Task 1
Haleakala Observatories
Wind Speed, Wind Direction, Temperature, Relative Humidity
1998-Present

The purpose of this study is to provide various climatalogical statistics as a means to evaluate the Haleakala site for new optical facilities. Two independent sets of data were available for this analysis; one from CAPS and the other from the University of Hawaii Mees Solar Observatory weather tower.

The Comprehensive Atmospheric Prediction System (CAPS) was designed and deployed for the U. S. Air Force AEOS facility on Haleakala, Maui and became operational in mid 1998. It consists of 10 surface weather stations (Remote Monitoring Stations or REMS) located to cover all azimuths around the summit of the mountain and at ranges from about 2 to 7 miles. There is also a base station at the Air Force's Advanced Electro-Optical System (AEOS) building that collects the data from the REMS using radio telemetry. The goal of Task 1 was to examine the weather data in the CAPS archive from the summit station which is located about forty meters East of the UH Mees Observatory.

In addition to the CAPS data, Task 1 included an examination of the UH Mees weather tower data collected over the same time frame. The weather data displayed on the MSO weather page is collected from a set of standard instruments mounted on a 10 meter tower 30 meters East of the observatory building. The UH analysis only includes wind speed and wind direction to provide a comparison between the sensors which are at different heights above ground level (AGL). The CAPS anemometer is about 8 feet AGL and the UH sensor is near 30 feet AGL.

General Notes

Because this data analysis only covers the years from 1998 onward[1], there are a few caveats regarding the composite summaries of multi-year measurements. The tropical Pacific (which certainly includes Hawaii) exhibits significant inter-annual changes due to large-scale patterns such as the El Nino/Southern Oscillation (ENSO). El Nino (also called the warm phase) is when the sea surface temperature (SST) of the equatorial Pacific Ocean is above normal; La Nina (also called the cold phase) is when the SST is below normal.

The National Weather Services (NWS) National Center for Environmental Prediction (NCEP) classifies each seasonal quarter[2] as warm (W), cold ©, or neutral (N); sub-classifications are (+) for a strong event, and (-) for a weak event. The NCEP determination uses as the key region of the Pacific an area along the equator from 150° West longitude to the data line (180°).

[1] The CAPS system only became operational in mid 1998.
[2] Quarters are Jan/Feb/Mar=JFM, Apr/May/Jun=AMJ, Jul/Aug/Sep=JAS, and Oct/Nov/Dec=OND.

For the years included in this study, the NWS/NCEP classification follows in Table 1.

Year	JFM	AMJ	JAS	OND
1998	W+	W	C-	C
1999	C+	C	C-	C
2000	C	C-	N	C-
2001	C-	N	N	N
2002	N	W-	W	W
2003	W-			

Table 1
Cold and Warm Episodes by Season

A preliminary analysis of the January, February, and March[3] CAPS data for the years 1999 to 2003 shows three general patterns in the wind rose charts:

Mostly east winds, 1999, 2000, 2001	correlates to a cold phase
Winds from all directions, 2002	correlates to the neutral phase
Significant winds from W/NW 2003	correlates to a warm phase

Therefore, it is clear that a multi-year composite obscures the inter-annual variation due to the warm/cold phases of the ENSO and complicate the probability of good/bad weather in a particular year. The multi-year seasonal (quarters) wind distribution is presented here but caution is advised to consider the inter-annual variation as well.

CAPS Weather Data

CAPS has been online since mid-1998 and all data has been archived. These archive files are the source for the analyses presented here.

The data logger program for CAPS remote stations scans all sensors once per 10 seconds. Every 5 minutes, the average value of the parameter is calculated and put in final storage as a separate archive file. These files are collected once per hour by the base station and eventually stored on compact disks (CDs). For this study, only the data from the summit REMS was analyzed.

Temperature

Temperature data from the CAPS summit station over the 5 years (July 1998 to June 2003) was analyzed to determine the average value, the highest value, and the lowest value for each month of the year. These data are presented in Figure 1.

Relative Humidity

Similarly, the relative humidity data from the CAPS summit station was analyzed to determine the average value for each month. These data are presented in Figure 2. Note that the maximum value for any month was 100% and the minimum was near 0%.

[3] The monthly data for each year is included as charts in the appendix.

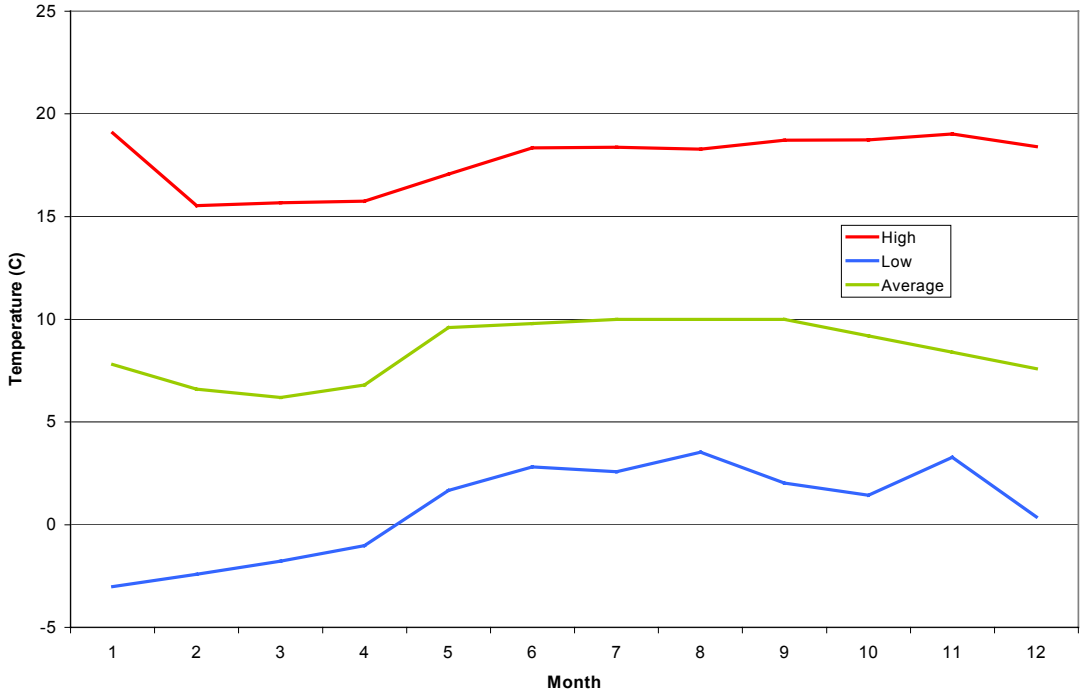


Figure 1—CAPS Temperature Variation by Month (1998-2003)

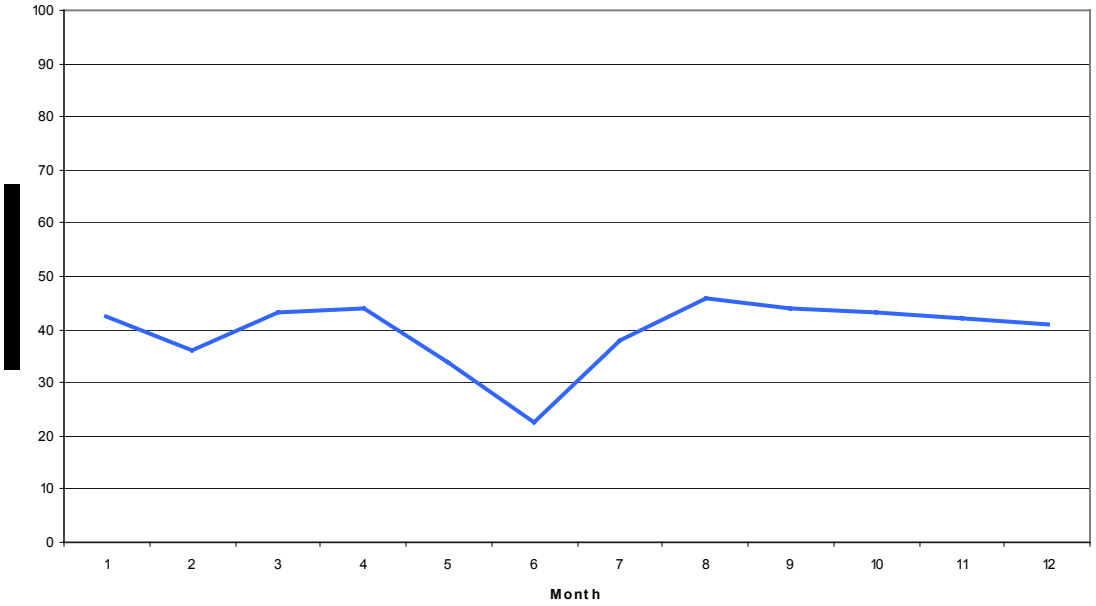


Figure 2—CAPS Humidity Variation by Month (1998-2003)

Winds

All wind data from both CAPS and MSO was processed to create a wind rose chart showing the distribution of directions and speeds for a specified time interval. The length of each rose petal is proportional to the percentage of events in that direction (16 compass bins were chosen for this analysis). The colored segments of each petal are proportional

to the percentage of events for each of the defined speed ranges. Calm winds are defined as less than 2 mph.

The anemometer on the CAPS summit station is located about 8 feet above the ground. This ground station (#100) east of the UH Mees Observatory is exposed to unperturbed air flow from the northeast (clockwise, CW) to the northwest. From the northwest to the northeast (CW), there are various buildings and higher ground that produce some wind shadowing effects[4].

Figures 3 to 6 include CAPS wind measurements for 5 years (July 98 to June 2003) with the data grouped seasonally (by quarters of the year). All CAPS charts are identified by "R0" in the sub-title (this is the designation of the summit station). The seasons are identified as "q1, q2, q3, and q4". The suffix "5" identifies the chart as a composite of 5 years of data.

[4] There is almost no location on the summit that does not suffer from shadowing from some obstructions in some directions.

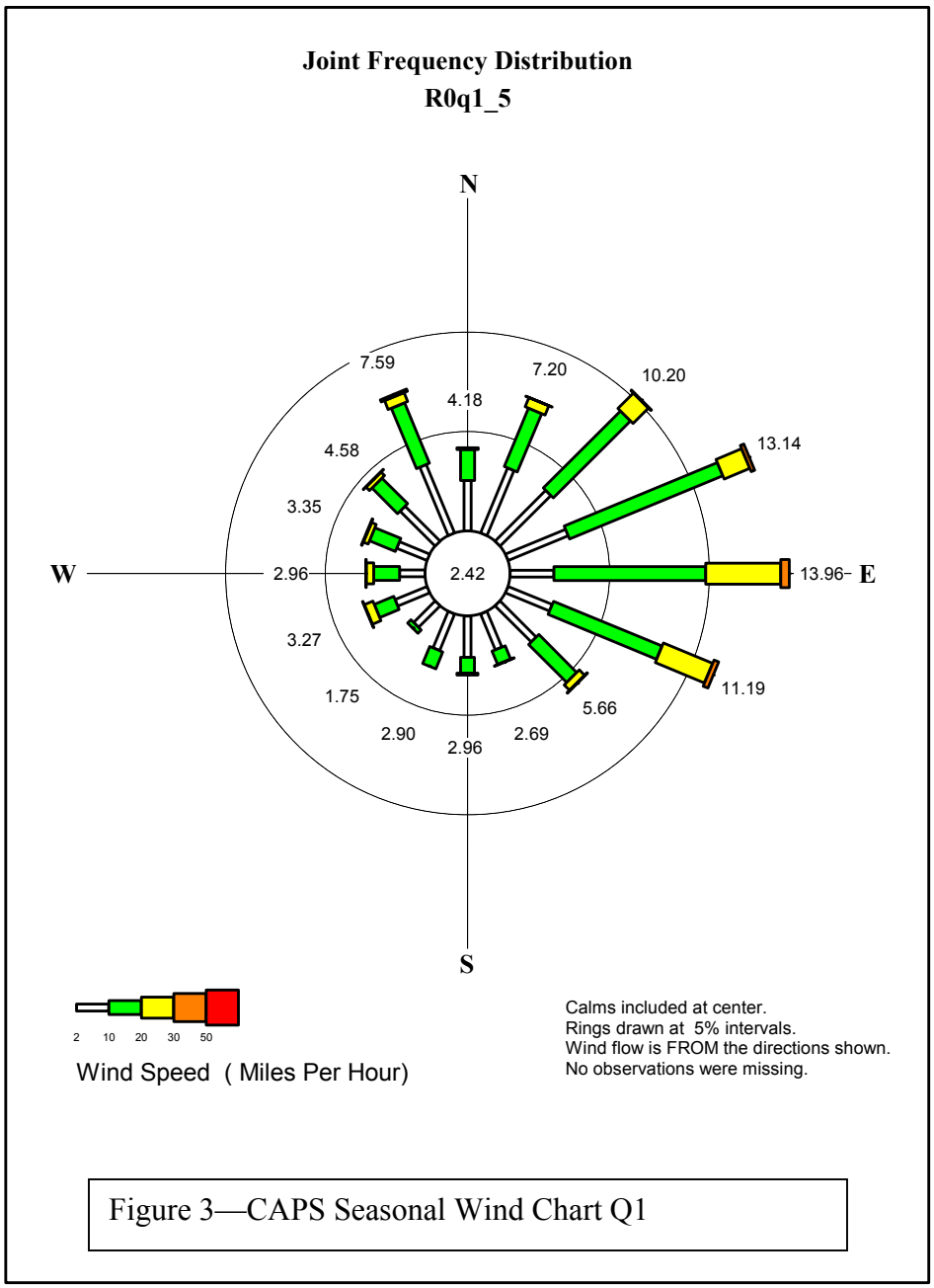


Figure 3—CAPS Seasonal Wind Chart Q1

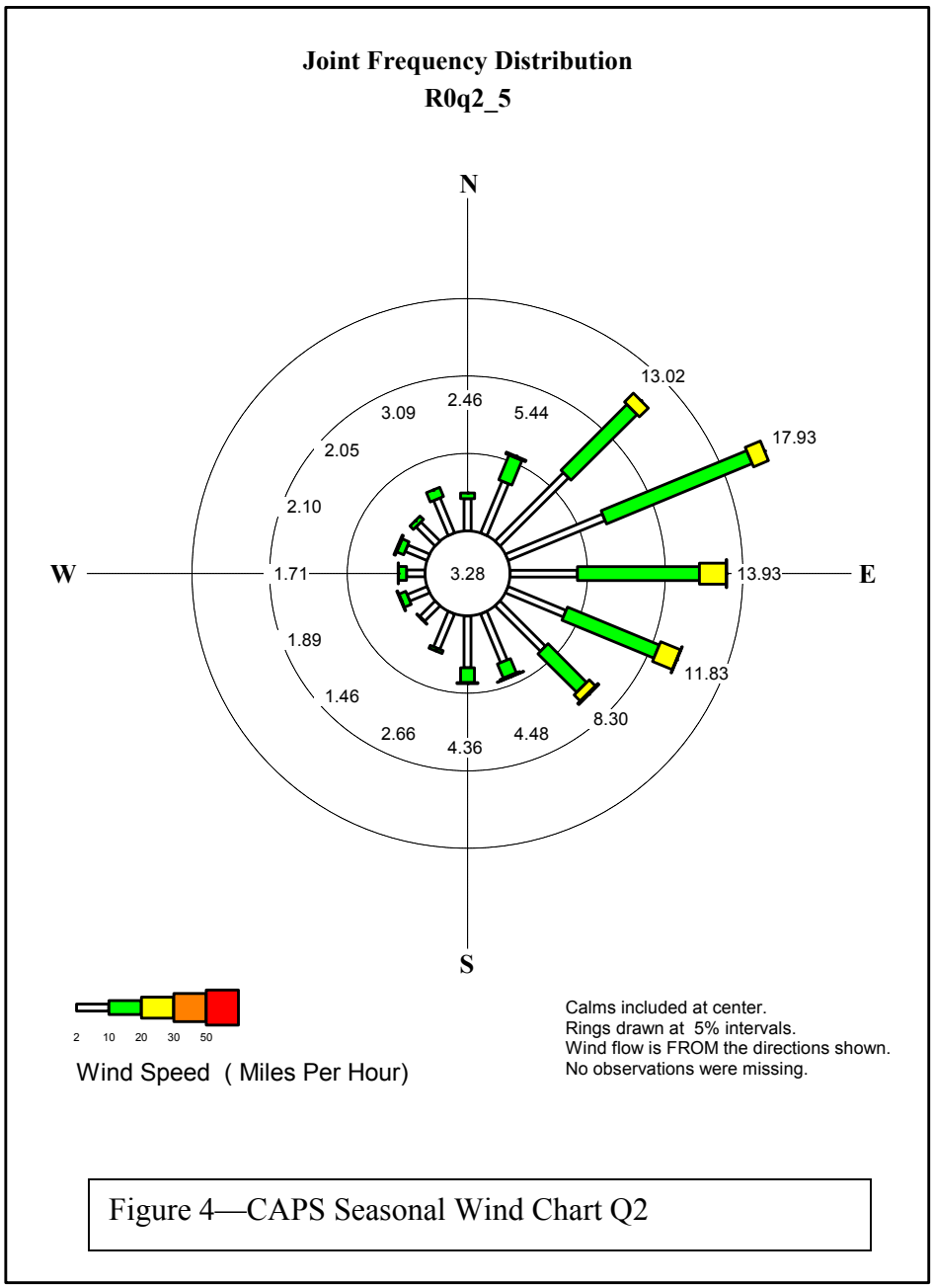


Figure 4—CAPS Seasonal Wind Chart Q2

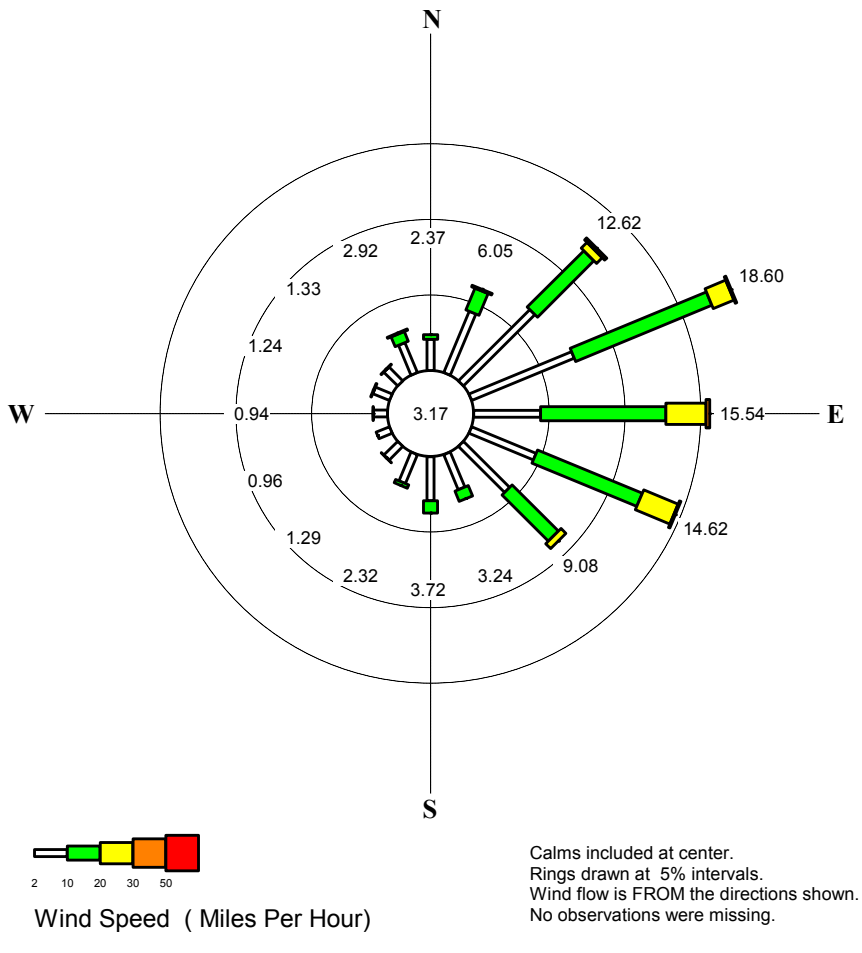


Figure 5—CAPS Seasonal Wind Chart Q3

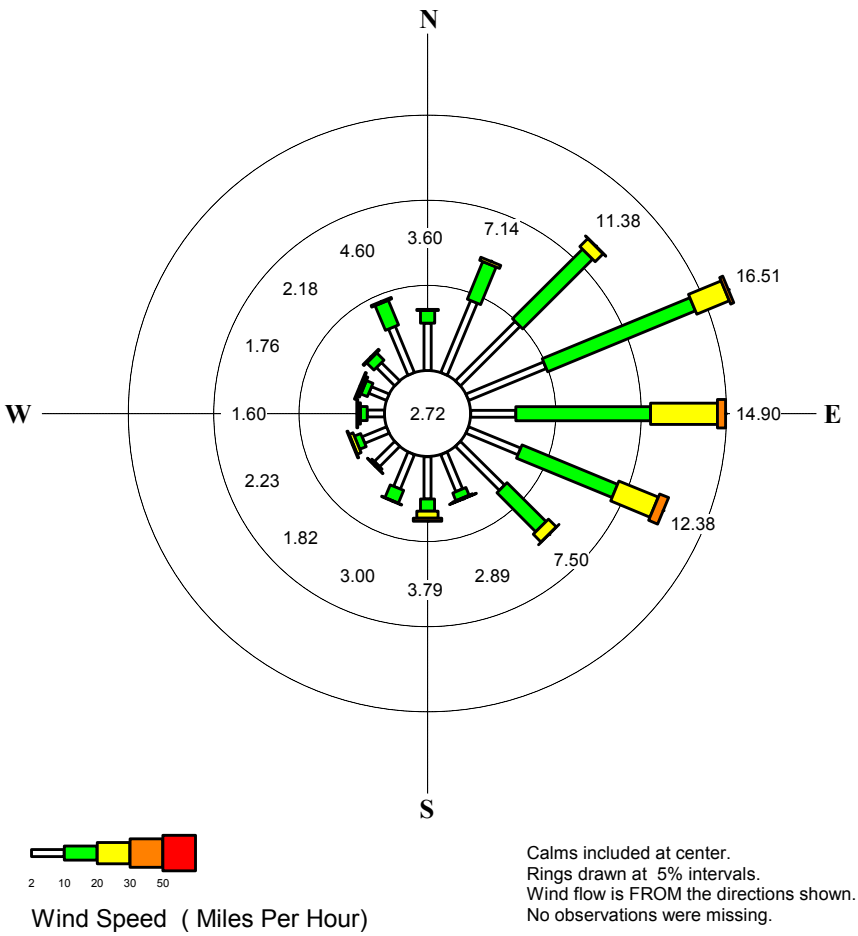


Figure 6—CAPS Seasonal Wind Chart Q4

The easterly trade winds dominate all seasons of the year (during the 5 years analyzed here). Only in Q1 are there significant westerly winds (about 25%); during the other seasons (Q2, Q3, Q4), westerly winds are less than 20%. Wind speeds are mostly less than 20 mph, with few occasions exceeding 30 mph. The percentage of events from each quadrant for each season is shown in Table 2.

	N	E	S	W	Calms
JFM	24	49	14	11	2
AMJ	13	57	20	7	3
JAS	13	61	18	4	3
OND	18	55	17	7	3

Table 2
Percentage of Events per Quadrant[5] per Season for CAPS

Wind speeds for the CAPS station were less than 30 mph more than 95% of the time. No winds were recorded over 50 mph, probably due to the position and height of the CAPS wind sensor.

UH Mees Tower Data: Winds

The anemometer on the UH Mees met tower is located about 33 feet (10 meters) above the ground. The Mees tower is located about 60 feet to the West of the CAPS station. The percentage of events from each quadrant for each season is shown in Table 3.

	N	E	S	W	Calms
JFM	19	51	14	13	2
AMJ	11	68	14	6	2
JAS	13	70	12	4	2
OND	16	64	13	6	2

Table 3
Percentage of Events per Quadrant per Season for UH Mees

The following 4 charts (Figs 7-10) include UH Mees wind measurements for 5 years (January 1998 to December 2002) with the data grouped seasonally (by quarters of the year). All UH charts are identified by "uh" in the sub-title with the seasons identified as "q1, q2, q3, and q4". The suffix "5" (or "4") identifies the chart as a composite of 5 (or 4) years of data.[6]

[5] Compass quadrants are defined as: N=NW to NNE, E=NE to ESE, S=SE to SSW, and W=SW to WNW.
[6] Due to sensor malfunction, several months of data were missing from the 5 year archive.

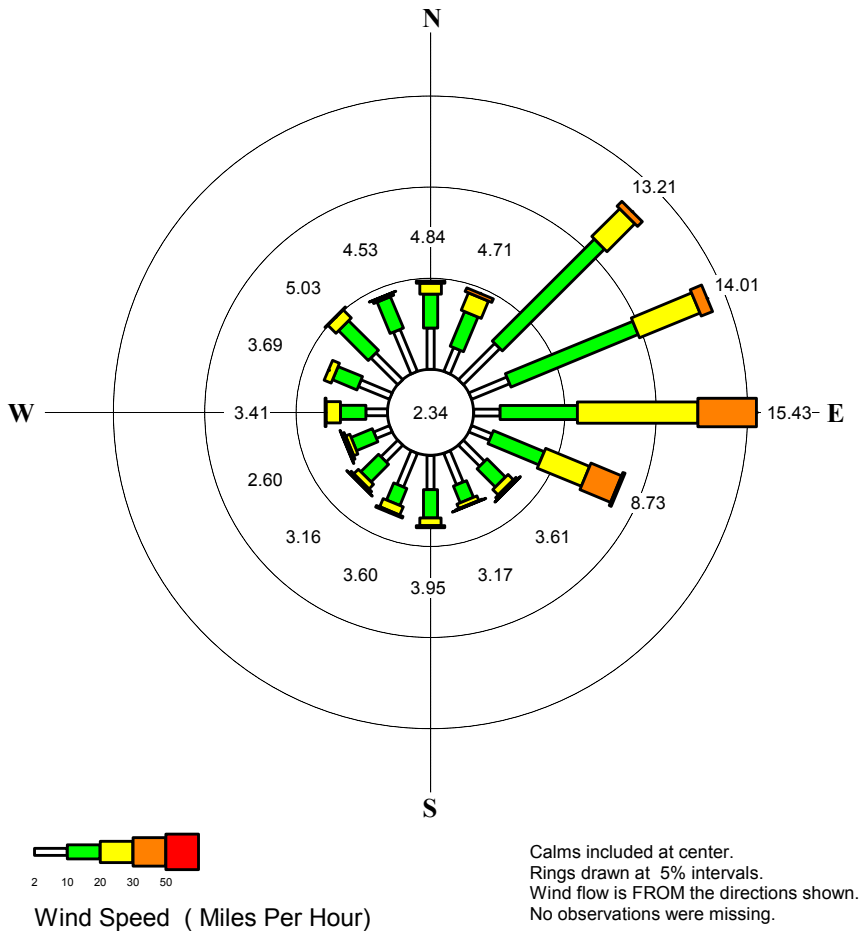


Figure 7—UH 4 Year Wind Chart Q1

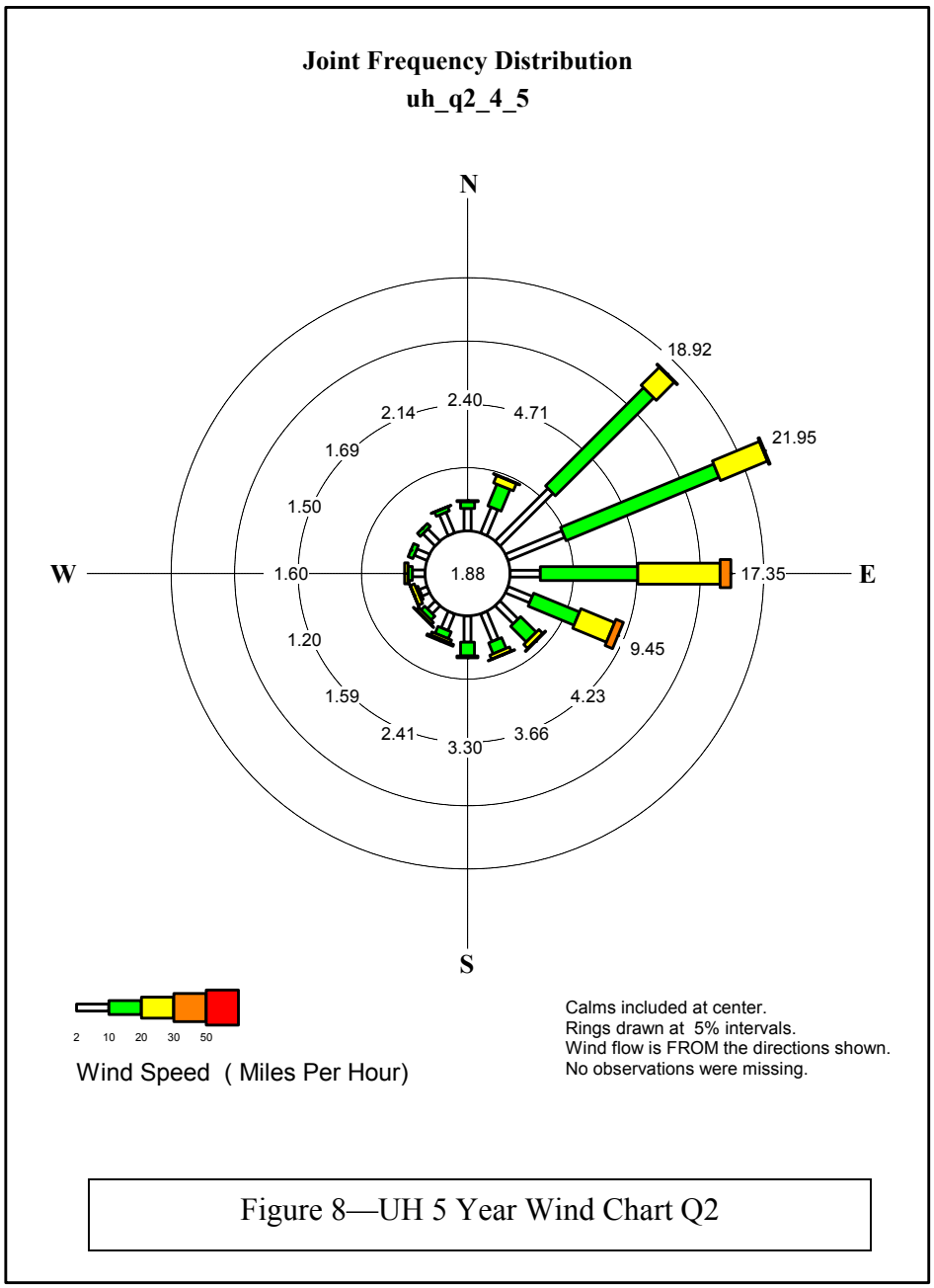


Figure 8—UH 5 Year Wind Chart Q2

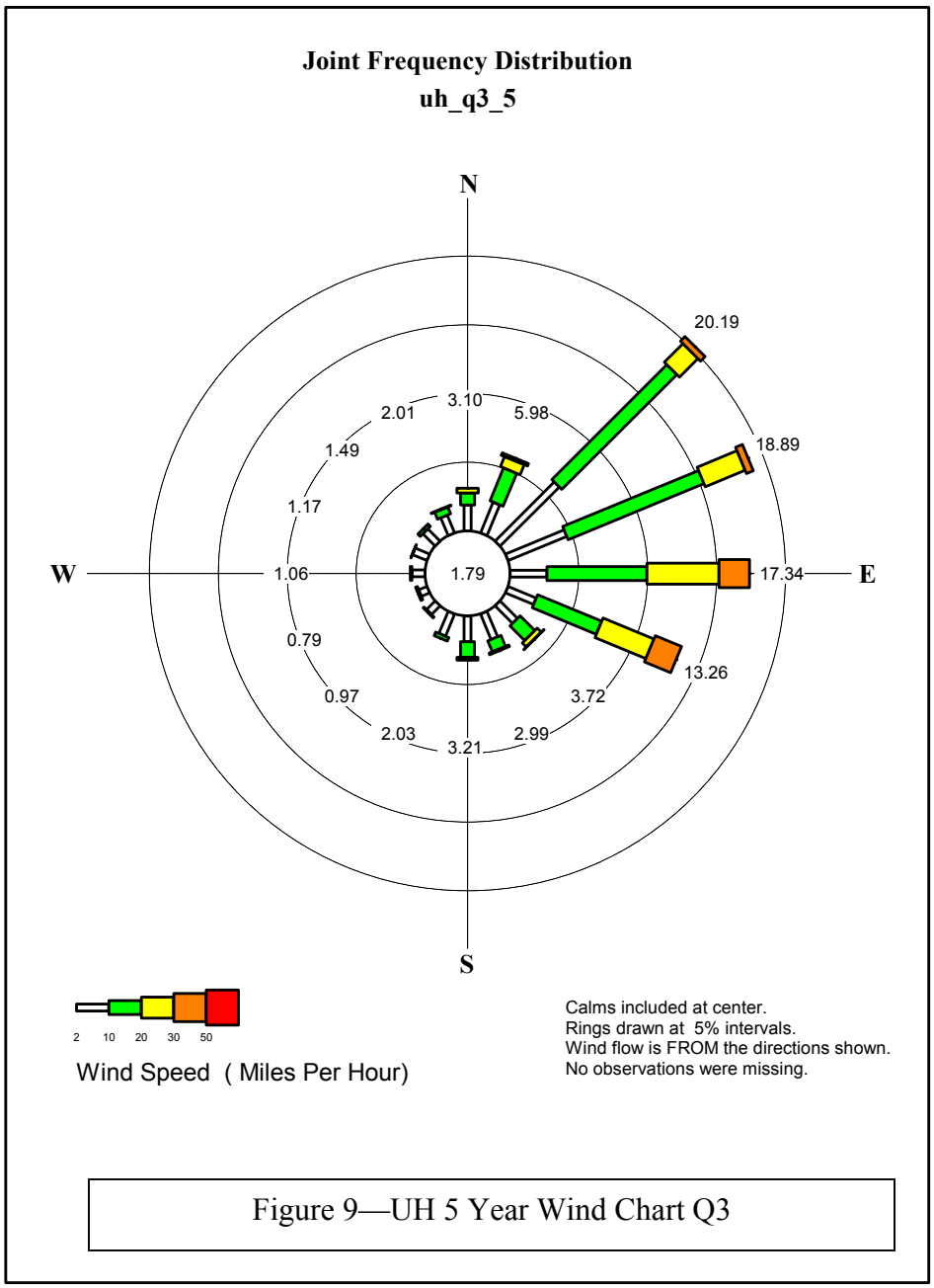


Figure 9—UH 5 Year Wind Chart Q3

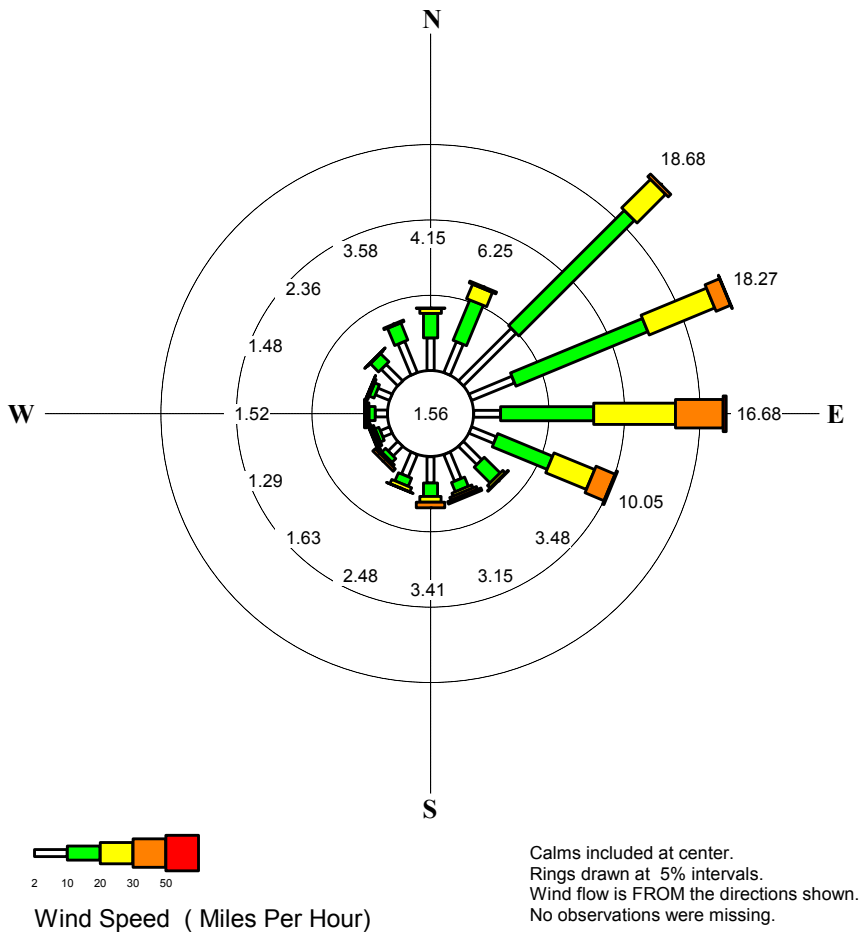


Figure 10—UH 5 Year Wind Chart Q4

Wind Speed Comparison: CAPS vs. UH

The wind speed data for all 5 years was compared to determine the difference due to the height of the sensor above the ground (AGL); CAPS is at 8 feet AGL and UH is at 33 feet AGL. The data is shown in Table 4.

