Smithsonian Tropical Research Institute

2019 Meteorological and Hydrological Summary for Barro Colorado Island

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Introduction

This is the 20th of a series of yearly reports summarising the past year's Smithsonian Tropical Research Institute's Physical Monitoring Program on BCI. This report is not meant to be exhaustive in its coverage in that it summarizes only some of the most 'important' or interesting parameters available. Any comments on how future yearly summaries could be improved would be appreciated. Additional copies of this report, reports from previous years, and downloadable data from BCI and other research locations, can be obtained from: http://biogeodb.stri.si.edu/physical_monitoring/research/barrocolorado

Setting

The meteorology and hydrology monitoring programs on BCI are described in detail in Climate and Moisture Variability in a Tropical Forest: Long-term Records from Barro Colorado Island, Panamá. Windsor (1990). Much of the information on the next five pages has been extracted from this source.

BCI (9°10'N, 79°51'W) is a completely forested, 1567 ha island with a 53.9 km perimeter, rising 137m above Lake Gatun. The island receives an average of 2657.8 mm of rain per year**.** The meteorological year is divided into two parts: a pronounced dry season (on average from December 19 to May 2), and a wet season (May to mid-December). On average, only 292 mm of rain falls during the dry season. Relative humidity, soil moisture, air pressure, solar radiation, evapotranspiration, wind speed and direction all show marked wet/dry season differences. On the other hand, temperature varies relatively little throughout the year.

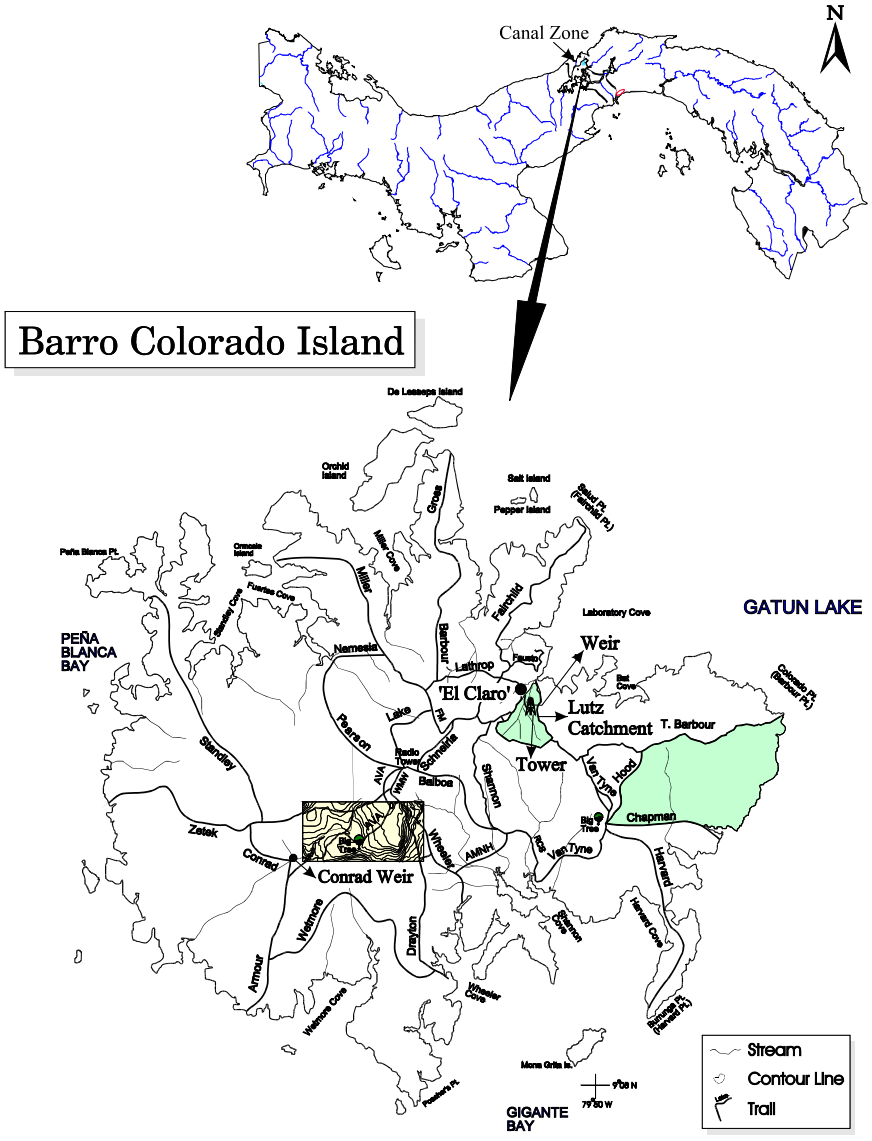
This report summarises data taken from two locations: a 48 m walk-up tower located within the Lutz catchment, and a small clearing ('El Claro') located among several laboratory buildings (see map on the following page). The station is in the northwest corner of the Clearing in a fenced in area measuring approximately 189cm x 183cm. The tower, with sensors at 10 m intervals, provides a vertical meteorological transect through the forest canopy. The Lutz catchment, located on the Northeast slope of BCI, and is probably typical of many small catchment areas on the island. The catchment encompasses 9.69 ha. The Lutz catchment is located immediately southwest of the laboratory clearing and dormitory area. The catchment has a steep grade that drains rapidly into the stream. The Conrad weir is located on the western side of the island and drains a 42.5ha catchment in the center of the island – including most of the 50ha plot. The catchment is divided into a small, gently sloped area near to the weir, and a much larger, nearly flat area in the center of the island.

The Clearing is a grass-covered area located near several laboratory buildings and is intended to represent a forest clearing.

The physical aspects of both the Clearing and the Tower have changed relatively little over time. However, cycles of vegetation removal and re-growth may have had subtle effects at both locations. The recent removal and construction of buildings near to the Clearing may also have affected the local climate. Furthermore, it is evident that the canopy surrounding the Tower has risen, perhaps by as much as 5m, since the Tower was erected – with possible measurement implications, especially at the highest levels.

In May of 2002, three new, 6-foot sections were added to the top of the tower. It was necessary to remove many branches from trees next to the tower during this operation. The new maximum height of the tower is now approximately 48m. A parallel series of meterological wind speed measurements were made a both the old maximum height and the new for several years. Temperature and humidity are collected at both heights. Wind direction (it was not possible to measure at the old height) and solar radiation (assumed to be unaffected by the change in height) were moved to the 48m level and never measured in parallel.

Data were collected using two different methods: electro-mechanically (electronic sensors, data loggers, chart recorders, etc.), and manually (rain gauges, max-min thermometers, sling psychrometers, soil samples, ETGages) by a field technician - Mr. Brian Harvey. In general, manual readings tend to provide the most stable measurements over the long-term and, as a result, when both types of data are available, the manual readings are used in this report. Some of the disadvantages of these measurements are that they are not available for every day, and they are usually taken only once a day (once a week for soil samples).



Some summaries (temperature, relative humidity, and soil humidity) are based entirely on manual measurements. Other summaries (solar radiation, wind direction) are based entirely on electro-mechanical measurements. Finally, some summaries (rainfall and wind speed) are based on combinations of manual and electro-mechanical measurements.

Major Treefall Event 2018

Sometime between April 27 and the 30th, 2018, a tree located approximately 40-50m SW of the tower, fell on the tension cables of the tower. This event created the largest gap ever observed in the area of the Lutz tower. Damaged to cables left the tower unsafe and, as a result, manual data on the data were not collected beginning on May 1. There is a high probability that the new gap will have affected temperature & humidity readings for all sensors from 1m to 42m. The tower was still not repaired at the writing of this report.

The Data

This report summarises the following data:

Lutz Tower	1m	relative humidity
		temperature
	20m	relative humidity
		temperature
	42m	evapotranspiration
		relative humidity
		temperature
	48m	evapotranspiration
		solar radiation
		relative humidity
		temperature
		wind speed and direction
Lutz catchment		run-off
		soil moisture
Conrad catchment		run-off
'El Claro'		air pressure
		evapotranspiration
		rainfall
		relative humidity
		temperature

Rainfall

Rainfall was collected by rain gauges in the Clearing, and by a tipping bucket in the Clearing. The rain gauges were read at approximately 9:00 am every day except weekends and holidays. Tipping buckets provide continuous rainfall information but tend to underestimate total rainfall by between 2% and 12% and for that reason are not used to provide data on absolute rainfall totals. Tipping buckets generate 'events' for every 0.254 mm of rainfall recorded. The underestimation seems to be due to the instruments' inability to properly record intense periods of rainfall. In order to 'fill in' the missing rain gauge data, a computer program was written by the author that uses tipping bucket rainfall data to distribute the rain gauge data for those days when readings were not made. The program takes the total rainfall collected in the rain gauge and divides it up proportionally according to the rainfall patterns recorded by the tipping bucket. The estimated rainfall for the missing days is exactly equal to the rainfall collected by the rain gauge. The daily rainfall for the Clearing is shown on page 8.

Rainfall Data prior to 1972 are provided by the Panama Canal Authority (ACP) station located approximately 360m to the NNW of the Clearing station.

Page 9 shows the monthly totals for this year. The graph on the same page compares this year's monthly totals with the average monthly totals (±SD) for the period 1929 to 2019.

Page 10 shows yearly rainfall totals for all year since 1925. Time series graph and frequency histograms are presented for these data.

Page 11 breaks yearly rainfall approximately into wet and dry seasons. The average beginning and end dates for the seasons as defined by the Autoridad de Canal de Panamá (ACP) (Dec. 21 and May 5) were used. The two graphs on this page are frequency histograms showing the distribution of rainfalls (1929 to 2019) for the Dry and Wet Seasons. The arrow ⟶ in each graph shows the rainfall for 2019 in relation to previous years. The small crossbar —|— above each graph represents the mean (vertical bar) and the standard deviation (horizontal bar) for the period 1929 - 2019.

Page 12 shows the beginning and end dates of the Panama Canal watershed dry season as defined by the Meteorological and Hydrological Branch of the ACP. The ACP defines the existence of dry season by tracking 11 variables (see list below) and then making a subjective decision based on the performance of these variables, and their prior experience with weather patterns in the Panama Canal area. There are no publications justifying the use of this system and any questions should be directed to Johnny Cuevas of the Met. & Hyd. Branch of the ACP (jcuevas@pancanal.com). The data from Page 11 are shown graphically on Page 13. At the time of printing of this report, the 2019 wet season had not yet ended.

Westerly Component of 300 HPA Wind
Gatun Lake Basin evaporation > 0.13" day^{-1}
Sea temperature at Amador < 80 °F
< 5 grams of water vapor kg^{-1} below 12.0 ft
Temp-Dew point difference SFC-400 HPA., > 10°C
Howard Airforce Base wind speed SFC-4000 ft., > 15 knots

Intertropical Convergence Zone > 2 deg. Lat. south of Panama
Pacific Coast sea breeze < 2 hours day^{-1}
Atlantic Coast surface wind average > 6.0 M.P.H.
Gatun Lake level (corrected for water usage) falling
Gatun Watershed daily rainfall average (of 26 stations) < .25"

Pages 14 and 15 show an analysis of rainfall 'events' (*storms*). For convenience, and again somewhat arbitrarily, I have defined a storm as any continuous period of rain separated by at least an hour from any other rainfall. Since this analysis required the timing of rainfall events, tipping bucket data were used. As a result, the absolute size of rainfall events should be considered as only an estimate since they will tend to disproportionately underestimate the size of storms - larger storms will be more underestimated than smaller ones. Keeping this in mind, the tables and graphs on this page compare the maximum storm size and the average storm size and duration per month for the period 1972 to 2018 and for the year 2019.

Run-off

Run-off at the Lutz catchment area was determined from the water level in a 120° V-notch weir. The height of the water was recorded by two separate instruments: continuously by a Stevens A-71 strip-chart, water level recorder and at five-minute intervals with a Sutton Radar level Recorder (replacing the ISCO Bubble Flow Meter in 2014). Data from these devices are converted (either directly or through a digitizing process) into run-off (m^3) and then into rainfall equivalents.

Daily Lutz creek weir run-off totals are shown on page 16. These data are shown in terms of the equivalents of precipitation in mm. These values are calculated by taking the run-off and dividing by the total surface area of the catchment area (9.73 ha). In this way, the run-off can be more conveniently compared to the amount of rainfall.

Pages 17 show the total monthly run-off. The graph on the bottom of page 18 compares average monthly run-off for the period 1973 to 2018 with 2019. The graph on the top of page 18 compares monthly-accumulated precipitation with 2019 and long-term monthly-accumulated run-off (in rainfall equivalents).

Run-off at the Catchment catchment area was determined from the water level in a two-stage, rectangular weir. Water level was originally measured using an ISCO Bubble Flow Meter, but recently has been measure with a pressure gauge. Pages 18 shows the total monthly run-off data for the Conrad Catchment as well as a comparison between the Lutz and Conrad weir run-off.

Soil Moisture

Soil moisture was determined gravimetrically based on samples collected weekly from Dec. and May, and bi-weekly from June to Nov. Samples are taken at two depths (0-10cm and 30-40cm) from ten sites in the Lutz catchment area. Samples of approximately 2.5 cm soil cores are made with an 'Oakfield punch'. Page 20 shows the average soil moistures (% water by wet weight of soil) per month at each sample depth. The graph on page 21 compares

monthly averages for the period 1986 to 2018 with those for 2019. The sampling locations where changed at the end of 2018 to near-by sites. This is done approximately every 4-5 years due to perturbations to the soil caused by the coring and trampling by the technician. The change in sites may have been responsible for the above average soil moistures - despite the below average rainfall.

Relative Humidity

Relative humidity was measured using the traditional method of wet and dry-bulb psychrometry. Measurements in the Clearing, at the 1m, 20m, 42m and 48m levels of the Lutz tower were made at approximately 12:30 p.m. using a Taylor Sling Psychrometer. Data were also collected at 15-minute intervales by dataloggers attached to Campbell Sci. CS215 temperature/humidity sensors (Viasala HMP 35/45 sensors prior to 2010) at the same locations. The average monthly relative humidities are shown in tabular and graphical form on pages 22 and 23, respectively.

Temperature

Shaded air temperature was measured in the Clearing and at the base of the Lutz Tower (1m) using Taylor max-min thermometers. Measurements were made by hand at approximately 9:30 am. Data were also collected at 15-minute intervales by dataloggers attached to to Campbell Sci. CS215 electronic temperature/humidity sensors (Viasala HMP 35/45 sensors prior to 2010) in the Clearing and at the 1m, 20m, 42m and 48m levels of the Lutz tower. The average monthly daily maximum and minimum temperatures are shown on pages 23 to 25.

Solar Radiation

Global solar radiation was measured at the top of the Lutz tower using one Kipp&Zonen SPLite2 and one LiCor LI200 pyranometer attached to a datalogger. 15-minute interval total (MJ m^{-2}), maximum and minimum (J m^{-2} s^{-1}) were recorded. Page 26 shows the Daily Global Radiation values. Page 27 shows total monthly Global Radiation.

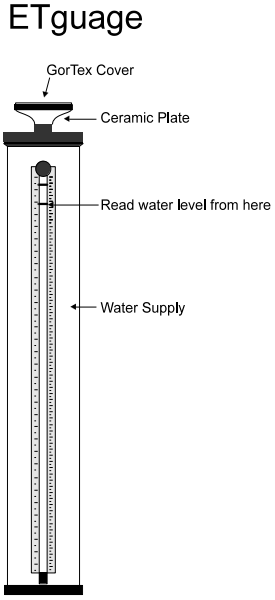
Wind Speed and Direction

15-minute interval average, maximum and minimum wind speed plus average wind direction was recorded at the top of the Lutz tower using a Model 05103 Young Anemometer connected to a data logger.

Page 28 shows daily average and maximum wind speeds from the Young Anemometer located at 48m. The page 29 shows daily average wind direction. The angles indicated in the table and graph on this page represent the direction into which the wind was predominately blowing on a given day. Page 30 shows the monthly average and average daily-maximum wind speeds from 48m, and monthly average directions (Young Anemometer) for the year.

In addition to the electronic anemometers, manually read, totalizing anemometers were in use to measure wind passage between 1998 and 2007. This includes the period 2001-7 when totalizing anemometers were in operation at both 42m and 48m. An analysis of these data are shown on Page 31.

Estimated Evapotranspiration and Water Balance



Evapotranspiration was added to the meteorological program on BCI beginning on December of 1992 and is estimated using ceramic plate atmometers known as ETgauges. ETgauges estimate evapotranspiration by allowing water to be drawn up through a ceramic disk and out through a GorTex cover. A recent study by Fontain and Todd (Measuring Evaporation with Ceramic Bellani Plate Atmometers, 1993, Water Resources Bulletin, Vol. 29, No. 5, p. 785-795) found that such devices perform very well compared with more traditional methods of measuring evaporation.

ETgauges provide data that are very comparable with Class-A open evaporation pans. A 4-year study on BCI showed that yearly totals of the two systems vary by approximately 2%. ETgauges slightly overestimate ET during the dry season and underestimate during the rainy season – compared to the pans.

There are two ETgauges located at a height of 1.5m in the Clearing (the ETgauges located on the Lutz tower were not used in 2019 due to damage to the tower) The ETgauges are read at approximately the same time of day and with the same frequency as the rain gauges.

The results from the ETgauges are given on page 33.

Long-term Monthly Averages/Totals

Pages 34 - 38 show the long-term, monthly Averages/Totals for rainfall, runoff, relative humidity, air temperatue, evapotranspiration, solar radiation, and wind speed.

Daily Averages/Totals for 2019

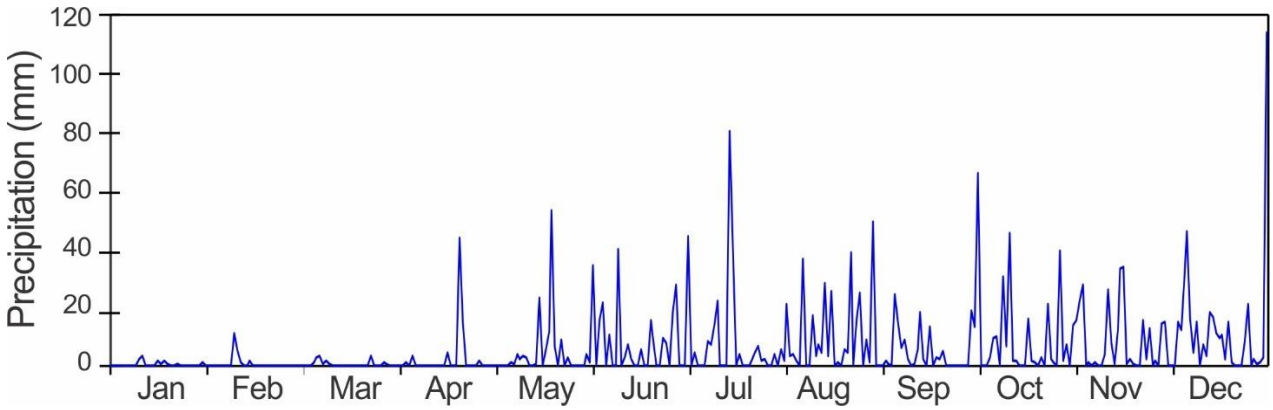
Pages 39 and 40 show the daily Averages/Totals for rainfall, runoff, relative humidity, air temperatue, evapotranspiration, solar radiation, and wind speed and direction.

Daily Patterns

Pages 41 and 42 show the daily patterns for air temperatue, relative humidity, solar radiation, rainfall and wind speed. These figures use electronic sensor data.

