	20.3	16.9	11.9	4.4	**7.2**	10.4
1952	0.2	-0.1	2.7	9.2	12.8	19.8	23.5	21.2	16.7	9.8	5.9	1.6	10.3
1953	1.2	1.6	3.8	8.4	14.6	18.3	21.5	20.2	17.4	**18.3**	6.2	3.1	11.2
1954	-3.1	1.4	2.8	8.6	11.9	18.9	20.8	19.4	16.1	13.1	4.7	0.0	9.6
1955	-2.4	-1.1	3.1	9.2	14.7	17.3	23.8	22.1	15.8	12.4	4.5	-4.1	9.6
1956	-2.2	0.3	0.7	**5.6**	11.4	18.4	20.3	20.4	15.2	15.0	5.4	2.3	9.4
1957	-4.6	0.5	3.4	9.0	13.7	20.7	21.9	19.2	17.4	10.9	7.4	2.7	10.2
1958	-1.2	-3.6	2.8	8.3	11.7	**16.3**	22.3	20.4	16.2	10.1	5.8	-4.3	8.7
1959	-2.4	-2.4	2.1	8.4	14.6	17.8	21.3	22.1	18.3	12.2	5.9	1.6	9.9
1960	-0.8	1.2	**-0.6**	8.6	14.2	18.9	20.4	20.5	15.6	10.1	6.8	-2.6	9.4
1961	-4.8	-1.4	2.5	7.1	12.3	18.9	21.6	21.3	**20.6**	12.5	6.1	0.3	9.7
1962	-1.2	-1.2	2.9	7.6	13.3	18.6	**19.3**	19.4	14.8	10.3	4.0	-2.2	8.8
1963	-2.2	-3.4	4.1	8.4	12.9	19.1	21.1	19.6	15.2	13.2	8.0	-2.9	9.4
1964	-1.0	-2.6	3.0	6.6	15.1	18.1	21.8	**18.8**	16.4	10.4	6.0	1.7	9.6
1965	-3.6	-1.6	2.1	6.6	15.3	18.2	20.3	20.3	17.1	10.5	4.8	1.2	9.3
1966	-2.3	-1.1	3.2	5.8	11.6	18.9	22.4	21.1	16.0	9.2	6.3	-0.4	9.2
1967	0.5	-4.1	0.1	6.8	**10.1**	18.5	21.6	20.6	15.4	9.9	3.5	0.4	**8.6**
1968	-4.3	-4.0	3.1	8.2	11.8	17.8	21.9	20.6	17.8	10.1	5.8	-1.2	8.9
1969	-2.3	-1.3	1.1	8.4	13.1	17.6	20.2	22.0	16.8	10.7	4.9	-0.7	9.2
1970	-5.7	-2.0	1.4	7.9	14.2	19.1	22.4	21.9	18.1	11.6	6.8	0.2	9.7
1971	-4.4	-0.7	2.8	5.9	12.2	18.6	20.7	20.3	18.9	14.4	5.0	2.8	9.7
1972	-0.4	-1.9	2.2	6.1	13.8	18.1	22.7	20.6	18.2	**8.5**	4.0	1.9	9.5
1973	-0.3	-0.8	6.1	9.6	13.0	20.8	22.4	22.2	16.7	11.3	6.6	2.2	10.8
1974	0.0	-2.5	4.1	9.7	12.9	18.4	22.2	22.1	17.1	8.8	6.3	1.6	10.1

1975	1.2	-0.8	1.7	6.6	15.4	19.2	22.9	19.1	16.1	12.3	8.5	0.8	10.2
1976	-4.6	1.6	3.6	9.8	13.1	20.1	21.1	21.2	16.4	9.7	**3.2**	-3.1	9.3
1977	**-6.9**	-1.4	5.6	8.3	14.9	18.1	22.3	22.0	18.4	10.3	6.6	0.0	9.8
1978	-3.3	-5.4	1.4	7.8	14.1	17.7	20.0	21.8	**14.5**	9.5	5.9	1.4	8.8
1979	-1.5	**-6.5**	5.4	7.4	15.2	17.1	22.6	21.9	16.8	11.5	8.4	3.3	10.1
1980	-1.2	-3.1	1.7	8.5	15.1	17.8	22.8	21.6	18.7	11.5	4.7	-1.7	9.7
1981	-6.9	0.3	2.6	9.3	14.6	20.2	23.6	21.6	17.1	9.7	6.5	0.5	9.9
1982	-5.2	-0.5	2.2	7.2	14.8	17.2	22.2	20.1	16.5	11.1	7.6	4.0	9.8
1983	0.0	-0.9	5.0	8.7	12.4	19.3	23.0	21.9	18.6	11.8	7.2	-0.3	10.6
1984	-4.0	2.8	0.7	8.4	12.8	20.1	21.4	22.1	15.6	13.0	6.1	3.9	10.2
1985	-4.2	-0.4	4.7	10.0	14.8	17.3	21.9	20.7	17.9	11.7	8.2	-0.9	10.2
1986	-1.1	-2.1	3.8	8.6	15.1	18.4	21.8	19.9	16.2	11.6	5.2	1.9	9.9
1987	-1.5	-1.5	4.4	9.7	14.4	20.2	22.9	20.2	17.2	9.6	6.7	1.5	10.3
1988	-4.2	-0.7	3.2	7.8	14.3	18.8	23.3	23.0	16.1	8.9	6.5	-0.2	9.7
1989	0.4	-1.1	3.2	7.7	14.3	20.3	21.9	21.8	17.7	11.9	5.6	**-4.5**	9.9
1990	2.9	1.8	4.4	8.7	13.2	19.3	22.5	22.3	17.0	14.2	7.6	4.1	11.5
1991	-0.6	1.9	5.4	10.6	**16.9**	20.3	22.7	22.7	16.8	12.6	7.1	2.6	11.6
1992	-0.5	0.4	2.3	7.2	13.2	18.2	20.6	20.1	17.3	10.2	5.9	1.6	9.7
1993	0.7	-2.9	1.9	9.1	15.3	19.8	23.3	22.1	17.7	10.4	5.8	1.2	10.3
1994	-4.1	-2.5	3.1	9.9	13.5	21.1	**24.9**	20.6	17.2	11.4	9.1	3.7	10.7
1995	2.6	-1.3	4.9	8.1	13.4	19.4	23.6	22.2	17.0	13.6	5.1	-1.1	10.6
1996	-1.6	-0.4	1.4	8.6	13.7	19.6	21.1	21.4	18.0	11.2	4.3	3.6	10.1
1997	-1.1	2.5	3.2	8.3	12.6	18.6	22.3	21.2	17.1	11.1	5.2	1.9	10.2
1998	3.3	2.9	4.8	9.2	15.6	18.7	22.4	22.4	18.7	12.2	6.7	3.4	11.7
1999	0.1	1.3	4.1	9.1	14.8	20.7	24.6	22.1	18.7	11.1	8.6	3.1	11.5
2000	-1.8	1.1	6.1	8.2	15.1	19.6	20.6	21.4	17.3	11.8	6.0	-1.6	10.3
2001	-1.4	0.2	2.6	9.6	15.2	21.1	20.7	23.5	17.6	12.3	9.0	4.7	11.3
2002	3.0	2.3	5.4	**10.8**	13.8	19.3	23.4	23.3	18.7	11.5	6.2	0.6	11.5
2003	-3.2	-2.2	3.6	8.0	12.9	18.8	22.7	23.7	18.8	11.2	8.5	2.3	10.4

2004	-4.7	0.3	4.4	9.7	16.2	19.4	22.1	21.6	19.0	11.9	7.1	1.6	10.7
2005	-1.8	0.1	1.7	9.5	12.3	20.8	23.4	**24.6**	20.2	13.2	8.3	0.7	11.1
2006	3.0	0.2	3.8	9.9	14.9	20.2	23.8	22.4	17.1	11.7	9.2	4.9	11.8
2007	2.1	-2.2	3.4	7.9	15.3	19.6	22.4	22.2	18.7	16.1	5.8	1.3	11.1
2008	1.0	1.3	2.7	10.1	13.3	21.3	23.6	21.6	17.7	11.1	5.8	3.7	11.1
2009	-3.3	1.1	3.4	10.1	14.6	17.8	21.1	22.8	16.9	11.4	9.3	1.3	10.6
2010	-1.3	-0.3	6.8	10.7	16.2	**21.3**	24.6	22.7	19.7	12.8	7.1	-0.4	11.7
2011	-2.7	0.3	4.0	9.9	15.8	20.2	24.1	22.3	19.6	12.7	**9.4**	4.7	11.7
2012	2.2	**3.2**	**8.0**	10.7	16.4	19.6	23.3	22.7	18.3	14.0	5.2	4.4	**12.3**
2013	0.9	0.2	3.2	9.2	14.4	20.1	24.4	21.1	17.1	13.3	5.9	2.1	11.0
Average	**-1.4**	-0.6	3.2	8.5	13.9	19.1	**22.2**	21.4	17.3	11.7	6.3	1.2	10.2
Max	3.3	3.2	8.0	10.8	16.9	21.3	**24.9**	24.6	20.6	18.3	9.4	7.2	12.3
Min	**-6.9**	-6.5	-0.6	5.6	10.1	16.3	19.3	18.8	14.5	8.5	3.2	-4.5	8.6

Min **Max**

Table 4. Historic Monthly Mean Maximum Temperatures (°F) for Brookhaven National Laboratory from 1949 to 2013 (@ 2 meters)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1949	6.6	7.1	8.4	15.0	20.4	26.0	28.7	27.9	21.7	19.9	11.5	6.9	16.7
1950	**8.3**	3.1	6.3	12.0	17.9	24.4	27.1	25.3	21.1	18.9	12.8	5.3	15.2
1951	5.8	6.1	8.3	15.8	21.4	23.6	27.5	26.2	23.8	17.7	10.4	7.3	16.2
1952	5.4	4.9	7.1	15.4	19.5	26.3	30.5	27.2	**29.1**	16.8	12.0	6.3	16.7
1953	6.2	7.0	8.7	**24.1**	20.2	26.1	28.6	27.0	24.7	18.8	13.4	8.6	**17.8**
1954	2.6	7.7	8.9	15.2	18.4	25.2	27.8	25.8	22.1	19.5	10.5	4.5	15.7
1955	1.7	4.2	8.2	14.9	22.4	23.9	29.6	27.9	22.1	18.4	9.8	1.0	15.3
1956	1.9	4.9	5.8	12.2	18.1	25.7	25.4	26.5	21.1	17.7	11.3	7.6	14.9
1957	0.4	5.6	9.2	15.5	20.6	**27.2**	28.6	25.8	23.4	16.9	13.0	7.9	16.2
1958	3.1	0.7	7.1	14.5	17.3	22.3	27.3	25.9	22.1	15.8	11.6	1.3	**14.1**
1959	2.8	3.1	7.1	14.5	21.3	23.5	26.2	27.4	24.6	17.7	11.2	6.6	15.5
1960	3.4	6.1	**4.1**	15.2	20.7	25.2	26.6	26.1	21.3	17.4	13.2	3.7	15.3
1961	1.1	4.7	7.7	12.4	18.3	25.1	27.1	26.7	25.9	18.7	11.3	4.7	15.3
1962	3.8	2.8	8.8	14.1	20.6	24.7	25.9	25.3	21.1	16.9	9.6	3.3	14.7
1963	3.2	2.2	9.0	15.5	20.1	25.8	27.4	25.6	**20.6**	20.6	12.9	1.6	15.3
1964	4.4	2.6	8.2	12.2	22.7	24.3	26.2	25.5	22.8	17.3	13.2	6.0	15.4
1965	1.5	3.2	6.9	12.8	22.6	24.8	26.6	26.0	22.4	16.3	10.6	6.5	15.0
1966	2.2	4.1	8.6	12.1	17.7	25.3	29.3	27.6	21.9	17.1	12.6	4.9	15.3
1967	5.7	2.1	5.7	12.8	**16.3**	24.8	26.6	**25.2**	22.2	17.0	8.9	6.2	14.4
1968	0.7	1.9	9.2	16.6	18.8	23.2	28.0	26.8	25.0	18.6	10.4	3.6	15.2
1969	2.1	2.2	6.3	14.6	19.9	23.8	**24.9**	27.6	22.9	17.5	10.3	3.6	14.7
1970	-0.7	3.9	6.3	14.1	19.9	24.4	27.4	28.1	24.1	18.1	11.9	4.5	15.2
1971	0.4	4.1	7.4	12.6	18.3	25.4	26.7	26.9	23.8	20.6	10.0	7.8	15.3
1972	5.3	3.6	7.2	12.4	20.4	22.9	27.8	26.9	24.3	15.2	**8.2**	5.4	14.9
1973	5.0	3.6	11.1	15.1	18.1	25.9	28.1	28.9	23.6	18.6	11.6	7.7	16.4
1974	5.0	2.8	9.4	15.7	18.9	23.9	28.4	28.5	22.4	15.7	12.3	6.7	15.8

1975	5.9	4.2	7.4	12.7	21.9	24.4	28.1	27.3	21.6	18.4	14.3	5.8	16.0
1976	1.1	8.2	9.1	17.1	19.2	25.9	26.7	26.9	22.9	**14.7**	8.6	2.5	15.3
1977	**-1.9**	3.5	11.1	14.8	22.3	23.8	28.6	27.6	23.2	15.9	11.2	4.5	15.4
1978	1.5	0.2	6.9	13.6	19.1	24.4	25.6	26.6	21.2	16.1	11.2	6.6	14.4
1979	2.8	**-2.6**	10.6	13.2	20.2	22.8	28.2	26.4	22.8	16.5	13.4	7.4	15.2
1980	3.5	1.6	6.3	14.0	21.7	24.1	27.6	28.6	24.9	16.7	9.6	3.7	15.2
1981	-1.5	5.6	8.1	14.7	20.8	25.7	29.2	26.9	22.0	15.1	11.1	4.6	15.2
1982	-0.1	3.6	7.7	13.8	20.8	**22.0**	28.2	25.8	22.7	18.2	13.1	9.0	15.4
1983	4.8	5.7	9.7	14.3	18.0	26.7	29.6	27.8	25.6	17.4	12.7	4.8	16.4
1984	1.2	7.5	5.7	13.9	18.8	26.2	26.4	27.8	22.4	18.7	11.8	9.8	15.8
1985	0.9	4.6	10.9	16.2	21.4	23.5	28.0	26.6	24.6	18.6	12.8	4.0	16.0
1986	4.6	2.3	10.3	15.0	22.3	24.6	27.2	25.4	21.7	17.7	10.8	6.3	15.7
1987	3.3	3.6	10.7	15.4	21.0	26.1	28.6	26.2	22.8	17.1	12.7	6.5	16.2
1988	1.6	4.5	9.3	13.1	20.2	25.7	28.6	28.6	22.8	15.0	12.9	5.4	15.7
1989	6.0	3.7	8.2	14.1	20.1	25.7	27.2	27.1	23.8	18.6	10.8	**0.4**	15.5
1990	7.3	7.4	10.4	13.9	18.9	25.1	27.2	27.1	23.1	19.9	13.8	9.1	16.9
1991	4.9	7.5	10.3	16.4	**23.7**	26.7	28.8	28.2	22.7	18.4	11.9	7.9	17.3
1992	5.0	5.7	7.7	12.9	20.1	23.9	26.2	25.5	22.3	16.4	10.8	6.4	15.2
1993	5.2	3.1	6.8	14.4	22.2	25.7	29.6	27.9	22.6	16.2	12.5	6.1	16.0
1994	1.1	2.6	8.3	16.5	20.1	26.7	29.9	26.2	23.0	18.1	14.4	9.1	16.3
1995	6.6	4.2	10.4	14.3	19.3	25.1	28.5	29.1	23.4	20.2	10.1	4.2	16.3
1996	3.1	4.4	7.3	14.1	19.8	24.6	25.3	26.3	22.8	17.4	9.5	7.8	15.2
1997	3.8	7.4	8.7	14.4	18.7	25.3	28.4	26.9	23.2	17.8	10.0	6.9	15.9
1998	7.7	7.8	9.7	15.2	21.7	23.7	28.1	28.3	24.7	17.8	12.3	9.2	17.2
1999	5.6	6.6	9.7	15.9	21.7	26.8	**30.7**	27.1	23.9	17.7	14.1	8.1	17.3
2000	3.2	6.2	12.2	**13.5**	21.1	25.0	25.8	26.3	23.1	18.0	11.1	3.2	15.7
2001	3.9	5.6	7.2	15.8	21.3	26.8	26.6	27.5	23.9	18.9	**15.2**	10.0	16.9
2002	7.7	**8.7**	10.8	16.9	19.9	25.3	29.4	28.9	24.4	16.6	10.9	5.6	17.1
2003	0.8	2.3	10.2	13.3	18.4	23.8	27.7	28.1	23.7	16.8	13.7	7.2	15.5

2004	-0.7	5.6	8.8	14.9	21.8	25.1	27.0	26.4	24.7	16.9	12.6	7.0	15.8
2005	2.7	5.6	7.3	16.5	18.0	25.9	28.5	**30.0**	27.3	17.6	13.7	5.4	16.6
2006	7.8	5.7	9.3	16.8	20.3	24.7	28.7	27.7	22.5	17.4	14.1	**10.1**	17.1
2007	6.1	2.0	9.2	13.7	22.3	25.3	27.6	27.4	24.9	**21.1**	11.1	5.7	16.4
2008	5.4	6.3	8.4	16.4	19.4	27.0	28.9	27.6	22.7	17.0	10.4	8.3	16.5
2009	1.0	6.1	8.9	15.8	19.8	22.9	26.3	28.1	22.4	16.6	13.2	5.3	15.6
2010	2.6	3.2	12.1	18.3	22.4	26.7	30.4	27.8	24.6	17.8	11.7	2.9	16.7
2011	0.9	5.4	8.9	14.9	21.3	25.7	29.6	27.3	24.3	17.8	14.8	9.7	16.7
2012	7.0	7.9	**13.2**	16.8	21.3	25.0	28.7	28.0	23.4	18.2	10.1	8.5	17.3
2013	4.9	3.7	7.4	15.1	20.6	25.3	29.0	26.6	23.3	19.3	11.4	6.7	16.1
Average	**3.5**	4.5	8.6	14.8	20.2	25.0	**27.8**	27.1	23.3	17.7	11.8	6.0	15.8
Max	8.3	8.7	13.2	24.1	23.7	27.2	**30.7**	30.0	29.1	21.1	15.2	10.1	17.8
Min	-1.9	**-2.6**	4.1	12.0	16.3	22.0	24.9	25.2	20.6	14.7	8.2	0.4	14.1

Min **Max**

Table 5. Historic Monthly Mean Minimum Temperatures (°F) for Brookhaven National Laboratory from 1949 to 2013 (@2 meters)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1949	-1.7	-3.1	-0.8	4.3	7.9	14.1	17.9	15.8	10.7	8.3	-0.4	-4.4	5.7
1950	-1.7	-6.6	-5.1	0.7	5.9	11.4	15.2	13.9	10.0	5.0	0.0	-4.2	3.7
1951	-5.6	-5.0	-2.5	1.4	6.7	12.2	15.8	14.4	9.9	5.9	-1.3	-4.2	4.0
1952	-5.0	-5.1	-2.1	3.4	6.8	13.2	16.4	15.4	9.2	2.7	0.1	-3.2	4.3
1953	-3.3	-3.8	-1.1	2.9	9.1	11.6	14.3	13.0	10.1	4.1	-1.2	-2.6	4.4
1954	-8.1	-4.1	-3.1	1.9	5.0	12.6	13.9	13.2	10.4	6.3	-1.4	-4.6	3.5
1955	-6.7	-6.4	-2.5	3.5	7.0	10.7	18.1	16.2	9.8	6.4	-0.6	-9.2	3.9
1956	-6.3	-4.2	-4.6	**-1.1**	4.8	10.9	15.1	14.3	9.2	3.1	-0.3	-2.9	3.2
1957	-9.7	-4.7	-2.2	2.6	6.8	14.3	15.3	12.6	11.4	4.8	1.8	-2.3	4.2
1958	-5.5	-7.8	-1.2	2.1	6.1	**10.3**	17.3	14.7	10.4	4.3	0.1	**-9.9**	3.4
1959	-7.6	-7.7	-2.9	2.3	7.8	12.2	16.5	16.8	12.1	6.7	0.6	-3.6	4.4
1960	-5.1	-3.1	-5.1	2.0	7.5	12.6	14.4	15.0	9.9	2.8	0.4	-8.7	3.6
1961	-10.7	-7.0	-2.7	1.8	6.7	12.4	16.1	15.8	15.2	6.4	0.8	-4.7	4.2
1962	-7.5	-6.7	-2.6	1.2	6.1	12.3	**12.3**	13.4	8.6	3.9	-1.5	-7.6	**2.7**
1963	-7.7	-9.0	-1.1	1.4	5.9	12.4	15.2	13.6	9.9	5.9	3.2	-6.8	3.6
1964	-6.4	-7.9	-2.2	0.9	7.6	12.1	17.4	**12.2**	10.1	3.6	-1.1	-2.6	3.7
1965	-8.9	-6.1	-2.8	0.3	8.1	11.6	13.9	14.5	11.8	4.4	-0.9	-4.0	3.5
1966	-6.8	-6.4	-2.4	-0.4	5.5	12.6	15.6	14.6	10.2	**1.4**	0.4	-5.7	3.2
1967	-4.5	-10.0	**-5.5**	0.8	4.1	12.3	17.4	16.2	8.9	3.1	-1.8	-5.4	2.9
1968	-9.1	-9.8	-2.8	-0.1	5.3	12.6	15.8	14.4	10.6	6.9	1.1	-6.1	3.3
1969	-6.7	-4.9	-4.1	2.2	6.2	11.4	15.6	16.1	10.7	4.5	-0.4	-4.9	3.8
1970	-10.7	-7.9	-3.6	1.9	8.4	13.6	17.3	15.6	12.1	5.4	1.7	-4.1	4.1
1971	-9.5	-5.4	-1.9	-0.7	6.1	12.2	14.8	13.6	14.2	8.6	0.0	-2.1	4.2
1972	-6.2	-7.5	-2.6	-0.3	6.9	13.2	17.7	13.9	12.0	1.8	-0.2	-1.6	3.9
1973	-6.0	-5.2	0.9	4.1	7.9	15.8	16.7	17.5	10.0	3.9	1.6	-2.2	5.4
1974	-5.0	-7.9	-1.3	3.7	6.9	13.2	16.0	15.4	11.9	2.1	0.2	-3.5	4.3

1975	-3.4	-5.9	-4.0	0.5	9.1	13.9	17.8	16.1	10.5	6.3	3.2	-4.8	4.9
1976	-10.4	-5.3	-1.8	2.6	6.9	14.2	15.4	15.4	9.8	4.7	**-2.3**	-8.6	3.4
1977	-12.2	-6.5	0.0	0.9	7.4	12.3	16.1	16.5	13.6	4.7	1.9	-4.5	4.2
1978	-8.1	**-11.5**	-3.9	1.9	8.9	11.0	14.4	17.0	**7.7**	2.9	0.5	-3.9	3.1
1979	-5.8	-10.5	-0.3	1.6	10.2	11.4	16.9	17.4	10.8	6.4	3.3	-1.0	5.1
1980	-5.8	-7.7	-2.9	2.9	8.6	11.6	18.0	17.9	12.3	6.3	-0.3	-6.9	4.5
1981	**-12.3**	-4.9	-3.4	4.0	8.3	14.7	18.0	15.9	12.2	4.3	2.0	-3.6	4.6
1982	-10.4	-4.6	-3.4	0.7	8.7	12.3	16.3	14.4	10.3	4.1	2.1	-1.0	4.1
1983	-4.8	-5.5	0.3	3.1	6.8	11.9	16.4	16.1	11.7	6.1	1.7	-5.3	4.9
1984	-9.3	**-1.8**	-4.2	2.9	6.9	13.9	16.3	16.4	8.8	7.3	0.2	-1.9	4.6
1985	-9.3	-5.4	-1.4	3.8	8.2	11.1	15.8	14.8	11.2	4.8	3.6	-5.8	4.3
1986	-6.7	-6.6	-2.7	2.1	7.8	12.2	16.4	14.5	10.8	5.4	-0.6	-2.5	4.2
1987	-6.3	-6.6	-1.9	3.9	7.8	14.4	17.2	14.1	11.5	2.2	0.7	-3.6	4.4
1988	-10.0	-5.9	-3.1	2.5	8.3	12.0	17.9	17.4	9.4	2.8	0.1	-5.8	3.8
1989	-5.2	-5.9	-2.4	1.3	8.6	14.9	16.6	16.7	11.6	5.3	0.3	-9.4	4.3
1990	-1.4	-3.8	-1.6	3.5	7.4	13.6	17.8	17.4	10.9	8.3	1.4	-0.9	6.1
1991	-6.0	-3.6	0.6	4.7	10.1	13.9	16.7	17.2	10.8	6.8	2.2	-2.6	5.9
1992	-5.9	-4.7	-3.1	1.7	6.2	12.5	15.1	14.7	12.4	3.9	1.1	-3.3	4.2
1993	-3.8	-8.9	-2.9	3.6	8.5	13.8	16.9	16.2	12.8	4.7	-1.1	-3.7	4.7
1994	-9.1	-7.7	-2.2	3.4	6.9	15.4	20.0	14.9	11.4	4.7	3.7	-1.7	5.0
1995	-1.6	-6.9	-0.6	1.8	7.5	13.8	18.7	15.3	10.7	6.9	0.2	-5.9	5.0
1996	-6.2	-5.3	-4.6	3.2	7.6	14.7	16.8	16.6	13.2	4.9	-0.9	-0.7	4.9
1997	-5.8	-2.4	-2.3	2.2	6.6	11.9	16.1	15.6	11.1	4.4	0.3	-3.1	4.6
1998	**-1.2**	-1.9	-0.1	3.1	9.6	13.8	16.7	16.4	12.7	6.6	1.2	-2.3	6.2
1999	-5.3	-4.0	-1.6	2.3	8.0	14.6	18.4	16.9	13.5	4.4	3.1	-1.9	5.7
2000	-6.9	-4.1	-0.1	2.9	9.1	14.2	15.3	16.4	11.5	5.7	0.9	-6.2	4.9
2001	-6.8	-5.1	-2.1	3.3	9.2	15.4	14.7	18.1	11.3	5.8	2.9	-0.6	5.5
2002	-1.7	-4.1	0.0	4.7	7.8	13.3	17.5	17.6	12.9	6.3	1.5	-4.4	5.9
2003	-7.2	-6.7	-2.9	2.7	6.8	13.8	17.7	**19.2**	13.9	5.6	3.3	-2.4	5.3

2004	-8.7	-5.0	0.2	4.6	10.6	13.8	17.2	16.8	13.3	6.8	1.6	-3.8	5.6
2005	-6.3	-5.6	1.7	2.5	6.6	15.6	18.2	19.1	13.1	8.8	2.9	-4.1	6.1
2006	-1.8	-5.3	-1.7	3.1	9.6	15.6	18.9	17.0	11.7	5.9	4.4	-0.1	6.4
2007	-2.7	-7.1	-2.6	2.2	8.4	13.9	17.3	16.9	12.6	**11.2**	0.5	-3.0	5.6
2008	-4.0	-4.1	-3.1	4.1	7.4	15.8	18.5	16.0	12.7	5.1	0.8	-1.7	5.6
2009	-7.9	-3.9	-1.9	4.2	9.6	13.8	15.8	18.1	11.2	6.0	**4.8**	-3.1	5.6
2010	-5.8	-4.2	1.5	**5.5**	10.0	**15.9**	19.1	17.3	14.6	7.3	1.9	-4.2	6.6
2011	-7.3	-5.4	-0.8	5.2	10.9	14.9	18.6	17.4	**15.8**	7.8	4.0	-1.5	6.7
2012	-3.2	-2.6	**3.0**	3.8	**11.9**	13.9	18.5	17.4	12.7	9.4	0.0	**-0.1**	**7.1**
2013	-4.5	-3.9	-1.4	3.4	8.3	15.0	**20.3**	15.3	10.8	7.0	0.1	-2.6	5.7
Average	**-6.4**	-5.8	-2.0	2.5	7.7	13.2	**16.7**	15.8	11.4	5.4	0.9	-3.9	4.6
Max	-1.2	-1.8	3.0	5.5	11.9	15.9	**20.3**	19.2	15.8	11.2	4.8	-0.1	7.1
Min	**-12.3**	-11.5	-5.5	-1.1	4.1	10.3	12.3	12.2	7.7	1.4	-2.3	-9.9	2.7

Min **Max**

Barometric Pressure

Barometric pressure is measured at the 2-meter level. The pressure sensors are connected to R.M. Young model 61002 pressure ports to reduce errors due to blowing winds. The sensors are sent off-site for calibration. Average daily pressure for 2013 is plotted in Figure 16. The lowest pressure, 982.5 mbar, occurred on January 31st. Monthly data plots of the 1-minute data for pressure are presented in Figures 17 through 28.

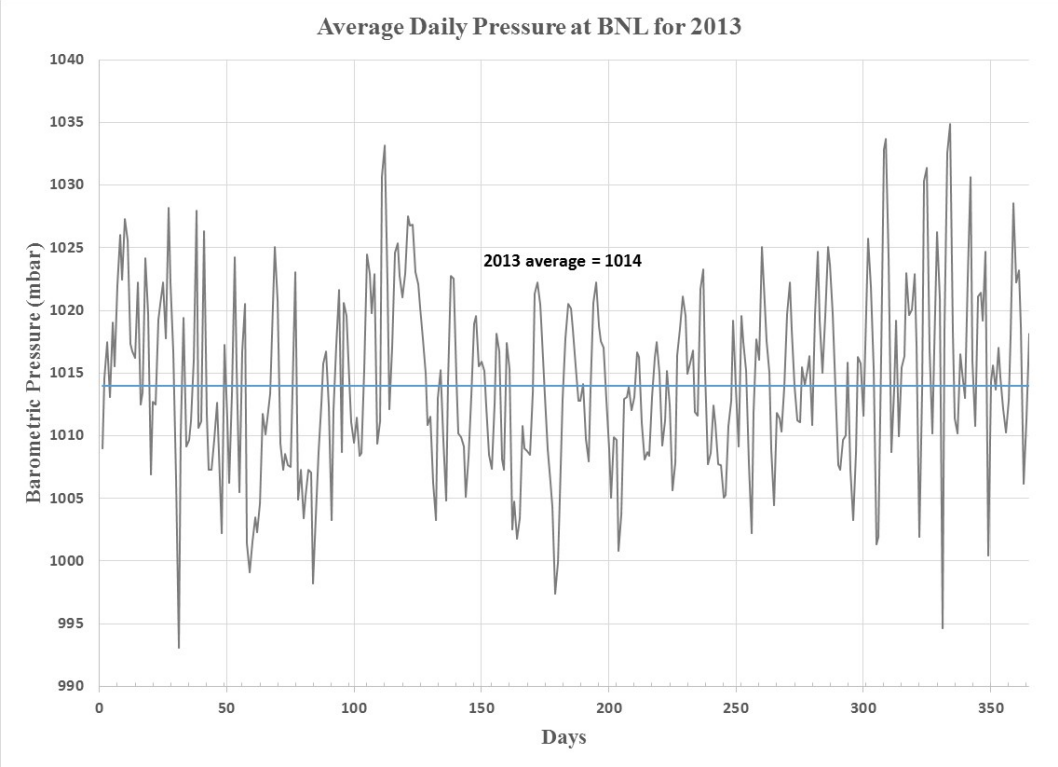

Figure 16. Average Daily Barometric Pressure at Brookhaven National Laboratory for 2013

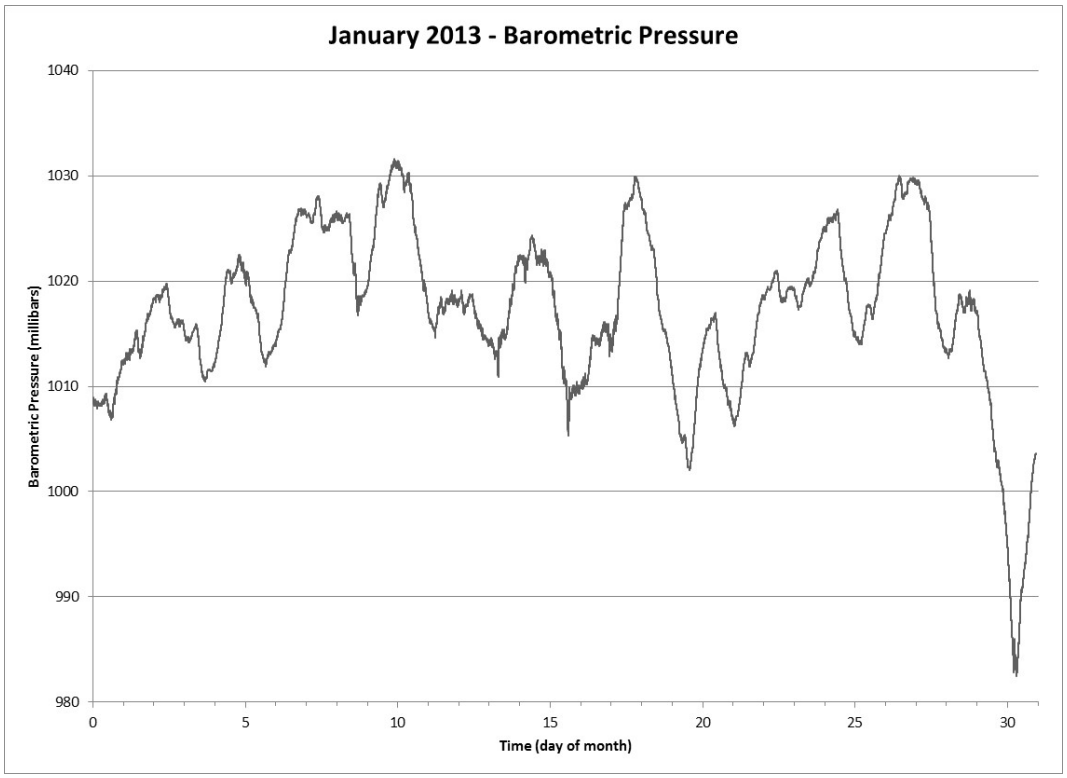

Figure 17. Barometric Pressure for the Month of January 2013

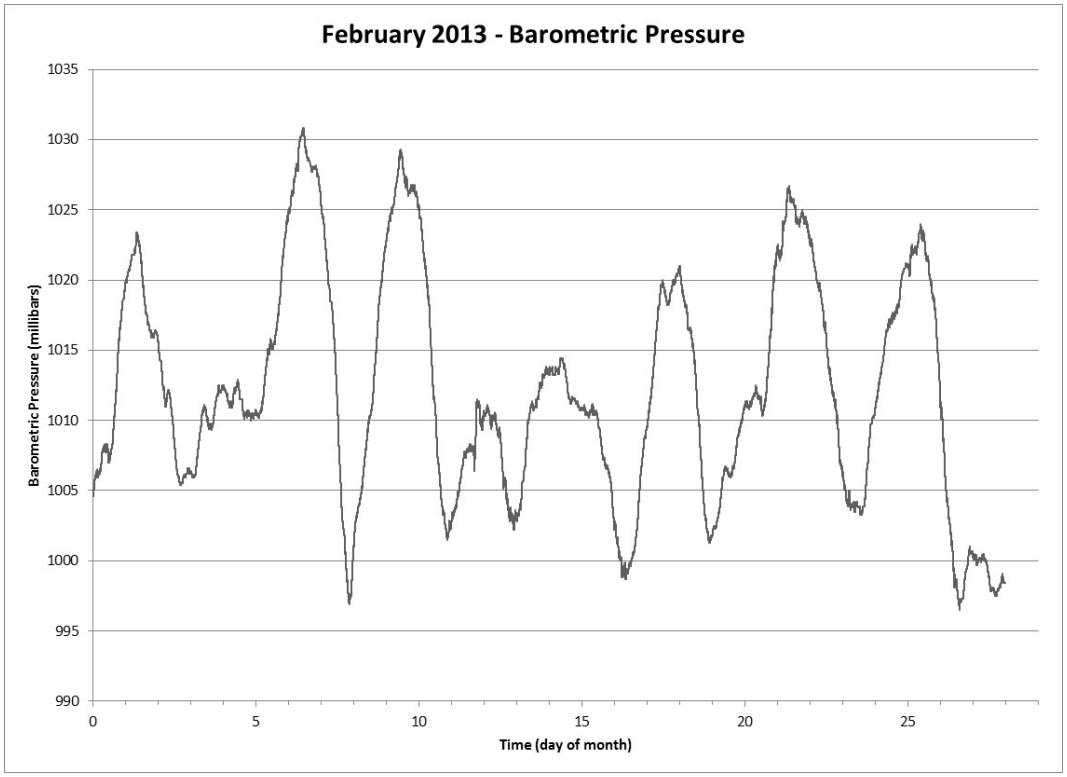

Figure 18. Barometric Pressure for the Month of February 2013

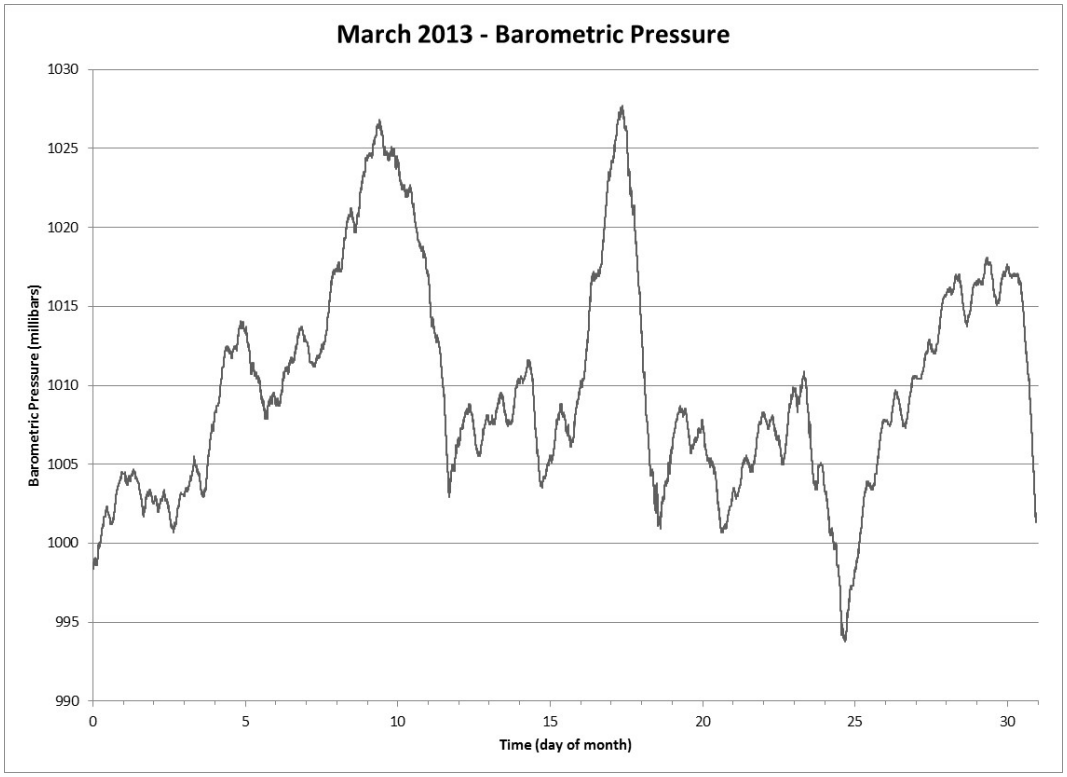

Figure 19. Barometric Pressure for the Month of March 2013

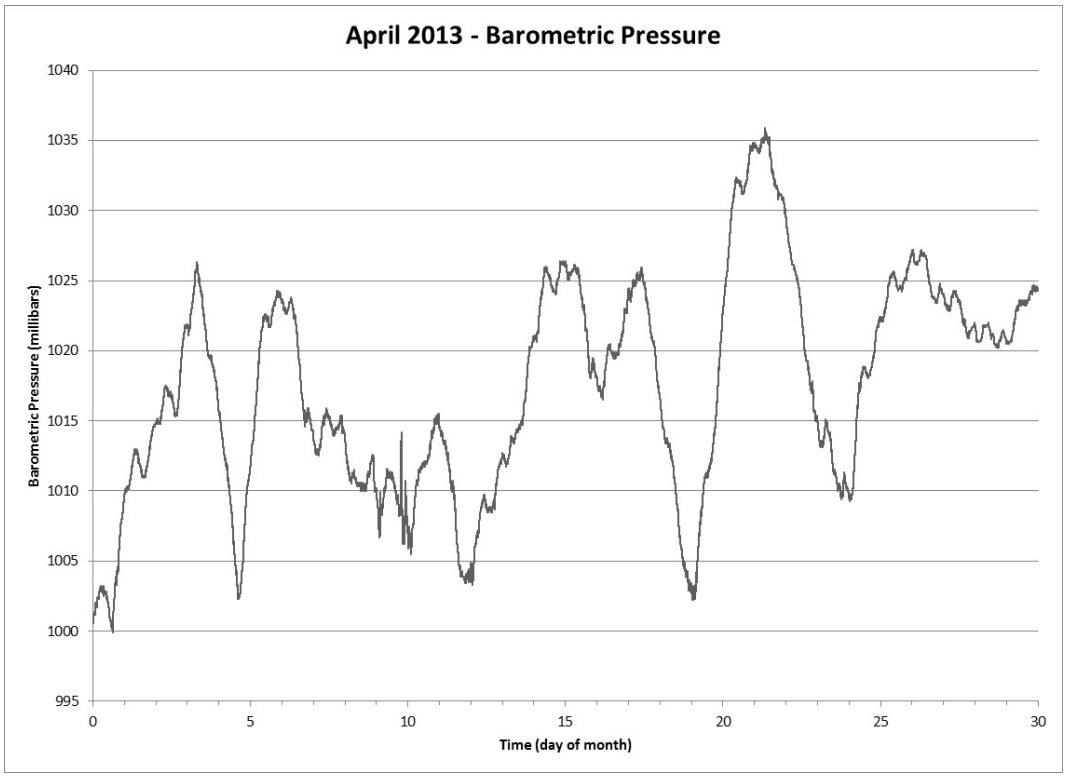

Figure 20. Barometric Pressure for the Month of April 2013

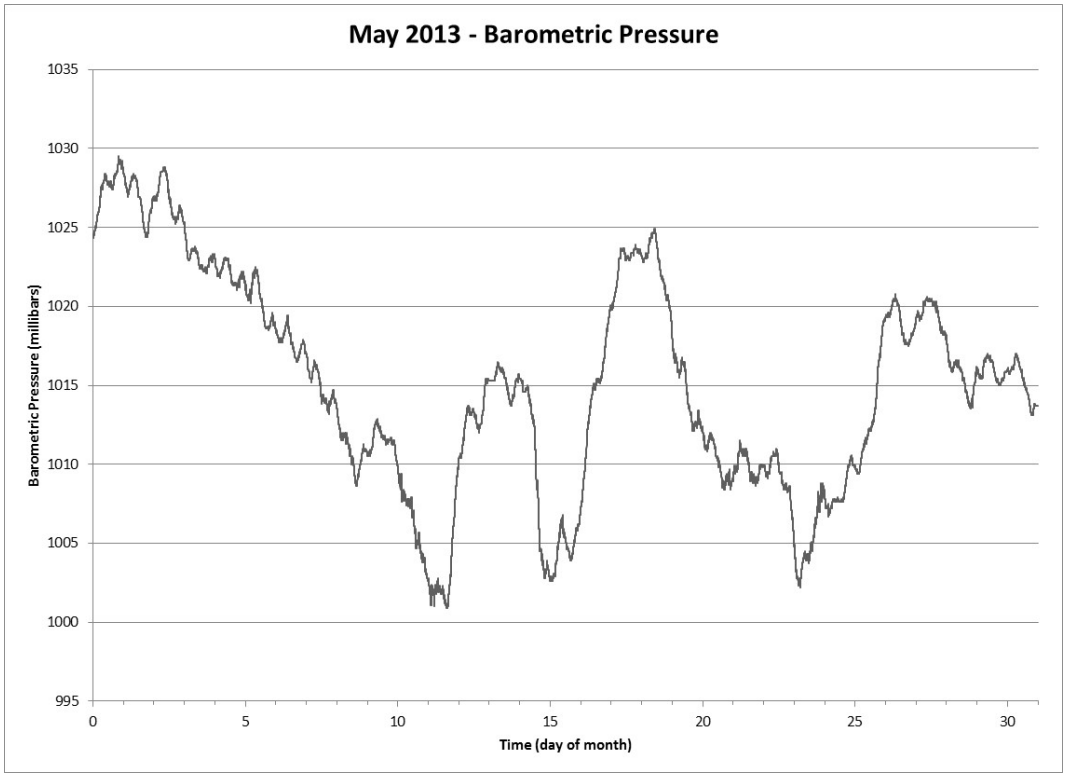

Figure 21. Barometric Pressure for the Month of May 2013

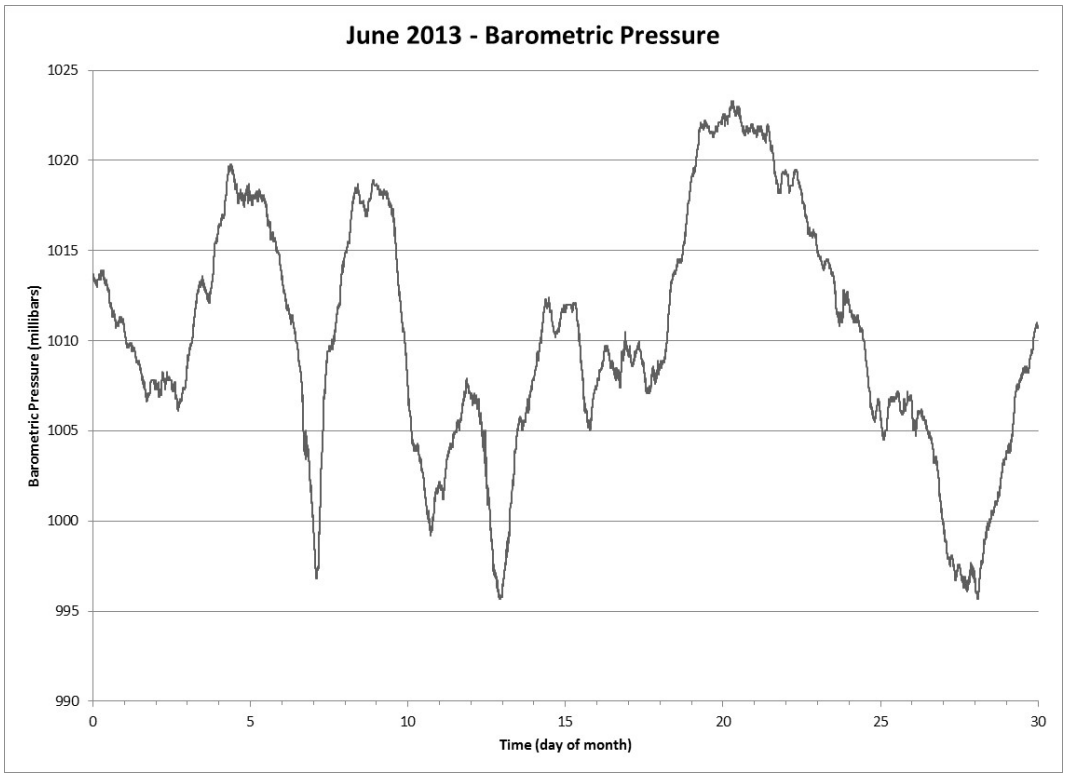

Figure 22. Barometric Pressure for the Month of June 2013

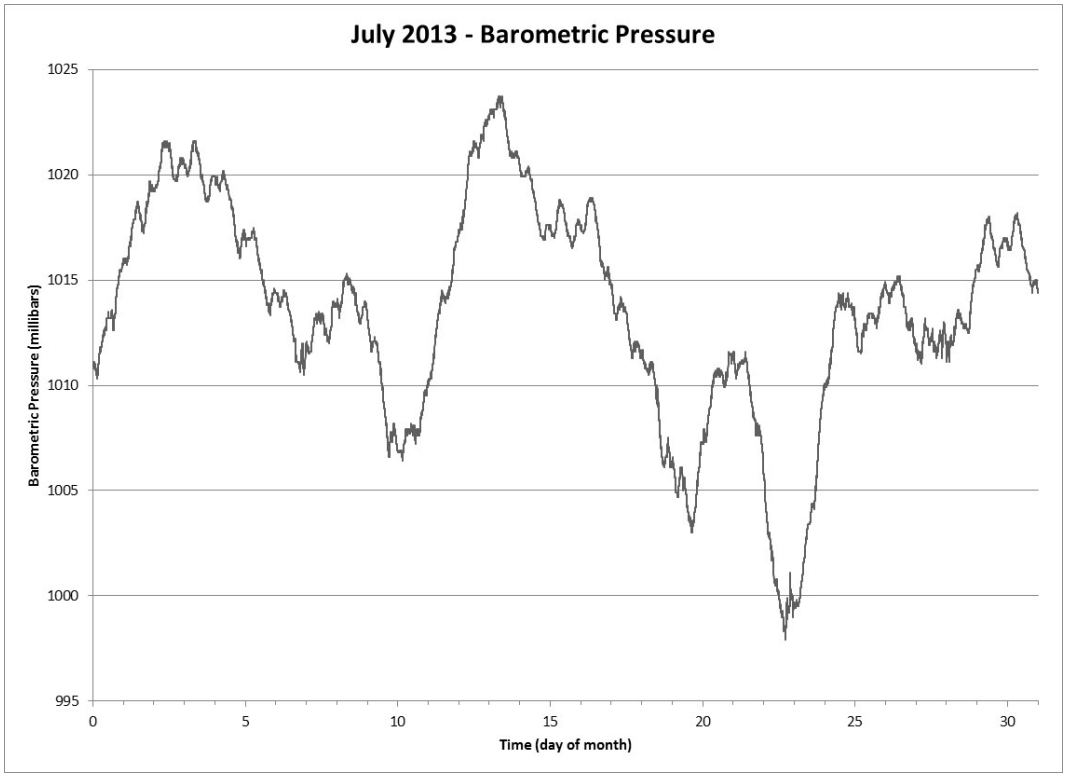

Figure 23. Barometric Pressure for the Month of July 2013

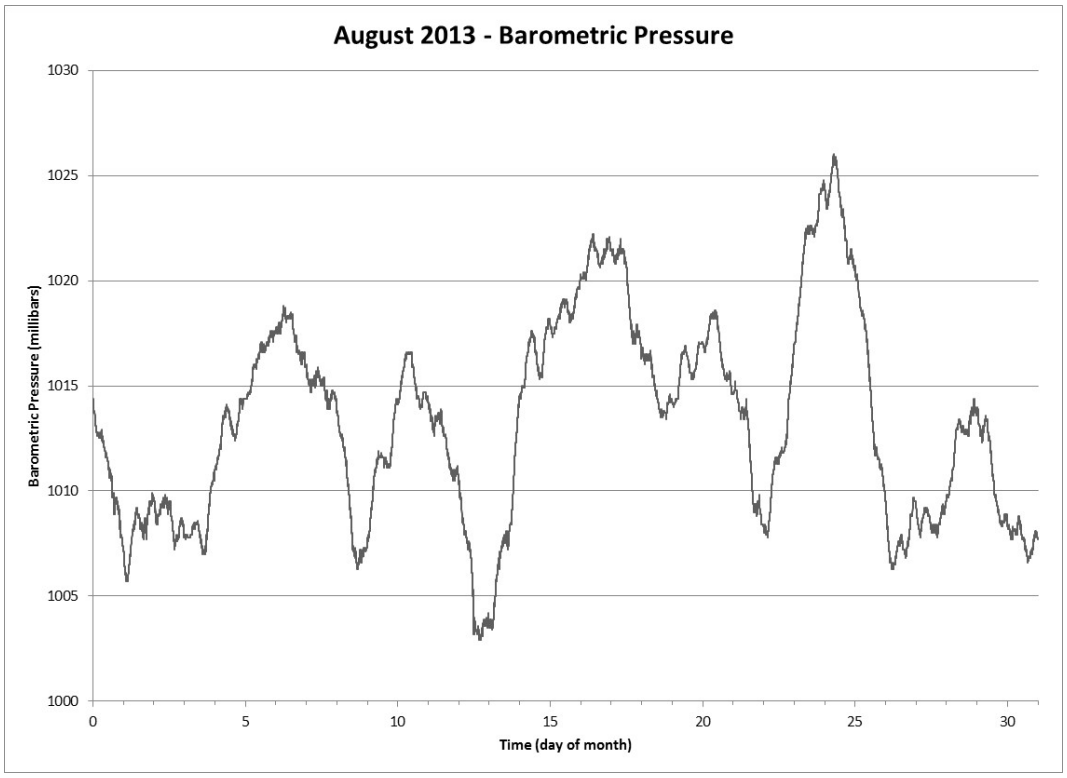

Figure 24. Barometric Pressure for the Month of August 2013

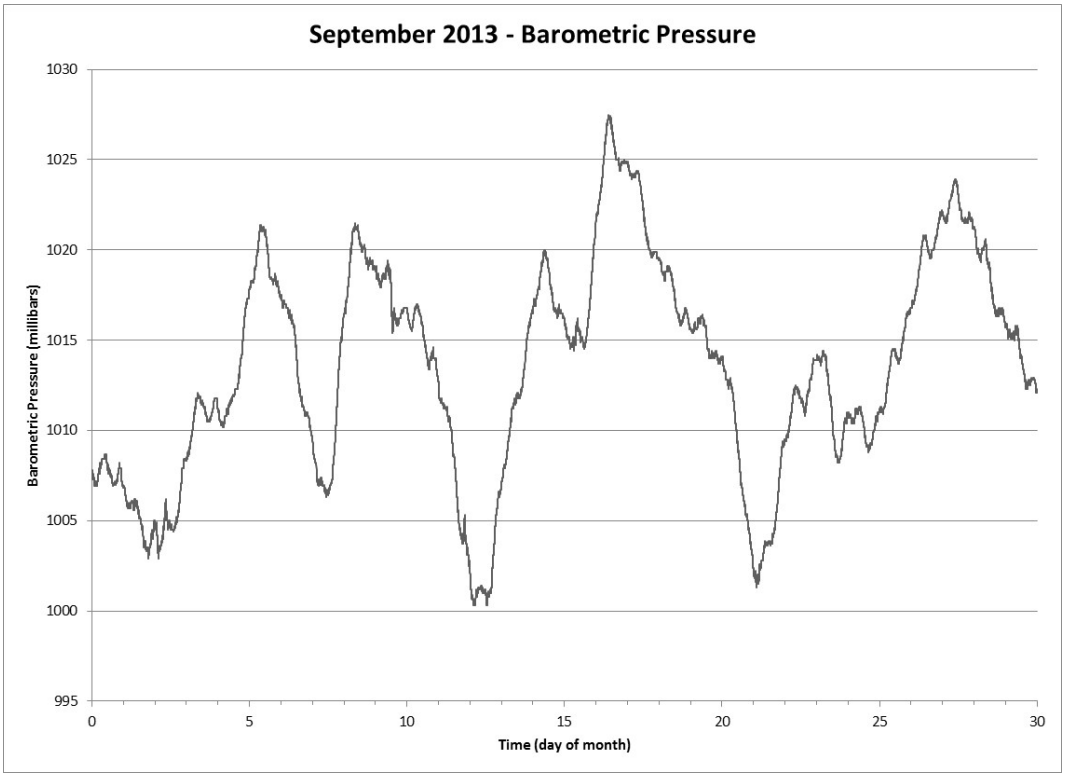

Figure 25. Barometric Pressure for the Month of September 2013

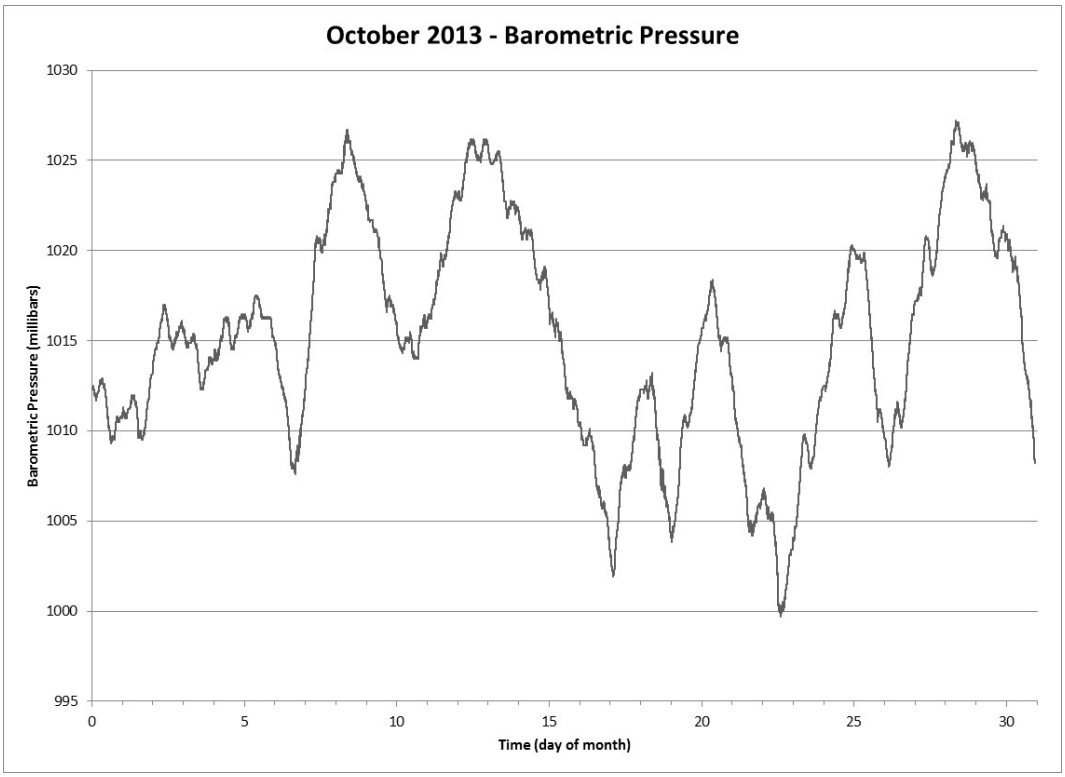

Figure 26. Barometric Pressure for the Month of October 2013

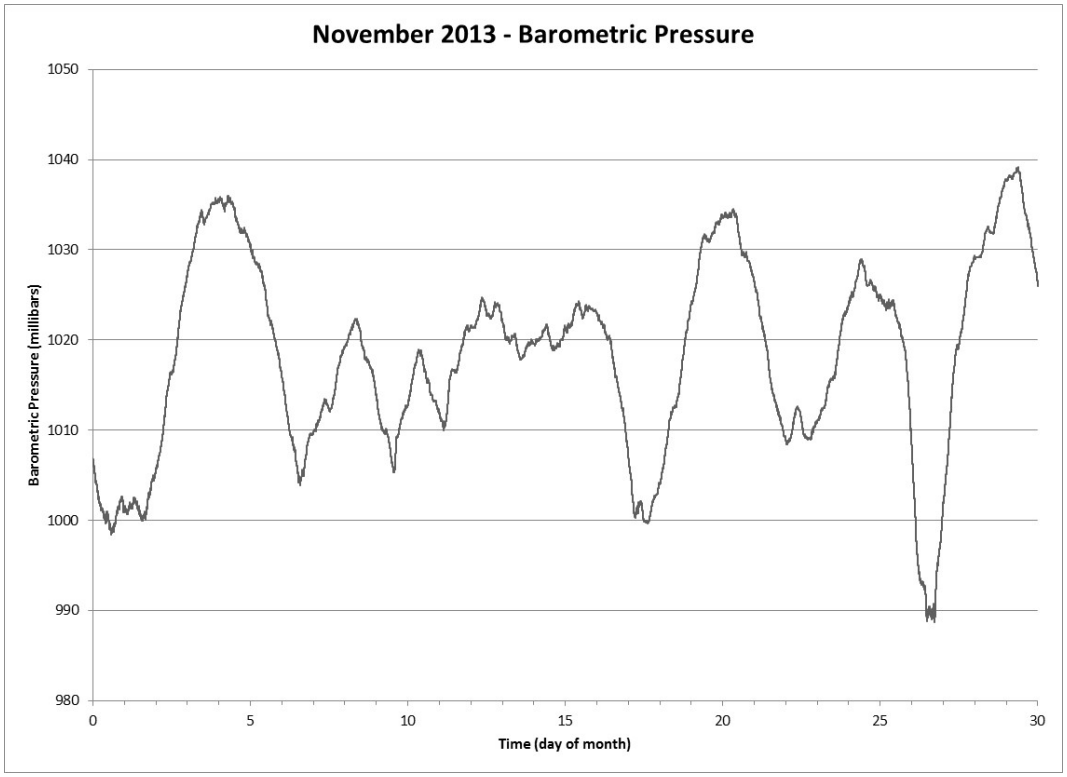

Figure 27. Barometric Pressure for the Month of November 2013

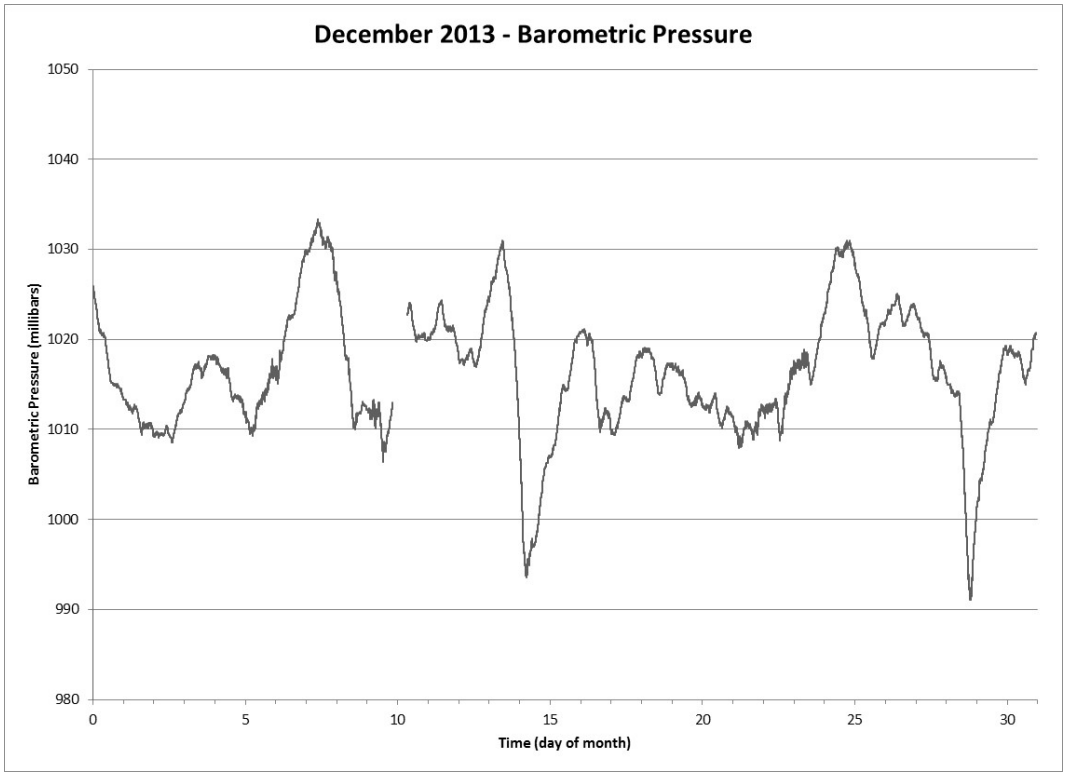

Figure 28. Barometric Pressure for the Month of December 2013

Relative Humidity

Relative Humidity is measured at the 2-meter level. The sensors are calibrated on site and maintained to ±4%. The relative humidity sensor is calibrated, in the laboratory, using saturated salt baths. The use of saturated salt baths is one of the oldest methods for generating humidity at different levels. The RH value is a function of the chemical properties of the salt when mixed with water, with different saturated salt solutions yielding different RH values. Although cumbersome, saturated salt solutions are very reliable. The saturated salt solutions are easy to make and result in a fairly constant humidity over a reasonable temperature range. BNL Met Services uses saturated aqueous salt solutions as described in ASTM E104-02 to obtain a three point calibration of the RH probes. Specific humidity calibration chamber covers that fit each probe type are used and separate chambers for each salt solution. The reference solutions are stored in sealed chambers. The specific solutions include; Sodium Chloride (NaCl) for 75.5 ±0.2 % RH @ 20°C, Sodium Bromide (NaBr) for 59.1 ± 0.5 % RH @ 20° and Magnesium Chloride (MgCl) for 33.1 ±0.2 % RH @ 20°C. In contrast, the Campbell HMP45C has an accuracy of ±2% RH (0 to 90% RH) ±3% RH (90% to 100% RH) and the R.M. Young 41372VC has a stated accuracy of ±1% @ 20-25°C. The ANS requirement is ±4%. If the probe fails to meet the ±4% it must be replaced.