	Wind	speed	(mph)		
	2-10	10-20	20-30	30-50	>50
CAPS	45	42	9	1	.0014
UH	32	43	18	5	0.18

Table 4
Wind Speed Distribution (%)

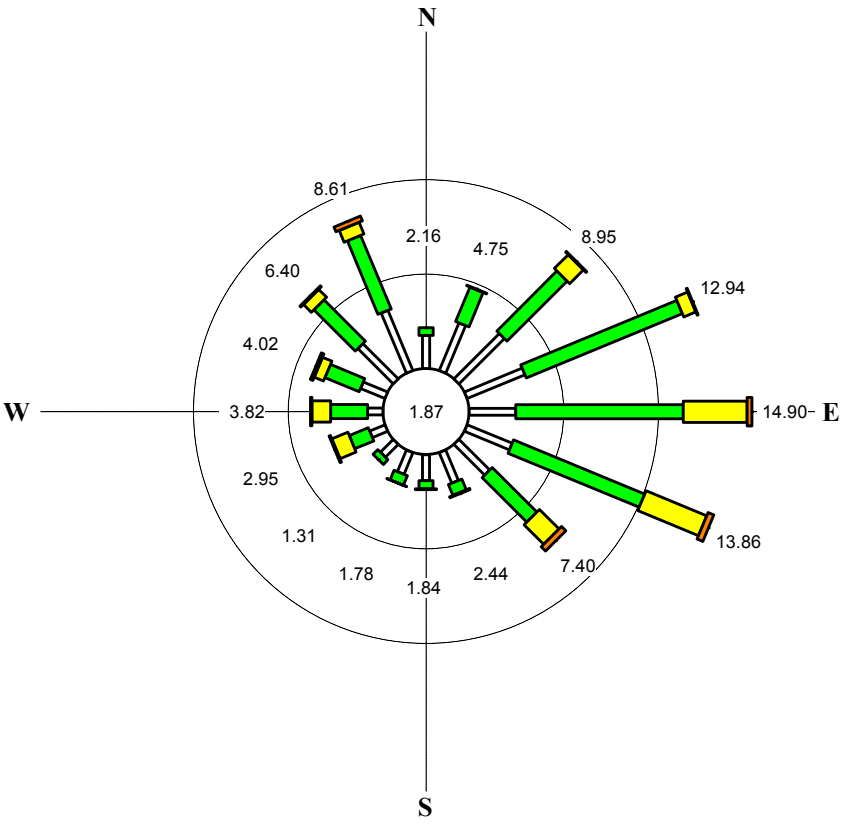
With regard to wind speed, CAPS data shows that nearly 99% of all measurements were below 30 mph. The UH Mees tower data shows that about 95% of all measurements are below 30 mph. For winds over 50 mph, CAPS experienced 0.0014% and UH experienced 0.18%.

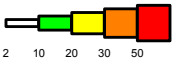
Appendices

Appendix A

CAPS Multi-year Charts
5 Year Composite

Joint Frequency Distribution
R0jan_5

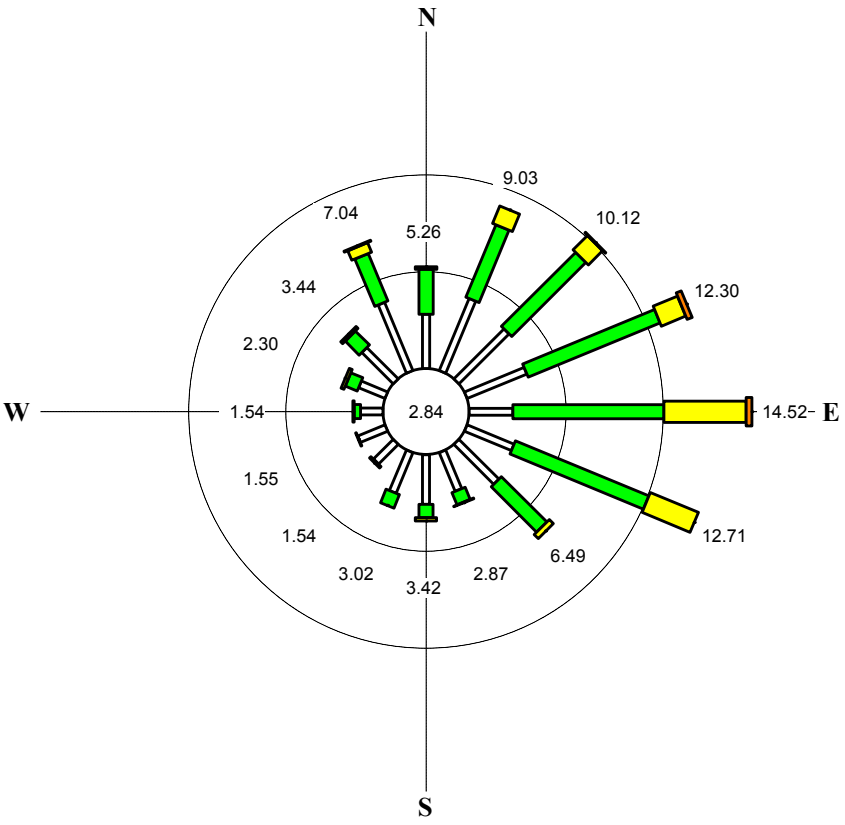




Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

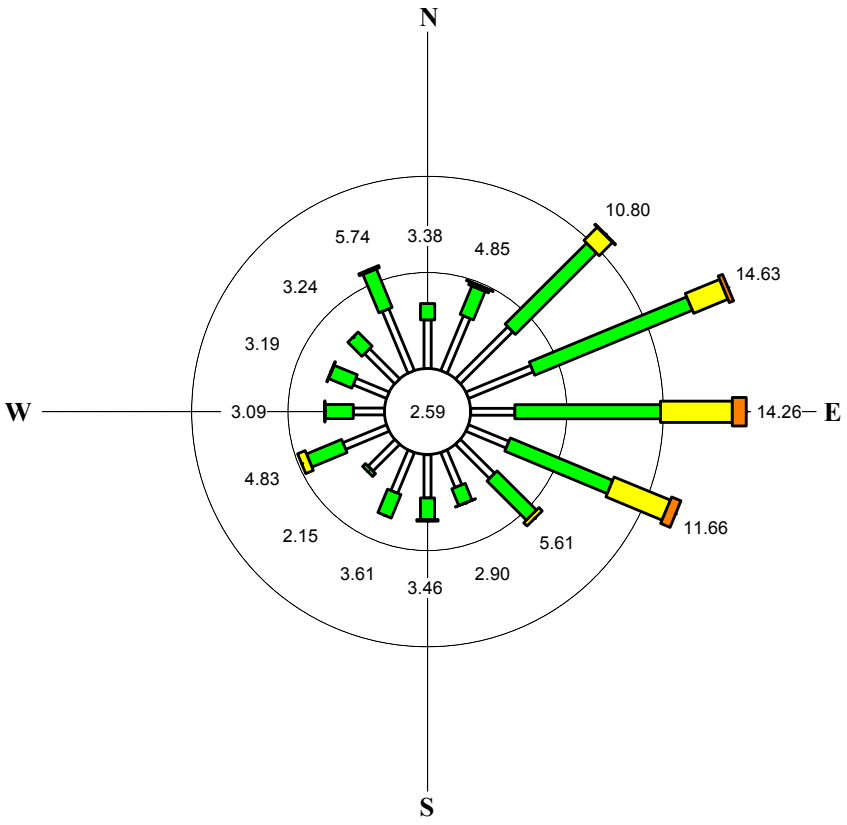
Joint Frequency Distribution
R0feb_5



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

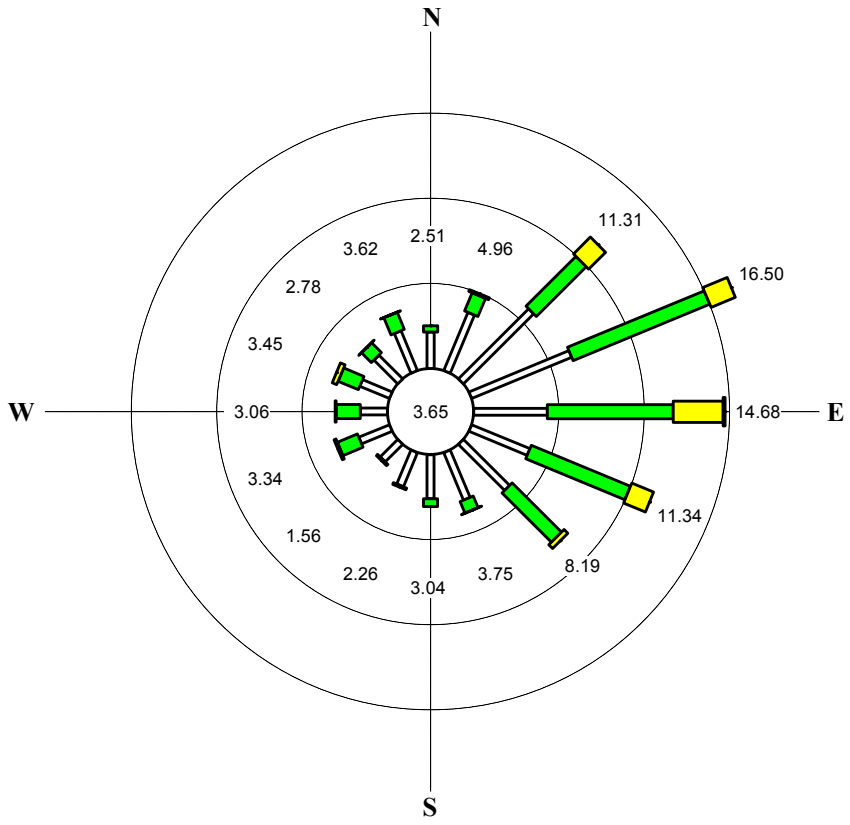
Joint Frequency Distribution
R0mar_5



Wind Speed (Miles Per Hour)

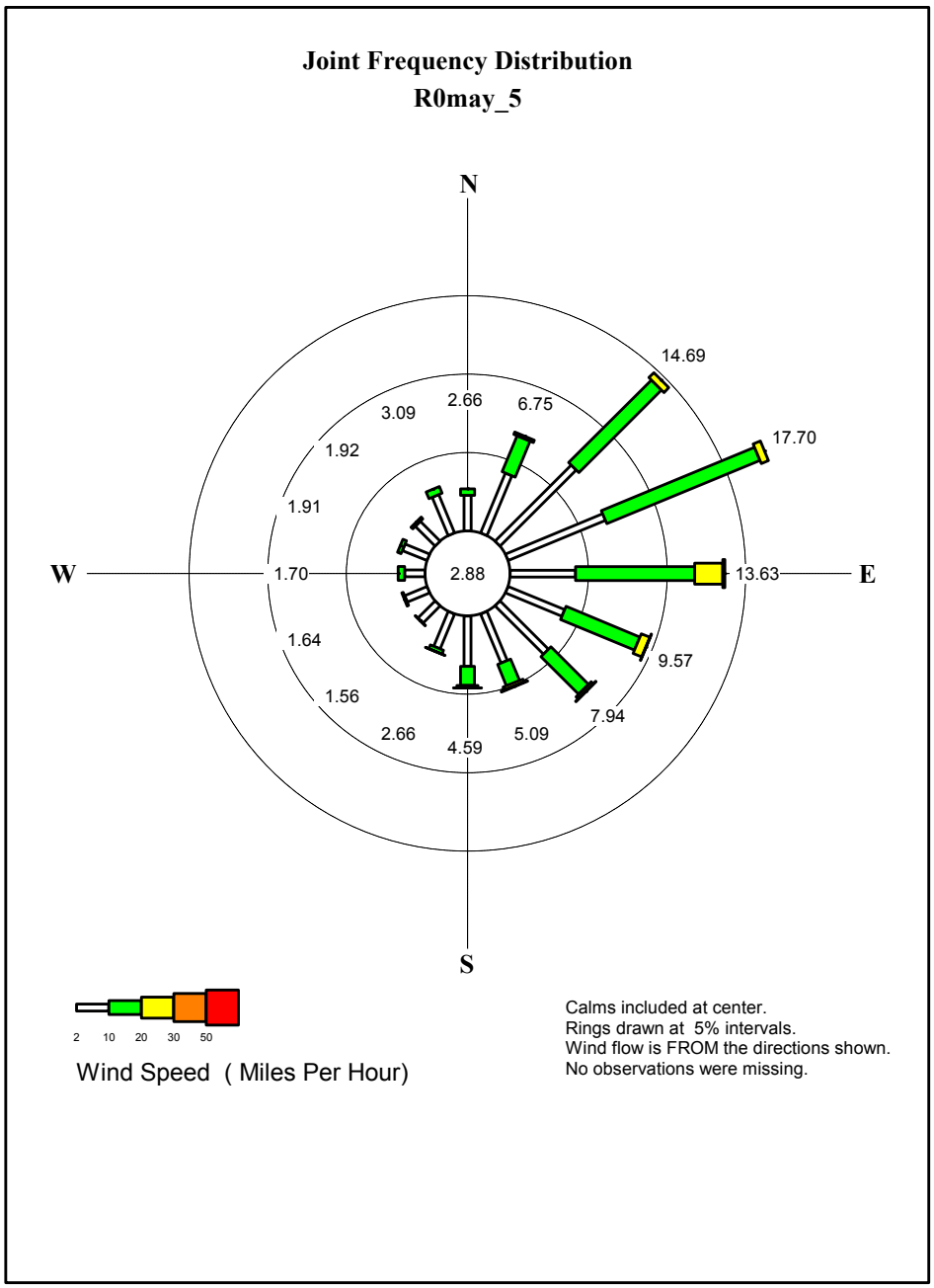
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0apr_5

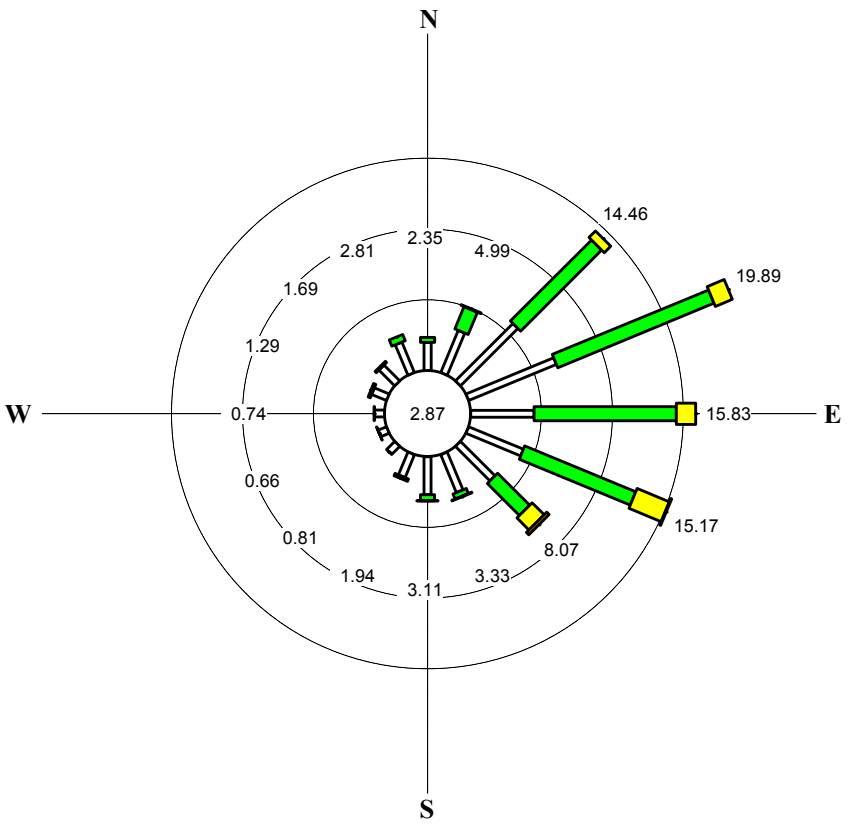


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0may_5
N
W
E
S
14.69
17.70
13.63
9.57
7.94
5.09
4.59
2.66
1.56
1.64
1.70
1.91
1.92
3.09
2.66
6.75
2.88
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

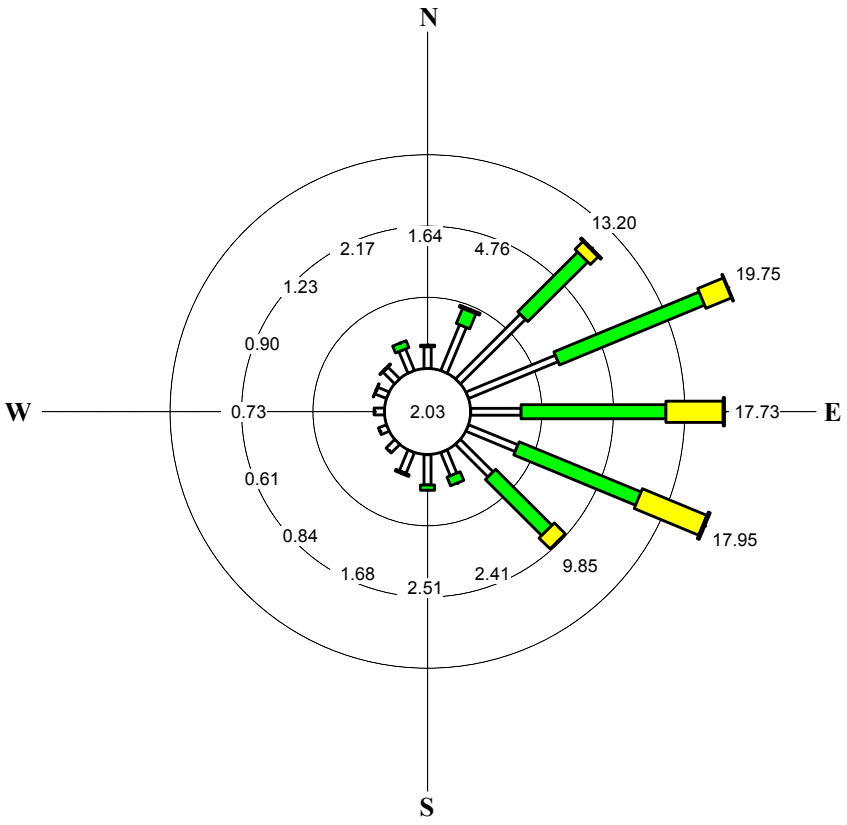
Joint Frequency Distribution
R0jun_5



Wind Speed (Miles Per Hour)

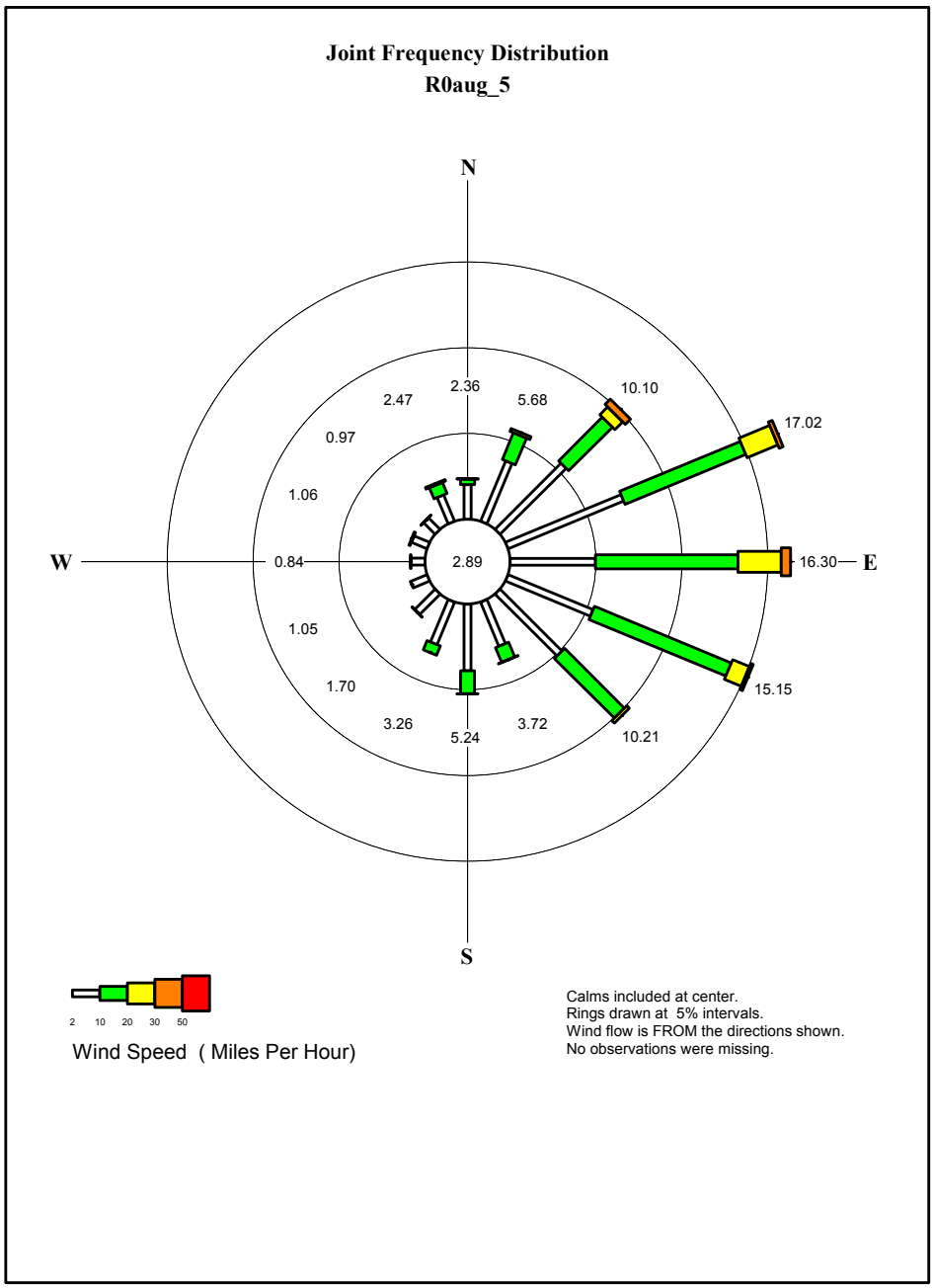
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0jul_5

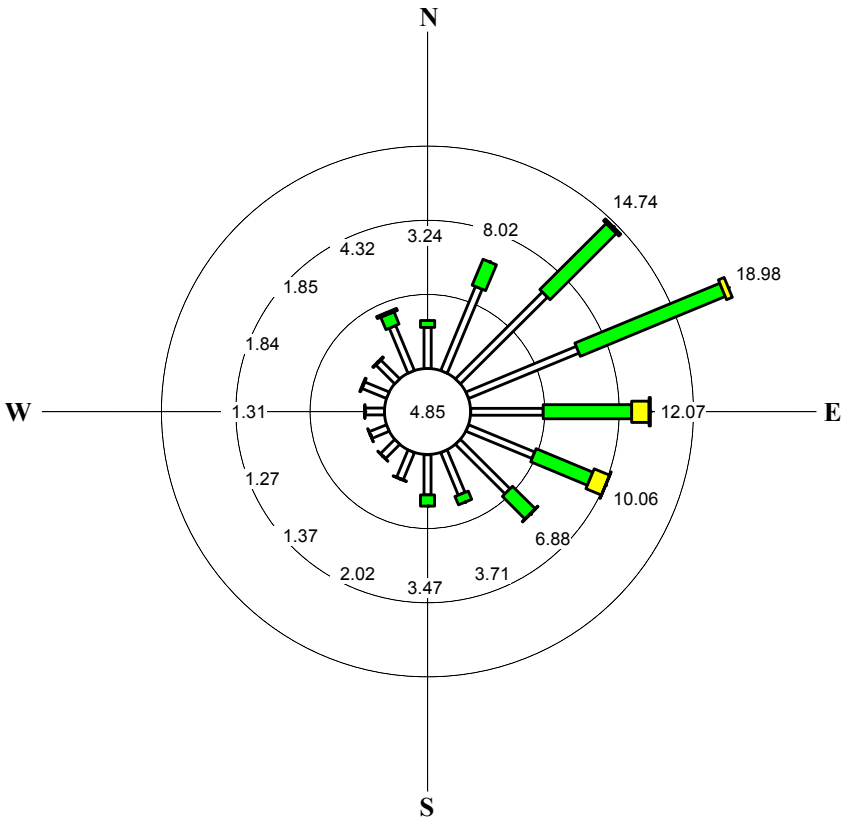


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

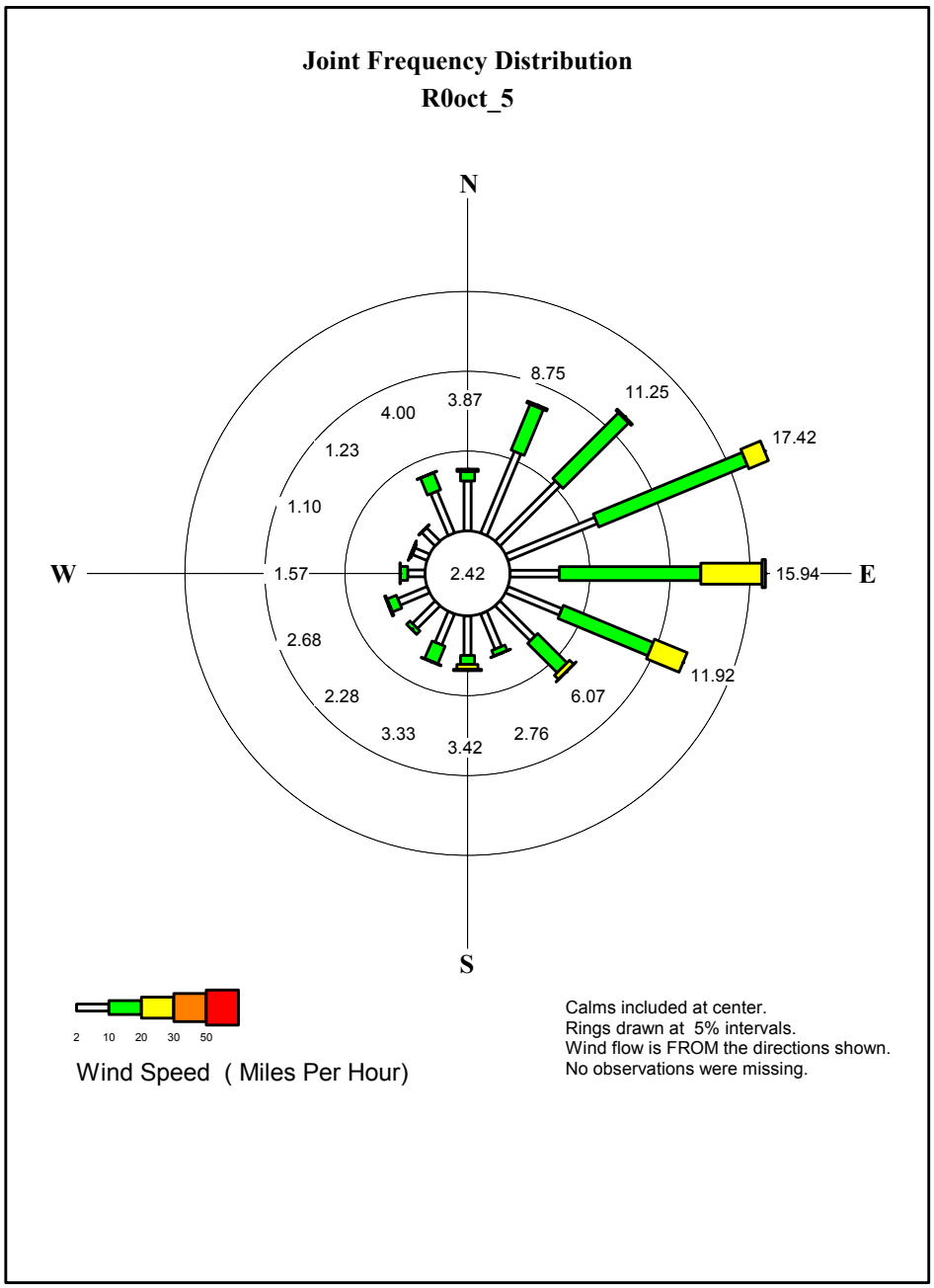

Joint Frequency Distribution
R0aug_5
N
S
W
E
2.36
5.68
10.10
17.02
2.47
0.97
1.06
0.84
2.89
16.30
1.05
1.70
15.15
3.26
3.72
10.21
5.24
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0sep_5