2019 Daily Rainfall (mm) on BCI recorded at ~930 hrs

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.9	0.0	65.8	15.5	0.0
2	0.0	0.0	0.0	0.0	0.0	34.5	44.2	21.0	1.5	0.0	22.1	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.3	0.5	0.0	27.9	15.2
4	0.0	0.0	0.0	1.3	0.0	15.5	4.7	4.0	0.3	0.0	0.3	12.2
5	0.0	0.0	0.0	0.0	0.0	21.7	0.3	1.8	24.4	2.8	1.3	31.8
6	0.0	0.0	1.3	3.3	0.3	0.0	0.0	0.0	14.2	9.4	0.3	46.0
7	0.0	0.0	3.1	0.0	1.0	10.8	0.0	36.4	6.1	9.9	1.0	16.0
8	0.3	0.0	3.6	0.0	0.8	0.0	8.3	0.0	9.1	0.0	0.3	4.3
9	0.0	11.2	0.8	0.0	3.9	0.0	7.5	0.0	2.5	30.5	0.0	15.2
10	2.2	5.2	1.5	0.0	2.2	39.9	14.0	17.0	0.0	6.6	4.1	0.0
11	3.3	1.1	0.8	0.0	3.4	0.3	22.2	3.2	0.8	45.2	25.9	7.4
12	0.0	0.0	0.0	0.0	3.1	2.8	0.0	7.5	5.6	2.0	7.9	3.6
13	0.0	0.0	0.0	0.0	0.0	7.2	0.0	4.6	18.5	1.8	0.5	18.5
14	0.0	2.0	0.0	0.0	0.0	2.5	0.0	28.4	2.5	0.3	12.4	16.5
15	0.0	0.0	0.0	0.0	0.8	0.0	80.4	3.4	0.0	0.3	33.3	11.4
16	1.5	0.0	0.0	0.0	23.4	0.0	39.4	25.8	13.2	0.3	33.8	9.4
17	0.5	0.0	0.0	4.6	0.3	5.7	0.3	0.0	0.0	16.0	0.5	10.7
18	1.8	0.0	0.0	0.0	5.9	0.0	4.1	1.2	2.8	1.5	2.3	2.5
19	0.8	0.0	0.0	0.0	11.7	0.0	0.0	0.0	2.3	1.3	0.5	15.0
20	0.0	0.0	0.0	0.0	53.0	15.5	0.0	5.7	5.1	0.3	0.3	1.3
21	0.2	0.0	0.0	43.9	6.7	8.8	0.0	4.3	0.0	2.8	0.0	0.3
22	0.5	0.0	0.0	15.2	0.0	0.0	1.9	38.9	0.0	0.0	15.7	0.0
23	0.0	0.0	0.0	0.3	8.8	0.0	4.4	0.3	0.0	21.3	2.5	0.0
24	0.0	0.0	3.6	0.0	0.3	9.3	6.6	15.8	0.0	2.5	13.0	8.6
25	0.0	0.0	0.0	0.0	2.6	7.7	2.0	24.9	0.0	1.0	0.0	21.1
26	0.0	0.0	0.3	0.0	0.0	0.0	2.3	0.3	0.0	0.0	2.0	0.0
27	0.0	0.0	0.0	1.5	0.3	18.4	0.0	8.9	0.0	39.4	0.0	2.3
28	0.0	0.0	1.3	0.3	0.0	27.6	0.0	1.1	0.0	1.5	14.5	0.5
29	0.0		0.5	0.0	0.0	0.0	4.2	49.3	18.8	7.4	15.2	1.0
30	1.4		0.0	0.0	0.0	0.0	0.3	0.3	13.2	0.3	0.0	2.8
31	0.0		0.0		3.8		5.5	0.0		14.0		114.0
	12.4	**19.6**	**16.5**	**70.3**	**132.2**	**229.2**	**252.6**	**309.2**	**141.5**	**284.0**	**253.0**	**387.6**

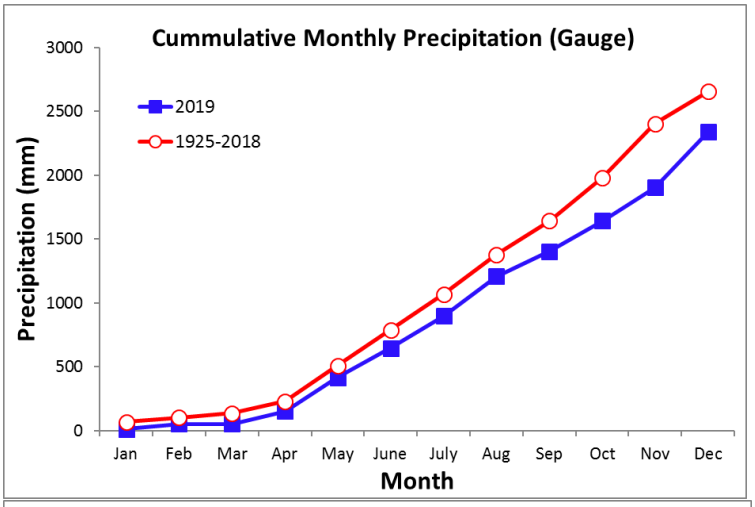


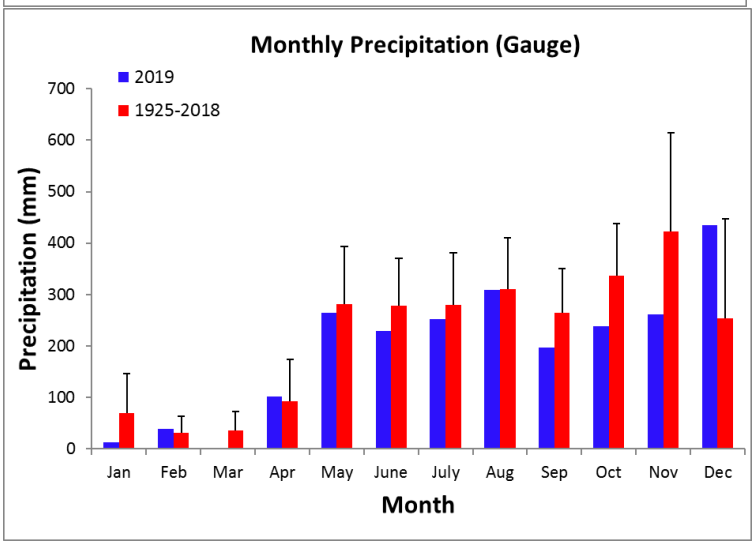
Monthly Rainfall at 'El Claro' - Rain Guage

Rainfall (mm)

	Average	Min	Max	S.D.	2019	Rank* (n=94)
January	69.4	0.5	376.4	77.1	12.4	78
February	31.9	0.5	186.4	31.9	39.1	29
March	35.6	0.0	172.6	36.4	0.0	92
April	92.2	0.0	463.8	81.6	101.6	36
May	281.6	78.5	699.8	111.4	264.4	51
June	278.5	66.8	556.8	91.3	229.2	64
July	280.4	90.6	725.9	100.1	252.6	58
August	310.4	142.7	677.2	99.3	309.5	39
September	264.9	107.6	507.0	85.3	196.3	69
October	336.5	115.3	588.7	101.4	237.9	78
November	423.3	117.1	1056.1	190.8	261.0	75
December	253.1	16.4	1182.9	193.6	434.7	14
Total	**2657.8**	**1698.9**	**4486.5**	**475.6**	**2338.8**	**66**

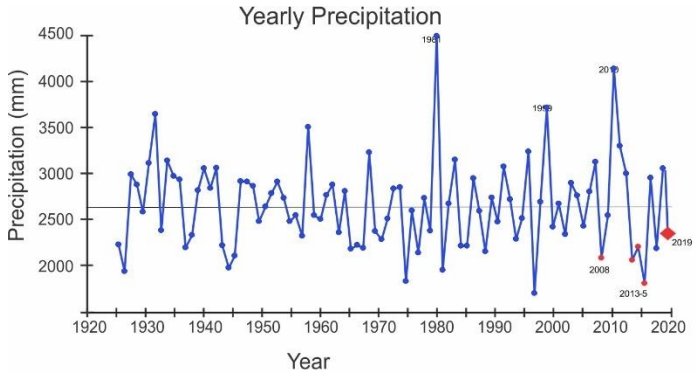
* Rank: 1 = wettest year

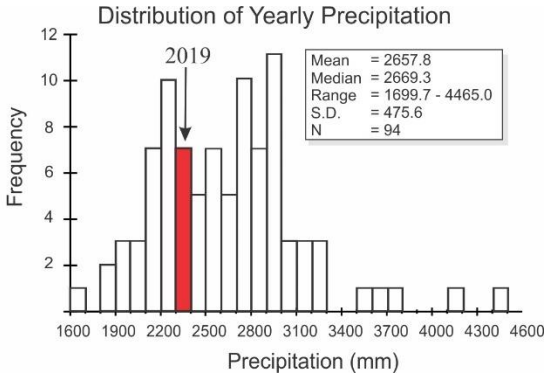




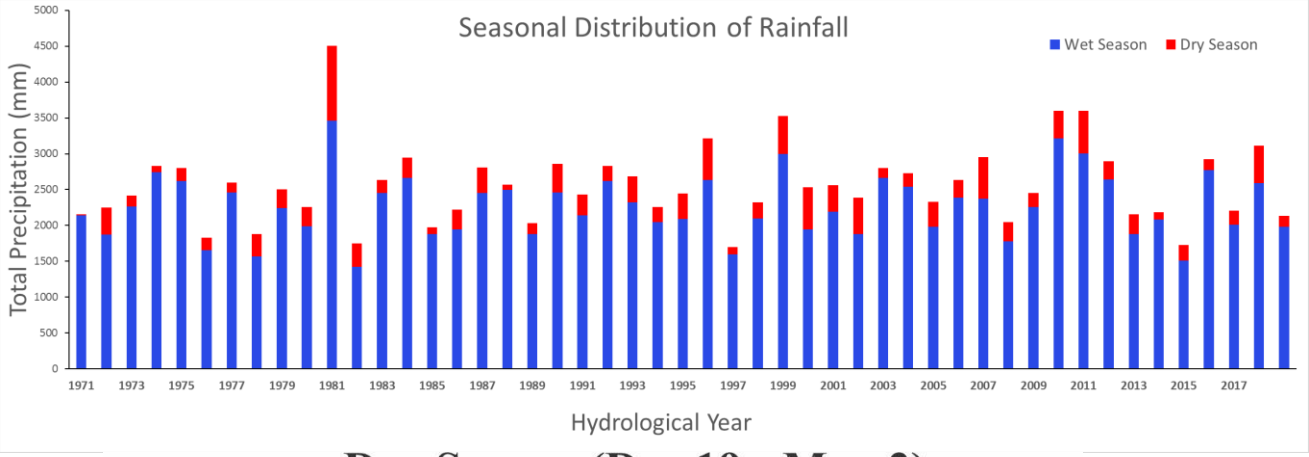
Yearly Rainfall (mm) at 'El Claro' - Rain Gauge

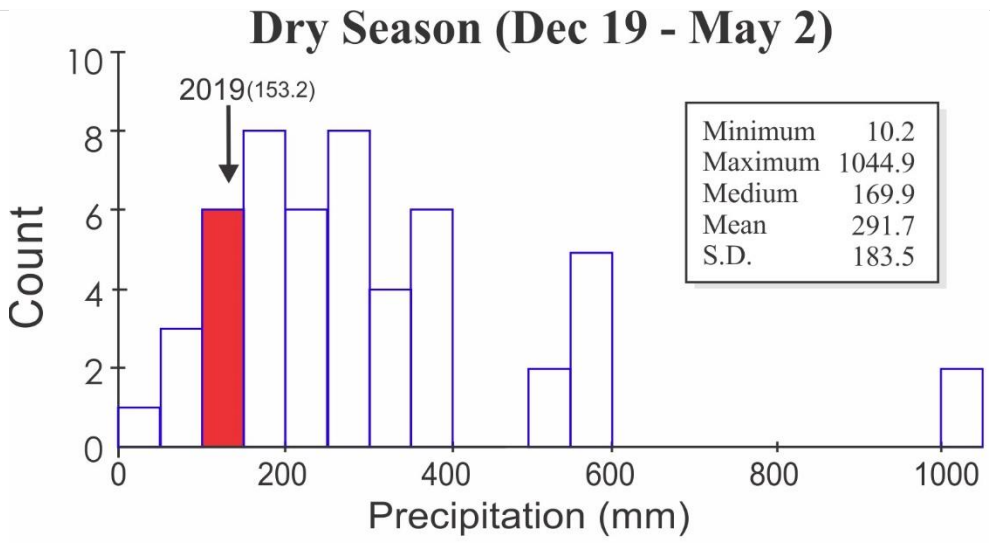
Year	Rain	Year	Rain	Year	Rain
1925	2228.5	1957	2482.1	1989	2152.7
1926	1940.6	1958	2545.1	1990	2736.2
1927	2987.4	1959	2319.5	1991	2475.2
1928	2878.5	1960	3502.3	1992	3071.3
1929	2581.8	1961	2545.4	1993	2718.9
1930	3109.6	1962	2502.8	1994	2289.0
1931	3642.7	1963	2767.1	1995	2511.2
1932	2384.4	1964	2875.2	1996	3236.3
1933	3136.8	1965	2357.2	1997	1698.9
1934	2969.0	1966	2807.7	1998	2688.8
1935	2933.0	1967	2181.4	1999	3712.1
1936	2195.9	1968	2223.4	2000	2420.4
1937	2332.2	1969	2192.5	2001	2669.3
1938	2816.8	1970	3226.7	2002	2338.7
1939	3055.4	1971	2373.6	2003	2896.7
1940	2838.8	1972	2282.4	2004	2760.9
1941	3058.9	1973	2506.0	2005	2428.0
1942	2221.0	1974	2837.3	2006	2800.9
1943	1978.2	1975	2847.0	2007	3125.3
1944	2105.6	1976	1830.5	2008	2085.5
1945	2916.3	1977	2599.1	2009	2544.1
1946	2908.3	1978	2139.7	2010	4135.2
1947	2863.8	1979	2730.9	2011	3298.4
1948	2228.5	1980	2377.5	2012	2998.0
1949	1940.6	1981	4486.5	2013	2058.4
1950	2987.4	1982	1950.7	2014	2203.2
1951	2878.5	1983	2669.5	2015	1810.1
1952	2481.7	1984	3147.7	2016	2950.4
1953	2637.5	1985	2213.3	2017	2188.1
1954	2781.7	1986	2213.4	2018	3054.9
1955	2910.4	1987	2945.2	**2019**	**2338.8**
1956	2732.8	1988	2592.6		