The average daily humidity at BNL for 2012 was 75.8 %. The average daily low humidity was 51.7 %. The average daily high humidity was 95.2 %. Daily average humidity is plotted in Figure 29, daily minimum in Figure 30 and daily maximum humidity in Figure 31. Monthly data plots of the 1-minute data for relative humidity are presented in Figures 32 through 43.

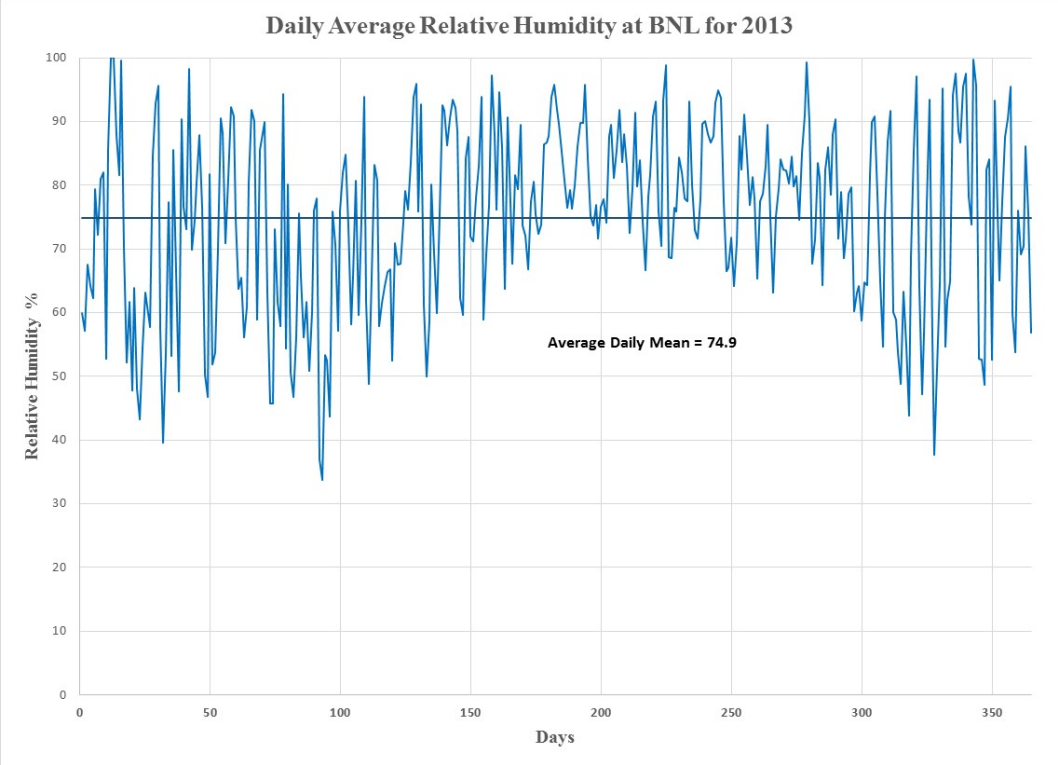

Figure 29. Daily Mean Relative Humidity at Brookhaven National Laboratory for 2013

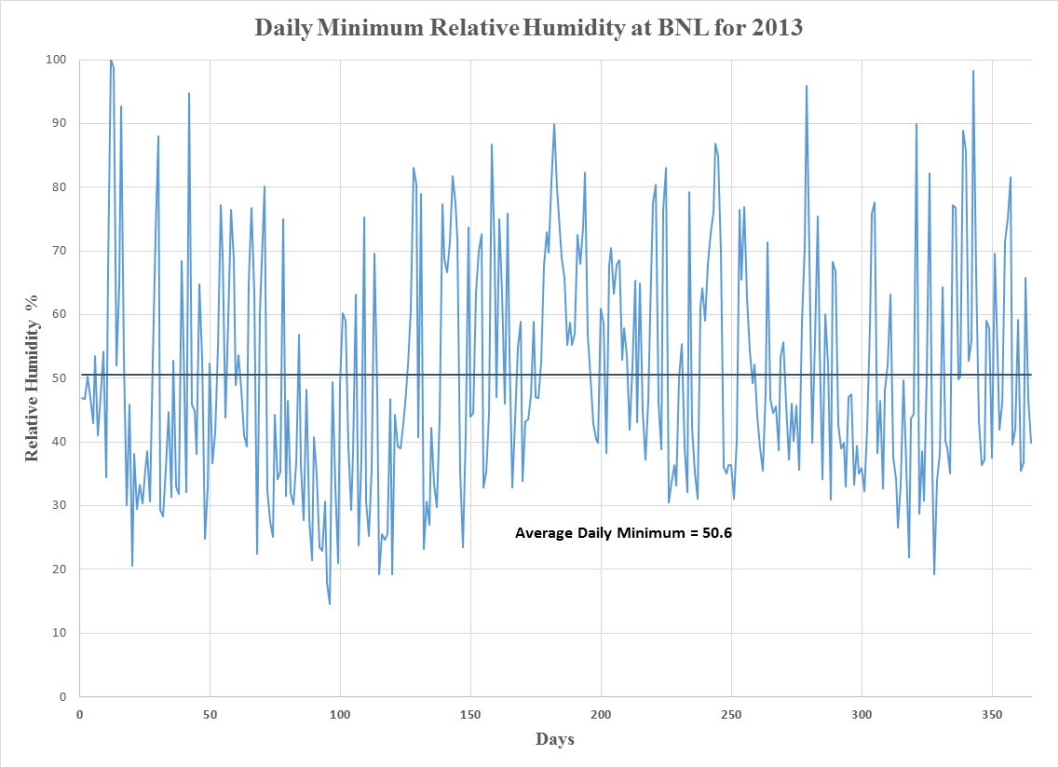

Figure 30. Minimum Daily Humidity at Brookhaven National Laboratory for 2013

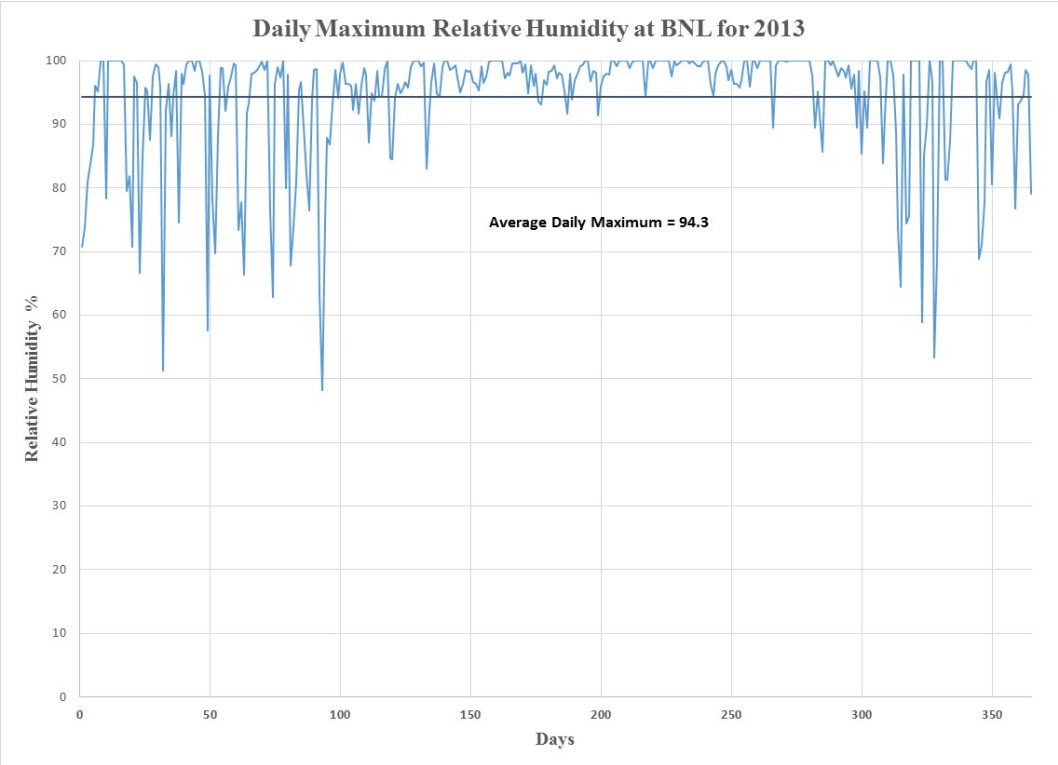

Figure 31. Maximum Daily Humidity at Brookhaven National Laboratory for 2013

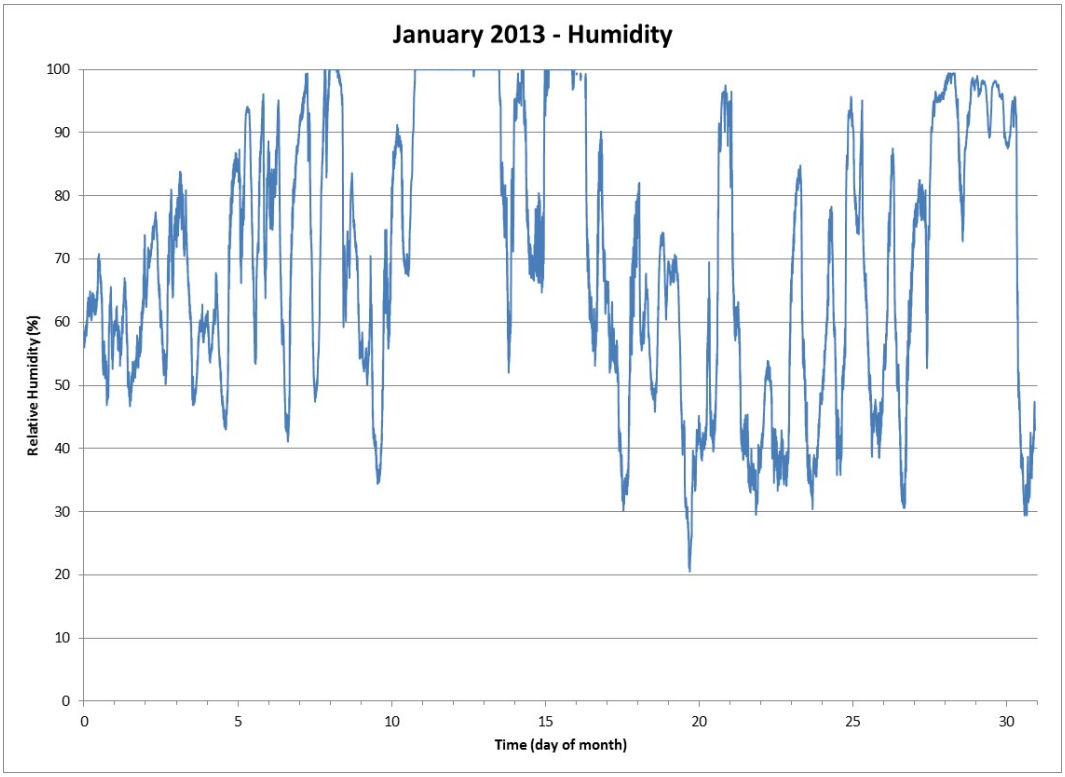

Figure 32. Relative Humidity for the Month of January 2013

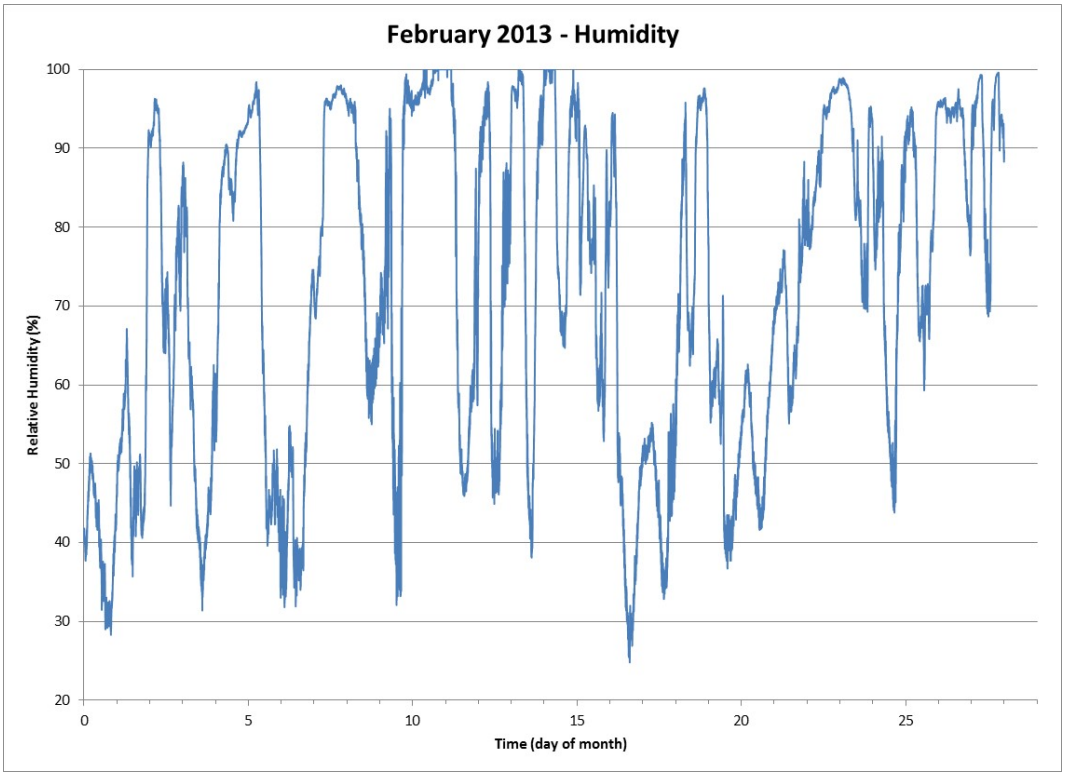

Figure 33. Relative Humidity for the Month of February 2013

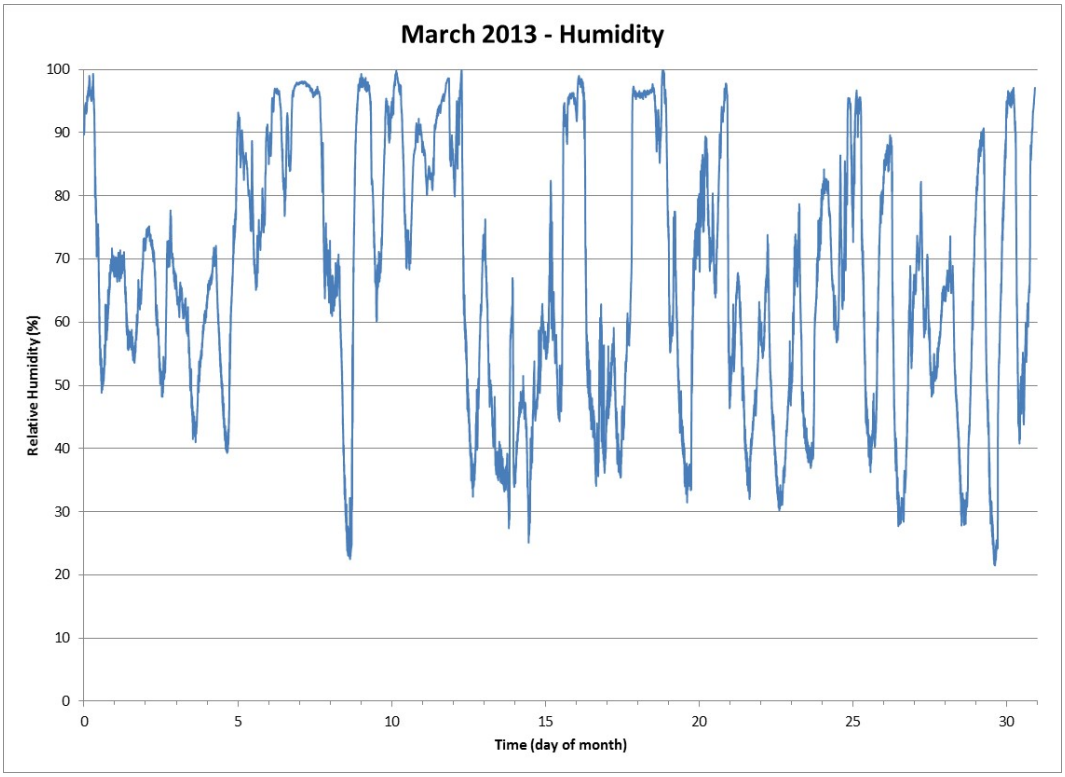

Figure 34. Relative Humidity for the Month of March 2013

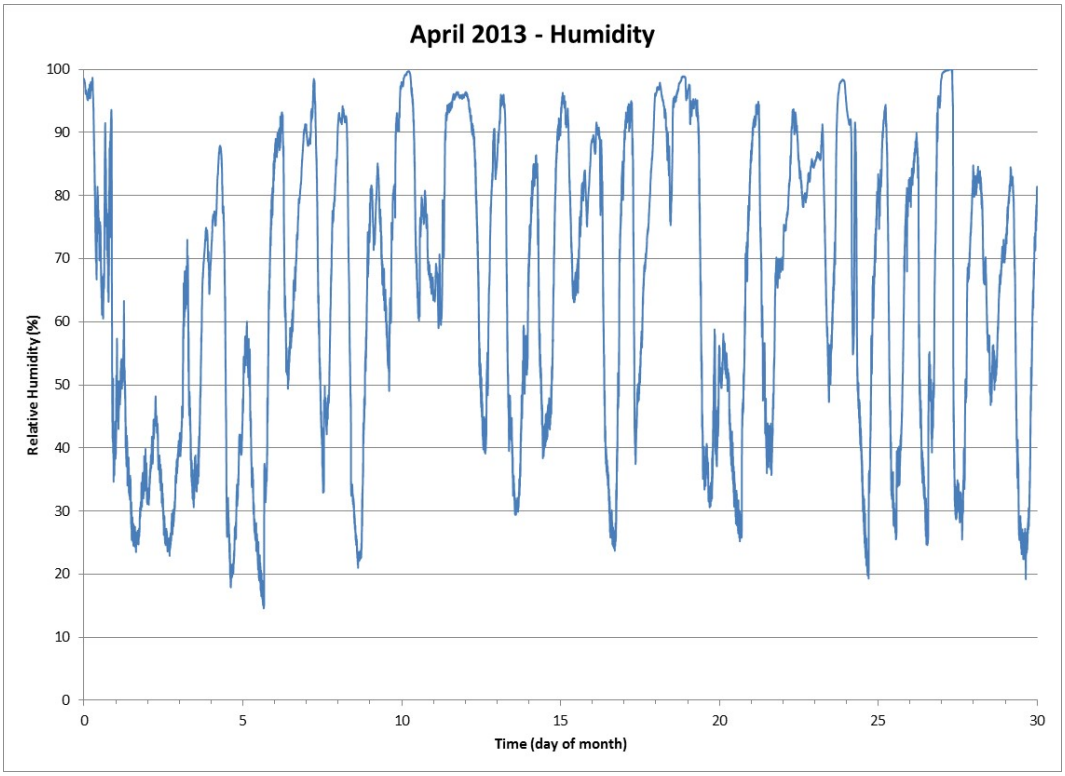

Figure 35. Relative Humidity for the Month of April 2013

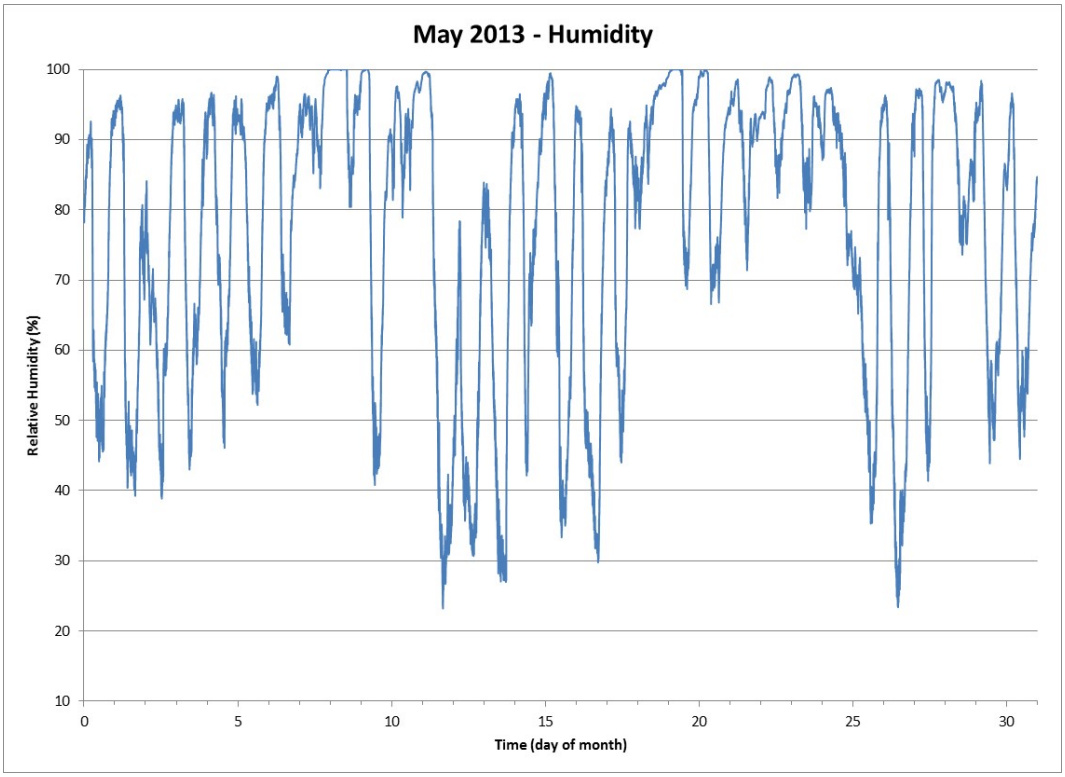

Figure 36. Relative Humidity for the Month of May 2013

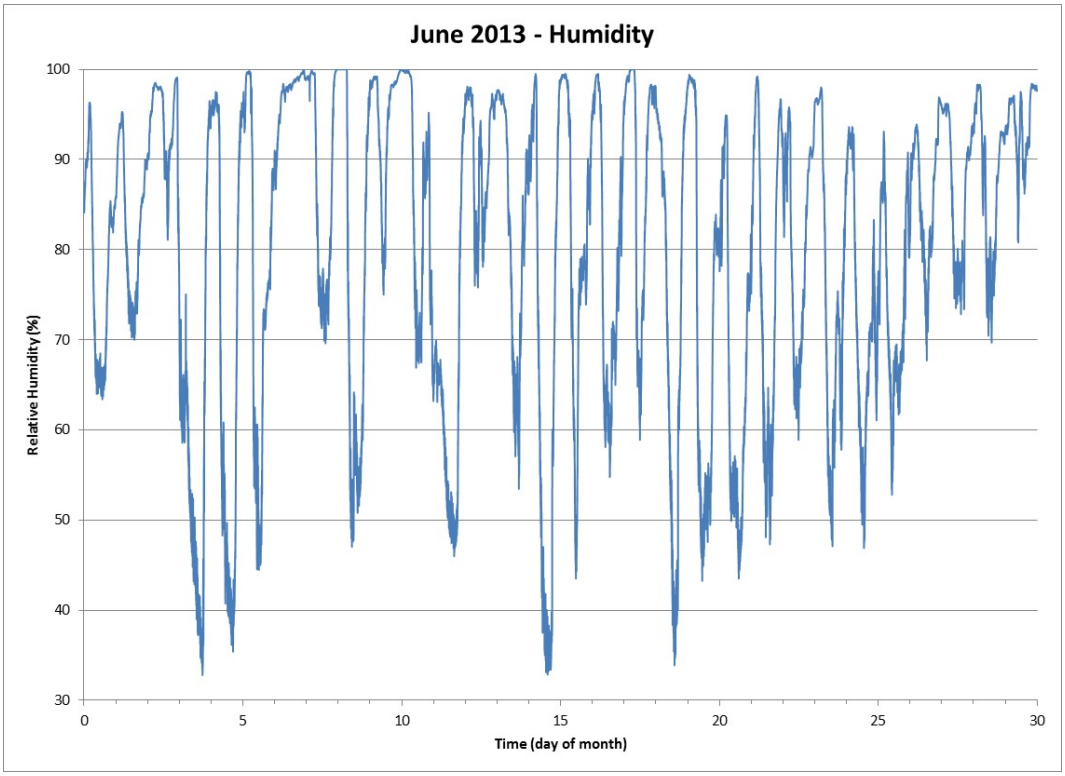

Figure 37. Relative Humidity for the Month of June 2013

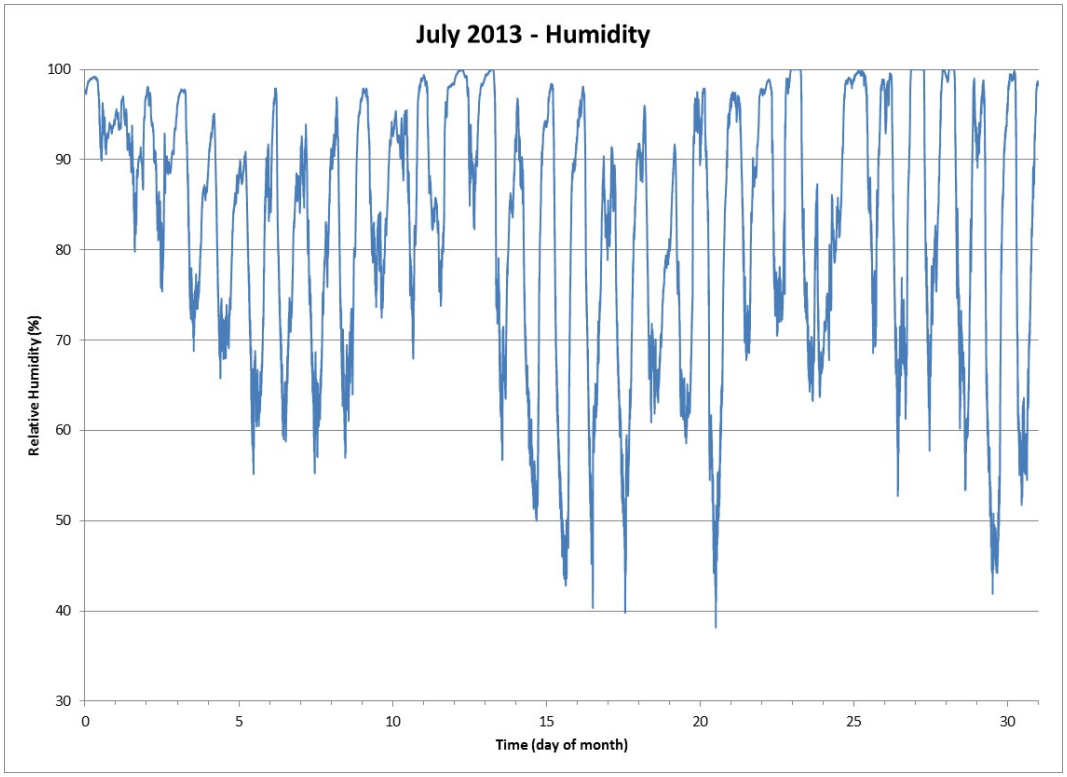

Figure 38. Relative Humidity for the Month of July 2013

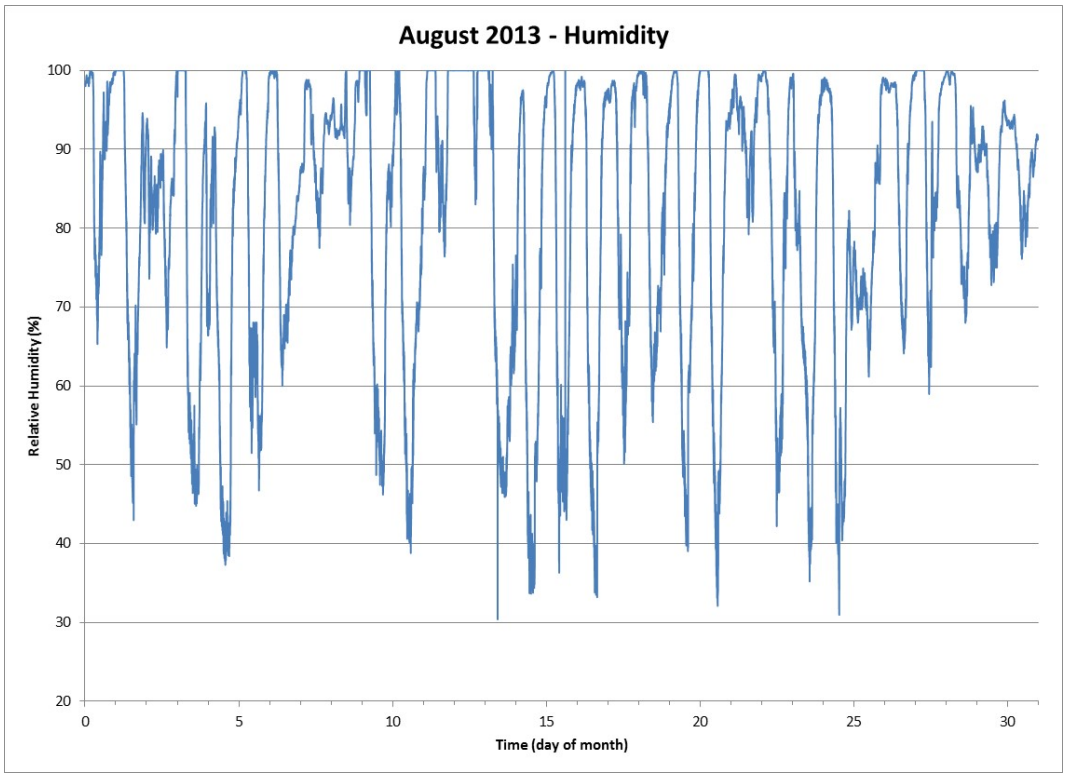

Figure 39. Relative Humidity for the Month of August 2013

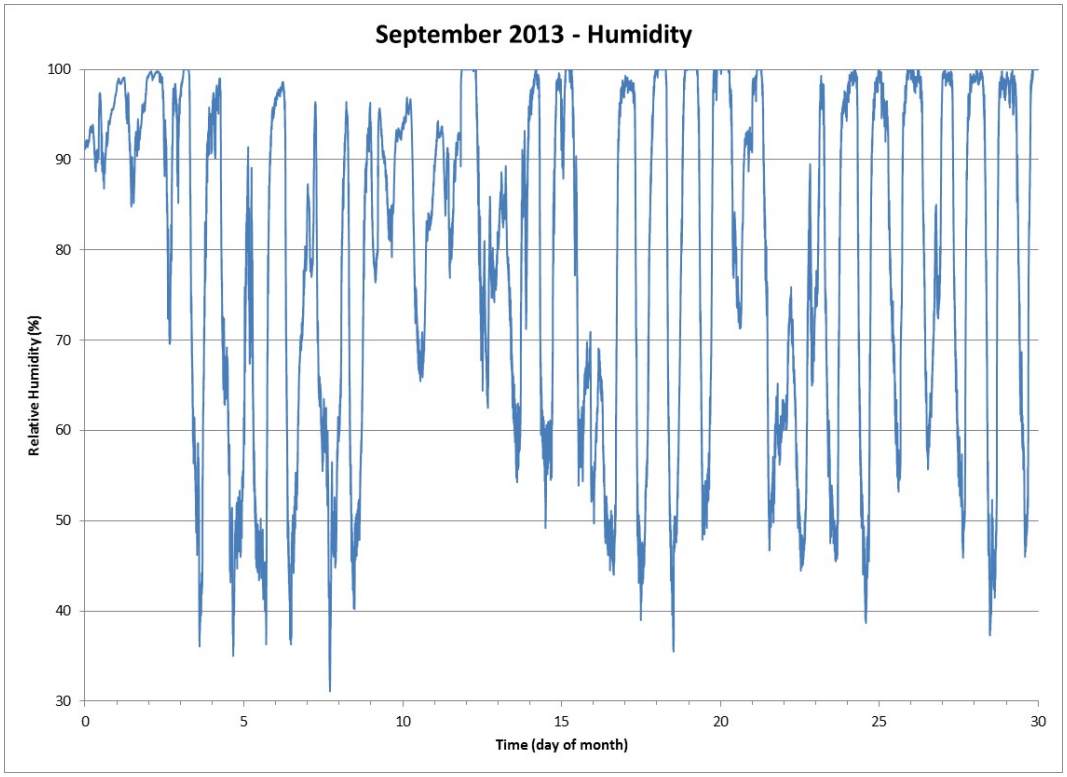

Figure 40. Relative Humidity for the Month of September 2013

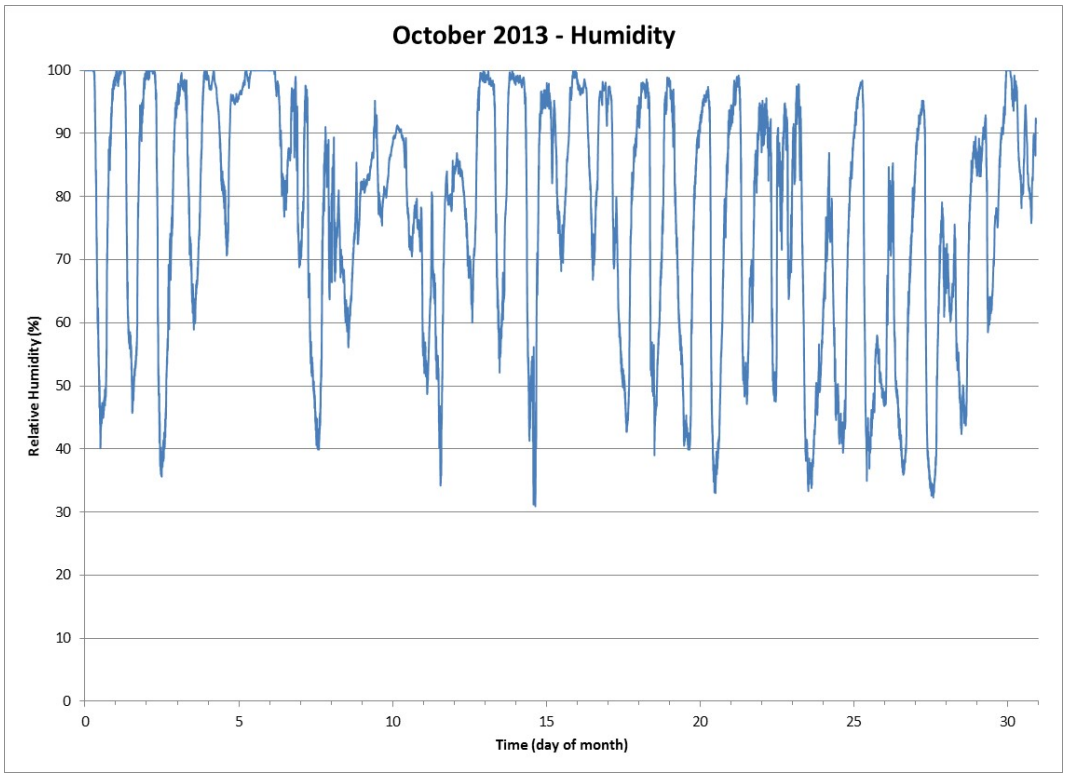

Figure 41. Relative Humidity for the Month of October 2013

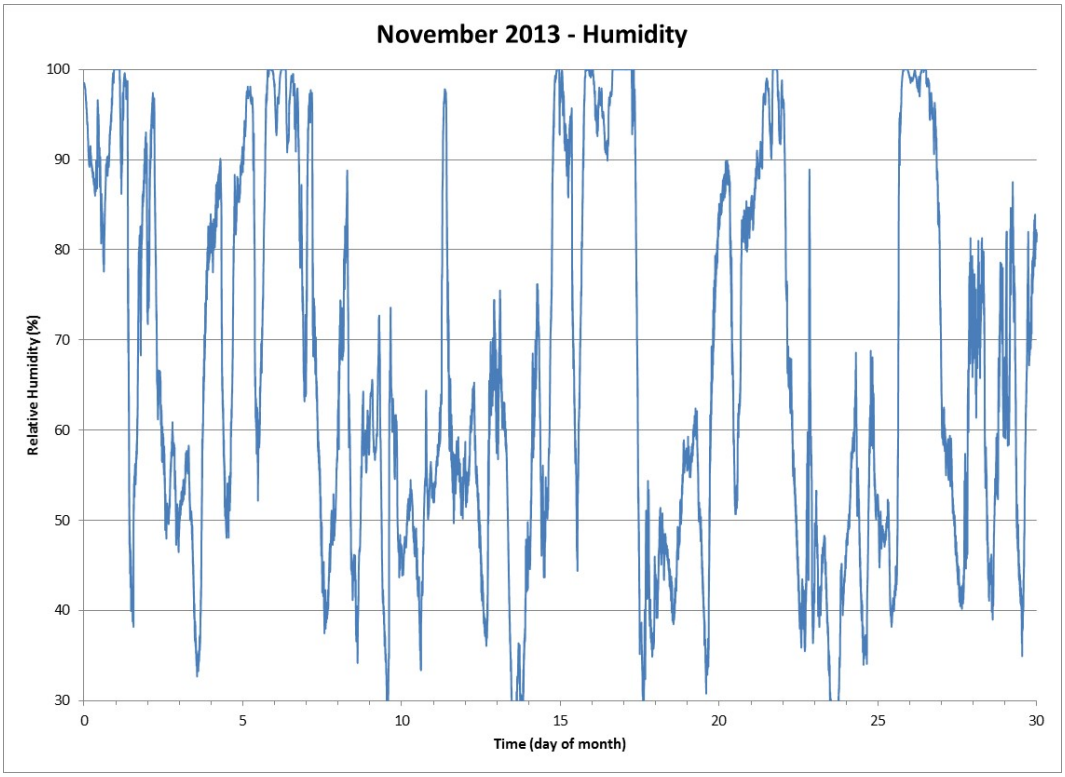

Figure 42. Relative Humidity for the Month of November 2013

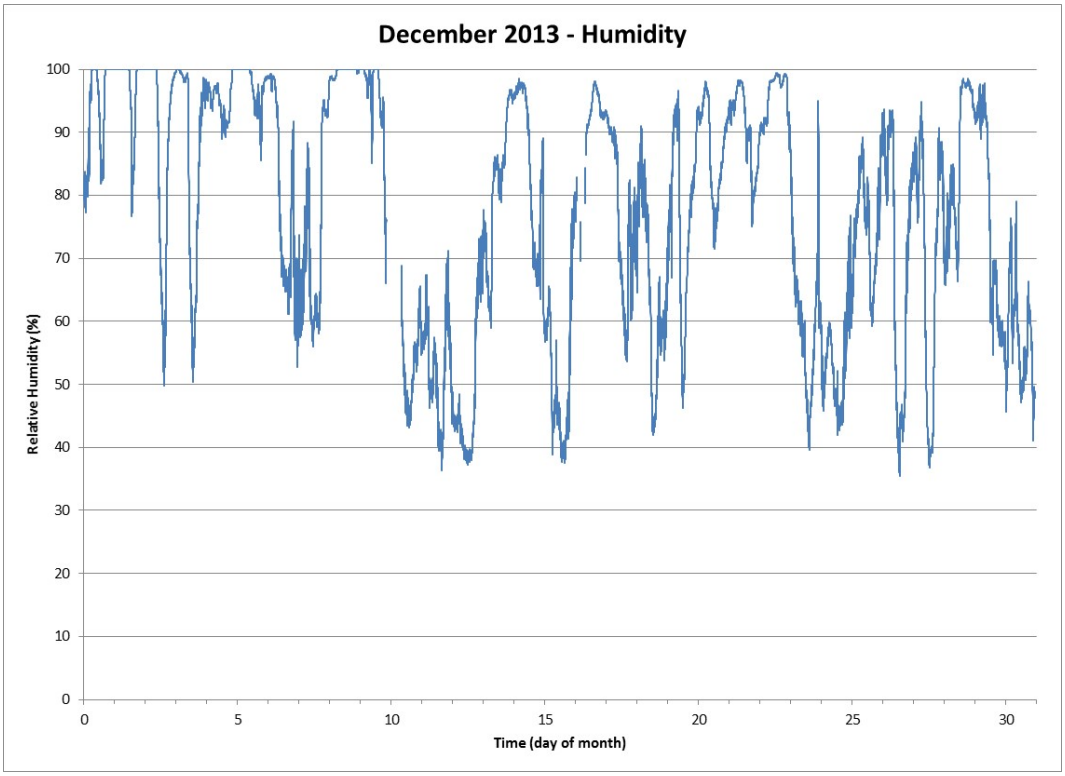

Figure 43. Relative Humidity for the Month of December 2013

Rainfall

Rainfall is measured using 12" NovaLynx 2500 electrically heated (for snowfall events), tipping bucket rain gauges which are calibrated annually. The gauges measure tips for each 0.01" of rain. Calibration is accomplished by BNL personnel using the NovaLynx Calibration Assembly (model 260-2595) and is completed in-situ. Accuracy is ±1% for 1 to 3 inches per hour rainfall and ±3% for 0 to 6 inches per hour. If the test results are outside this accuracy requirement the tipping bucket is adjusted to bring it within specs. Daily rainfall totals for 2013 are depicted in Figure 44. Monthly data charts of daily rainfall totals are presented in Figures 45 through 56. Table 6 lists the historic monthly rainfall totals along with monthly averages, maximums and minimums from 1949 to 2012.