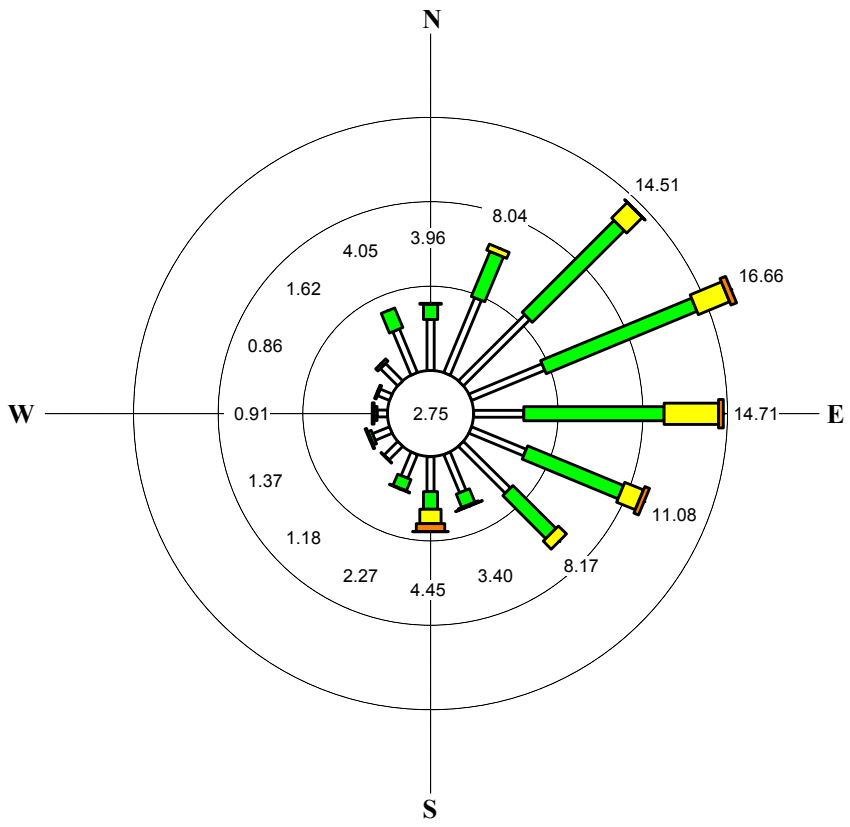


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0oct_5
N
S
W
E
8.75
11.25
17.42
15.94
11.92
6.07
2.76
3.42
3.33
2.28
2.68
1.57
1.10
1.23
4.00
3.87
2.42
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

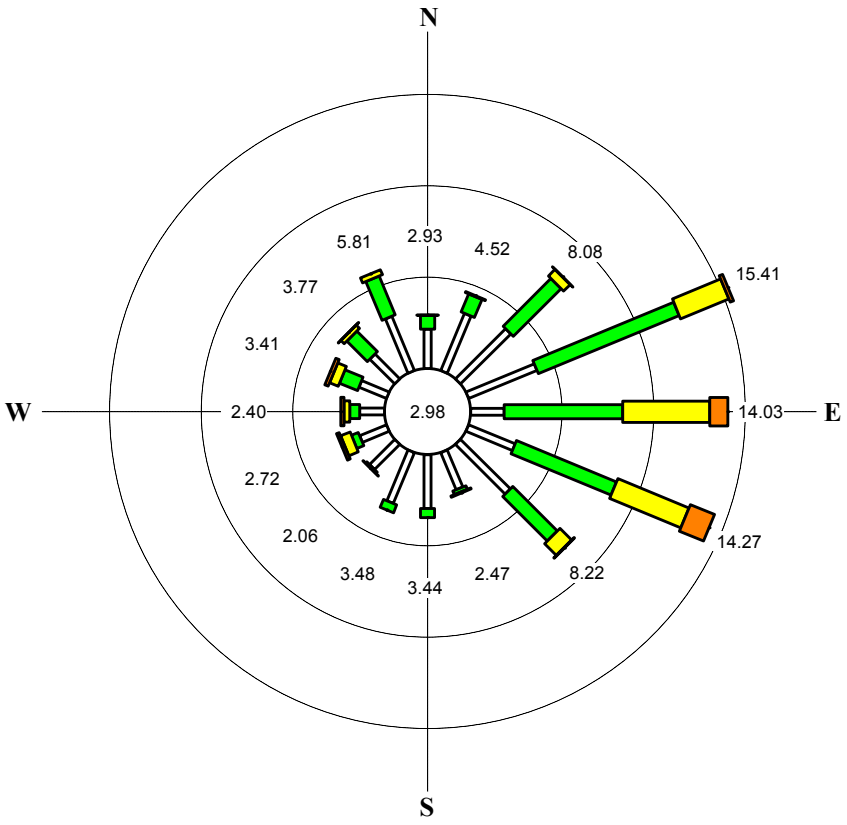
Joint Frequency Distribution
R0nov_5



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0dec_5



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Appendix B

Yearly Wind Rose Charts
1998 to 2003

CAPS Data

Wind rose charts are presented here for each month of the years from July 1998 through June 2003[7]. Note that all charts for the CAPS system are titled by:

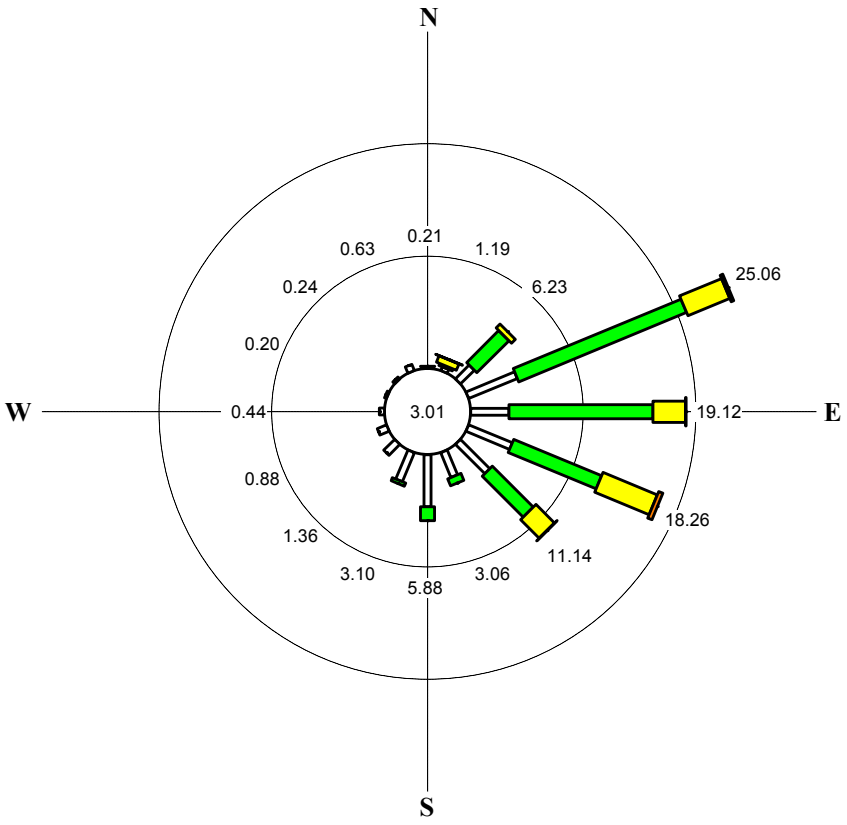
R0"month"_"year"

The "Joint Frequency Distribution" charts show considerable information. The petal lengths show the percentage of events that occurred at each of the 16 points of the compass (percentage numbers are at the petal ends). The wind speed distribution is shown by the different color bars of the rose petals and the percentages (of each speed range) are indicated by the color-bar length. Wind speeds below 2 mph are considered "calms" and the percentage of calms is indicated in the central circle of the rose.

The wind speed thresholds were chosen to reflect operational constraints; 0 to 30 mph generally does not impact operations, 30 to 50 mph is a major operational concern, and over 50 mph is a site hazard regime.

[7] Note: Mid 1998 is when the CAPS system first became operational.

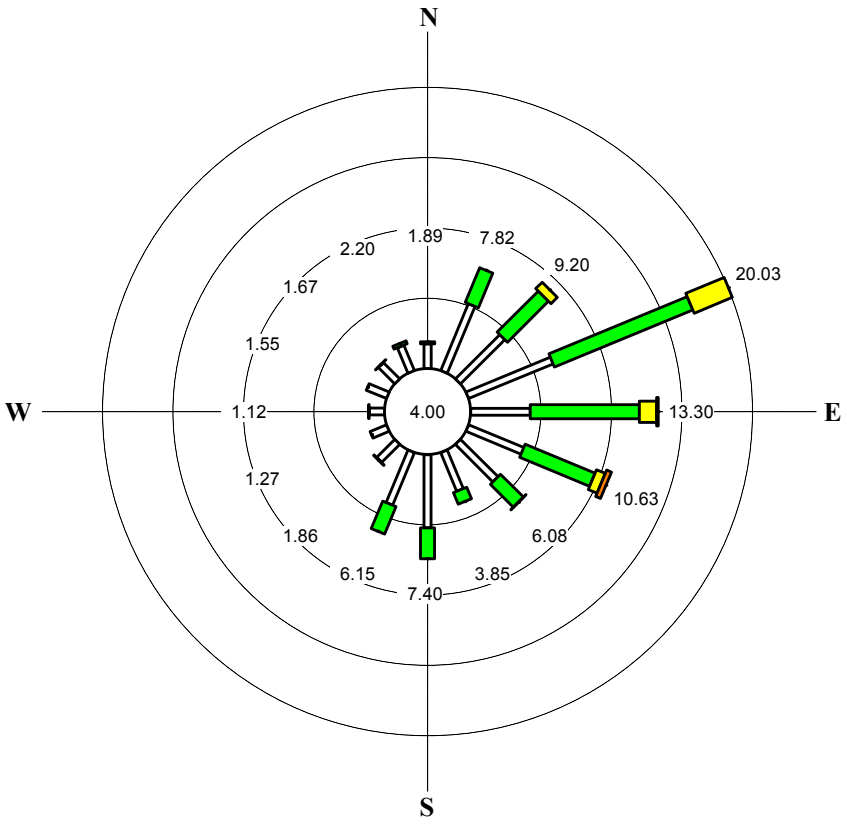
Joint Frequency Distribution
R0jul_98



Wind Speed (Miles Per Hour)

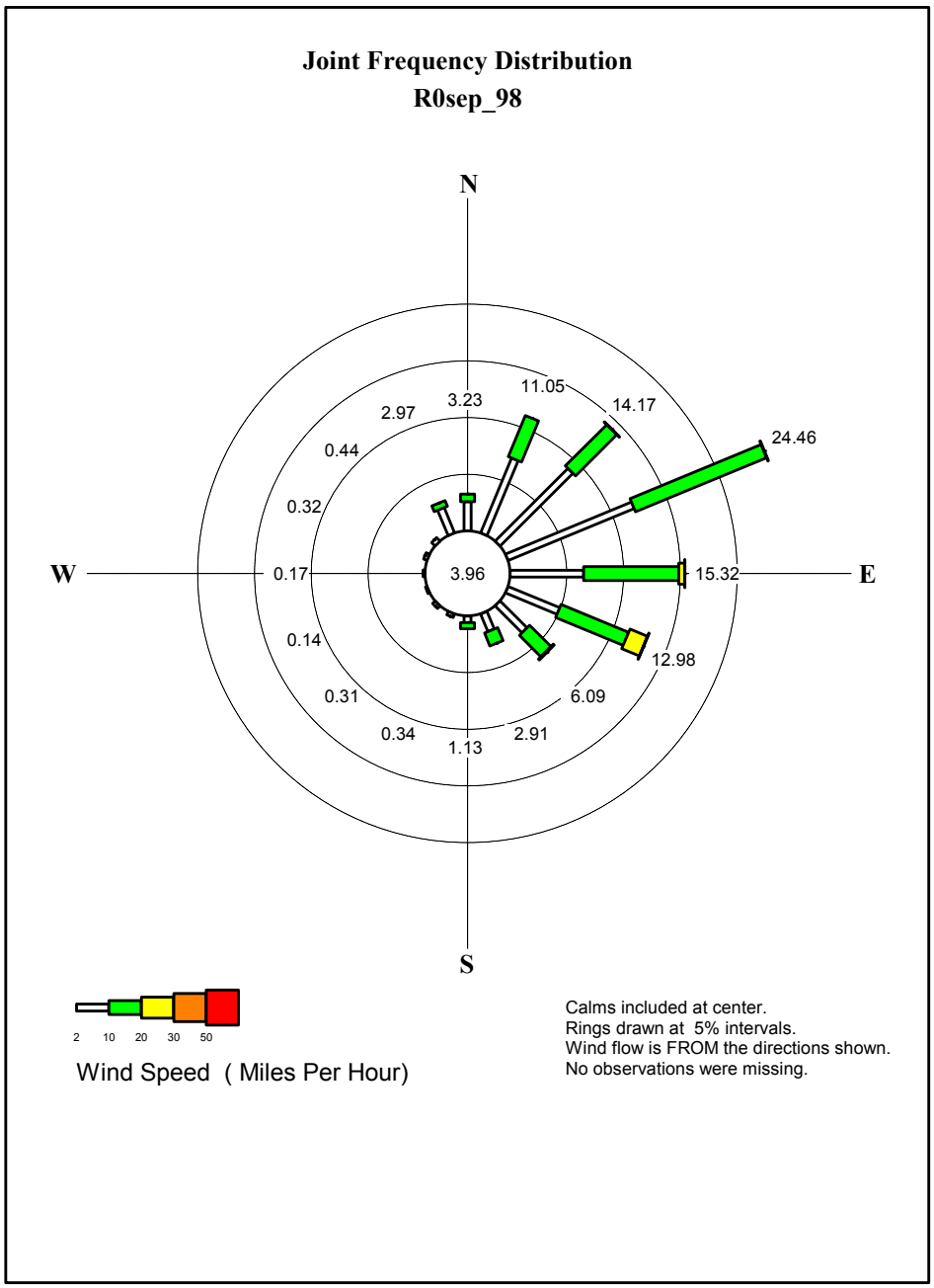
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0aug_98

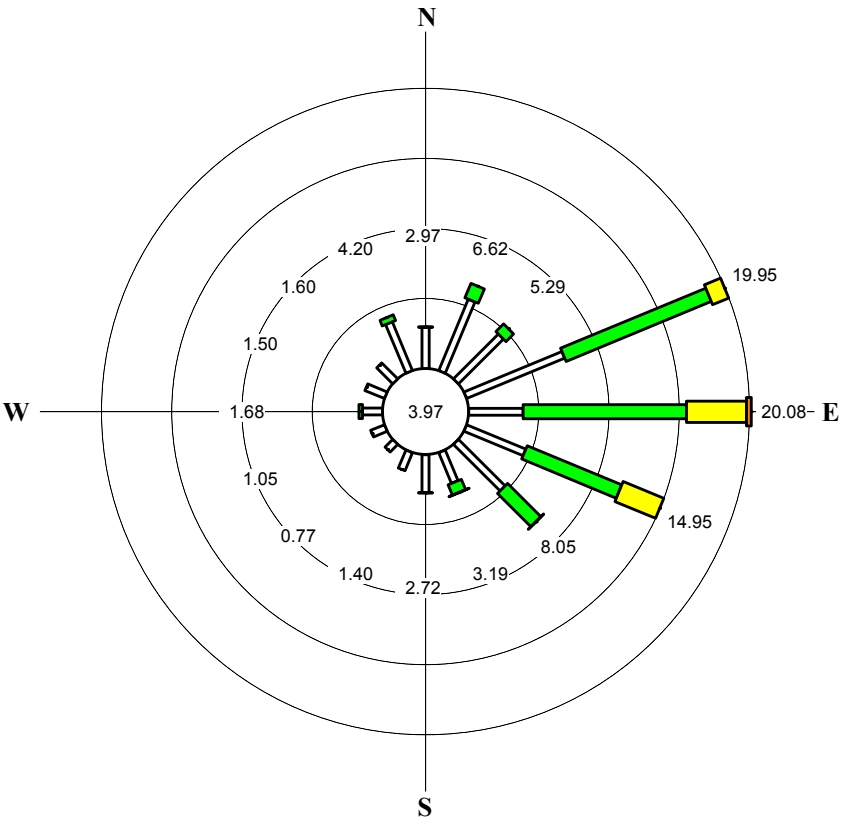


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0sep_98
N
W
E
S
3.23
11.05
14.17
24.46
2.97
0.44
0.32
0.17
3.96
15.32
0.14
12.98
0.31
6.09
0.34
2.91
1.13
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

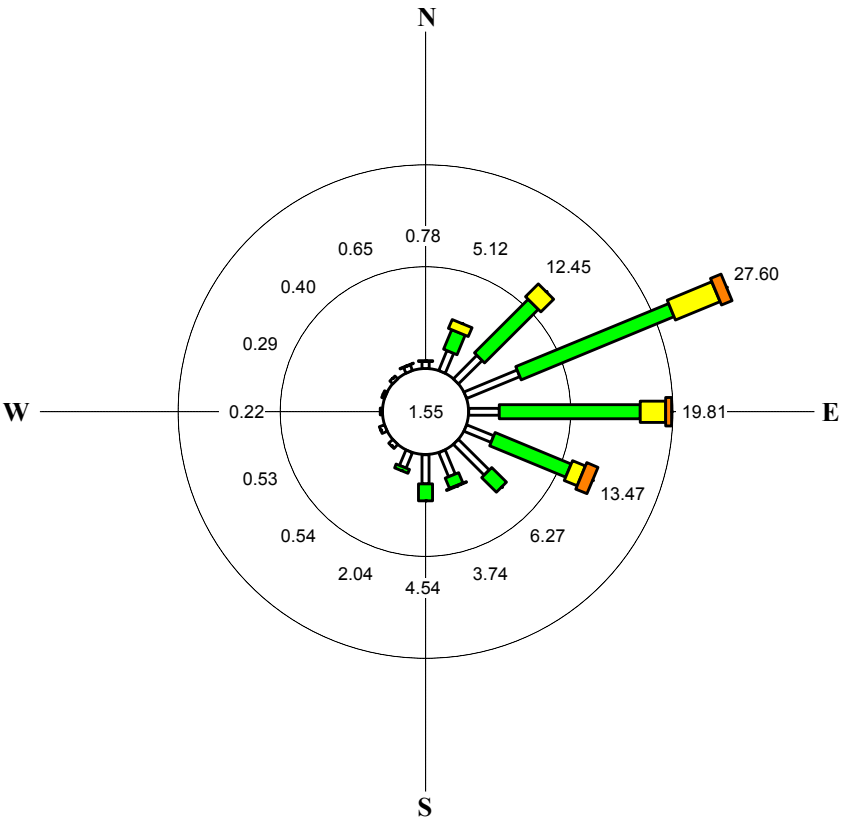
Joint Frequency Distribution
R0oct_98



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

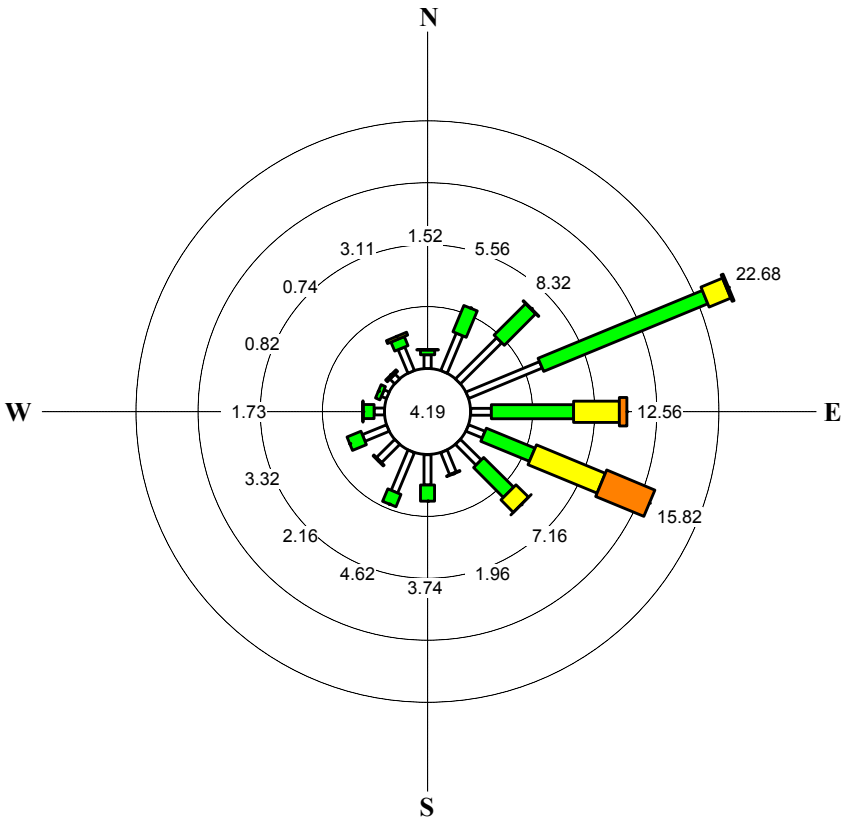
Joint Frequency Distribution
R0nov_98



Wind Speed (Miles Per Hour)

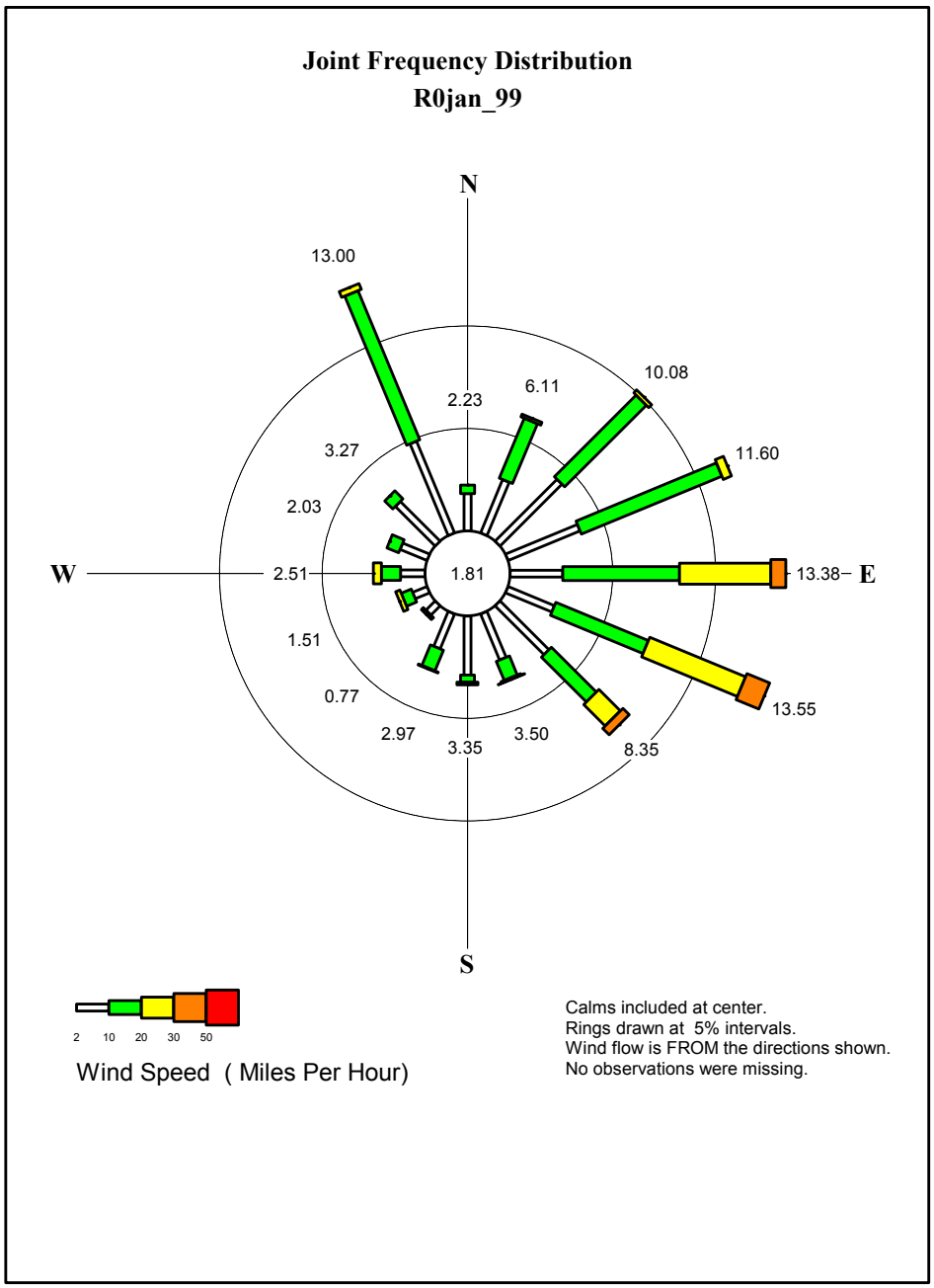
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0dec_98

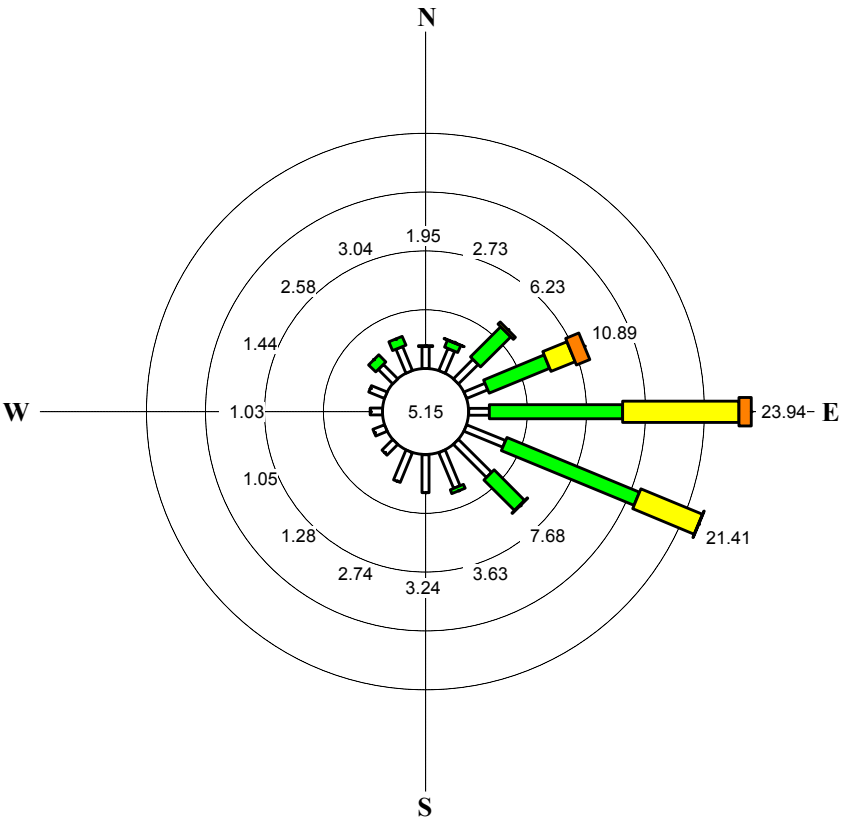


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0jan_99
N
E
S
W
13.00
6.11
10.08
2.23
3.27
11.60
2.03
2.51
1.81
13.38
1.51
0.77
13.55
2.97
3.35
3.50
8.35
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

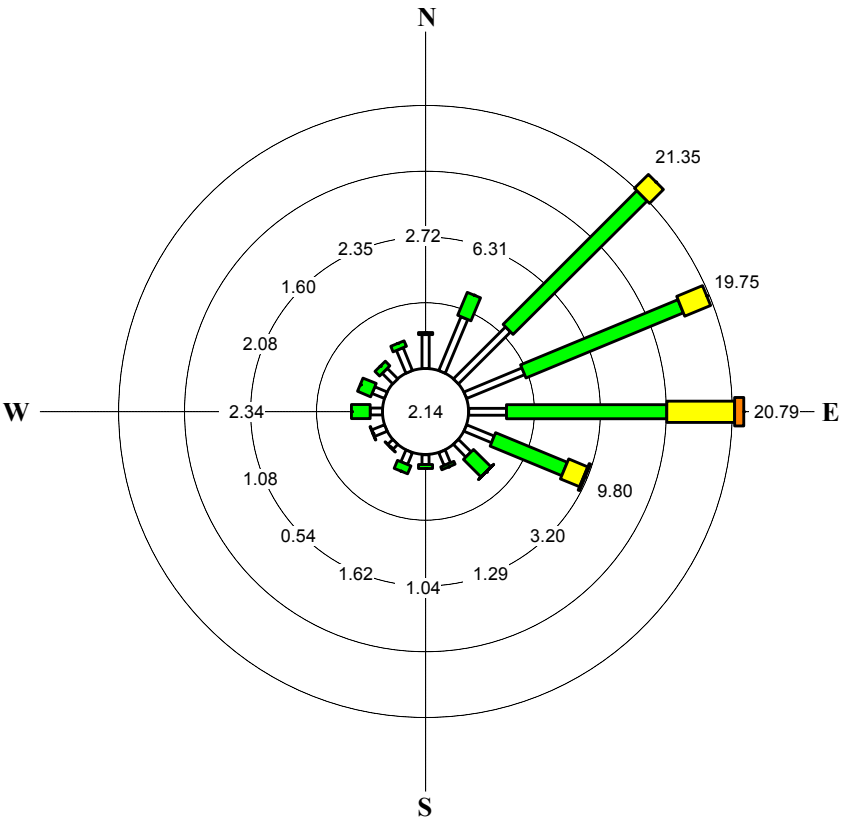
Joint Frequency Distribution
R0feb_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

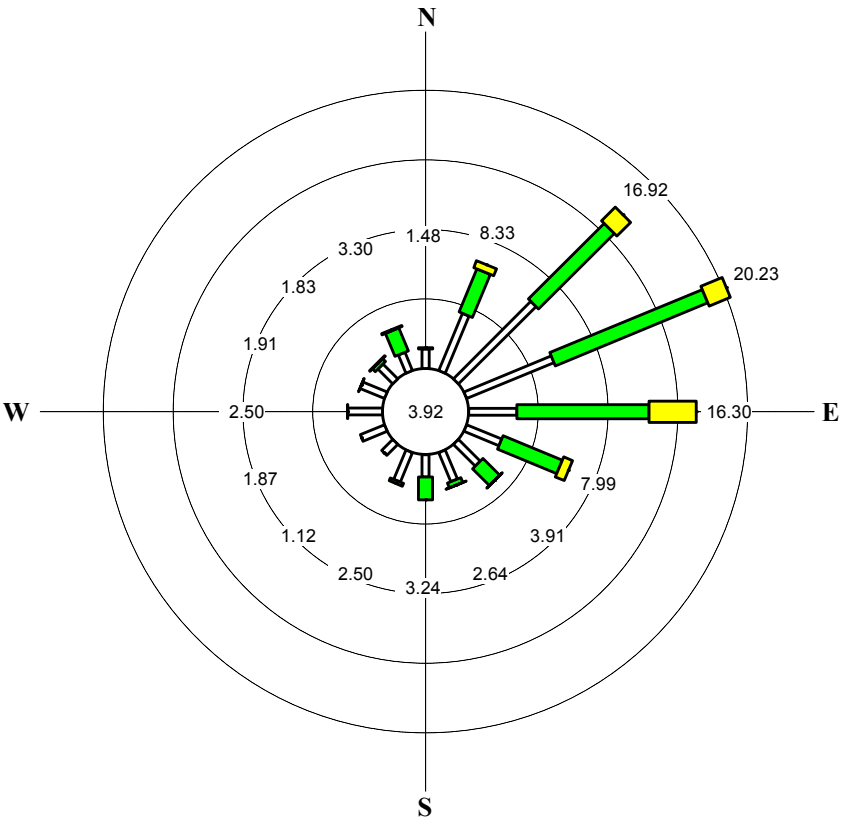
Joint Frequency Distribution
R0mar_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