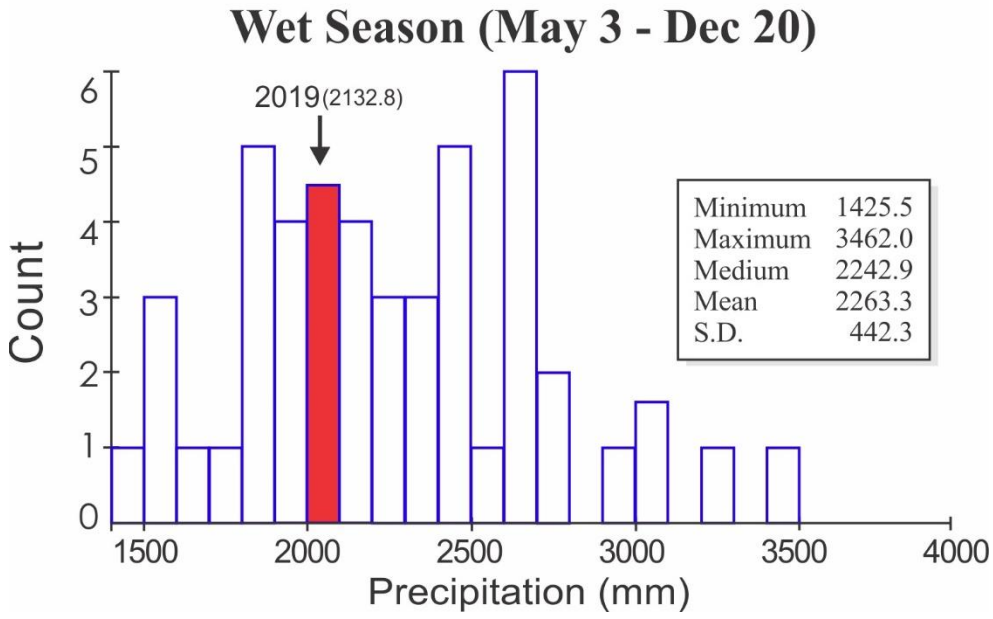




Seasonal Distribution of Precipitation







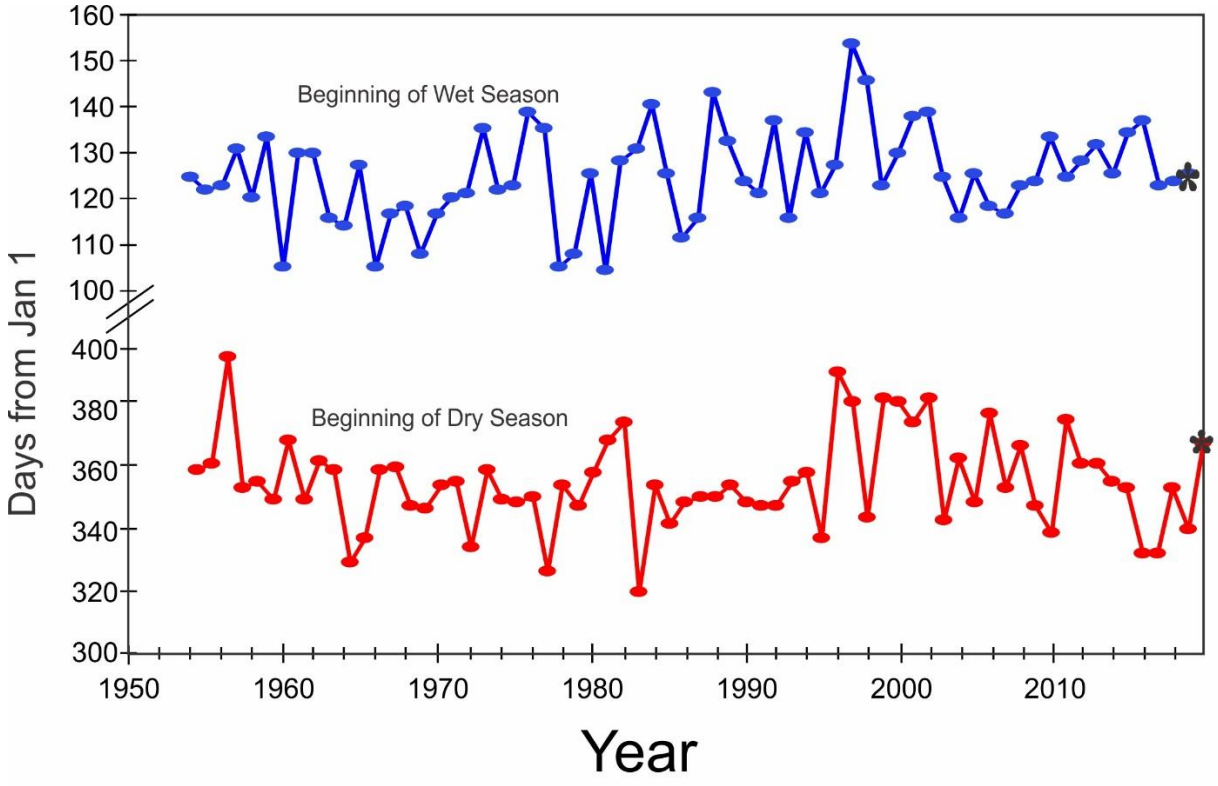
ACP Dry Season Beginning and End Dates

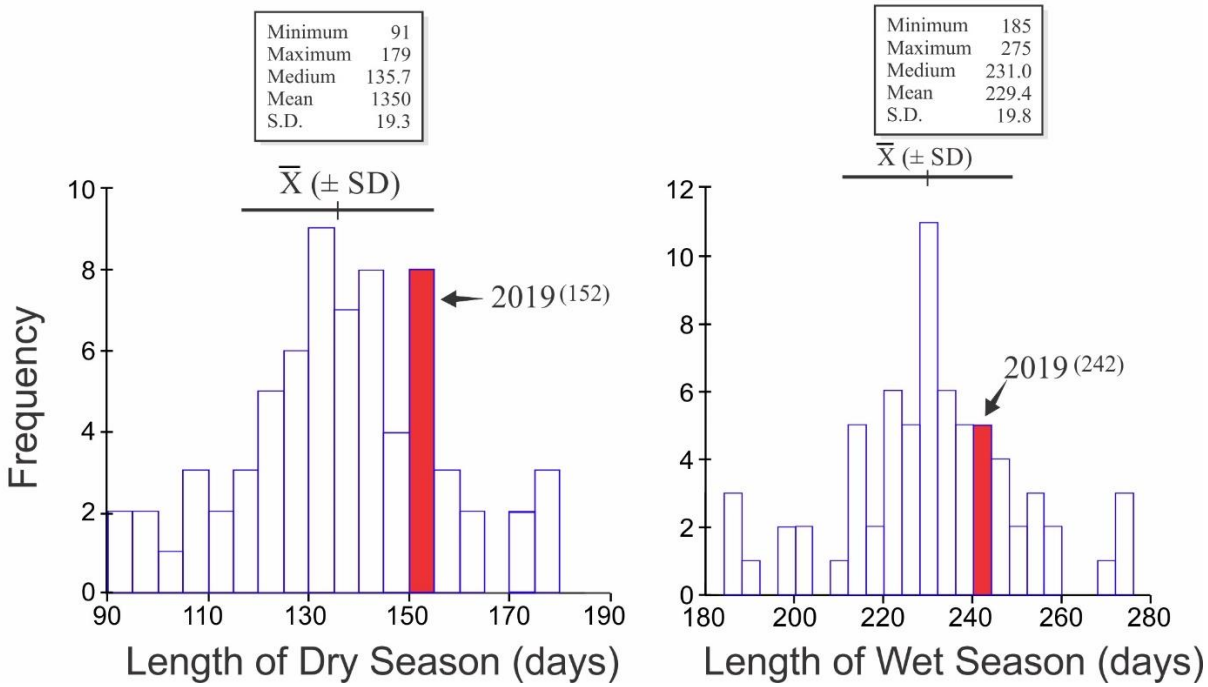
Year	Begin	End	Length		Year	Begin	End	Length	
			Dry Season	Wet Season				Dry Season	Wet Season
1954	25-Dec-53	05-May-54	131	236	1998	09-Dec-97	29-May-98	171	234
1955	27-Dec-54	02-May-55	126	275	1999	18-Jan-99	03-May-99	105	259
1956	01-Feb-56	02-May-56	91	231	2000	17-Jan-00	10-May-00	114	245
1957	19-Dec-56	12-May-57	144	223	2001	10-Jan-01	26-May-01	136	237
1958	21-Dec-57	30-Apr-58	130	229	2002	18-Jan-02	21-May-02	123	201
1959	15-Dec-58	15-May-59	151	234	2003	08-Dec-02	05-May-03	148	238
1960	04-Jan-60	12-Apr-60	99	247	2004	29-Dec-03	24-Apr-04	117	234
1961	15-Dec-60	11-May-61	147	231	2005	14-Dec-04	6-May-05	143	234
1962	28-Dec-61	11-May-62	134	228	2006	13-Jan-06	28-Apr-06	105	252
1963	25-Dec-62	25-Apr-63	121	213	2007	19-Dec-06	26-Apr-07	128	235
1964	24-Nov-63	22-Apr-64	150	224	2008	2-Jan-08	2-May-08	121	251
1965	02-Dec-64	08-May-65	157	231	2009	13-Dec-08	4-May-09	142	225
1966	25-Dec-65	13-Apr-66	109	257	2010	4-Dec-09	15-May-10	162	214
1967	26-Dec-66	26-Apr-67	121	231	2011	11-Jan-11	5-May-11	114	241
1968	13-Dec-67	27-Apr-68	136	229	2012	27-Dec-11	8-May-12	133	236
1969	12-Dec-68	16-Apr-69	125	248	2013	27-Dec-12	13-May-13	137	233
1970	20-Dec-69	26-Apr-70	127	239	2014	21-Dec-13	06-May-14	136	222
1971	21-Dec-70	30-Apr-71	130	213	2015	19-Dec-14	16-May-15	148	195
1972	29-Nov-71	30-Apr-72	153	239	2016	27-Nov-15	18-May-16	173	193
1973	25-Dec-72	17-May-73	143	212	2017	27-Nov-16	3-May-17	157	230
1974	15-Dec-73	02-May-74	138	226	2018	19-Dec-17	4-May-18	136	215
1975	14-Dec-74	03-May-75	140	227	**2019**	**05-Dec-18**	**6-May-19**	**152**	**242**
1976	16-Dec-75	20-May-76	156	185	**2020**	**3-Jan-20**			
1977	21-Nov-76	17-May-77	177	217					
1978	20-Dec-77	13-Apr-78	114	244					
1979	13-Dec-78	16-Apr-79	124	252					
1980	24-Dec-79	05-May-80	133	244					
1981	04-Jan-81	12-Apr-81	98	273					
1982	10-Jan-82	09-May-82	119	189					
1983	14-Nov-82	12-May-83	179	222					
1984	20-Dec-83	22-May-84	154	199					
1985	07-Dec-84	06-May-85	150	222					
1986	14-Dec-85	20-Apr-86	127	240					
1987	16-Dec-86	25-Apr-87	130	235					
1988	16-Dec-87	25-May-88	161	209					
1989	20-Dec-88	14-May-89	145	214					
1990	14-Dec-89	04-May-90	141	223					
1991	13-Dec-90	01-May-91	139	226					
1992	13-Dec-91	18-May-92	157	217					
1993	21-Dec-92	25-Apr-93	125	243					
1994	24-Dec-93	16-May-94	143	200					
1995	02-Dec-94	01-May-95	150	271					
1996	27-Jan-96	07-May-96	101	255					
1997	17-Jan-97	07-Jun-97	141	185					

Avg	**19-Dec**	**02-May**	**135**	**229.4**
SD	**±16 days**	**±12 days**	**19.3**	**19.8**

Estimated date, subject to confirmation

Seasonality Distribution



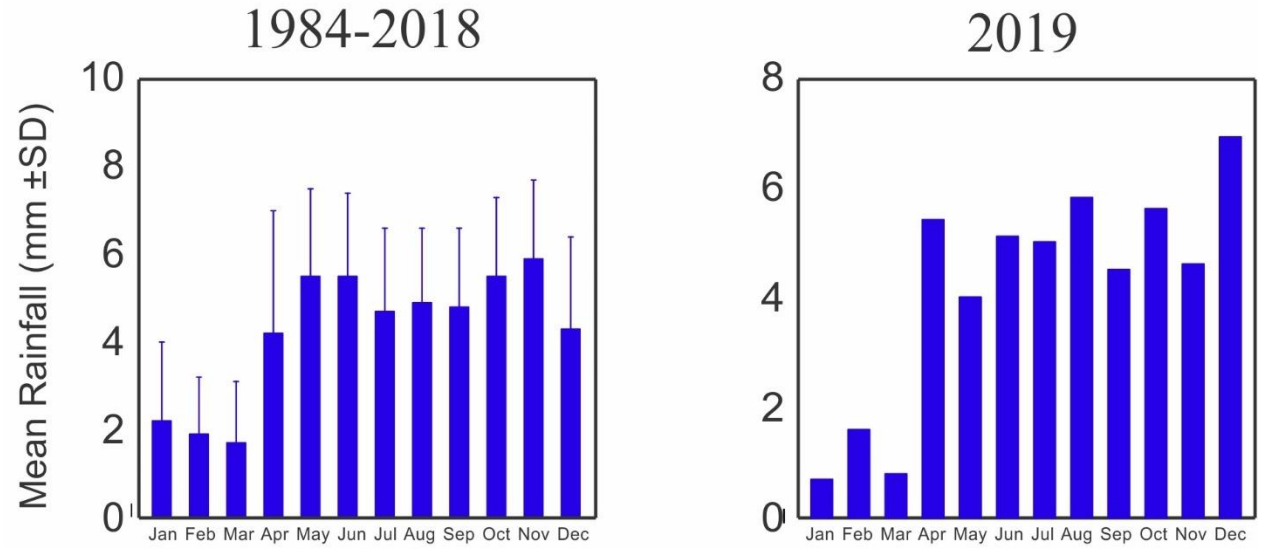


Storm Analysis

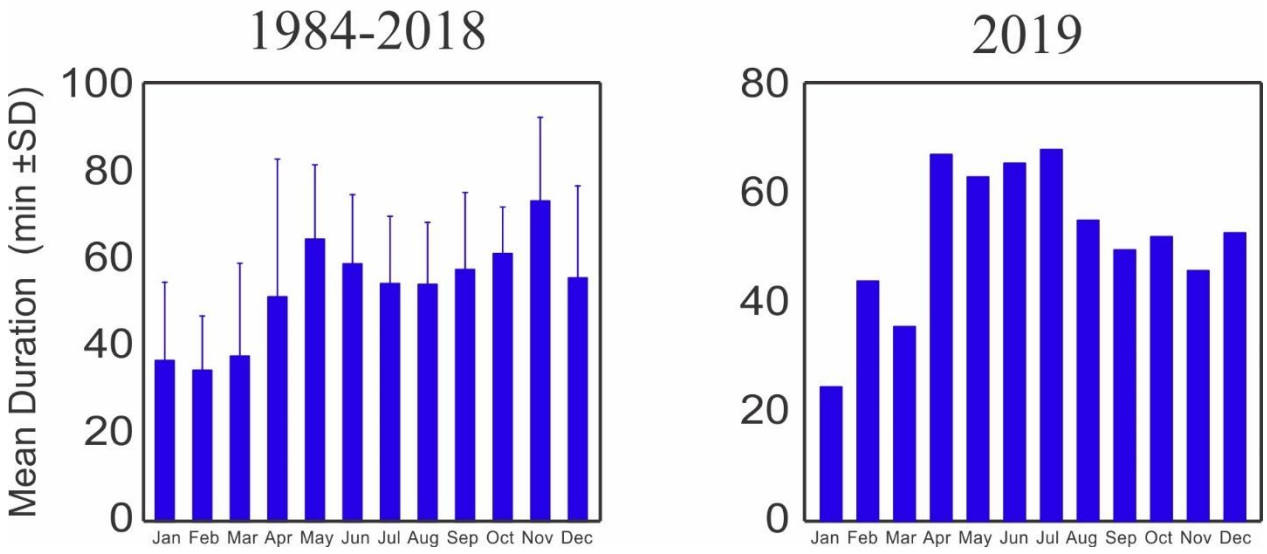
	Max. Rainfall per Storm (mm)			Storm Duration (min.)		
	1994-2018		**2019**	**1994-2018**		**2019**
	Mean	S.D.		Mean	S.D.	
January	18.7	23.7	**3.0**	37.5	18.0	24.5
February	13.3	13.2	**6.4**	35.3	12.3	43.8
March	14.6	19.4	**2.0**	39.0	20.7	35.5
April	35.0	27.2	**33.3**	50.9	30.2	66.9
May	50.8	22.9	**50.3**	64.9	16.3	62.8
June	53.6	24.1	**33.8**	59.6	15.5	65.3
July	46.9	22.7	**38.9**	55.1	15.0	67.8
August	43.7	20.5	**49.3**	54.4	13.8	54.9
September	41.9	15.5	**51.1**	57.9	16.8	49.5
October	49.2	24.0	**45.2**	61.4	11.8	51.9
November	70.5	48.5	**33.0**	72.2	18.5	45.7
December	49.1	50.8	**92.2**	54.2	20.7	52.6

	Av. Rainfall per Storm (mm)		
	1994-2018		**2019**
	Mean	S.D.	
January	2.3	1.8	0.7
February	1.8	1.2	1.6
March	1.9	1.6	0.8
April	4.4	3.0	5.4
May	5.7	2.0	4.0
June	5.6	1.9	5.1
July	4.7	1.8	5.0
August	4.8	1.7	5.8
September	4.8	1.7	4.5
October	5.6	2.0	5.6
November	5.8	1.8	4.6
December	4.2	2.1	6.9

Average Monthly Storm Size

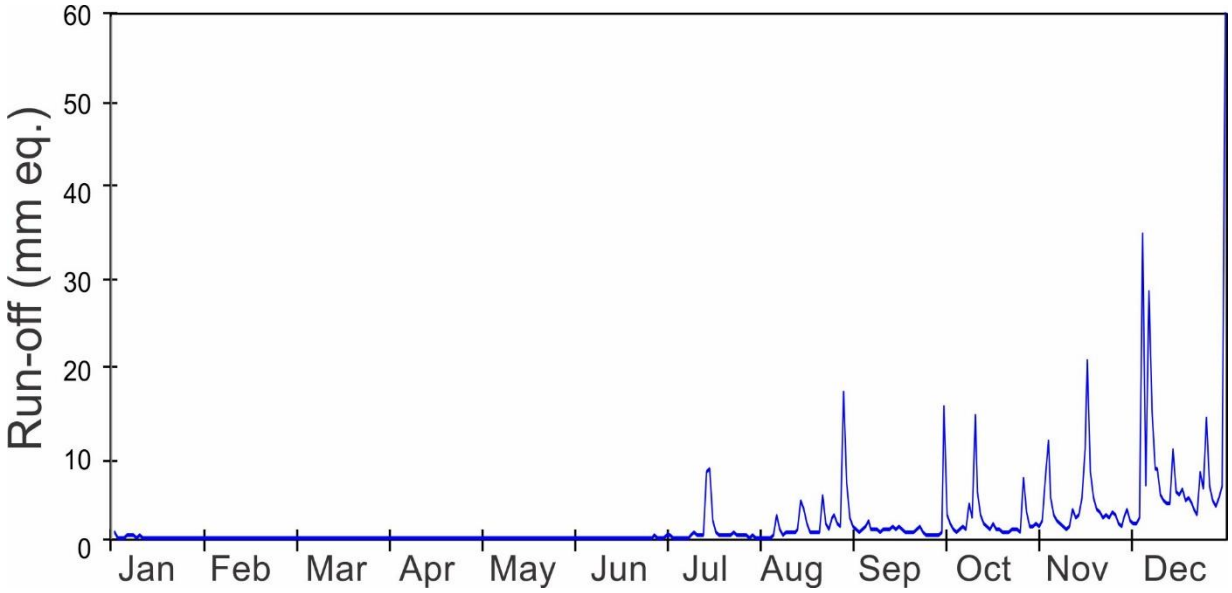


Average Monthly Storm Duration



2019 Daily Lutz Weir Run-off (mm. eq.)

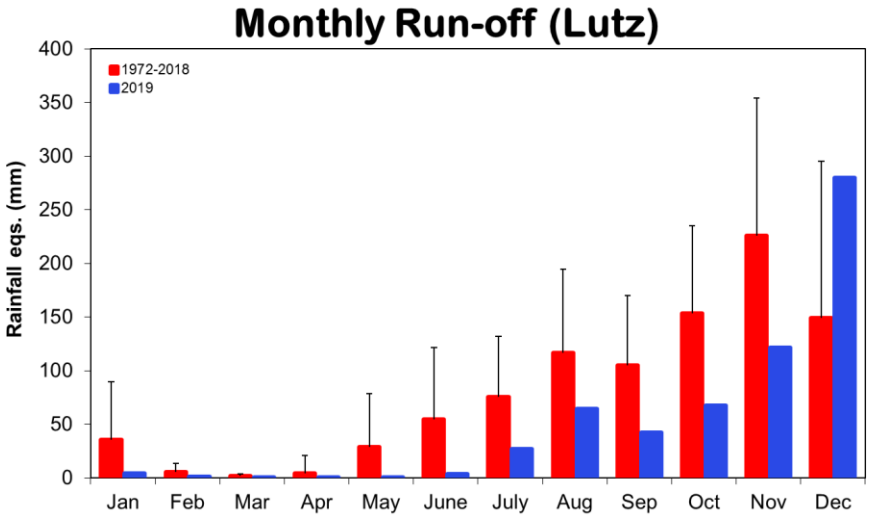
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	0.6	0.0	0.0	0.0	0.0	0.2	0.5	0.1	0.9	2.8	2.0	1.7
2	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.7	1.5	7.0	1.7
3	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.2	1.0	1.0	11.0	2.5
4	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.2	1.4	0.8	4.6	34.8
5	0.2	0.1	0.0	0.0	0.0	0.1	0.2	0.2	1.9	1.0	2.8	6.0
6	0.3	0.1	0.0	0.0	0.0	0.1	0.2	2.8	1.2	1.2	2.0	28.4
7	0.3	0.1	0.0	0.0	0.0	0.1	0.1	1.0	1.0	1.0	1.6	14.4
8	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.5	1.1	4.1	1.4	7.9
9	0.3	0.1	0.0	0.0	0.0	0.1	0.3	0.6	0.8	2.2	1.2	7.8
10	0.2	0.1	0.0	0.0	0.1	0.2	0.7	0.9	0.9	14.3	1.2	5.0
11	0.1	0.1	0.0	0.0	0.0	0.1	0.4	0.7	0.9	5.2	3.4	4.3
12	0.1	0.1	0.0	0.0	0.0	0.1	0.3	0.8	1.0	2.6	2.4	3.8
13	0.1	0.1	0.0	0.0	0.0	0.0	0.4	1.1	1.3	1.8	2.8	4.1
14	0.1	0.1	0.0	0.0	0.0	0.0	7.6	4.3	1.1	1.4	4.6	10.2
15	0.1	0.0	0.0	0.0	0.0	0.0	8.0	3.5	1.5	1.1	10.4	5.2
16	0.1	0.1	0.0	0.0	0.0	0.1	2.0	1.7	1.0	1.5	20.5	4.9
17	0.1	0.0	0.0	0.0	0.0	0.0	0.7	0.8	0.8	1.0	7.5	5.8
18	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.8	0.9	4.5	4.2
19	0.1	0.0	0.0	0.0	0.1	0.1	0.5	0.7	0.8	0.8	3.4	4.6
20	0.1	0.0	0.0	0.0	0.0	0.1	0.5	0.8	0.7	0.8	2.9	4.1
21	0.1	0.0	0.0	0.0	0.0	0.1	0.5	5.0	1.2	0.6	2.3	3.2
22	0.1	0.0	0.0	0.1	0.1	0.1	0.4	1.8	1.5	1.2	2.8	2.8
23	0.1	0.0	0.0	0.0	0.0	0.1	0.6	1.2	0.8	1.0	2.4	7.5
24	0.1	0.0	0.0	0.0	0.0	0.0	0.5	2.4	0.4	0.9	3.1	5.7
25	0.1	0.0	0.0	0.0	0.0	0.1	0.4	2.6	0.5	0.6	2.5	13.8
26	0.1	0.0	0.0	0.0	0.0	0.1	0.3	1.7	0.3	7.0	1.7	6.0
27	0.1	0.0	0.0	0.0	0.0	0.3	0.2	1.2	0.3	2.9	1.5	4.5
28	0.0	0.0	0.0	0.0	0.0	0.2	0.2	16.6	0.5	1.5	2.3	3.7
29	0.0	0.0	0.0	0.0	0.0	0.2	0.2	6.2	0.7	1.3	3.4	4.7
30	0.0		0.0	0.0	0.0	0.1	0.1	2.4	15.3	1.6	2.1	5.9
31			0.0		0.0		0.1	1.3		1.4		59.8

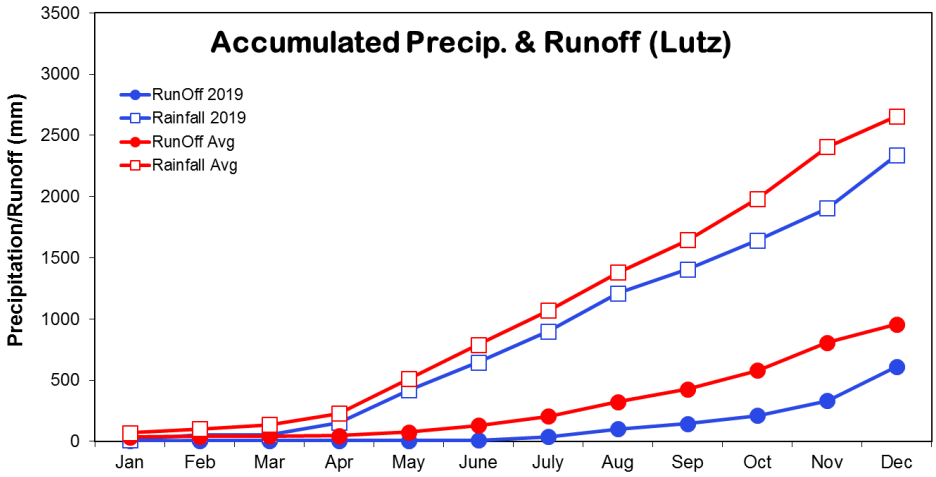


Monthly Run-off

Run-off, Lutz Weir (mm eq.)