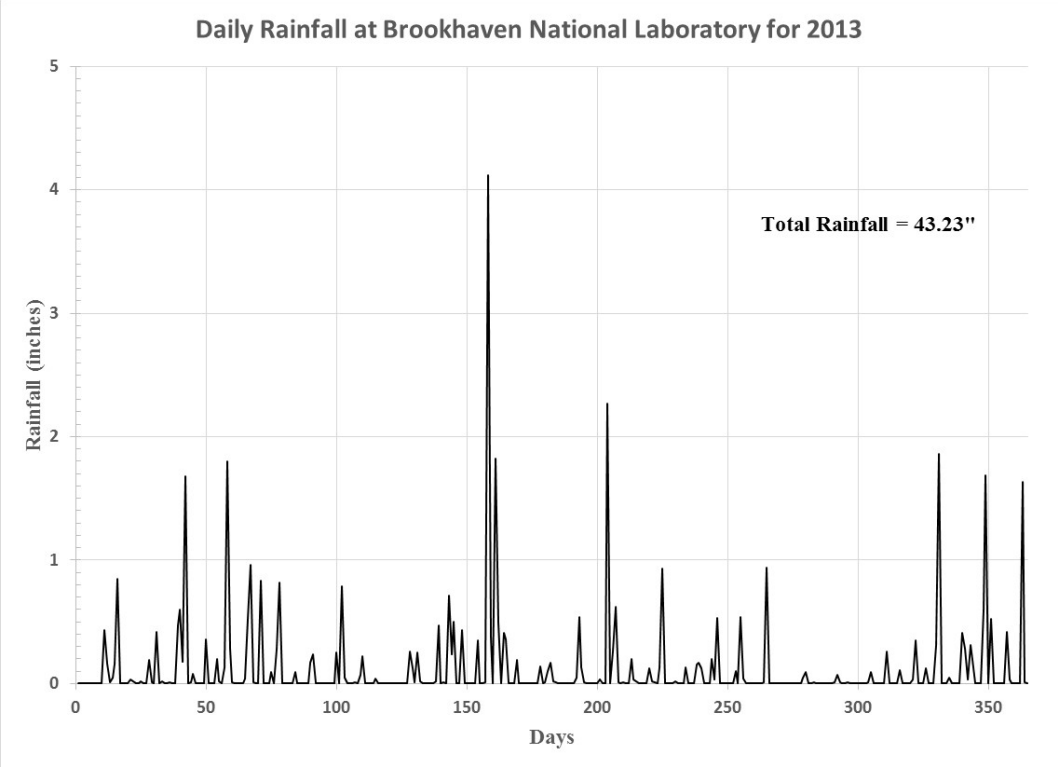

Figure 44. Daily Rainfall Totals at Brookhaven National Laboratory for 2013

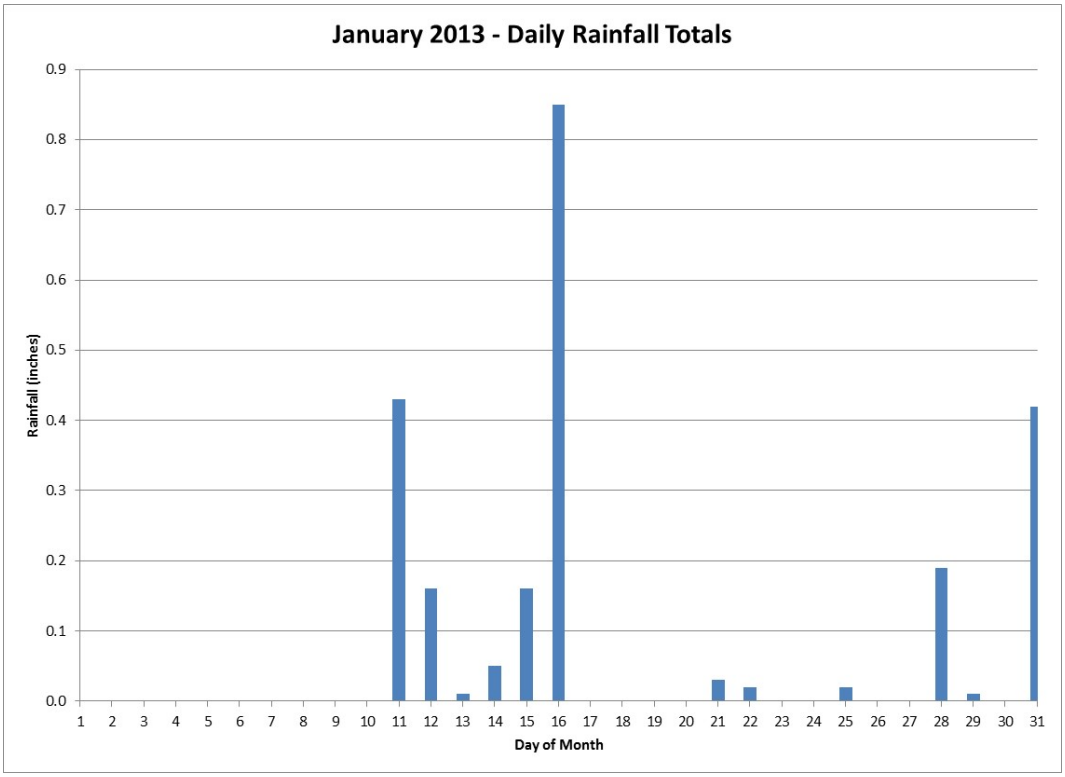

Figure 45. Daily Rainfall for the Month of January 2013

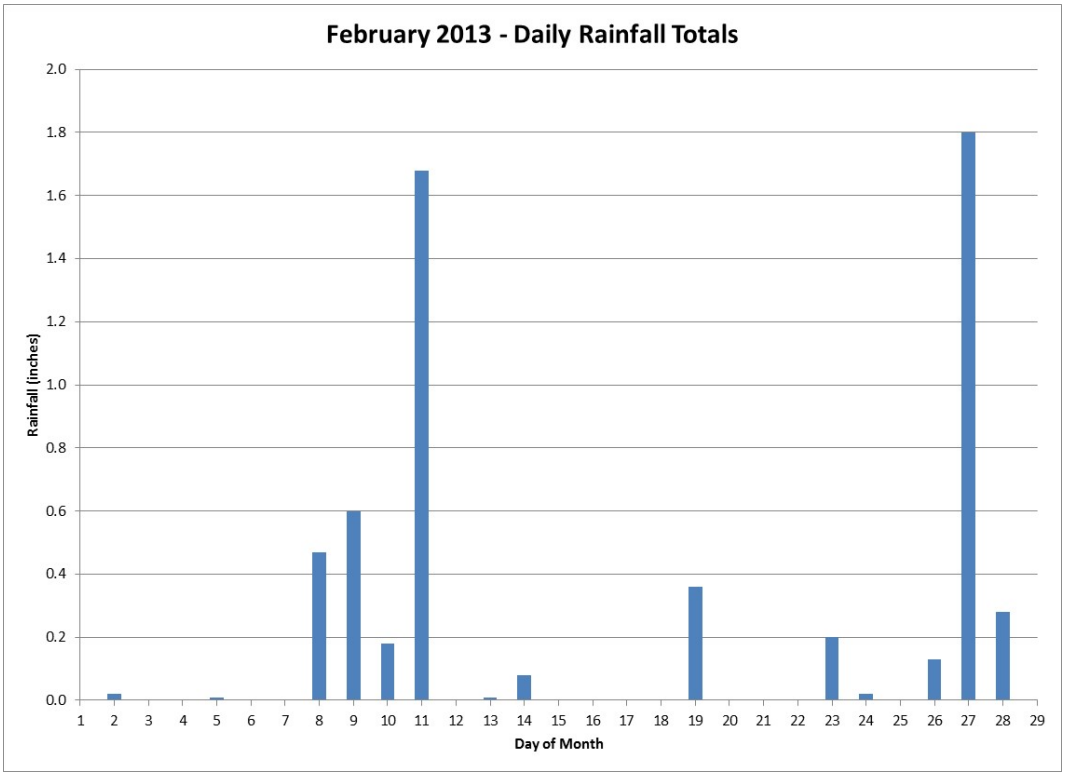

Figure 46. Daily Rainfall for the Month of February 2013

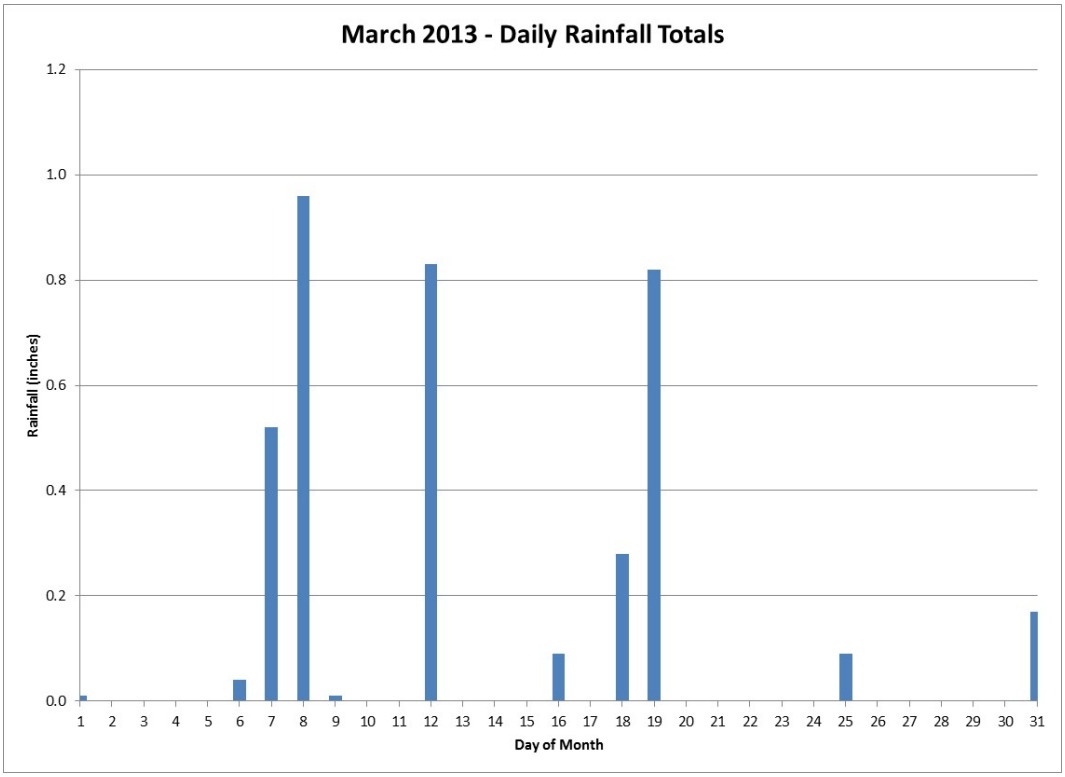

Figure 47. Daily Rainfall for the Month of March 2013

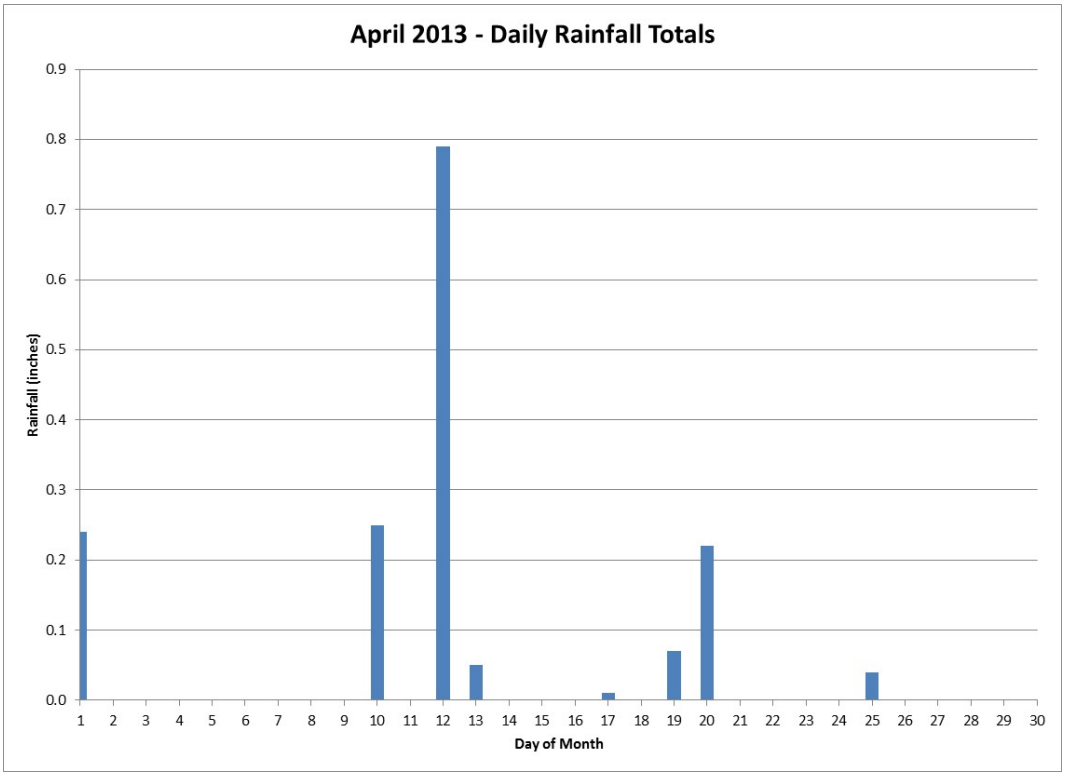

Figure 48. Daily Rainfall for the Month of April 2013

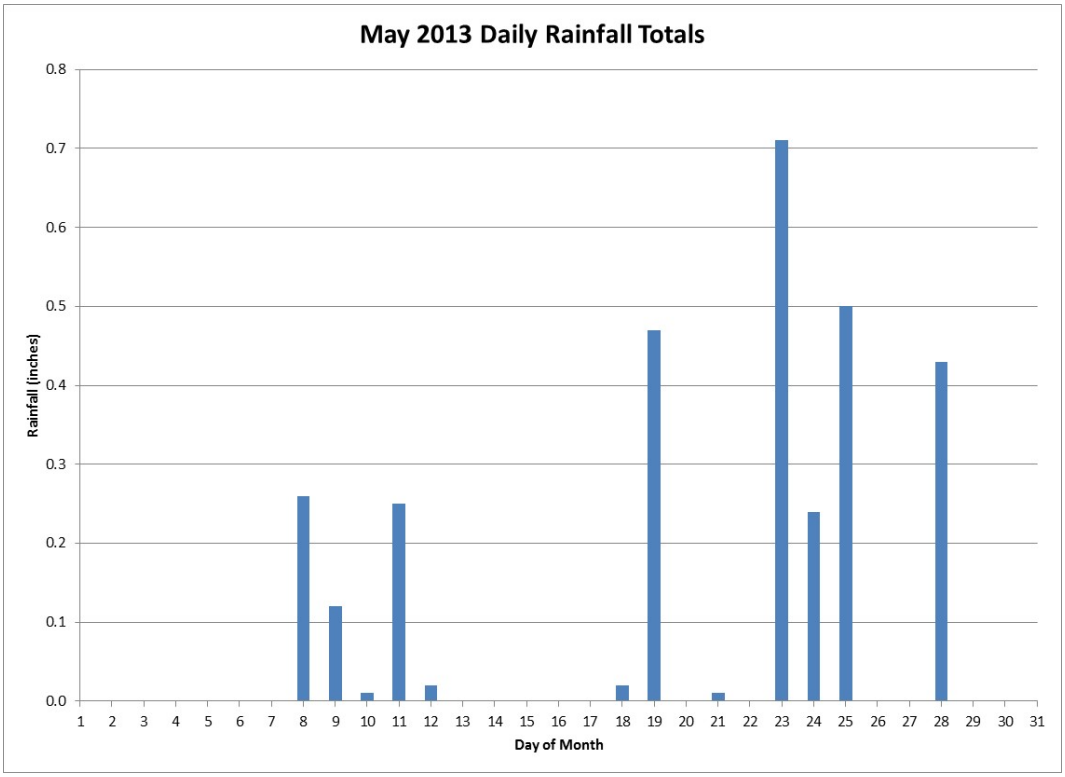

Figure 49. Daily Rainfall for the Month of May 2013

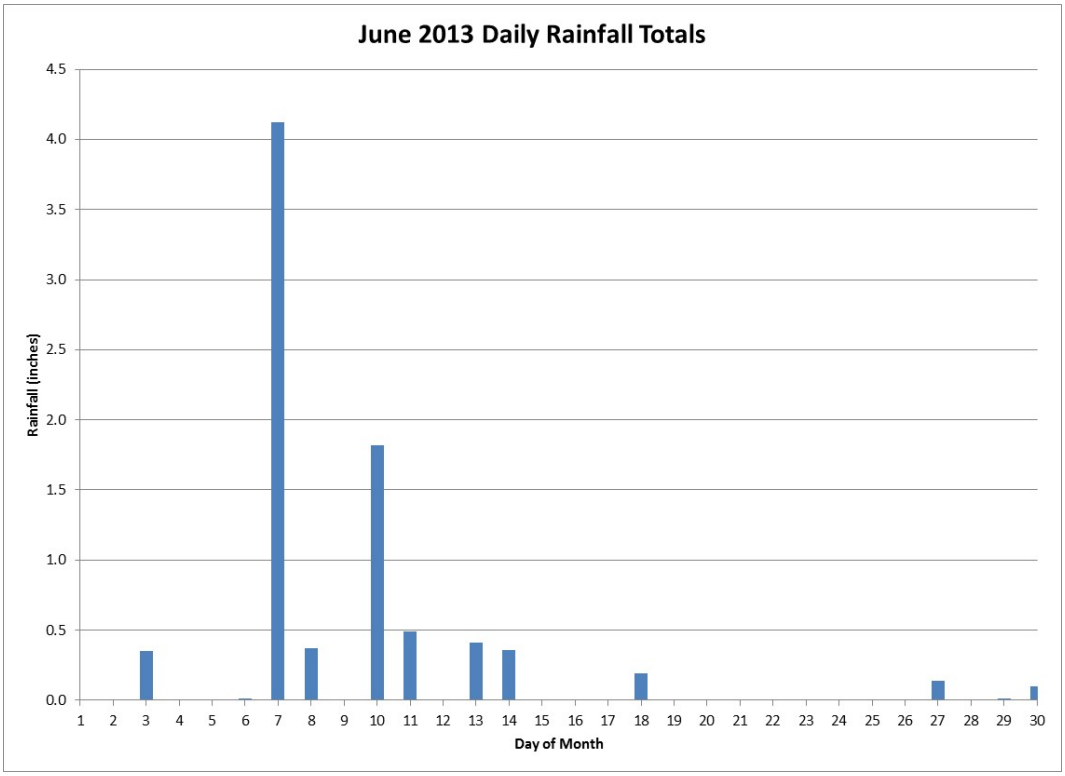

Figure 50. Daily Rainfall for the Month of June 2013

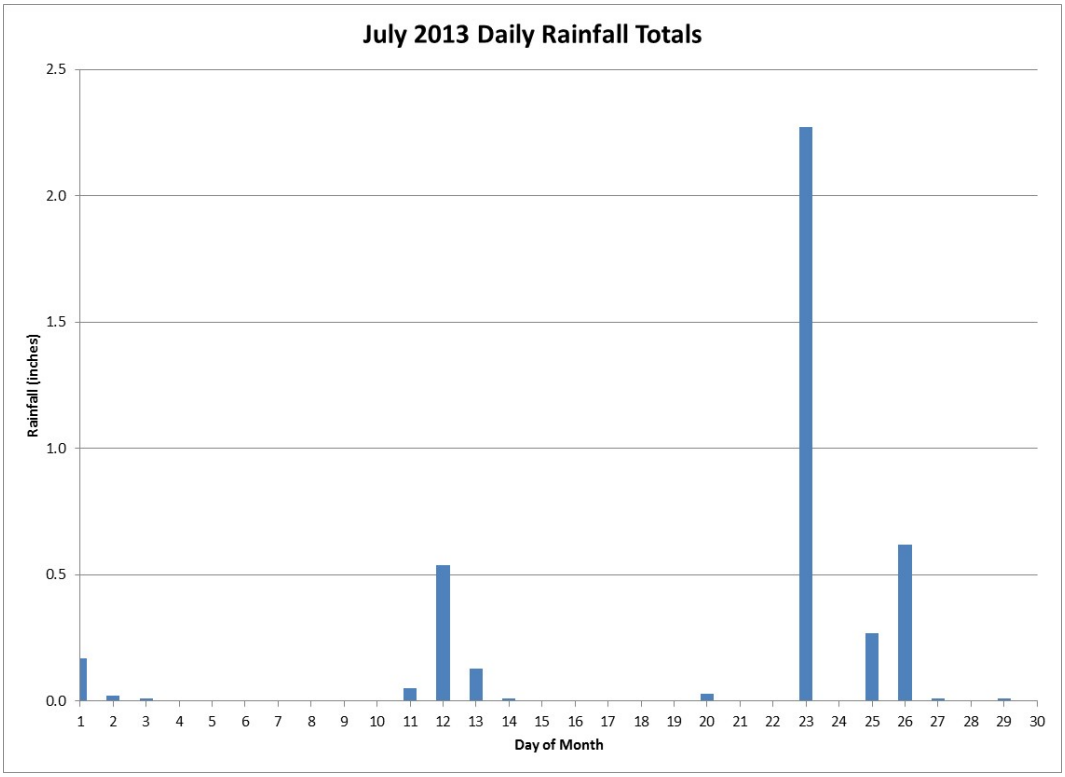

Figure 51. Daily Rainfall for the Month of July 2013

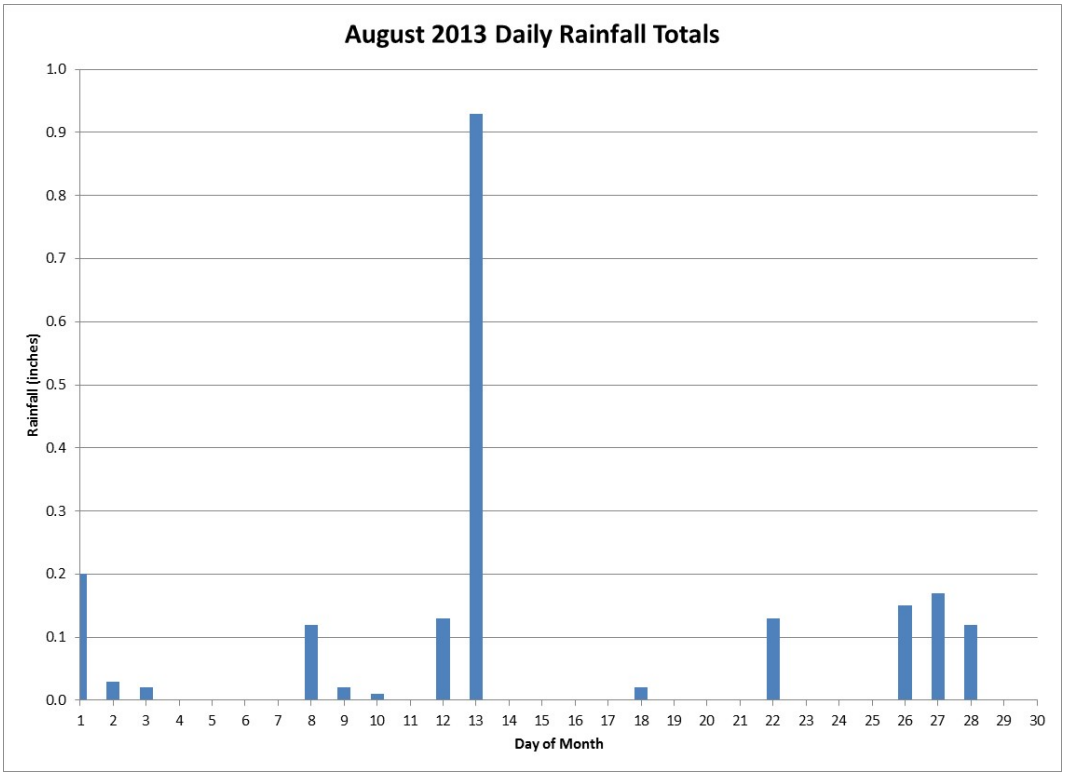

Figure 52. Daily Rainfall for the Month of August 2013

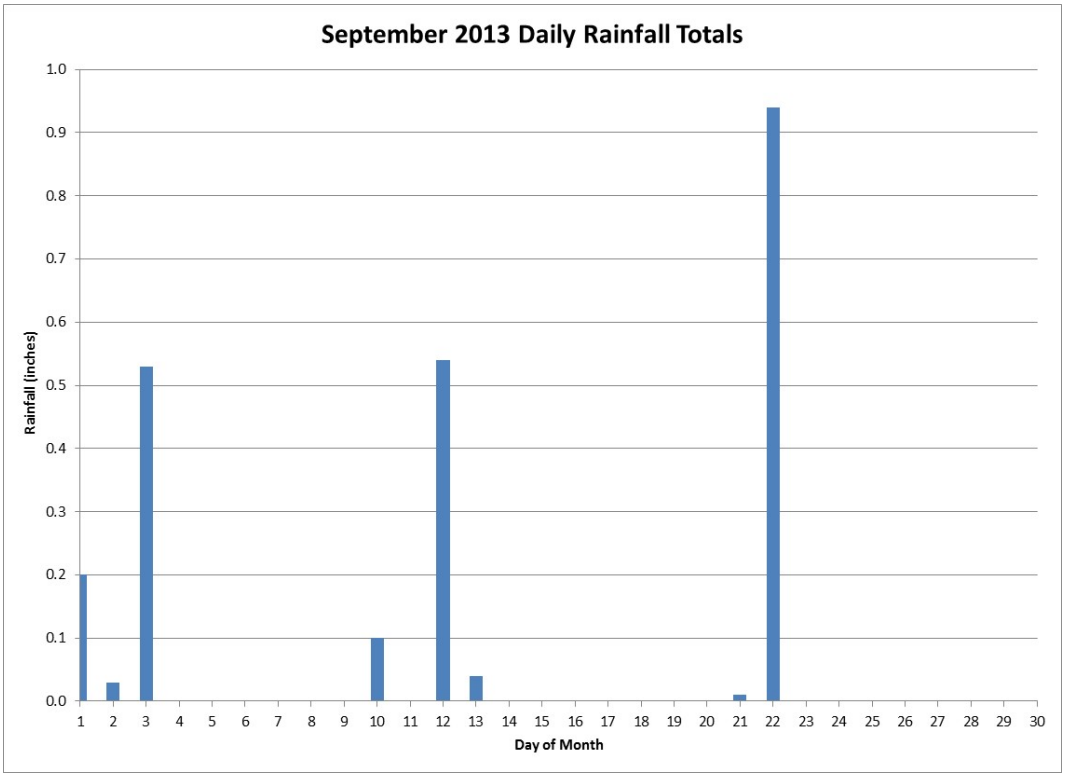

Figure 53. Daily Rainfall for the Month of September 2013

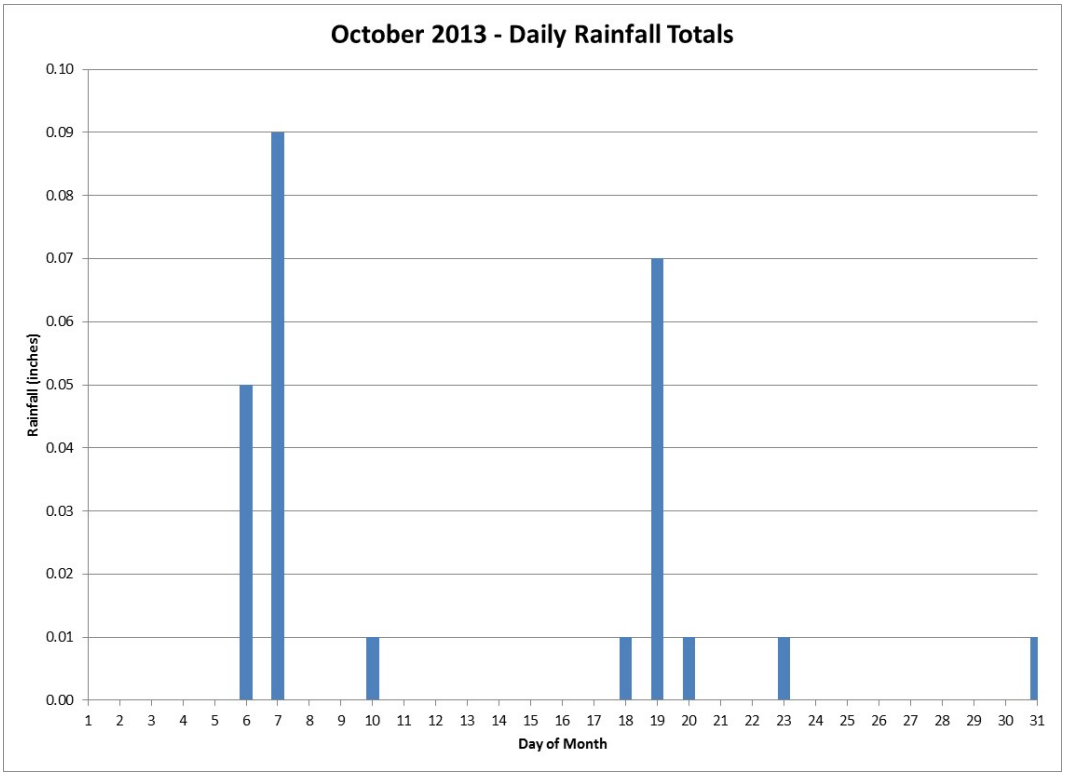

Figure 54. Daily Rainfall for the Month of October 2013

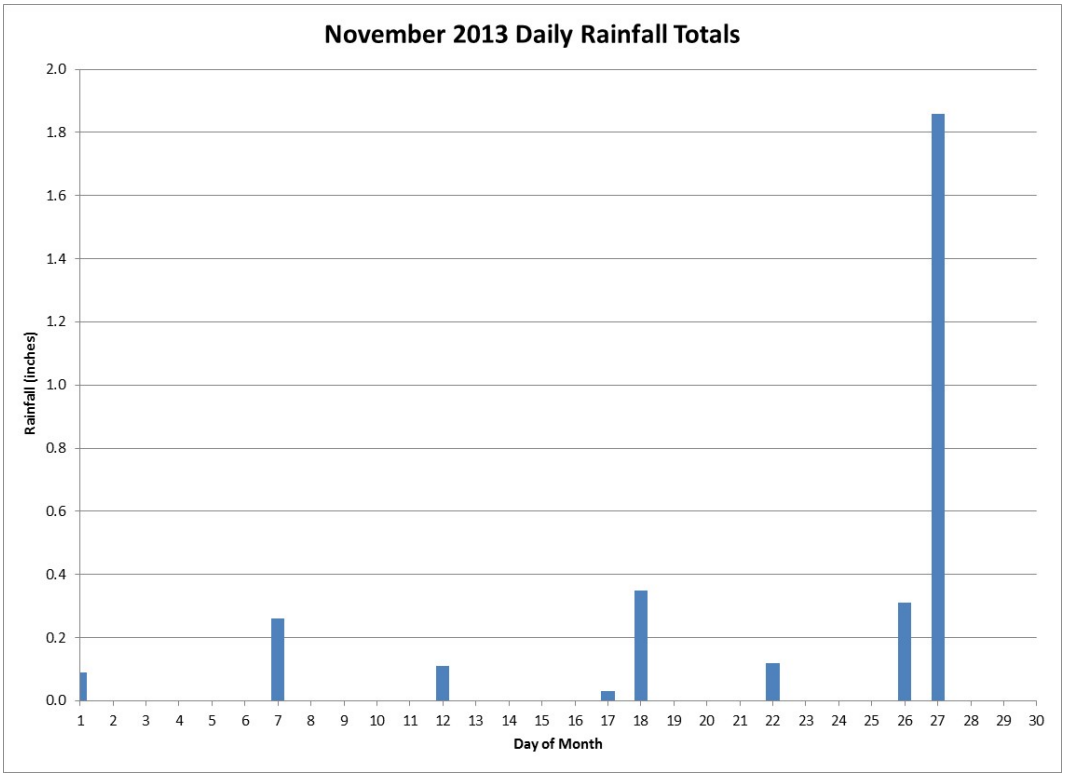

Figure 55. Daily Rainfall for the Month of November 2013

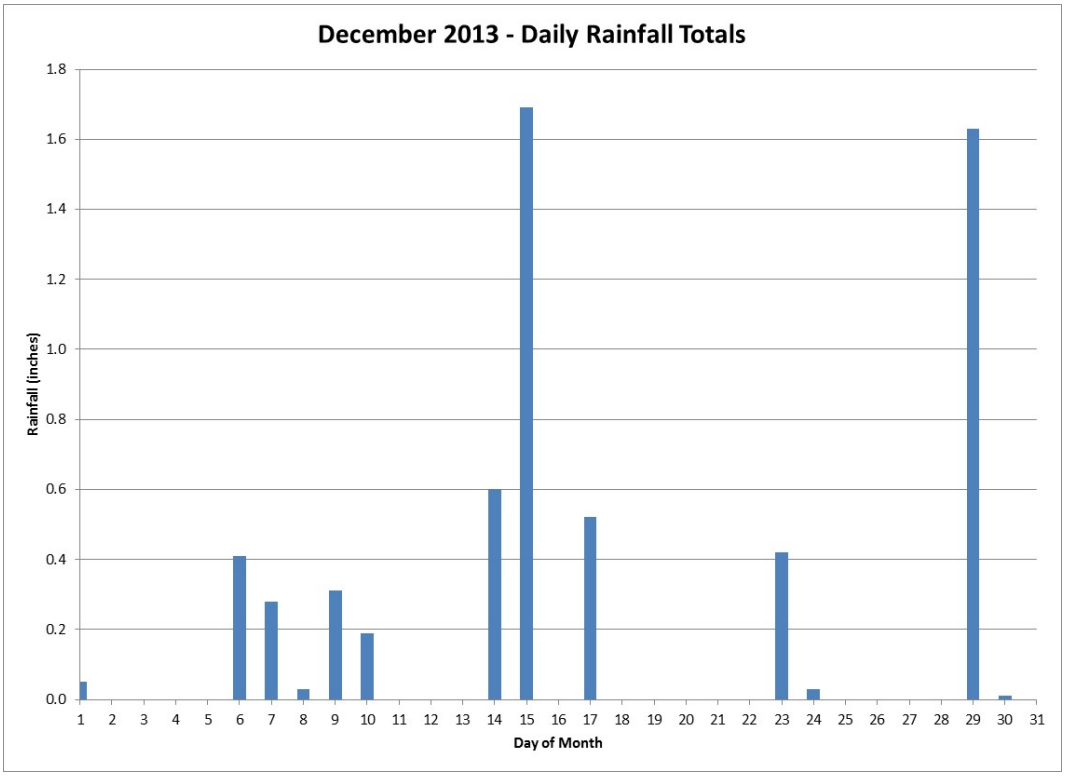

Figure 56. Daily Rainfall for the Month of December 2013

Table 6. Historic Monthly Precipitation for Brookhaven National Laboratory from 1949 to 2013 (@ 2 meters)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	5.55	4.71	2.88	3.63	3.32	Trace	3.07	5.21	3.49	1.74	2.96	3.36	39.92
1950	2.80	4.28	3.98	2.41	5.23	2.72	3.22	4.26	1.38	1.69	4.34	4.36	40.67
1951	3.75	4.99	5.02	3.42	3.68	2.64	2.08	4.50	1.06	5.48	6.01	6.17	48.80
1952	7.10	3.54	5.44	3.61	7.64	2.78	1.00	7.61	1.35	0.31	3.56	4.45	48.39
1953	6.73	4.16	10.36	5.59	3.34	1.66	2.76	2.40	0.90	3.17	5.03	6.43	52.53
1954	2.74	2.18	4.21	5.36	4.08	1.69	0.94	**11.98**	**10.47**	2.44	5.42	6.39	57.90
1955	**0.62**	3.26	4.79	4.28	0.95	2.53	1.65	9.04	3.96	11.43	7.19	**0.82**	50.52
1956	3.52	6.32	5.47	2.97	2.63	3.00	5.79	1.50	3.64	2.95	4.63	6.03	48.45
1957	2.36	2.53	3.20	4.44	1.46	**0.42**	2.84	4.25	3.57	3.86	4.41	8.45	41.79
1958	7.96	4.58	6.65	6.34	5.81	2.28	3.42	5.37	4.24	7.39	2.88	2.68	59.60
1959	2.60	2.06	6.71	3.93	1.75	5.35	6.85	3.72	1.36	3.13	4.46	5.12	47.04
1960	3.59	5.48	3.38	3.27	2.54	2.13	6.03	1.79	7.49	3.94	2.62	4.31	46.57
1961	3.56	4.10	4.60	5.70	6.17	2.30	5.61	4.23	6.23	3.06	2.89	3.70	52.15
1962	4.38	5.77	3.63	3.31	1.12	3.55	1.64	7.64	4.07	4.62	5.04	2.83	47.60
1963	3.27	3.88	4.27	2.56	3.08	5.51	2.65	2.10	3.66	**0.18**	6.89	2.78	40.83
1964	5.89	4.76	3.56	8.37	**0.63**	1.41	4.40	1.16	3.02	4.29	3.07	6.63	47.19
1965	4.88	3.03	2.74	4.20	1.63	1.69	3.43	5.15	1.51	2.15	1.83	2.11	**34.35**
1966	4.57	5.18	1.73	2.13	6.55	1.40	1.12	3.23	6.53	4.45	2.89	4.15	43.93
1967	1.65	3.98	8.18	4.14	7.98	5.30	6.01	5.43	2.24	2.11	4.00	7.60	58.62
1968	3.00	2.21	7.54	2.00	4.95	4.24	**0.50**	3.10	2.08	3.01	8.09	8.22	48.94
1969	1.04	4.03	3.62	5.15	2.44	2.06	**8.62**	5.51	3.60	3.69	4.48	7.83	52.07
1970	0.81	4.37	5.44	4.57	3.44	1.77	3.10	6.08	2.42	1.41	6.52	3.73	43.66
1971	2.95	**6.45**	3.55	3.30	3.80	0.92	5.03	3.86	2.12	3.41	6.86	2.57	44.82
1972	2.41	6.12	5.40	4.53	6.10	7.30	1.03	1.29	3.08	7.64	7.51	6.22	58.63
1973	4.44	4.36	4.38	7.77	5.46	3.25	4.45	3.11	2.51	2.79	2.22	8.00	52.74
1974	4.96	2.82	5.06	3.49	3.13	2.50	0.81	2.55	5.10	2.66	1.94	6.78	41.80
1975	6.50	4.06	4.27	3.89	3.45	5.37	3.33	2.01	5.58	3.61	5.89	4.92	52.88
1976	5.98	3.57	3.30	2.27	3.89	3.27	4.32	7.57	2.07	5.42	**0.54**	2.96	45.16

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1977	3.09	2.46	5.47	4.28	2.04	4.31	1.51	5.49	5.73	6.12	6.39	6.93	53.82
1978	10.72	2.60	3.33	2.39	6.47	0.81	4.63	5.22	4.26	4.11	2.79	6.12	53.45
1979	**13.01**	5.27	3.53	4.96	4.09	2.15	0.61	7.76	3.20	4.57	3.95	3.02	56.12
1980	2.02	1.18	7.20	6.16	1.52	3.60	1.92	1.56	0.98	3.59	4.20	1.06	34.99
1981	1.15	5.16	1.80	4.59	2.17	3.14	2.69	0.96	5.17	4.49	3.16	5.55	40.03
1982	7.20	2.90	3.38	5.44	1.71	**12.85**	1.77	3.45	1.40	2.07	3.87	2.38	48.42
1983	4.07	4.36	8.68	**11.09**	4.22	2.63	4.20	4.48	2.09	3.67	8.68	5.67	63.84
1984	2.87	6.38	6.92	5.41	8.08	6.68	7.06	1.02	4.16	3.20	2.40	2.98	57.16
1985	1.07	1.82	2.62	1.56	4.87	6.38	2.30	4.89	1.54	1.53	6.85	1.10	36.53
1986	3.96	3.46	3.17	2.35	1.09	1.66	5.02	5.69	**0.86**	2.25	6.72	7.50	43.73
1987	6.74	1.21	5.95	4.32	1.83	1.86	1.48	4.38	4.05	2.22	3.55	3.20	40.79
1988	3.59	4.81	4.22	2.17	2.58	1.43	3.93	1.36	3.52	3.87	**9.05**	2.52	43.05
1989	2.23	4.09	5.20	4.66	**10.47**	7.24	5.84	9.17	4.45	8.90	5.16	1.25	**68.66**
1990	5.24	2.92	2.14	4.96	6.52	3.95	2.64	6.75	3.04	7.17	1.78	5.90	53.01
1991	4.41	1.86	5.45	4.30	2.78	1.87	2.11	9.19	4.45	2.61	1.80	4.30	45.13
1992	2.40	2.18	3.34	1.78	3.05	4.90	4.76	5.61	3.51	1.07	5.96	6.60	45.16
1993	2.47	4.10	7.11	3.81	1.71	1.37	1.84	1.61	4.36	4.69	3.72	6.11	42.90
1994	5.78	4.04	6.55	2.26	2.93	0.51	0.91	5.04	4.41	1.09	6.34	4.30	44.16
1995	2.93	3.74	1.53	2.52	2.79	3.12	1.78	**0.54**	4.91	5.97	5.83	3.74	39.40
1996	5.22	3.51	3.58	6.40	3.39	4.41	4.94	2.68	6.08	8.24	3.11	**8.66**	60.22
1997	3.82	2.64	5.10	4.21	2.67	2.16	2.21	3.33	1.27	2.55	5.42	4.66	40.04
1998	7.01	5.66	8.08	6.55	8.58	8.43	0.94	3.68	2.50	1.91	2.05	1.22	56.61
1999	8.85	4.81	5.32	2.35	2.41	1.04	2.12	8.71	5.90	4.78	2.58	2.85	51.72
2000	3.75	2.58	5.49	6.29	4.28	5.18	8.37	3.38	6.86	0.31	3.79	4.09	54.37
2001	3.28	2.63	10.37	2.03	4.22	6.46	3.47	4.68	4.04	1.04	0.74	2.59	45.55
2002	3.07	**1.16**	5.05	4.58	4.48	4.37	1.37	3.94	5.84	6.40	6.18	5.63	52.07
2003	2.48	5.74	5.99	5.11	6.07	12.28	2.38	5.19	5.22	4.80	3.63	4.22	63.11
2004	2.15	3.14	3.47	4.94	2.59	1.34	3.05	4.30	5.14	1.62	2.16	1.96	35.86
2005	3.32	2.10	2.47	2.53	2.36	1.48	2.16	0.87	1.09	**22.14**	5.00	4.60	50.12
2006	5.52	2.87	**0.89**	7.17	6.73	6.73	5.73	6.44	3.21	7.22	6.61	2.47	61.59

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2007	4.32	2.00	5.58	6.87	2.06	3.18	7.58	2.78	1.69	1.71	3.31	4.25	45.33
2008	2.36	5.84	5.90	4.04	3.66	2.28	1.97	3.07	9.31	4.02	3.82	4.37	50.64
2009	1.27	1.74	1.79	5.39	6.05	7.99	7.19	1.15	3.18	6.13	4.65	7.64	54.17
2010	2.15	6.01	**11.98**	**0.74**	3.88	1.64	6.70	2.21	4.56	3.08	2.91	4.08	49.94
2011	3.23	3.61	3.00	4.34	3.37	4.33	2.34	9.81	4.74	5.75	3.52	3.16	51.20
2012	3.01	1.27	1.11	3.81	4.53	7.74	8.26	4.57	3.49	3.24	2.49	7.30	50.82
2013	2.35	5.84	3.82	1.67	3.04	8.37	4.14	2.05	2.39	0.26	3.13	6.17	43.23
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average	4.03	3.80	**4.77**	4.23	3.87	3.73	3.50	4.35	**3.71**	4.01	4.33	4.59	48.87
Max	13.01	8.34	11.98	11.09	10.47	12.85	8.62	11.98	10.47	**22.14**	9.05	8.66	**68.66**
Min	0.62	1.16	0.89	0.74	0.63	0.42	0.50	0.54	0.86	**0.18**	0.54	0.82	**34.35**

Min **Max**

Wind Direction and Wind Speed

Wind speed and direction are recorded via R.M. Young 5106 marine grade mechanical wind sensor. This unit has a 0 to 100 m/s wind speed range and has been modified to have a 0.5 m/s wind speed threshold sensitivity. Accuracy is ±0.3 m/s. The direction sensor has a 355° electrical range and 360° mechanical. Direction accuracy is ±3° and sensitivity is 1.1 m/s (wind speed needed for accurate measurement). These units require a wind tunnel calibration and are sent out for calibration on an annual basis. Enough spare units are stocked to allow change out without data loss.

Average daily wind speed recorded at the 10-meter and 85-meter locations is given in Figure 57. Monthly wind roses are presented in Figures 58 through 69. A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. The wind rose data used in the plots are daily averages generated from one minute data. Each figure has two roses presented for the 10- and 85-meter locations. Speed bins are 0-5 m/s, 5 to 10 m/s and >10 m/s. Percent calm data and percent bad data are also listed. Prevailing winds at BNL are from the west southwest with a secondary south-southwest component at both the 85 meter level and the 10 meter level.

Figures 70 through 93 present the 1-minute data for wind speed and wind gust. Plots for January to June have 10-meter and 85-meter data. July and later plots also contain data from 50-meters, which represents a new sensor location installed in June of 2012 following earlier recommendations from the DOE Meteorological Coordinating Council.

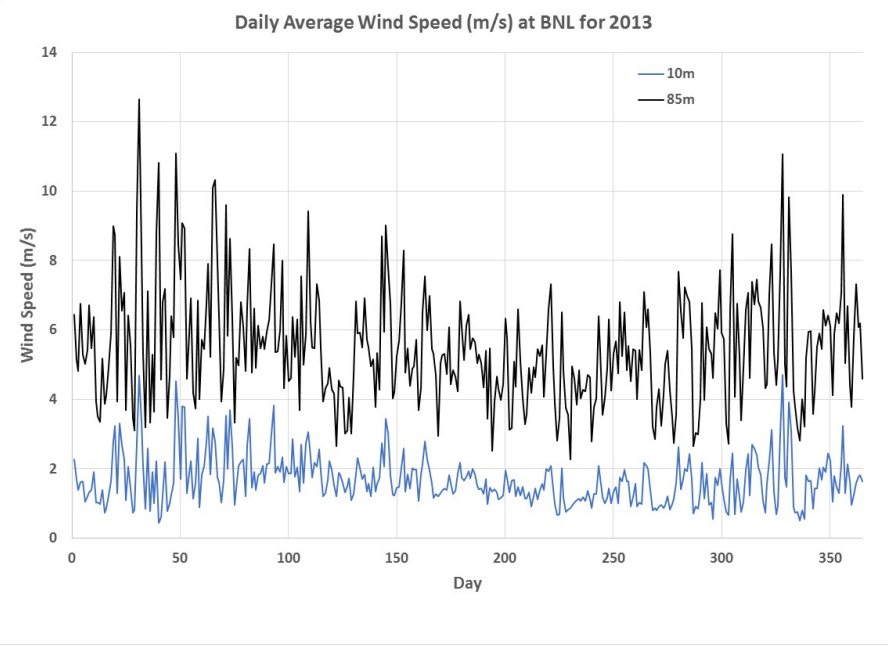

Figure 57. Average Daily Wind Speed (M/s) at the 10-meter and 85-meter heights at BNL for 2013