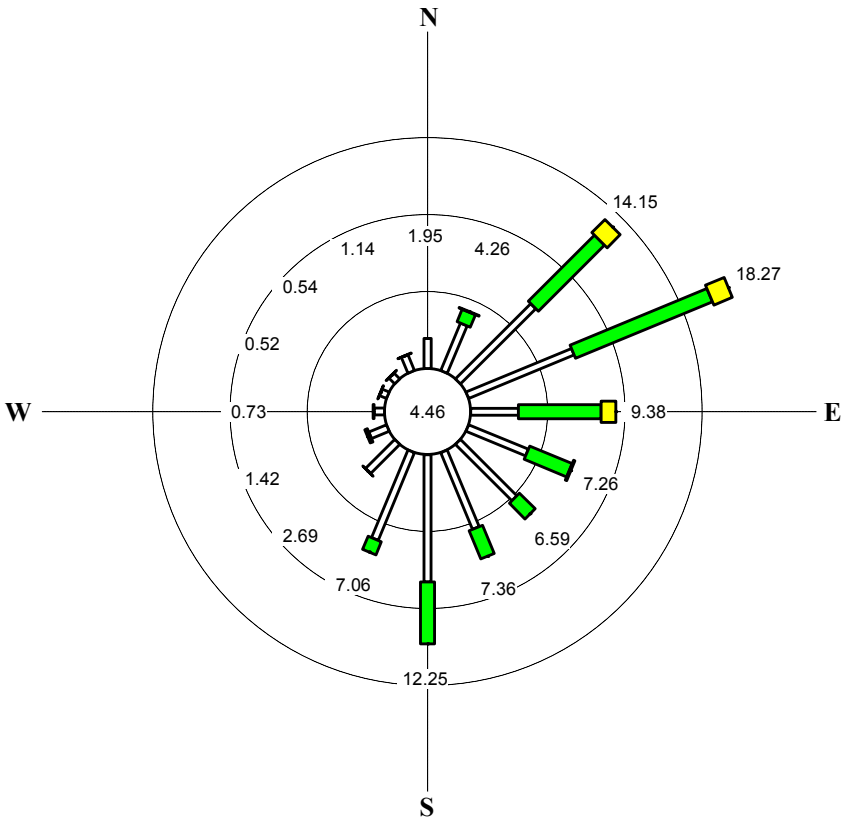
Joint Frequency Distribution
R0apr_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

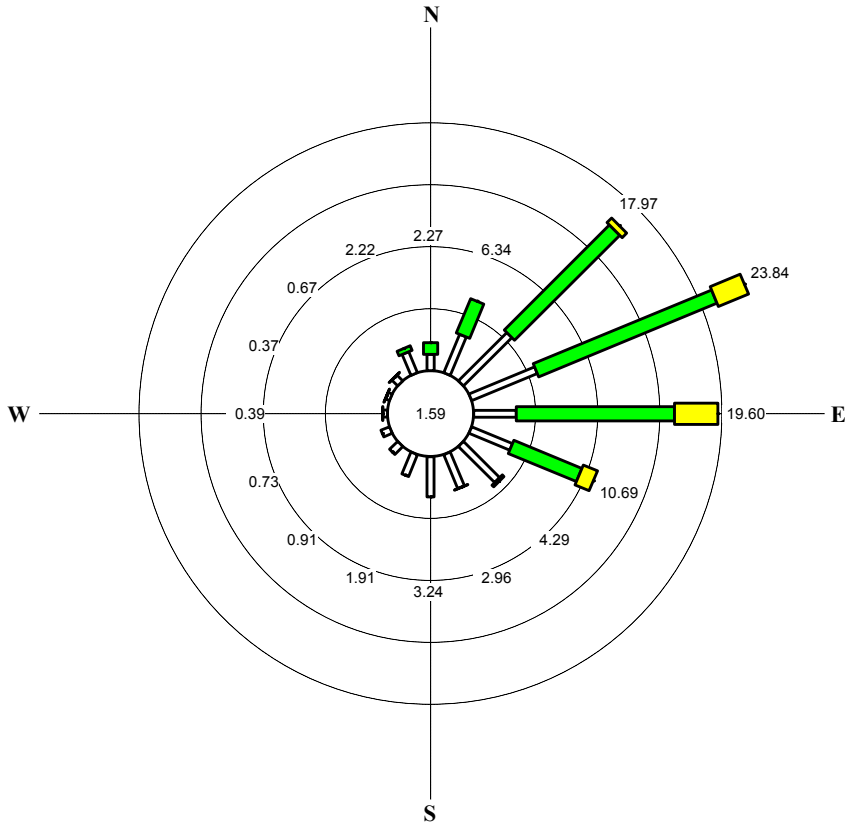
Joint Frequency Distribution
R0may_99



Wind Speed (Miles Per Hour)

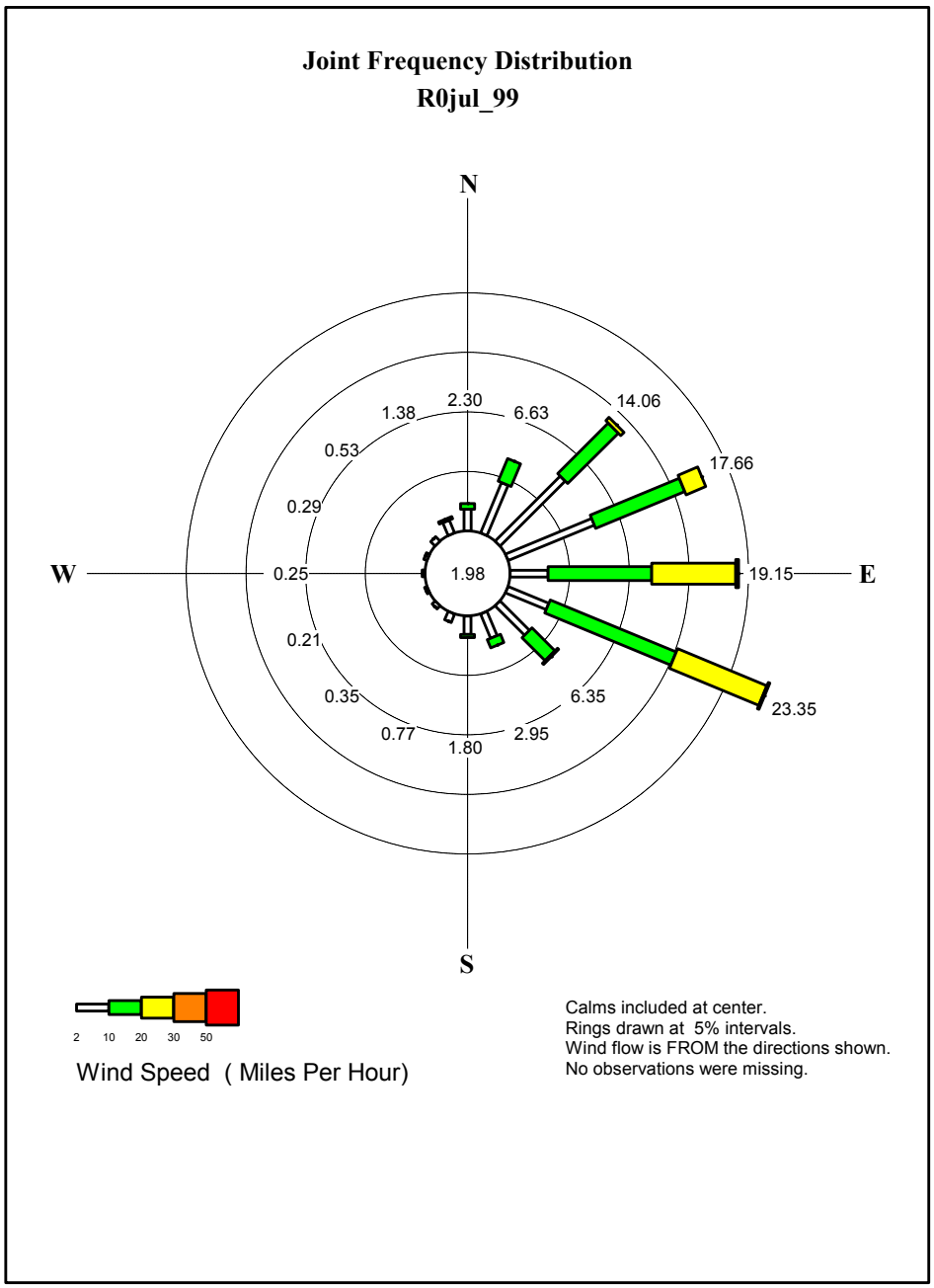
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

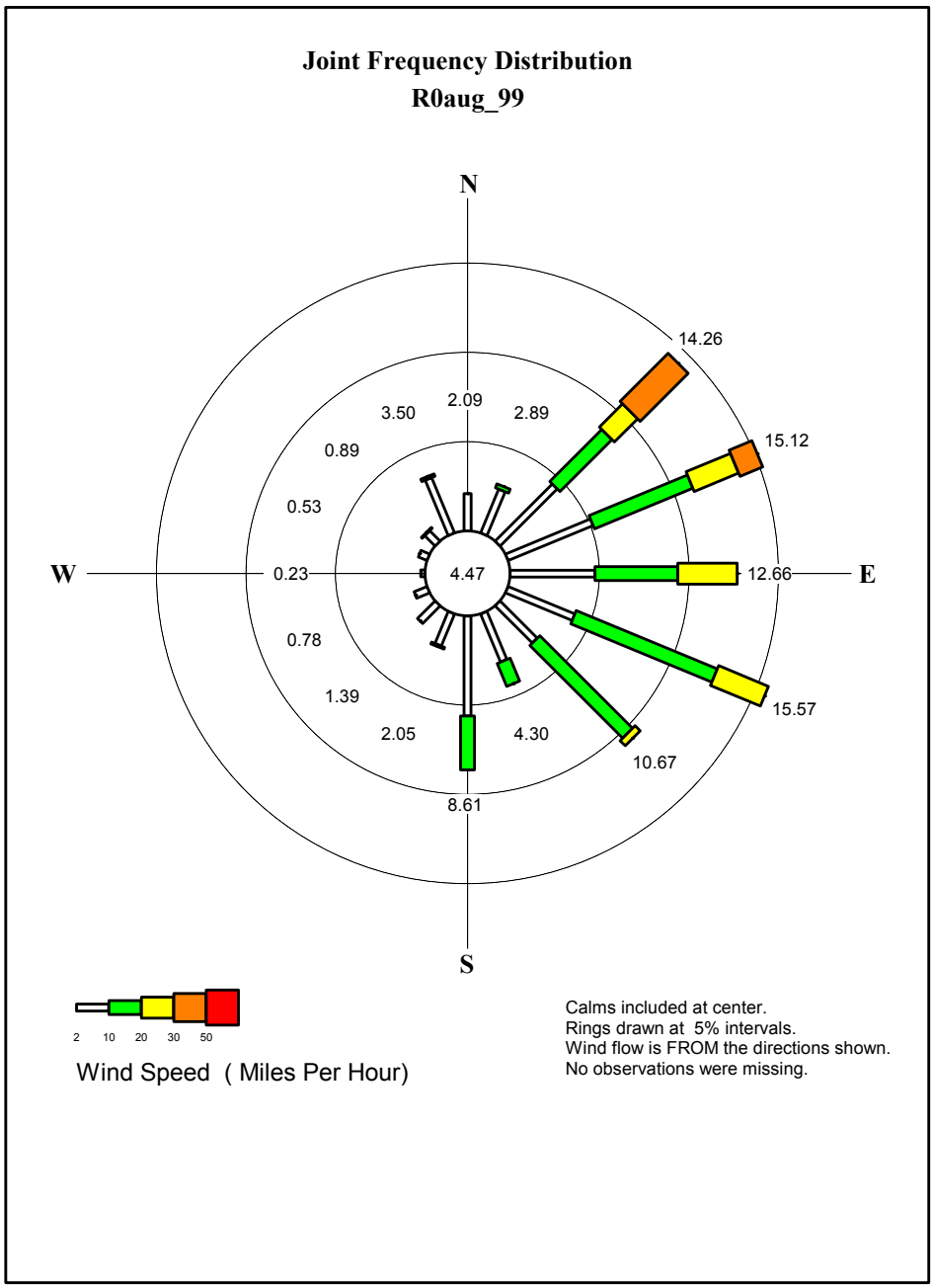
Joint Frequency Distribution
R0jun_99



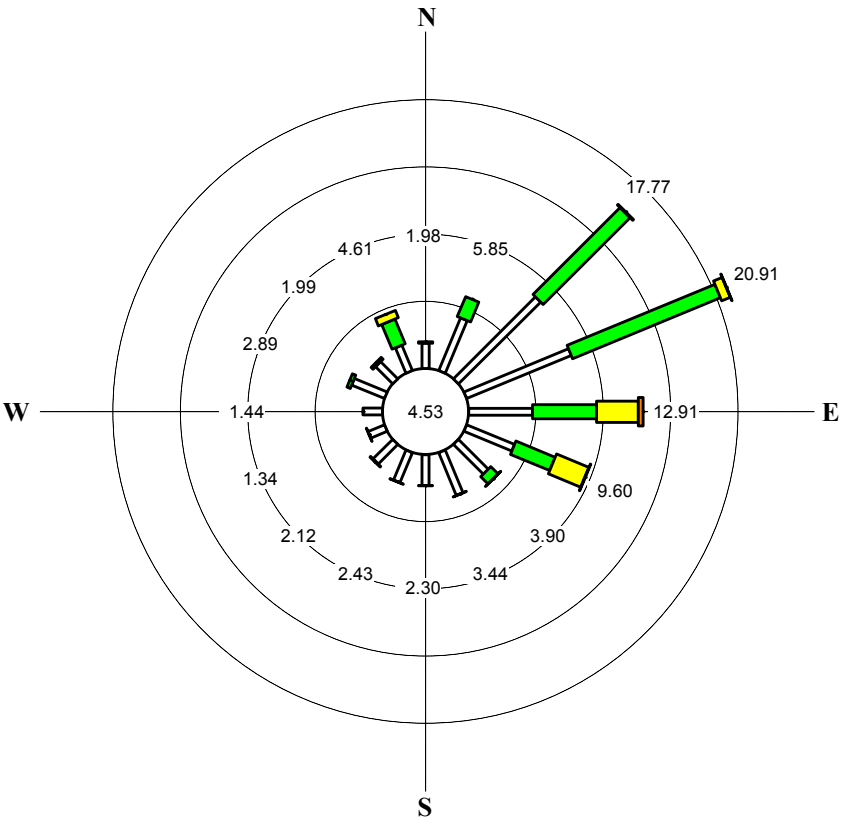
Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0jul_99
N
W
E
S
2.30
6.63
14.06
17.66
19.15
23.35
6.35
2.95
1.80
0.77
0.35
0.21
0.25
0.29
0.53
1.38
1.98
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

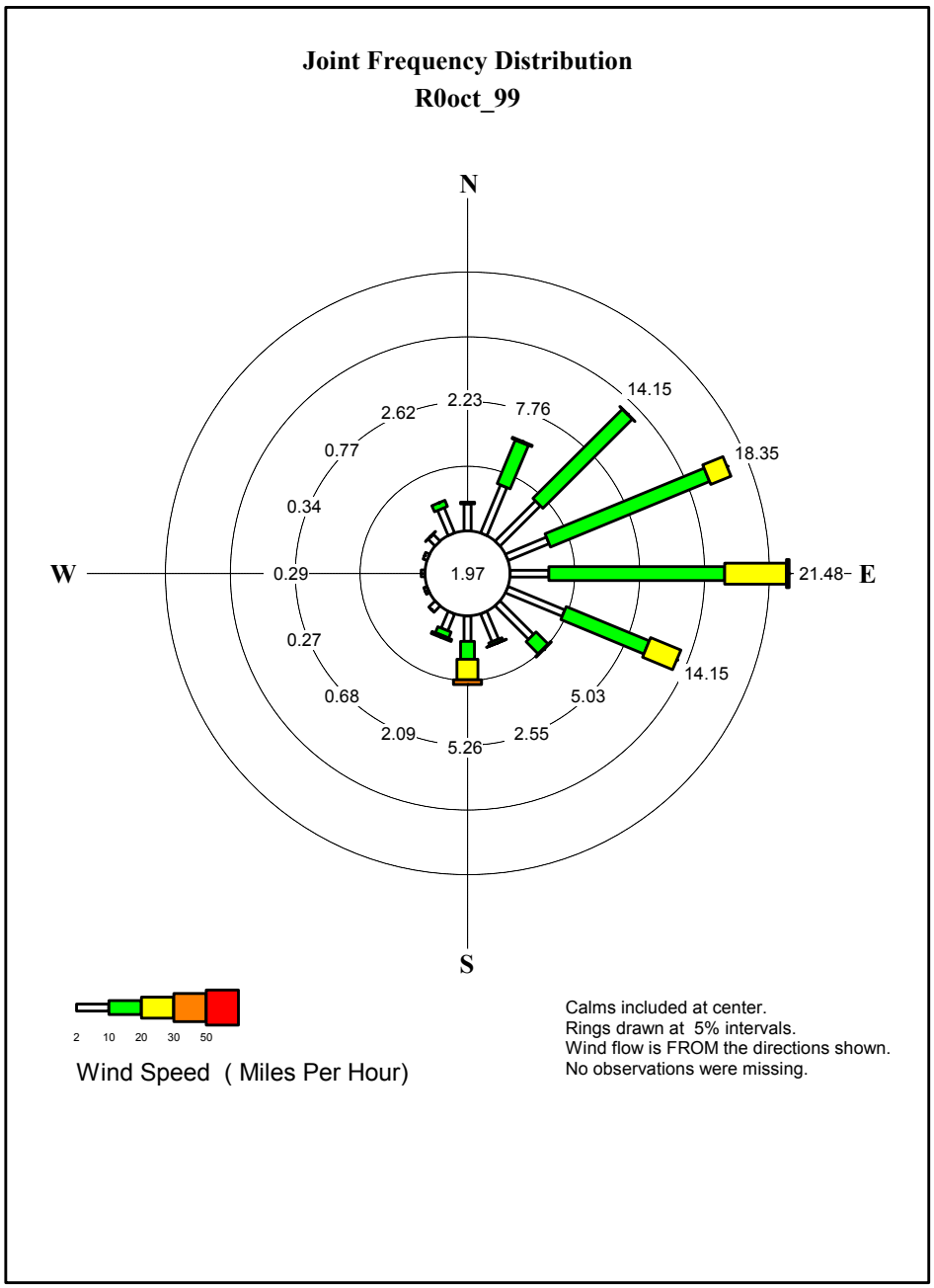

Joint Frequency Distribution
R0aug_99
N
S
W
E
14.26
15.12
12.66
15.57
10.67
8.61
4.30
2.05
1.39
0.78
0.23
0.53
0.89
3.50
2.09
2.89
4.47
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0sep_99

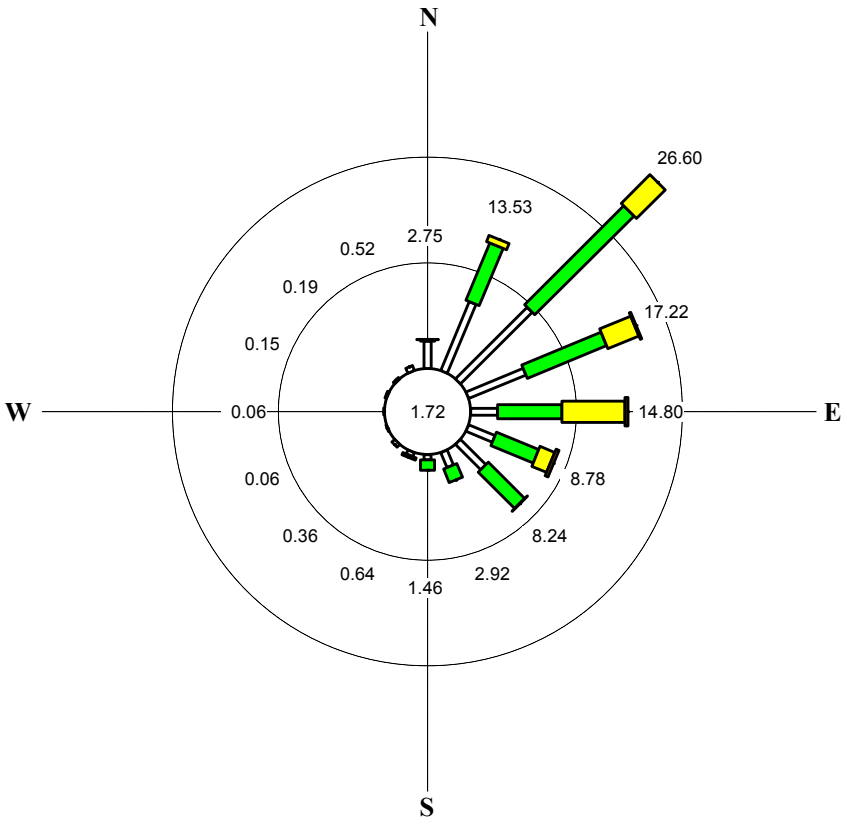


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0oct_99
N
W
E
S
2.23
7.76
14.15
18.35
21.48
14.15
5.03
2.55
5.26
2.09
0.68
0.27
0.29
0.34
0.77
2.62
1.97
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

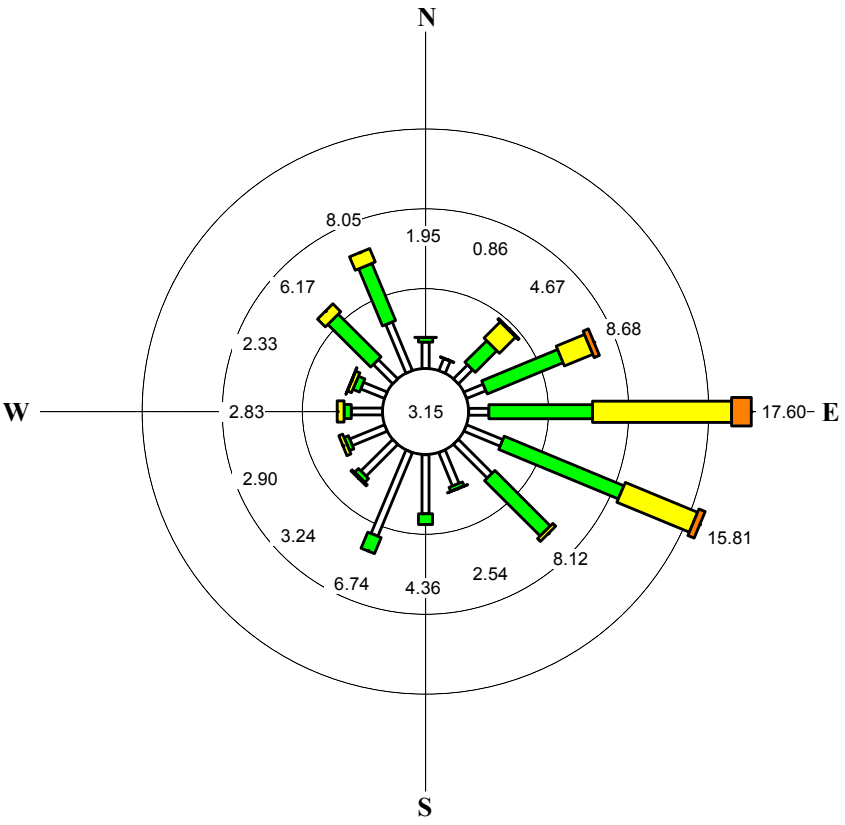
Joint Frequency Distribution
R0nov_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

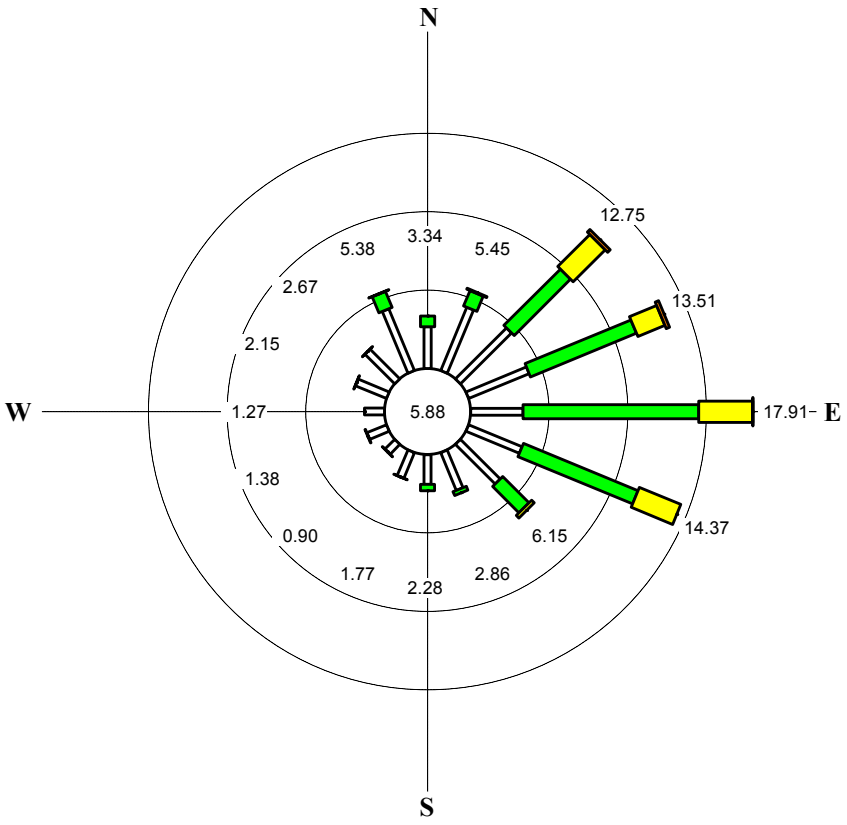
Joint Frequency Distribution
R0dec_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

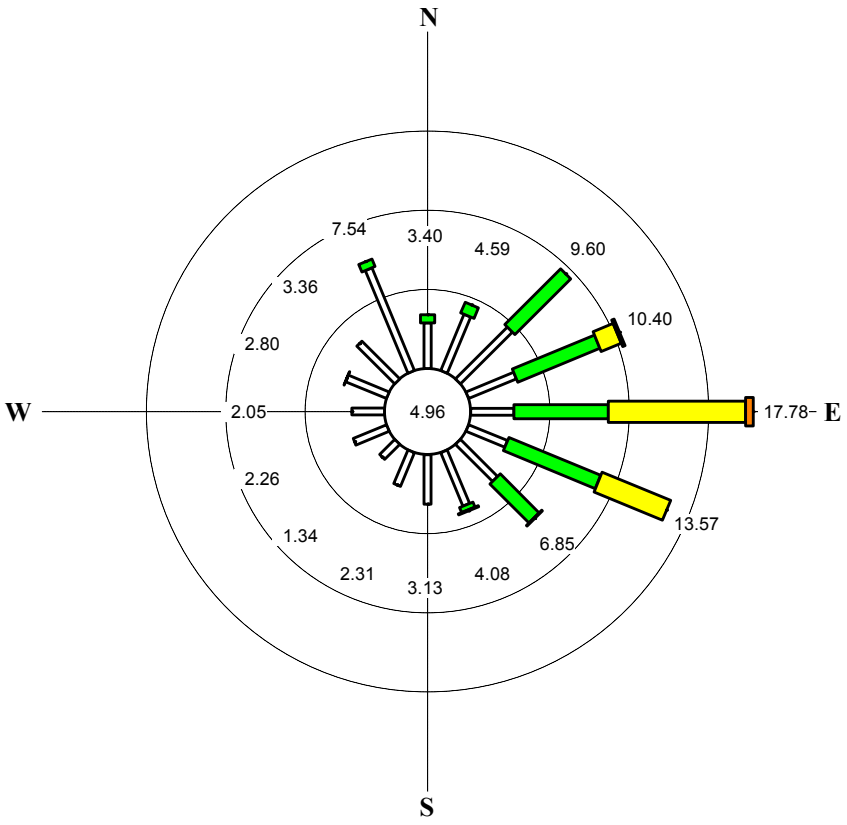
Joint Frequency Distribution
R0jan_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

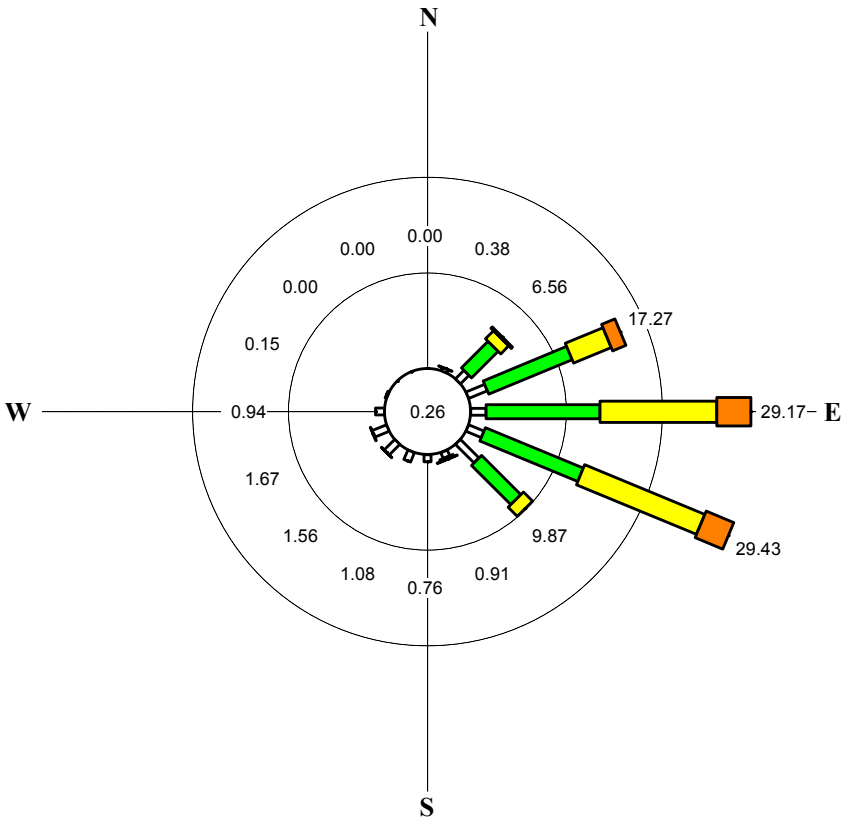
Joint Frequency Distribution
R0feb_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

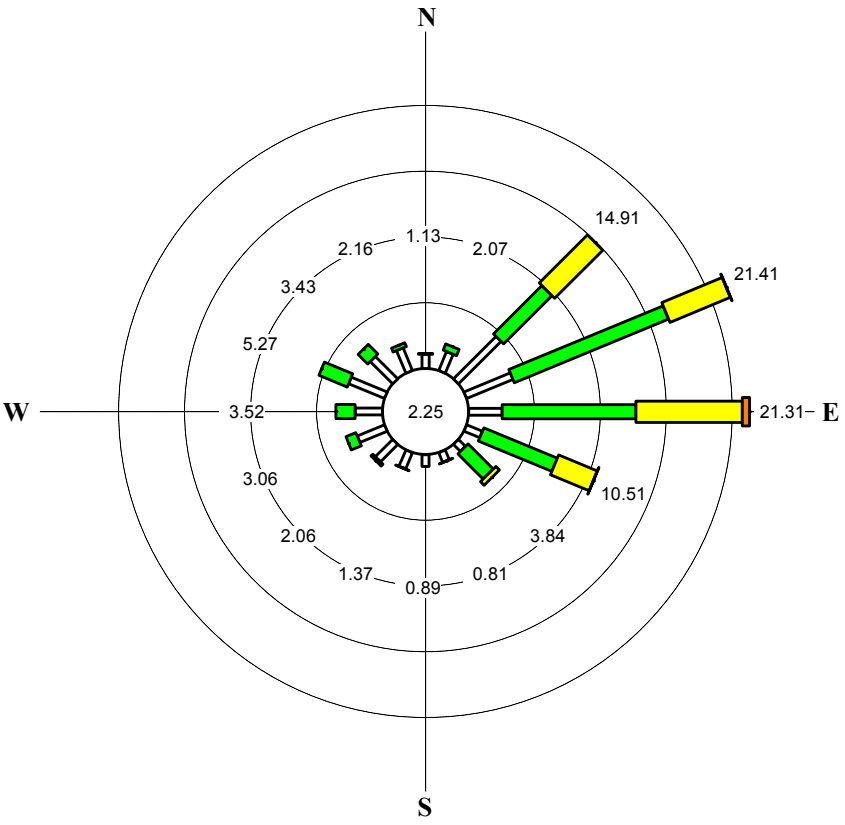
Joint Frequency Distribution
R0mar_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