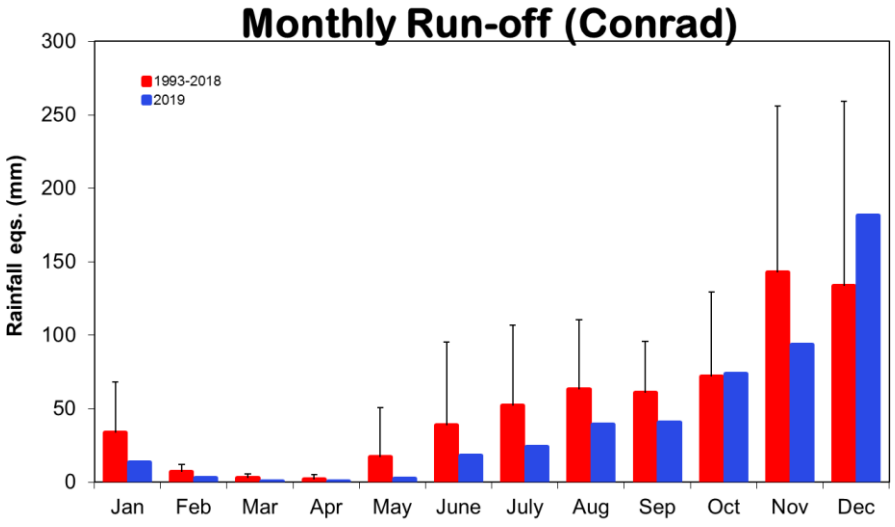
	Long-term Averages (1972 - 2018)		2019
	Total	S.D.	Total
January	35.5	54.1	4.2
February	5.2	8.5	1.2
March	1.7	2.3	0.0
April	4.5	16.6	0.1
May	28.9	49.7	0.4
June	54.7	66.9	3.8
July	75.4	56.3	27.1
August	116.4	78.4	64.3
September	104.9	65.3	42.2
October	153.3	81.5	67.5
November	226.1	128.2	121.6
December	149.2	145.9	280.1
Total	951.1	440.3	609.9

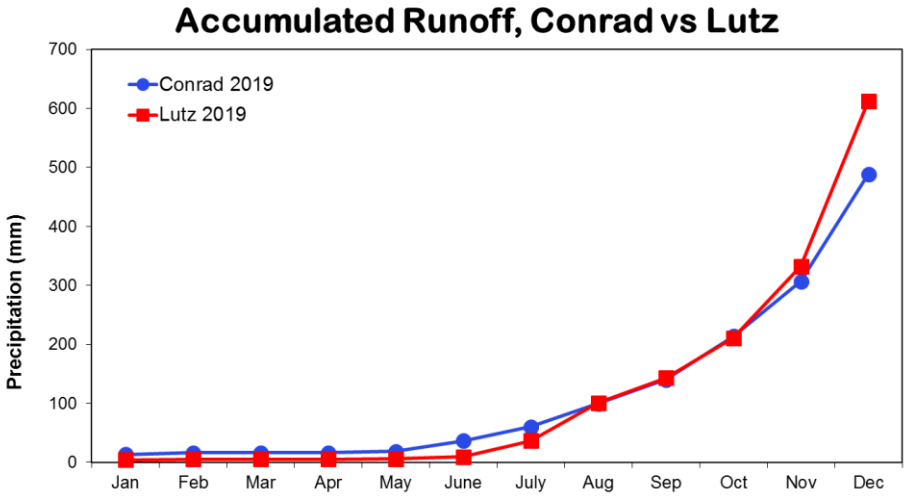




Run-off, Conrad Weir (mm eq.)

	Long-term Averages (1972 - 2018)		2019
	Total	S.D.	Total
January	33.7	34.4	13.5
February	6.9	5.2	2.8
March	2.9	2.5	0.0
April	2.0	3.0	0.0
May	17.2	33.5	2.3
June	38.7	56.6	17.9
July	52.1	54.9	24.0
August	63.2	47.1	39.1
September	60.6	35.3	40.5
October	72.0	57.5	73.5
November	142.8	113.3	93.3
December	133.7	125.3	181.5
Total	674.7	344.5	488.5





Lutz Catchment Soil Moisture

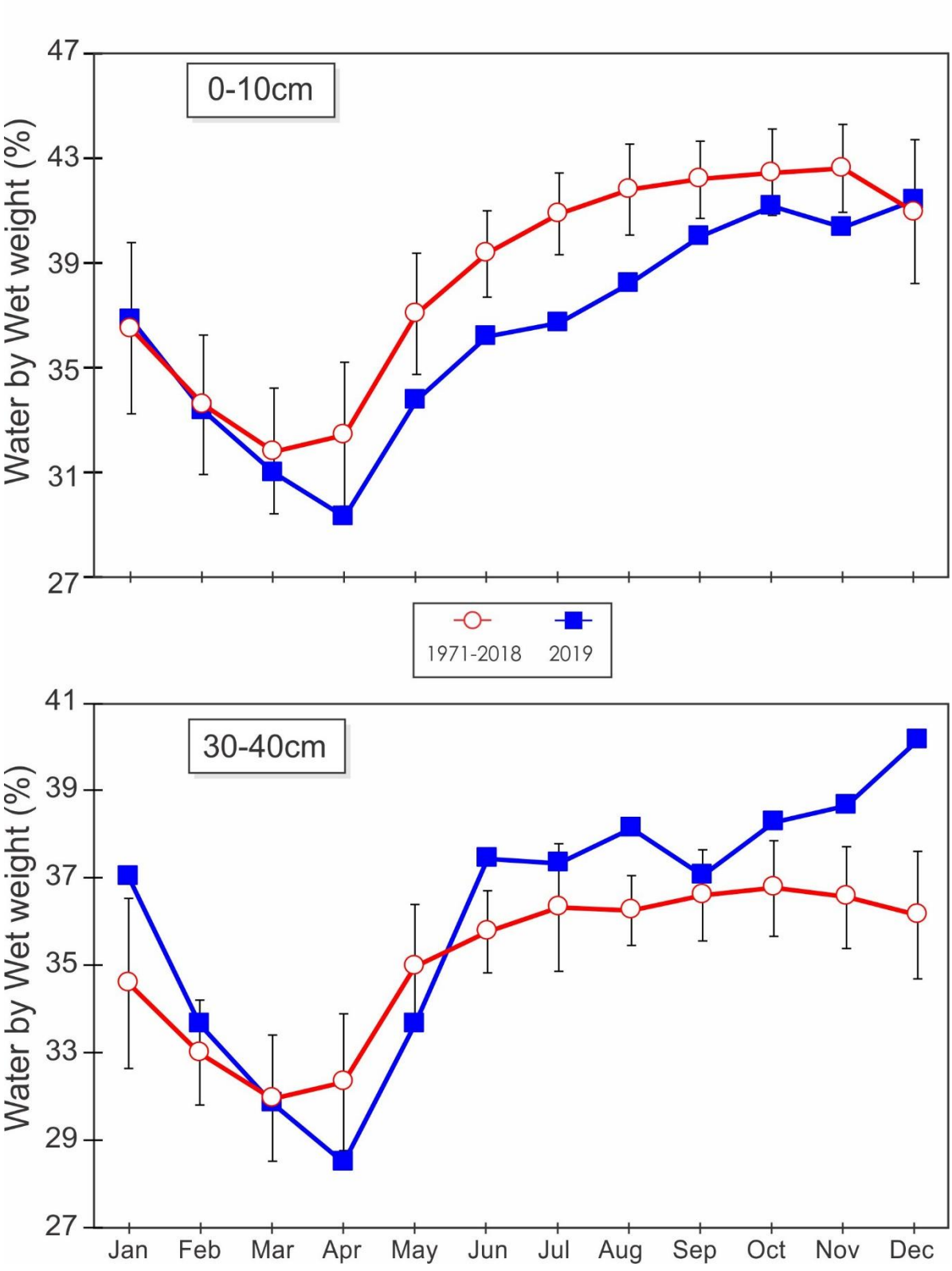
(H_2O/wet weight of soil)

	Long-term Averages (1972-2018)				2019	
	0-10 cm		30-40 cm		0-10 cm	30-40 cm
	Mean	S.D.	Mean	S.D.		
January	36.4	3.3	33.5	2.3	**36.8**	**36.4**
February	33.5	2.7	31.6	1.4	**33.3**	**32.4**
March	31.7	2.4	30.4	1.7	**30.9**	**30.3**
April	32.3	2.8	30.8	1.8	**29.2**	**28.7**
May	37.0	2.3	33.9	1.7	**33.7**	**32.4**
June	39.3	1.7	34.9	1.1	**36.1**	**36.8**
July	40.8	1.6	35.5	1.7	**36.7**	**36.7**
August	41.7	1.7	35.4	0.9	**38.1**	**37.6**
September	42.1	1.5	35.8	1.2	**40.0**	**36.4**
October	42.4	1.6	36.0	1.3	**41.1**	**37.8**
November	42.5	1.7	35.8	1.4	**40.3**	**38.2**
December	40.9	2.8	35.3	1.7	**41.3**	**40.0**

(H_2O/dry weight of soil)

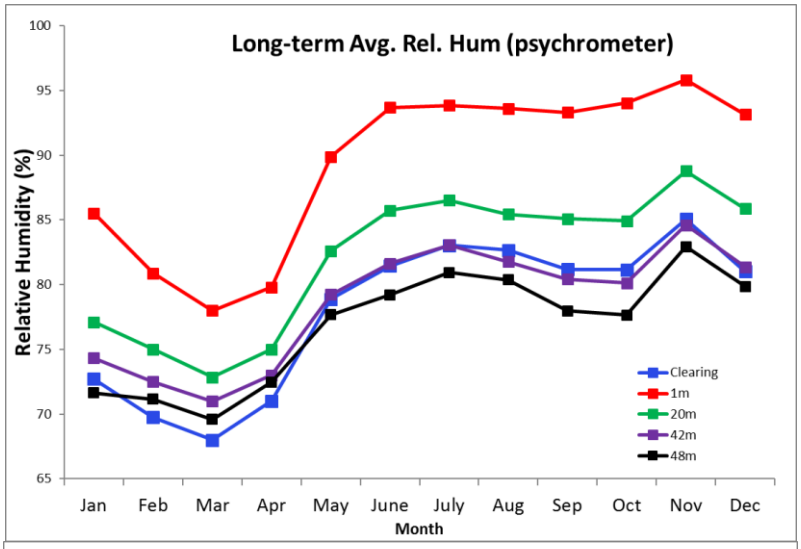
	Long-term Averages (1972-2018)				2019	
	0-10 cm		30-40 cm		0-10 cm	30-40 cm
	Mean	S.D.	Mean	S.D.		
January	58.5	7.7	51.2	5.7	**58.7**	**57.5**
February	51.2	6.8	46.9	3.1	**50.3**	**48.3**
March	47.4	5.5	44.4	3.6	**45.4**	**44.1**
April	49.1	7.4	45.4	4.2	**41.9**	**40.9**
May	60.2	5.9	52.2	4.3	**51.0**	**48.4**
June	65.8	4.4	54.7	3.0	**57.0**	**58.6**
July	70.2	4.4	56.1	4.5	**58.2**	**58.7**
August	72.7	4.0	55.7	2.6	**62.1**	**60.7**
September	73.7	4.4	56.7	3.1	**67.1**	**57.9**
October	74.8	4.5	57.1	3.3	**70.7**	**61.2**
November	75.3	4.2	56.8	3.4	**68.2**	**62.3**
December	70.8	7.1	55.6	4.4	**71.0**	**67.0**

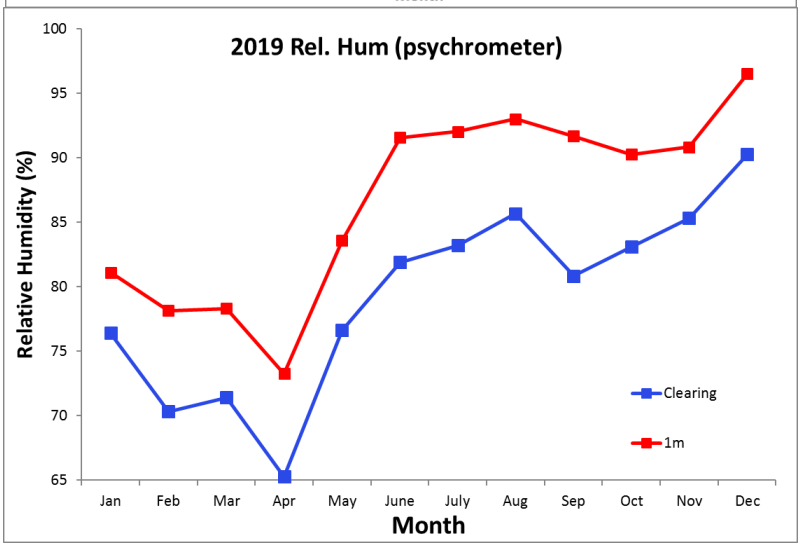
Lutz Catchment Soil Moisture



Relative Humidity (%) - Mid-day Psychrometer

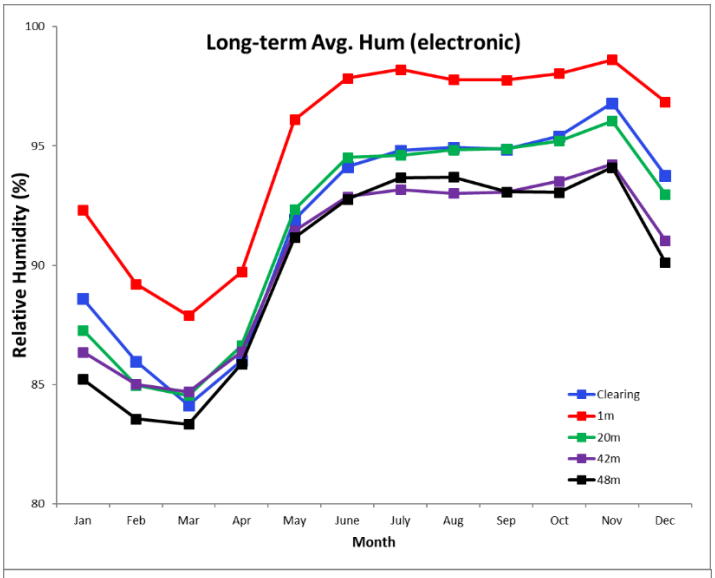
	'El Claro'		1m	
	Avg.	2019	Avg.	2019
January	73.3	**76.4**	85.6	**81.1**
February	69.9	**70.3**	80.8	**78.2**
March	68.3	**71.4**	78.1	**78.3**
April	70.9	**65.3**	79.6	**73.3**
May	79.0	**76.6**	89.7	**83.6**
June	81.6	**81.9**	93.7	**91.6**
July	83.2	**83.2**	93.9	**92.0**
August	82.8	**85.7**	93.6	**93.0**
September	81.2	**80.8**	93.2	**91.7**
October	81.2	**83.1**	93.9	**90.3**
November	85.1	**85.3**	95.6	**90.8**
December	81.1	**90.3**	92.9	**96.5**

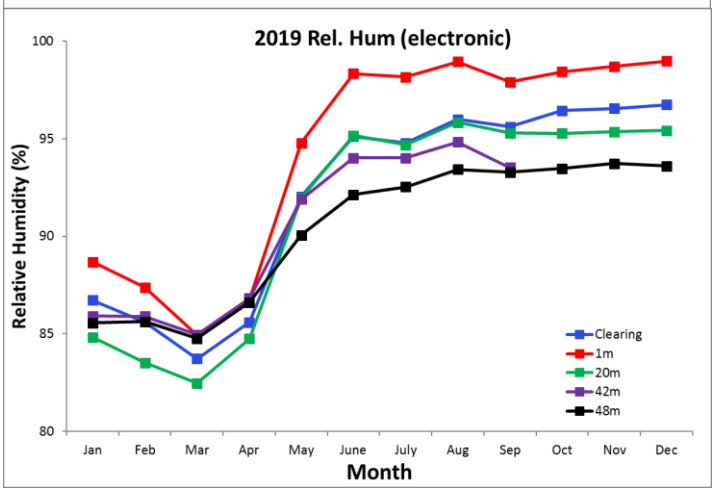




Relative Humidity (%) - Electronic Sensor

	'El Claro'		1m		20m		42m		48m	
	Avg.	2019	Avg.	2019	Avg.	2019	Avg.	2019	Avg.	2019
January	88.4	**86.7**	92.1	**88.7**	87.1	**84.8**	86.5	**85.9**	85.2	**85.6**
February	85.9	**85.6**	89.1	**87.4**	84.9	**83.5**	84.8	**85.9**	83.7	**85.6**
March	84.1	**83.7**	87.7	**84.9**	84.4	**82.5**	84.7	**85.0**	83.4	**84.8**
April	86.0	**85.6**	89.5	**86.8**	86.5	**84.8**	86.9	**86.8**	85.9	**86.6**
May	91.9	**92.0**	96.0	**94.8**	92.3	**92.0**	91.8	**91.9**	91.1	**90.1**
June	94.2	**95.1**	97.9	**98.3**	94.6	**95.2**	93.2	**94.0**	92.7	**92.1**
July	94.8	**94.8**	98.2	**98.2**	94.6	**94.7**	93.5	**94.0**	93.6	**92.5**
August	95.0	**96.0**	97.8	**98.9**	94.9	**95.8**	93.5	**94.8**	93.7	**93.4**
September	94.9	**95.6**	97.8	**97.9**	94.9	**95.3**	93.2	**93.5**	93.1	**93.3**
October	95.5	**96.4**	98.1	**98.4**	95.2	**95.3**	93.5		93.1	**93.5**
November	96.8	**96.5**	98.6	**98.7**	96.0	**95.3**	94.4		94.1	**93.7**
December	94.0	**96.7**	97.0	**99.0**	93.1	**95.4**	91.4		90.3	**93.6**





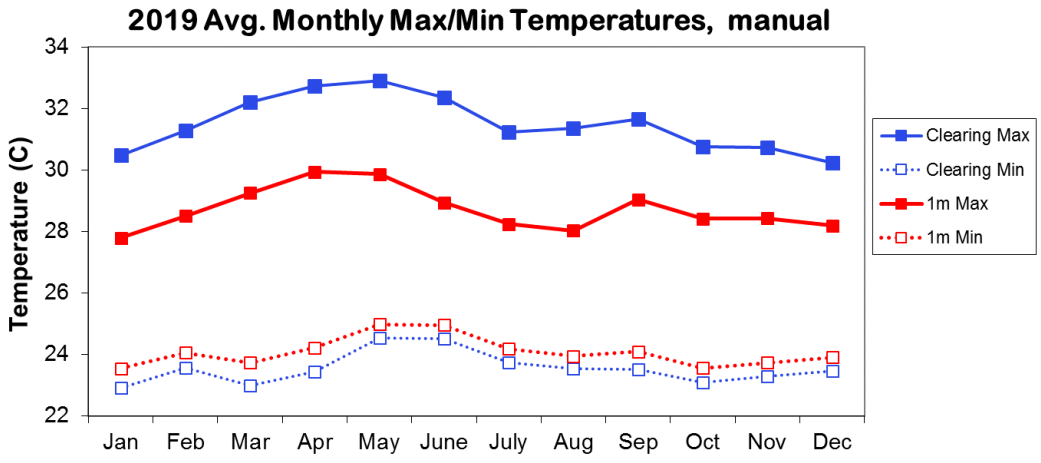
Max/Min Temperatures (°C) - Thermometer

(No data at 10m 42 & 48m after April due to damage to the Lutz tower)