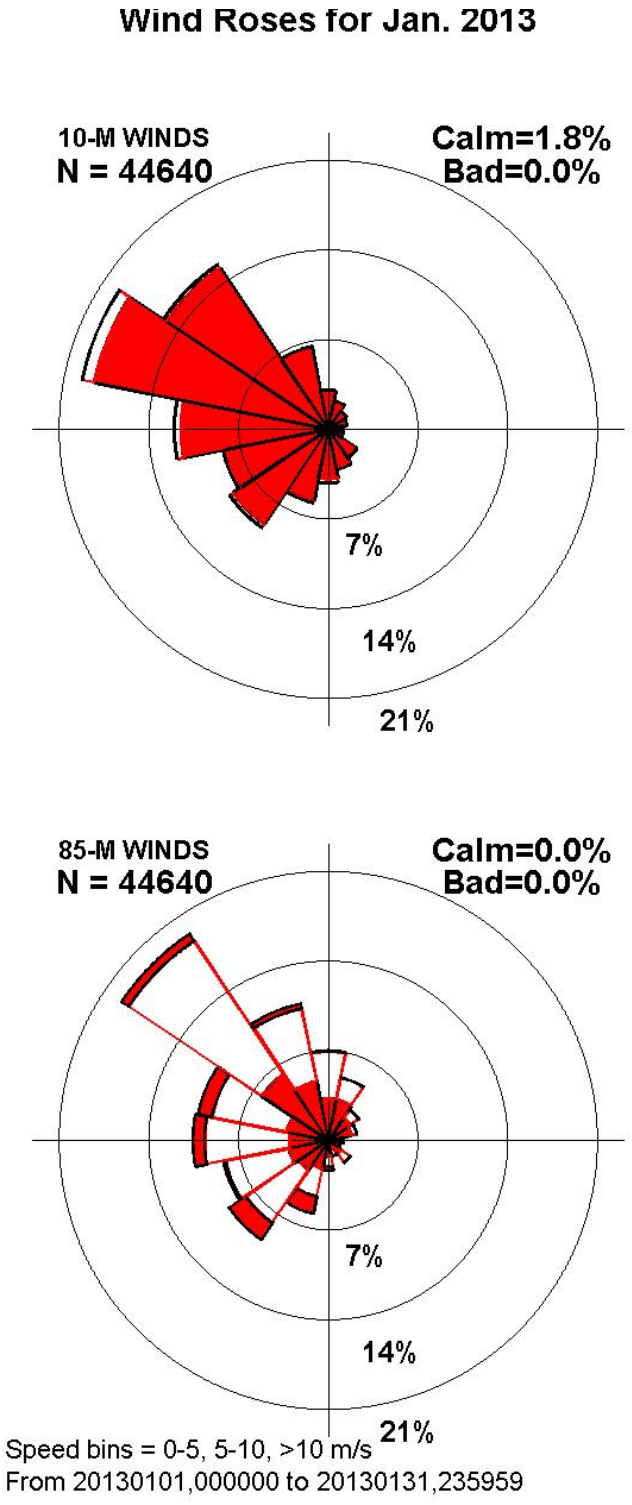

Figure 58. Wind Roses for the Month of January 2013

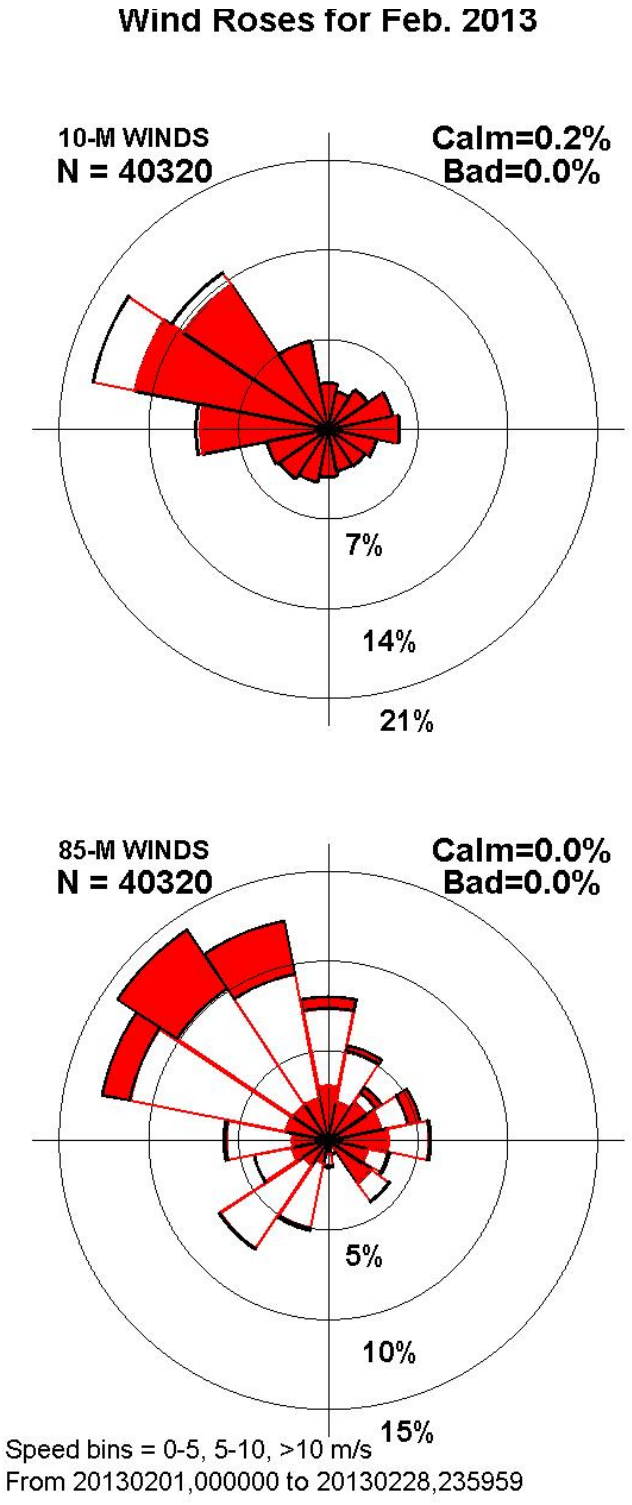

Figure 59. Wind Roses for the Month of February 2013

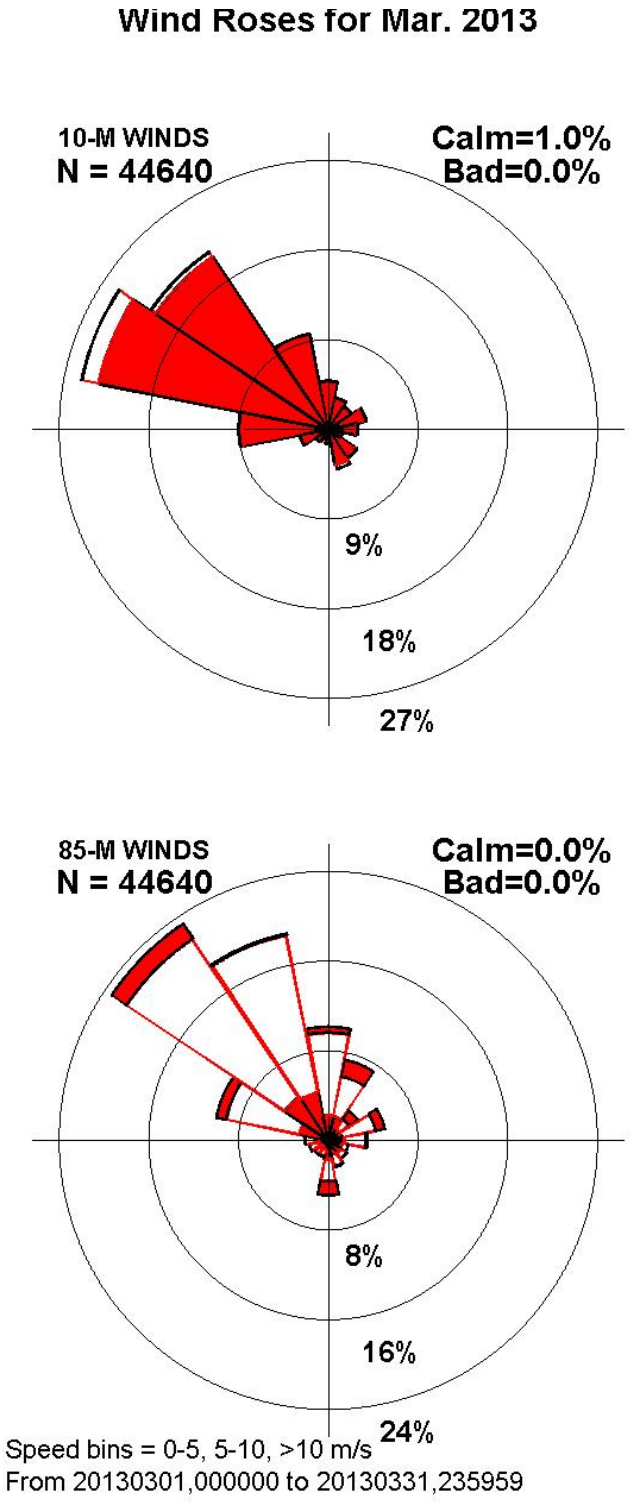

Figure 60. Wind Roses for the Month of March 2013

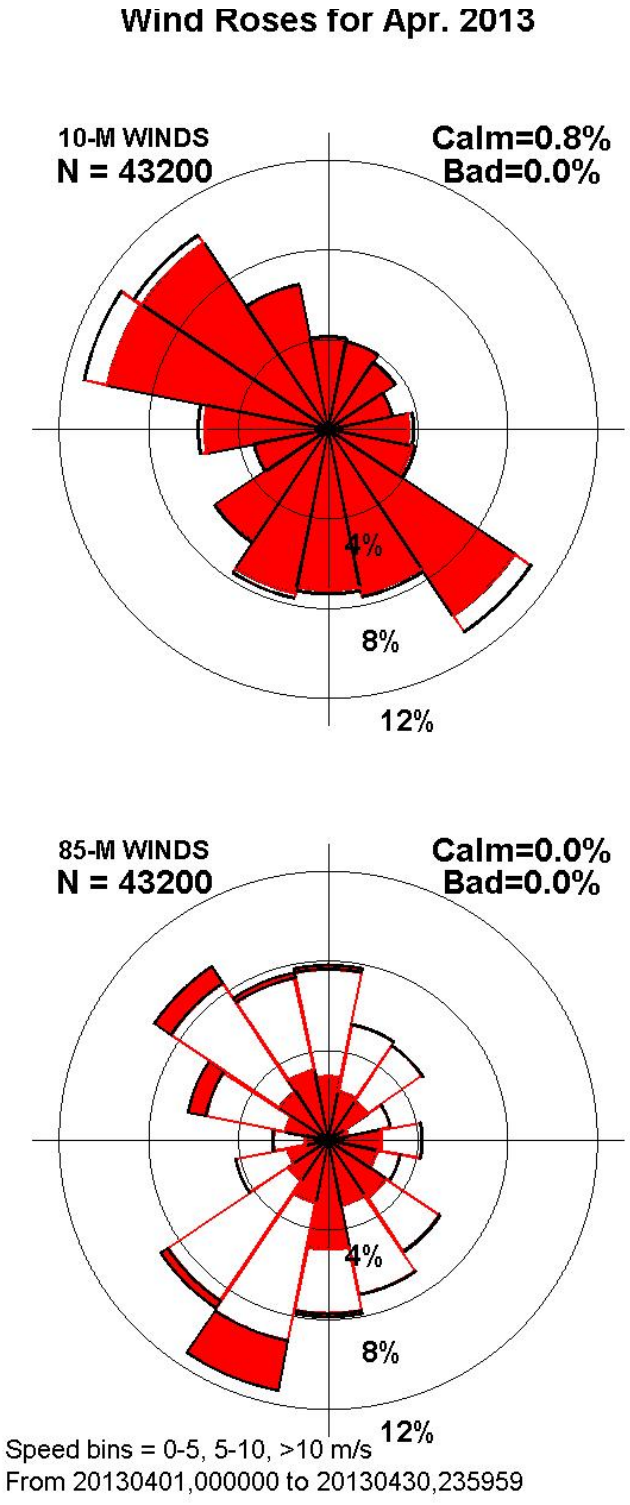

Figure 61. Wind Roses for the Month of April 2013

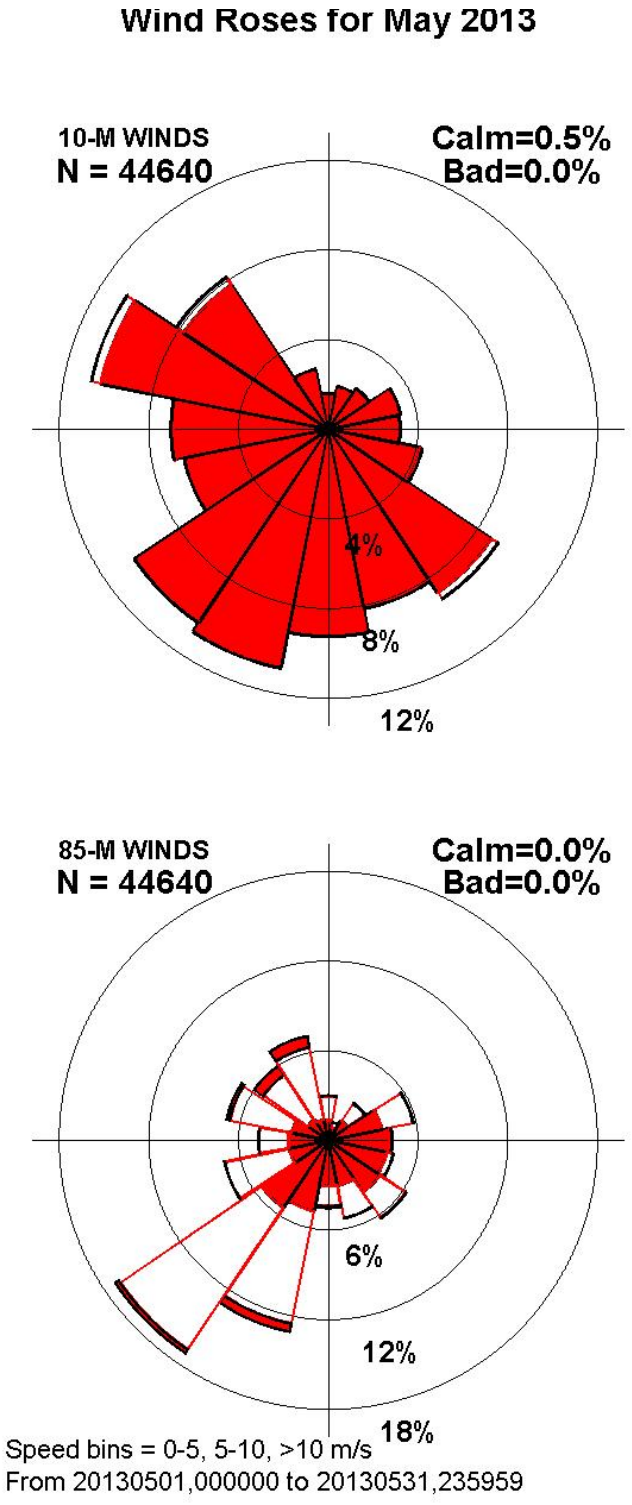

Figure 62. Wind Roses for the Month of May 2013

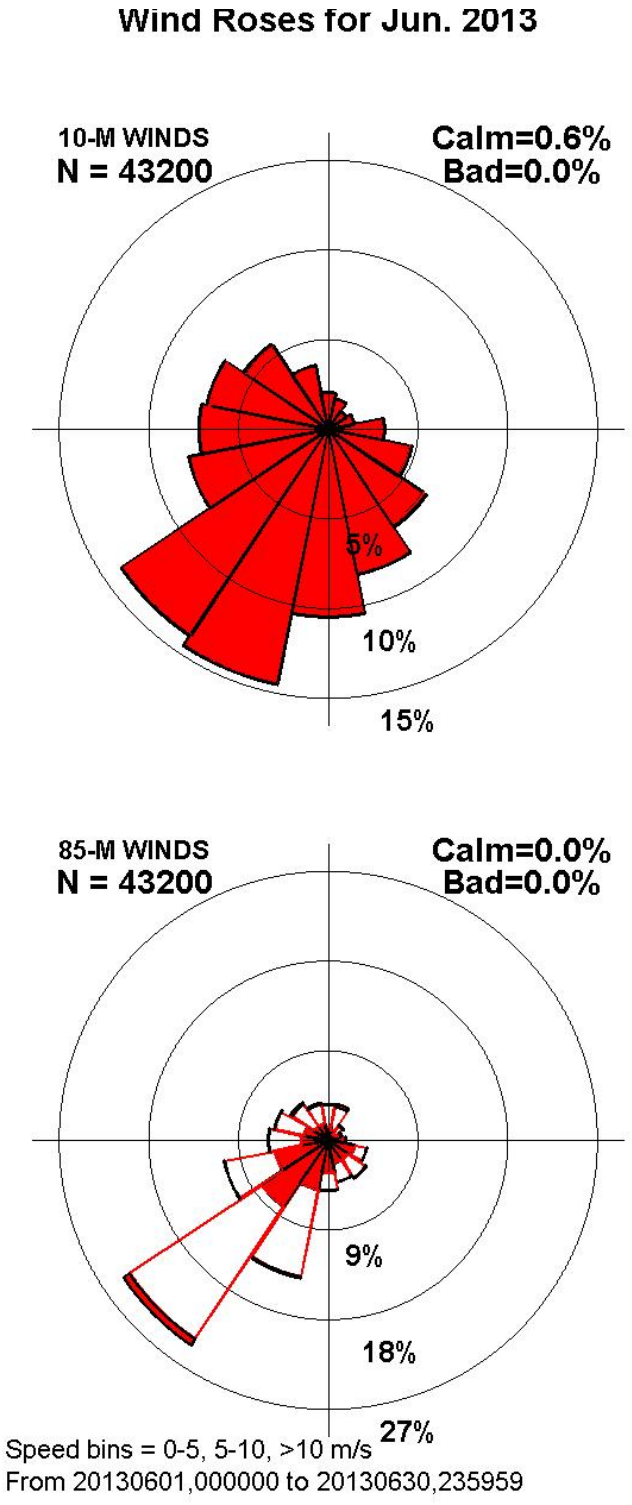

Figure 63. Wind Roses for the Month of June 2013

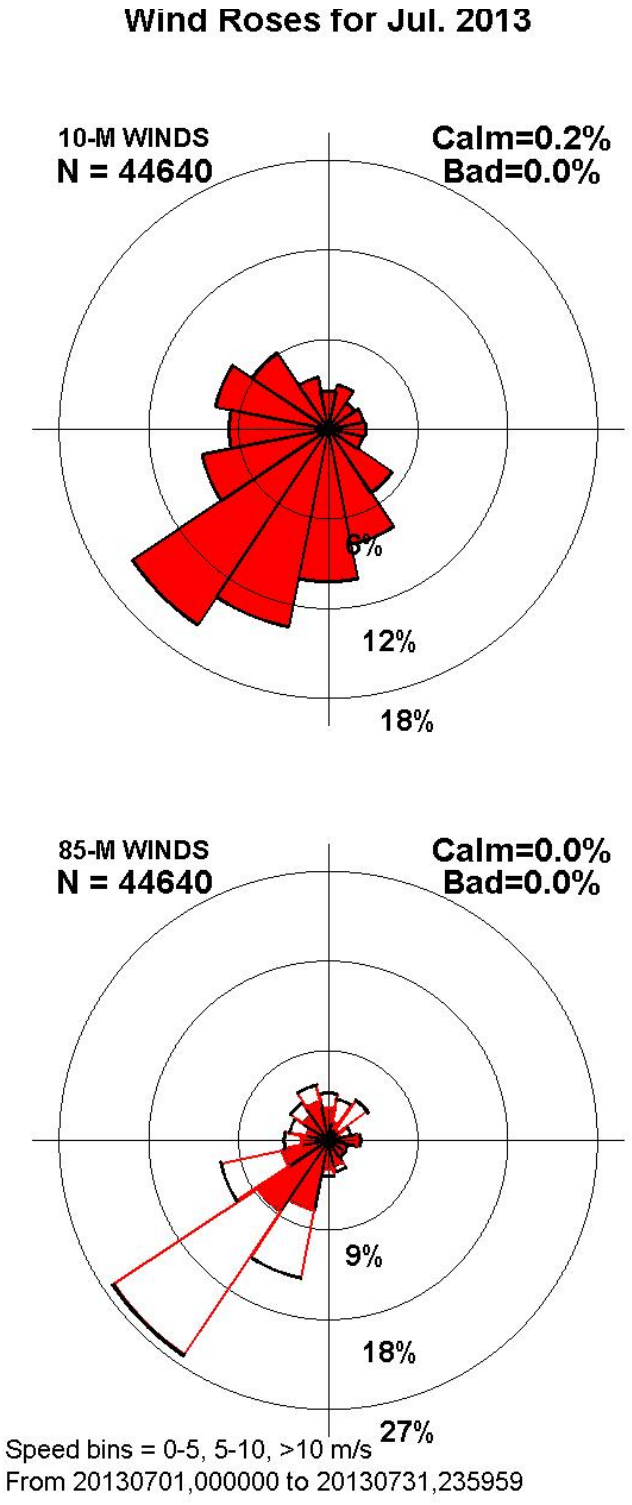

Figure 64. Wind Roses for the Month of July 2013

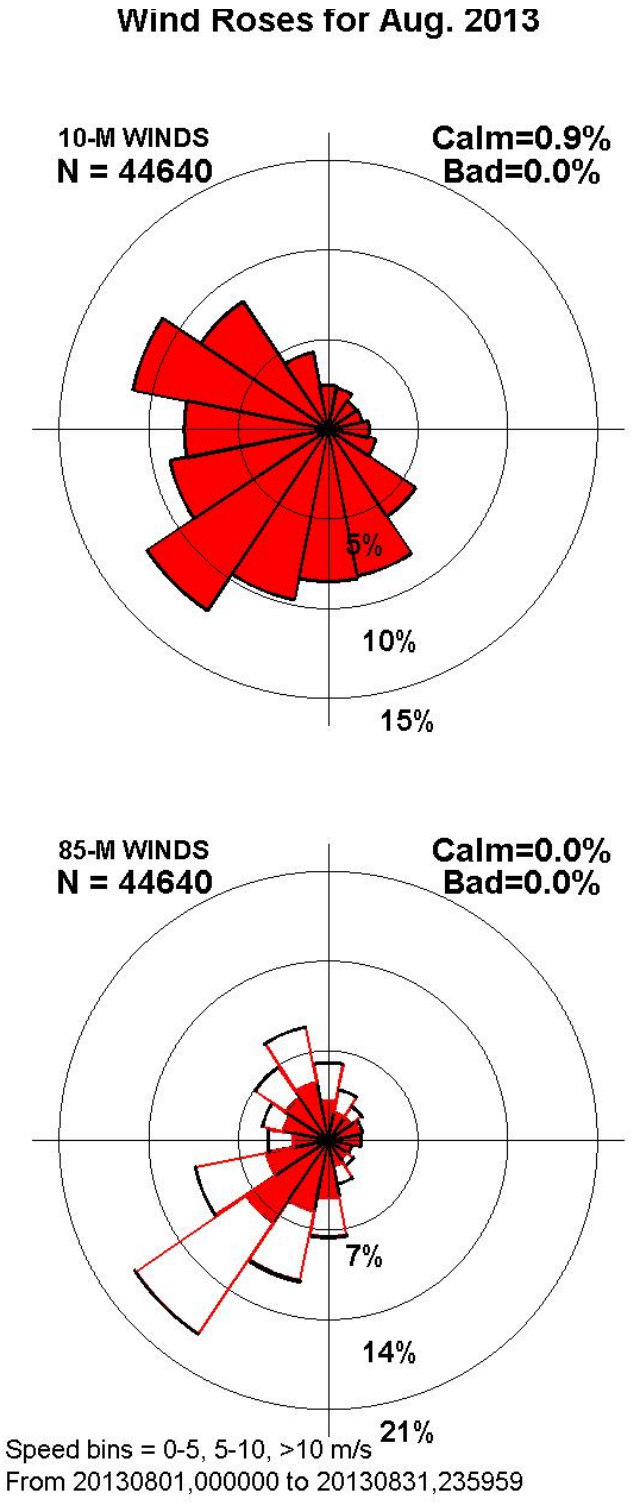

Figure 65. Wind Roses for the Month of August 2013

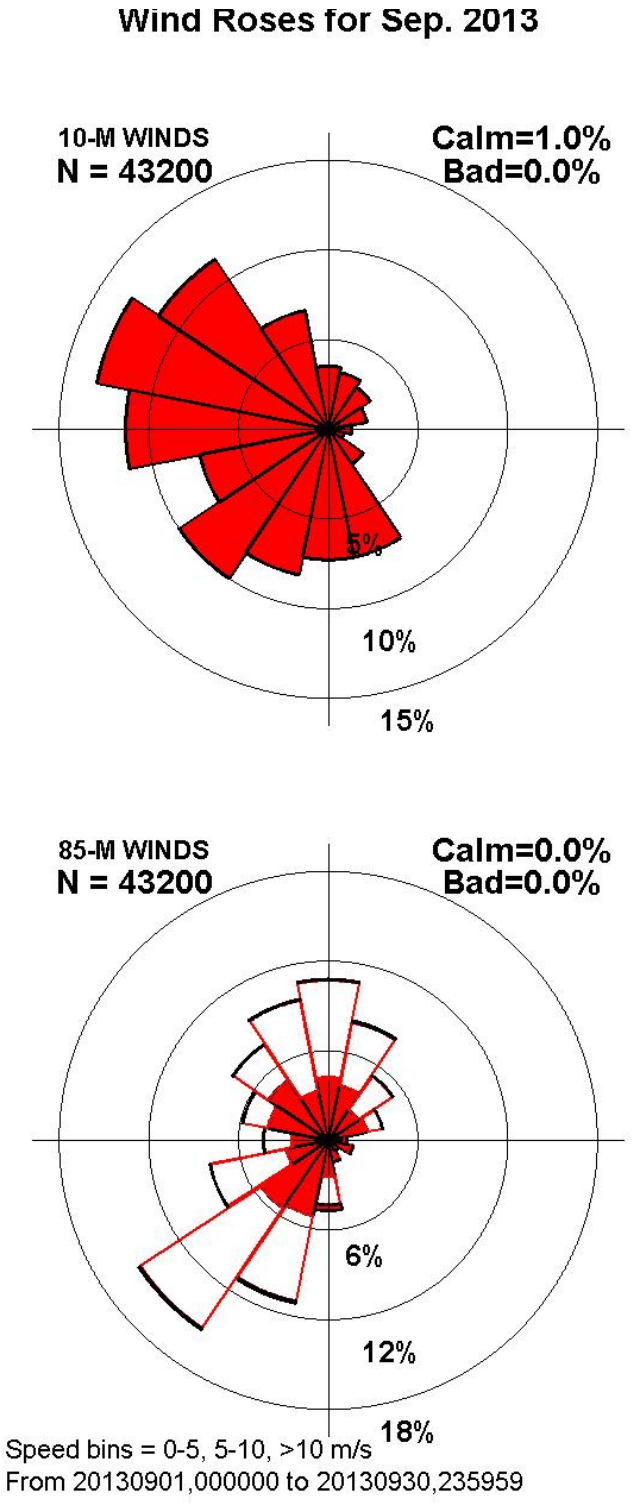

Figure 66. Wind Roses for the Month of September 2013

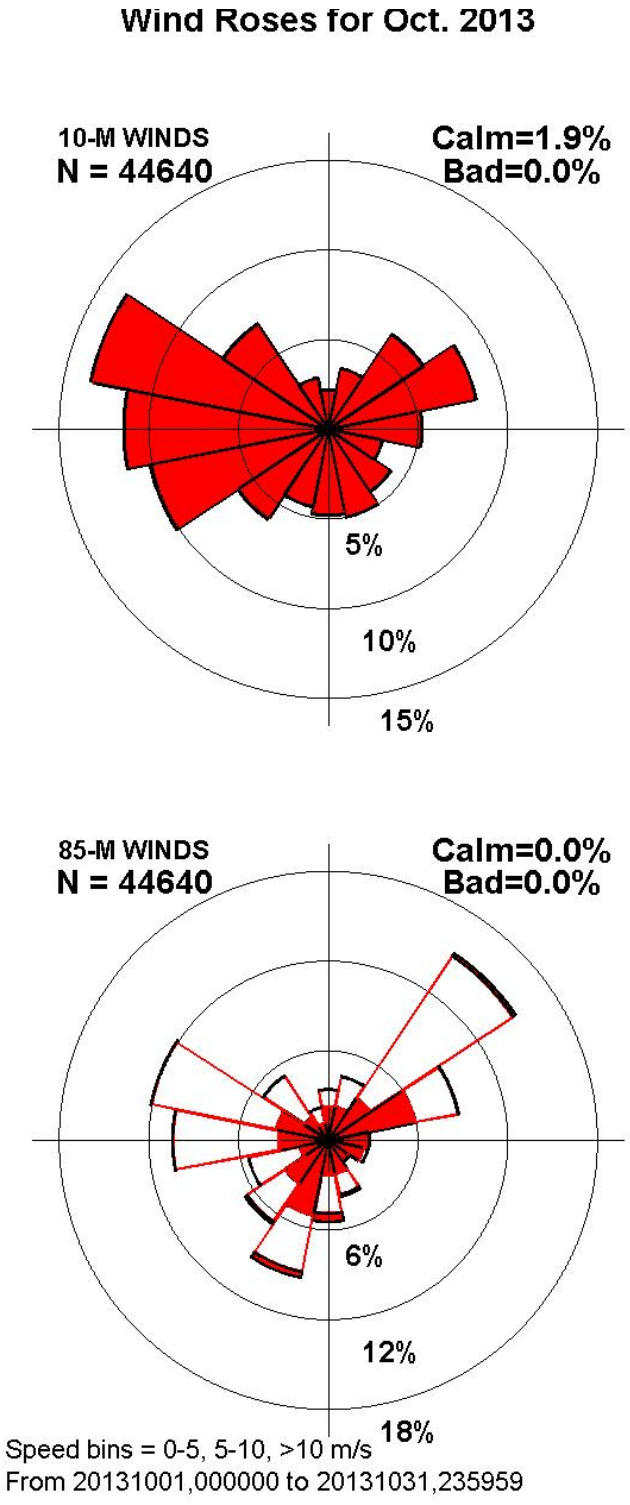

Figure 67. Wind Roses for the Month of October 2013

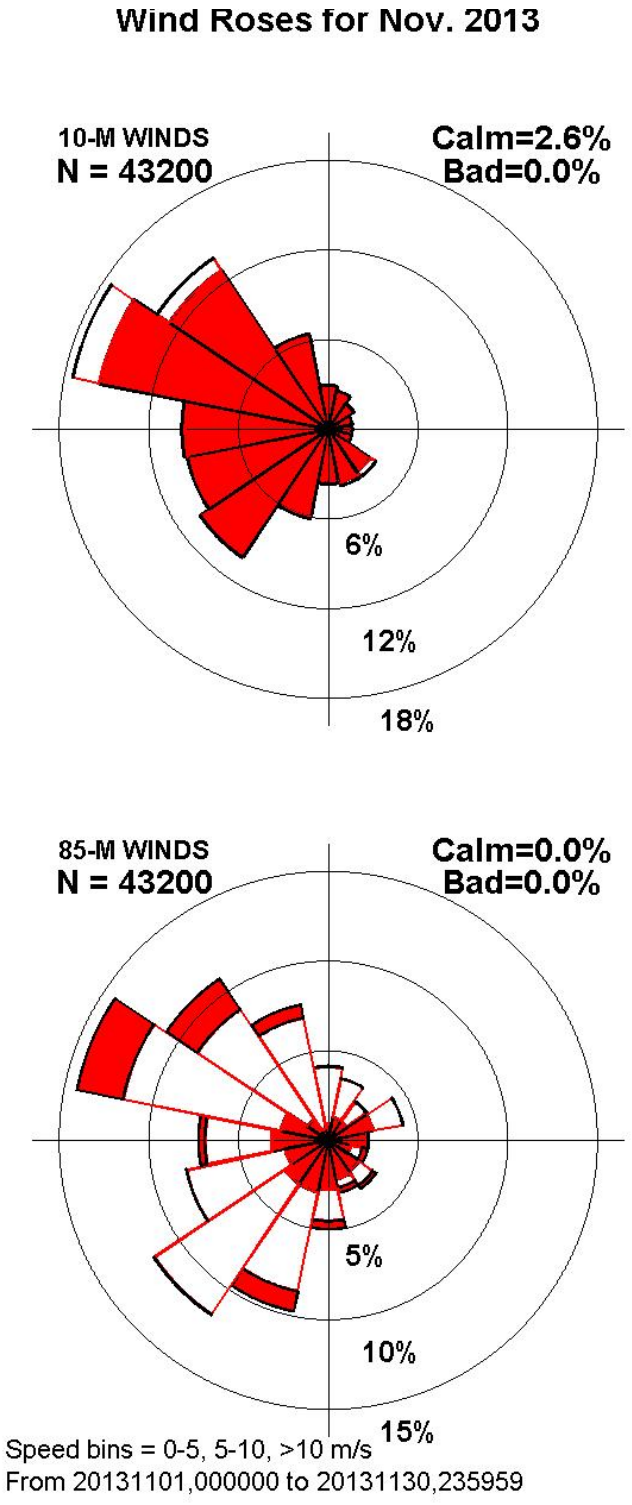

Figure 68. Wind Roses for the Month of November 2013

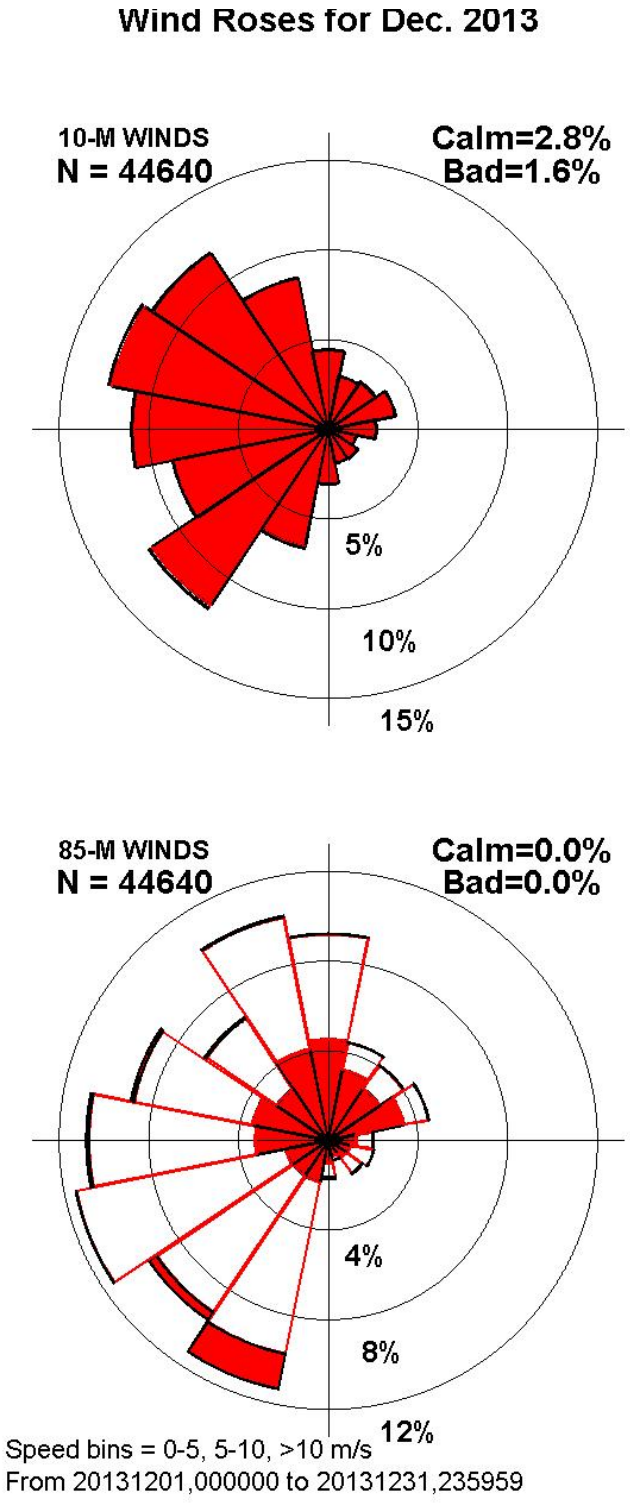

Figure 69. Wind Roses for the Month of December 2013

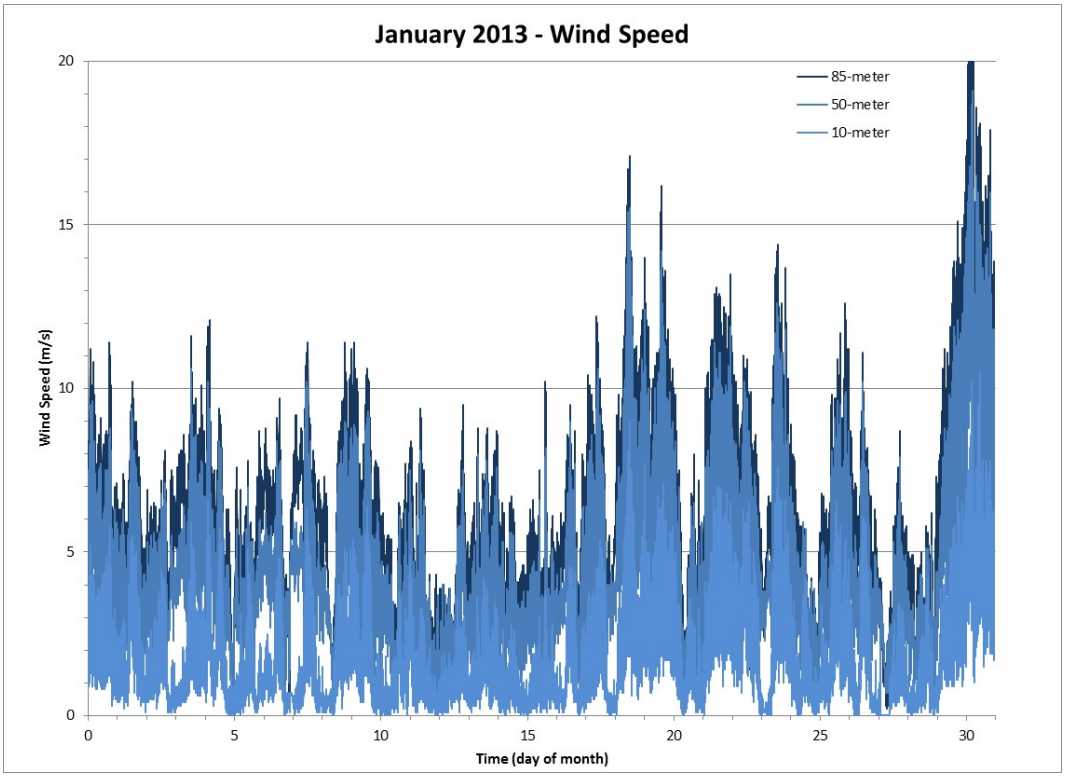

Figure 70. Wind Speed for the Month of January 2013

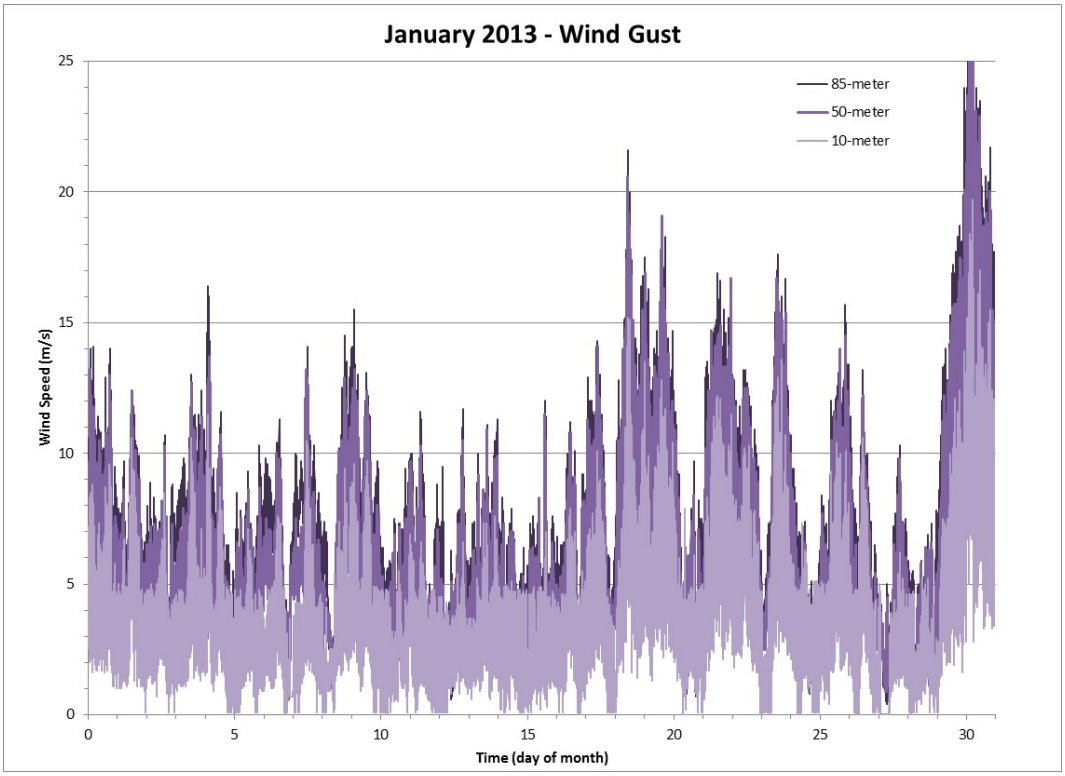

Figure 71. Wind Gust data for the Month of January 2013

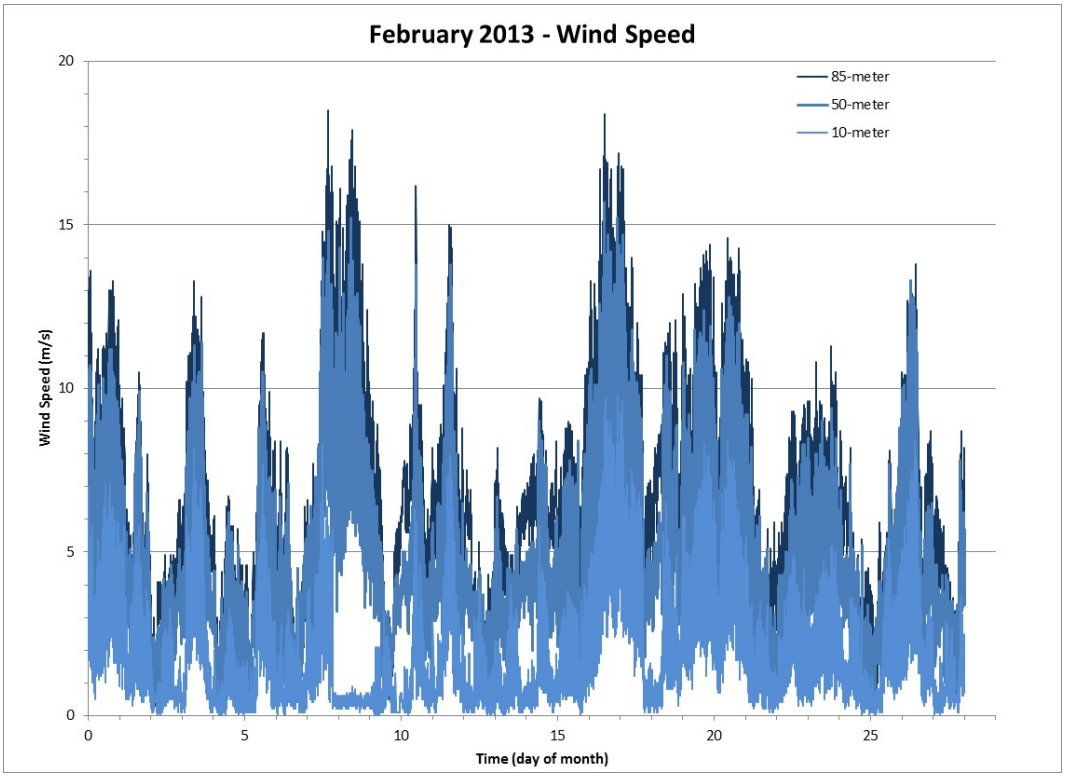

Figure 72. Wind Speed for the Month of February 2013

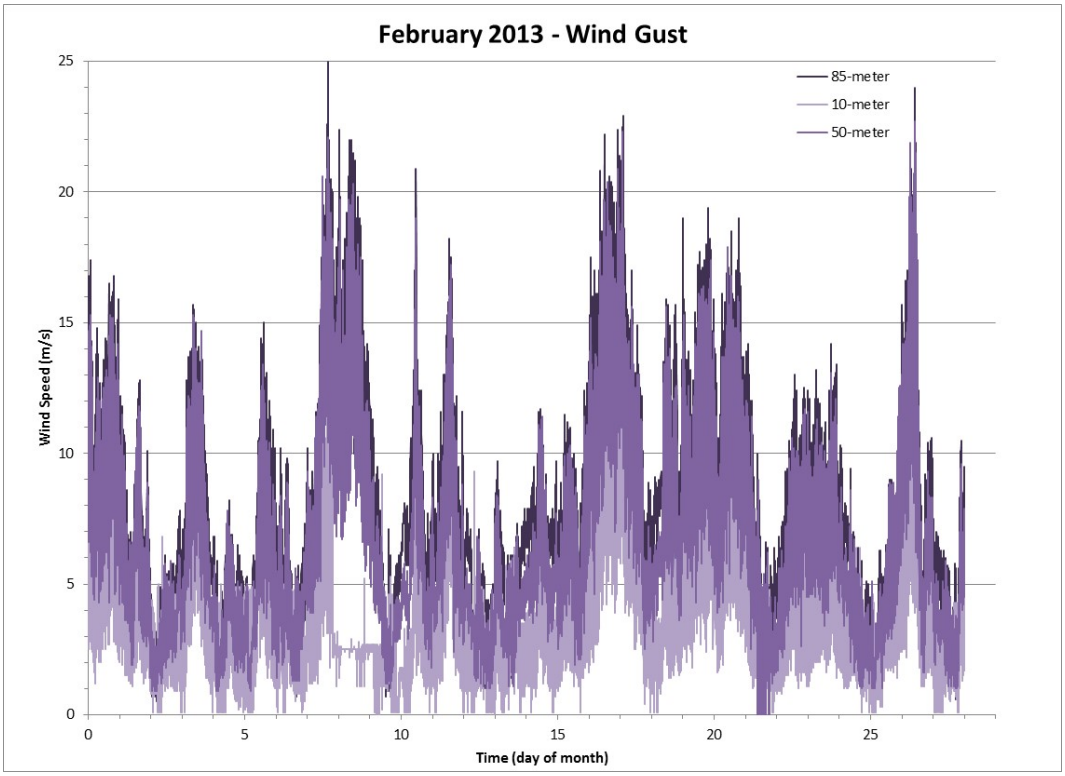

Figure 73. Wind Gust data for the Month of February 2013

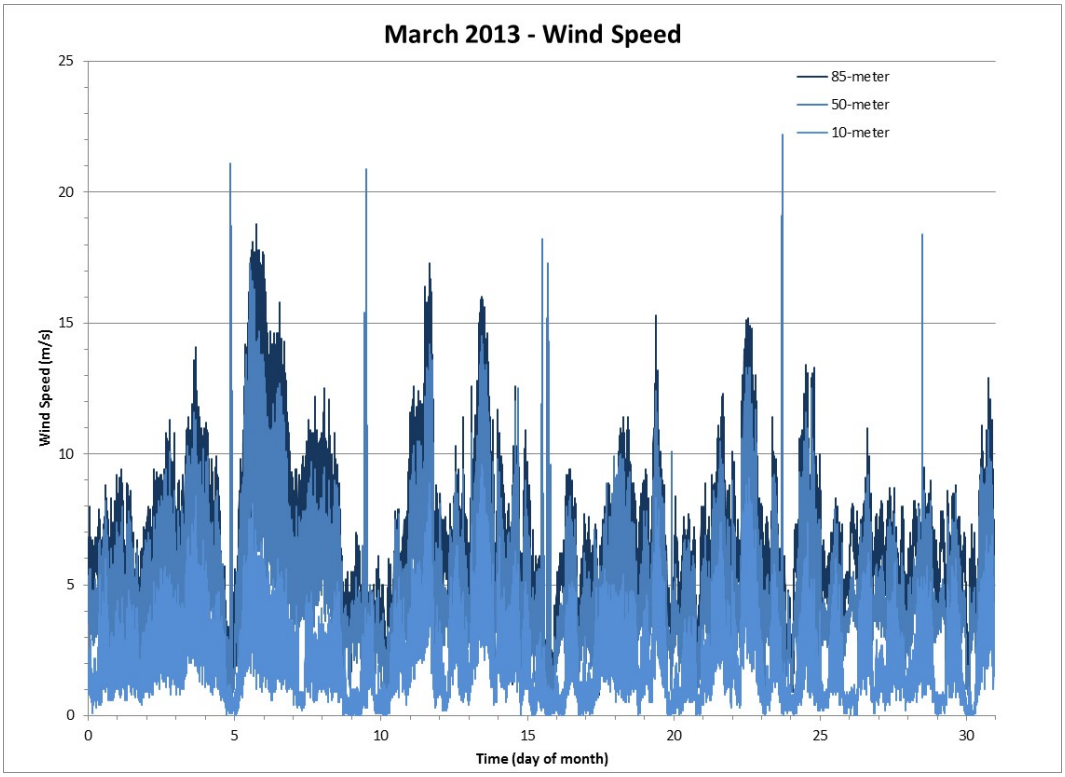

Figure 74. Wind Speed for the Month of March 2013

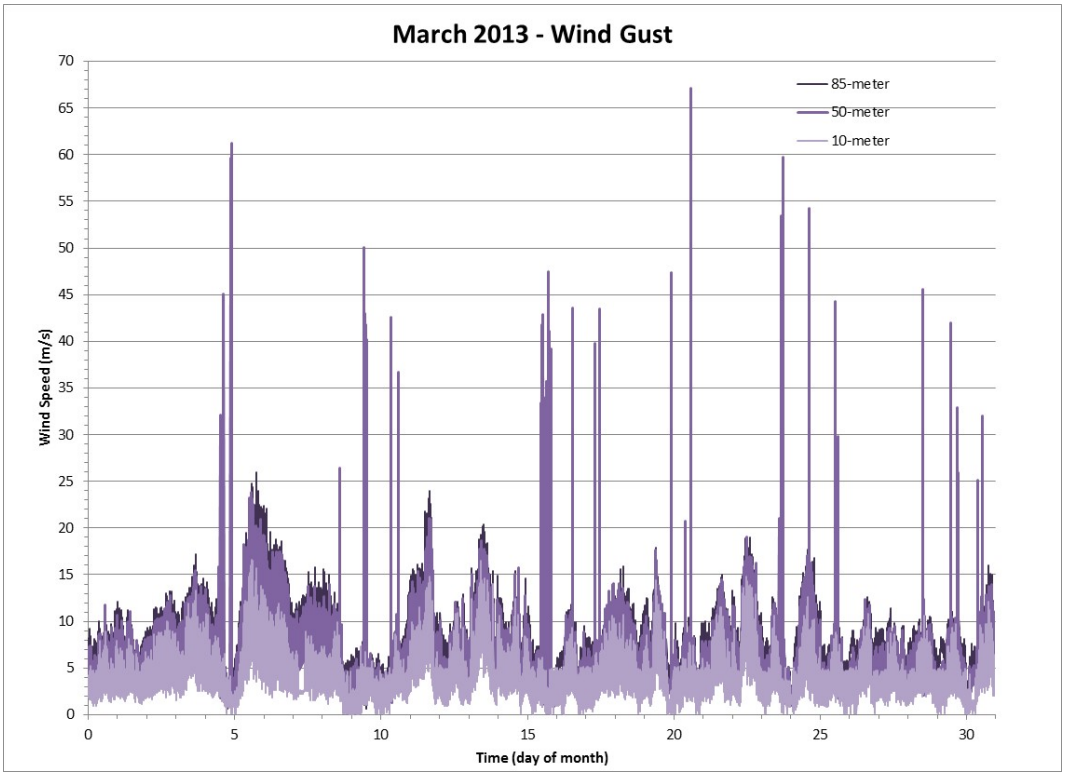

Figure 75. Wind Gust data for the Month of March 2013

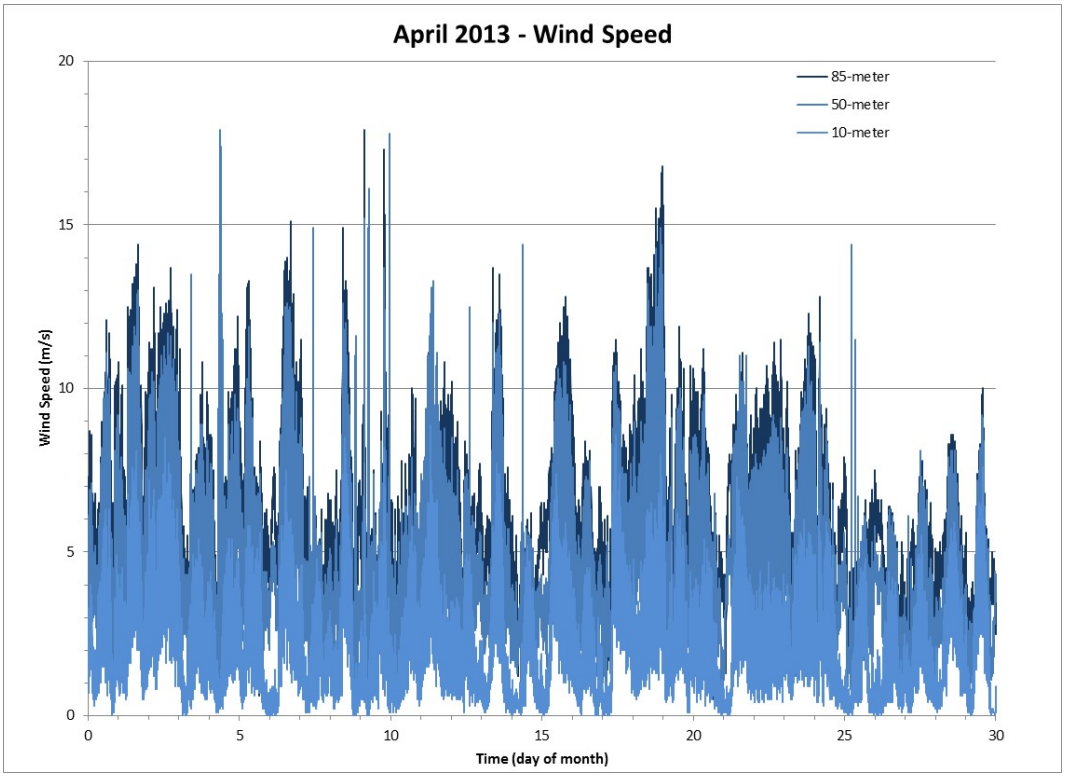

Figure 76. Wind Speed for the Month of April 2013

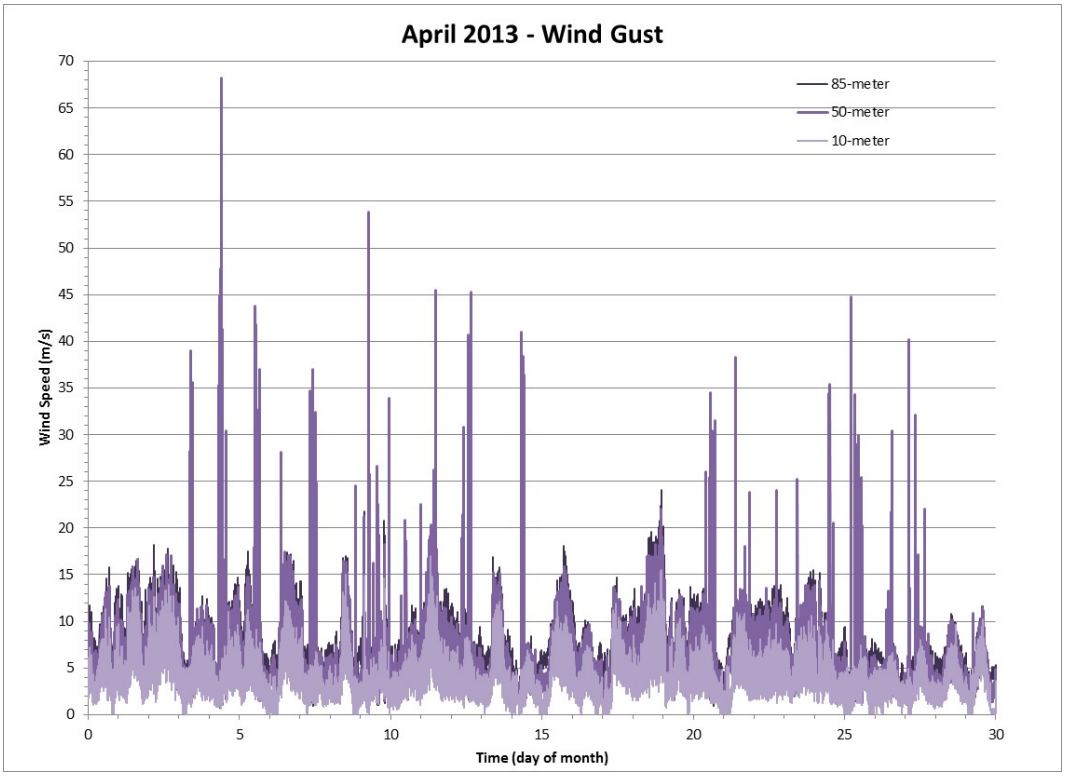

Figure 77. Wind Gust data for the Month of April 2013

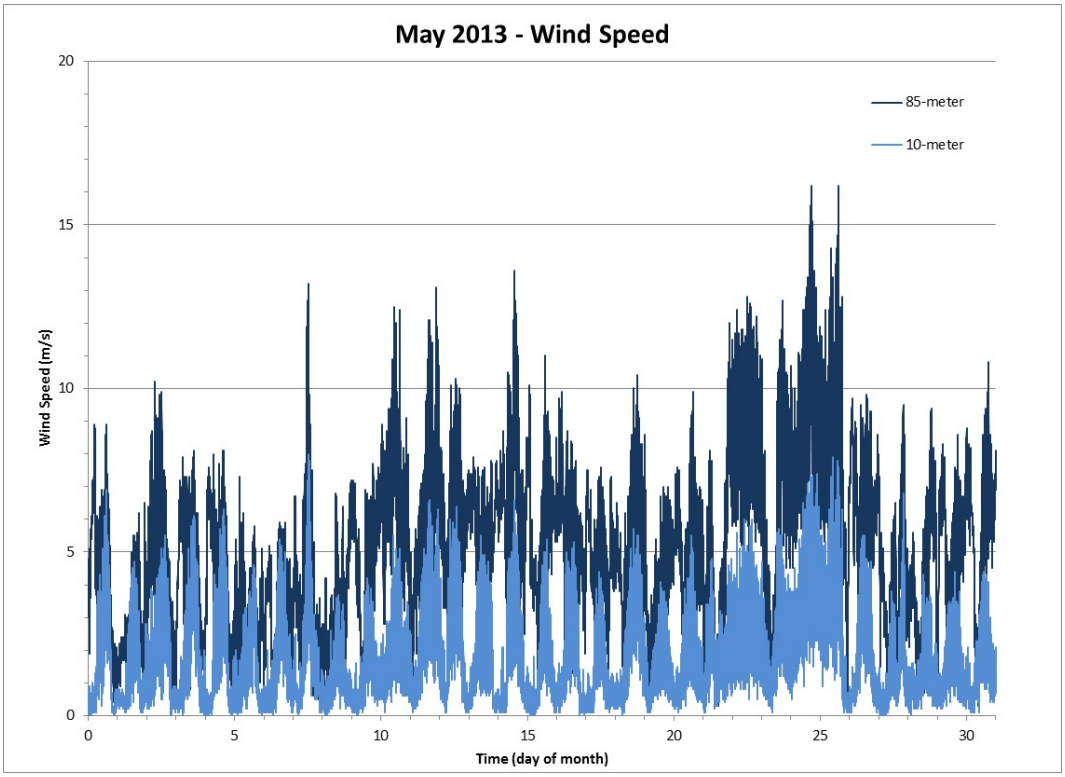

Figure 78. Wind Speed for the Month of May 2013

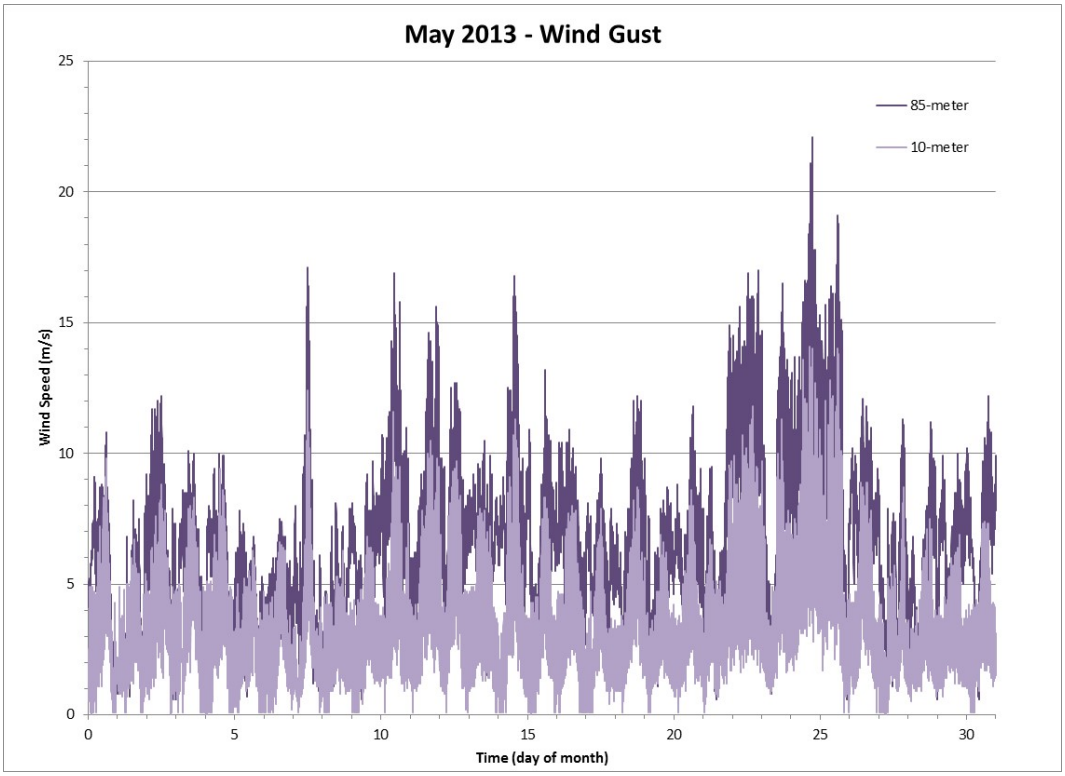

Figure 79. Wind Gust data for the Month of May 2013

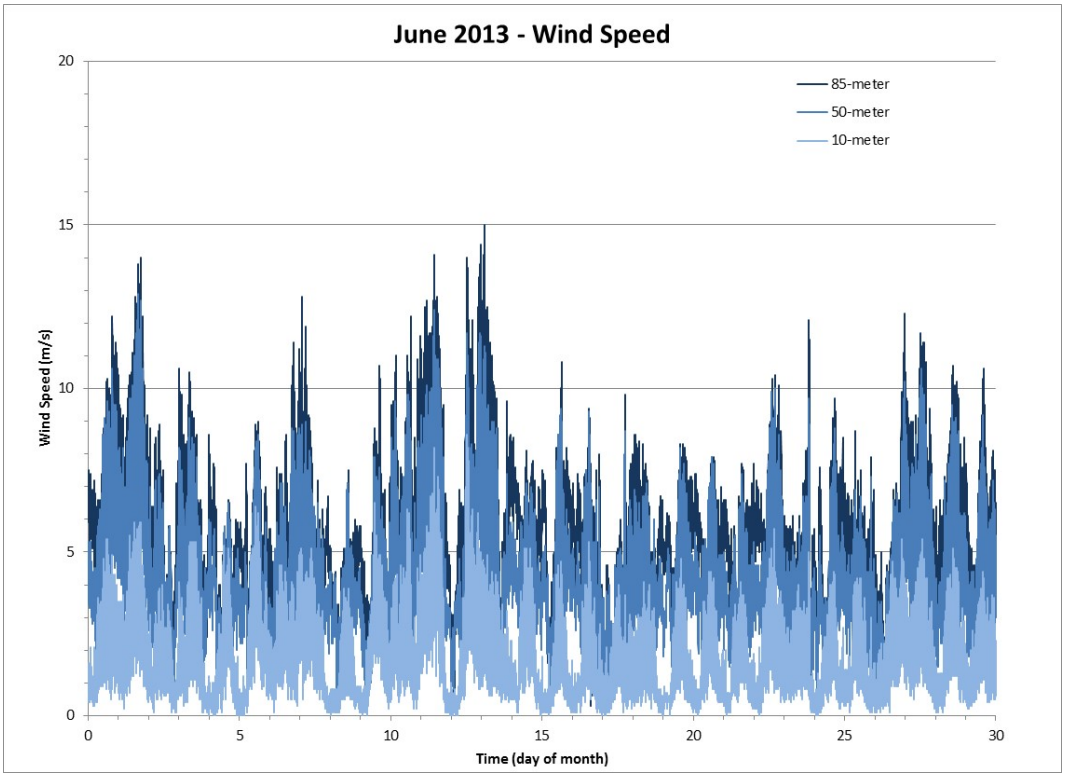

Figure 80. Wind Speed for the Month of June 2013

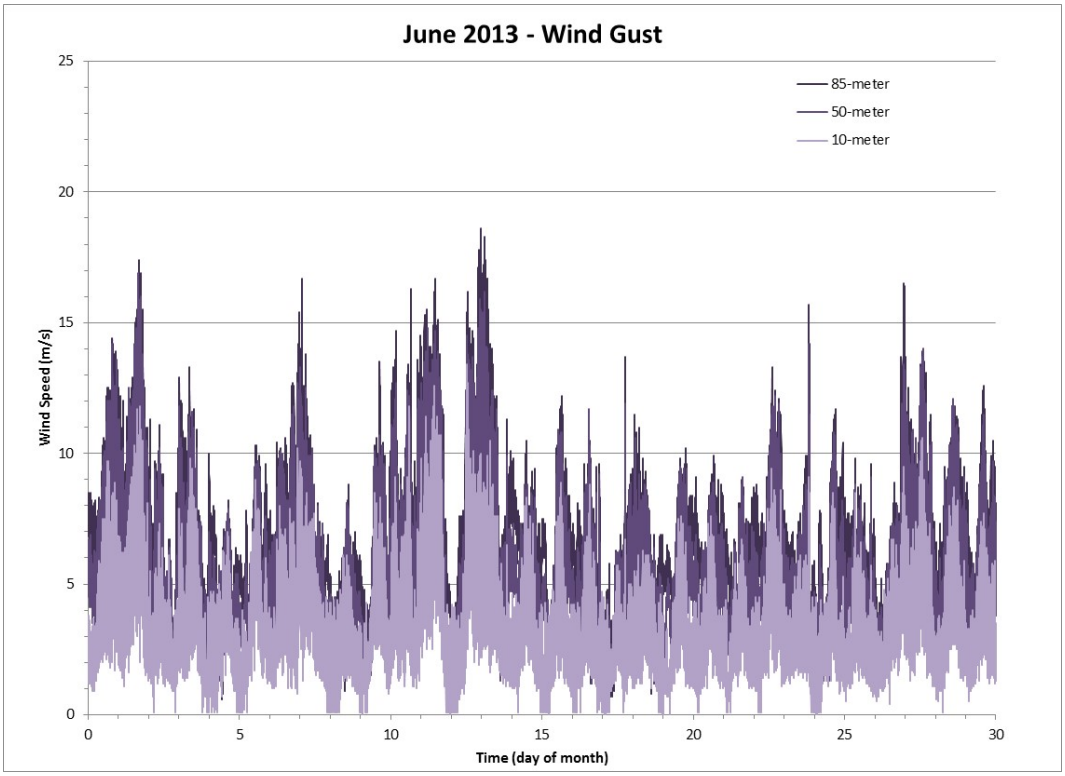

Figure 81. Wind Gust data for the Month of June 2012

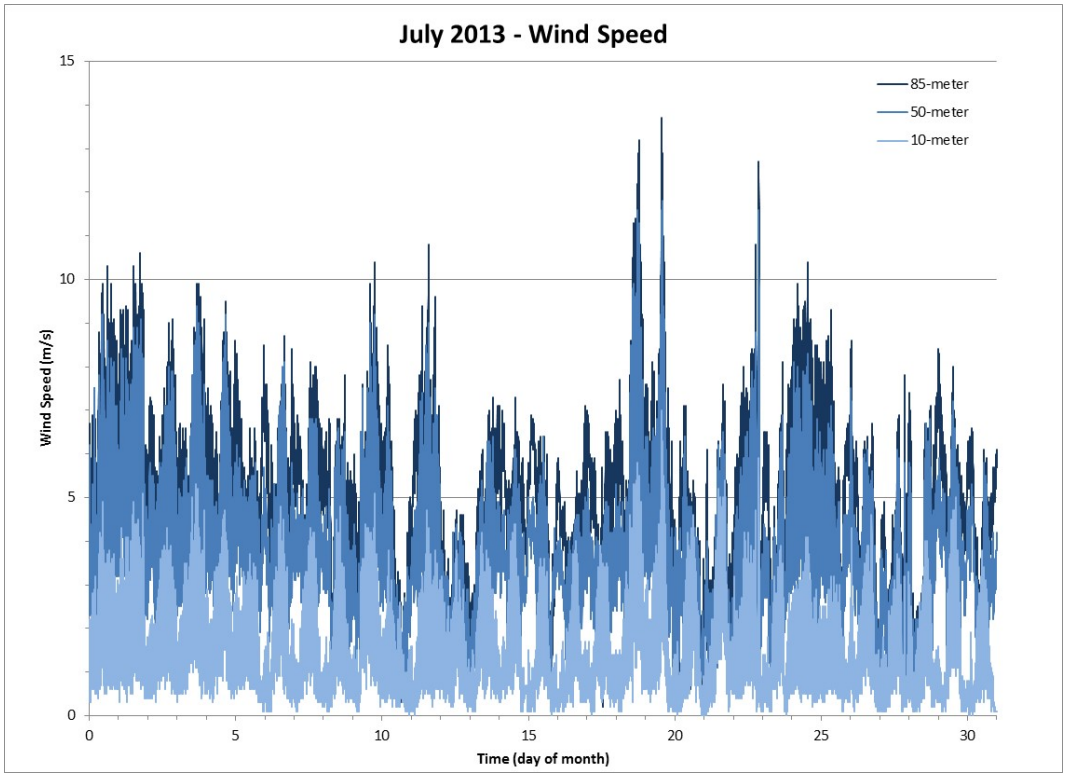

Figure 82. Wind Speed for the Month of July 2013

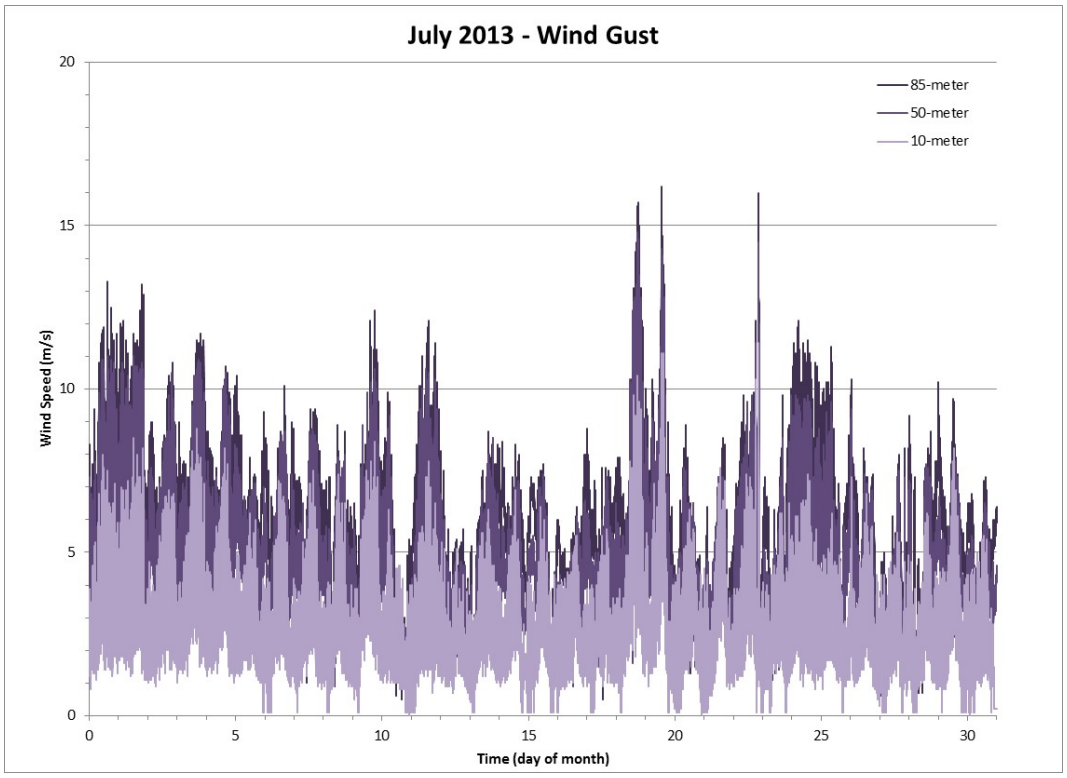

Figure 83. Wind Gust data for the Month of July 2013

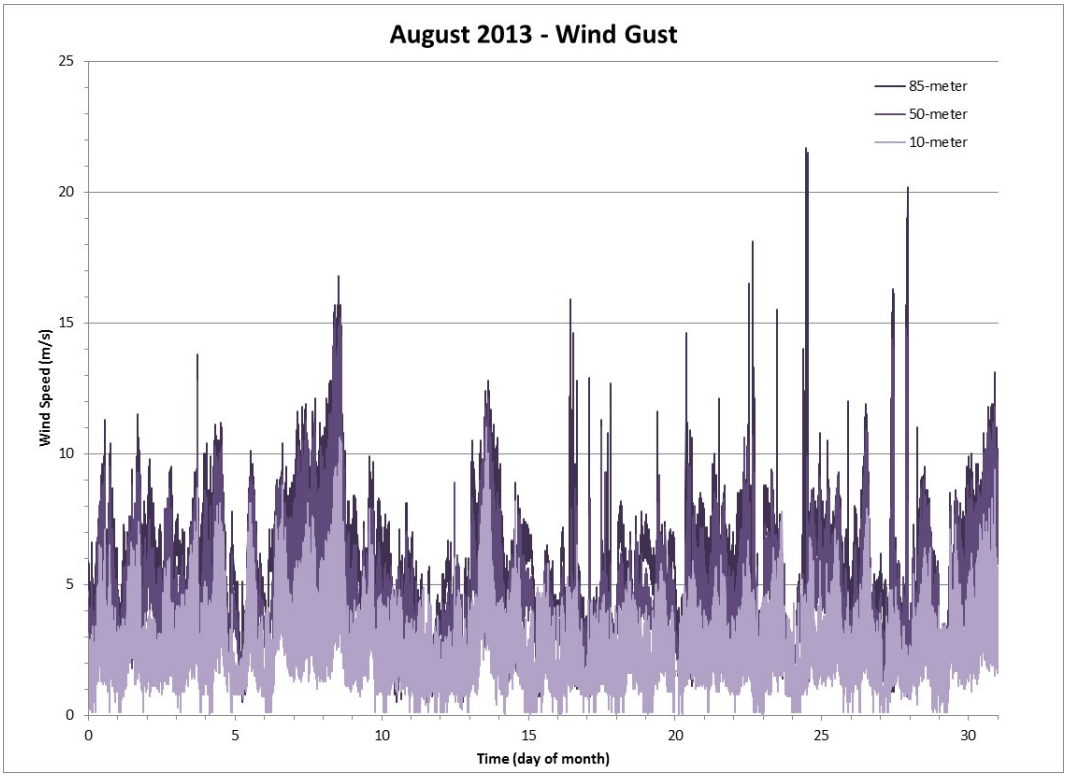

Figure 84. Wind Speed for the Month of August 2013

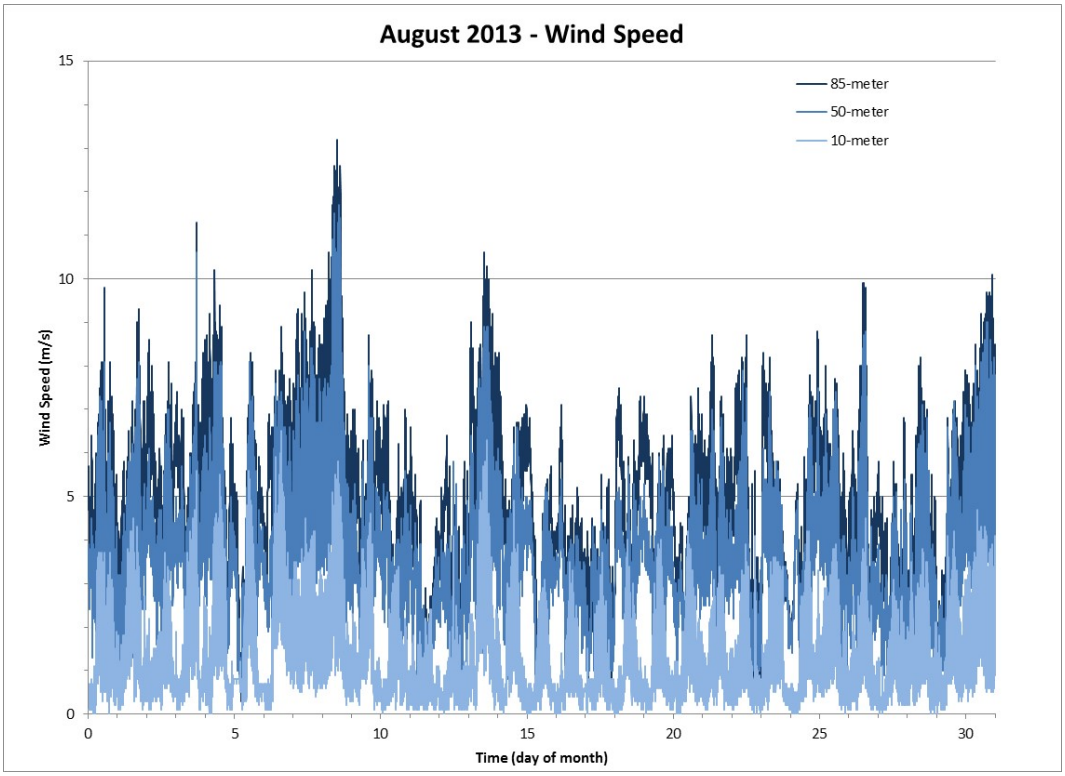

Figure 85. Wind Gust data for the Month of August 2013

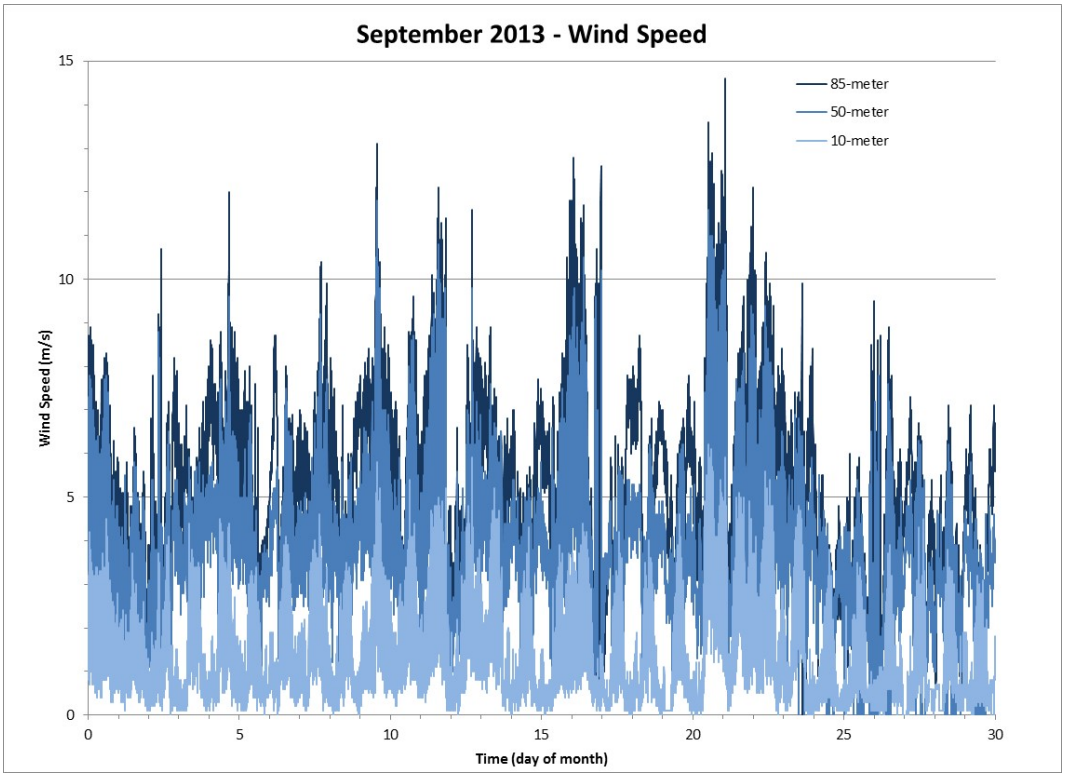

Figure 86. Wind Speed for the Month of September 2013

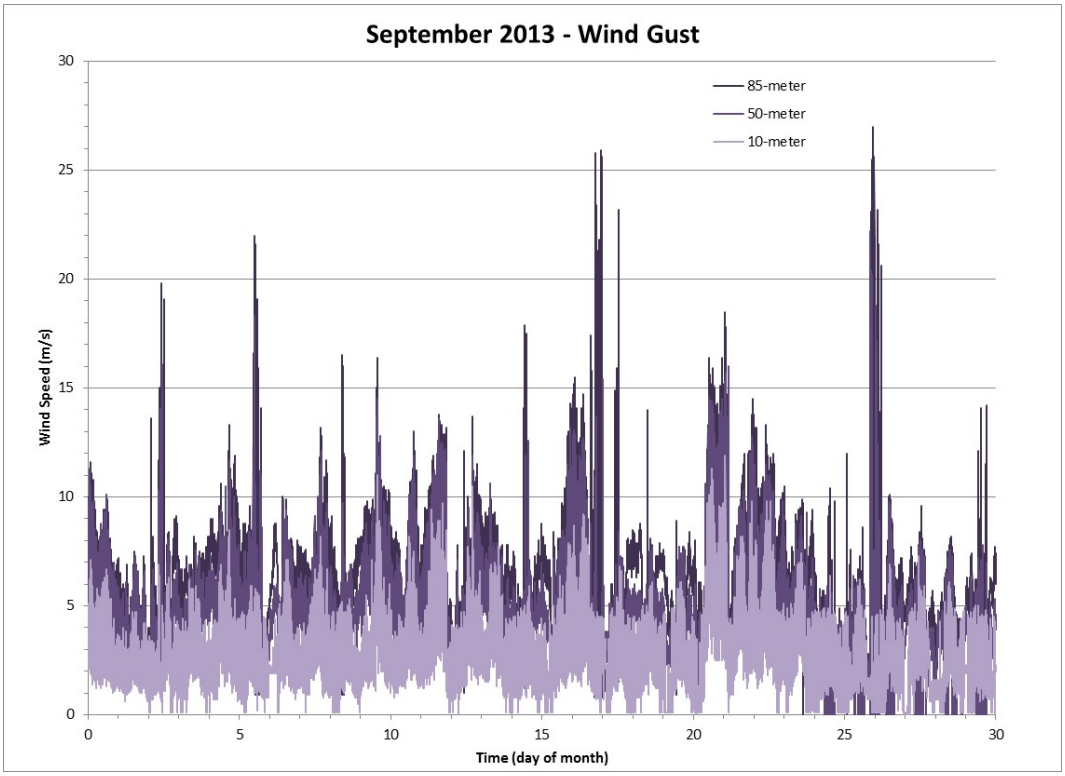

Figure 87. Wind Gust data for the Month of September 2013

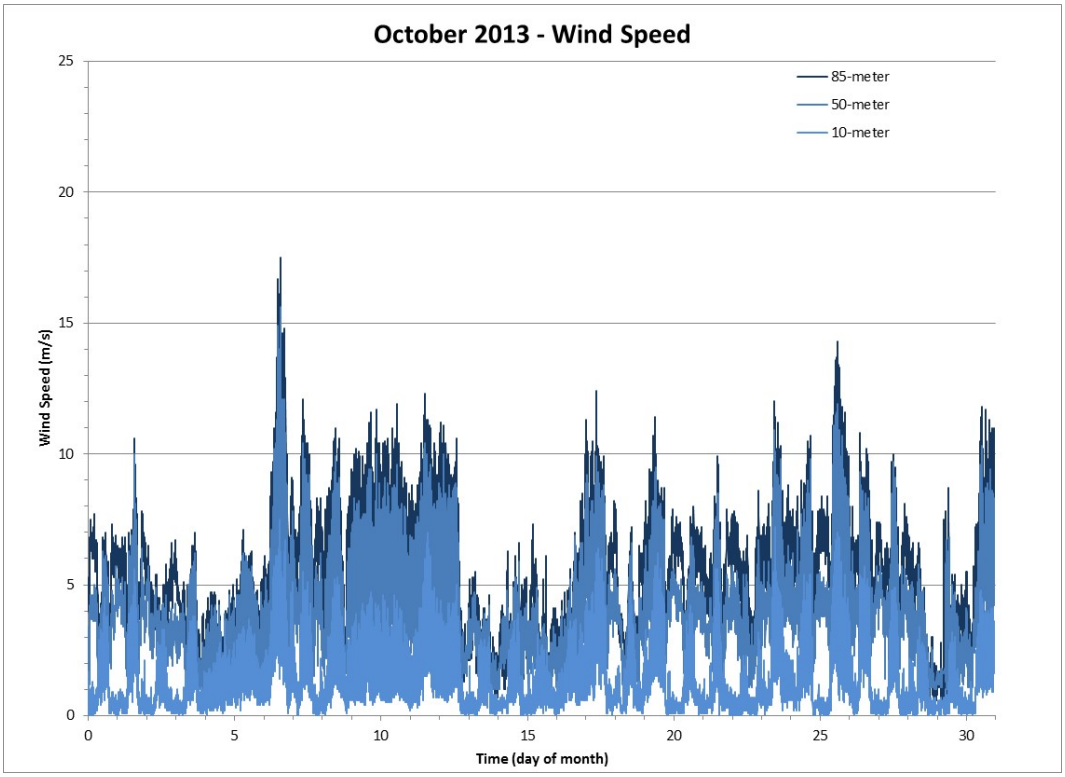

Figure 88. Wind Speed for the Month of October 2013

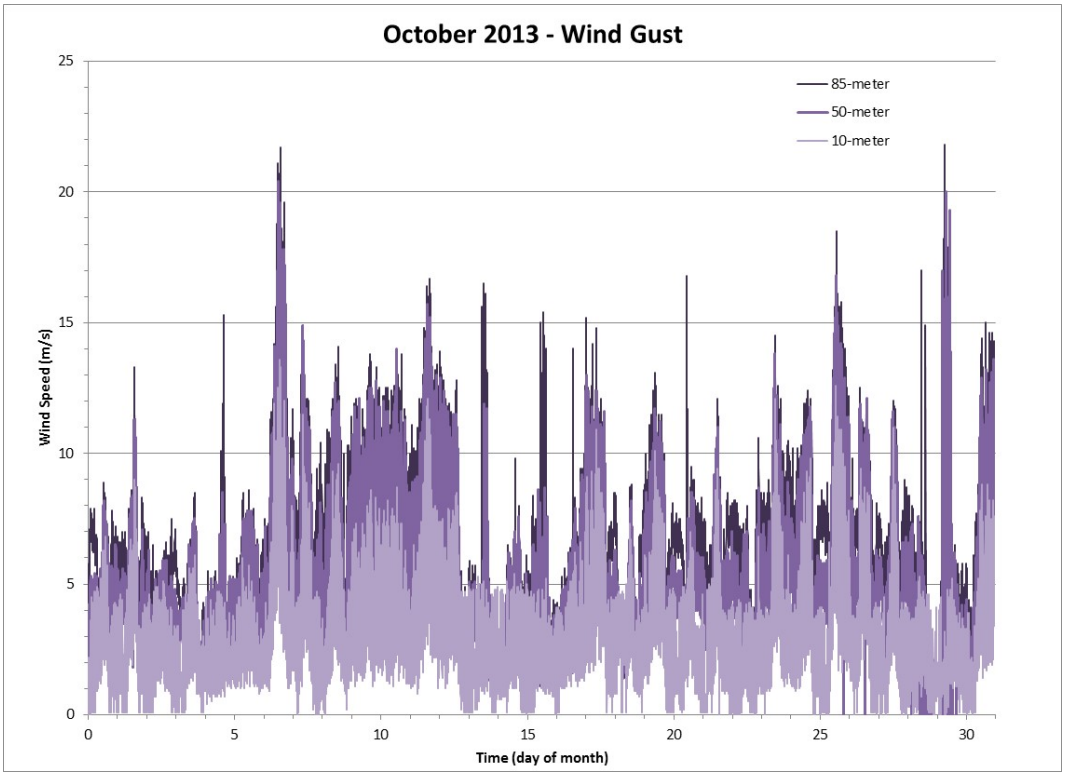

Figure 89. Wind Gust data for the Month of October 2013

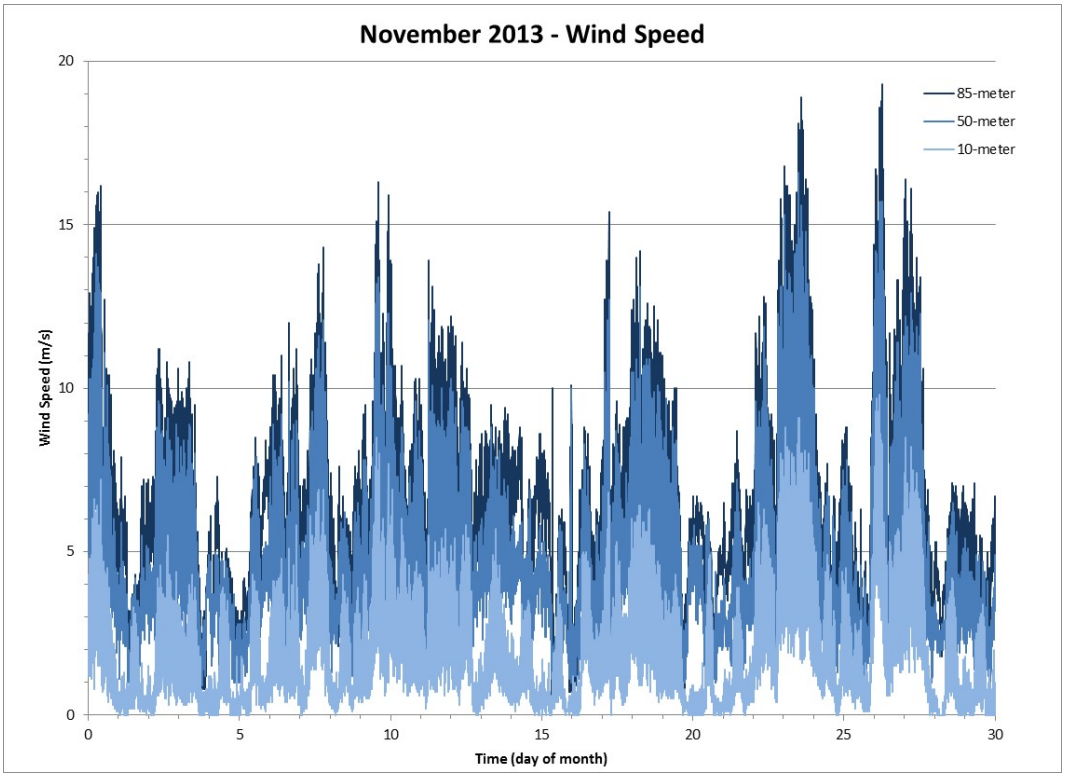

Figure 90. Wind Speed for the Month of November 2013

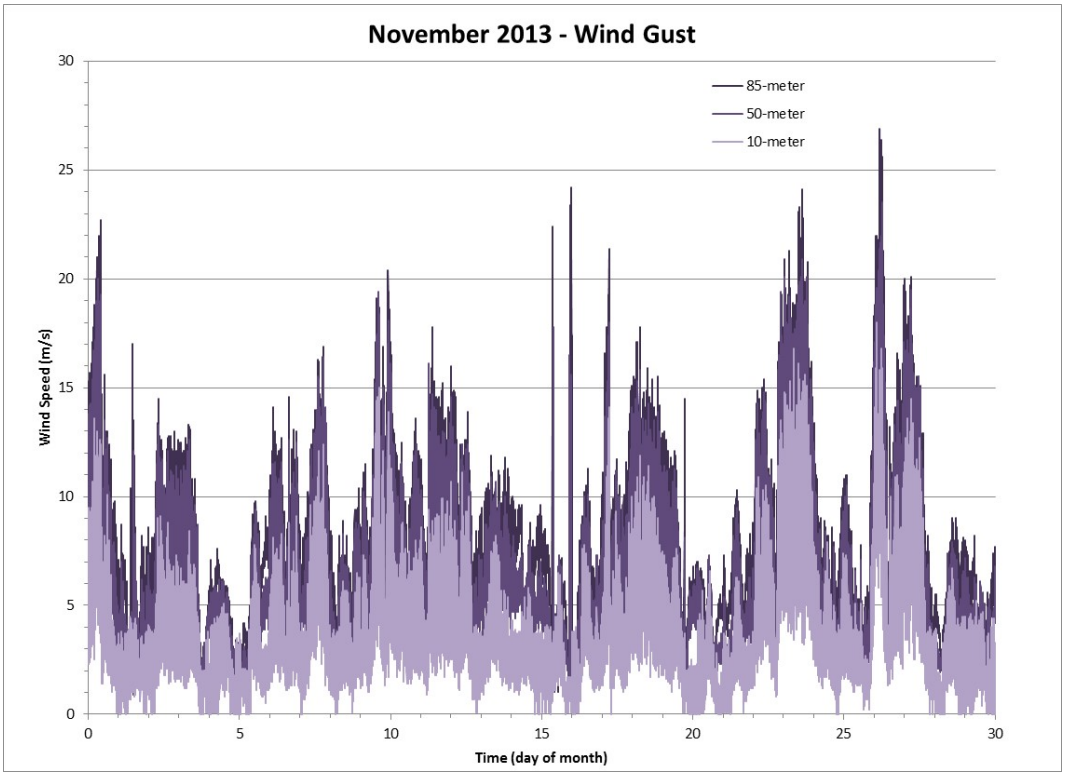

Figure 91. Wind Gust data for the Month of November 2013

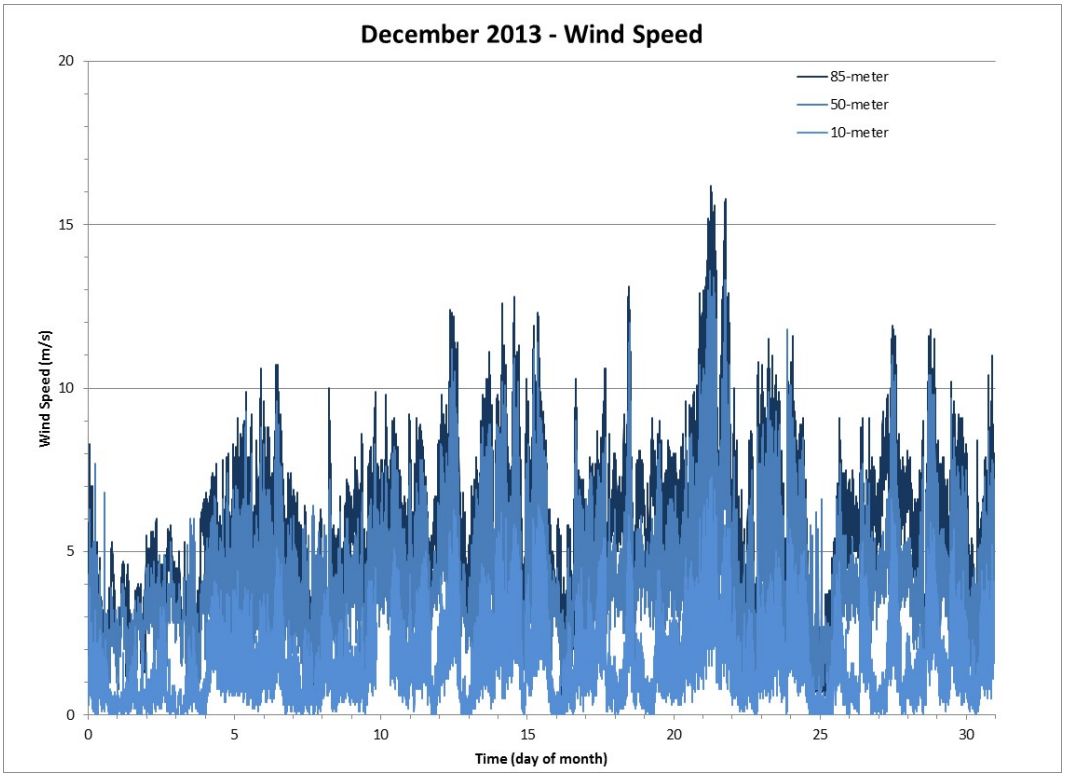

Figure 92. Wind Speed for the Month of December 2013

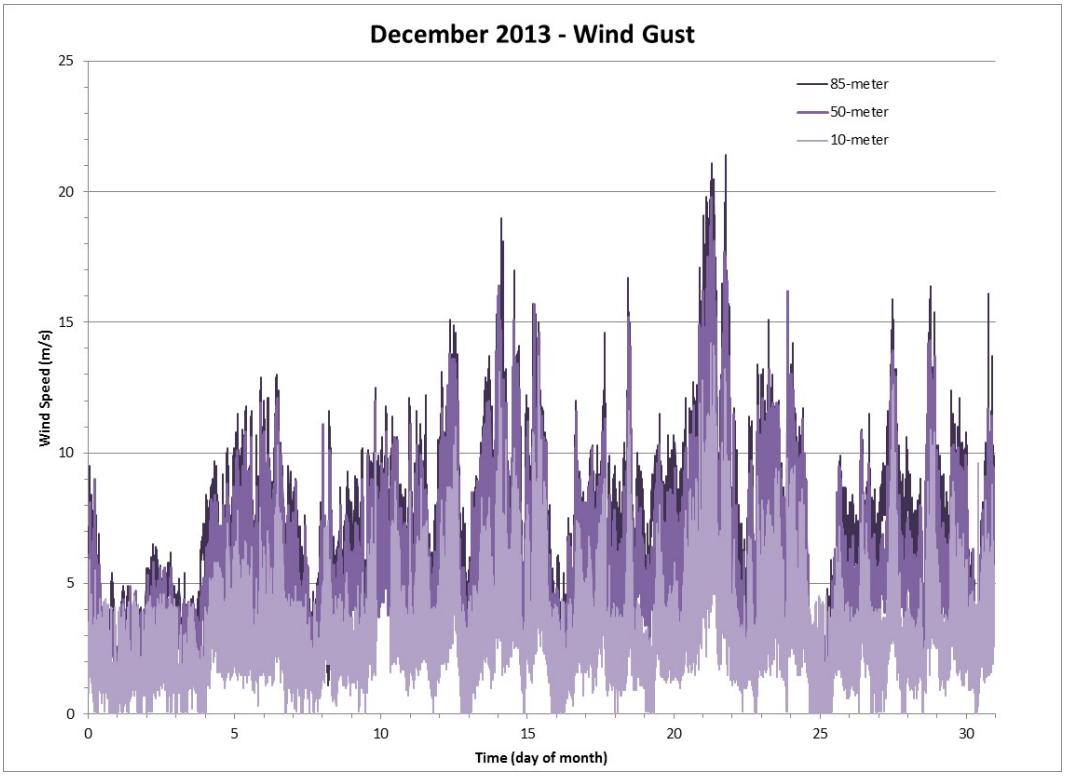

Figure 93. Wind Gust data for the Month of December 2013

2012 Solar Resource Data

High quality solar resource data is important to research in the field of renewable energy. With BNL being home to the Long Island Solar Farm (LISF) and future site of the Northeast Solar Energy Research Center (NSERC), it is important that BNL have a local source of dependable, quality assured data on solar radiation. As such BNL maintains a solar base station that records research grade one-minute data. This section reports solar incidence data including monthly data plots of the one-minute data. The SOLYS-2 tracker was out of service from May 9 to July 11, 2011, so data plots for May and July for diffuse, direct and long-wave far infrared radiation are incomplete and June is missing.

Global Solar Radiation

Global solar irradiance is the total irradiance falling on a horizontal surface. It is the total of diffuse radiation plus the direct normal radiation multiplied by the cosine of the solar zenith angle. Global short-wave radiation (near ultraviolet, visible & near-infrared) is measured using a Kipp & Zonen CMP-22 pyranometer attached to a powered ventilator and mounted on a SOLYS-2 sun tracker. This unit is sent off-site for calibration in the NREL BORCAL program. Currently, when the unit is out for calibration it is replaced with a calibrated CMP-21 pyranometer. The CMP-21 is a high precision research grade pyranometer that includes an integrated housing temperature sensor. The CMP-22 is also a high precision research grade pyranometer with a higher optical quality and higher refractive index quartz dome housing the sensor. Figures 97 through 108 present the monthly plots of global solar radiation.

Figure 94 presents the peak global solar irradiance at BNL for 2012. Figure 95 presents the average daily global solar irradiance at BNL for 2012. Figure 96 shows the monthly average daily irradiance for global and in-plane (angled to match the LISF panels). Table 7 gives the 2012 and historical monthly daily averages for global solar irradiance.