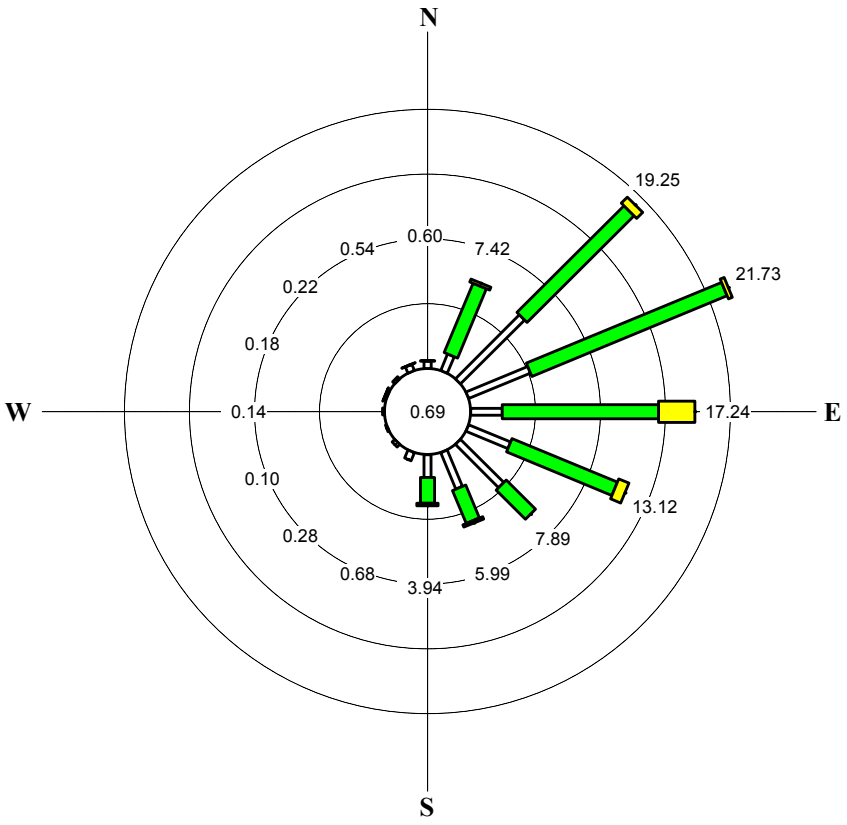
Joint Frequency Distribution
R0apr_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

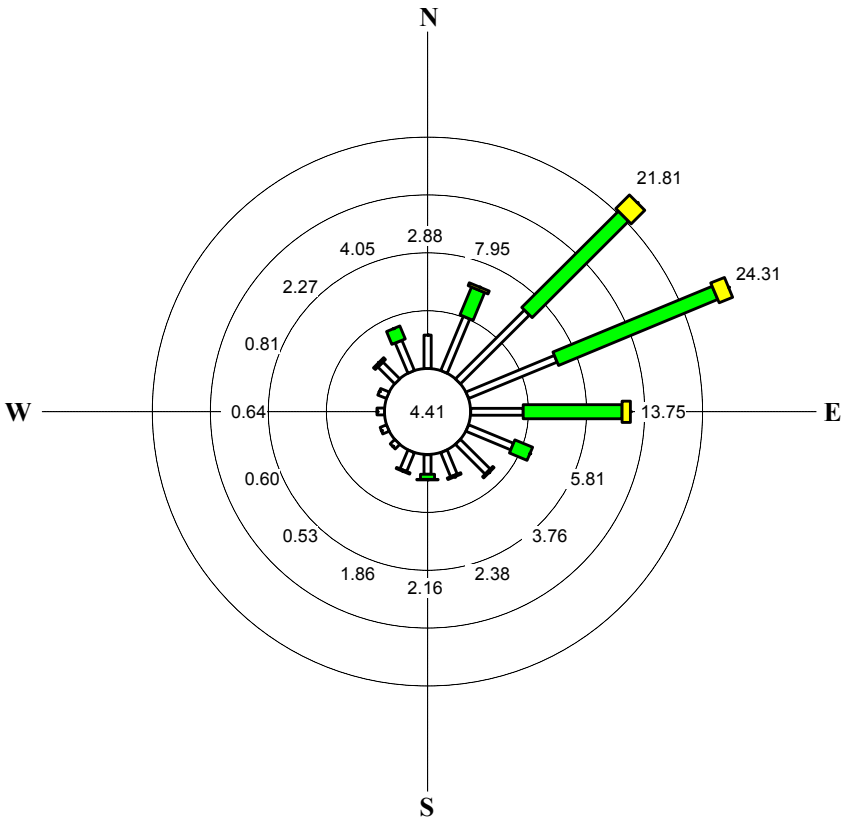
Joint Frequency Distribution
R0may_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

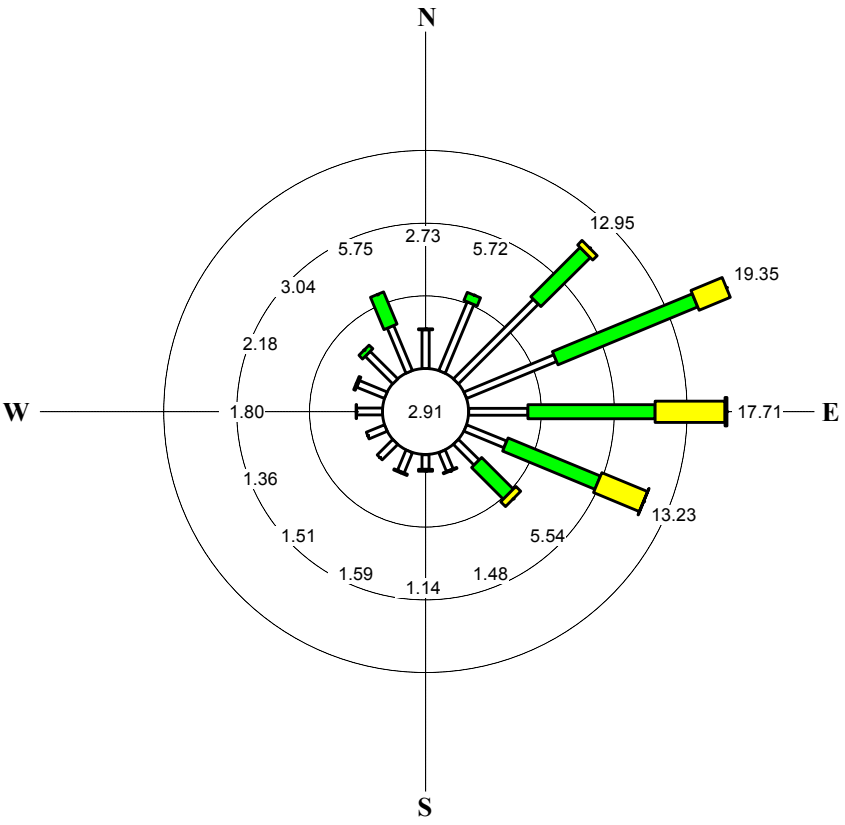
Joint Frequency Distribution
R0jun_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

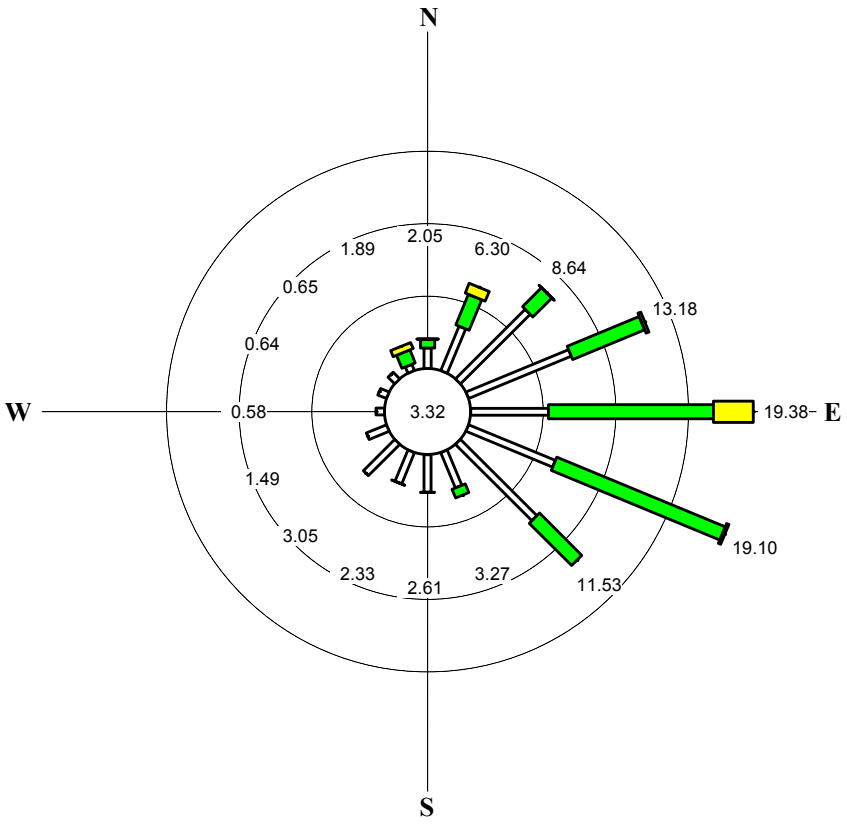
Joint Frequency Distribution
R0jul_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

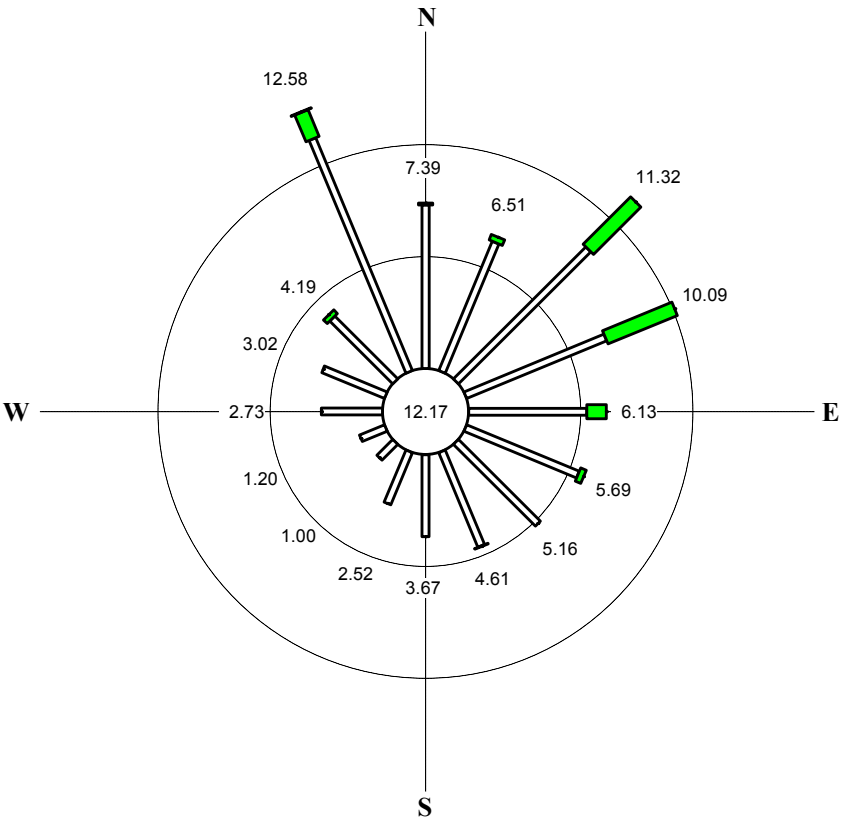
Joint Frequency Distribution
R0aug_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

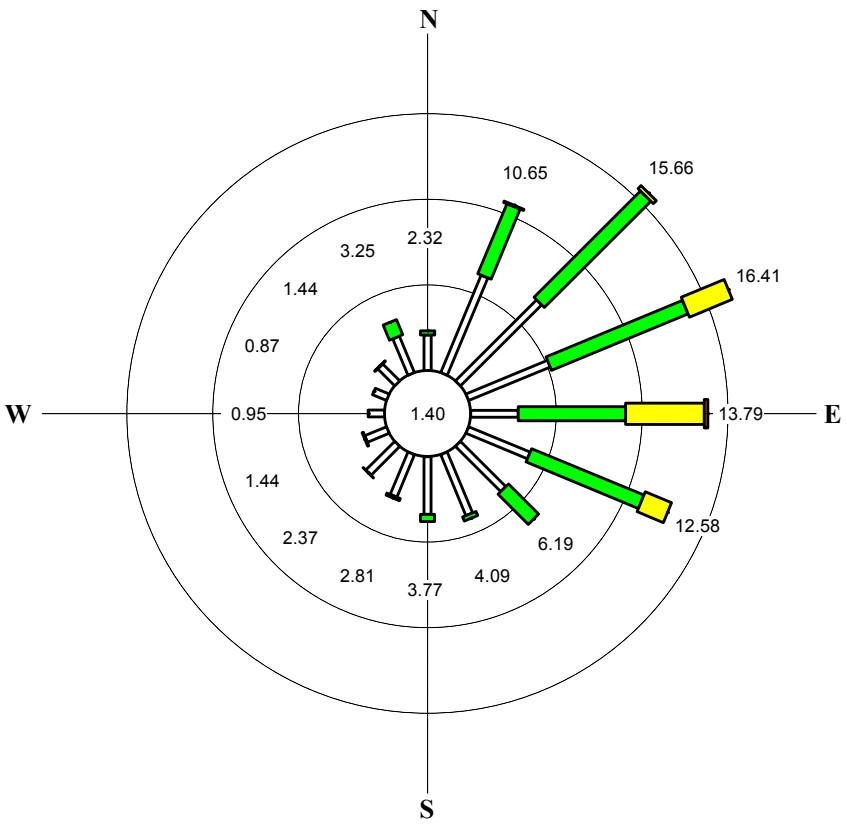
Joint Frequency Distribution
R0sep_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

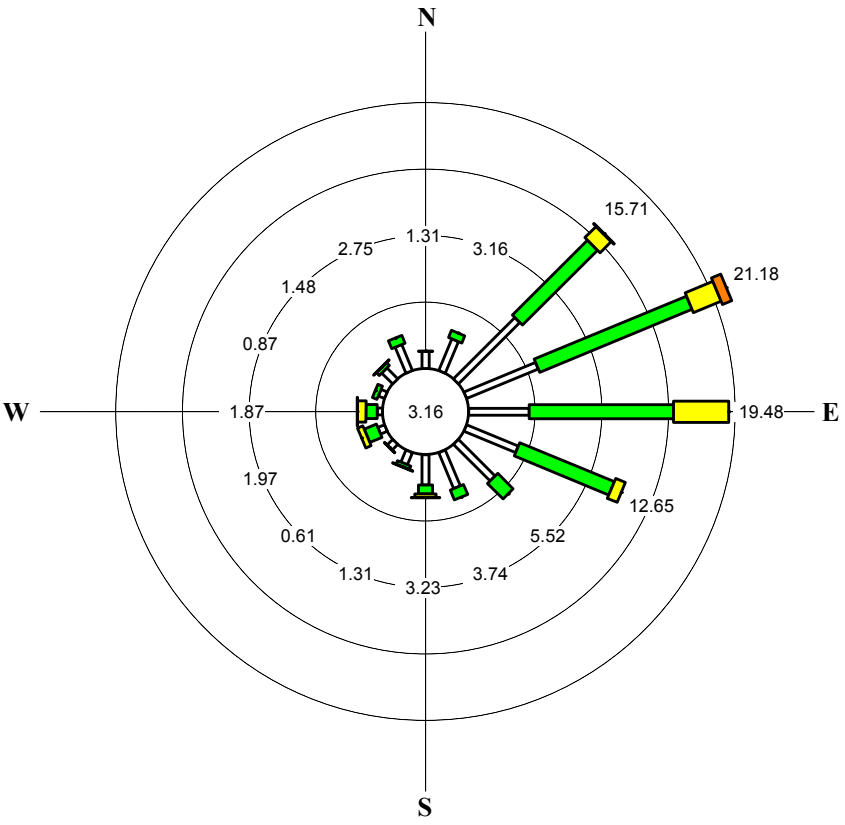
Joint Frequency Distribution
R0oct_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

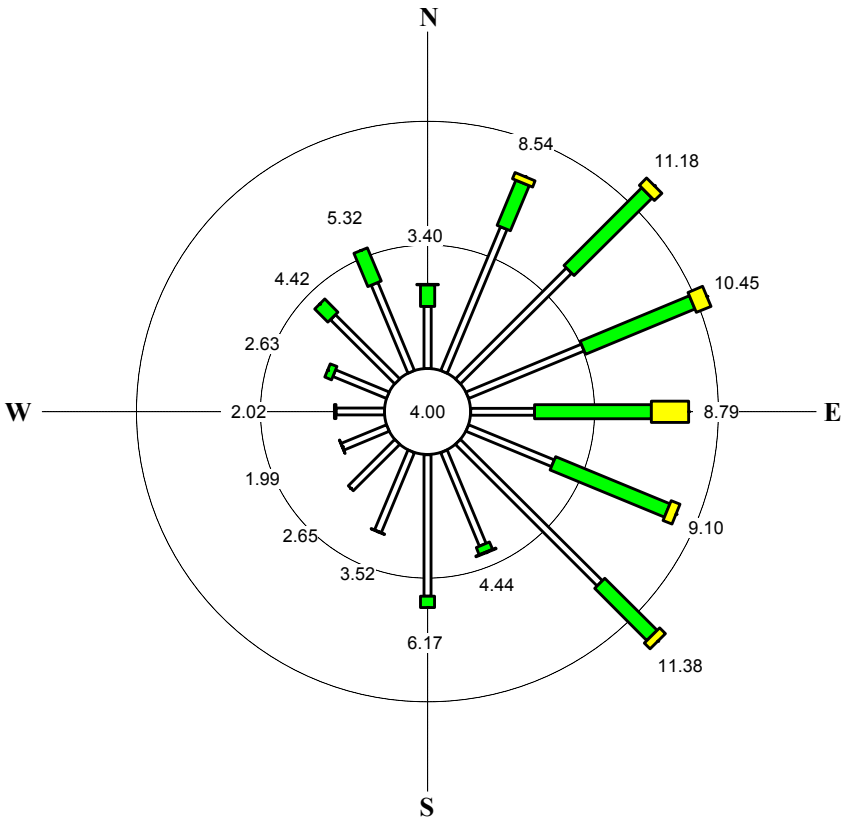
Joint Frequency Distribution
R0nov_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

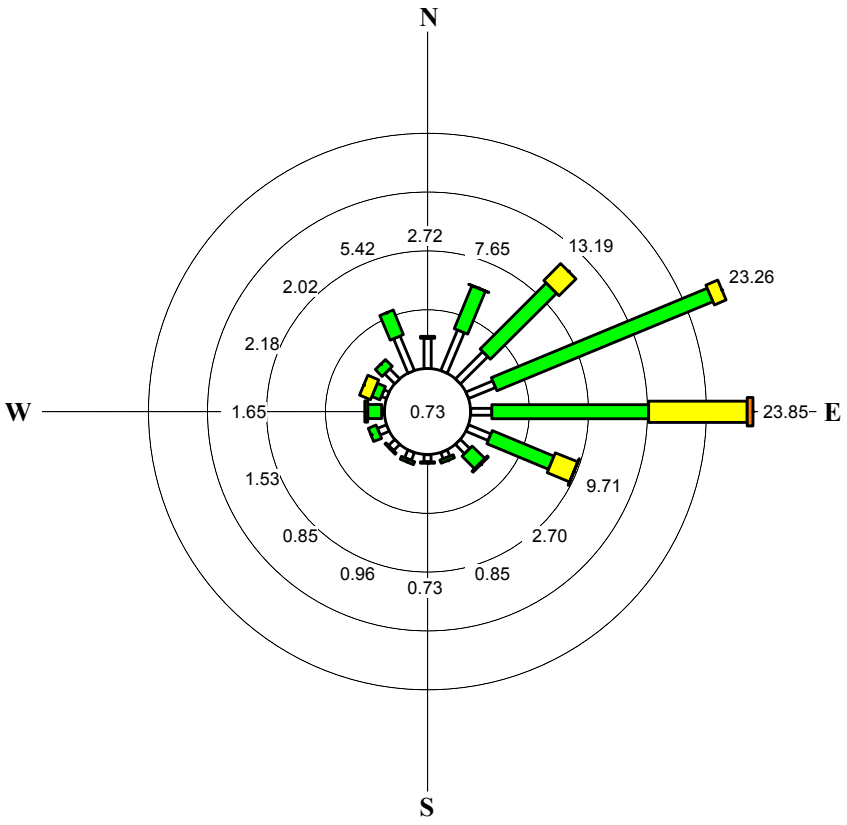
Joint Frequency Distribution
R0dec_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

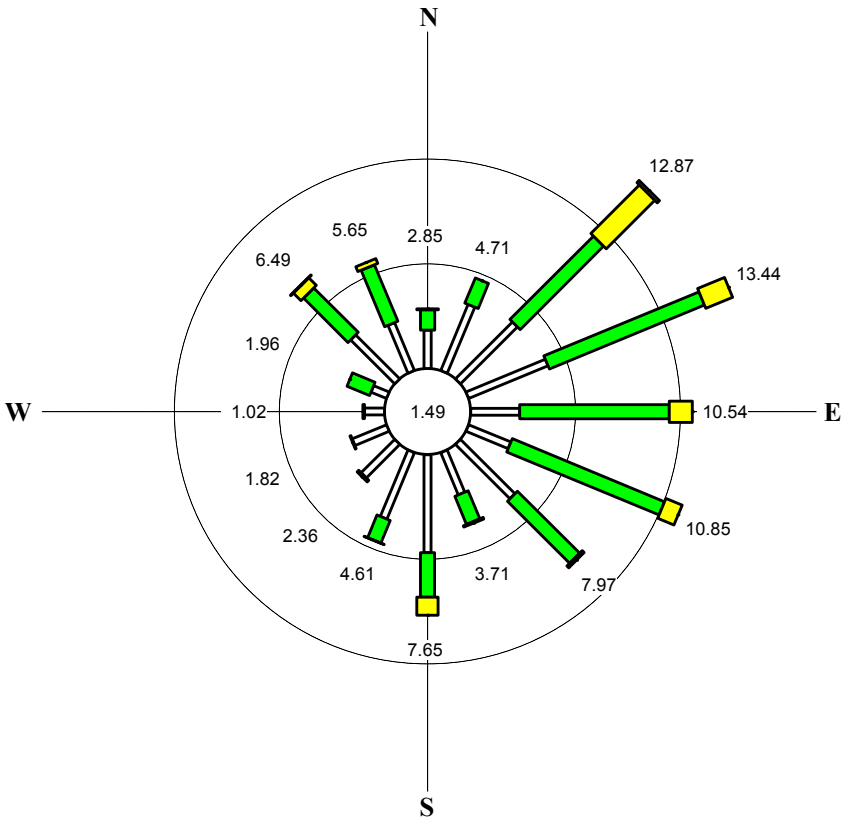
Joint Frequency Distribution
R0jan_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

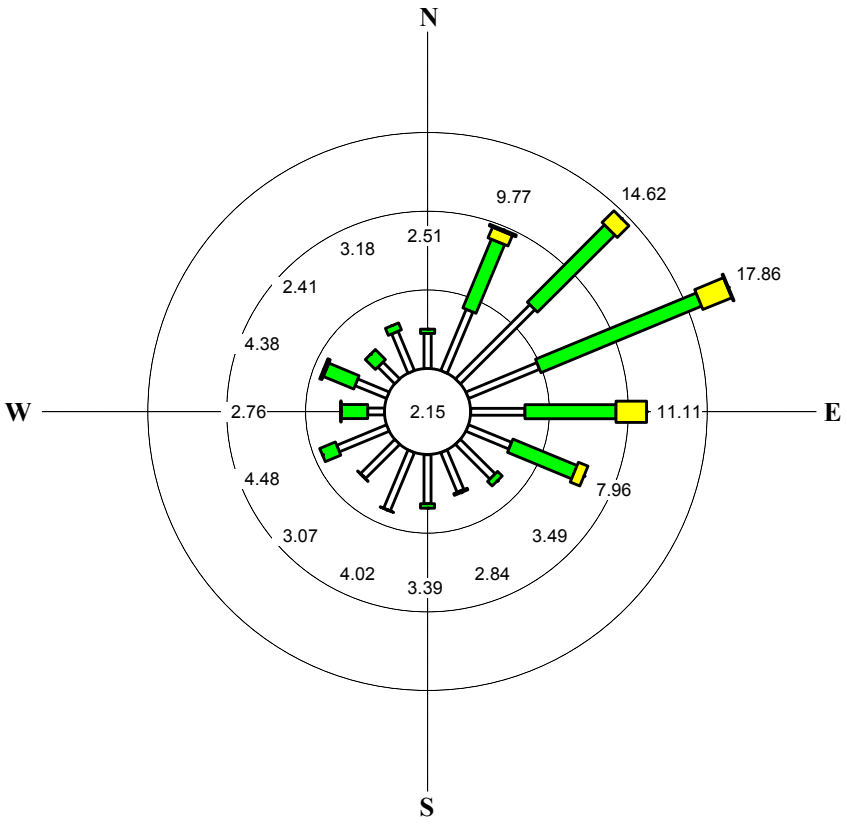
Joint Frequency Distribution
R0feb_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

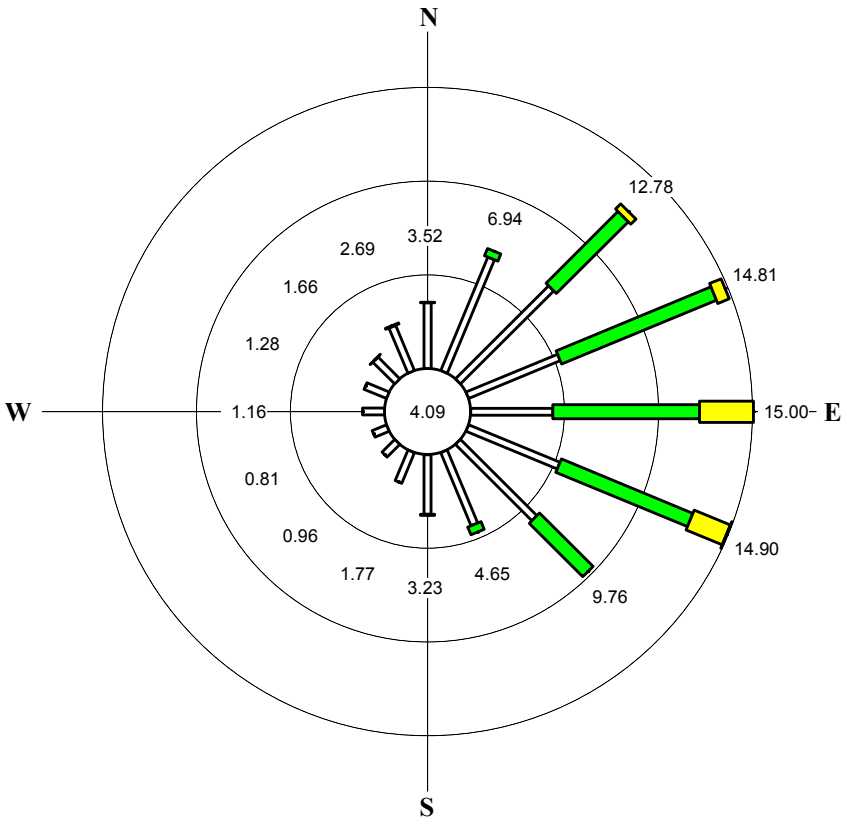
Joint Frequency Distribution
R0mar_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

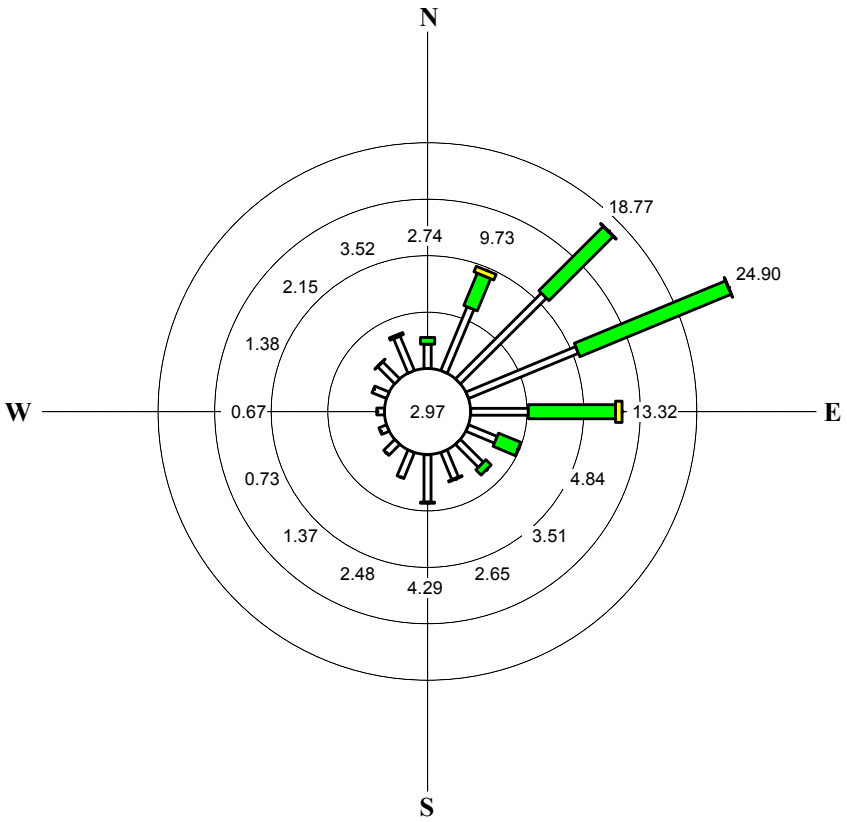
Joint Frequency Distribution
R0apr_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

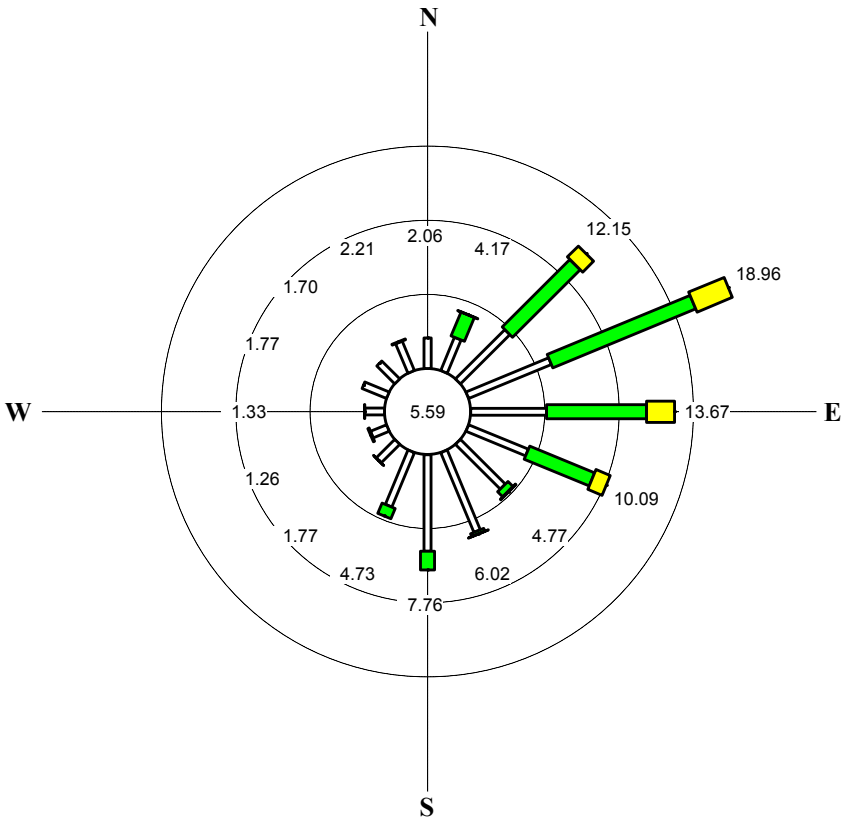
Joint Frequency Distribution
R0may_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

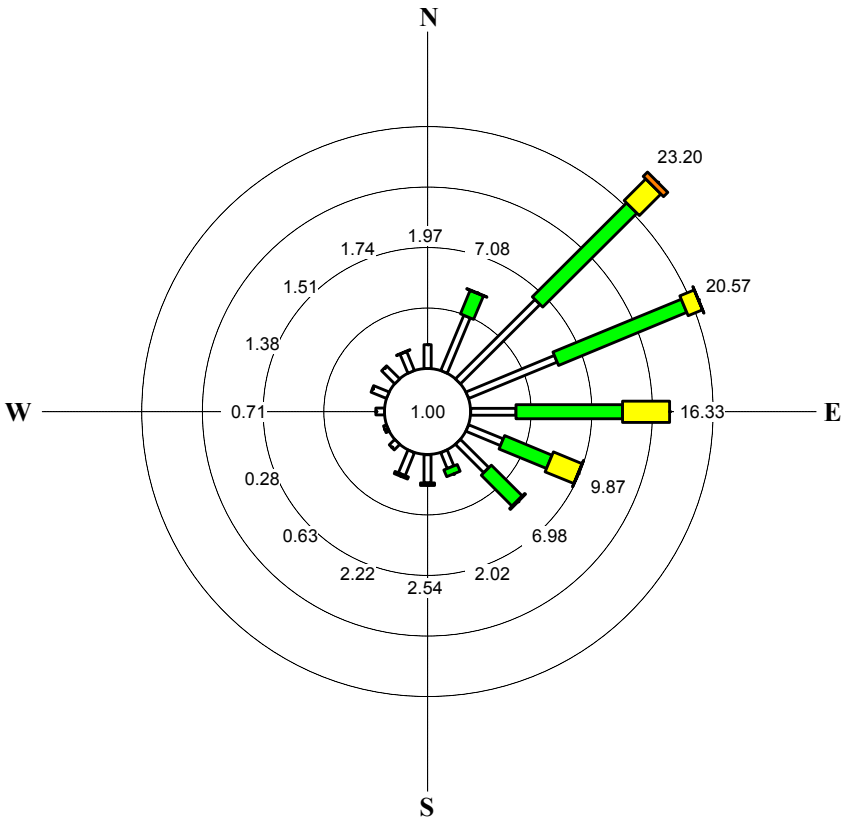
Joint Frequency Distribution
R0jun_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