Long-term Averages

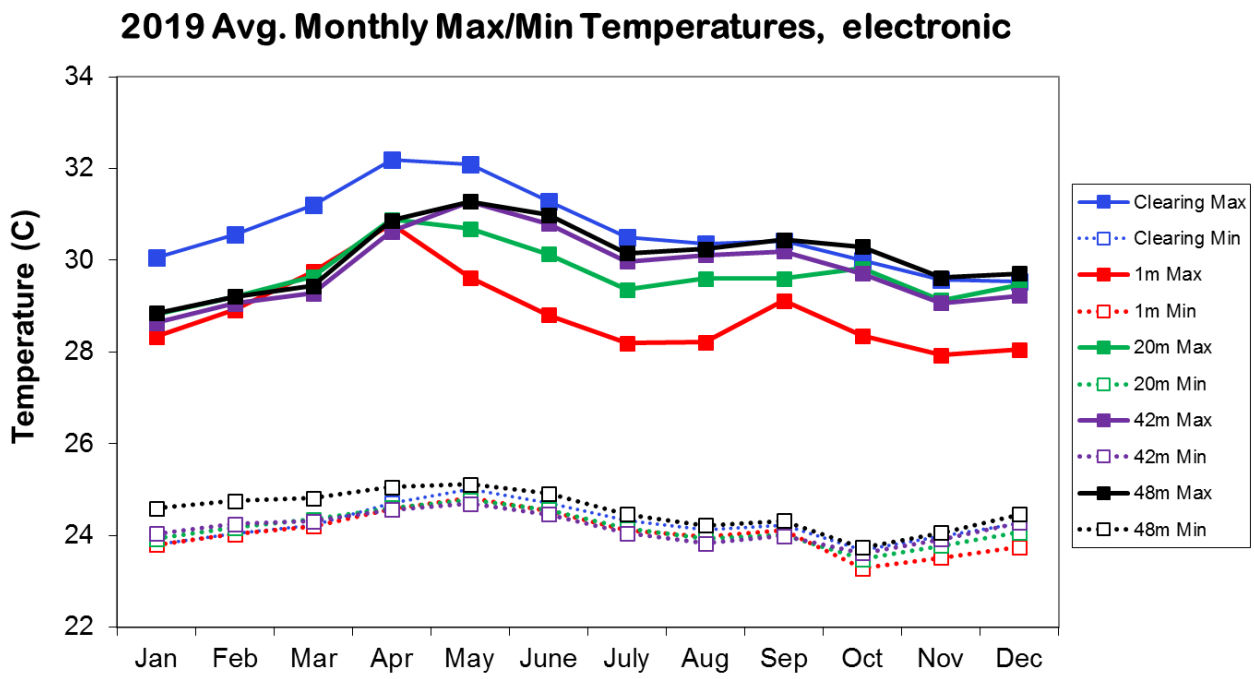
	'El Claro'		1m	
	Max.	Min.	Max.	Min.
January	30.5	23.3	27.8	23.3
February	31.0	23.4	28.4	23.4
March	31.6	23.6	29.2	23.6
April	32.2	24.0	29.8	24.0
May	31.7	24.1	29.0	24.1
June	31.1	23.9	28.2	23.9
July	30.6	23.9	27.9	23.8
August	30.7	23.7	28.0	23.7
September	30.9	23.6	28.0	23.5
October	30.6	23.3	27.7	23.4
November	29.9	23.2	27.2	23.2
December	30.0	23.2	27.3	23.3

2019	'El Claro'		1m	
	Max.	Min.	Max.	Min.
January	**30.5**	**22.9**	**27.8**	**23.6**
February	**31.3**	**23.6**	**28.5**	**24.1**
March	**32.2**	**23.0**	**29.3**	**23.7**
April	**32.7**	**23.4**	**29.9**	**24.2**
May	**32.9**	**24.5**	**29.9**	**25.0**
June	**32.4**	**24.5**	**28.9**	**25.0**
July	**31.2**	**23.7**	**28.2**	**24.2**
August	**31.3**	**23.5**	**28.0**	**23.9**
September	**31.7**	**23.5**	**29.0**	**24.1**
October	**30.7**	**23.1**	**28.4**	**23.6**
November	**30.7**	**23.3**	**28.4**	**23.7**
December	**30.2**	**23.5**	**28.2**	**23.9**



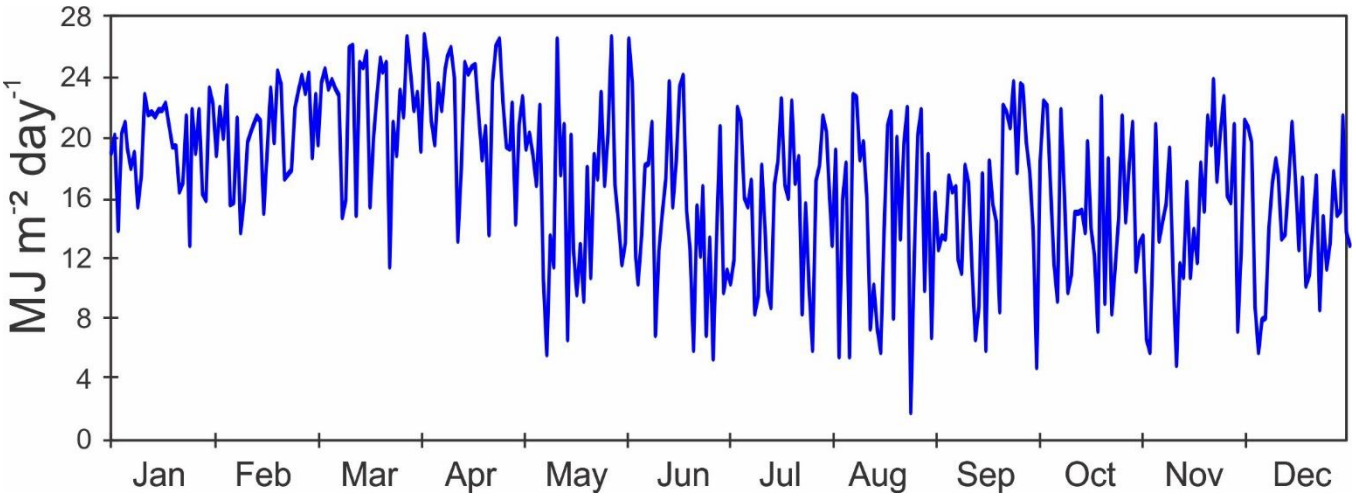
Max/Min/Avg Temperatures (°C) - Electronic

	'El Claro'			1m			20m			42m			48m		
Average	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg
January	30.2	23.5	25.4	27.8	23.7	25.1	29.2	23.6	25.6	29.0	24.0	25.8	28.7	23.9	25.9
February	30.6	23.6	25.8	28.3	23.6	25.2	29.2	23.7	25.7	29.1	24.0	25.8	28.6	23.9	25.8
March	31.0	23.8	26.2	29.0	23.8	25.6	29.7	23.9	26.0	29.3	24.2	26.1	29.0	24.0	26.1
April	31.5	24.2	26.9	29.5	24.2	26.0	30.2	24.3	26.4	30.0	24.5	26.5	29.8	24.2	26.5
May	31.1	24.2	25.9	28.5	24.3	25.7	29.9	24.1	26.0	30.2	24.2	26.2	30.0	23.8	26.2
June	30.8	23.9	25.9	27.9	24.1	25.5	29.5	23.8	25.6	30.1	23.9	26.0	29.8	23.6	26.0
July	30.3	23.9	25.8	27.6	24.0	25.2	29.0	23.8	25.5	29.6	23.9	25.8	29.3	23.7	25.8
August	30.4	23.8	25.7	27.8	24.0	25.2	29.1	23.7	25.5	29.7	23.8	25.8	29.4	23.5	25.7
September	30.5	23.5	25.9	28.0	23.8	25.0	29.3	23.4	25.3	30.0	23.6	25.7	29.7	23.4	25.7
October	30.2	23.4	25.8	27.6	23.7	24.8	29.2	23.3	25.1	29.8	23.4	25.4	29.5	23.2	25.4
November	29.0	23.3	24.6	26.8	23.6	24.6	28.3	23.2	24.9	28.9	23.3	25.3	28.8	23.2	25.1
December	29.3	23.4	24.9	27.1	23.8	24.8	28.7	23.4	25.3	28.9	23.6	25.5	28.7	23.6	25.6
	'El Claro'			**1m**			**20m**			**42m**			**48m**		
2019	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg	Max.	Min.	Avg
January	**30.1**	**23.8**	**26.2**	**28.3**	**23.8**	**25.6**	**28.8**	**23.9**	**26.0**	**28.6**	**24.0**	**25.9**	**28.9**	**24.6**	**26.3**
February	**30.6**	**24.0**	**26.4**	**28.9**	**24.0**	**25.9**	**29.2**	**24.2**	**26.1**	**29.1**	**24.2**	**26.1**	**29.2**	**24.8**	**26.4**
March	**31.2**	**24.2**	**26.8**	**29.7**	**24.2**	**26.3**	**29.6**	**24.4**	**26.5**	**29.3**	**24.3**	**26.2**	**29.4**	**24.8**	**26.6**
April	**32.2**	**24.7**	**27.6**	**30.8**	**24.6**	**27.0**	**30.9**	**24.6**	**27.2**	**30.6**	**24.6**	**27.3**	**30.9**	**25.1**	**27.3**
May	**32.1**	**25.0**	**27.2**	**29.6**	**24.8**	**26.4**	**30.7**	**24.8**	**26.7**	**31.3**	**24.7**	**26.8**	**31.4**	**25.1**	**27.1**
June	**31.3**	**24.7**	**26.9**	**28.8**	**24.5**	**26.1**	**30.1**	**24.6**	**26.6**	**30.8**	**24.5**	**26.8**	**31.0**	**24.9**	**27.1**
July	**30.5**	**24.3**	**26.4**	**28.2**	**24.1**	**25.7**	**29.4**	**24.2**	**26.1**	**30.0**	**24.0**	**26.2**	**30.2**	**24.5**	**26.5**
August	**30.4**	**24.1**	**26.3**	**28.2**	**24.0**	**25.6**	**29.6**	**23.9**	**26.1**	**30.1**	**23.8**	**26.2**	**30.2**	**24.2**	**26.5**
September	**30.4**	**24.2**	**26.3**	**29.1**	**24.1**	**25.7**	**29.6**	**24.0**	**25.9**	**30.2**	**24.0**	**26.1**	**30.4**	**24.3**	**26.4**
October	**30.0**	**23.7**	**25.7**	**28.4**	**23.3**	**24.8**	**29.8**	**23.5**	**25.4**	**29.7**	**23.6**	**25.7**	**30.3**	**23.7**	**25.9**
November	**29.6**	**24.0**	**25.9**	**27.9**	**23.5**	**25.1**	**29.1**	**23.8**	**25.7**	**29.1**	**23.9**	**26.0**	**29.6**	**24.1**	**26.2**
December	**29.5**	**24.3**	**26.0**	**28.1**	**23.7**	**25.2**	**29.5**	**24.1**	**25.9**	**29.2**	**24.3**	**26.1**	**29.7**	**24.5**	**26.4**


2019 Avg. Monthly Max/Min Temperatures, electronic
Temperature (C)
34
32
30
28
26
24
22
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
Clearing Max
Clearing Min
1m Max
1m Min
20m Max
20m Min
42m Max
42m Min
48m Max
48m Min

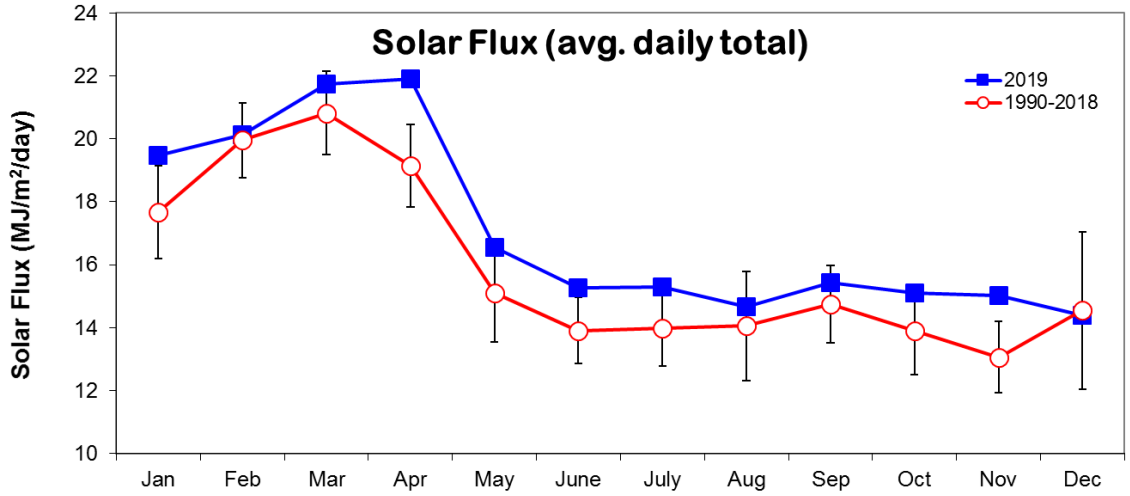
2019 Daily Total Radiation (MJ m^{-2} day^{-1})

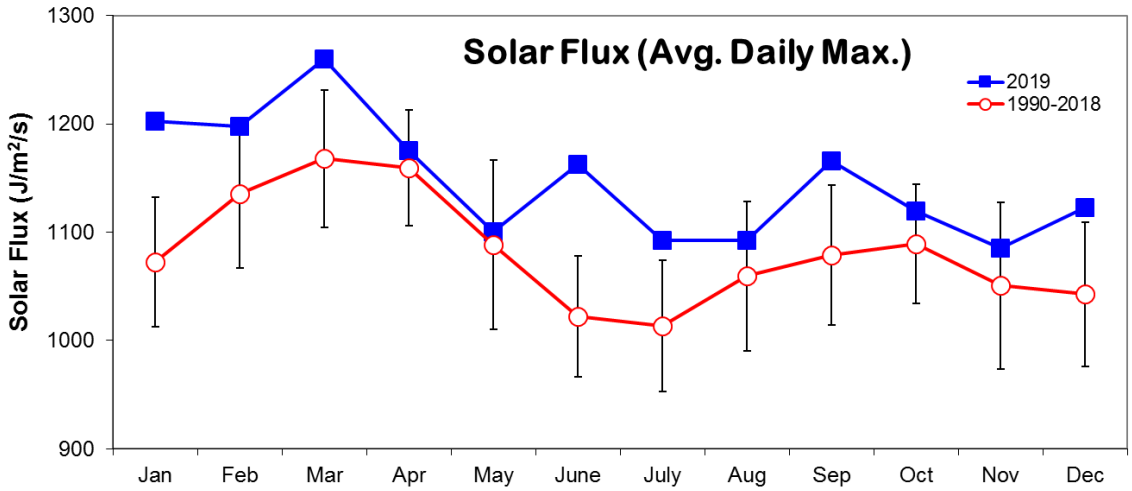
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	18.9	18.9	18.7	23.0	20.9	13.0	11.2	12.9	12.6	18.4	6.7	20.7
2	20.1	21.9	22.8	19.1	22.7	26.4	10.3	19.1	13.5	22.3	5.8	19.7
3	13.8	19.9	19.5	26.8	19.3	23.7	11.9	5.5	13.3	22.1	11.3	8.8
4	20.2	23.3	23.7	25.1	20.2	12.0	21.9	15.9	17.4	16.7	20.8	5.8
5	20.9	15.6	24.5	21.1	18.8	10.3	21.1	18.3	16.4	11.6	13.1	7.9
6	19.3	15.7	23.1	19.5	16.9	13.4	16.0	5.5	16.7	9.3	14.4	8.1
7	18.0	21.2	23.7	23.5	22.1	18.2	15.4	22.7	11.9	21.7	15.5	14.0
8	19.0	13.7	23.1	21.8	10.7	18.3	17.1	22.7	11.1	16.2	19.3	17.1
9	15.4	15.9	22.7	24.4	5.7	21.0	8.4	18.5	18.1	9.8	11.1	18.5
10	17.5	19.7	14.8	25.3	13.5	7.0	9.5	19.7	17.0	11.0	4.9	17.6
11	22.8	20.4	15.9	25.8	11.4	12.4	18.2	16.0	11.3	15.1	11.6	13.3
12	21.6	20.8	26.0	23.9	26.4	14.9	13.7	7.3	6.7	15.0	10.8	13.6
13	21.7	21.4	26.0	13.1	17.6	17.2	9.9	10.2	8.8	15.2	17.0	17.0
14	21.4	21.2	14.9	18.0	20.9	23.6	8.8	7.4	17.6	13.7	10.8	20.9
15	21.7	14.9	24.9	24.9	6.6	15.4	16.8	5.8	6.0	19.6	13.9	17.1
16	21.9	19.1	24.6	24.3	20.1	18.4	18.3	14.0	18.4	14.0	11.8	12.6
17	22.2	23.2	25.6	24.7	12.6	23.3	22.6	20.9	15.6	12.2	18.3	17.3
18	20.8	19.7	15.4	24.8	9.6	24.1	16.8	21.7	14.5	7.3	15.2	10.2
19	19.4	24.4	20.0	21.5	12.9	15.1	16.0	8.1	8.5	22.7	21.4	10.9
20	19.4	23.5	22.8	18.5	9.2	12.6	22.3	20.0	22.1	9.1	19.6	14.1
21	16.5	17.3	25.1	20.7	18.0	6.0	17.1	13.3	21.7	18.5	23.8	17.3
22	16.9	17.6	24.4	13.6	10.8	15.4	18.7	19.5	20.6	8.4	17.2	8.7
23	21.4	17.9	24.9	23.6	18.8	12.2	8.3	22.0	23.6	11.5	20.4	14.7
24	12.9	22.0	11.4	26.0	17.2	16.7	15.5	1.9	17.7	14.7	22.6	11.3
25	21.7	23.1	21.0	26.5	23.0	6.9	10.0	11.9	23.4	21.3	16.1	13.0
26	19.0	24.1	18.9	22.4	16.9	13.3	6.0	20.1	23.3	14.5	15.7	17.7
27	21.8	23.0	23.0	19.4	20.3	5.4	17.2	21.8	19.7	18.2	20.9	14.8
28	16.3	24.2	21.3	19.3	26.6	13.7	18.1	10.0	17.7	20.9	7.2	15.2
29	15.8		26.6	22.2	16.9	20.7	21.3	18.8	13.8	11.3	12.5	21.4
30	23.2		24.3	14.3	14.4	9.9	20.3	6.8	4.9	13.1	21.0	13.8
31	22.2		21.8		11.6		15.7	16.3		13.4		12.9



Monthly Average Total Daily Solar Radiation (Pyranometer)

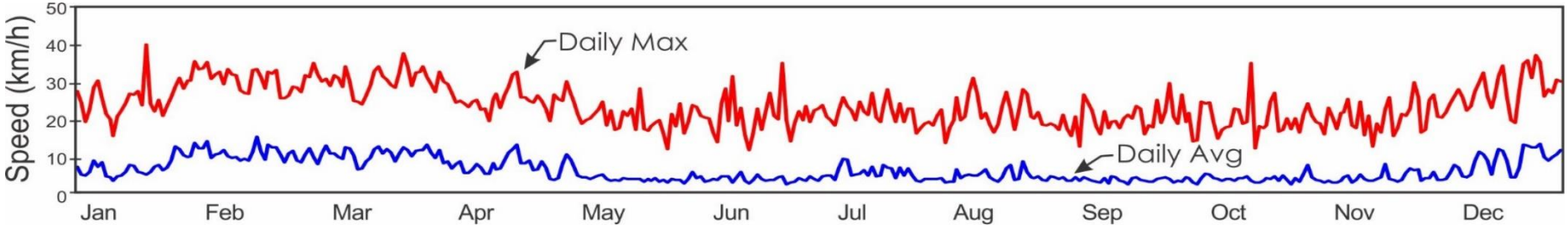
	1984-2018		2019	
	Avg Daily Total (Mj/m^2)	Avg Daily Max. ($J/m^2/s$)	Avg Daily Total (Mj/m^2)	Avg Daily Max. ($J/m^2/s$)
January	17.7	1066.2	**20.1**	**1202.1**
February	20.0	1130.5	**21.7**	**1197.9**
March	20.8	1160.9	**21.9**	**1260.0**
April	19.1	1156.4	**16.5**	**1175.7**
May	15.1	1081.3	**15.3**	**1100.7**
June	13.9	1017.0	**15.3**	**1162.7**
July	14.0	1004.7	**14.7**	**1092.5**
August	14.1	1055.0	**15.4**	**1166.2**
September	14.8	1069.2	**15.1**	**1119.7**
October	13.9	1085.2	**15.0**	**1085.2**
November	13.1	1045.1	**14.4**	**1122.6**
December	14.6	1038.7	**20.1**	**1202.1**





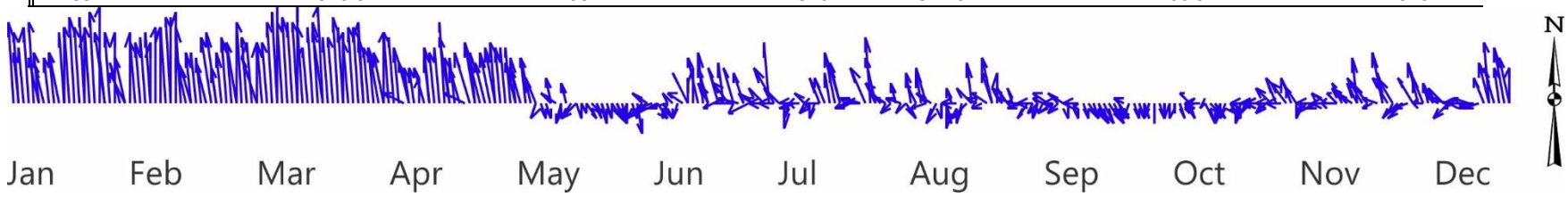
2019 Daily Average Wind Speed (km/h)