Table 7. Average Daily Solar Irradiance (Global) at BNL by Month (W/m^2)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1994	72.2	116.7	147.7	207.9	246.9	265.2	259.8	193.4	187.5	152.3	92.6	72.5	167.9
1995	74.9	108.1	182.7	231.9	281.6	168.3	97.4	*301.1*	290.0	151.1	85.5	77.4	170.8
1996	63.2	113.9	171.6	193.7	242.0	239.0	222.8	227.1	158.6	145.2	92.9	*52.5*	160.2
1997	80.1	119.4	152.4	226.6	261.3	283.7	288.6	225.2	180.4	145.4	78.4	70.8	176.0
1998	72.4	113.4	146.5	215.0	243.3	283.5	268.4	255.5	204.3	139.5	98.3	64.7	175.4
1999	73.5	114.4	195.3	223.2	249.6	285.3	270.1	223.9	219.4	156.0	97.1	77.6	182.1
2000	82.7	122.4	182.8	171.7	278.3	267.5	265.5	212.8	208.4	194.6	120.7	81.9	182.4
2001	81.7	125.1	148.3	220.6	289.4	281.5	284.2	227.5	202.6	159.3	105.9	74.7	183.4
2002	78.0	162.4	161.2	230.5	264.4	289.4	291.7	271.6	191.7	122.8	78.8	70.3	184.4
2003	83.9	74.3	174.1	191.8	190.4	262.6	249.8	294.6	175.3	118.8	80.4	58.8	162.9

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2004	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2005	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2006	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2007	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2008	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2009	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2010	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2011	86.2	121.1	177.5	172.6	223.6	254.2	276.7	223.7	130.0	130.3	97.5	75.2	164.1
2012	91.5	126.5	163.7	254.3	199.2	268.3	249.0	231.8	179.6	110.0	92.8	59.8	168.9
2013	82.6	109.8	163.0	243.9	236.7	256.7	239.0	210.4	189.8	128.6	96.1	60.9	168.1
Average	**78.7**	**117.5**	**166.7**	**214.1**	**246.7**	**261.9**	**251.0**	**238.4**	**193.7**	**143.8**	**93.6**	**69.0**	**172.8**
Max	91.5	162.4	195.3	254.3	289.4	289.4	291.7	*301.1*	290.0	194.6	120.7	81.9	184.4
Min	63.2	74.3	146.5	171.7	190.4	168.3	97.4	193.4	130.0	110.0	78.4	*52.5*	160.2

nan indicates missing data, Values in fields filled in yellow are the monthly averages inserted because of partially missing data, the average then changes with addition of this value.

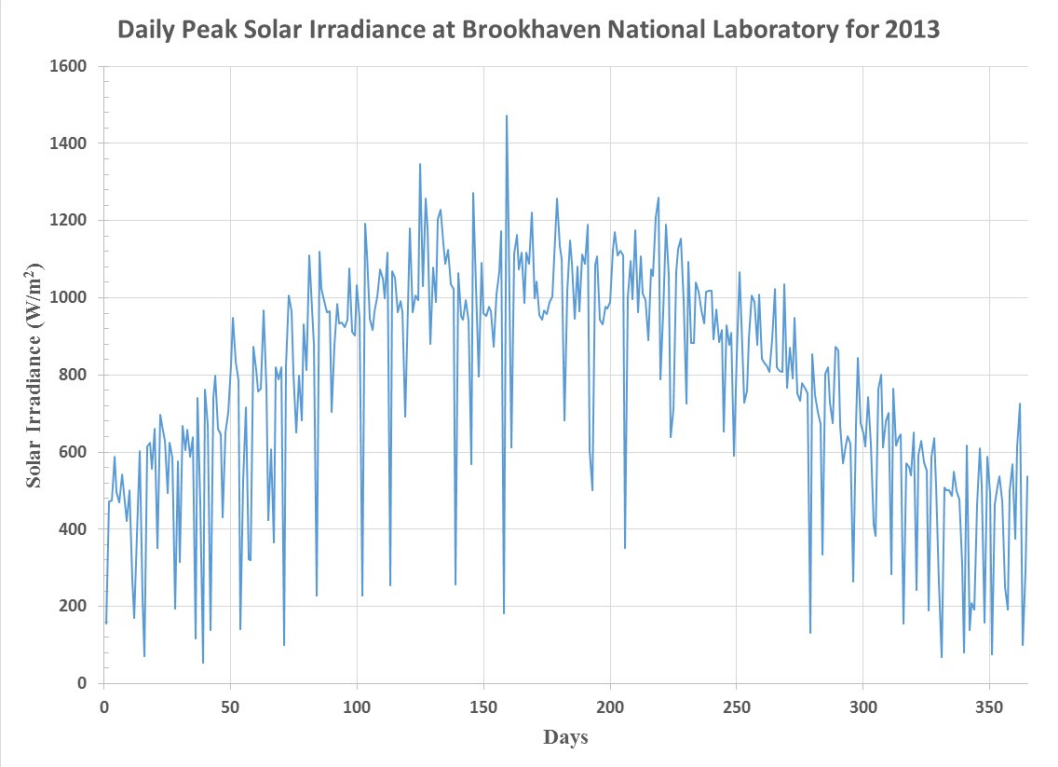

Figure 94. Daily Peak Solar Irradiance at Brookhaven National Laboratory for 2013

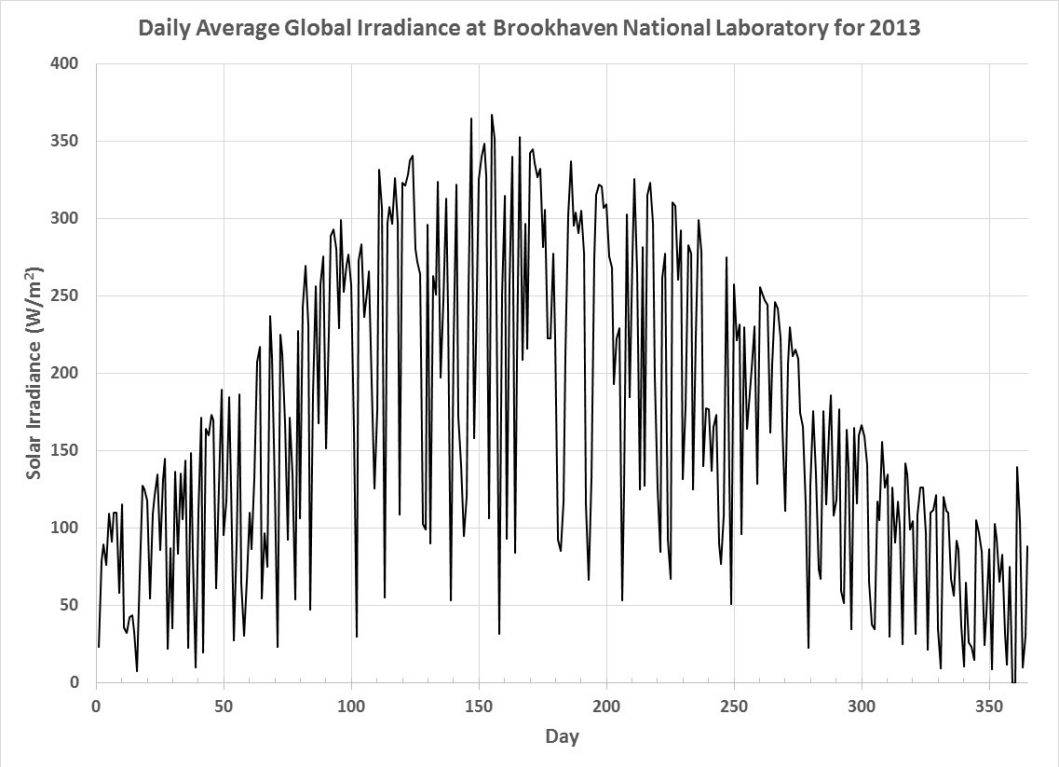

Figure 95. Average Daily Solar Irradiance at Brookhaven National Laboratory for 2013

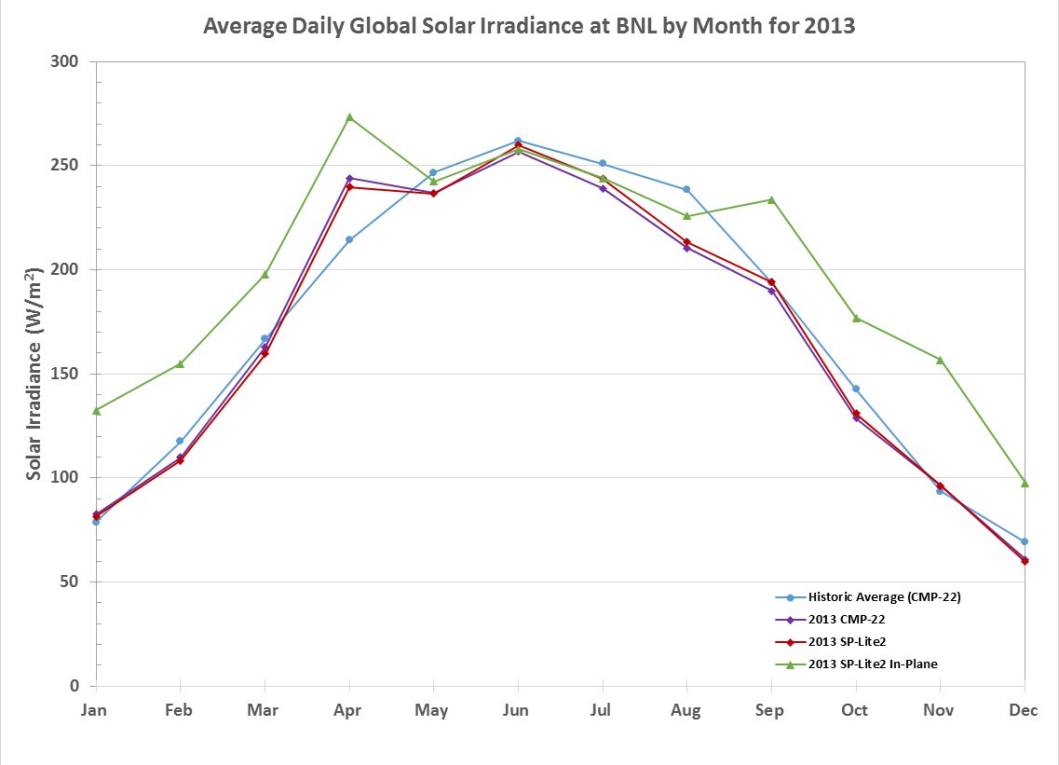

Figure 96. Global Solar Irradiance – 2013 Monthly Daily-Average

Diffuse Solar Radiation

Diffuse solar irradiance is the radiation that is scattered (i.e., by clouds and dust particles) as it passes through the atmosphere. Diffuse short-wave radiation (ultraviolet, visible & near-infrared) is measured using a shaded Kipp & Zonen CMP-22 pyranometer with a powered ventilator mounted on a SOLYS-2 sun tracker. This unit is sent off-site for calibration in the NREL BORCAL program. Currently, when the unit is out for calibration it is replaced with a calibrated CMP-21 pyranometer. Figures 109 through 120 present the monthly plots of diffuse solar radiation.

Direct Solar Radiation

Direct solar irradiance is the solar radiation that travels in a straight path to a detector that is perpendicular to the light path. The direct short-wave radiation is measured with a Kipp & Zonen CHP-1 pyrheliometer attached to a SOLYS-2 sun tracker. The CHP-1 is a thermopile that absorbs 97-98% of the total incident radiation. The reported maximum uncertainty is 2% for hourly measurements and 1% for daily totals. BNL has only one pyrheliometer and direct normal radiation is not directly measured during the time the sensor is out for calibration. [During the calibration interval, direct solar radiation can be calculated from the global and diffuse measurements.] Figures 121 through 132 present the monthly plots of direct solar radiation.

Long-wave Far Infrared Radiation

Downward long-wave far infrared radiation is measured using a shaded Kipp & Zonen CGR-4 pyrgeometer with a powered ventilator mounted on the SOLYS-2 sun tracker. The CGR-4 is a research grade thermopile. This unit is sent off-site for calibration in the NREL BORCAL program. A duplicate unit is stocked which is sent to NREL for calibration and replaces the in service unit when returned. The CGR-4 has a built in temperature sensor and temperature correction is applied. The reported maximum daily uncertainty is 3%. Figures 133 through 144 present the monthly plots of direct solar radiation.

LISF Reference Pyranometers

The LISF has a network of pyranometers and meteorological sensors to provide data for solar research. Each of the 25 powerblocks has a pair of Kipp & Zonen pyranometers that measure global and tilted global solar radiation. As a reference for the LISF sensor array, two Kipp and Zonen model SP-lite2 pyranometers are maintained at the base station on building 490D, one in-plane (tilted global radiation) at the 27° angle of inclination used for the panels at the LISF and one horizontal (global radiation). The horizontal (global) solar radiation plots are presented in Figures 145 through 156. The in-plane or tilted global radiation is presented in Figures 157 through 168.