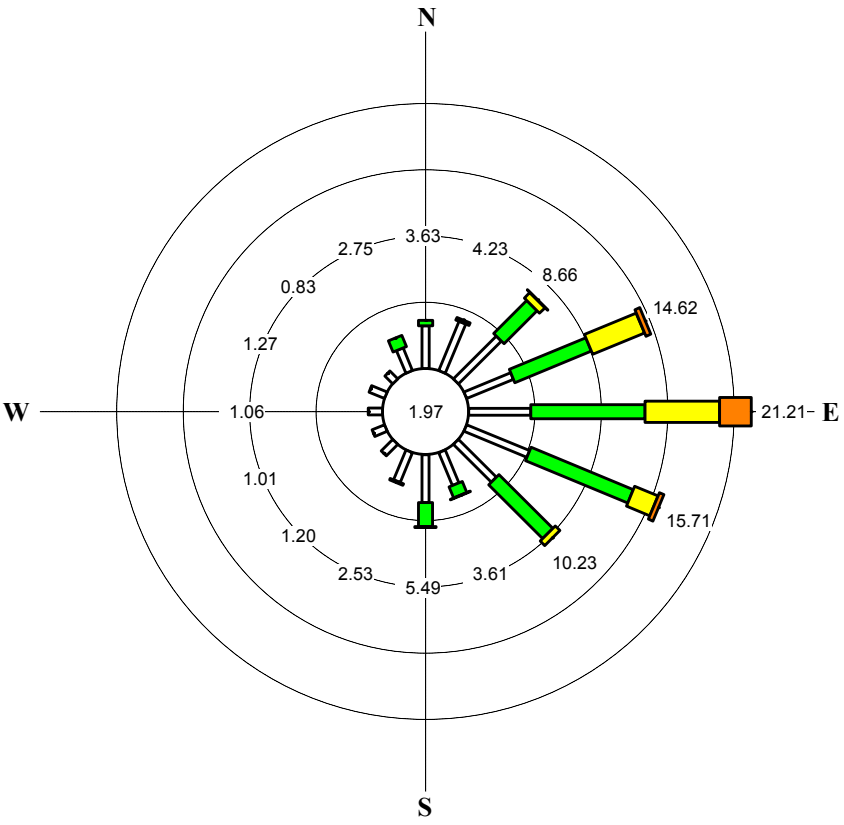
Joint Frequency Distribution
R0jul_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

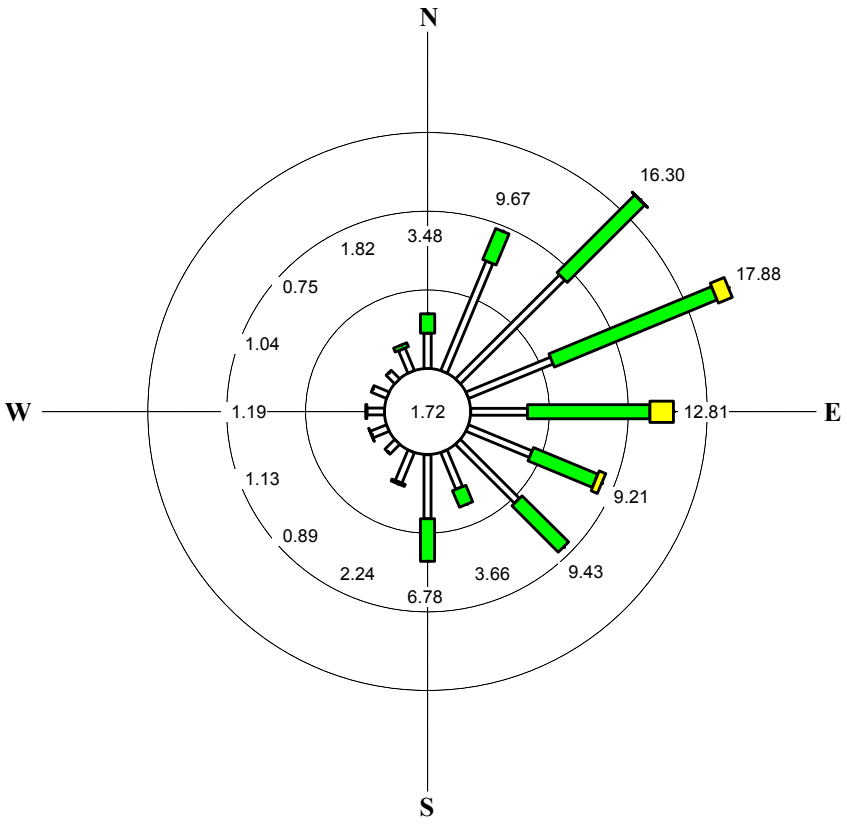
Joint Frequency Distribution
R0aug_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

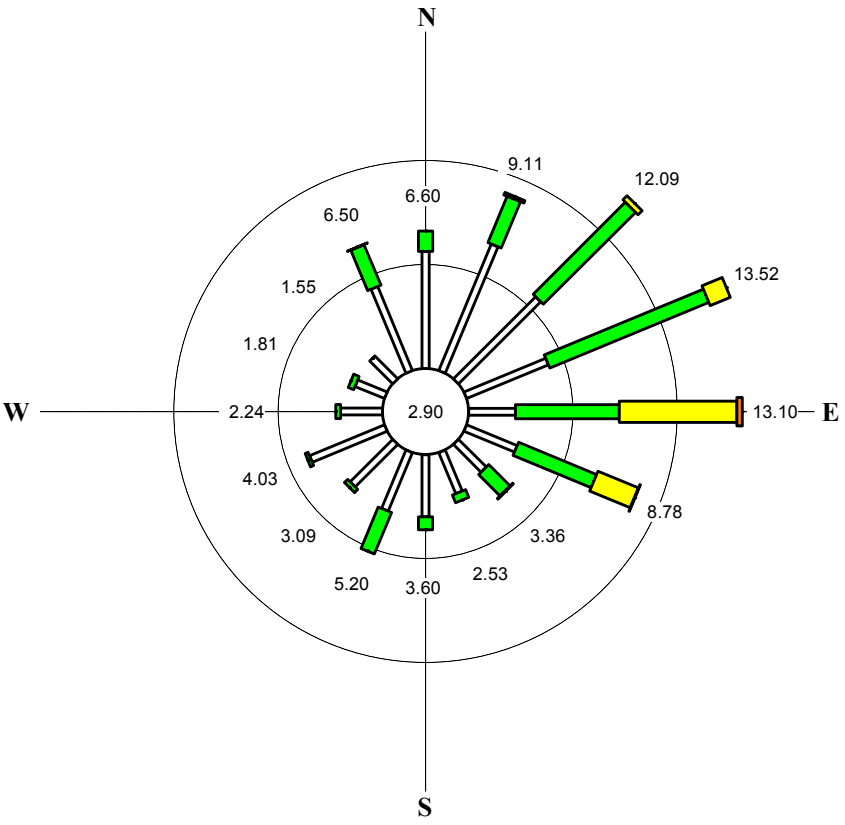
Joint Frequency Distribution
R0sept_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

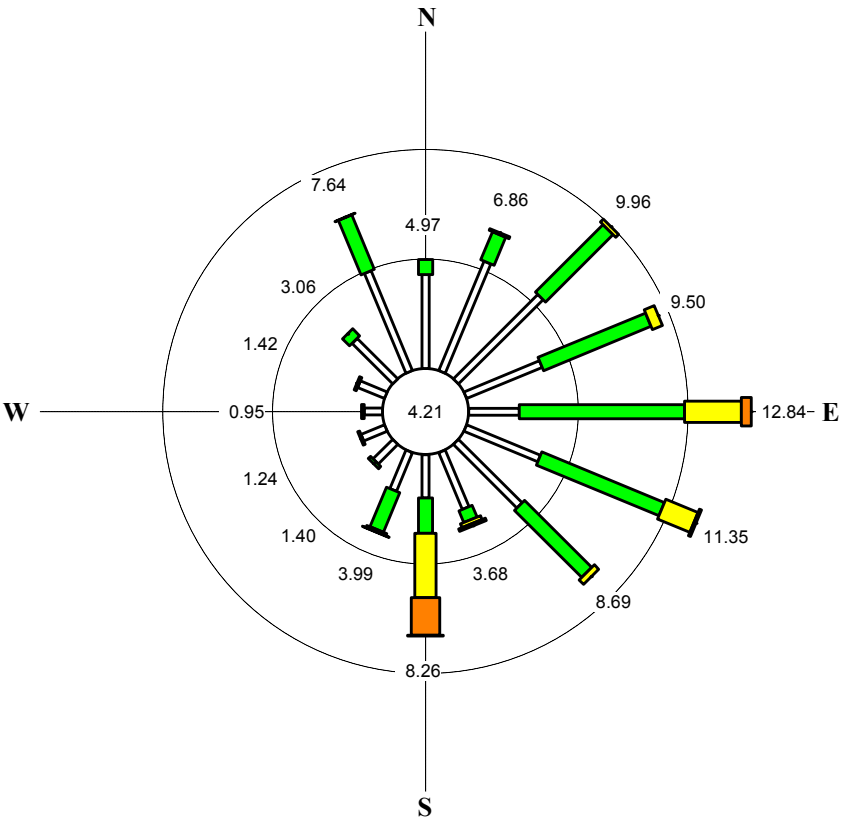
Joint Frequency Distribution
R0oct_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

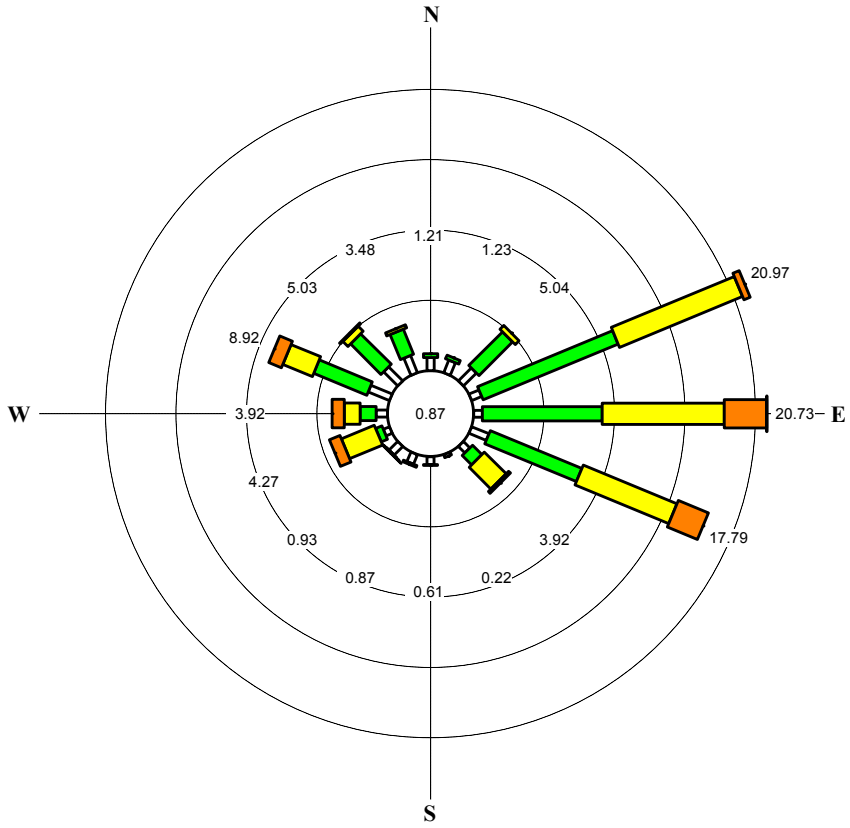
Joint Frequency Distribution
R0nov_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

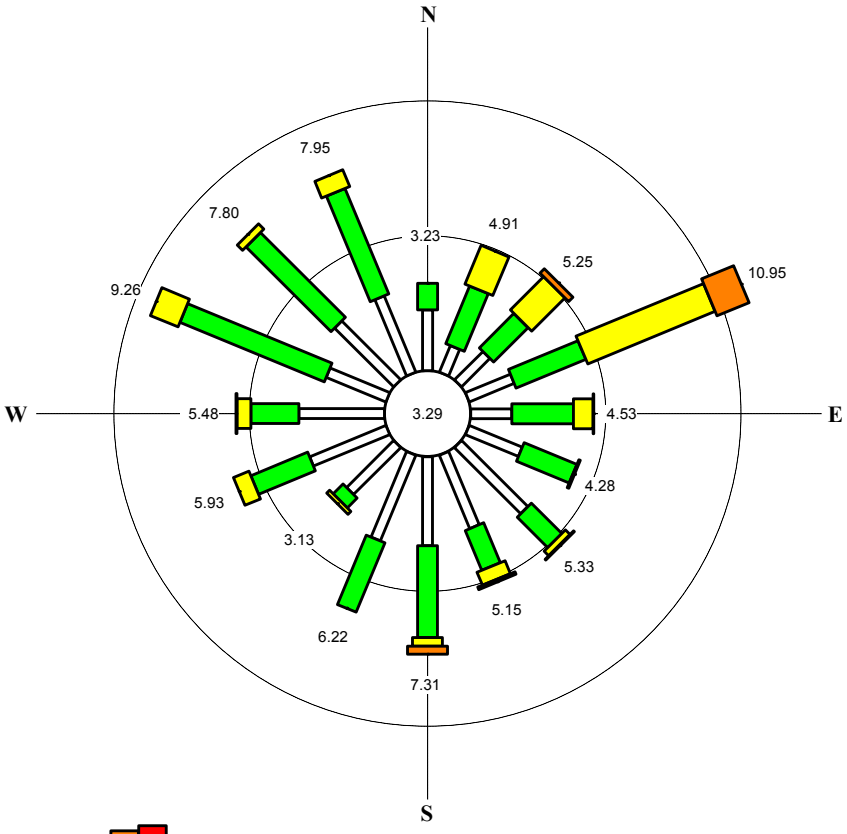
Joint Frequency Distribution
R0dec_01



Wind Speed (Miles Per Hour)

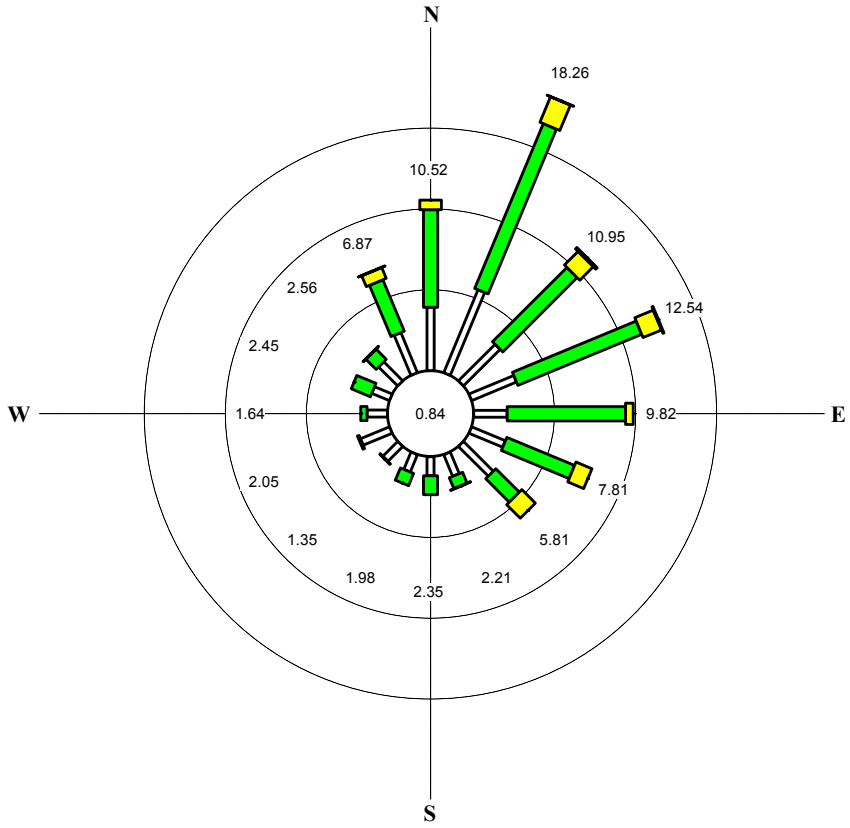
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0jan_02



Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

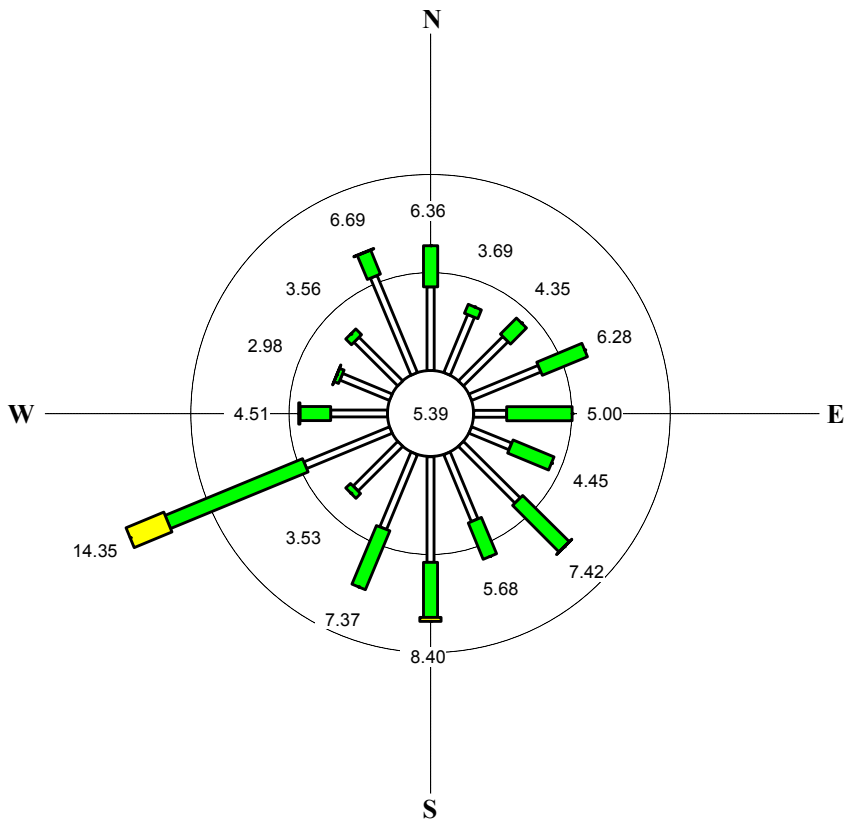
Joint Frequency Distribution
R0feb_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

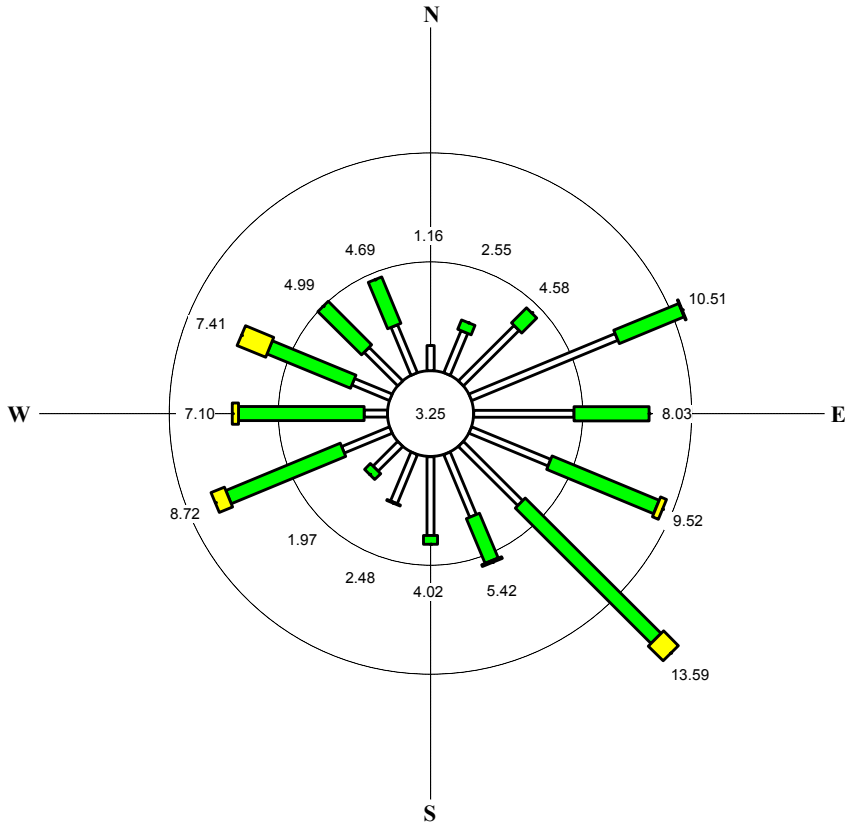
Joint Frequency Distribution
R0mar_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

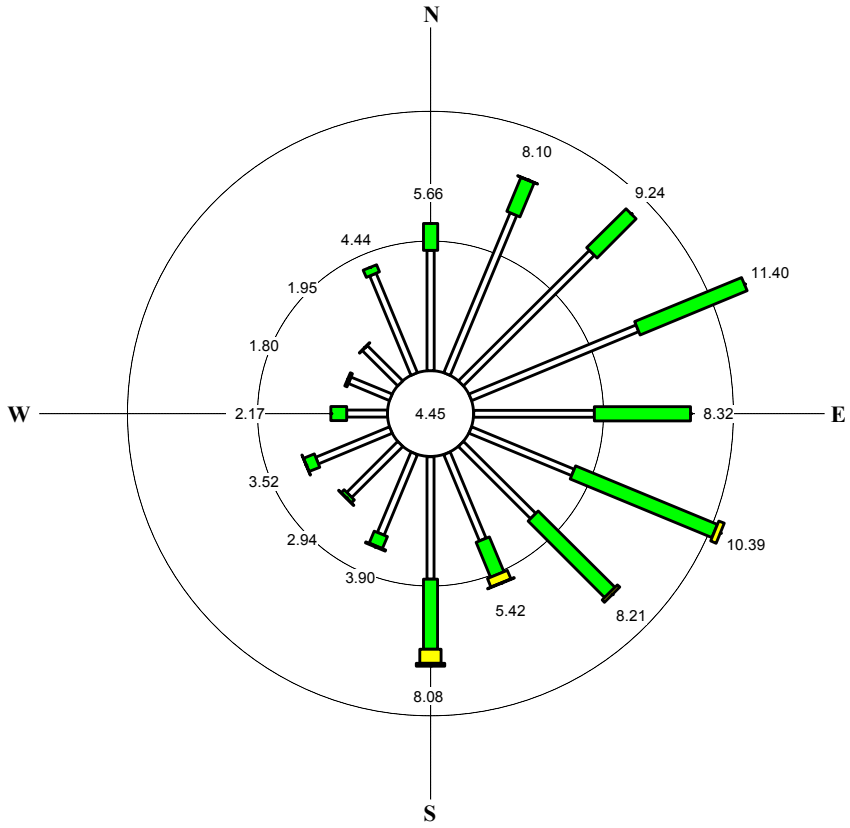
Joint Frequency Distribution
R0april_02



Wind Speed (Miles Per Hour)

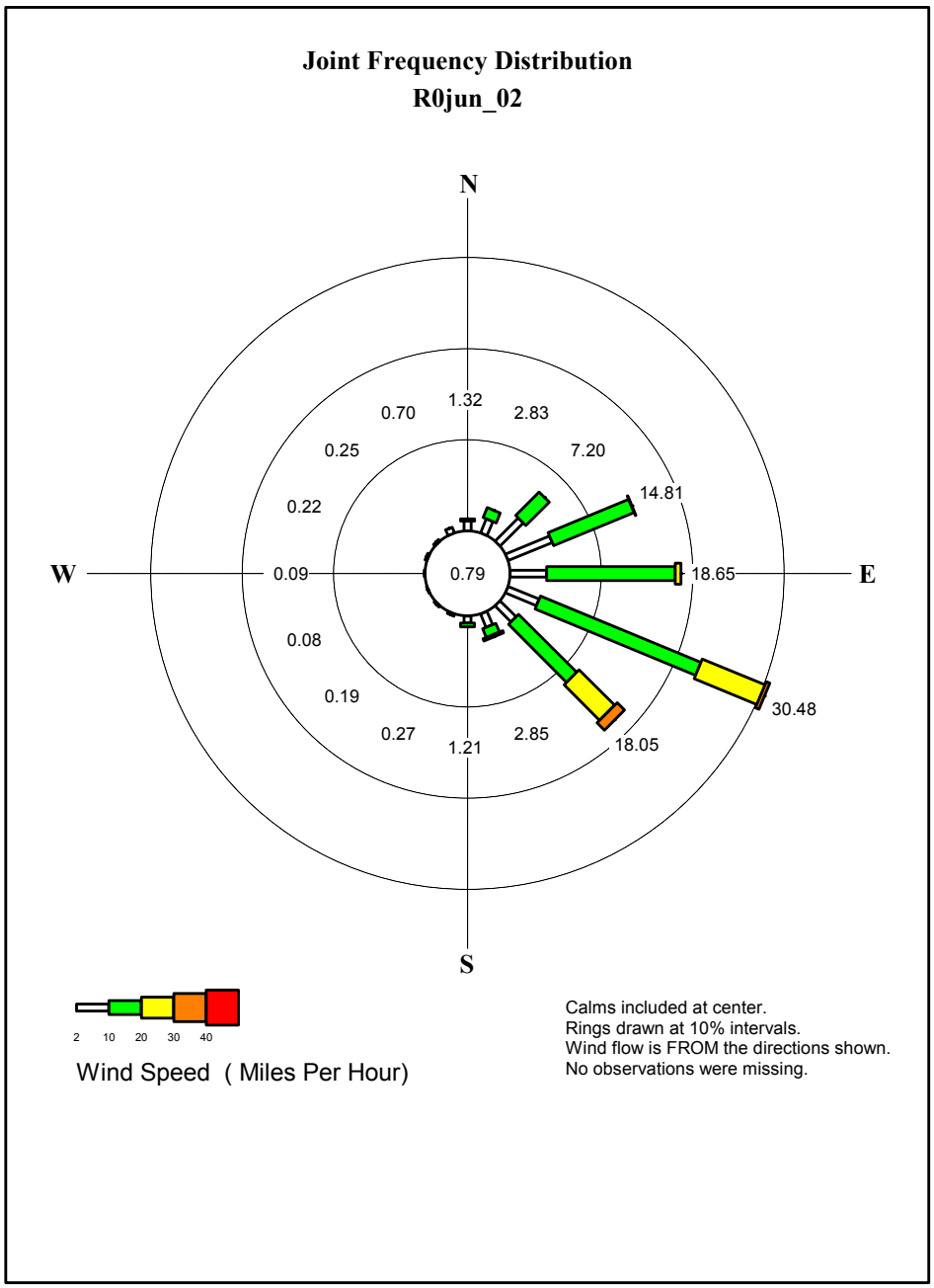
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0may_02

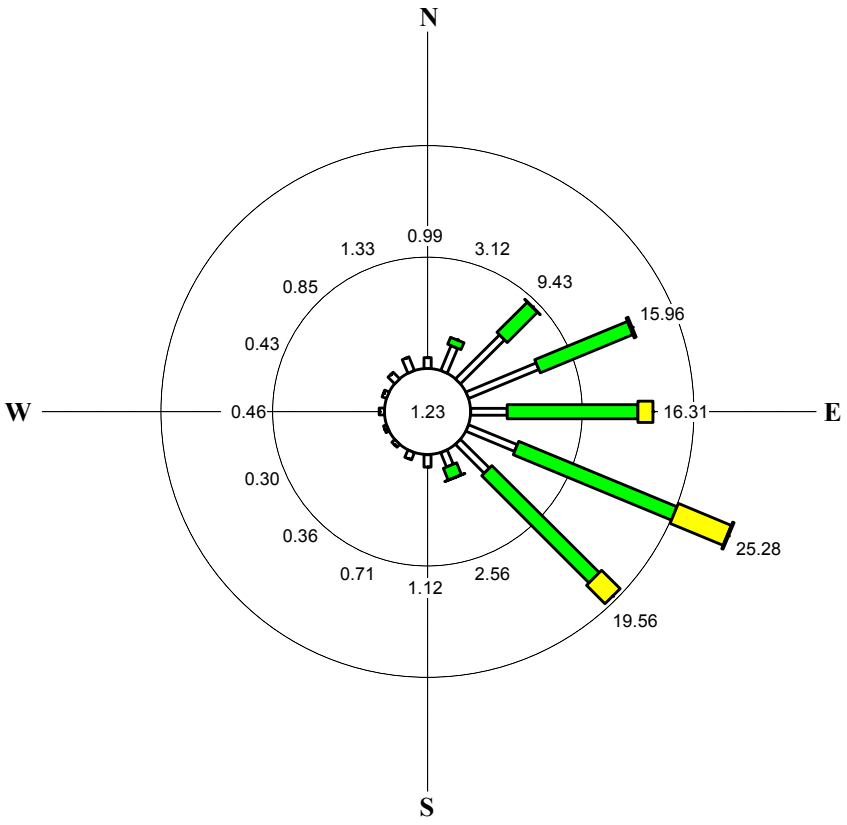


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0jun_02
N
W
E
S
1.32
0.70
2.83
0.25
7.20
0.22
14.81
0.09
0.79
18.65
0.08
0.19
30.48
0.27
2.85
1.21
18.05
2 10 20 30 40
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

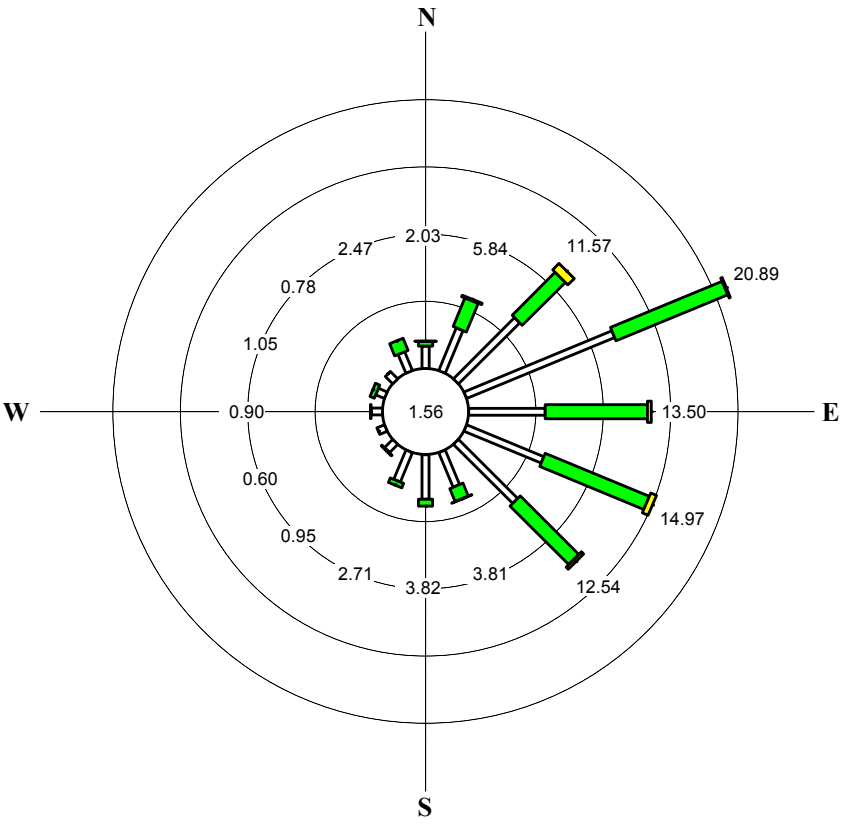
Joint Frequency Distribution
R0jul_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