	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sep.		Oct.		Nov.		Dec.	
	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
1	12.4	30.9	9.2	26.9	7.5	23.2	8.0	30.3	8.8	28.6	2.7	22.1	2.6	15.0	3.7	20.3	3.7	19.0	2.9	16.6	3.0	21.0	4.6	26.8
2	11.3	33.7	9.9	31.9	9.4	25.4	11.1	29.5	9.0	27.1	4.8	22.9	2.7	17.2	3.2	19.9	2.8	19.1	2.7	18.9	2.7	14.3	5.2	26.0
3	8.2	24.2	10.7	29.7	9.1	24.8	11.3	32.1	6.7	21.1	3.8	22.6	4.5	22.5	2.9	15.1	2.9	20.7	2.8	16.5	2.7	24.3	4.9	21.0
4	8.4	27.2	9.2	32.5	9.7	25.9	10.5	32.8	6.9	24.3	3.0	17.3	9.2	27.9	3.4	17.2	3.1	19.0	2.3	19.1	4.6	25.1	4.2	18.7
5	11.5	32.3	11.9	30.7	12.6	33.6	8.6	26.2	5.8	24.3	2.8	16.4	6.6	23.8	3.5	23.5	3.5	21.2	2.5	20.9	4.3	19.7	3.5	17.9
6	12.7	34.4	11.9	30.7	13.8	39.6	4.7	28.3	7.4	24.4	3.5	18.0	3.8	20.4	2.6	13.6	3.2	18.9	2.9	20.9	3.1	16.7	4.3	21.0
7	7.6	24.8	11.4	32.9	14.6	34.9	6.8	26.5	7.4	24.6	3.3	20.8	4.9	24.2	3.0	16.6	2.6	26.4	2.9	14.8	4.5	23.1	3.5	19.5
8	8.2	26.3	13.5	33.3	12.7	34.7	5.7	24.5	4.3	19.3	3.2	23.9	3.6	26.7	5.1	24.5	3.3	20.2	2.4	21.6	4.4	25.7	5.4	25.1
9	6.4	26.9	13.3	34.0	13.3	35.0	5.6	23.0	2.5	17.8	3.9	23.8	2.6	17.4	4.1	19.3	2.9	18.5	2.2	14.3	3.4	16.6	6.1	31.7
10	7.1	28.4	14.1	38.1	12.3	33.8	4.0	21.5	2.7	16.9	3.1	13.6	2.9	26.3	4.7	19.7	3.9	24.8	2.6	14.9	2.1	21.1	4.2	21.2
11	8.2	29.4	11.4	30.6	12.7	32.0	5.9	25.2	2.7	15.9	3.3	16.2	3.5	17.2	5.5	24.9	3.4	17.2	1.9	15.3	2.3	29.1	3.1	22.4
12	8.0	26.5	7.3	28.7	14.6	38.1	6.8	27.0	4.3	21.6	2.8	18.0	3.2	18.6	4.4	21.2	3.0	17.2	2.4	21.8	2.6	15.3	3.6	21.1
13	10.6	31.8	6.0	25.3	12.0	34.0	8.5	26.3	3.3	24.8	3.9	20.3	2.4	20.7	3.9	15.8	3.1	15.6	2.5	21.8	2.9	19.0	3.8	22.8
14	12.1	38.6	7.8	23.6	9.0	29.9	8.1	24.2	3.5	21.1	5.5	22.1	2.6	27.7	3.4	16.7	3.6	19.9	2.8	15.9	2.3	16.1	3.6	18.9
15	12.1	36.3	7.9	24.6	11.4	29.4	8.5	26.1	2.6	17.9	3.8	25.8	2.5	26.1	2.4	14.2	2.7	31.4	3.5	21.0	2.9	18.0	4.0	22.0
16	13.2	33.3	7.0	23.4	12.5	32.7	12.7	33.6	3.6	22.1	5.2	22.6	3.4	20.9	3.4	18.7	3.0	13.8	2.5	21.7	2.7	20.7	3.8	24.2
17	12.0	35.4	6.7	24.7	15.1	36.2	10.4	28.1	3.2	23.7	7.6	26.4	4.7	26.5	3.6	24.8	2.7	15.7	3.2	18.9	3.8	19.7	4.5	26.3
18	13.5	38.3	10.3	29.4	11.4	31.9	7.4	28.4	3.4	16.9	7.6	25.8	4.9	22.3	3.0	17.9	2.4	19.7	1.5	19.0	2.6	15.0	3.0	16.1
19	11.0	34.8	10.8	29.2	10.2	28.3	7.4	26.7	2.2	19.6	6.1	22.2	4.8	23.8	3.2	14.1	2.6	16.4	3.5	19.1	3.5	18.4	2.2	19.6
20	12.0	33.2	5.9	22.7	10.6	29.9	5.8	25.9	2.0	13.3	3.8	15.5	7.6	26.5	3.0	19.2	2.9	17.0	2.7	15.4	3.6	19.8	4.1	17.5
21	14.1	36.9	7.7	25.4	13.1	31.3	5.1	25.6	3.4	22.4	3.2	12.3	6.7	21.1	3.9	37.4	3.1	15.4	3.3	16.0	4.4	26.3	3.6	21.5
22	15.1	39.3	9.8	25.7	11.5	34.6	8.0	30.3	2.7	15.5	5.7	20.5	6.3	23.3	4.1	21.7	2.9	16.9	3.1	19.9	4.0	21.2	3.2	18.7
23	11.3	30.2	9.6	29.0	11.1	30.9	9.2	31.1	2.8	23.4	6.1	19.7	3.3	30.0	6.2	25.1	3.1	16.7	2.3	12.8	3.2	21.3	4.1	20.7
24	7.7	24.0	9.8	30.0	9.6	28.3	7.8	28.4	3.0	17.1	4.3	21.2	2.8	17.6	2.9	26.5	3.5	20.6	2.2	13.5	3.3	18.6	3.5	20.7
25	10.8	28.6	11.0	31.5	11.8	30.5	7.0	24.9	3.0	21.2	4.2	26.2	3.6	18.6	2.5	14.0	3.5	19.7	2.8	15.6	7.0	23.9	4.6	19.1
26	10.6	28.7	12.9	33.5	11.8	32.6	7.0	26.9	2.4	16.4	6.0	27.7	3.2	18.8	3.9	21.7	3.7	20.8	2.8	21.2	6.0	21.5	6.4	27.6
27	6.2	23.5	10.6	29.4	12.6	36.2	7.8	25.6	3.1	17.2	5.4	23.4	4.6	21.9	7.1	28.0	3.4	19.9	3.2	25.6	4.4	17.7	9.5	29.0
28	6.1	26.5	9.4	28.2	10.2	31.9	8.5	25.9	3.7	18.6	5.2	20.4	6.4	24.5	5.9	29.0	2.7	21.9	3.2	21.3	2.6	19.7	5.7	28.3
29	7.5	28.8			8.9	28.0	9.5	27.9	3.3	16.2	5.1	21.6	9.9	28.9	4.6	21.3	2.9	19.2	2.6	16.5	3.7	19.7	5.9	25.7
30	11.0	29.9			8.4	28.6	8.4	22.8	3.0	16.5	3.4	13.3	7.6	24.3	3.4	23.7	3.2	28.9	2.6	21.9	7.7	25.5	8.4	28.6
31	9.8	29.1			8.5	31.6			2.5	20.0			4.5	23.9	3.1	19.6			2.5	24.3			7.5	29.4



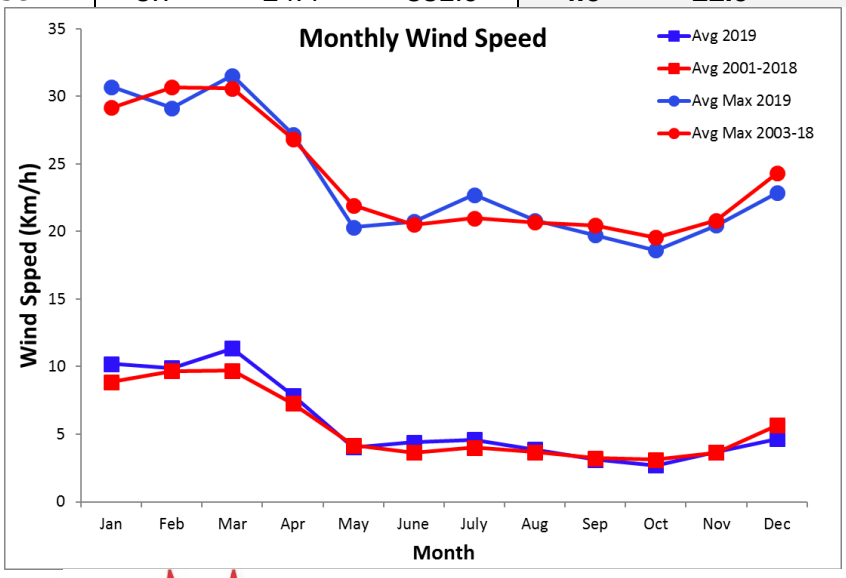
2019 Average Daily Mean Vector Wind Direction

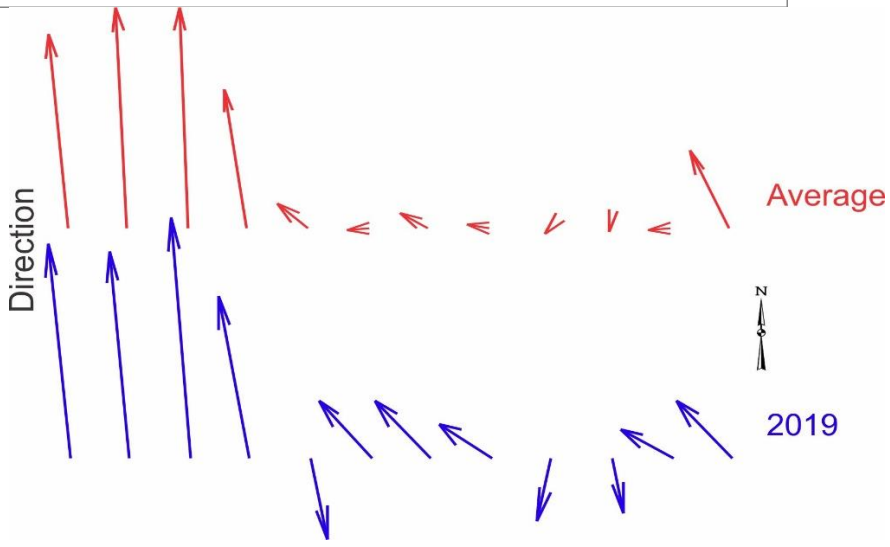
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	357.4	353.5	339.6	342.0	350.1	160.3	294.8	294.1	283.9	151.3	270.0	340.5
2	356.5	353.3	354.4	355.3	352.0	166.8	269.8	286.1	330.8	148.6	235.9	322.8
3	351.9	355.7	352.1	354.1	343.5	230.2	302.6	233.4	270.8	135.9	268.7	317.9
4	347.5	355.4	353.4	350.6	344.5	305.6	351.9	342.8	258.1	177.2	296.8	241.0
5	351.2	356.8	356.1	354.1	333.7	237.4	322.2	277.4	218.1	209.7	325.9	246.0
6	356.8	357.7	356.1	293.4	346.5	255.4	270.0	233.1	265.4	177.2	263.9	235.0
7	343.4	353.4	357.8	344.4	346.9	140.9	298.9	148.8	198.9	142.1	319.8	252.6
8	348.6	357.7	355.3	339.3	331.4	130.4	173.7	338.1	234.2	167.9	331.4	314.7
9	339.5	358.2	355.4	341.9	208.5	253.7	213.6	327.0	282.0	181.9	317.6	343.7
10	352.2	357.1	354.3	354.5	152.9	224.7	255.7	343.0	297.9	186.5	188.3	331.1
11	352.8	354.1	357.8	342.9	168.1	291.5	274.6	340.1	249.4	174.6	208.8	266.8
12	348.4	340.8	357.5	351.7	342.1	212.0	265.9	263.9	265.3	158.0	238.1	338.8
13	356.2	343.7	353.5	350.7	300.5	298.8	304.3	287.7	243.7	136.6	271.8	312.9
14	358.3	346.4	348.3	348.6	195.4	329.2	236.1	214.1	295.9	138.3	243.6	309.2
15	356.2	345.8	353.7	348.4	177.8	344.3	201.0	174.9	188.0	302.4	262.1	300.2
16	356.8	345.4	358.2	355.0	336.2	352.4	269.1	160.4	147.5	257.5	275.1	276.0
17	356.4	342.3	356.7	351.1	223.8	345.9	322.9	188.5	273.1	272.5	289.8	237.1
18	357.2	351.7	347.8	350.8	234.3	352.1	322.2	318.8	240.8	227.3	268.4	248.5
19	355.4	353.3	351.1	345.1	164.1	337.7	339.2	265.1	159.9	150.2	272.0	270.9
20	354.0	339.5	354.1	334.8	144.8	317.2	346.9	197.6	138.7	135.7	301.9	274.1
21	357.1	348.3	356.4	286.9	139.3	252.3	342.1	225.8	139.8	132.7	321.8	287.3
22	359.3	355.6	356.2	337.5	135.1	339.9	329.2	309.2	145.8	204.3	310.1	256.6
23	353.3	351.8	354.9	351.6	149.5	344.2	249.7	343.0	155.0	202.7	300.4	266.2
24	343.3	350.6	351.1	347.2	145.3	314.0	260.0	287.4	154.2	133.0	328.5	250.3
25	353.1	357.7	354.9	338.2	157.8	272.7	278.0	256.7	134.6	142.2	346.7	332.4
26	357.2	356.4	355.3	340.3	151.3	338.1	274.0	294.7	147.2	169.4	313.8	348.6
27	344.9	353.6	355.0	342.7	132.7	277.3	280.9	347.0	136.9	199.6	309.6	353.3
28	324.9	351.8	351.2	348.4	148.0	336.8	327.0	327.8	157.4	269.7	256.9	337.9
29	338.9		353.6	348.8	151.5	254.4	353.0	350.2	290.9	233.2	284.9	344.9
30	356.3		348.7	353.4	163.8	290.3	346.3	321.6	215.2	264.7	350.2	348.4
31	352.7		346.6		208.4		320.4	317.0		266.9		343.7



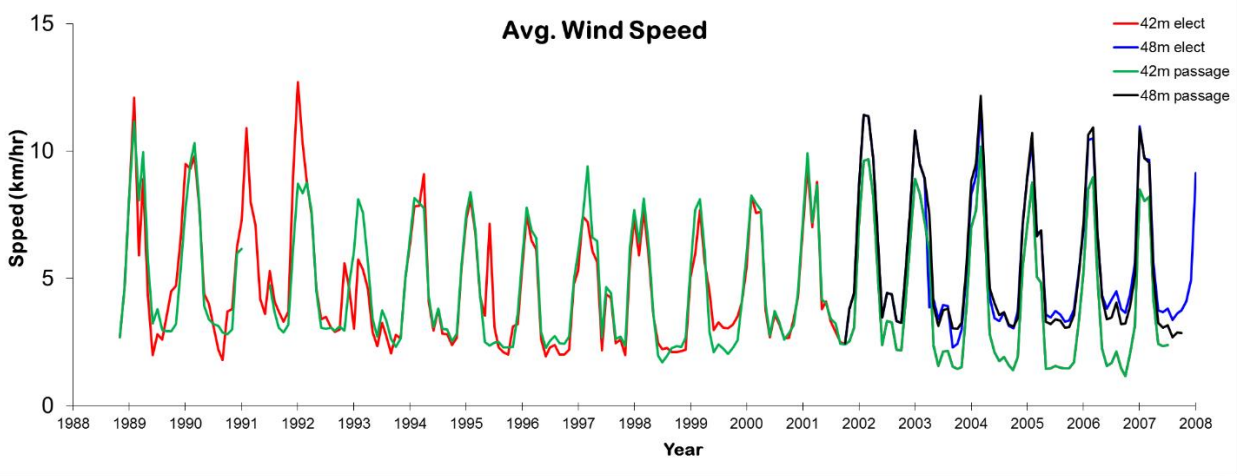
Average Monthly Wind Speed and Direction

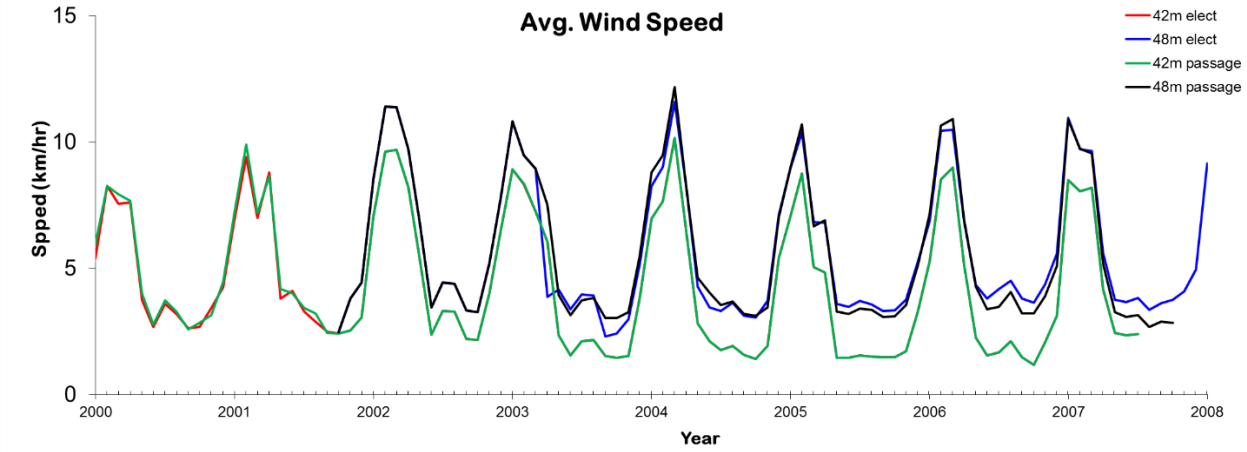
	Long-term Av.			2019		
	Speed	Max	Dir.	Speed	Max	Dir.
January	8.8	29.1	354.6	**10.2**	**30.7**	**351.8**
February	9.7	30.8	357.0	**9.9**	**29.1**	**351.8**
March	9.6	30.5	357.8	**11.4**	**31.5**	**353.5**
April	7.2	26.8	350.4	**7.9**	**27.2**	**344.7**
May	4.2	22.0	308.6	**4.0**	**20.3**	**162.9**
June	3.6	20.5	262.5	**4.4**	**20.7**	**308.3**
July	4.0	20.9	296.3	**4.6**	**22.7**	**305.8**
August	3.7	20.7	278.3	**3.9**	**20.8**	**294.6**
September	3.2	20.5	222.7	**3.1**	**19.7**	**198.4**
October	3.2	19.6	192.7	**2.7**	**18.6**	**164.8**
November	3.6	20.9	266.7	**3.7**	**20.5**	**291.3**
December	5.7	24.4	331.9	**4.6**	**22.9**	**305.7**