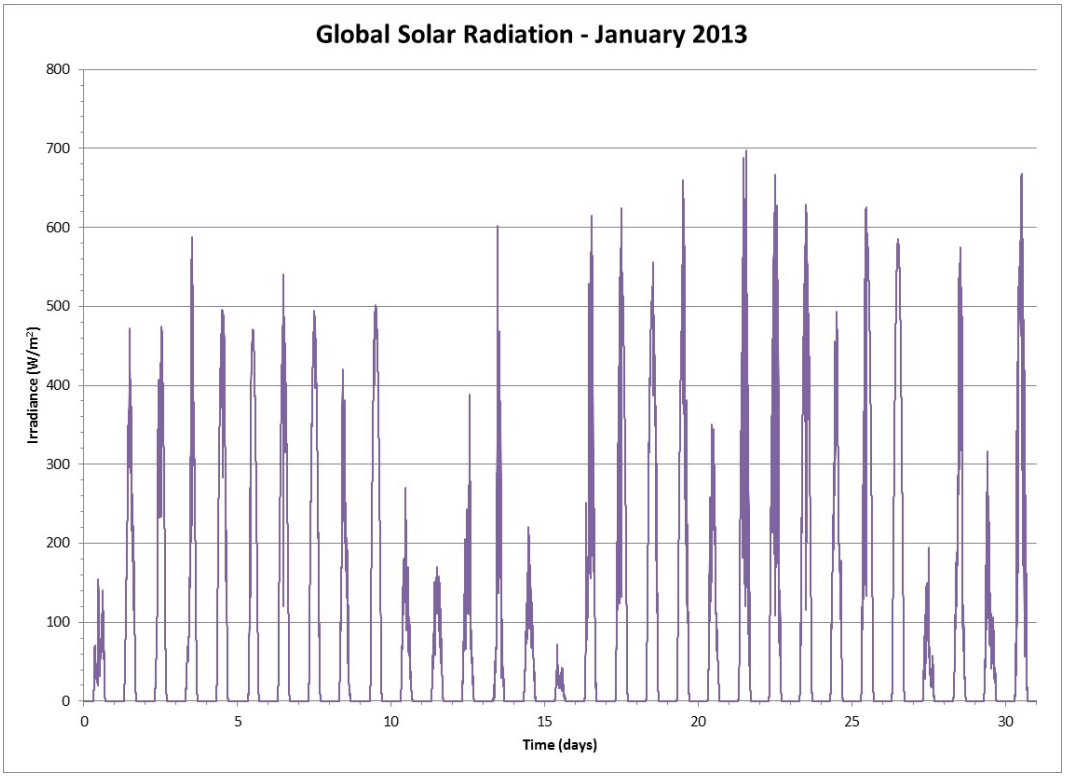

Figure 97. Global Solar Radiation for the Month of January 2013

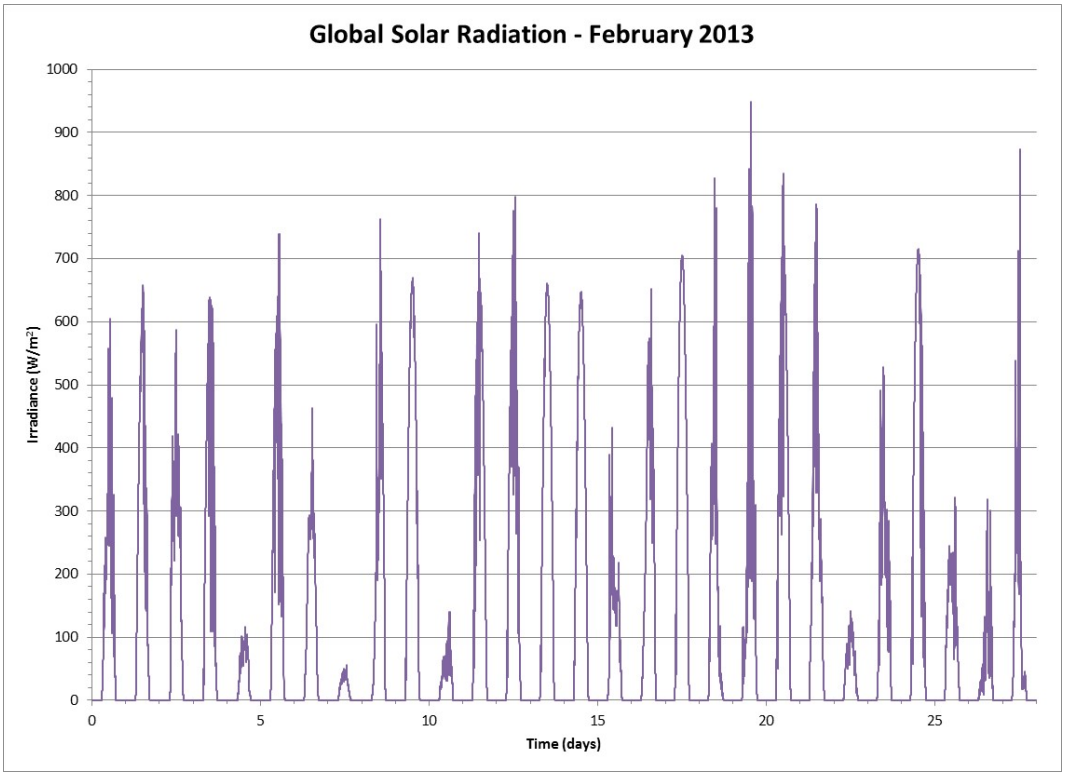

Figure 98. Global Solar Radiation for the Month of February 2013

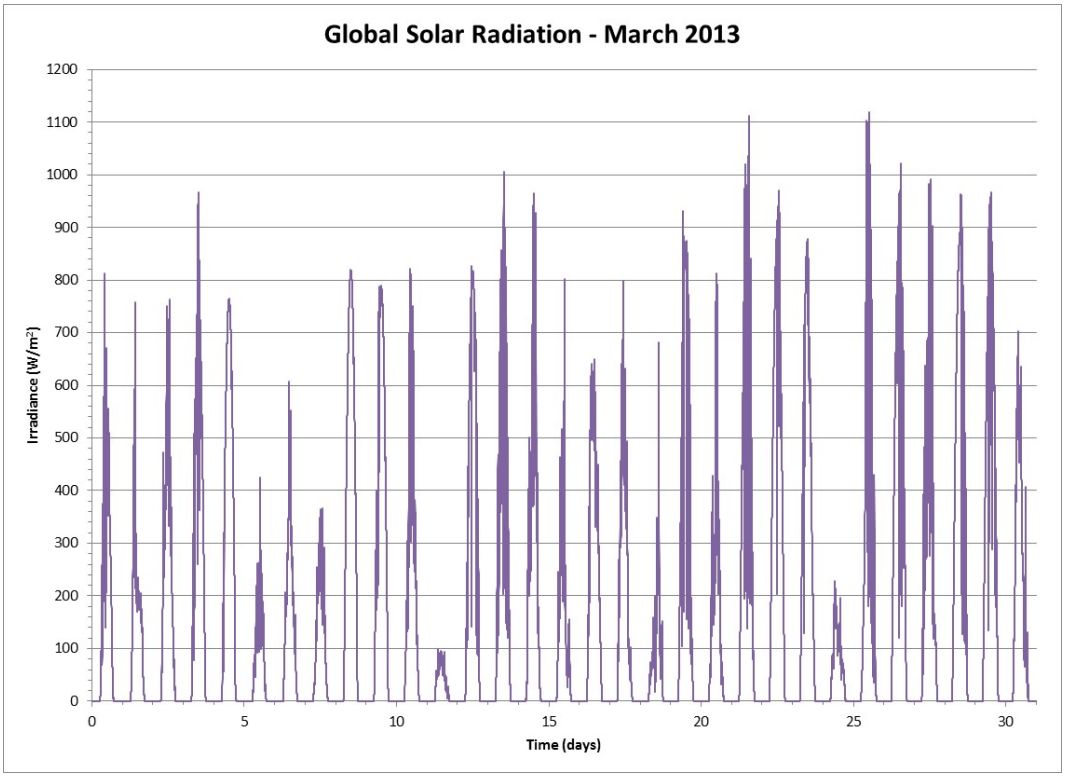

Figure 99. Global Solar Radiation for the Month of March 2013

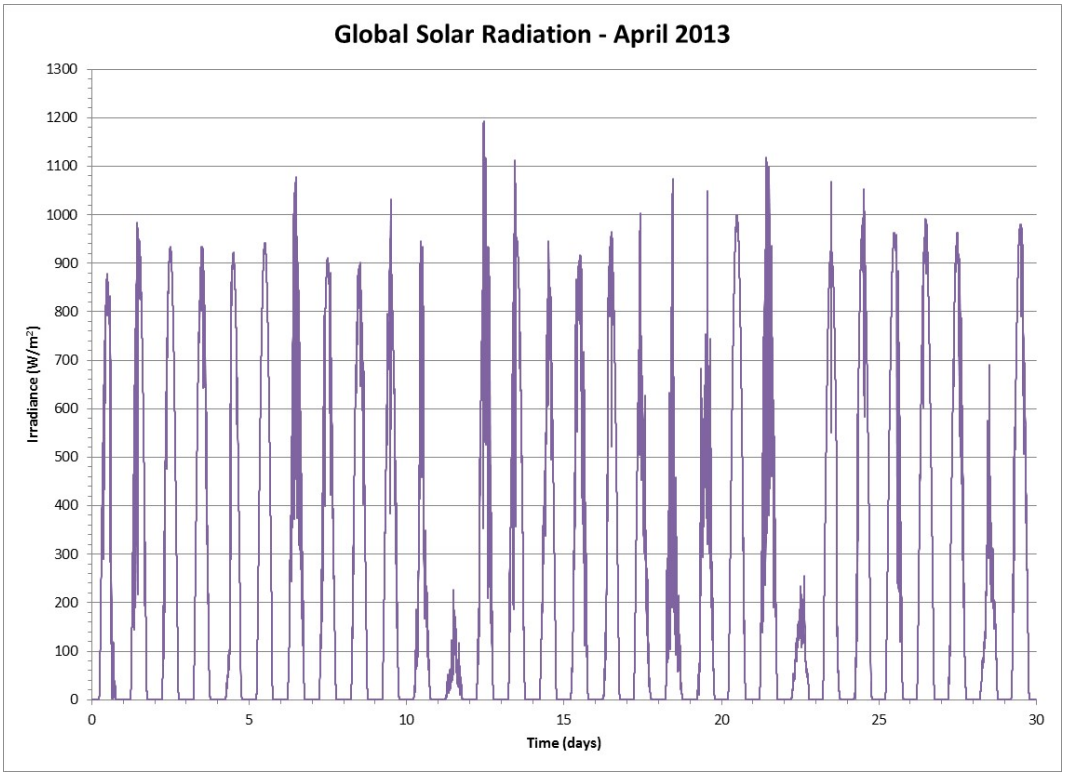

Figure 100. Global Solar Radiation for the Month of April 2013

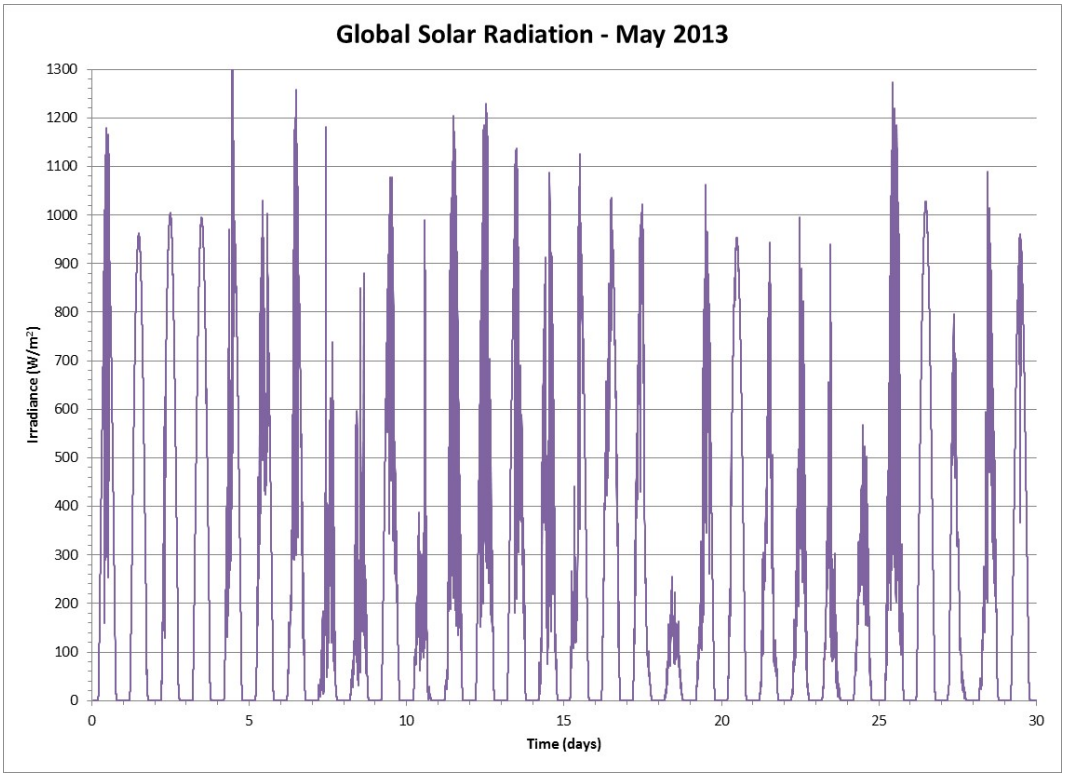

Figure 100. Global Solar Radiation for the Month of May 2013

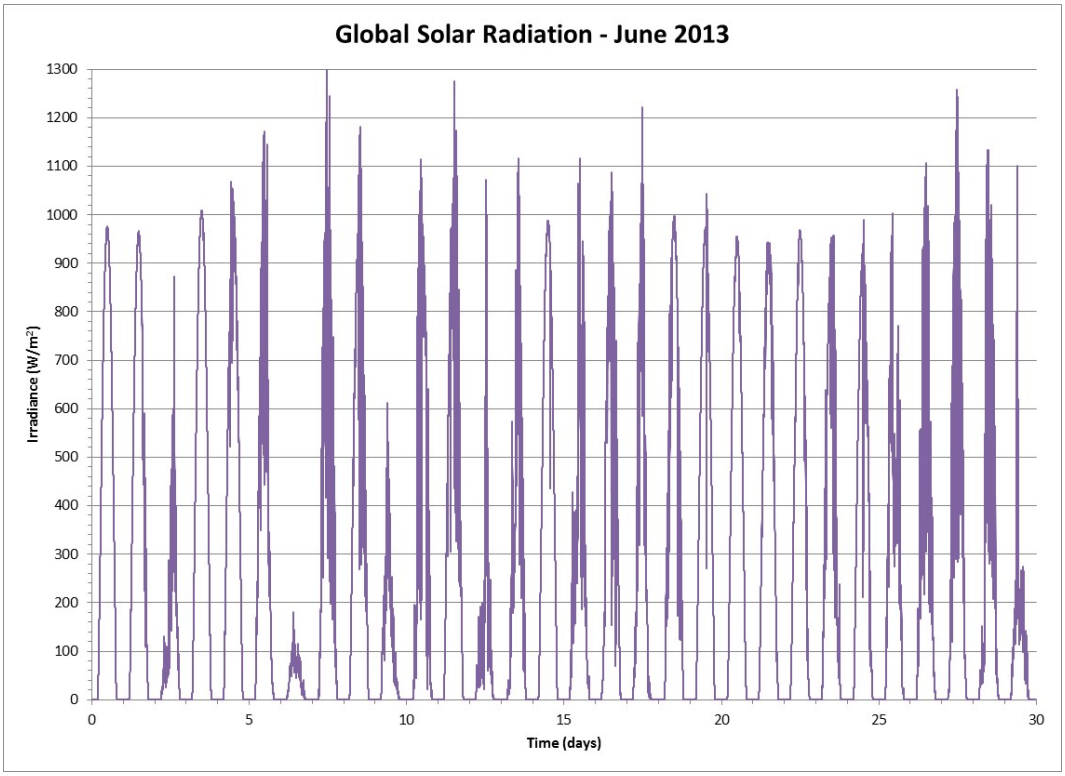

Figure 101. Global Solar Radiation for the Month of June 2013

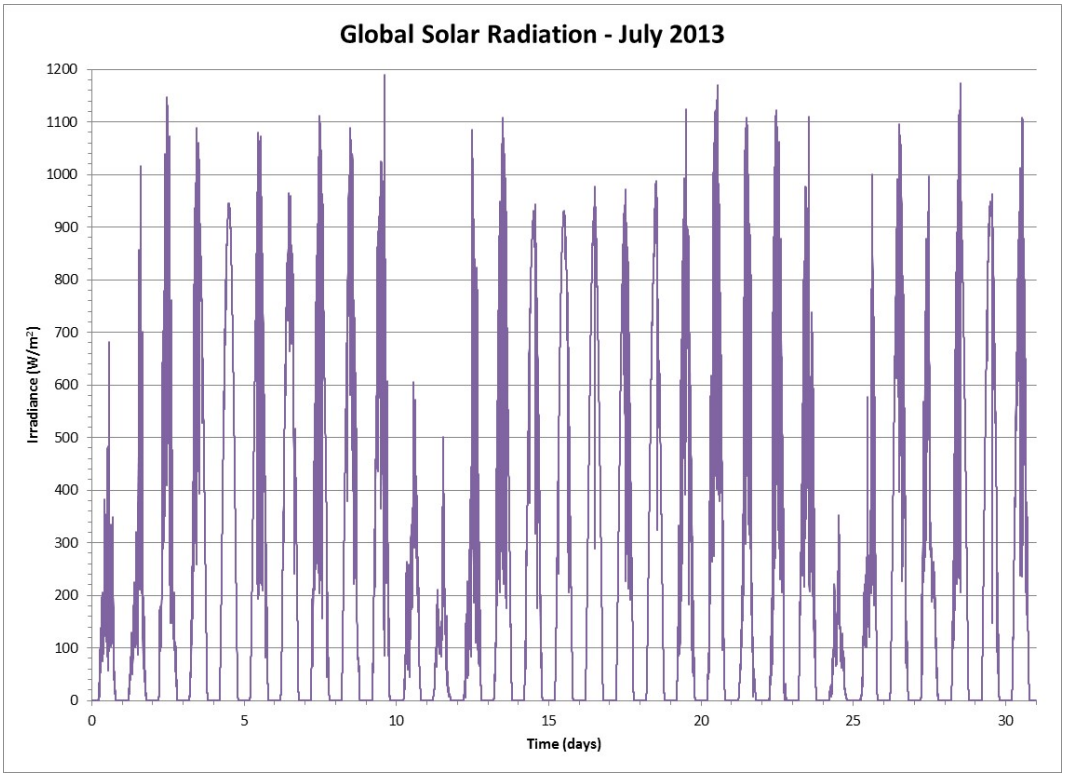

Figure 102. Global Solar Radiation for the Month of July 2013

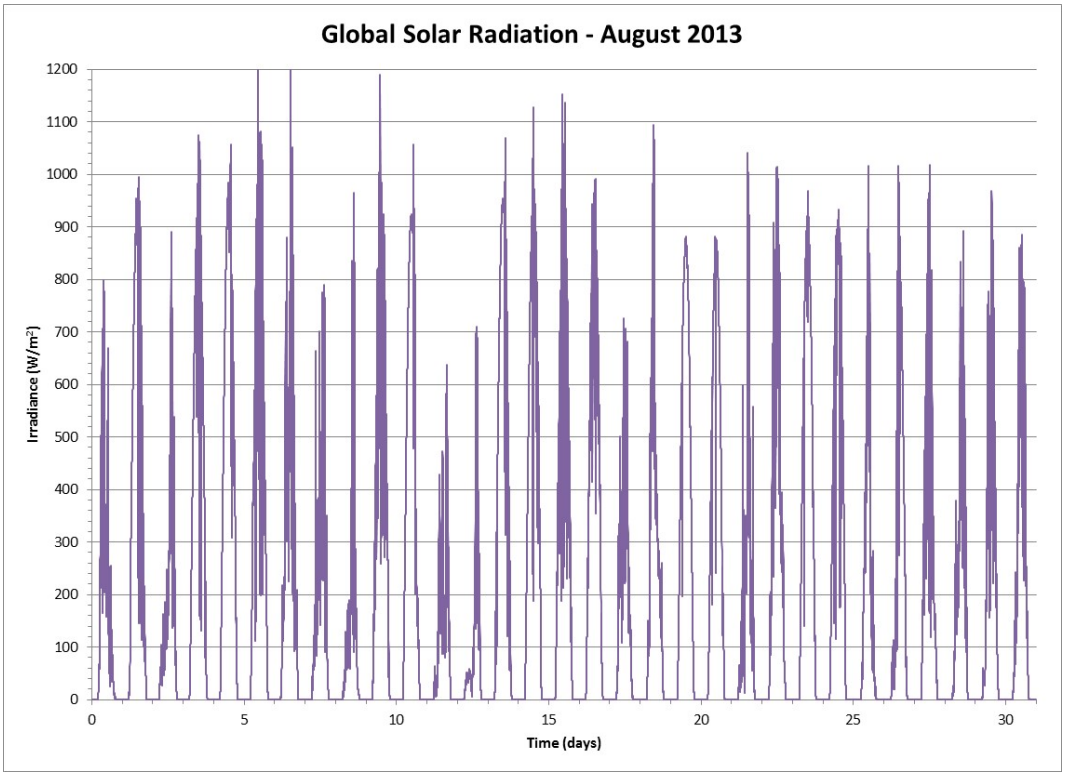

Figure 103. Global Solar Radiation for the Month of August 2013

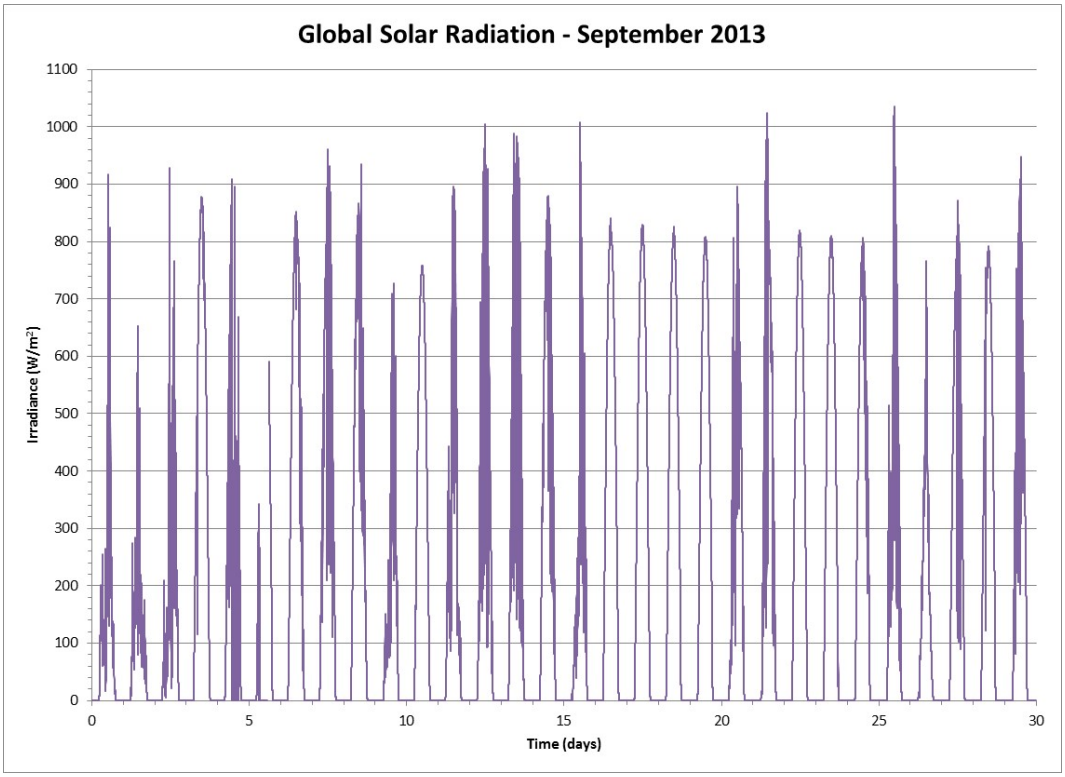

Figure 104. Global Solar Radiation for the Month of September 2013

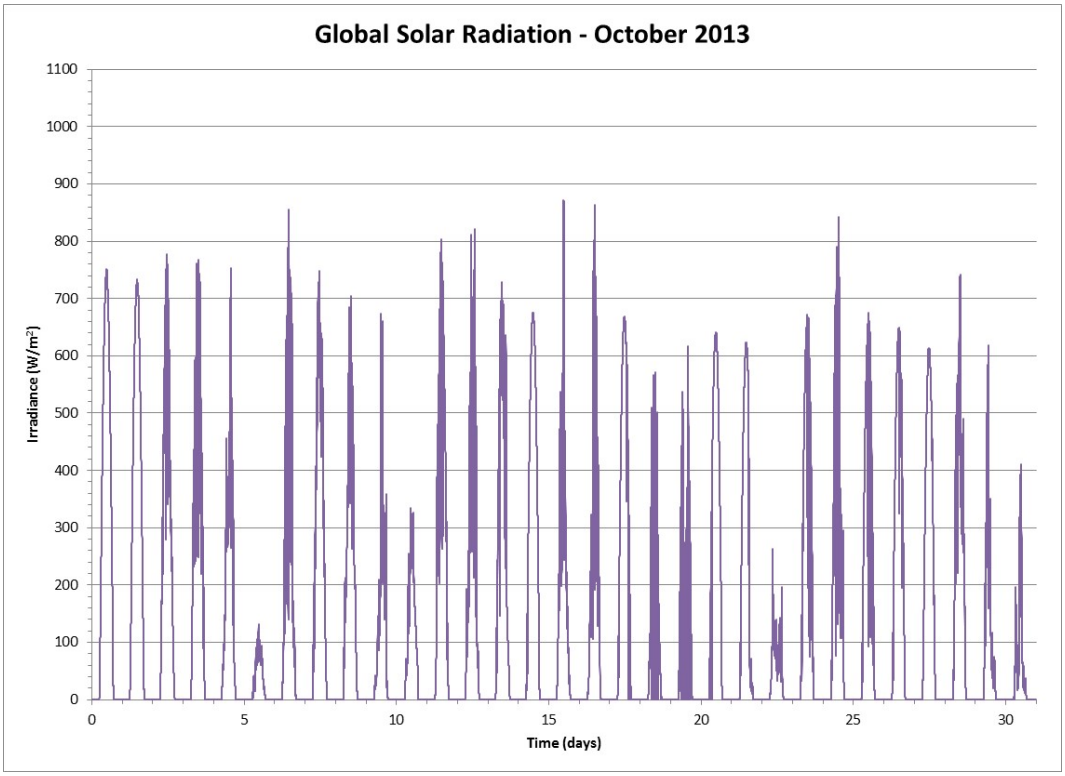

Figure 105. Global Solar Radiation for the Month of October 2013

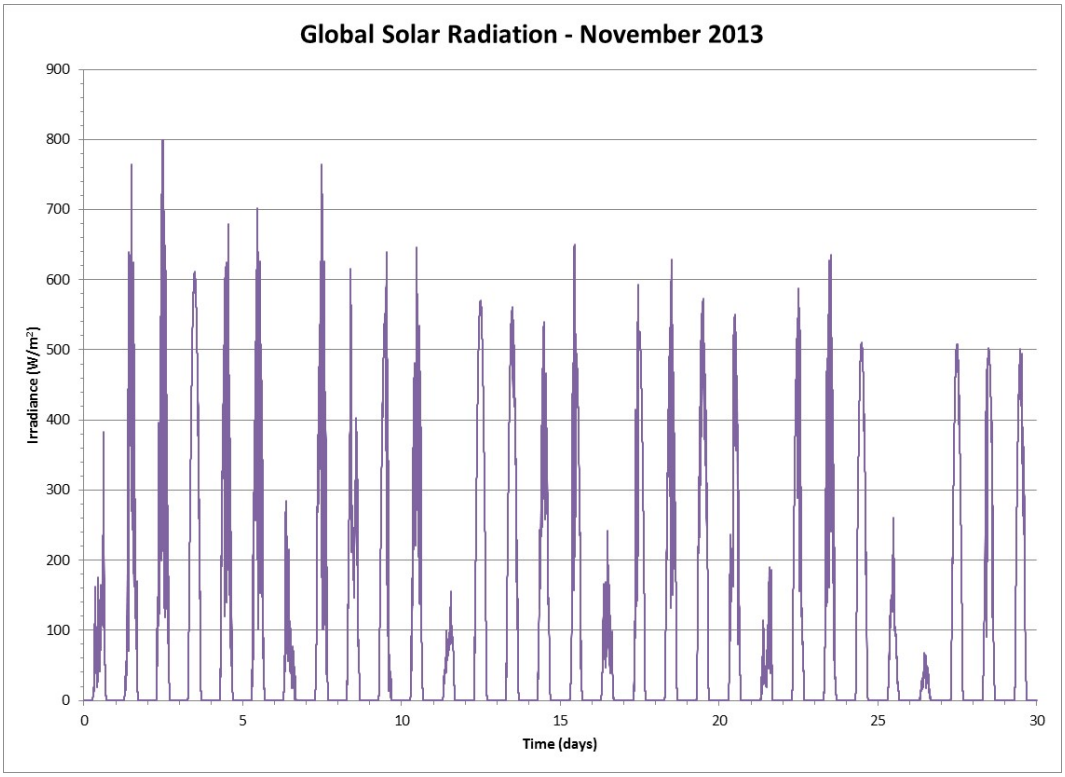

Figure 106. Global Solar Radiation for the Month of November 2013

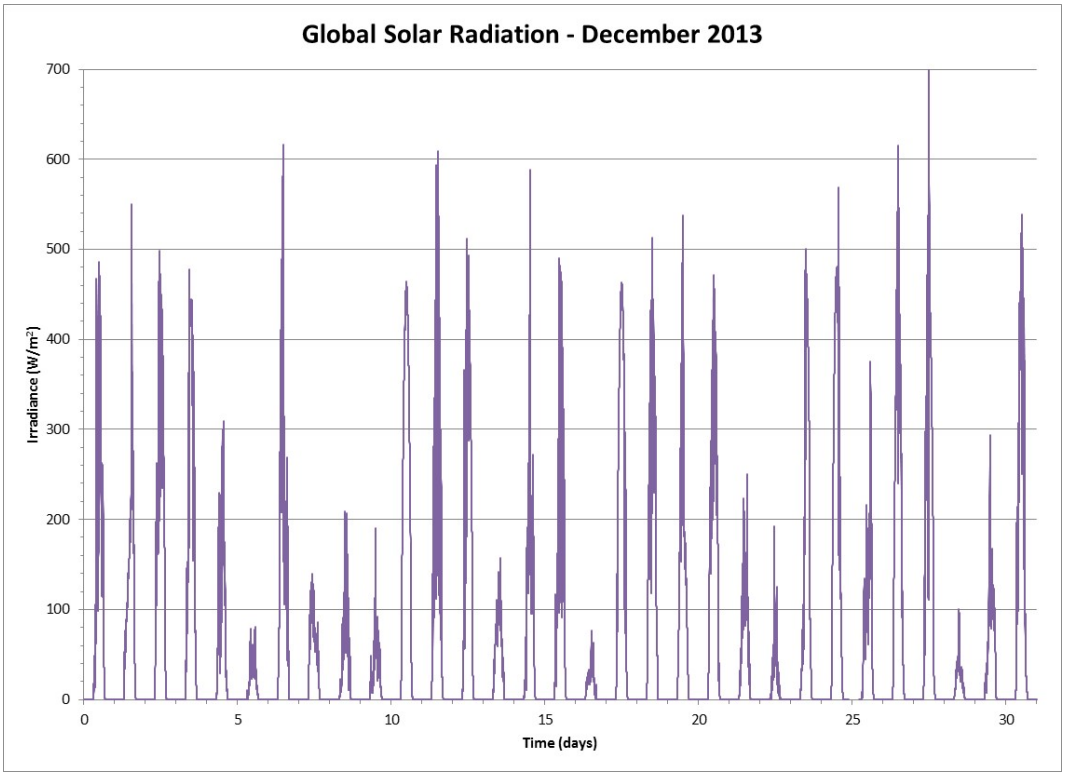

Figure 107. Global Solar Radiation for the Month of December 2013

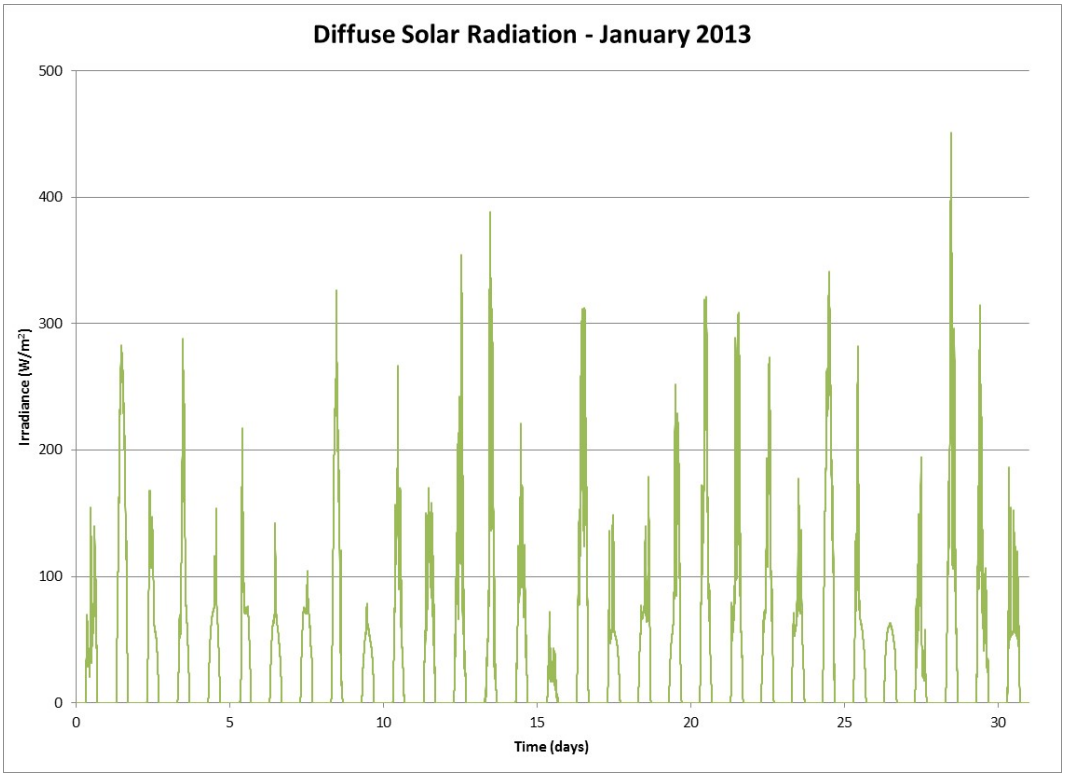

Figure 108. Diffuse Solar Radiation for the Month of January 2013

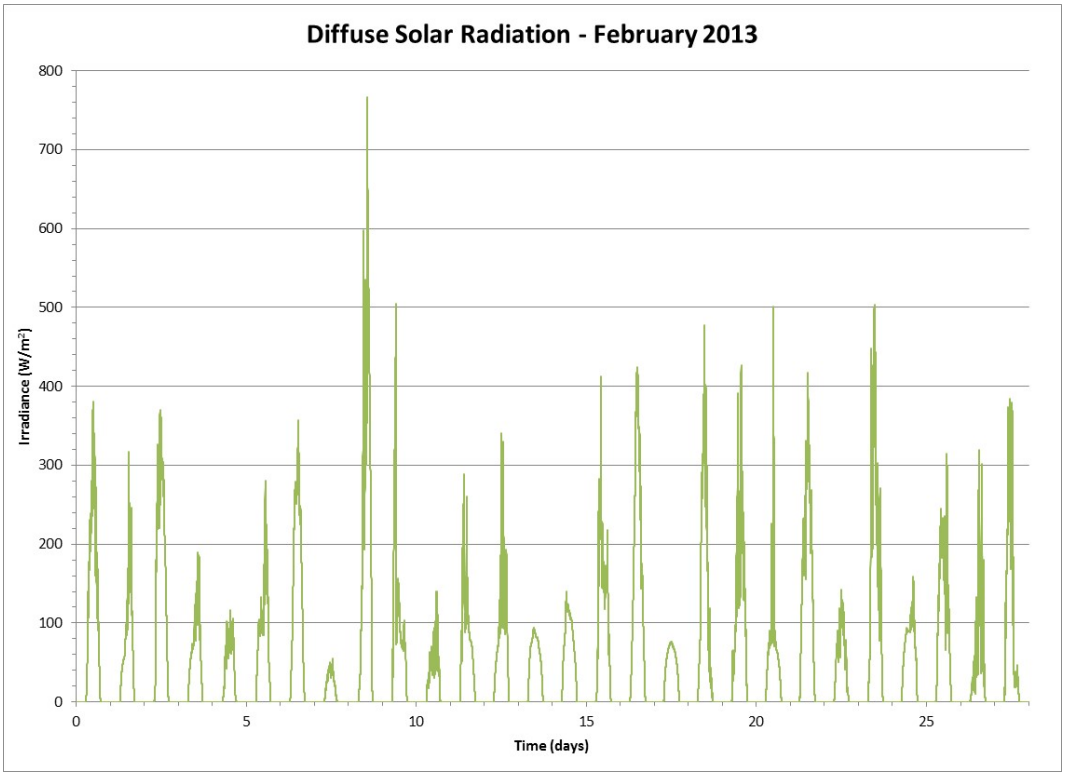

Figure 109. Diffuse Solar Radiation for the Month of February 2013

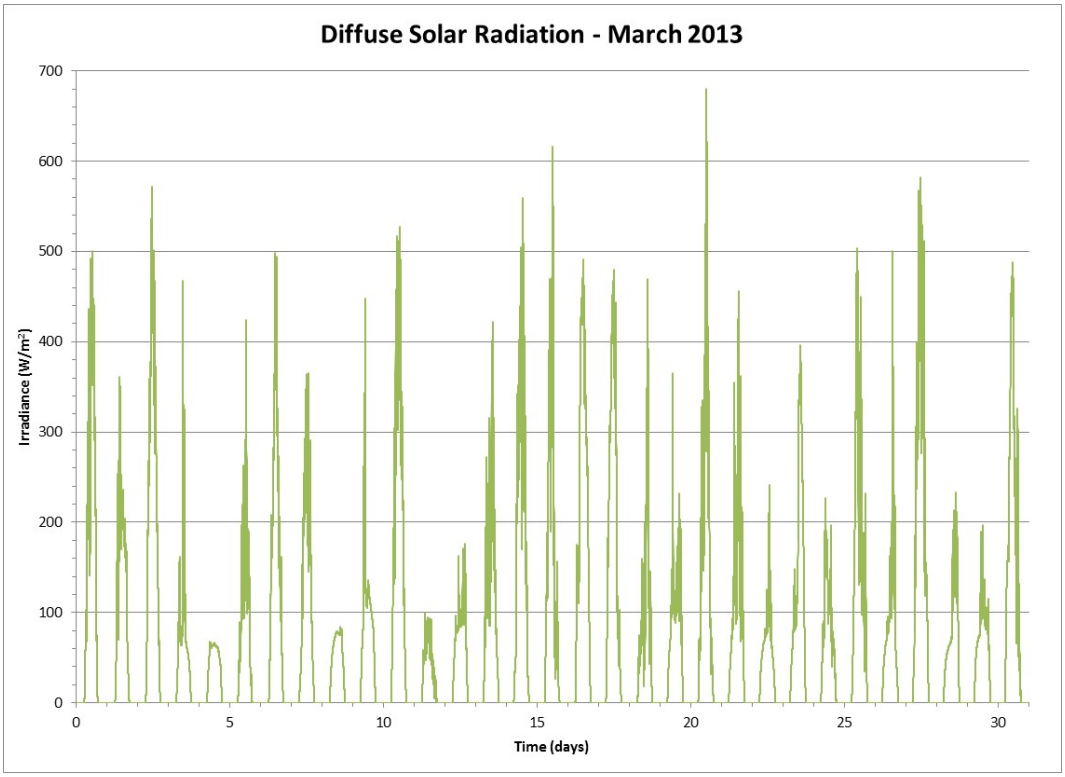

Figure 110. Diffuse Solar Radiation for the Month of March 2013

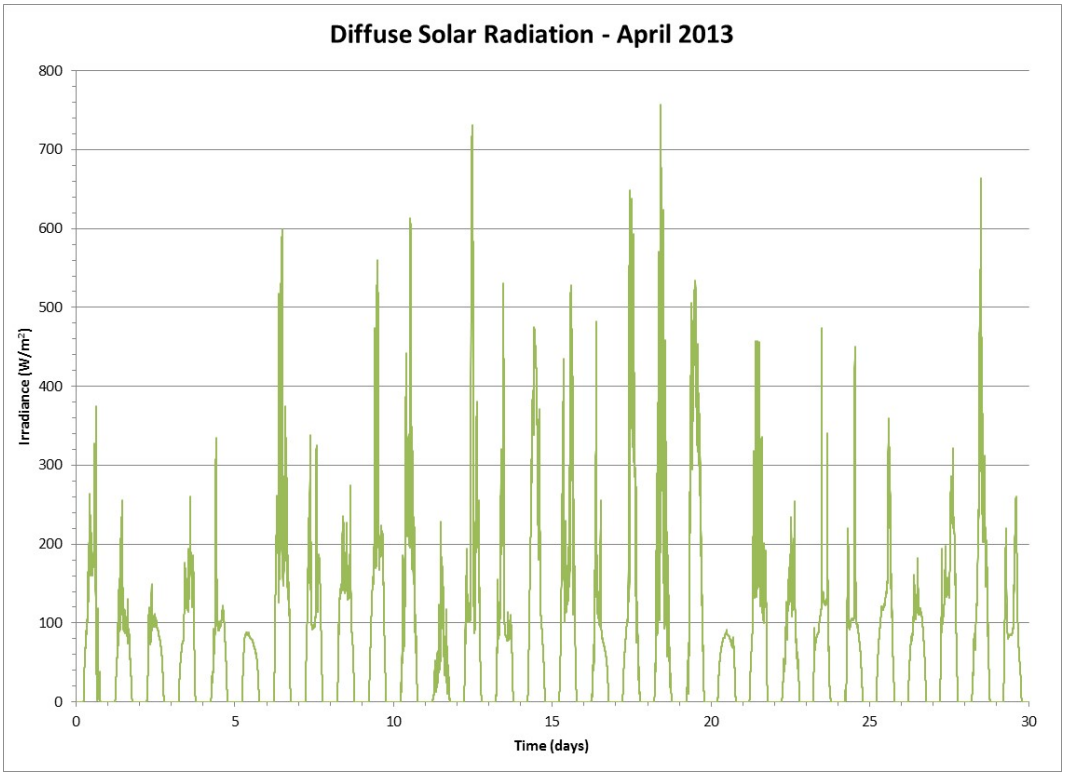

Figure 111. Diffuse Solar Radiation for the Month of April 2013

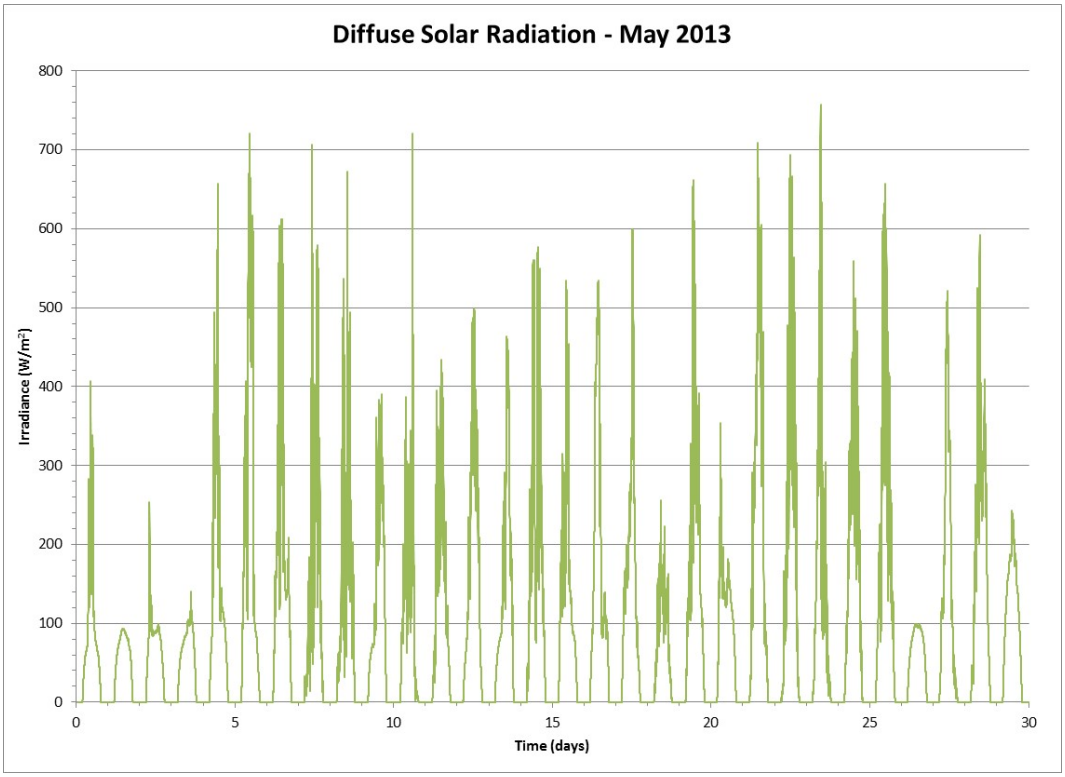

Figure 112. Diffuse Solar Radiation for the Month of May 2013

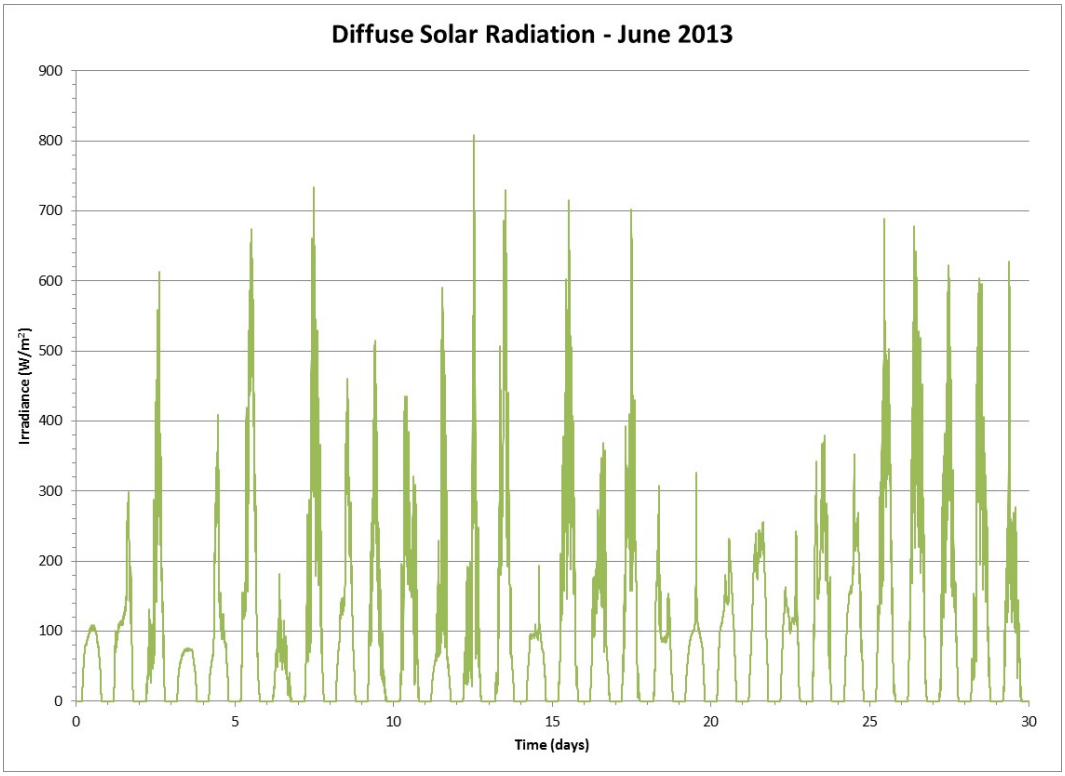

Figure 113. Diffuse Solar Radiation for the Month of June 2013

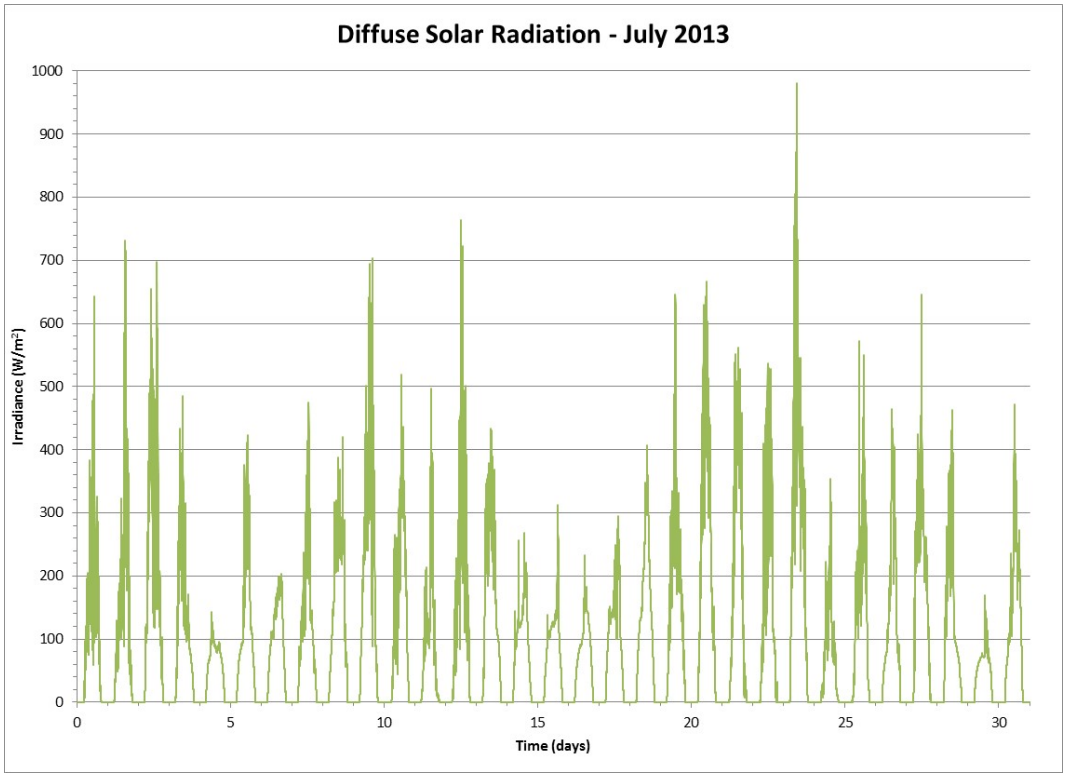

Figure 114. Diffuse Solar Radiation for the Month of July 2013

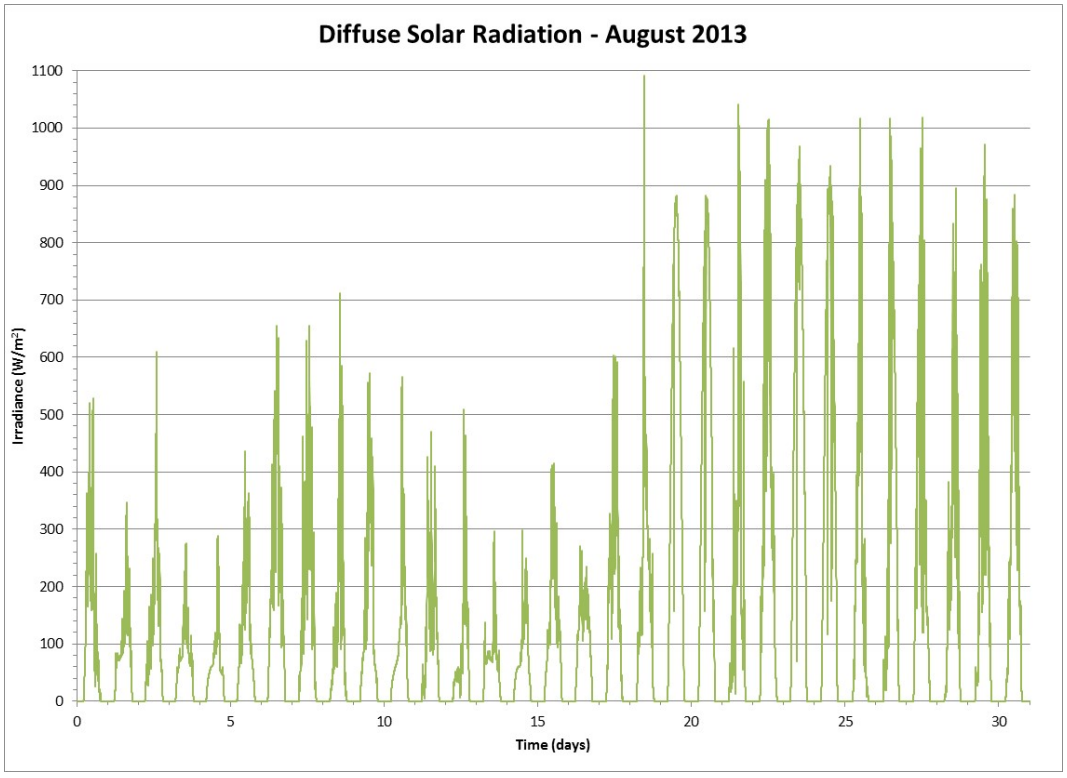

Figure 115. Diffuse Solar Radiation for the Month of August 2013

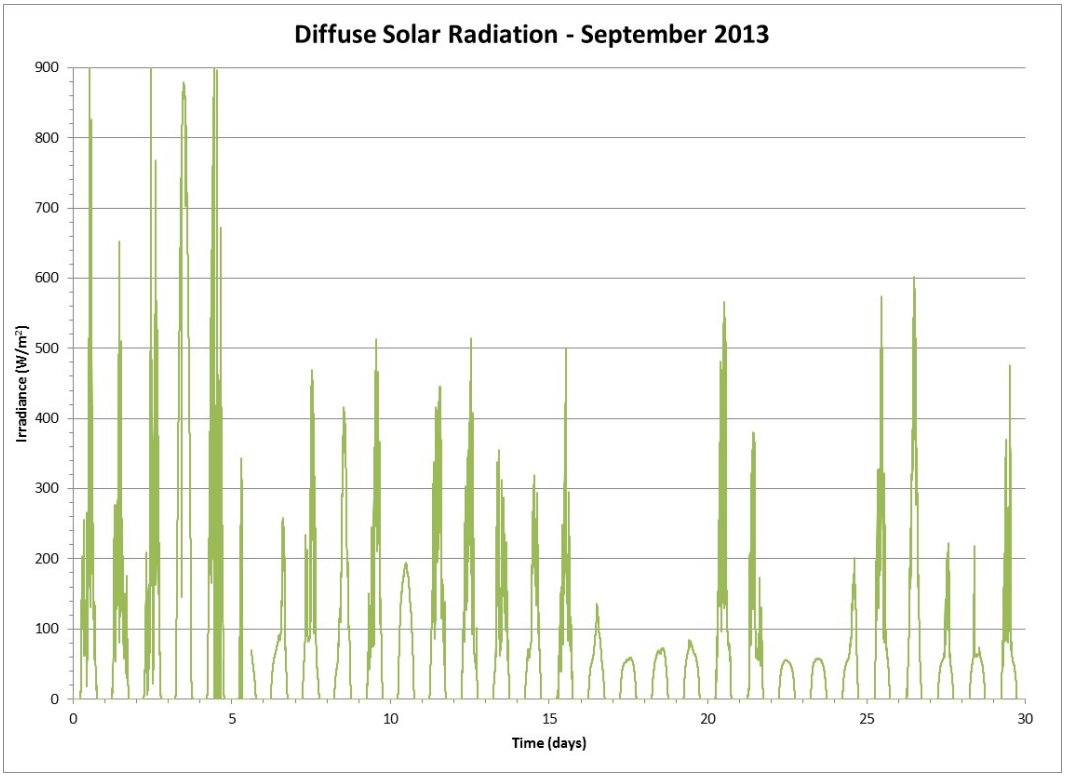

Figure 116. Diffuse Solar Radiation for the Month of September 2013

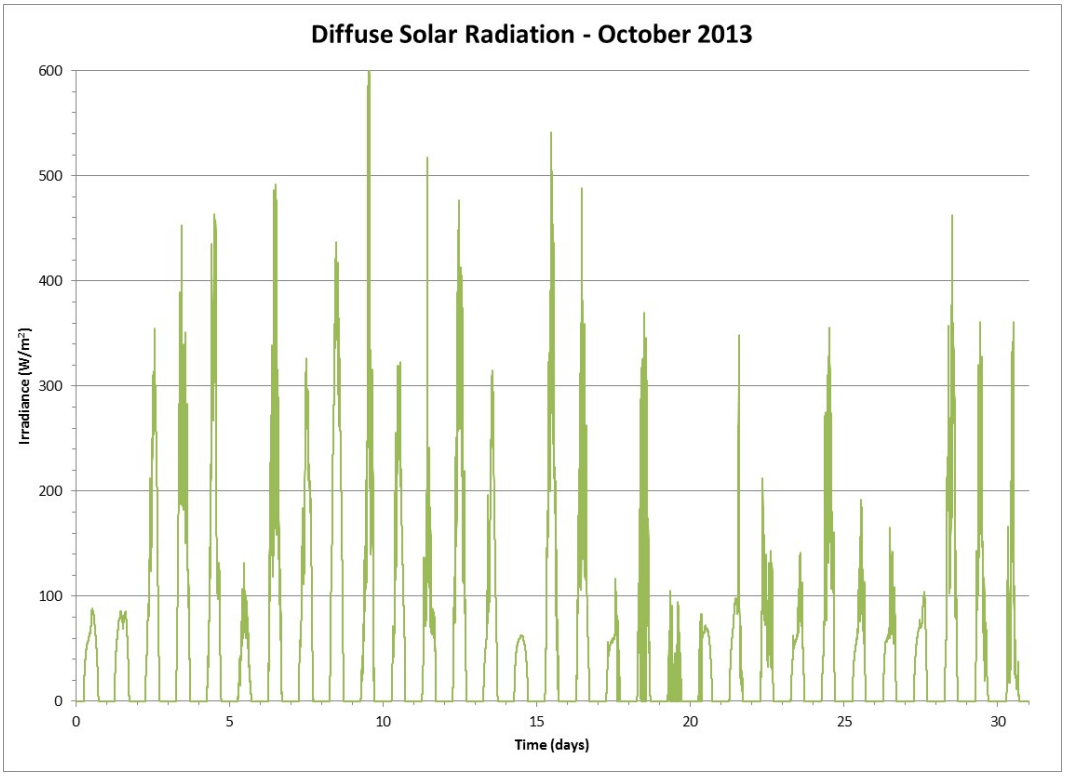

Figure 117. Diffuse Solar Radiation for the Month of October 2013

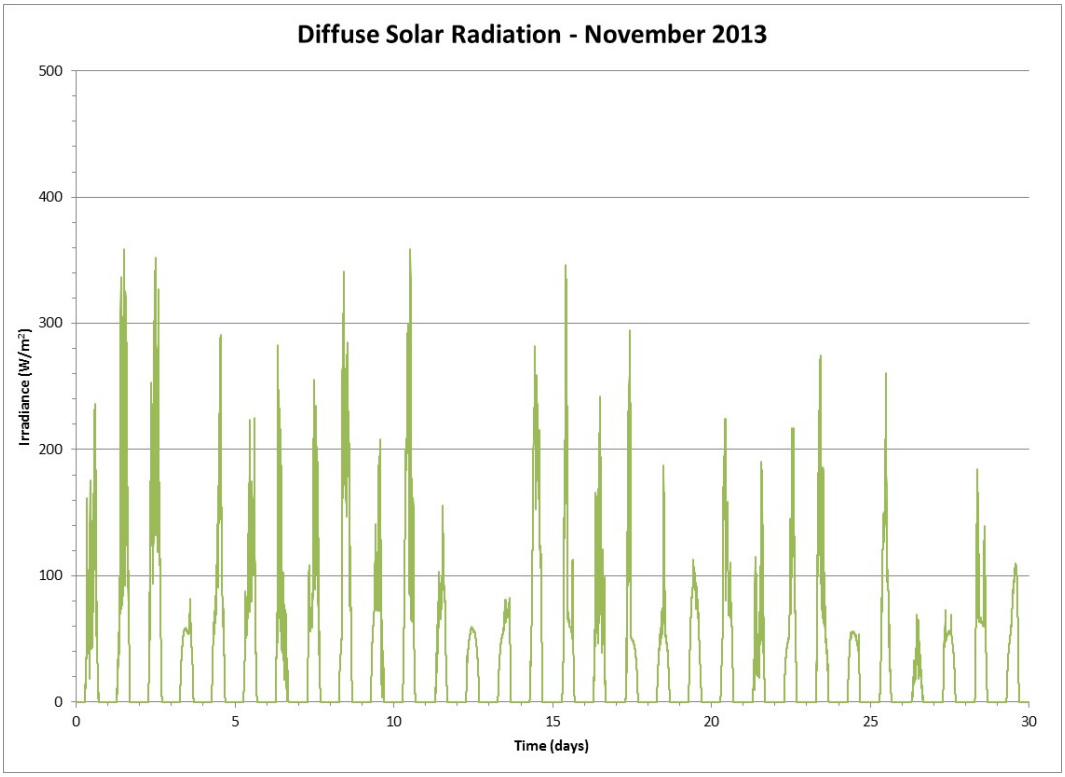

Figure 118. Diffuse Solar Radiation for the Month of November 2013

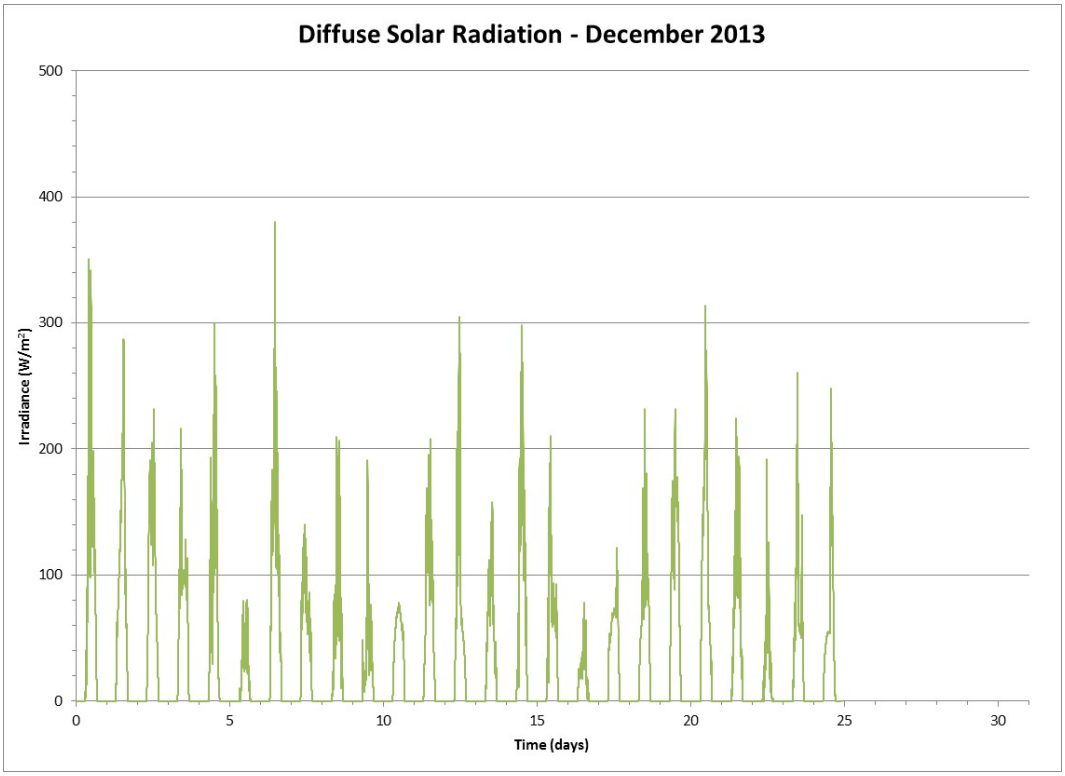

Figure 119. Diffuse Solar Radiation for the Month of December 2013

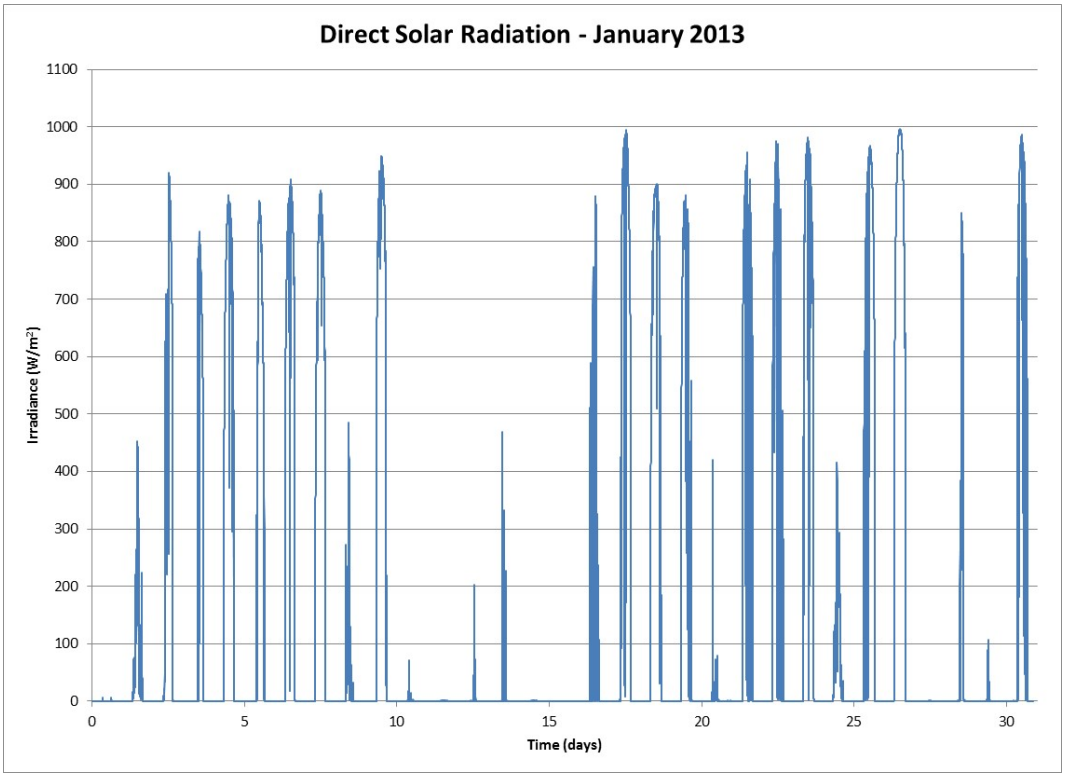

Figure 121. Direct Solar Radiation for the Month of January 2013

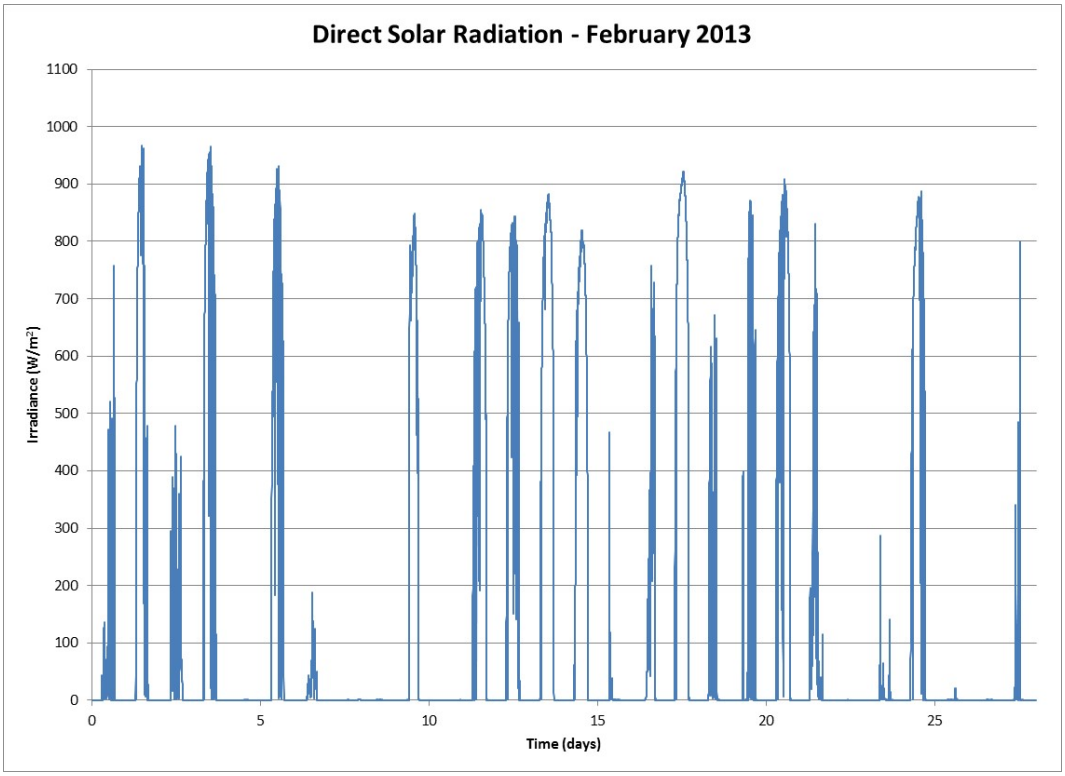