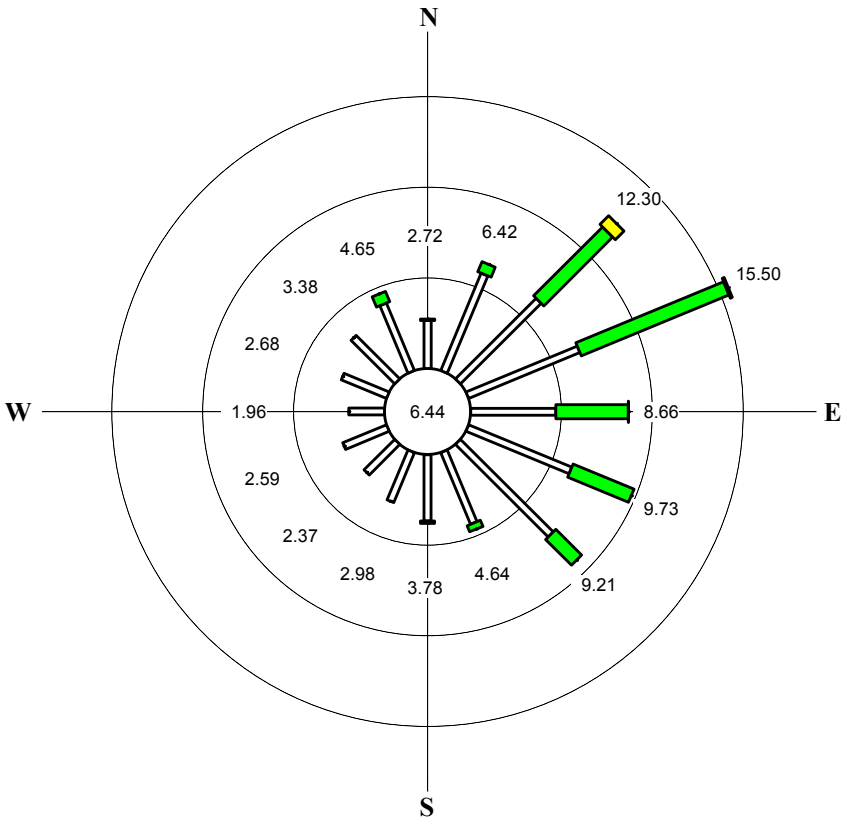
Joint Frequency Distribution
R0aug_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

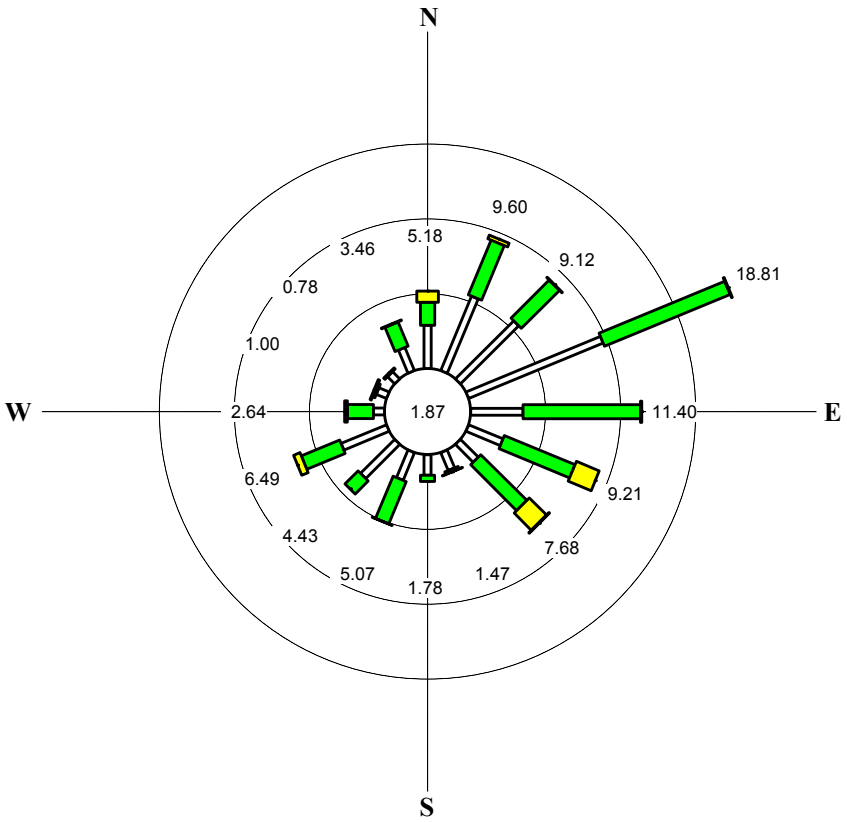
Joint Frequency Distribution
R0sep_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

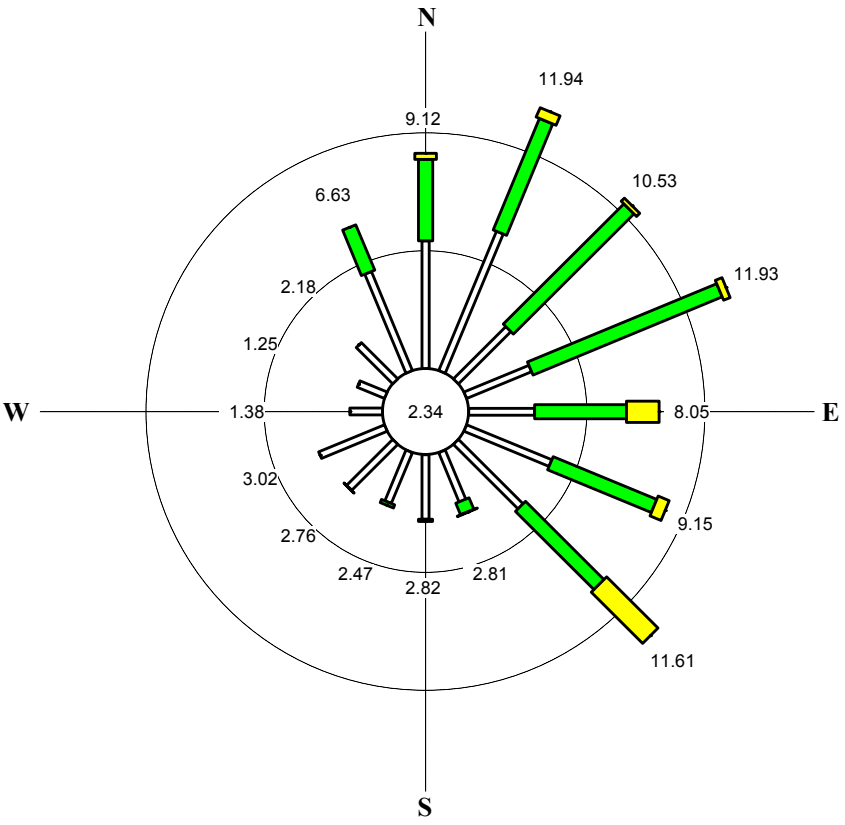
Joint Frequency Distribution
R0oct_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

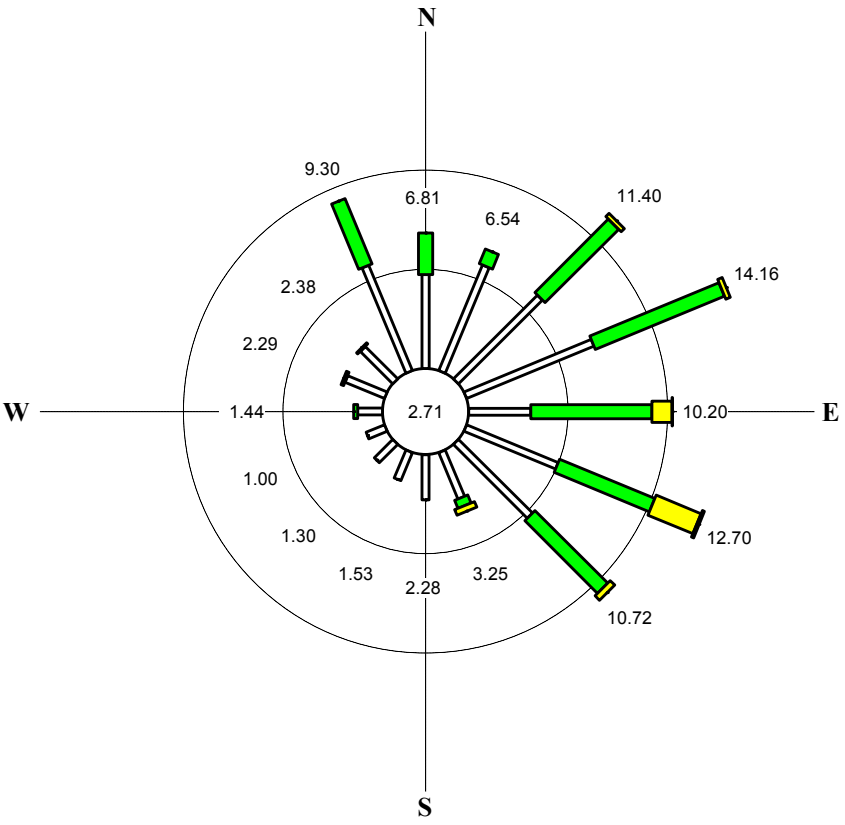
Joint Frequency Distribution
R0nov_02



Wind Speed (Miles Per Hour)

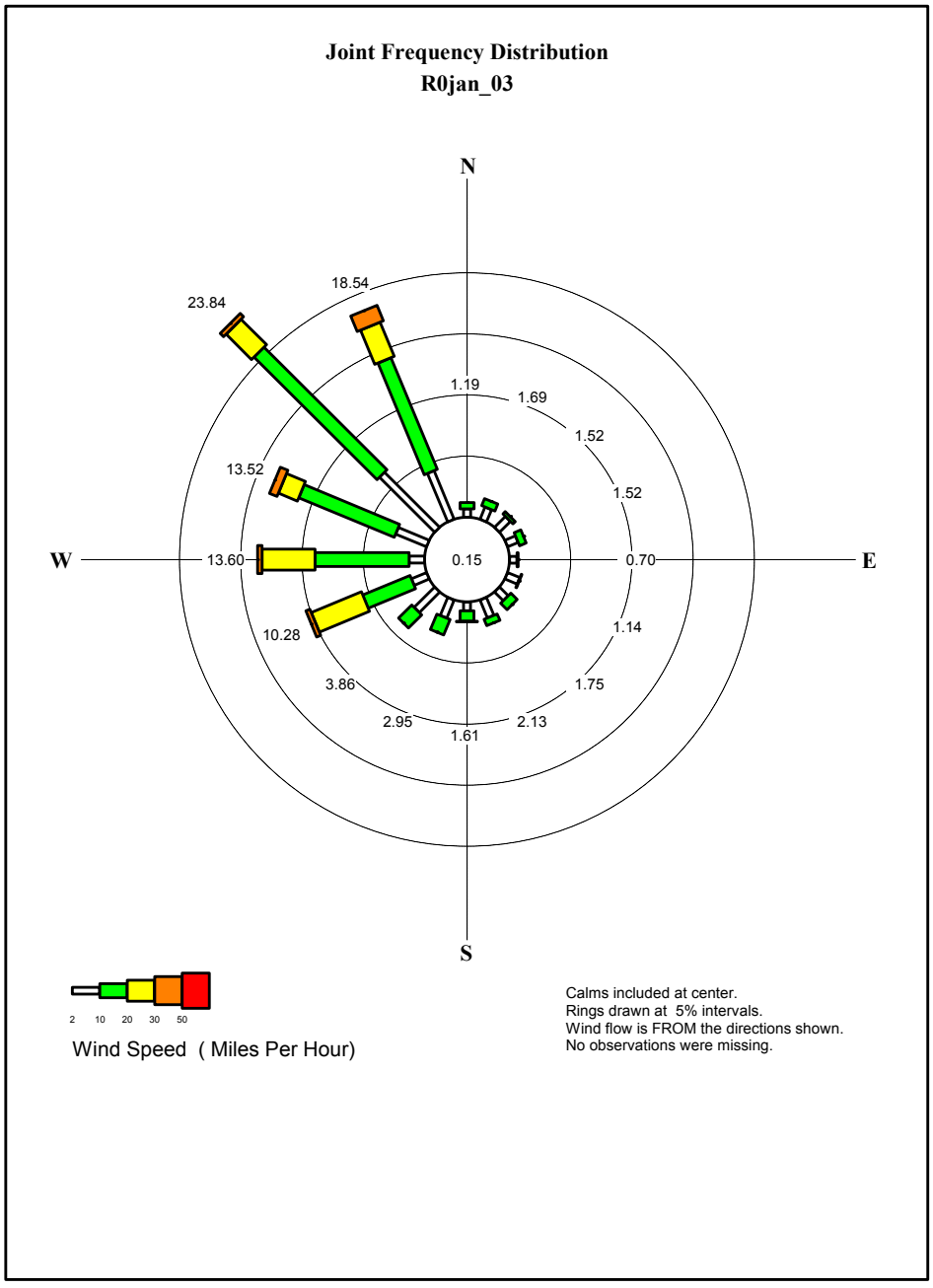
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0dec_02

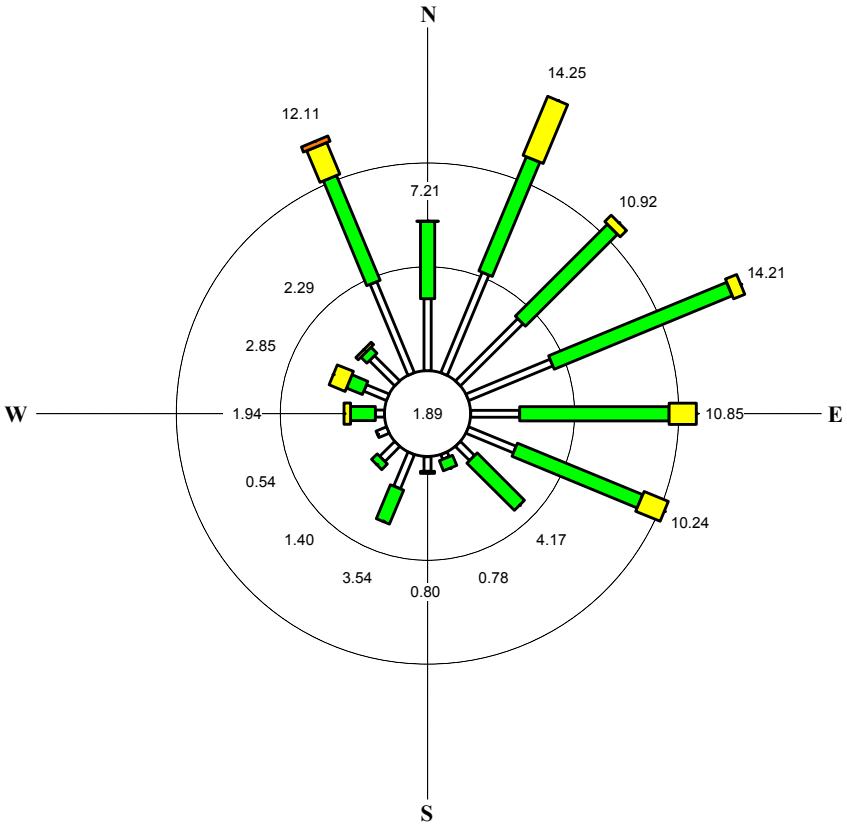


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
R0jan_03
N
E
S
W
18.54
23.84
1.19
1.69
1.52
1.52
13.52
13.60
0.15
0.70
1.14
10.28
1.75
3.86
2.95
2.13
1.61
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

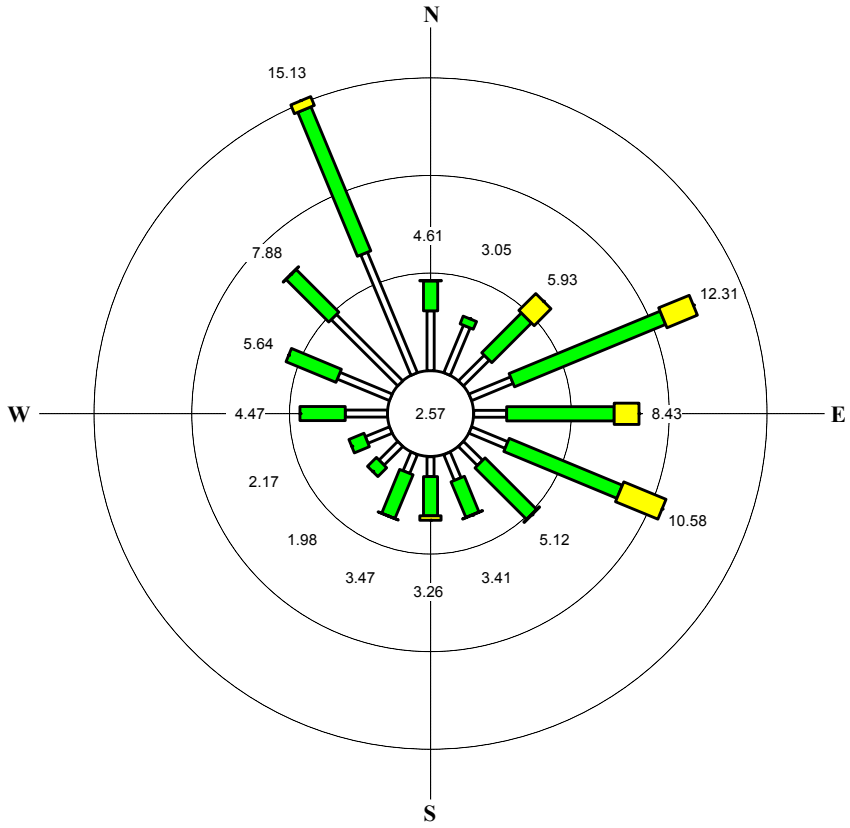
Joint Frequency Distribution
R0feb_03



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

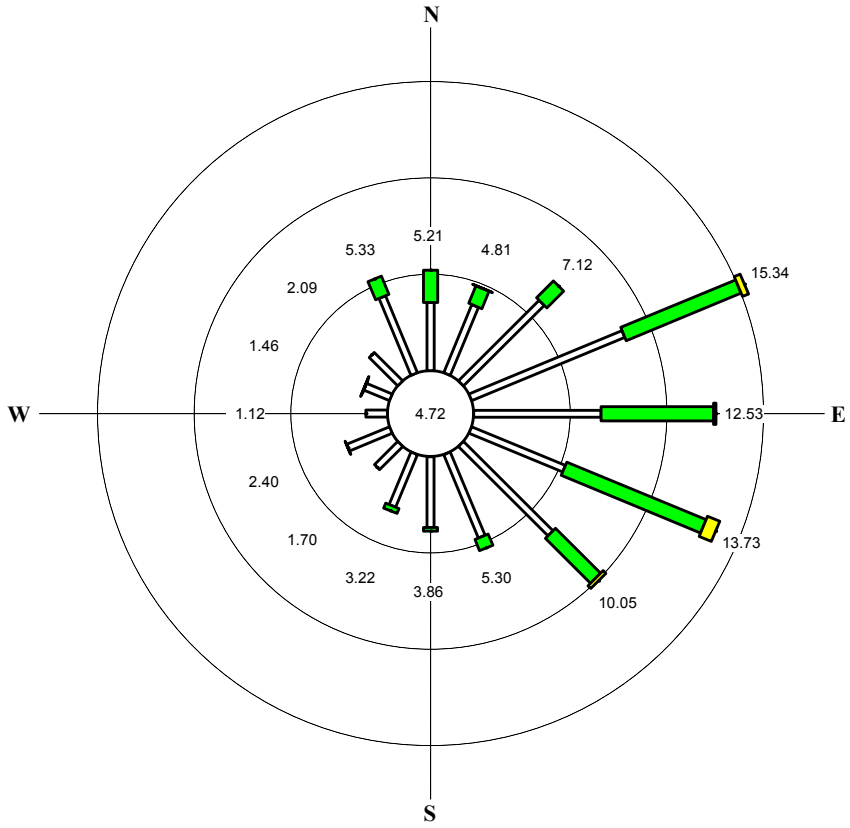
Joint Frequency Distribution
R0mar_03



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

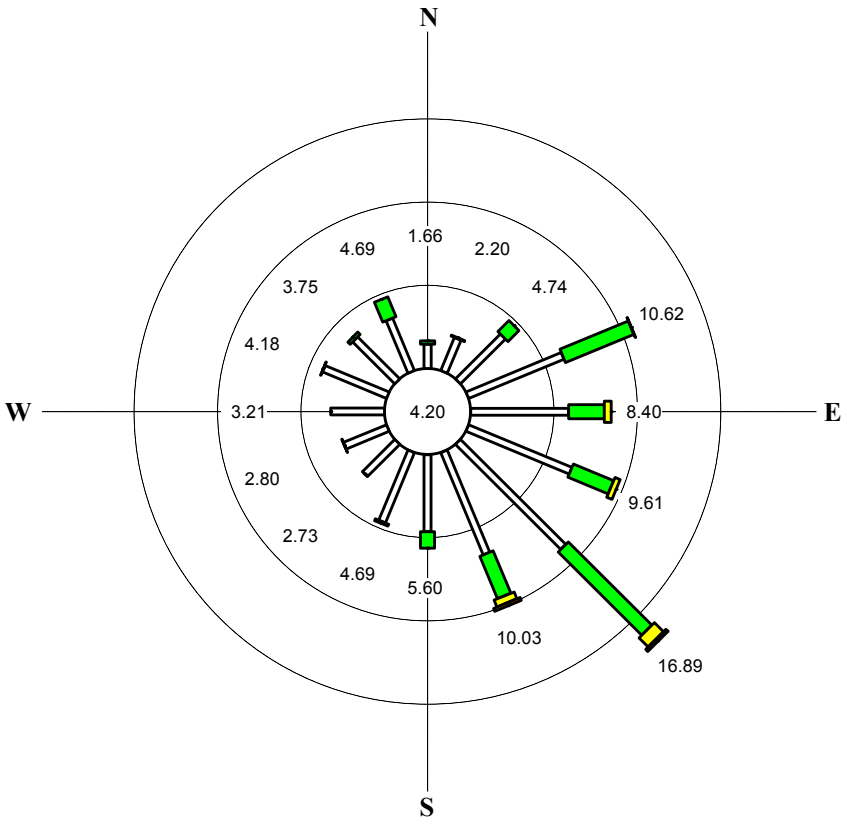
Joint Frequency Distribution
R0apr_03



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

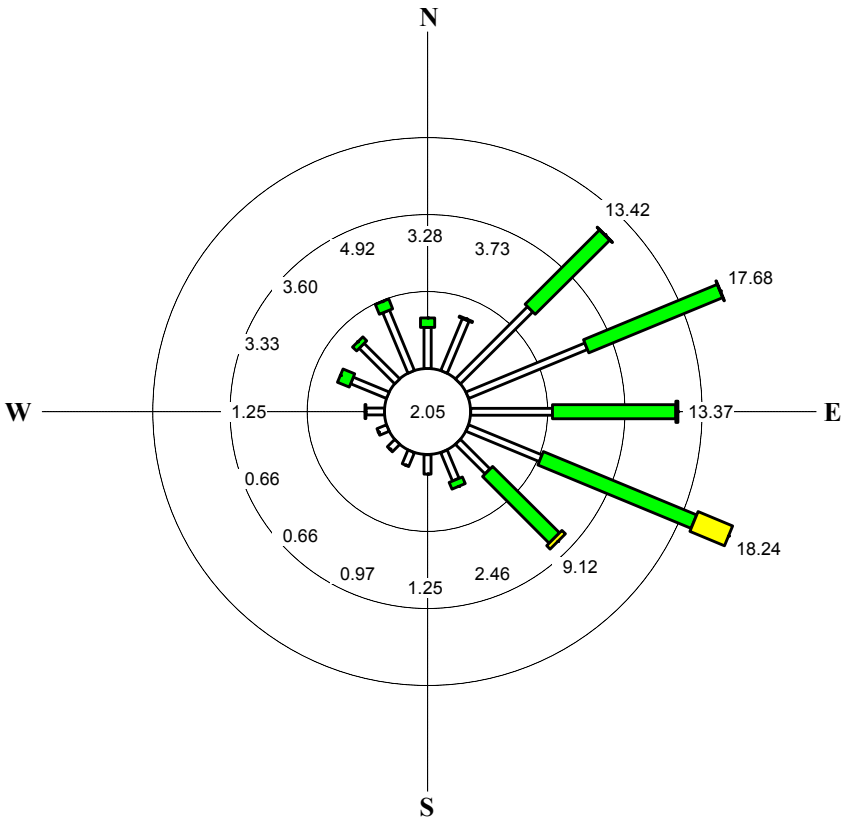
Joint Frequency Distribution
R0may_03



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
R0jun_03



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Appendix C

MSO Multi-Year Charts
5 Year Composite

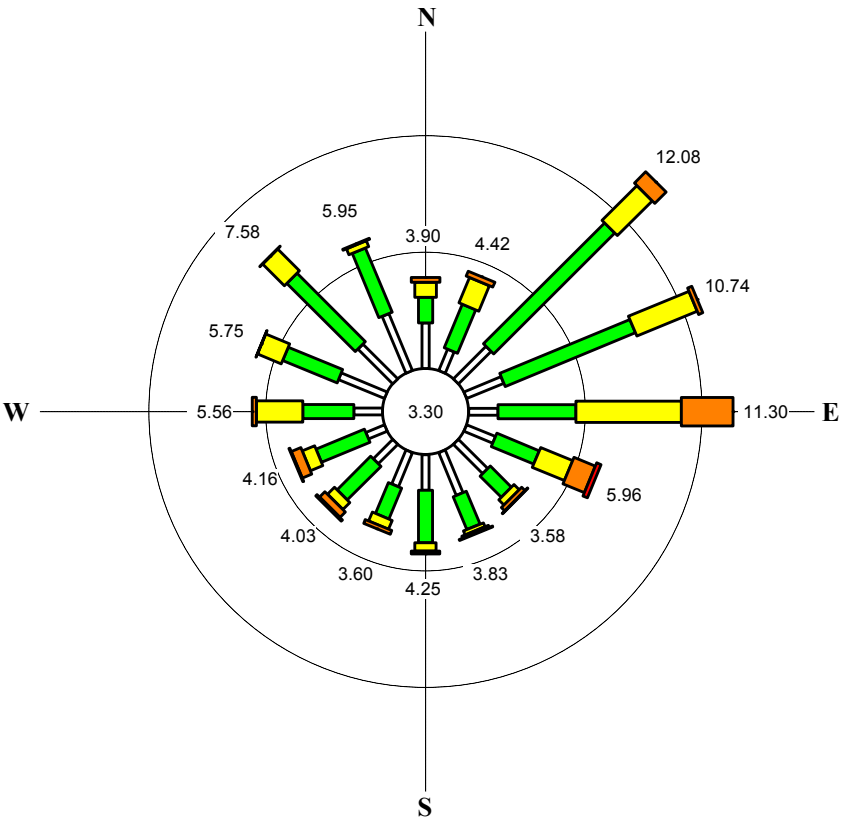
These charts are composites of the 5 years of data, except in cases where data was missing in a particular year. For those cases, the composite is for 4 years.

Wind data is missing for the following months:

February 1998
March 1998
April 1998
December 1999
January 2000

For the above months, the composite includes only 4 years; this is indicated in the sub-title by the suffix "_4" instead of "_5".