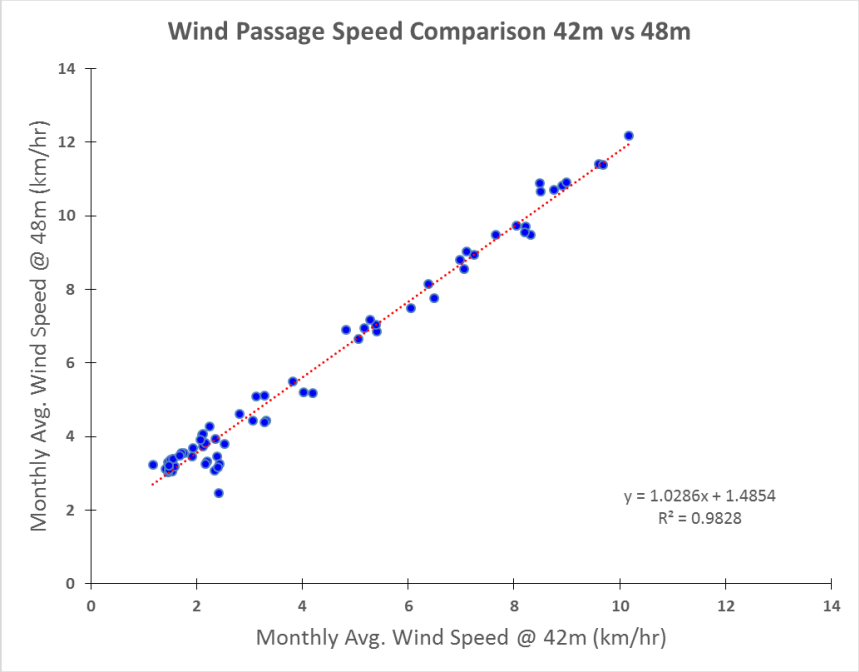




Comparison of Totalizing & Electronic Anemometers



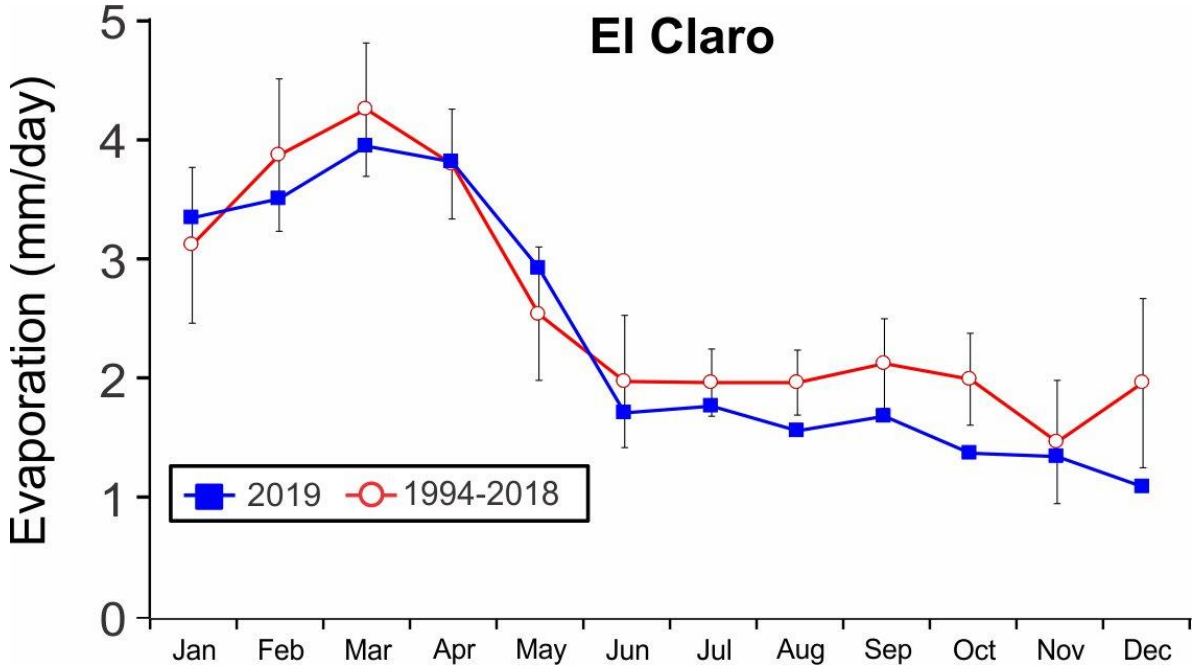



Wind Passage Speed Comparison 42m vs 48m
Monthly Avg. Wind Speed @ 48m (km/hr)
Monthly Avg. Wind Speed @ 42m (km/hr)
y = 1.0286x + 1.4854
R² = 0.9828
0
2
4
6
8
10
12
14

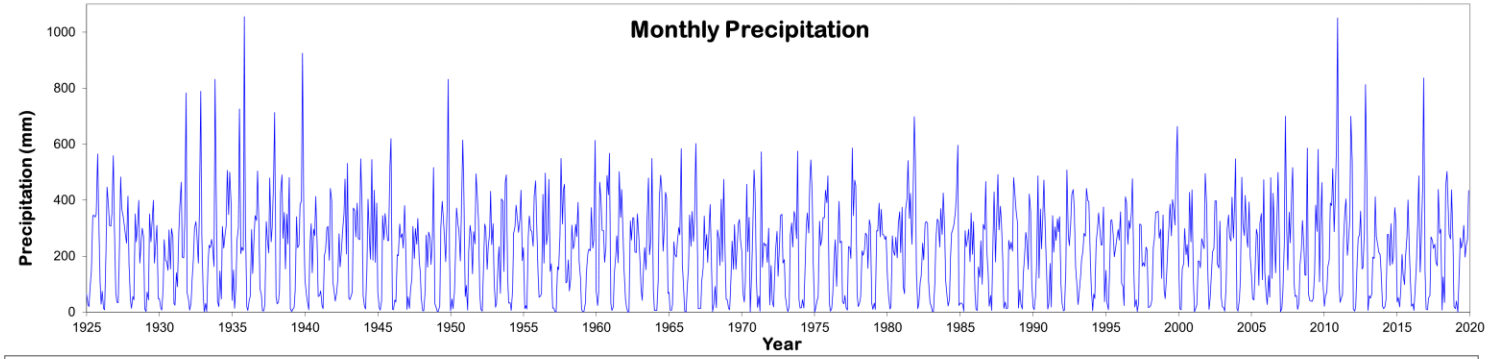
Estimated Evapotranspiration

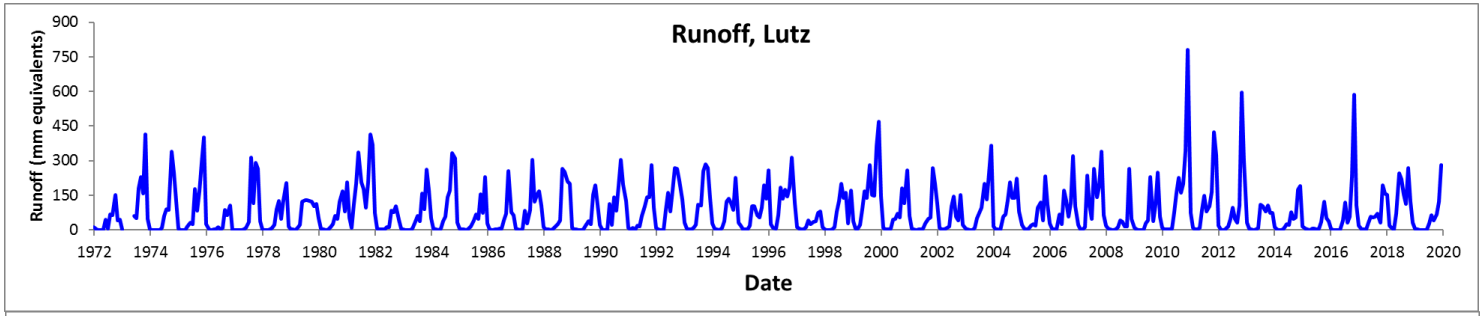
(No data at 10m 42 & 48m after April due to damage to the Lutz tower)

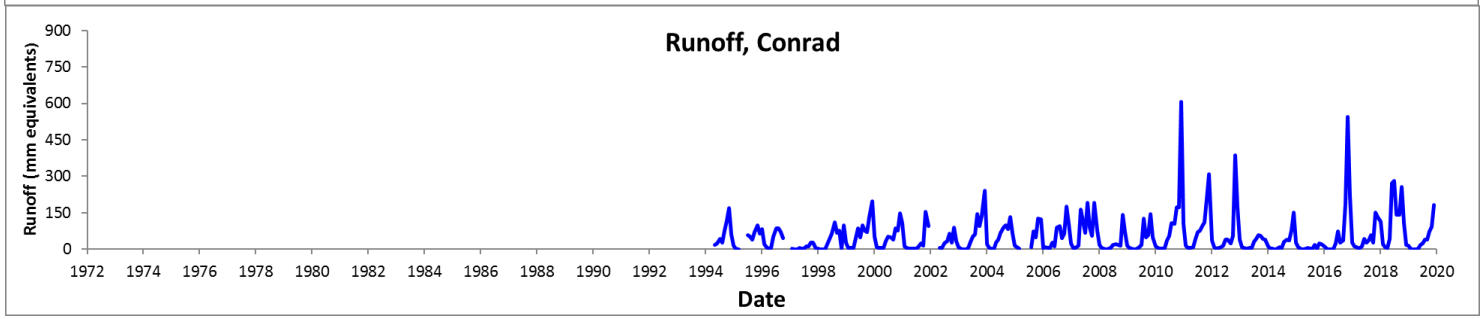
	Average (1993-2018)		2019	
	Month^{-1}	Day^{-1}	Month^{-1}	Day^{-1}
January	93.4	3.0	**104.2**	**3.4**
February	107.3	3.8	**102.0**	**3.6**
March	127.5	4.1	**123.0**	**4.0**
April	110.1	3.7	**115.0**	**3.8**
May	76.2	2.5	**88.0**	**2.8**
June	58.2	1.9	**51.5**	**1.7**
July	59.4	1.9	**55.0**	**1.8**
August	59.3	1.9	**48.5**	**1.6**
September	63.2	2.1	**50.5**	**1.7**
October	60.7	2.0	**42.7**	**1.4**
November	40.1	1.3	**40.4**	**1.3**
December	58.6	1.9	**33.9**	**1.1**

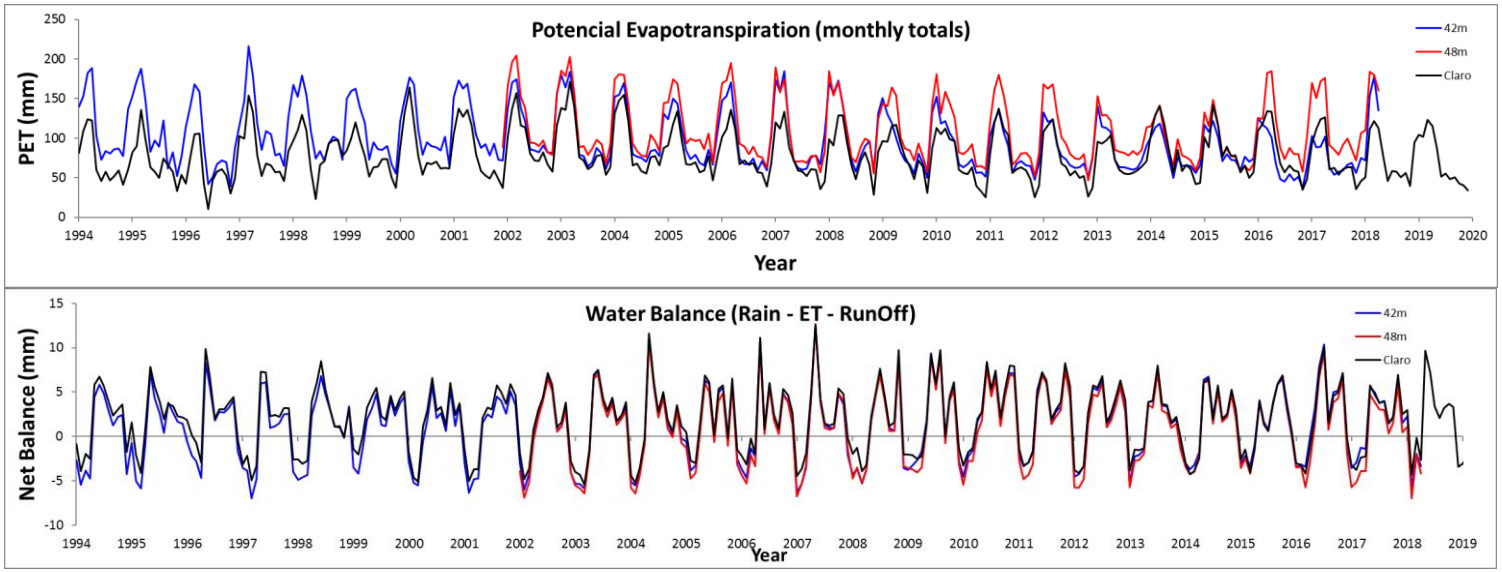


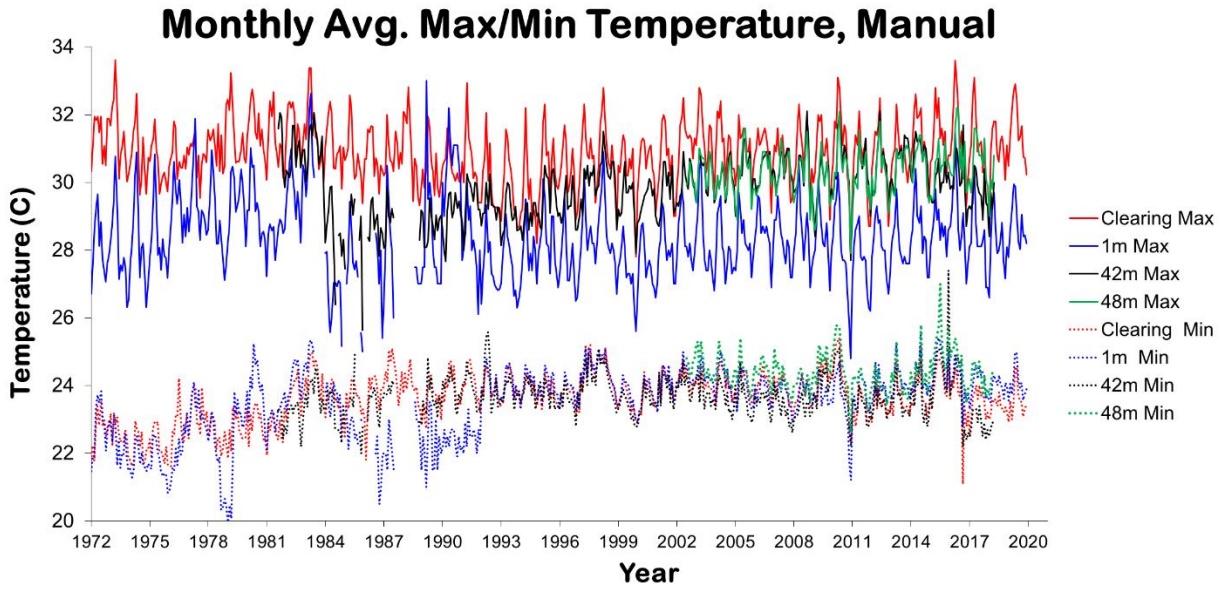
Long-term Monthly Averages/Totals

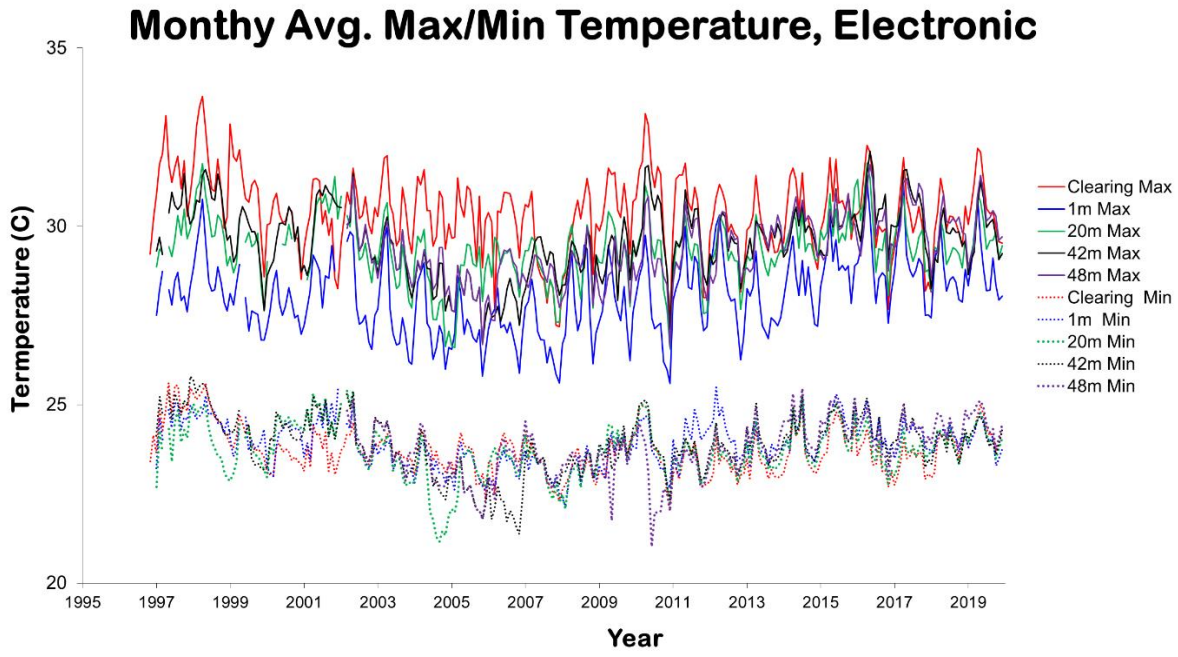


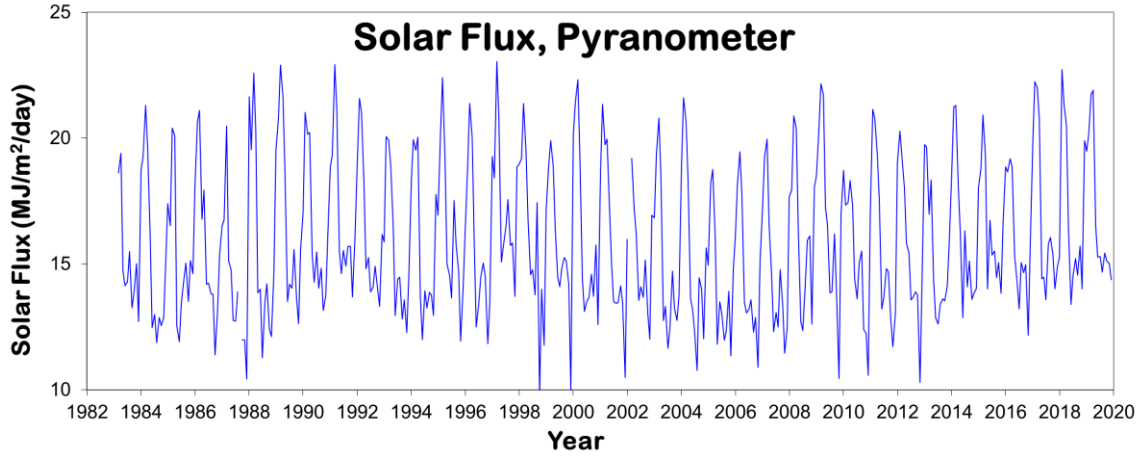


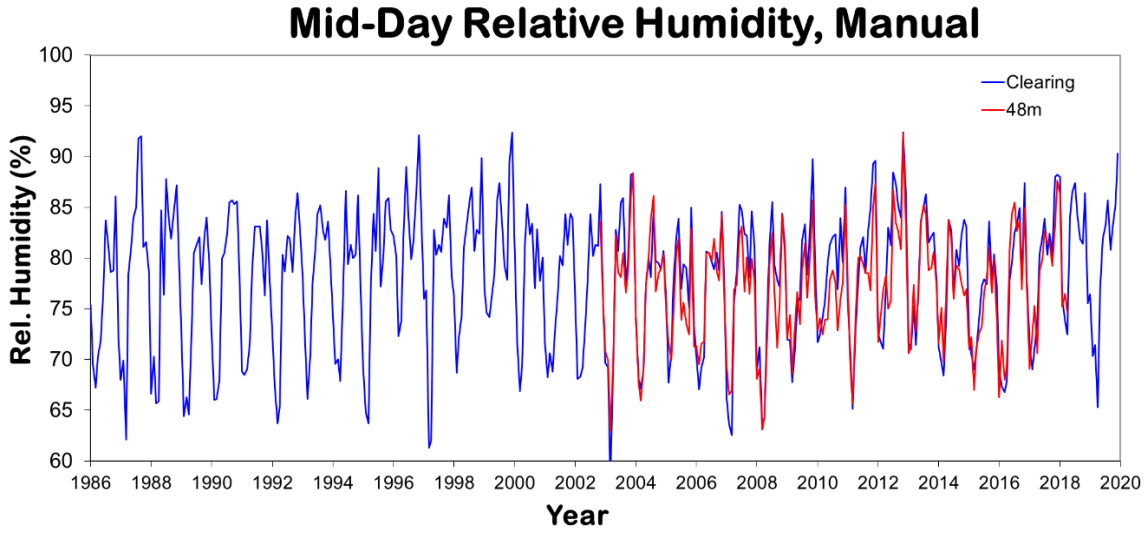


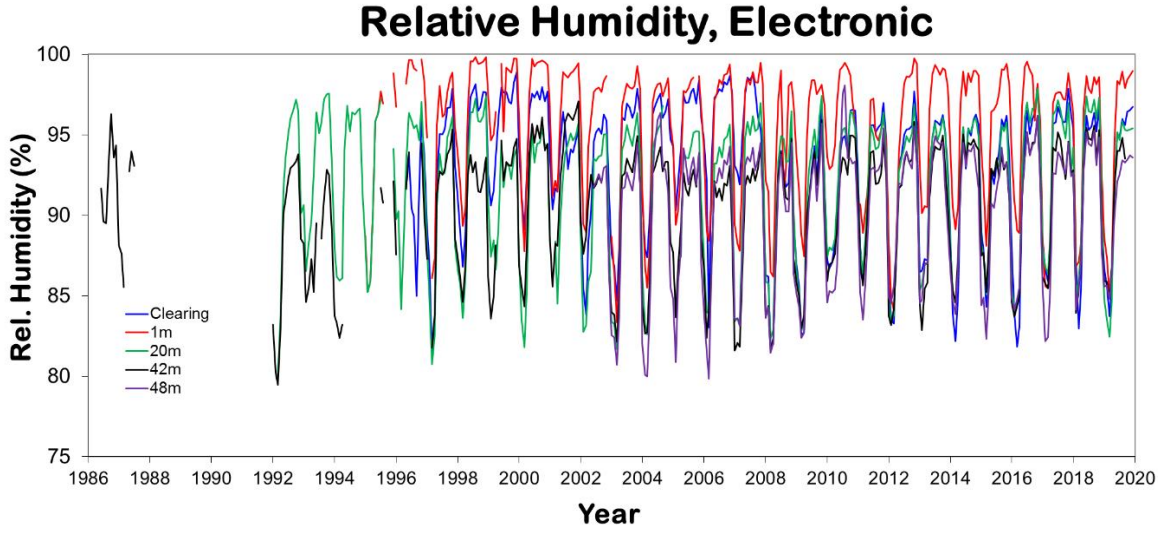

Potencial Evapotranspiration (monthly totals)
PET (mm)
Year
42m
48m
Claro
Water Balance (Rain - ET - RunOff)
Net Balance (mm)
Year
42m
48m
Claro