Figure 122. Direct Solar Radiation for the Month of February 2013

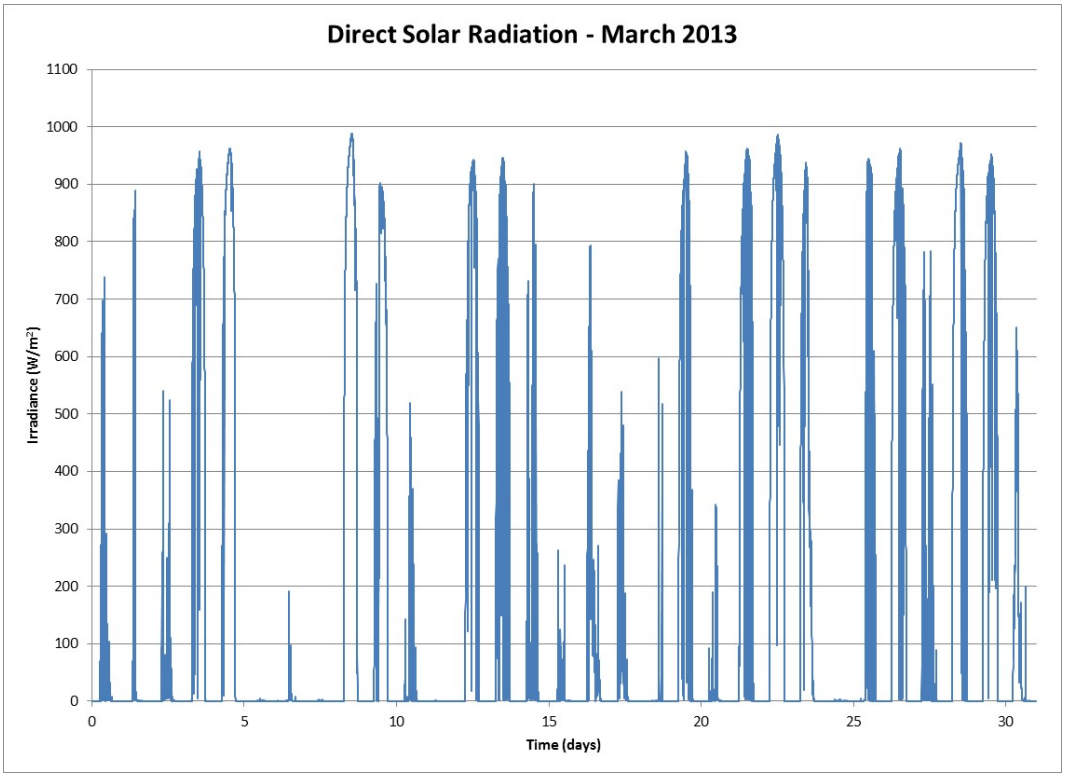

Figure 123. Direct Solar Radiation for the Month of March 2013

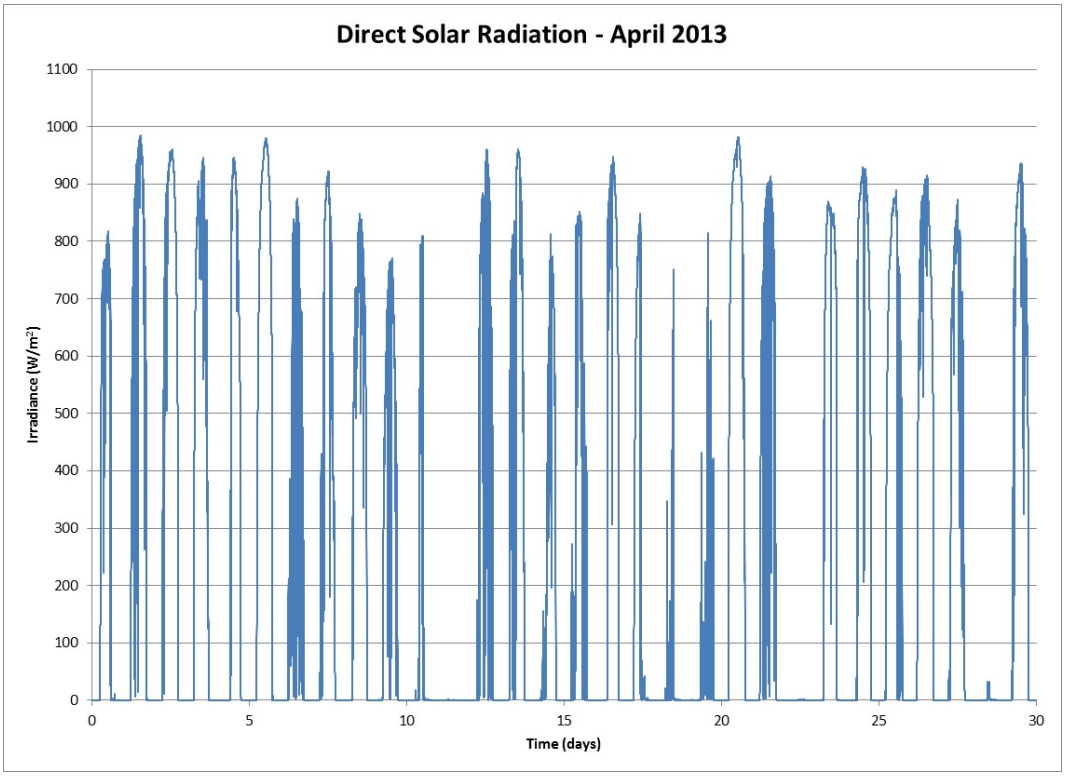

Figure 124. Direct Solar Radiation for the Month April 2013

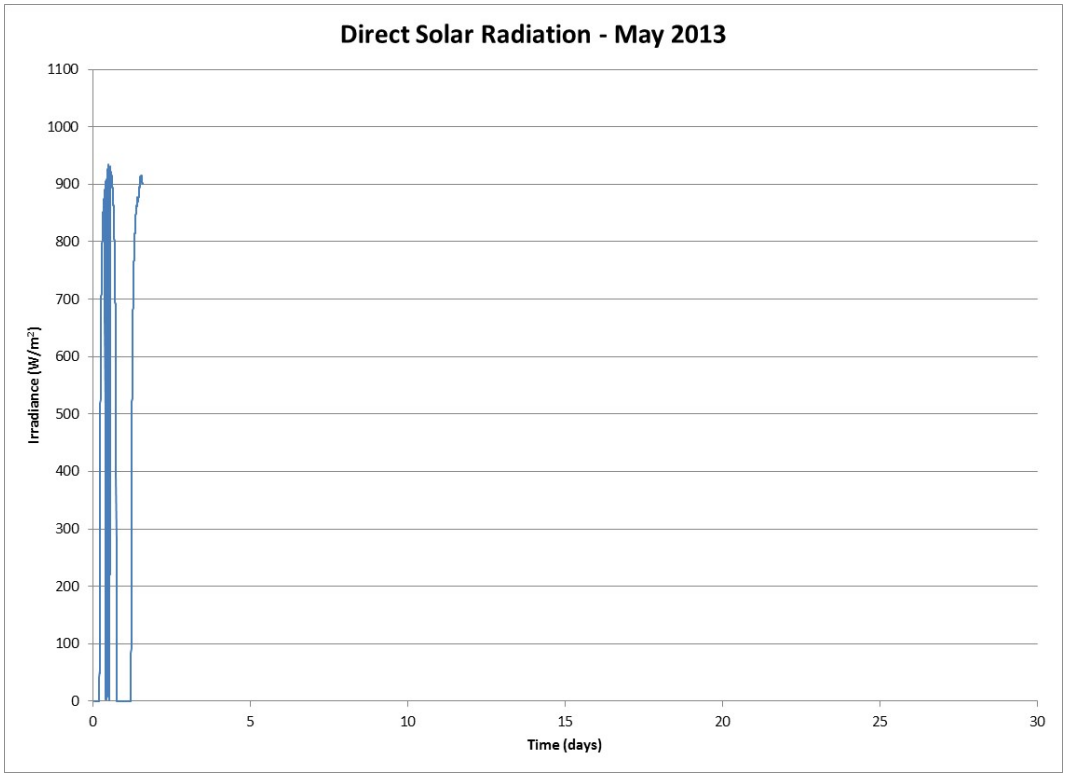

Figure 125. Direct Solar Radiation for the Month May 2013

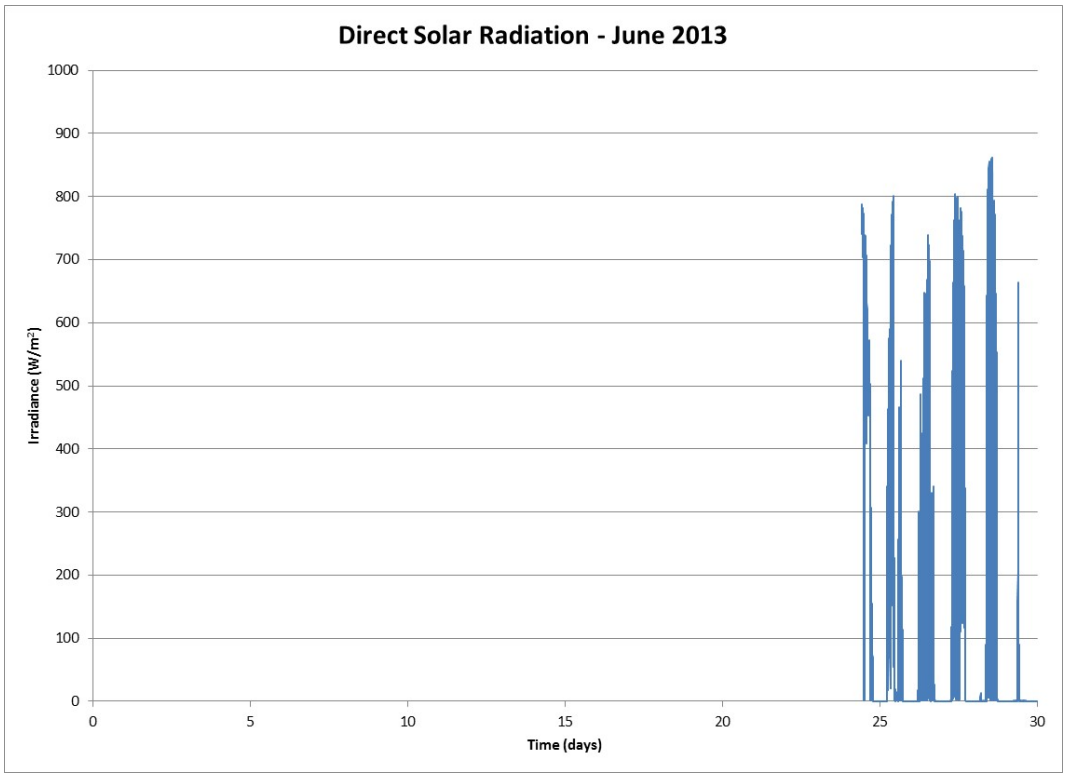

Figure 126. Direct Solar Radiation for the Month June 2013

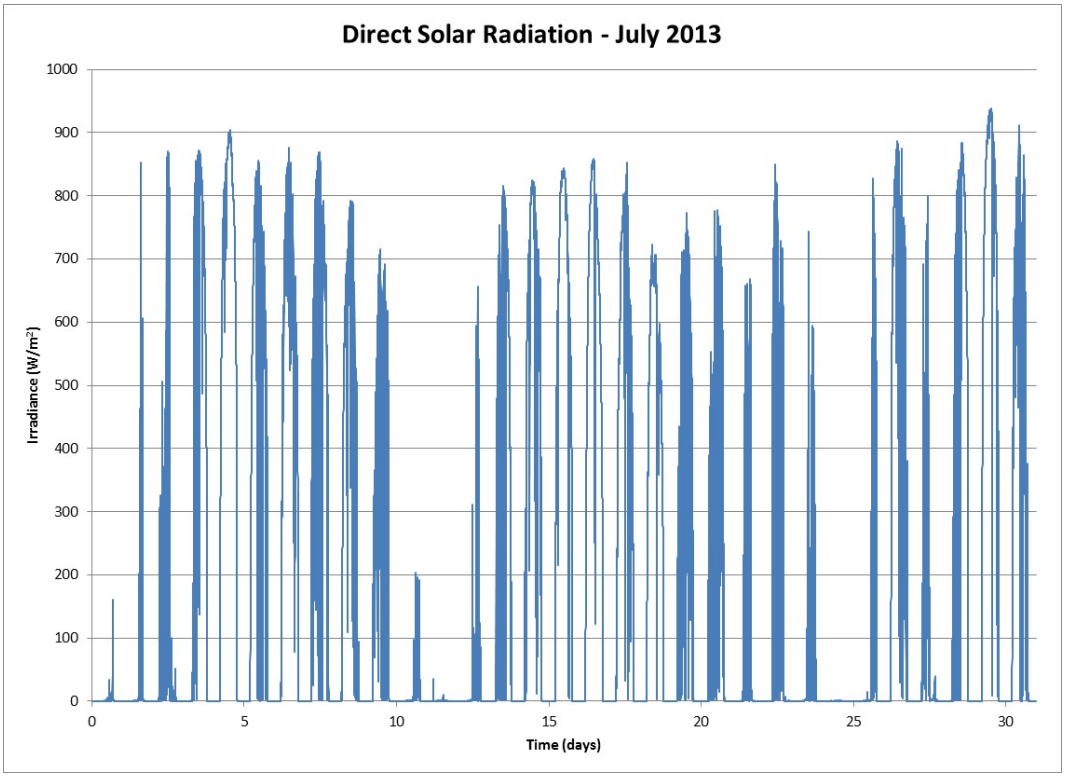

Figure 127. Direct Solar Radiation for the Month July 2013

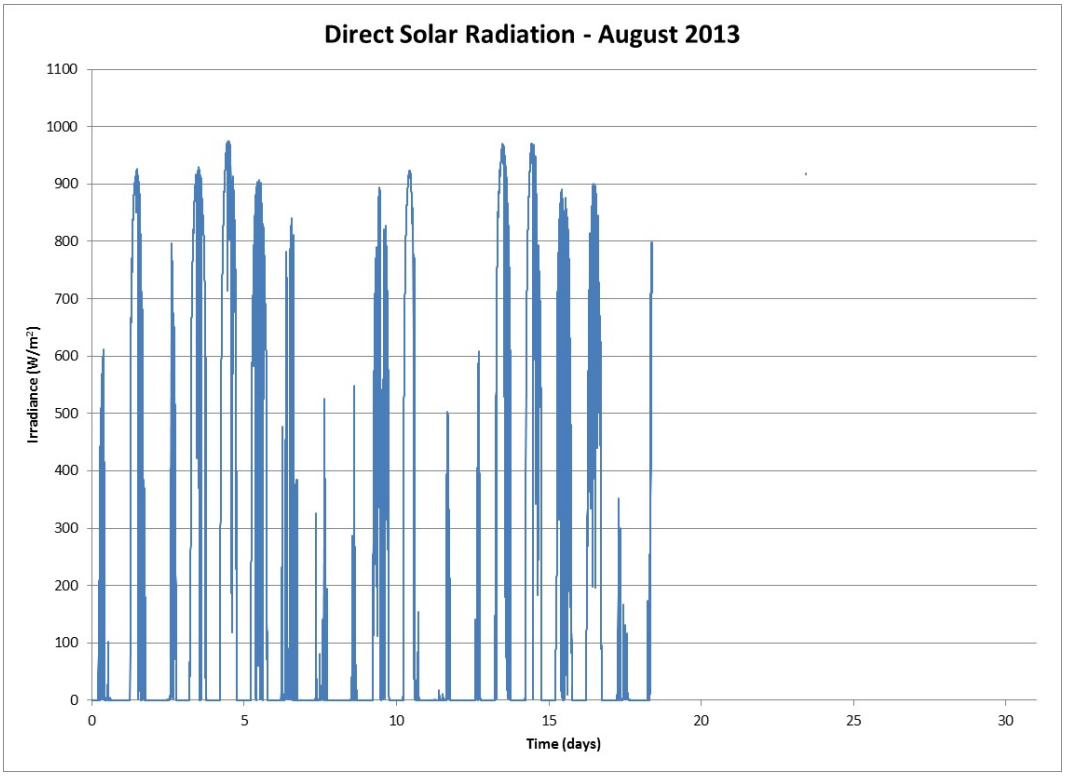

Figure 128. Direct Solar Radiation for the Month August 2013

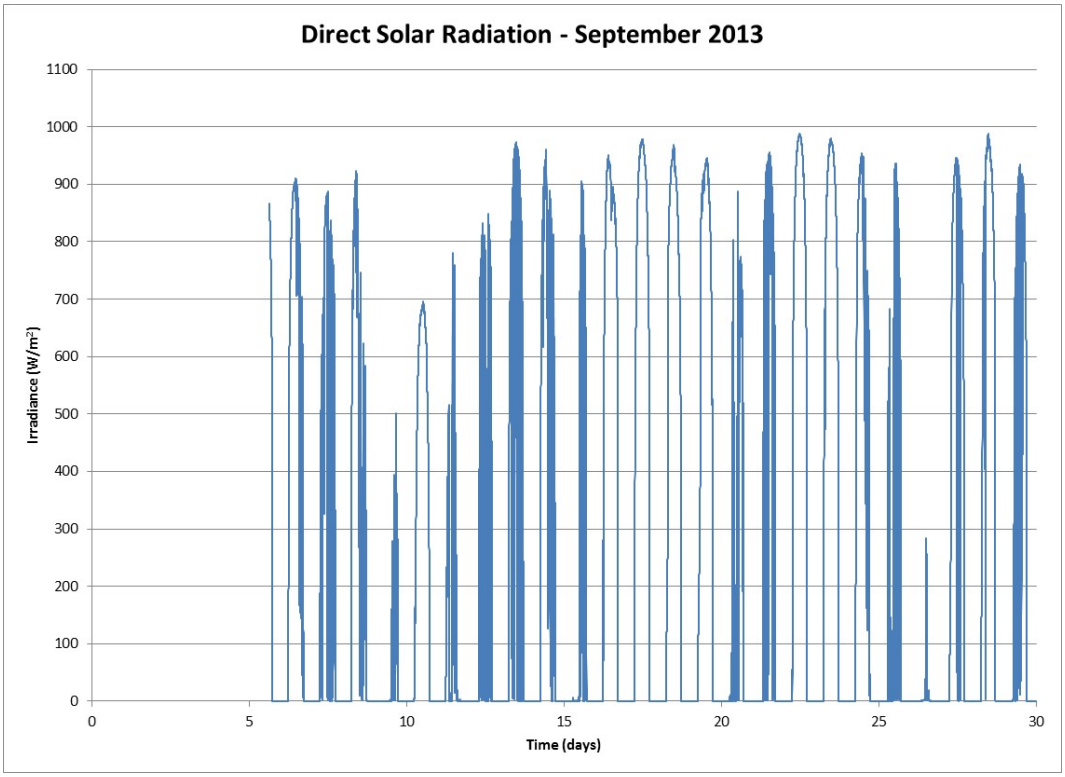

Figure 129. Direct Solar Radiation for the Month September 2013

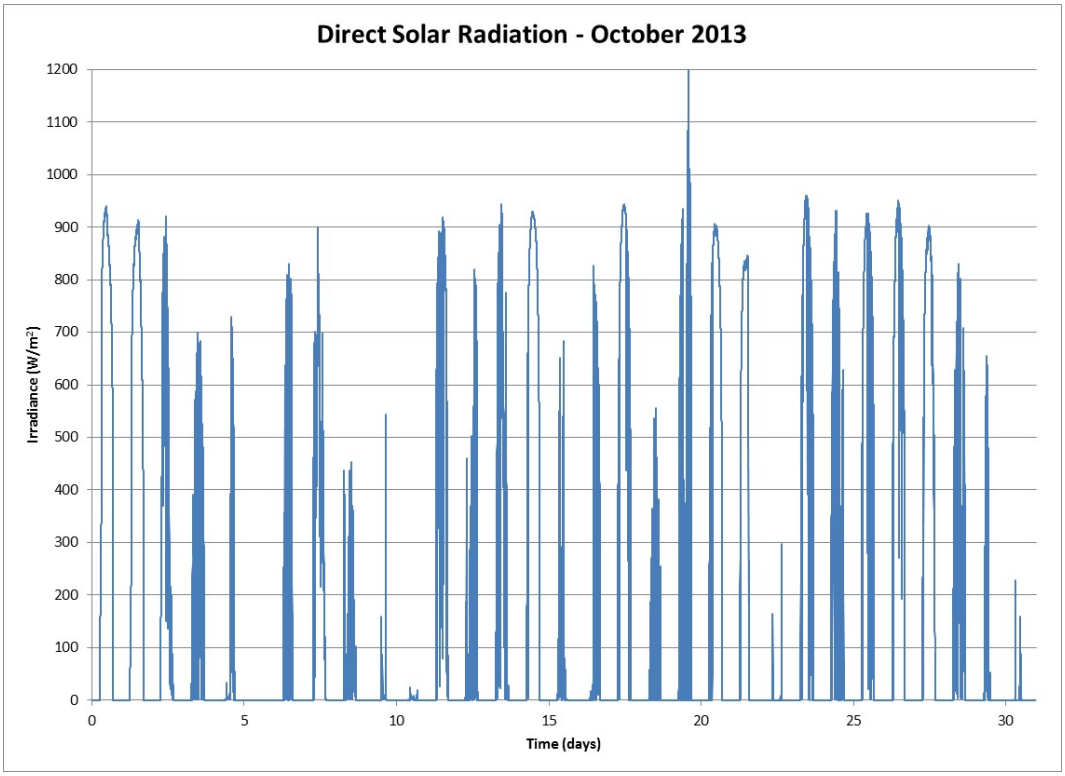

Figure 130. Direct Solar Radiation for the Month October 2013

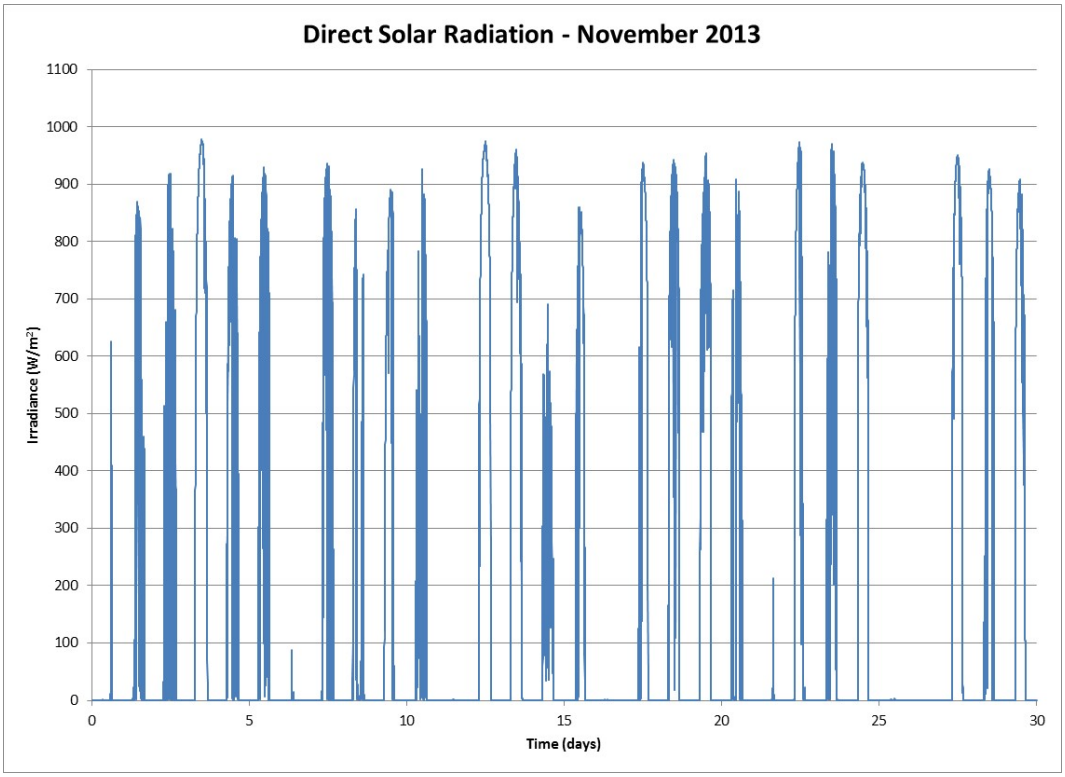

Figure 131. Direct Solar Radiation for the Month November 2013

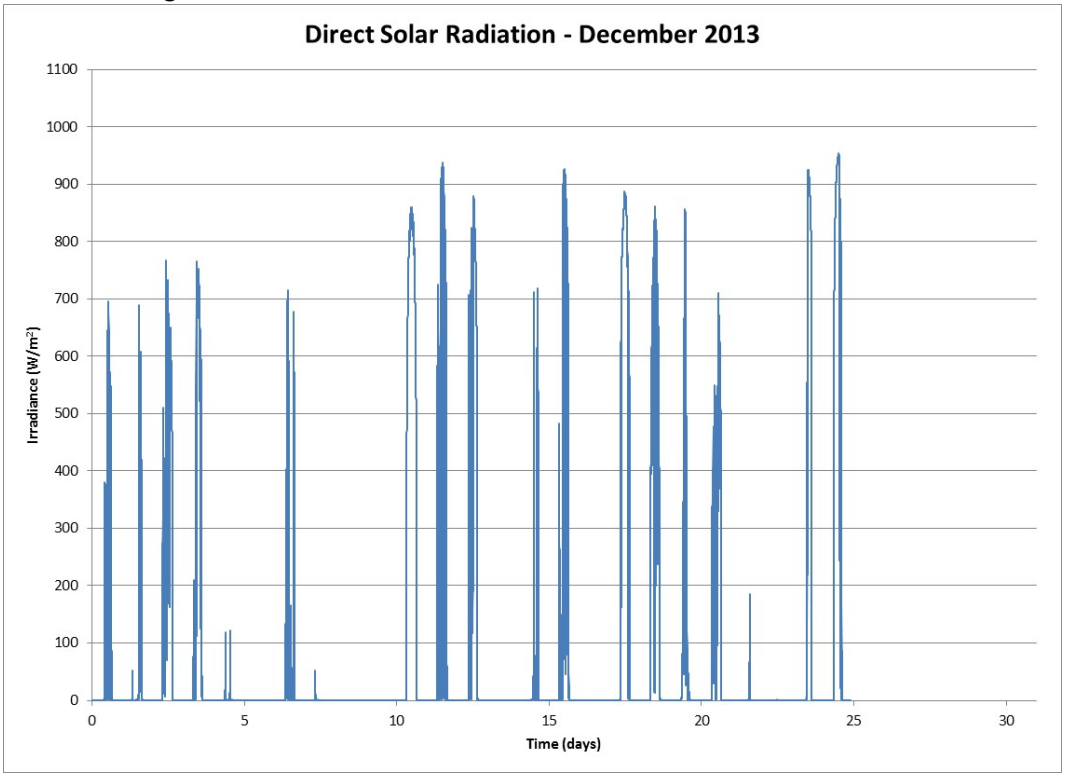

Figure 132. Direct Solar Radiation for the Month December 2013

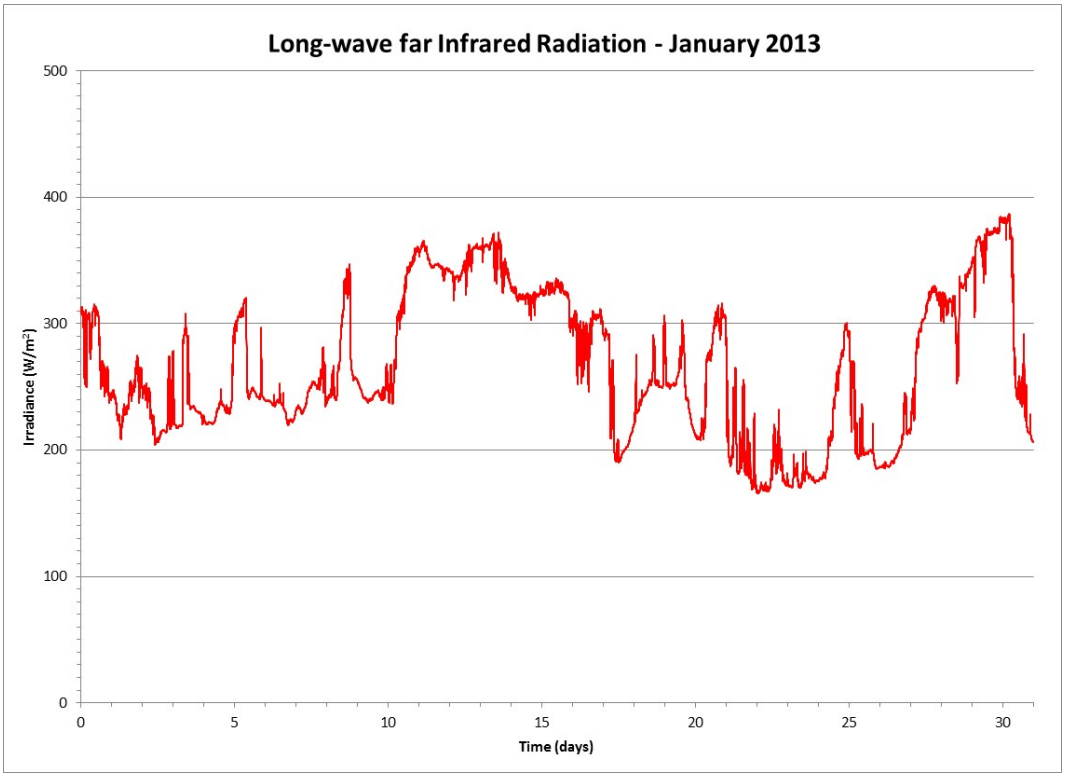

Figure 133. Long-wave Far Infrared Radiation for the Month of January 2013

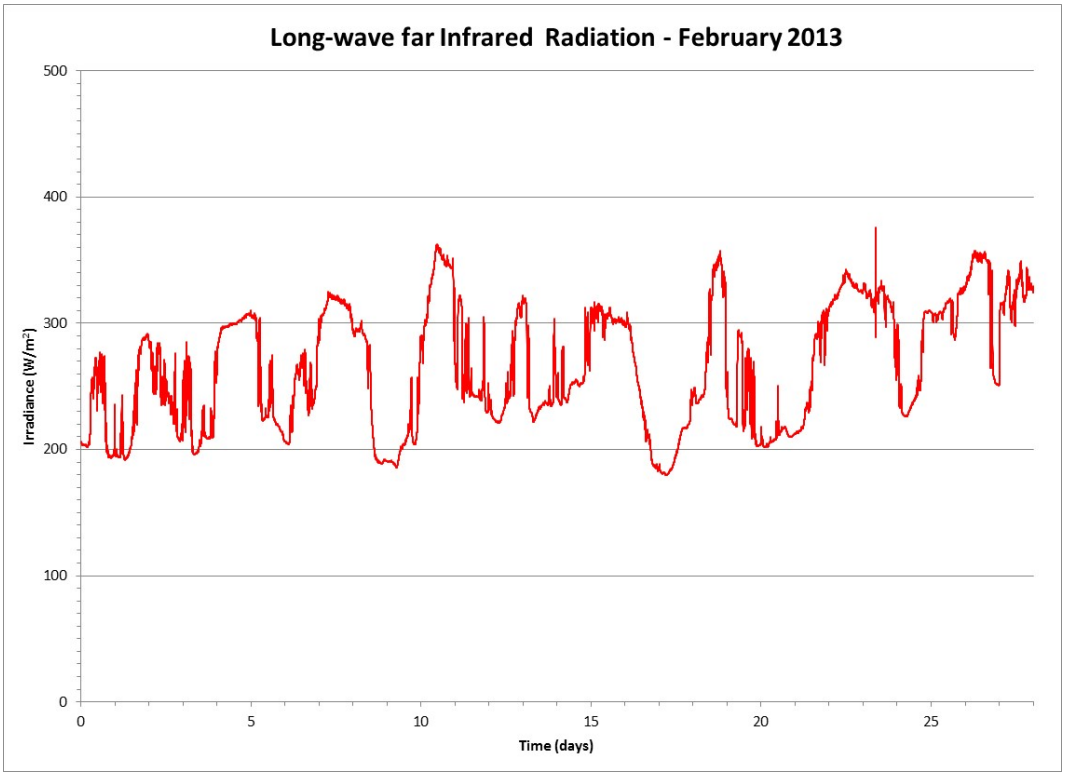

Figure 134. Long-wave Far Infrared Radiation for the Month of February 2013

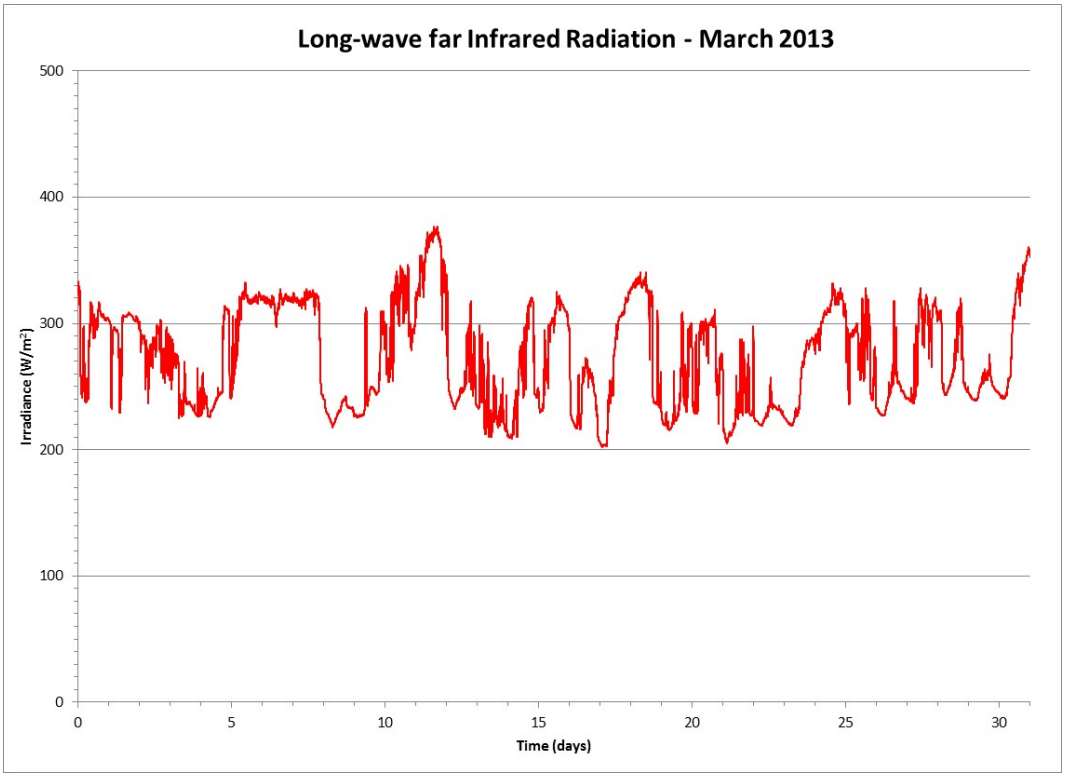

Figure 135. Long-wave Far Infrared Radiation for the Month of March 2013

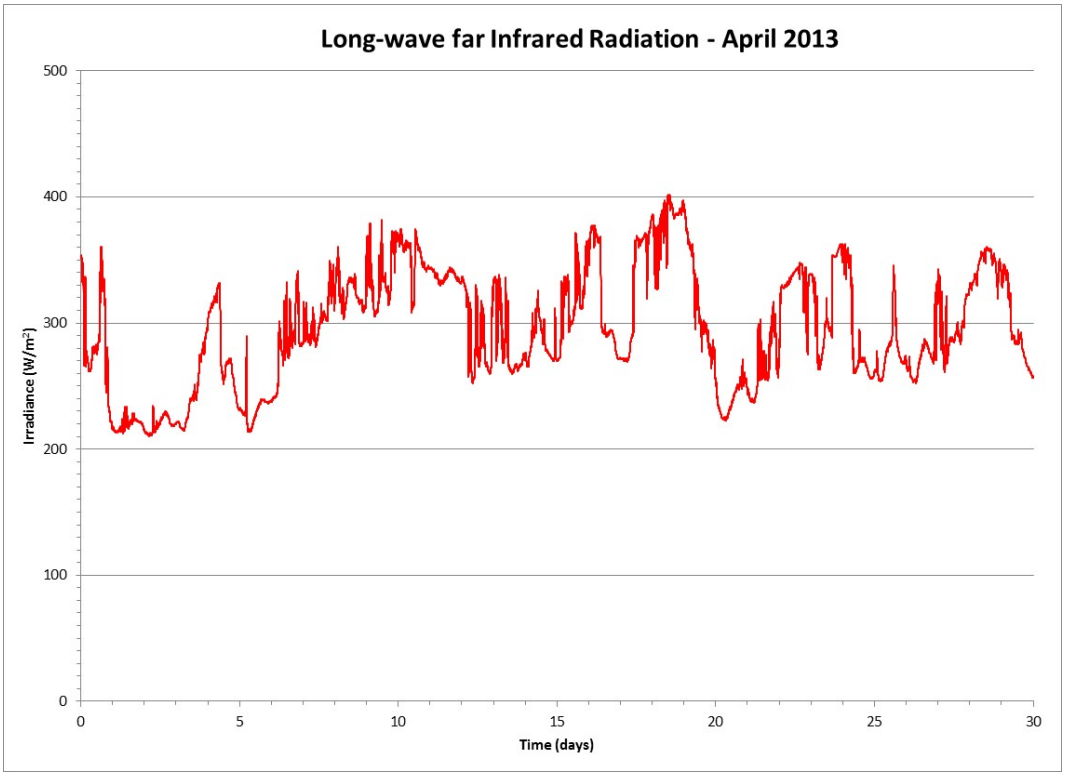

Figure 136. Long-wave Far Infrared Radiation for the Month of April 2013

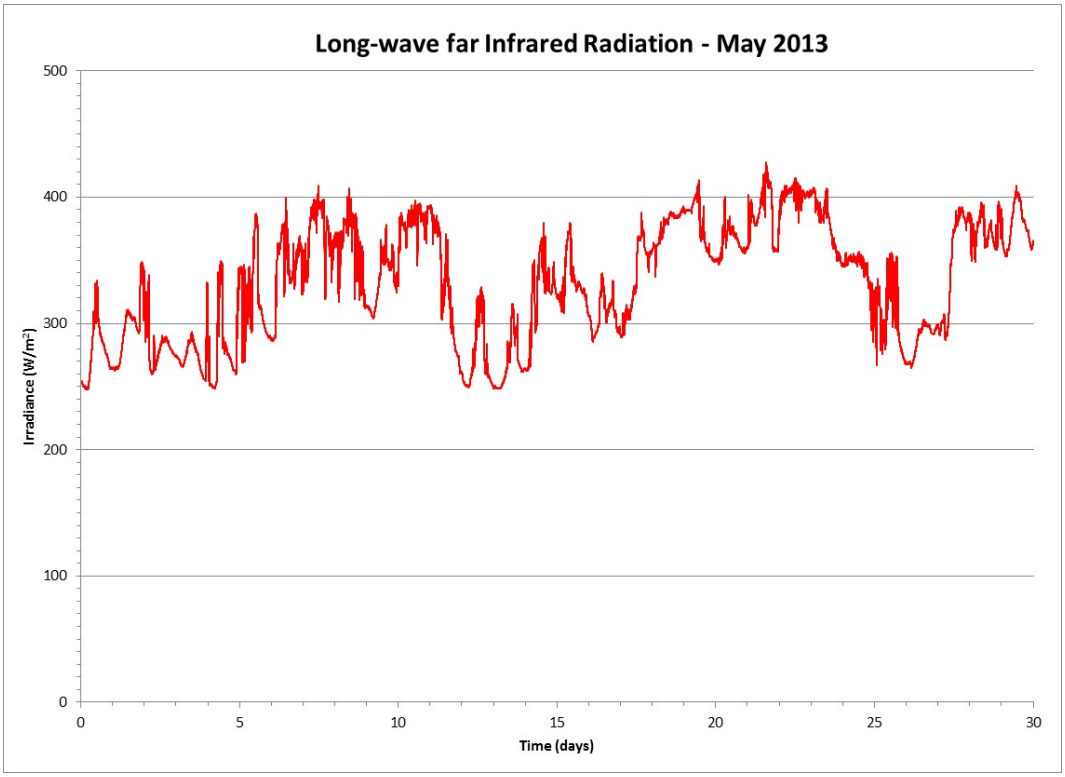

Figure 137. Long-wave Far Infrared Radiation for the Month of May 2013

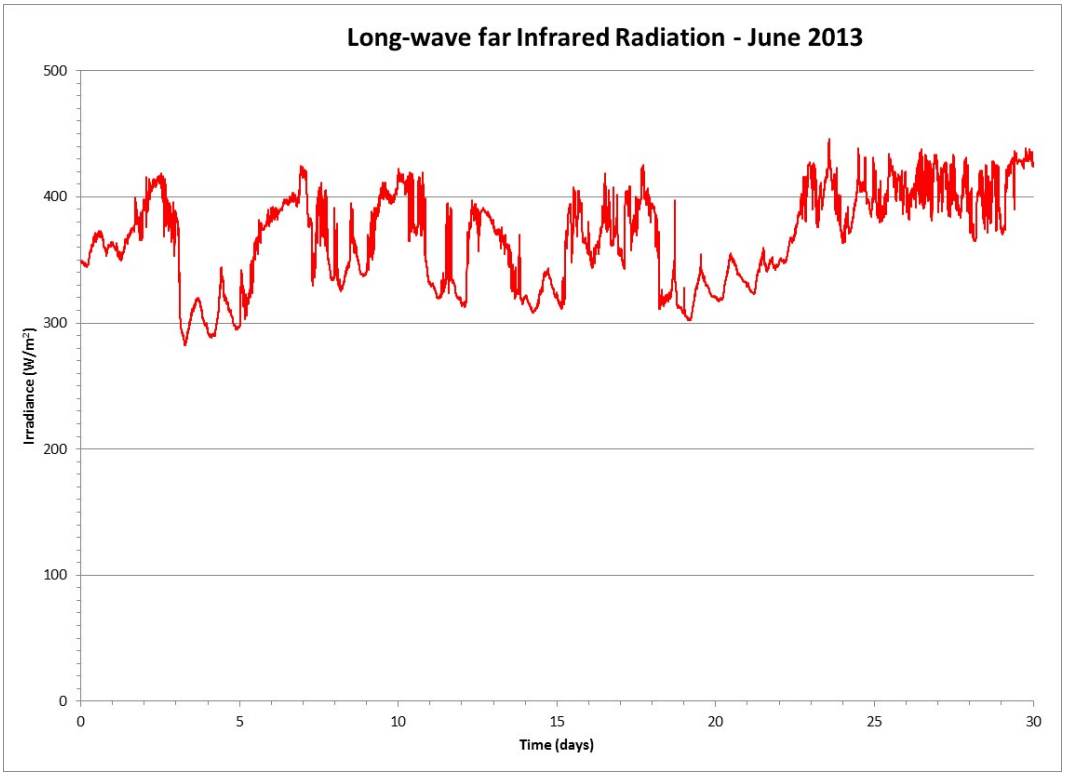

Figure 138. Long-wave Far Infrared Radiation for the Month of June 2013

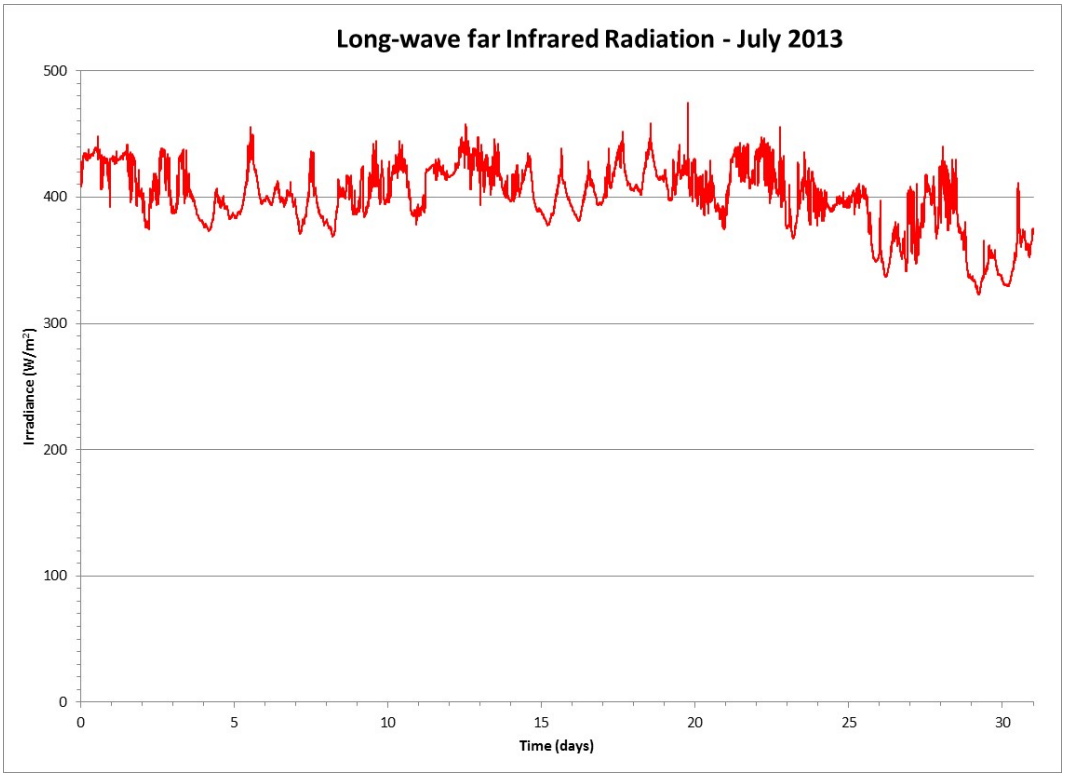

Figure 139. Long-wave Far Infrared Radiation for the Month of July 2013

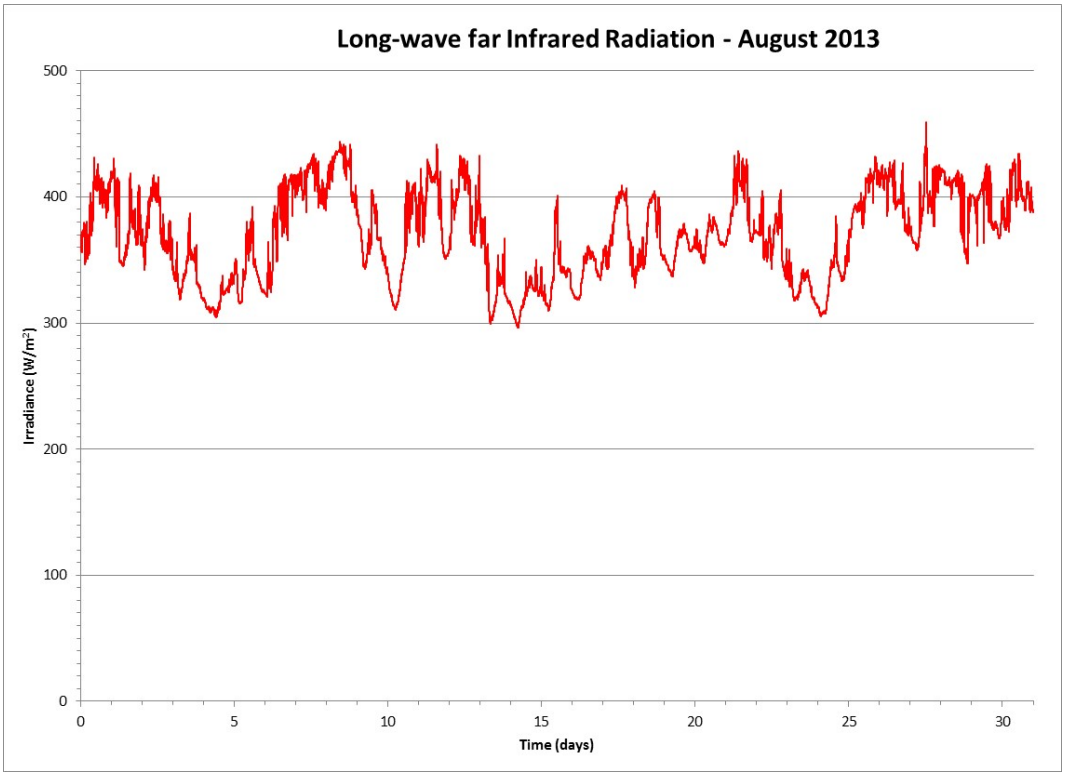

Figure 140. Long-wave Far Infrared Radiation for the Month of August 2013

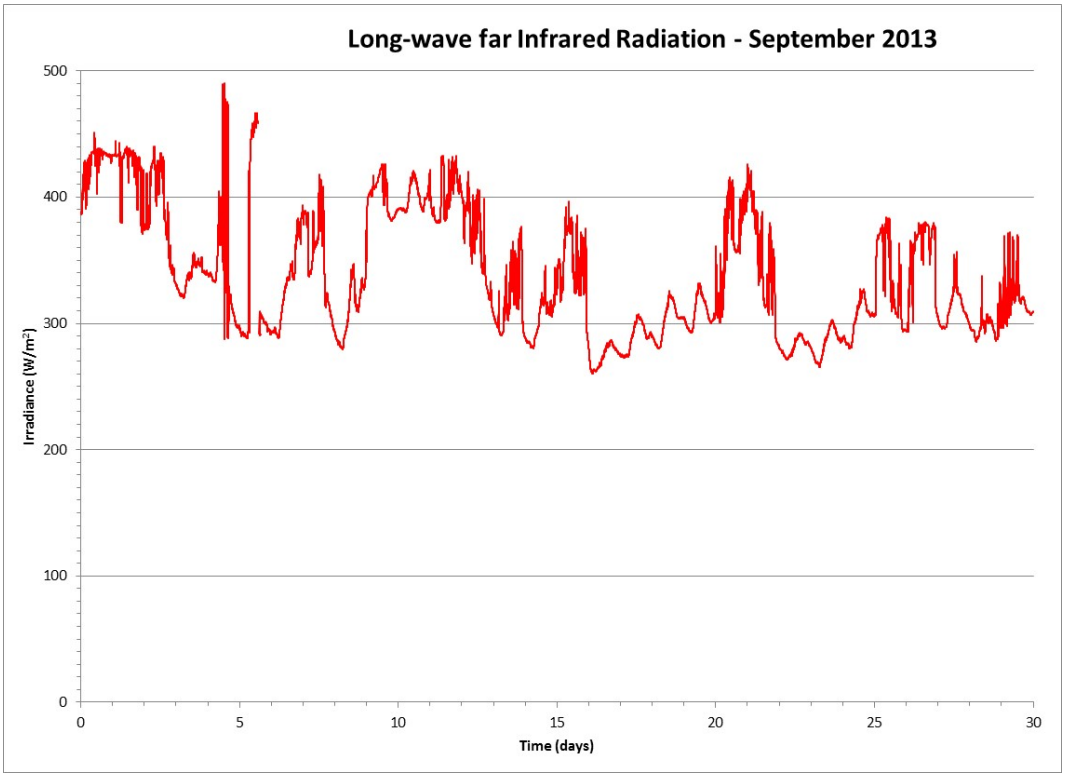

Figure 141. Long-wave Far Infrared Radiation for the Month of September 2013

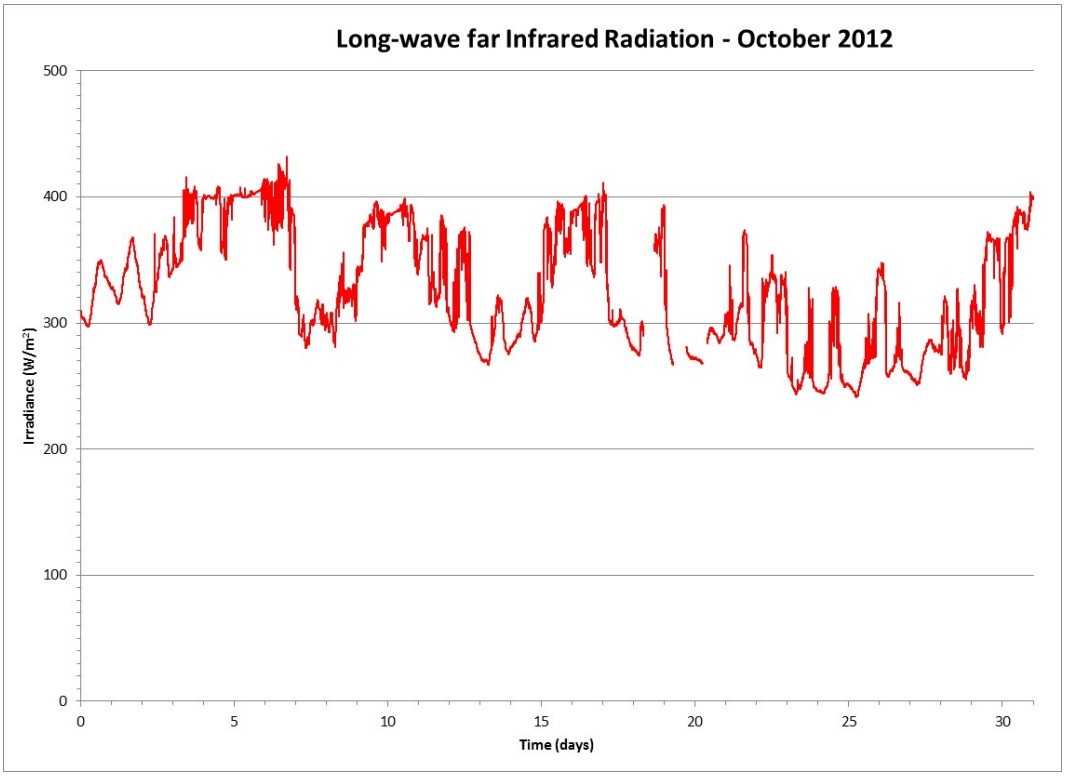

Figure 142. Long-wave Far Infrared Radiation for the Month of October 2013

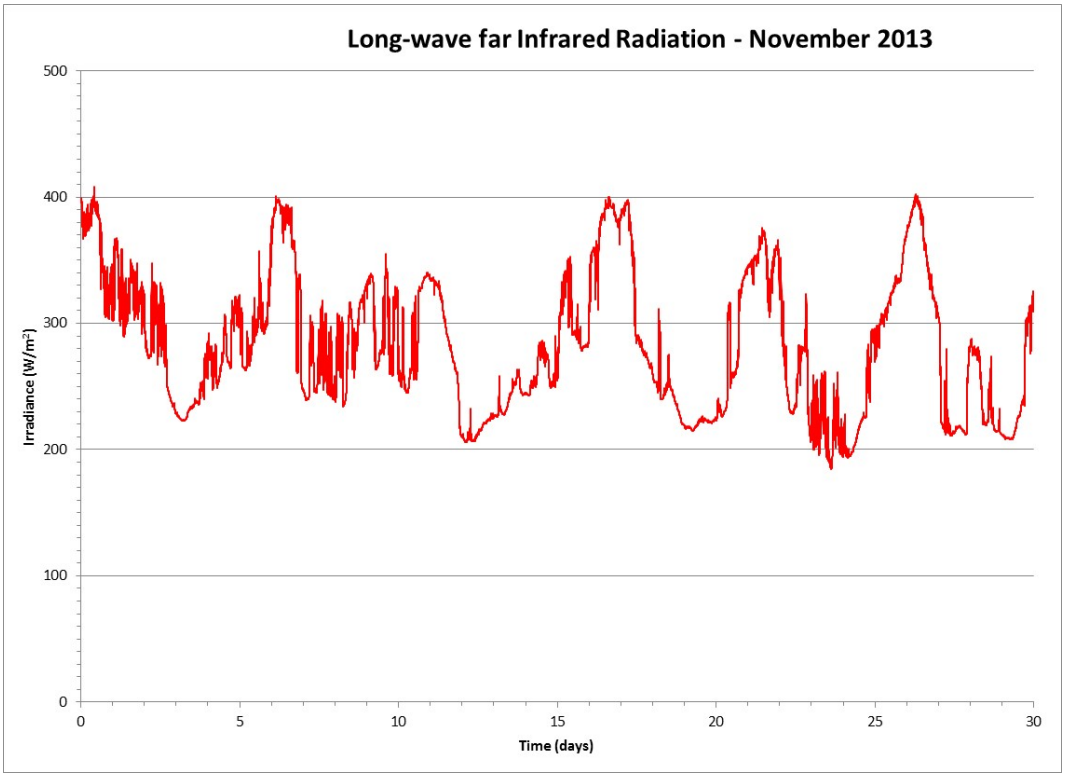

Figure 143. Long-wave Far Infrared Radiation for the Month of November 2013

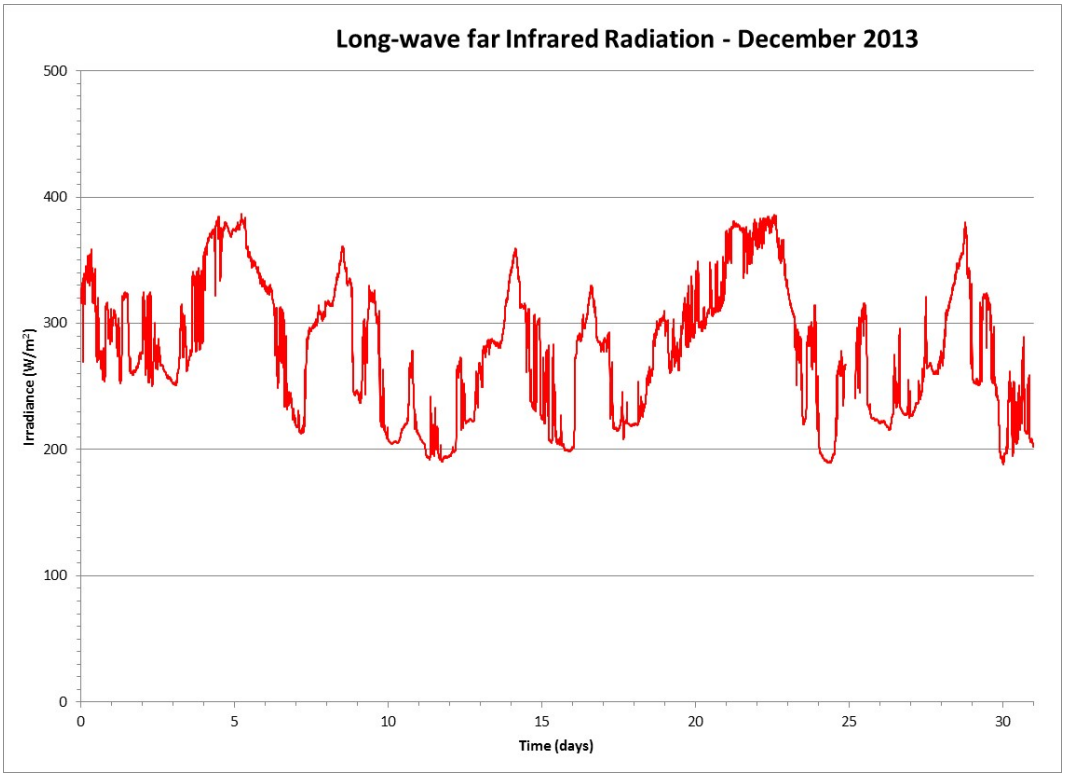

Figure 144. Long-wave Far Infrared Radiation for the Month of December 2013

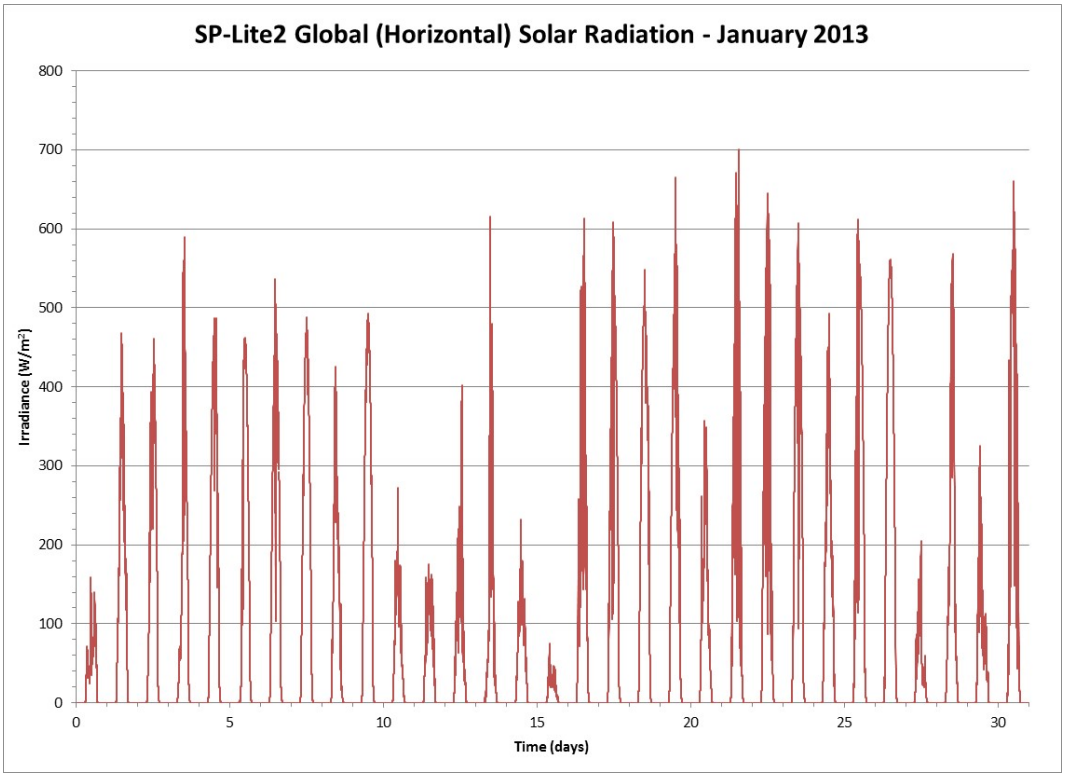

Figure 145. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of January 2013

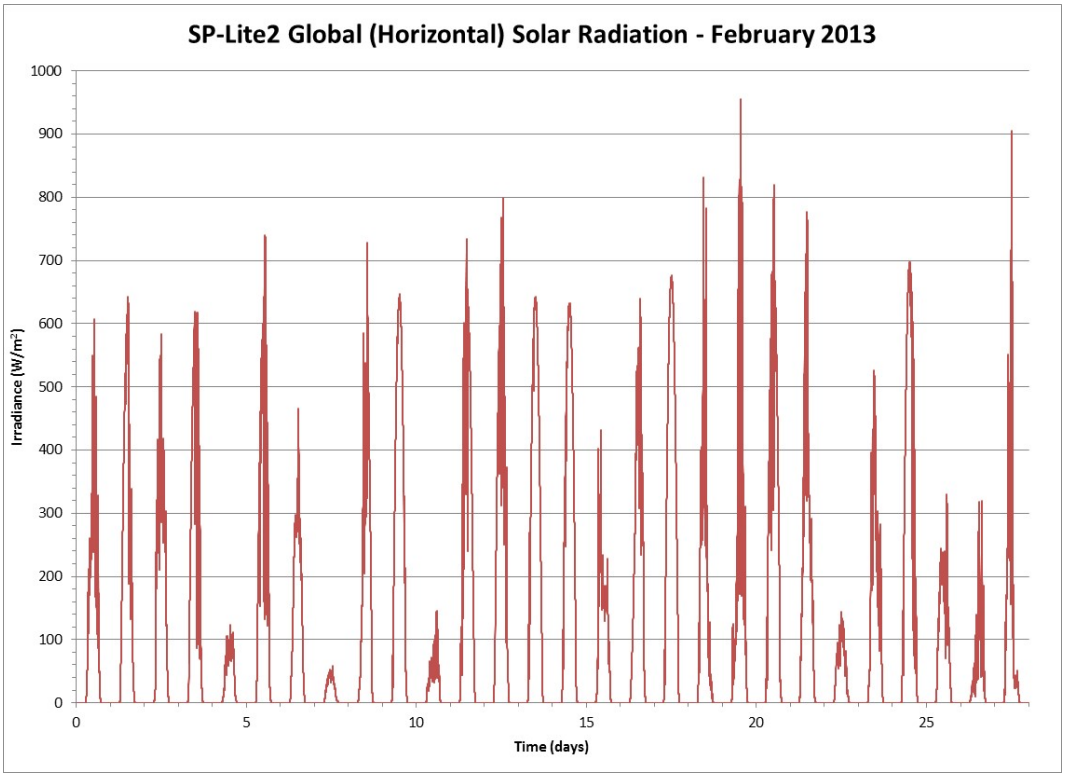

Figure 146. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of February 2013