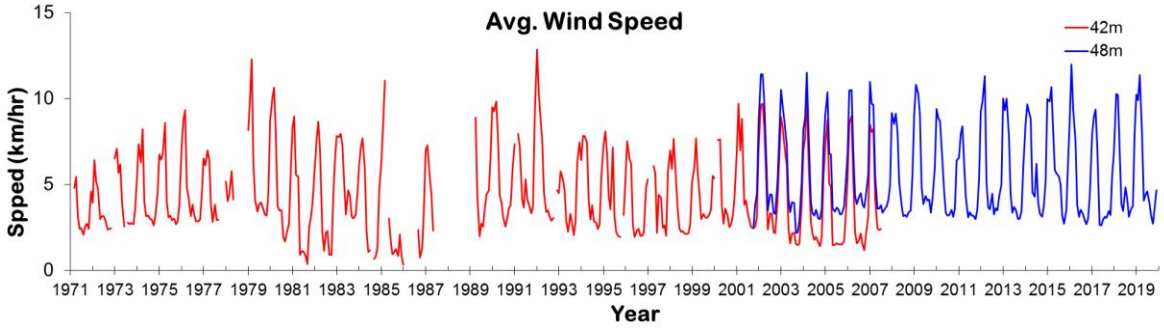

Monthly Avg. Max/Min Temperature, Manual
Temperature (C)
34
32
30
28
26
24
22
20
1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020
Year
Clearing Max
1m Max
42m Max
48m Max
Clearing Min
1m Min
42m Min
48m Min


Monthy Avg. Max/Min Temperature, Electronic
Termperature (C)
35
30
25
20
1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019
Year
Clearing Max
1m Max
20m Max
42m Max
48m Max
Clearing Min
1m Min
20m Min
42m Min
48m Min

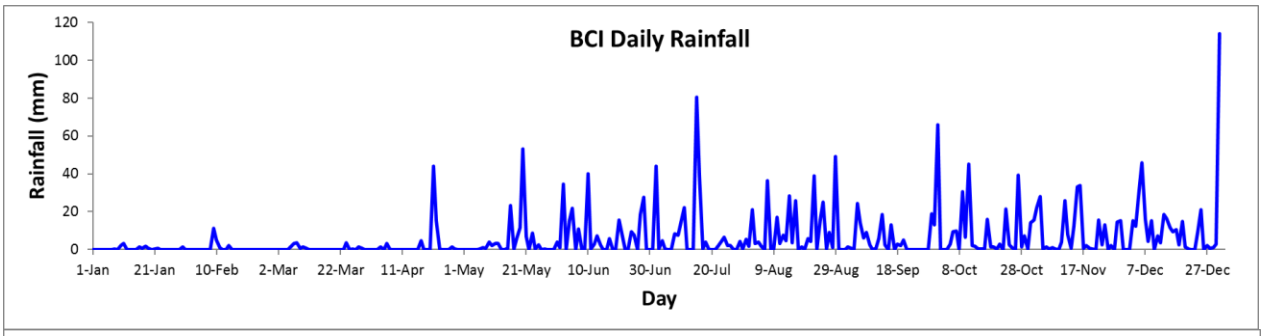

Solar Flux, Pyranometer
Solar Flux (MJ/m²/day)
25
20
15
10
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020
Year

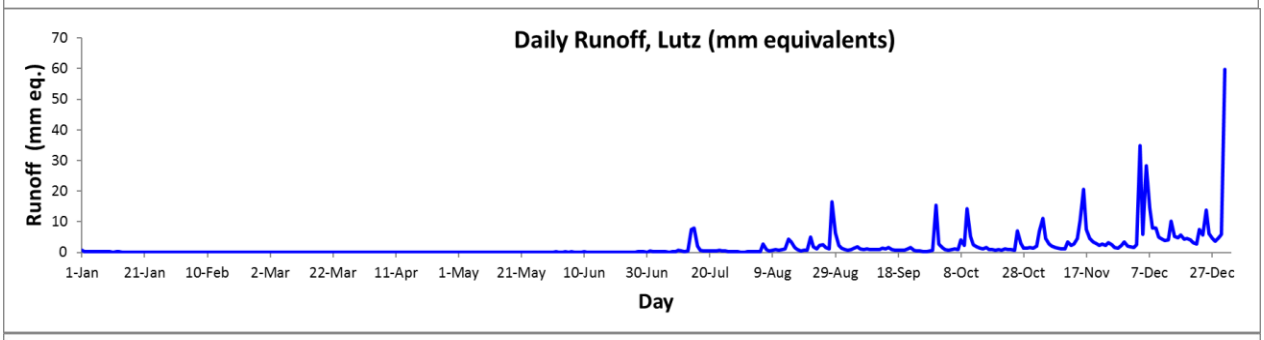

Mid-Day Relative Humidity, Manual
Rel. Humidity (%)
100
95
90
85
80
75
70
65
60
Clearing
48m
1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020
Year

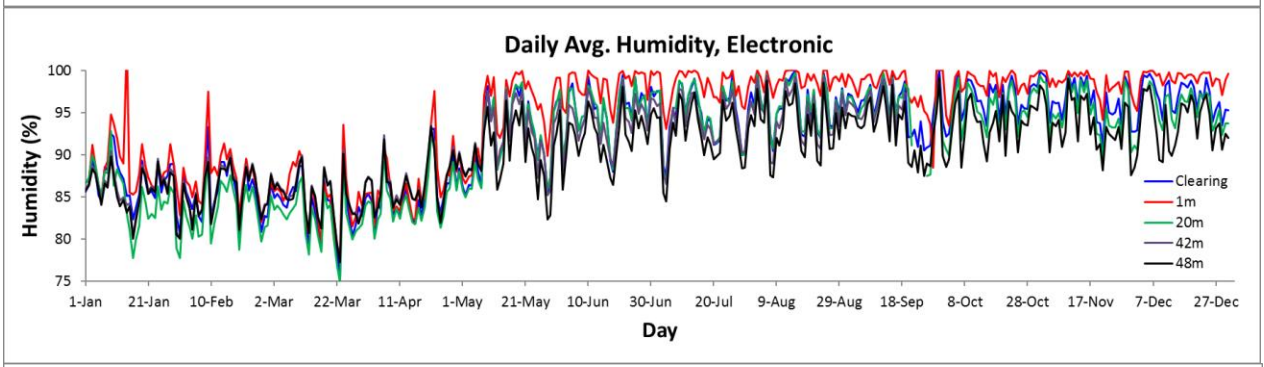

Relative Humidity, Electronic
Rel. Humidity (%)
100
95
90
85
80
75
Clearing
1m
20m
42m
48m
1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020
Year

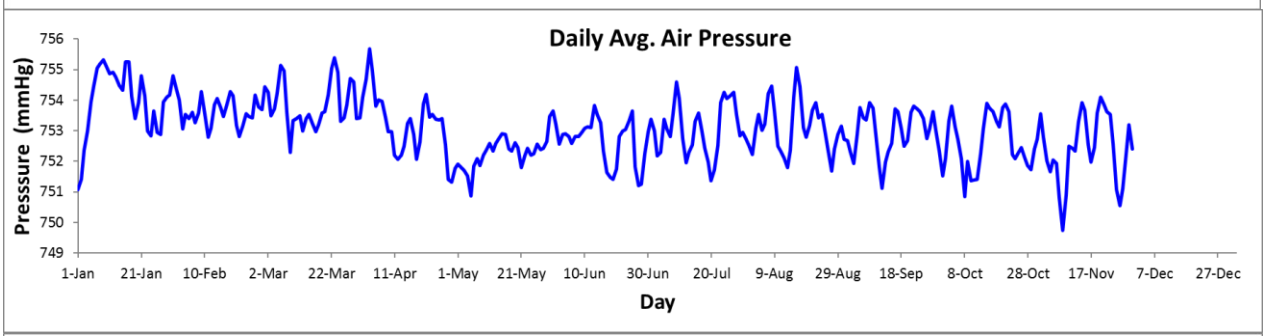

Avg. Wind Speed
42m
48m
Spped (km/hr)
15
10
5
0
1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019
Year

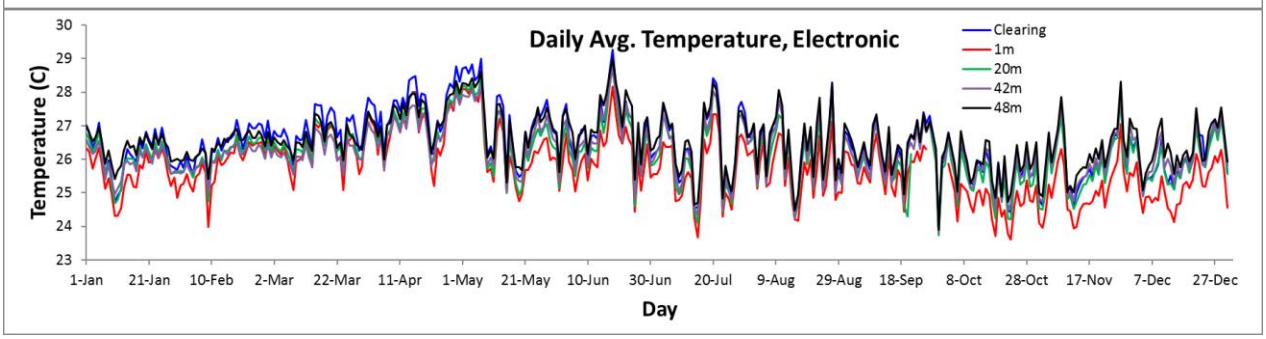
2019 Daily Averages/Totals



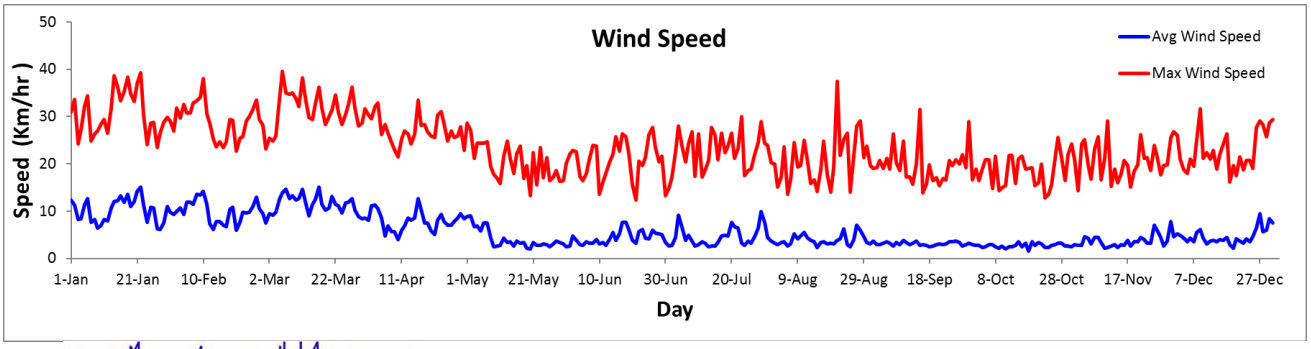


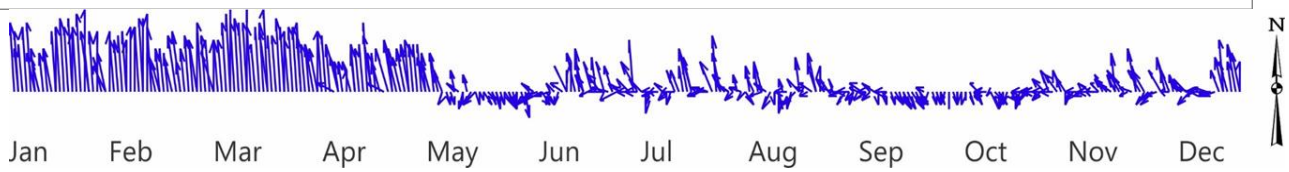




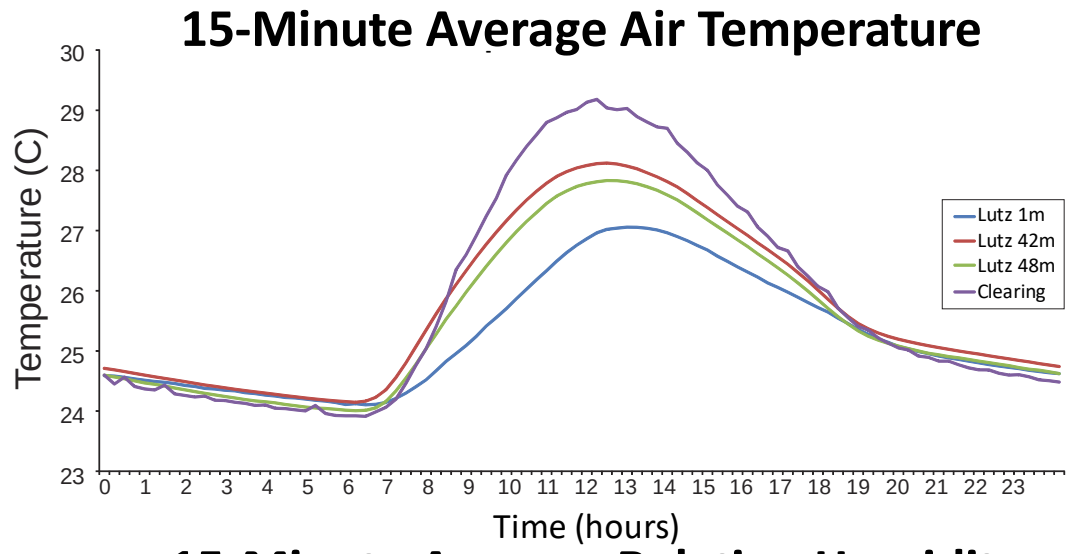


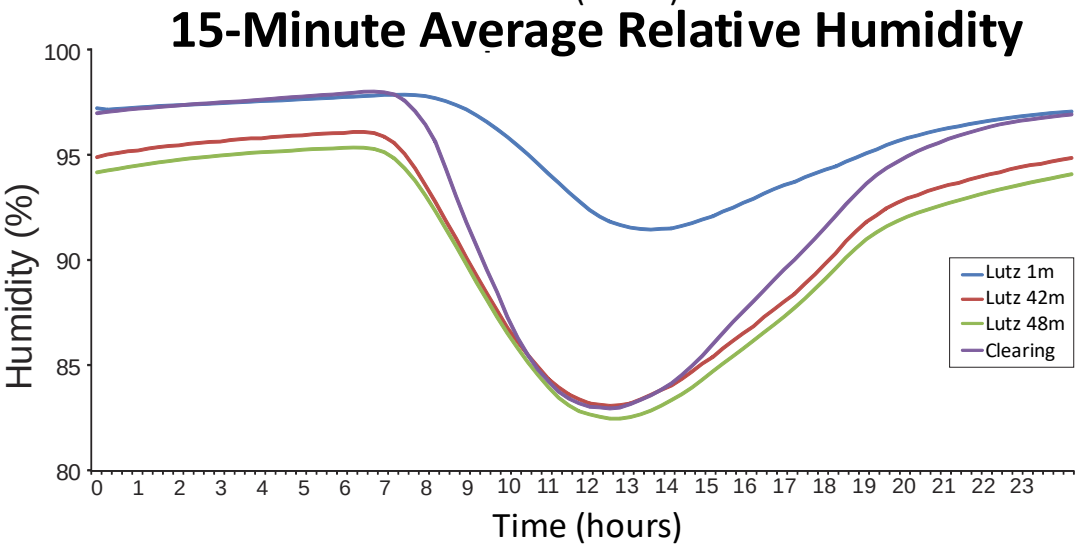
2019 Daily Averages/Totals

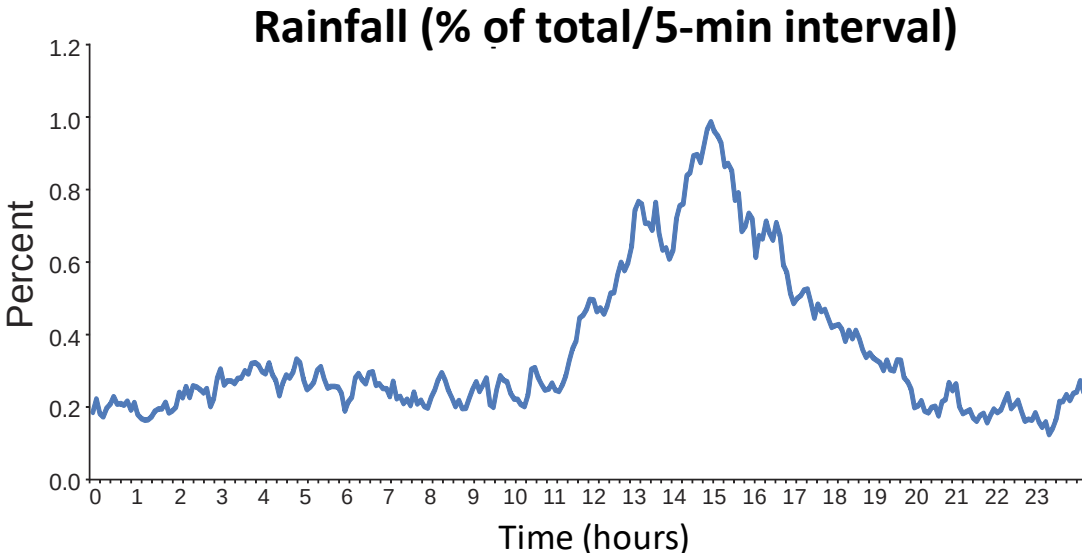




Long-term Hour Averages







Long-term Hour Averages