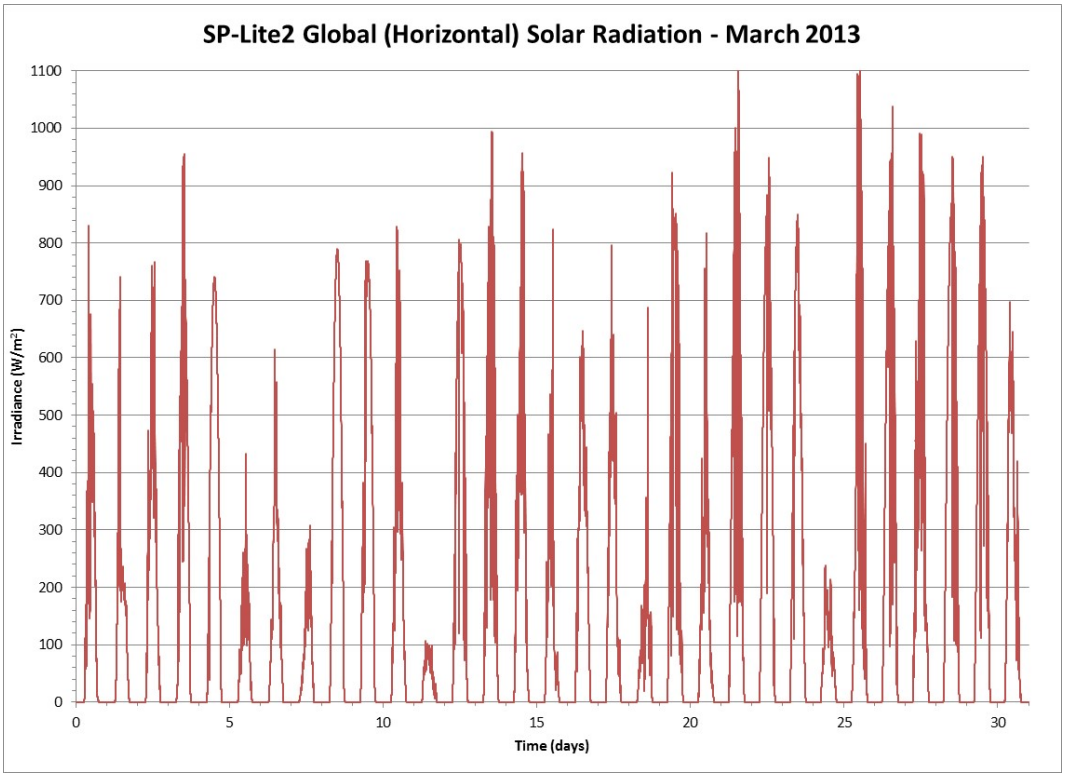

Figure 147. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of March 2013

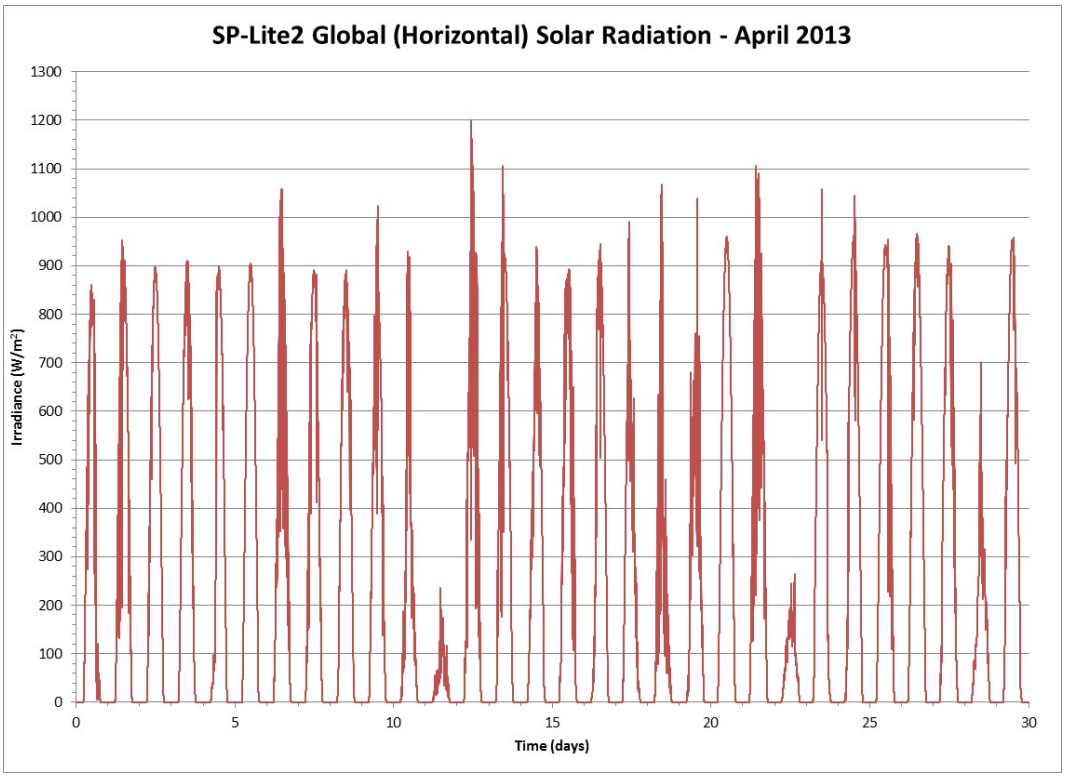

Figure 148. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of April 2013

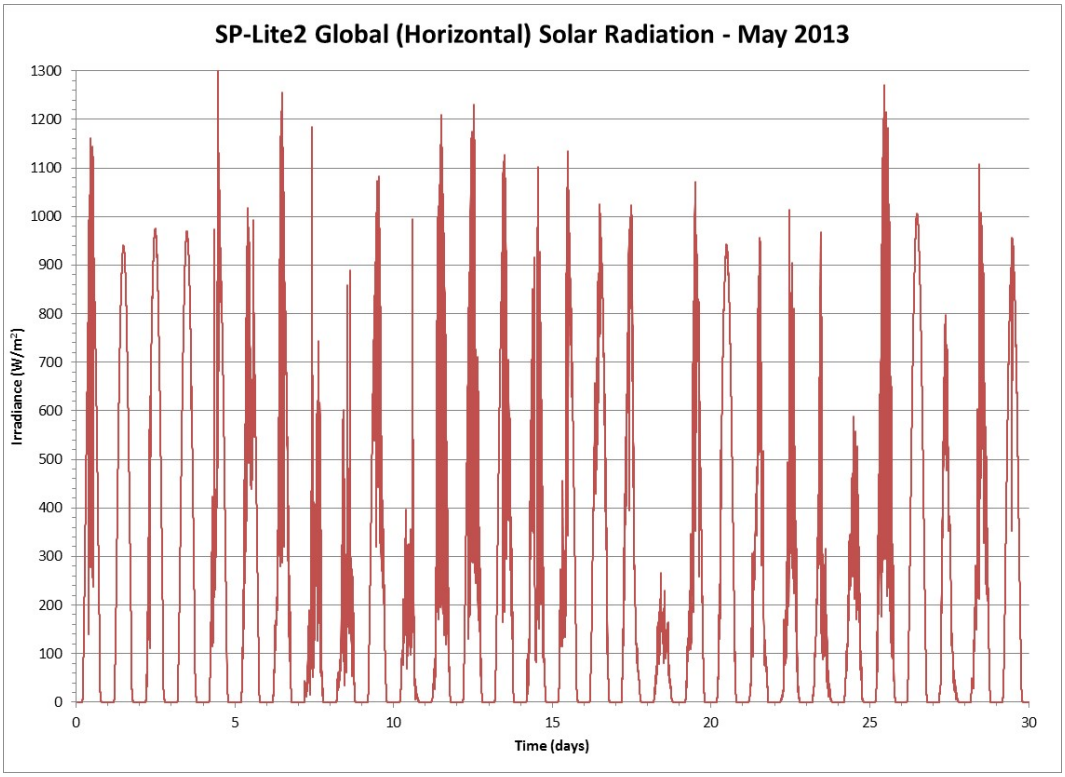

Figure 149. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of May 2013

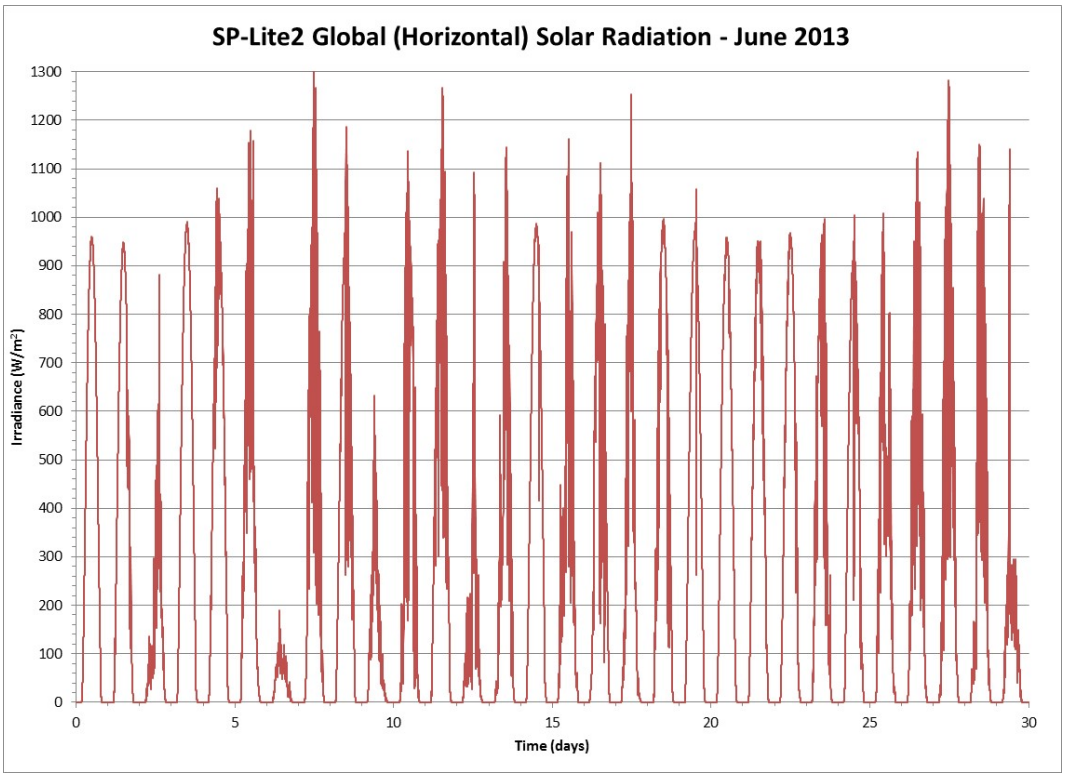

Figure 150. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of June 2013

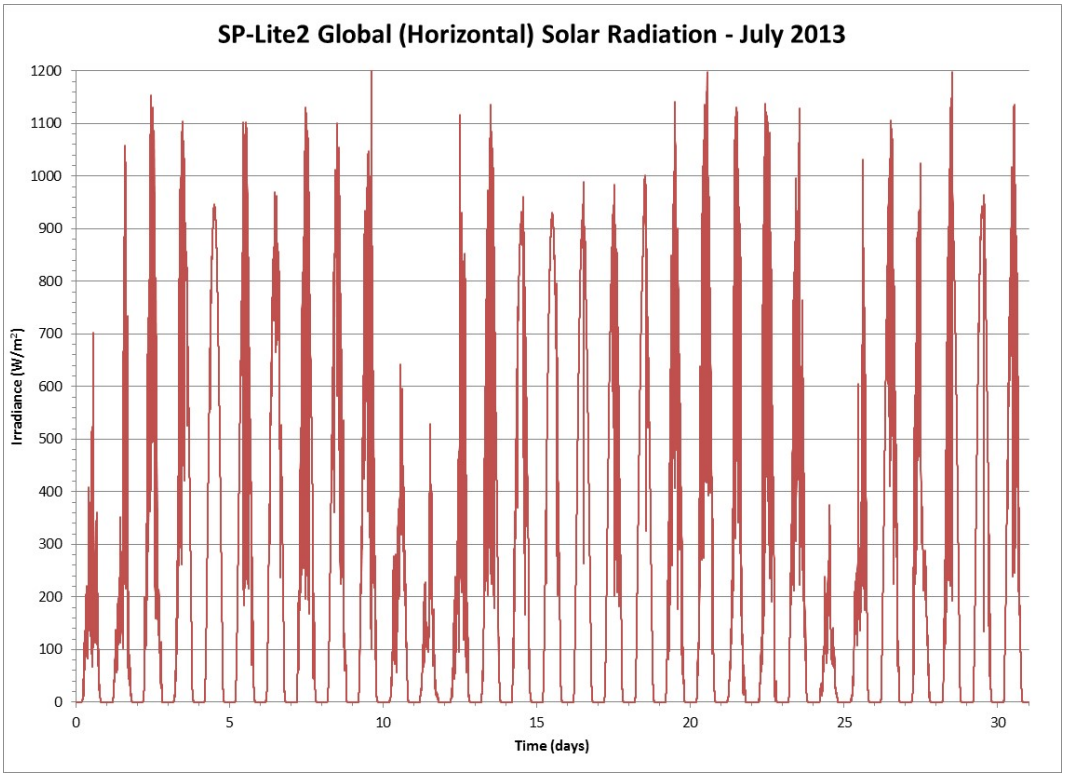

Figure 12051. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of July 2013

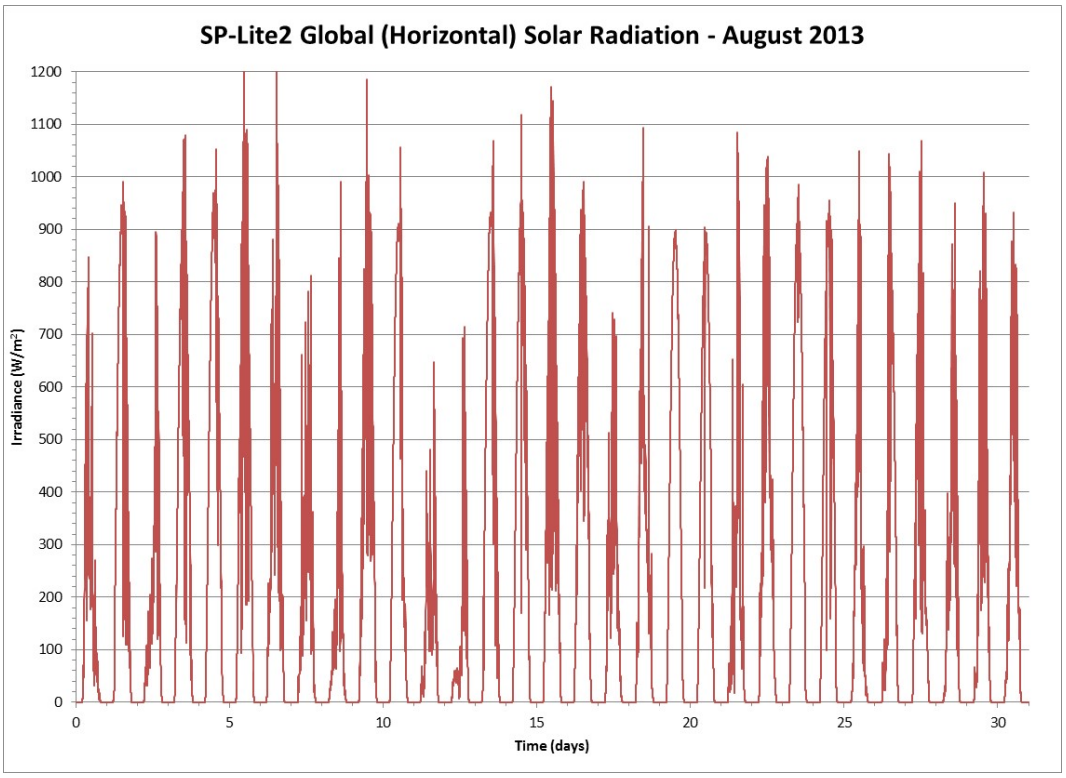

Figure 152. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of August 2013

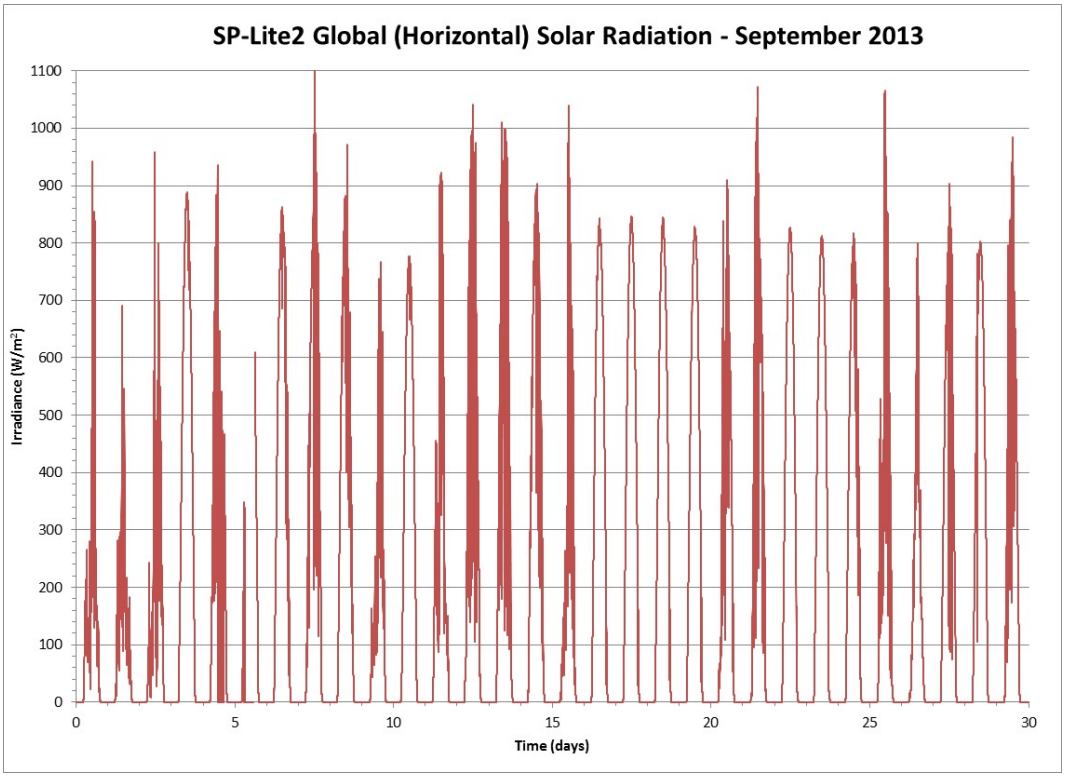

Figure 153. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of September 2013

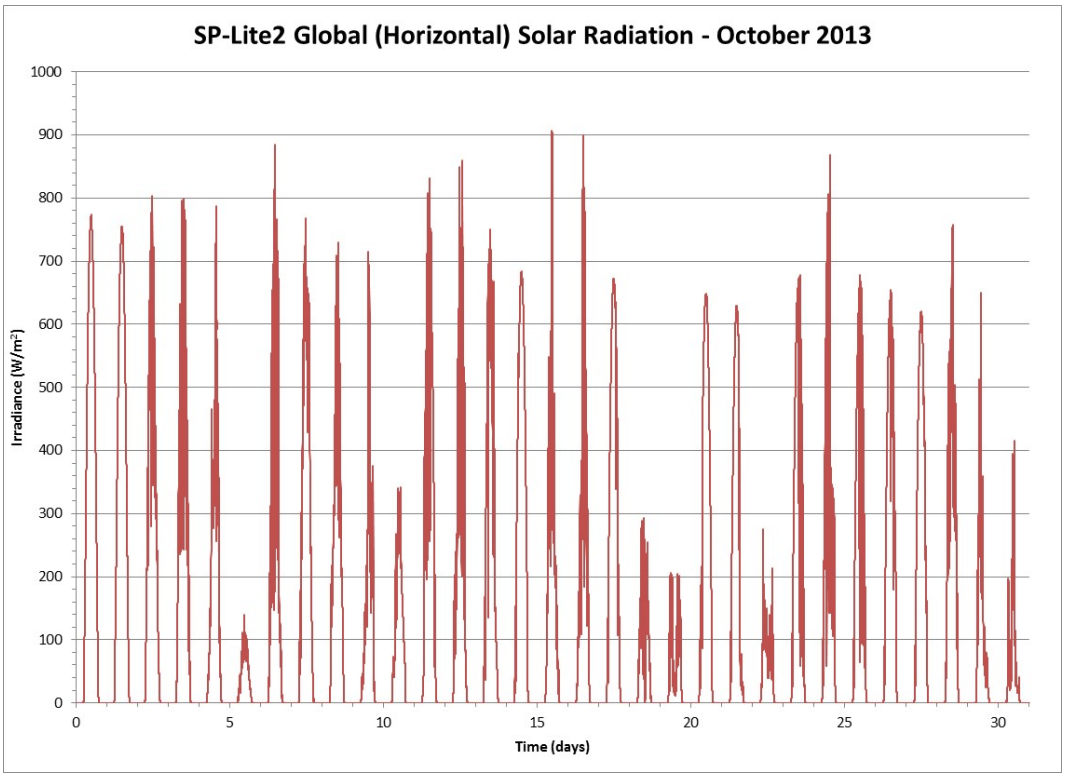

Figure 154. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of October 2013

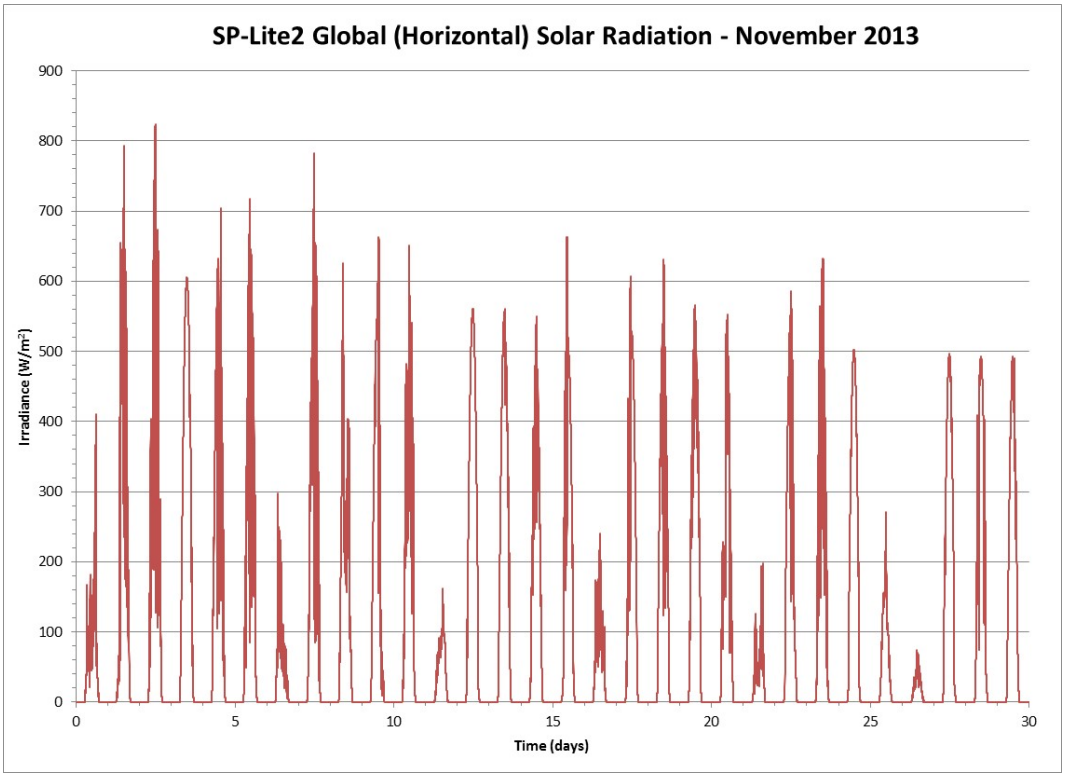

Figure 155. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of November 2013

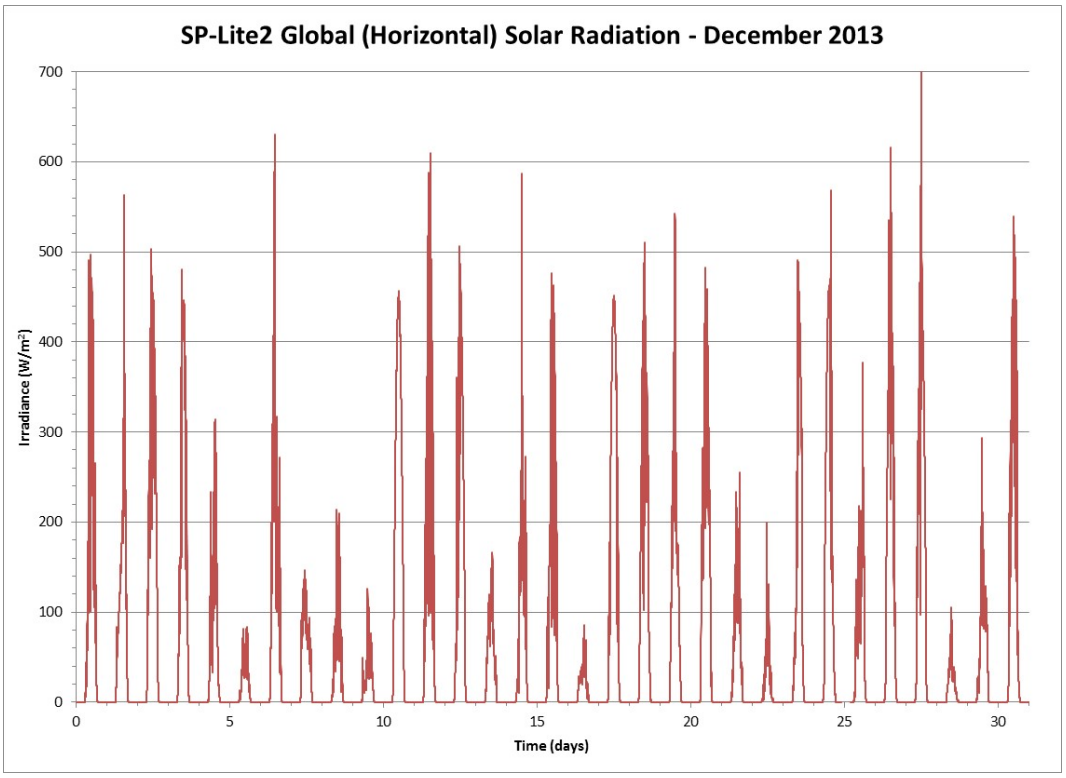

Figure 156. Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of December 2013

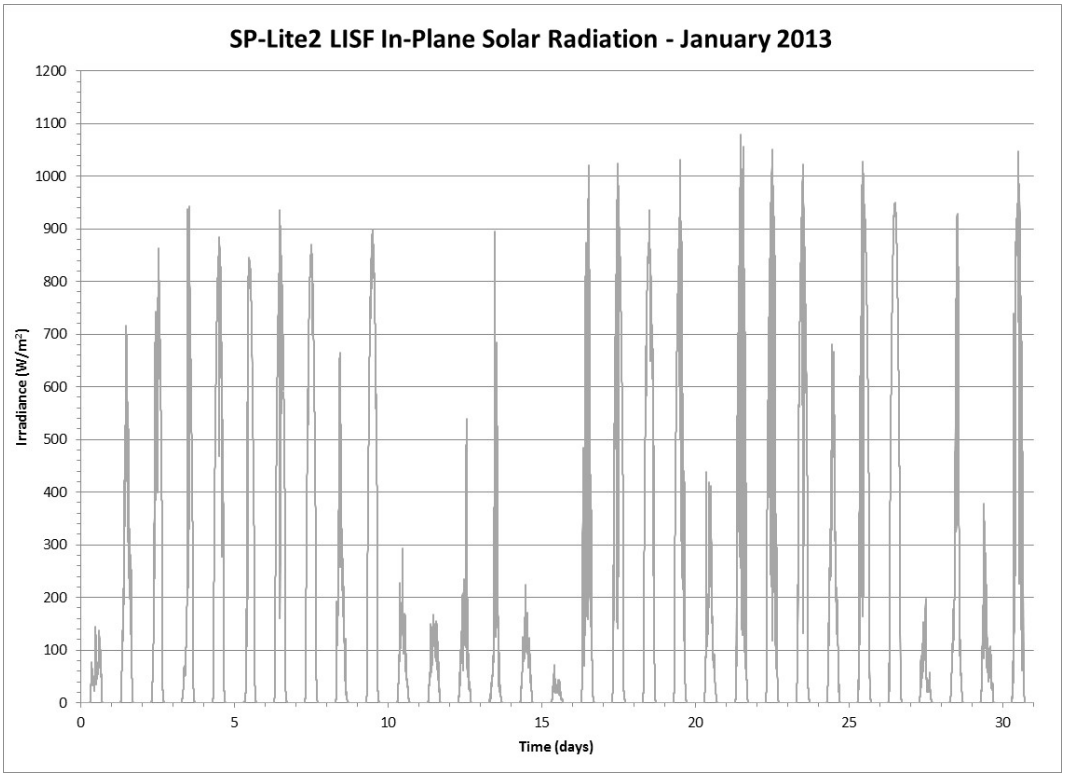

Figure 157. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of January 2013

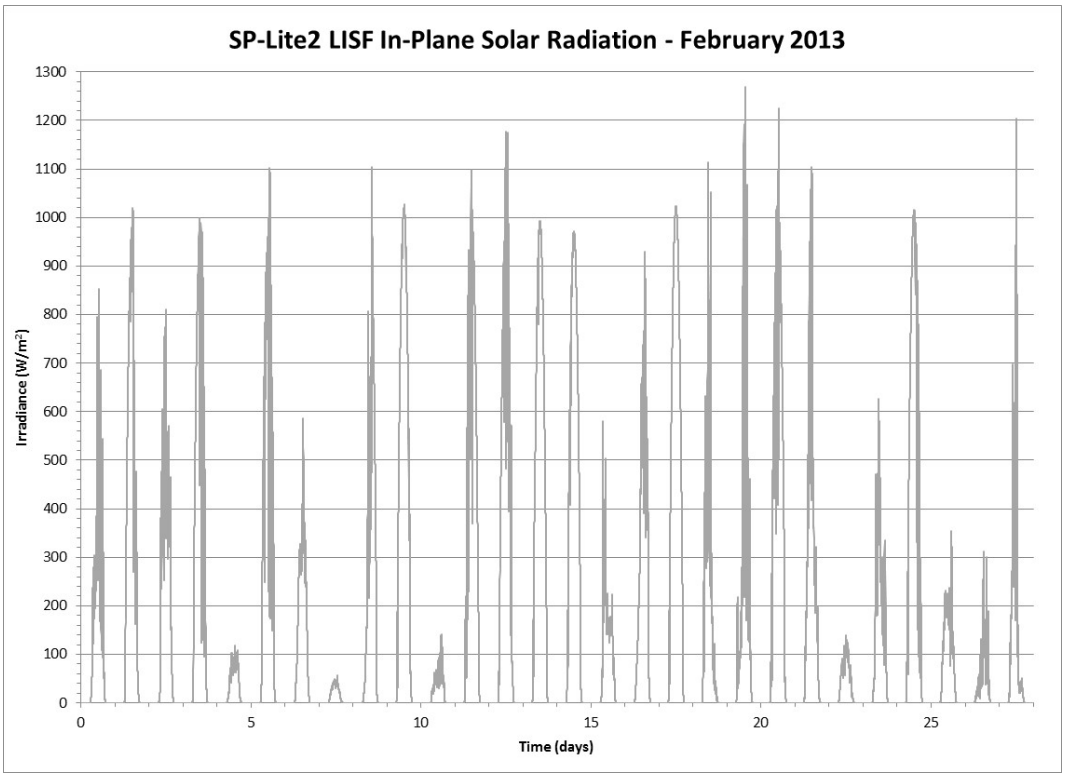

Figure 158. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of February 2013

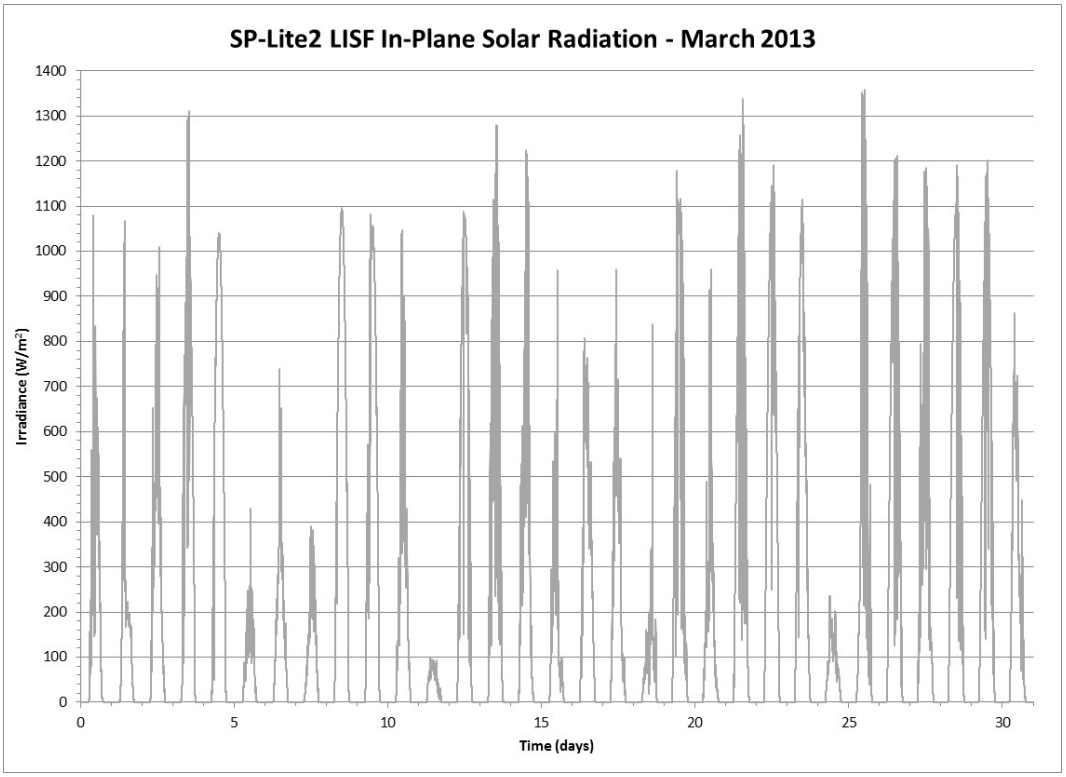

Figure 159. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of March 2013

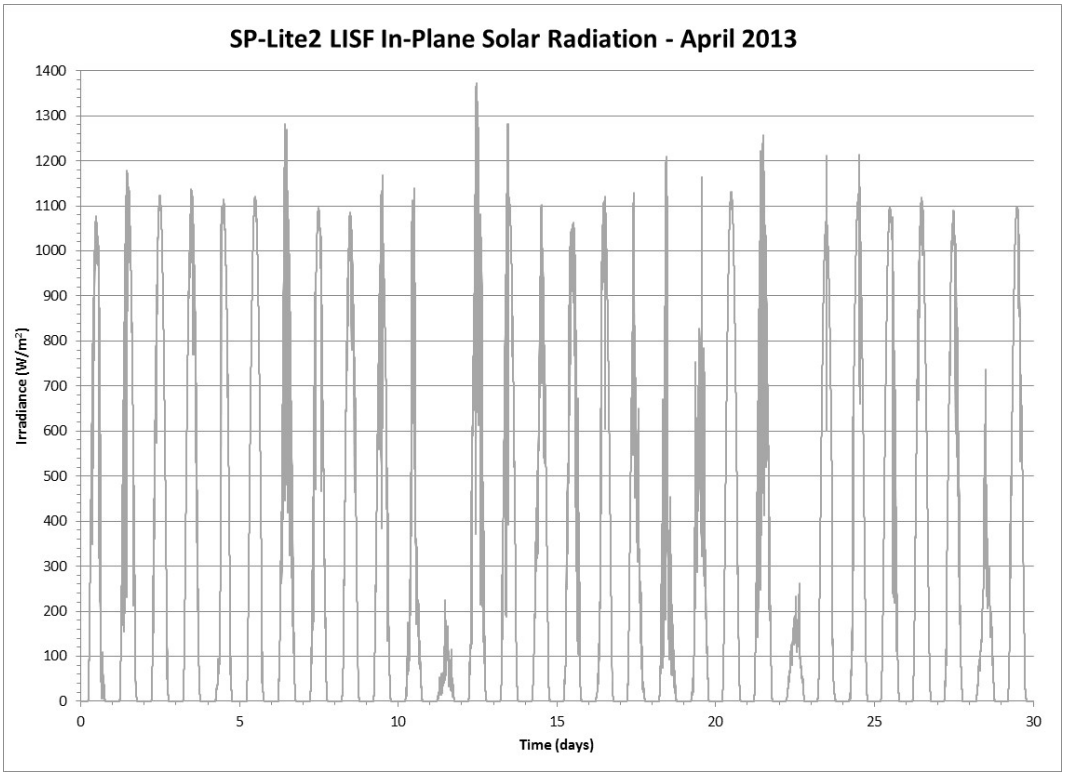

Figure 160. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of April 2013

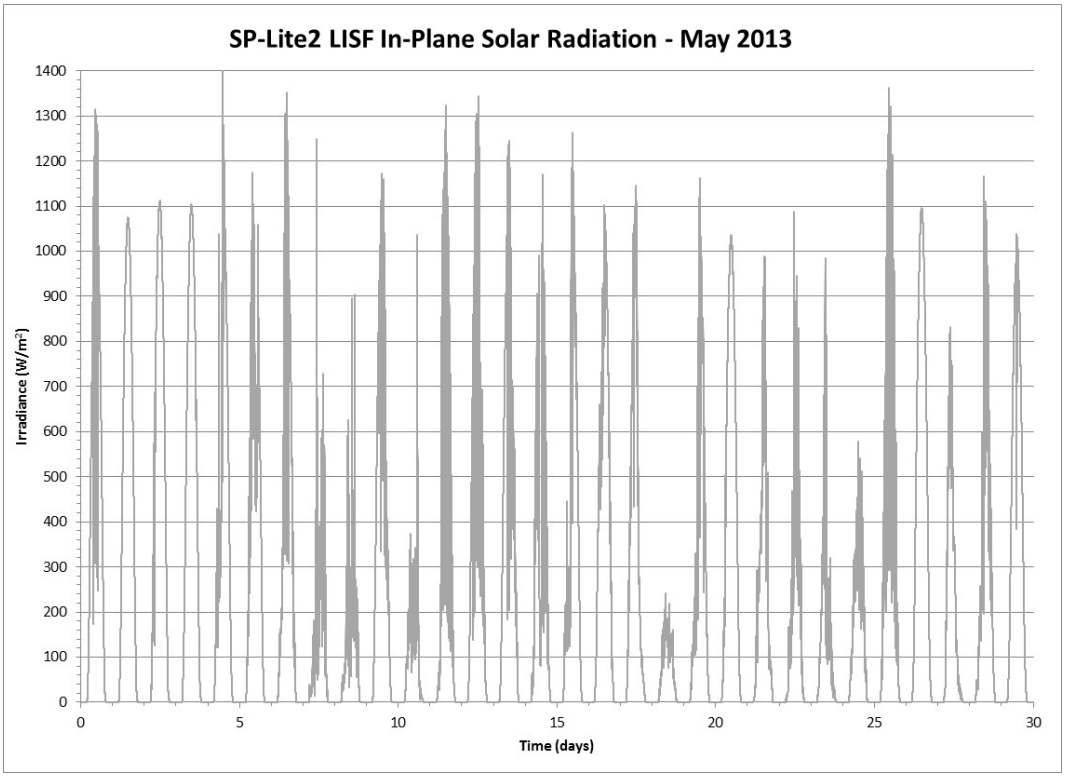

Figure 161. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of May 2013

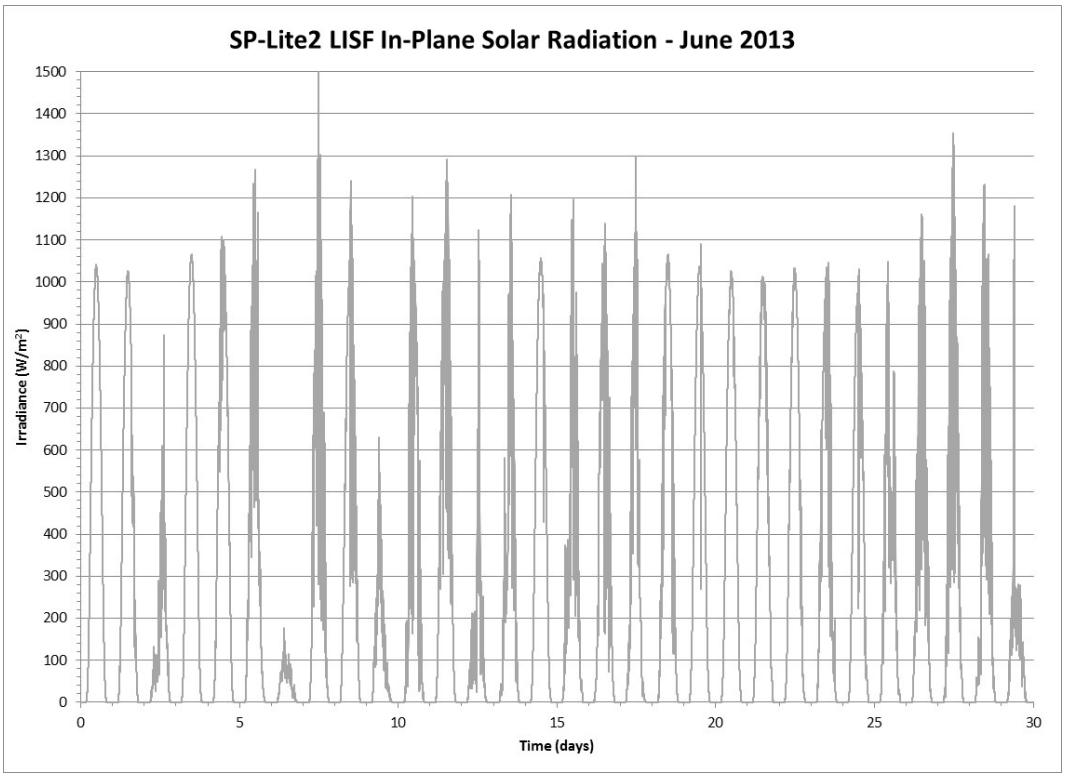

Figure 162. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of June 2013

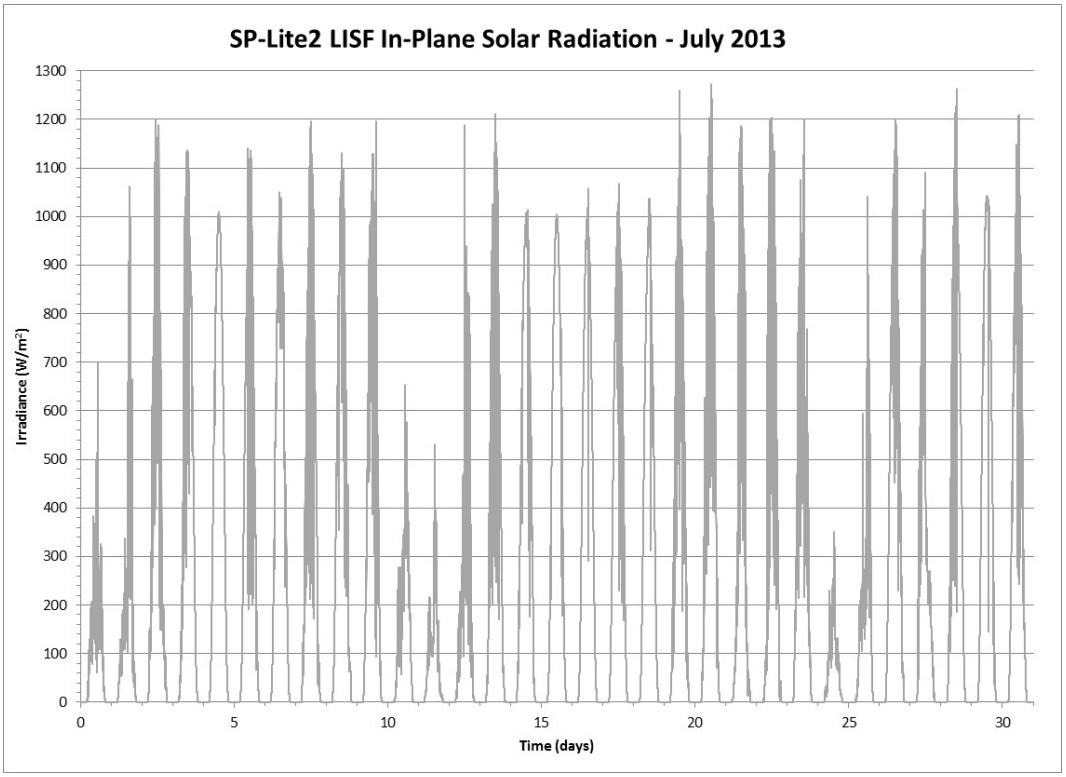

Figure 163. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of July 2013

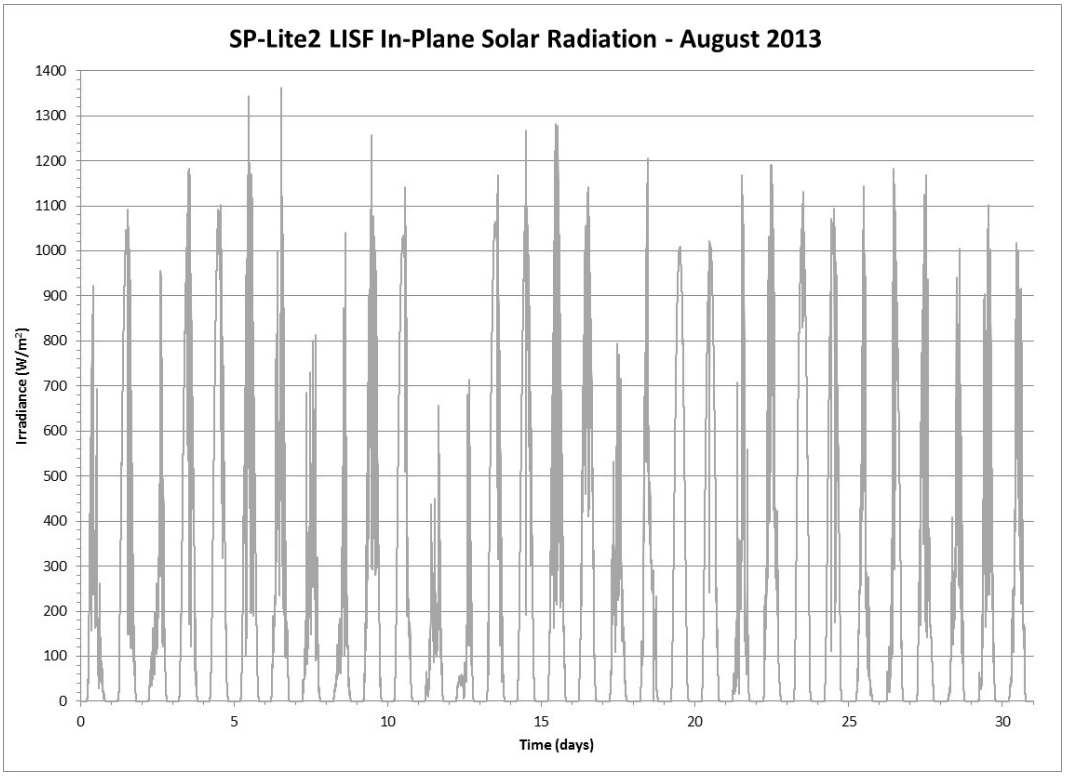

Figure 164. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of August 2013

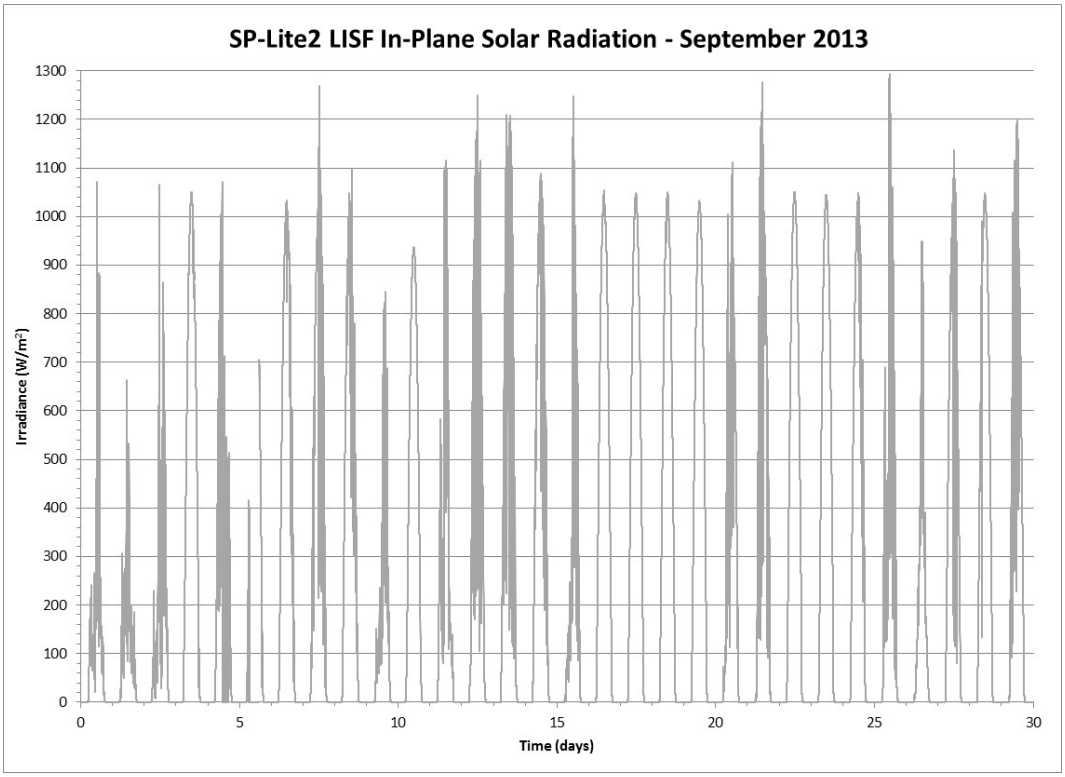

Figure 165. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of September 2013

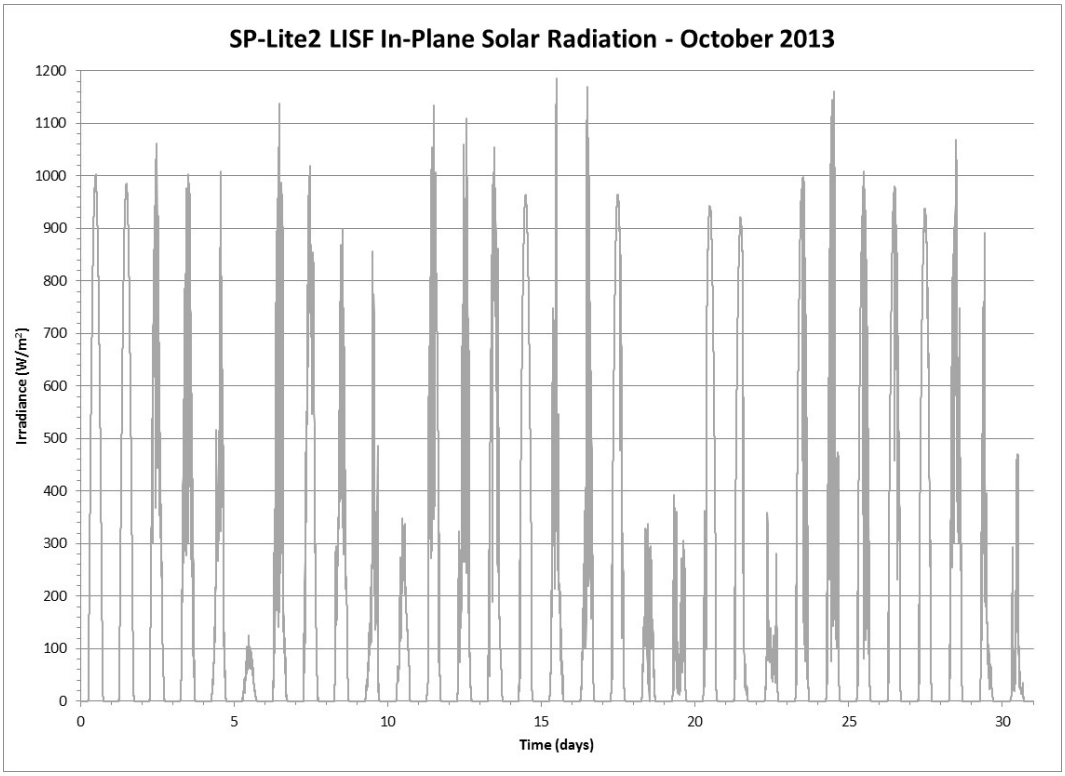

Figure 166. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of October 2013

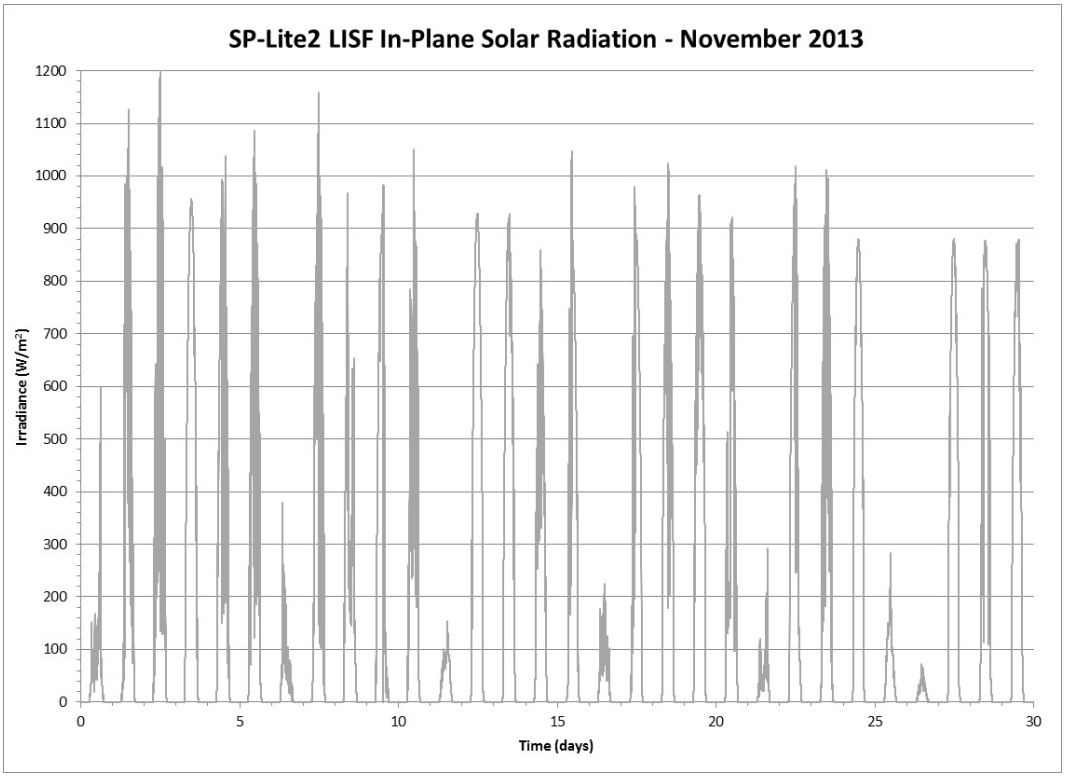

Figure 167. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of November 2013

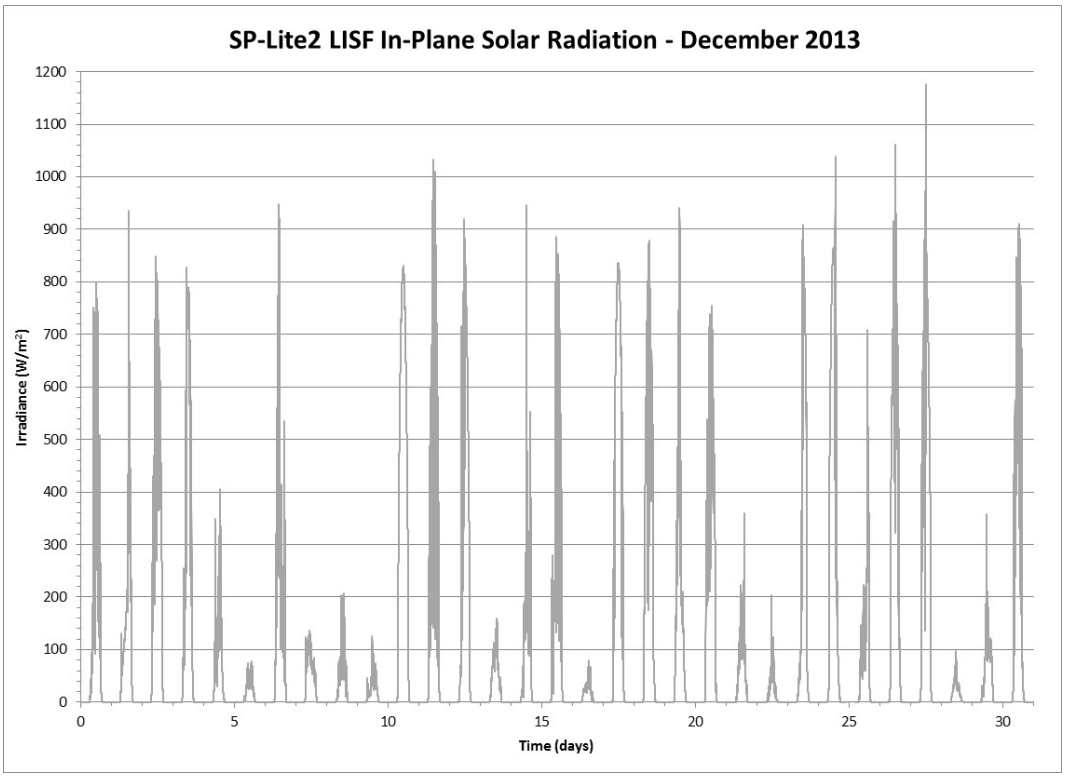

Figure 168. Tilted Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of December 2013

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