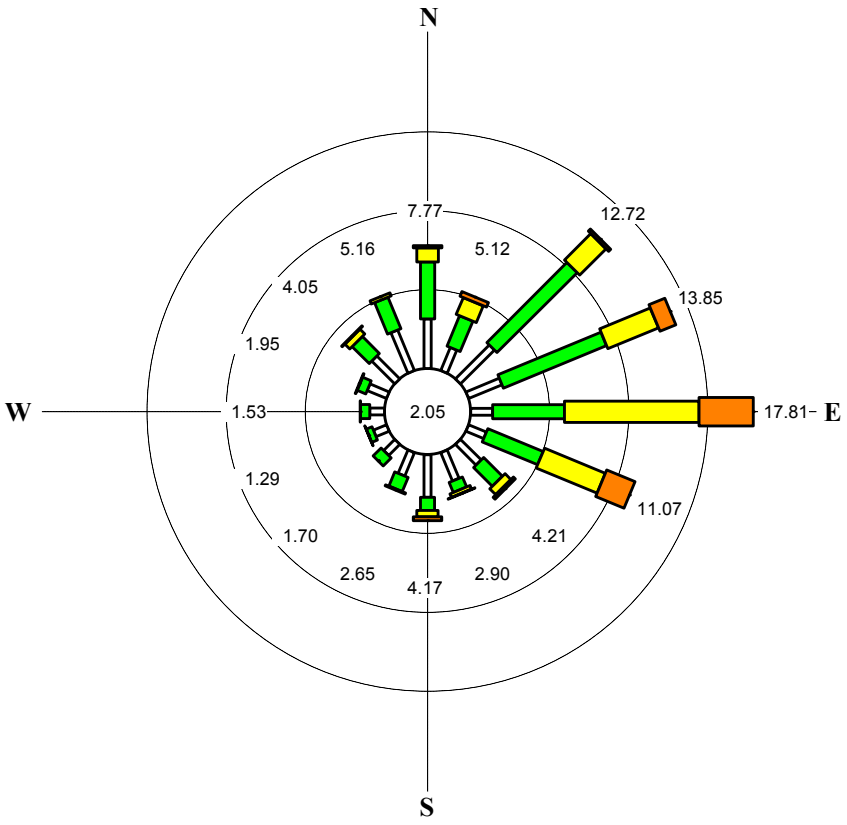
Joint Frequency Distribution
uh_jan_4

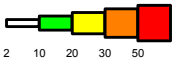


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_feb_4

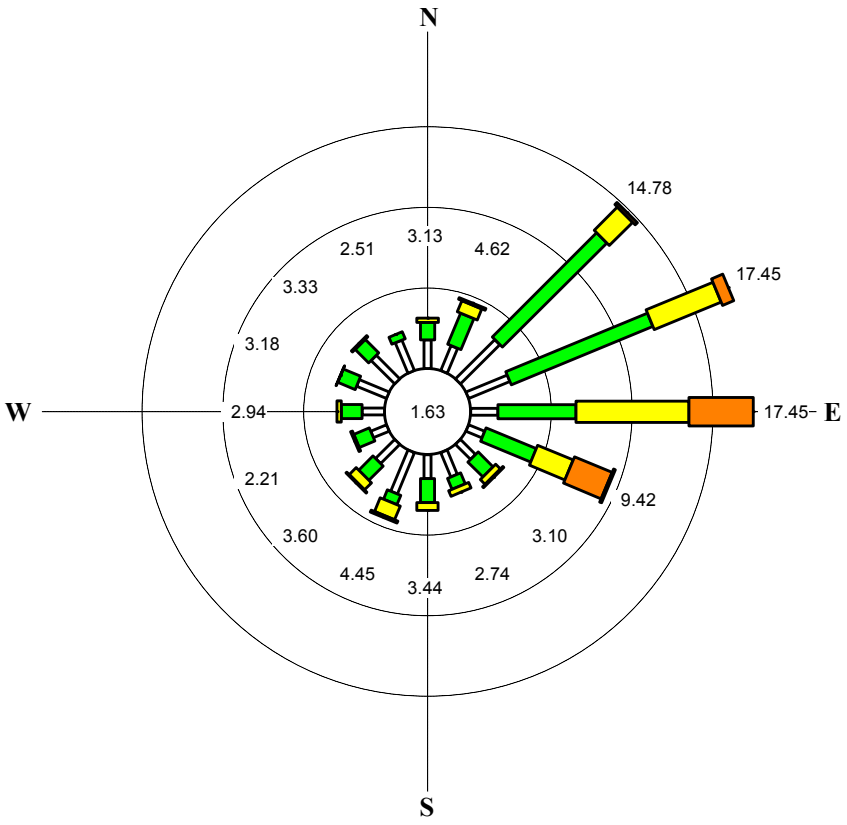




Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

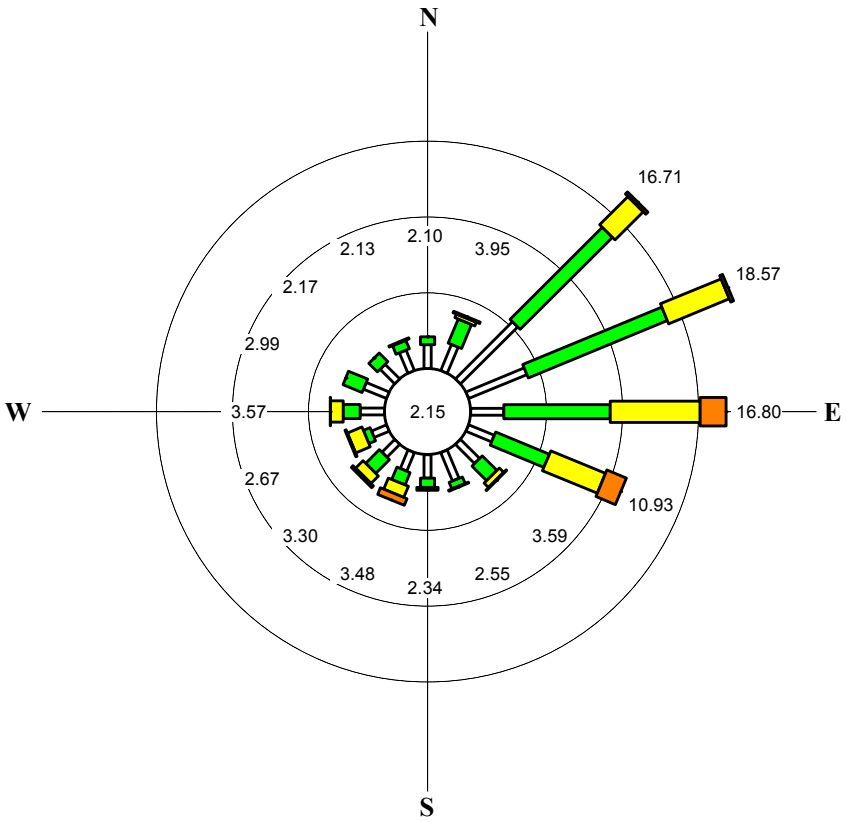
Joint Frequency Distribution
uh_mar_4



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

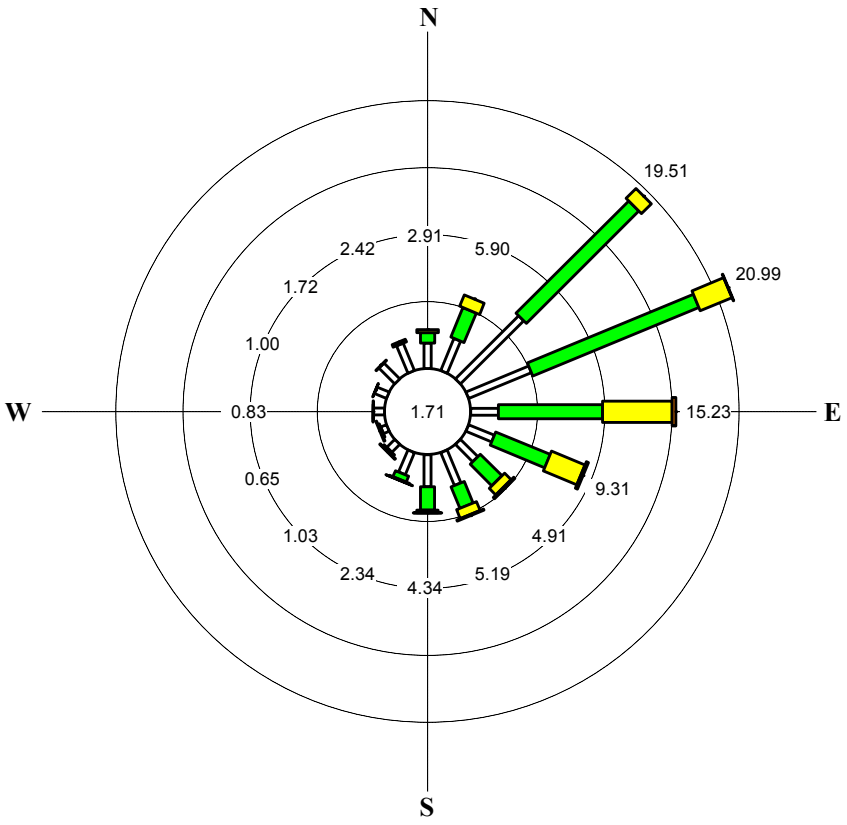
Joint Frequency Distribution
uh_apr_4



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

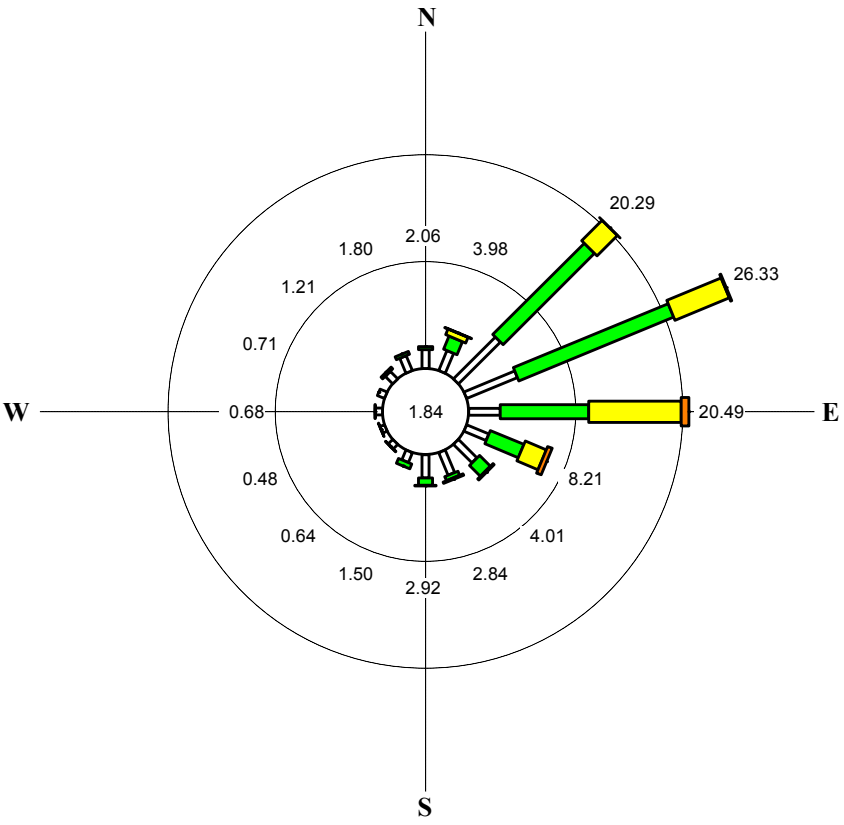
Joint Frequency Distribution
uh_may_5



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

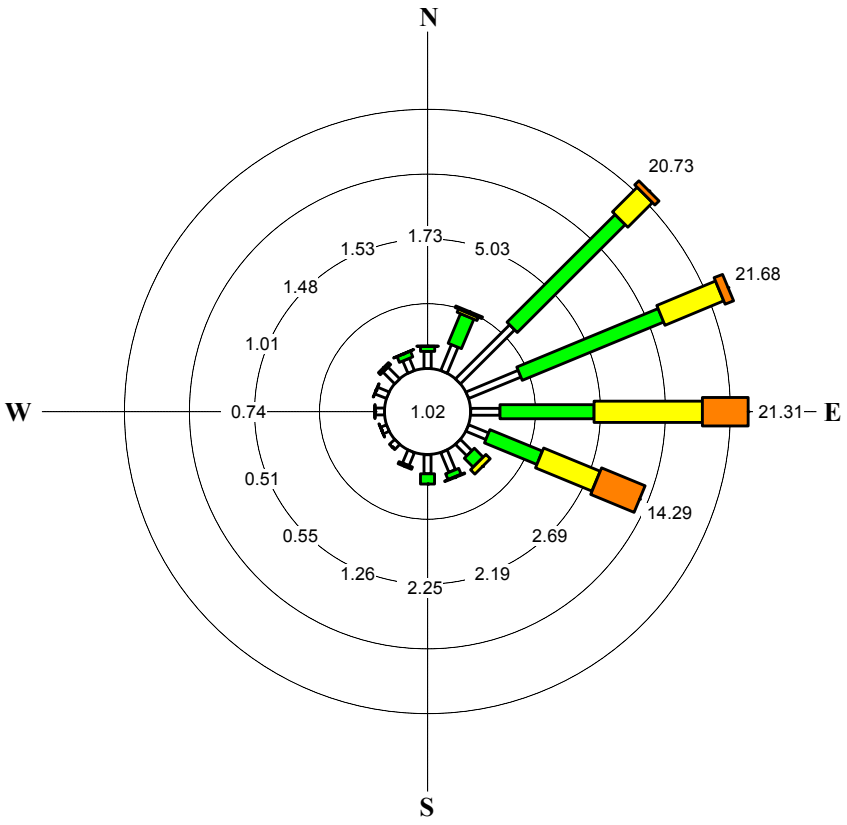
Joint Frequency Distribution
uh_jun_5



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_jul_5

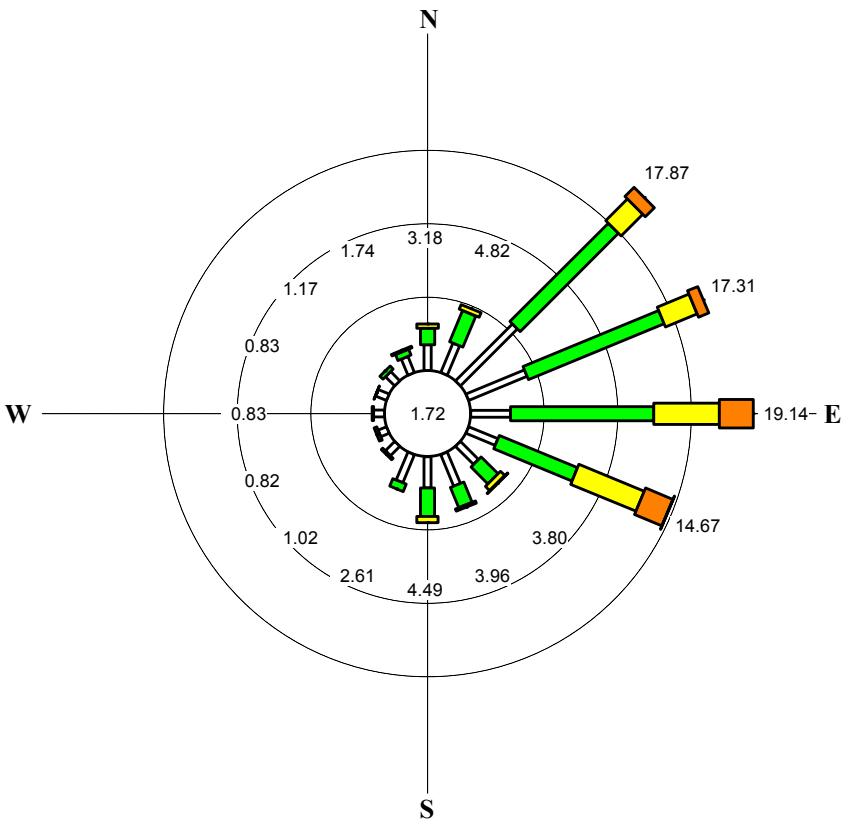


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution

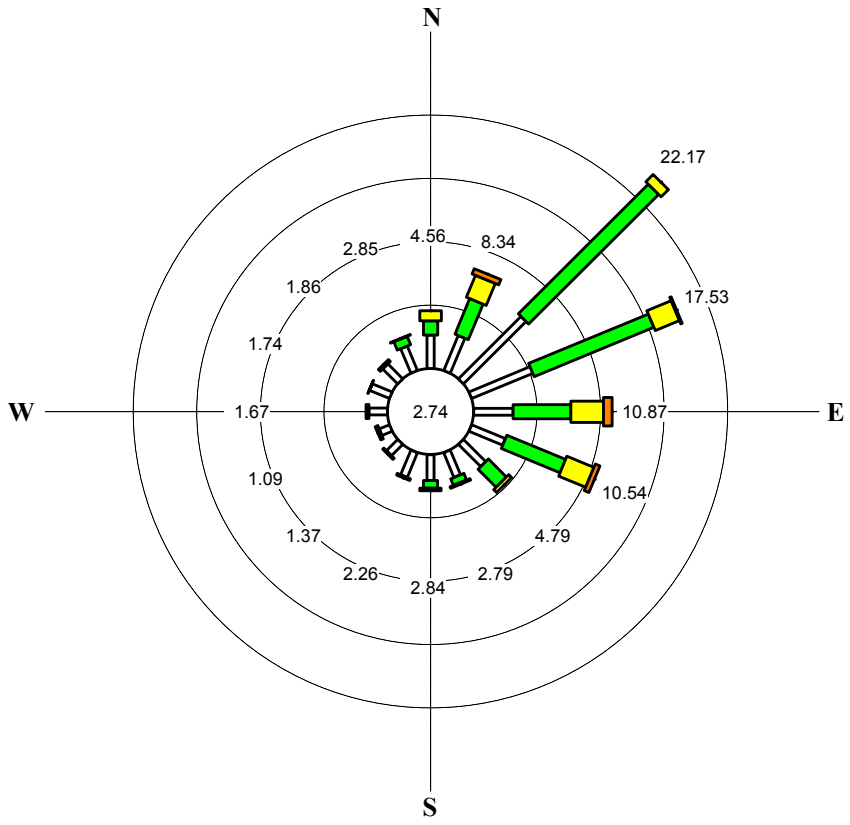
uh_aug_5



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

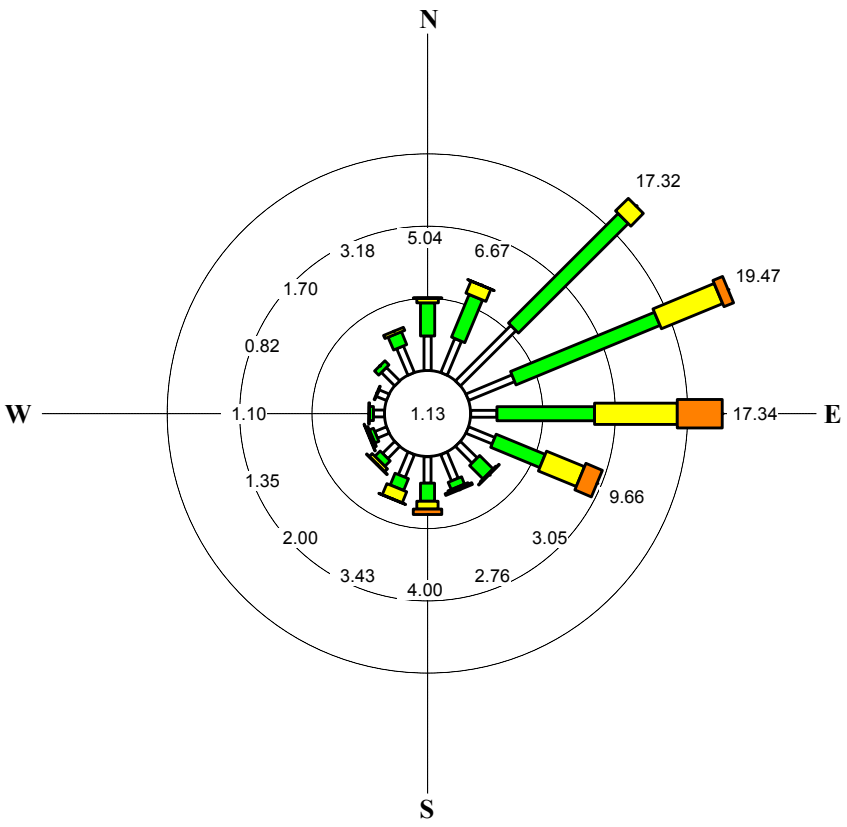
Joint Frequency Distribution
uh_sep_5



Wind Speed (Miles Per Hour)

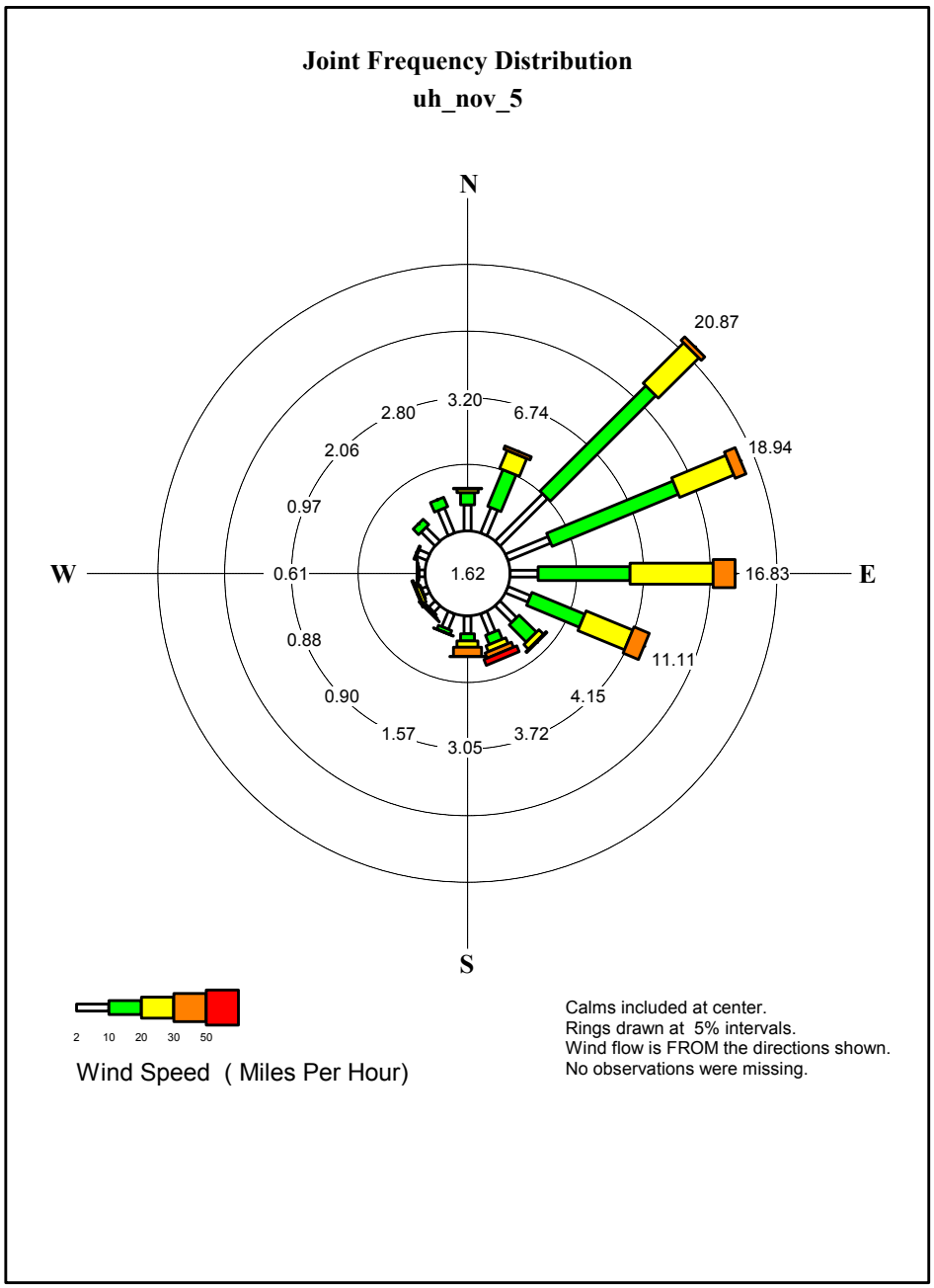
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_oct_5

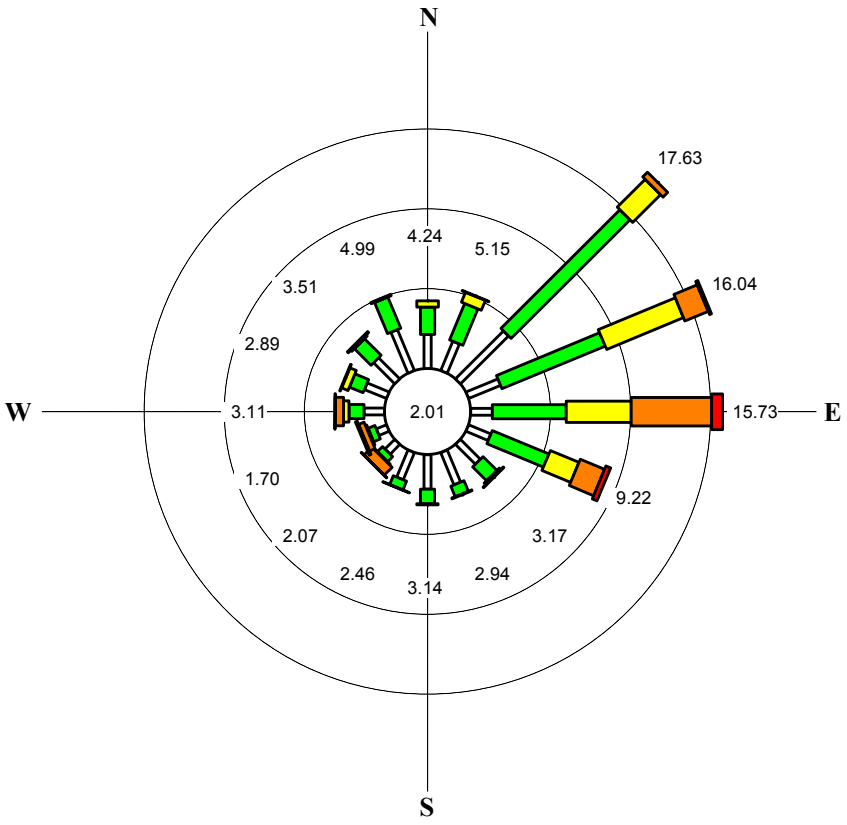


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_nov_5
N
E
S
W
20.87
18.94
16.83
11.11
4.15
3.72
3.05
1.57
0.90
0.88
0.97
2.06
2.80
3.20
6.74
0.61
1.62
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_dec_4



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Appendix D

Yearly Wind Rose Charts
1998 to 2002

Mees Observatory Data

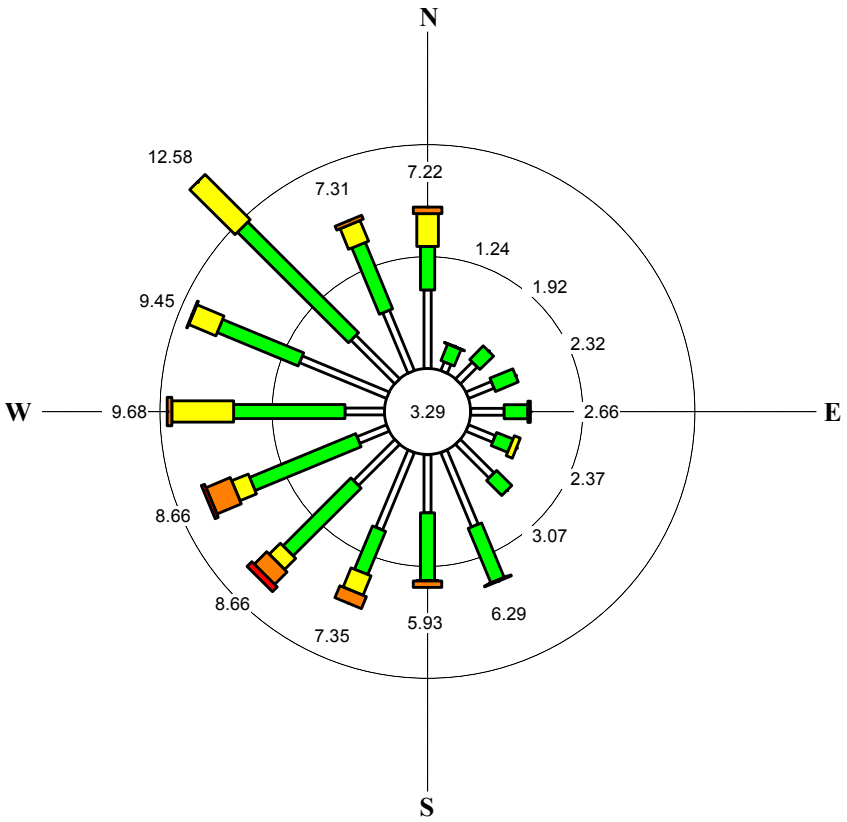
Wind rose charts are presented here for each month of the years from January 1998 through December 2002. Note that all charts for the Mees weather system are titled by:

uh"month"_"year"

The "Joint Frequency Distribution" charts show considerable information. The petal lengths show the percentage of events that occurred at each of the 16 points of the compass (percentage numbers are at the petal ends). The wind speed distribution is shown by the different color bars of the rose petals and the percentages (of each speed range) are indicated by the color-bar length. Wind speeds below 2 mph are considered "calms" and the percentage of calms is indicated in the central circle of the rose.

The wind speed thresholds were chosen to reflect operational constraints; 0 to 30 mph generally does not impact operations, 30 to 50 mph is a major operational concern, and over 50 mph is a site hazard regime.

Joint Frequency Distribution
uh_jan_98



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

February 1998

(There is no data for this month.)

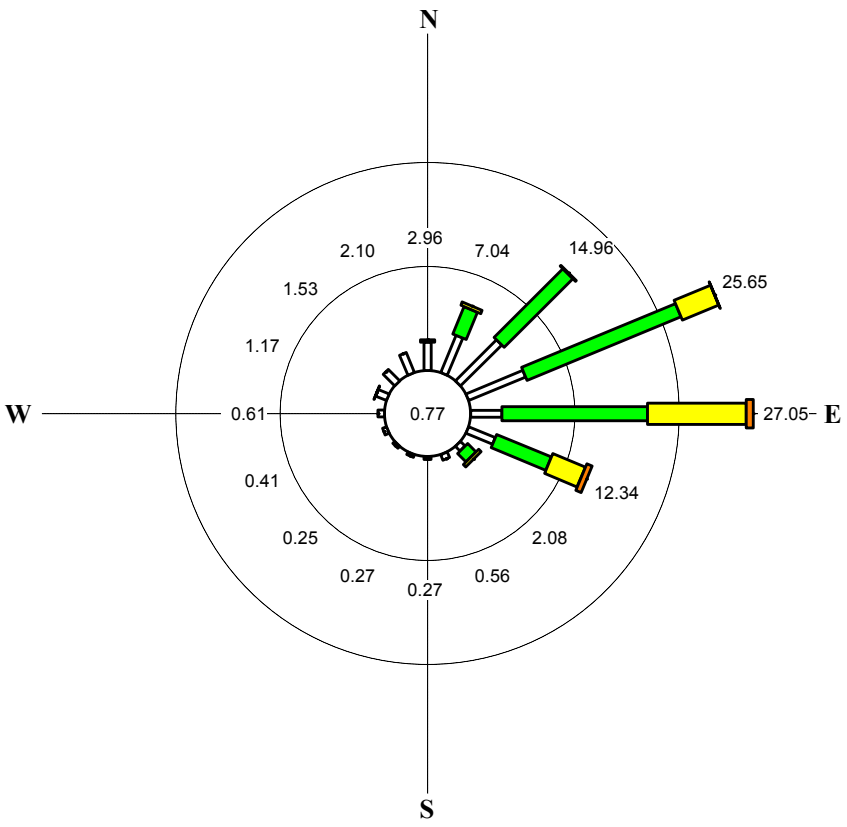
March 1998

(There is no data for this month.)

April 1998

(There is no data for this month.)

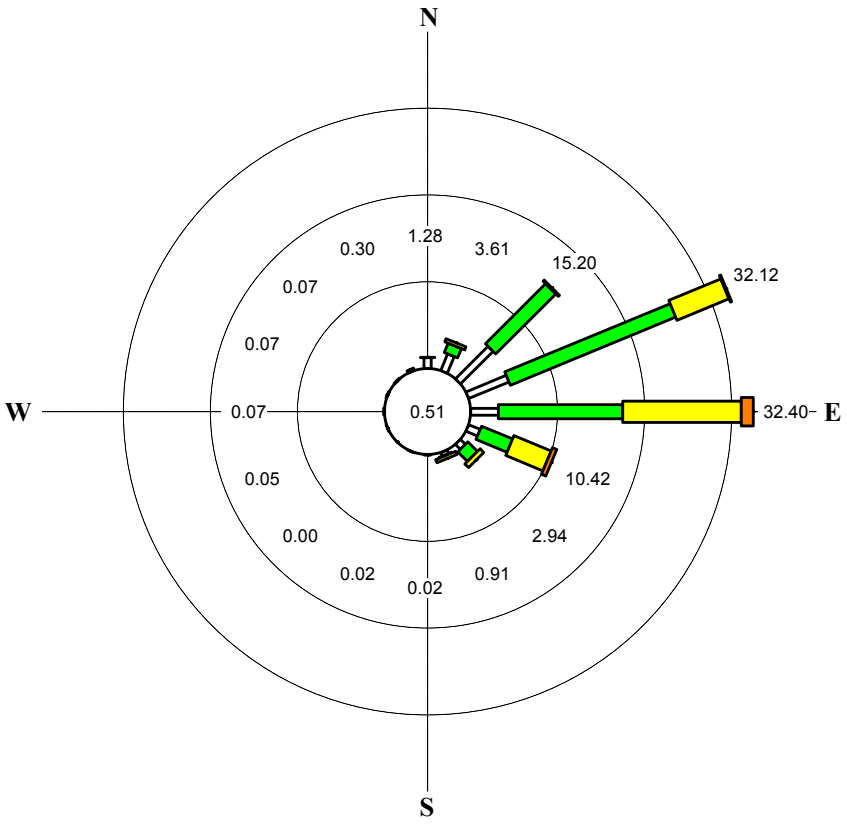
Joint Frequency Distribution
uh_may_98



Wind Speed (Miles Per Hour)

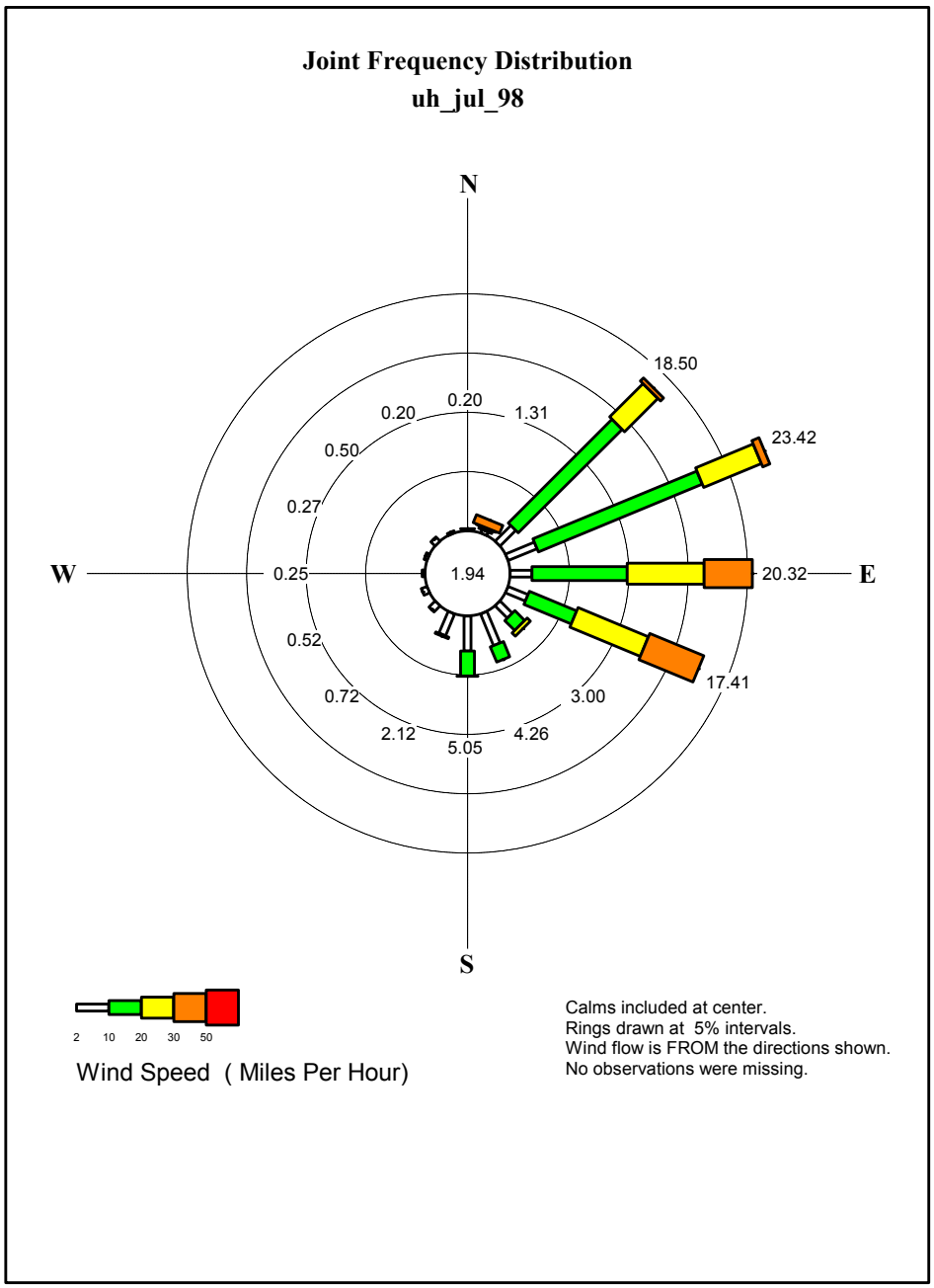
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_jun_98

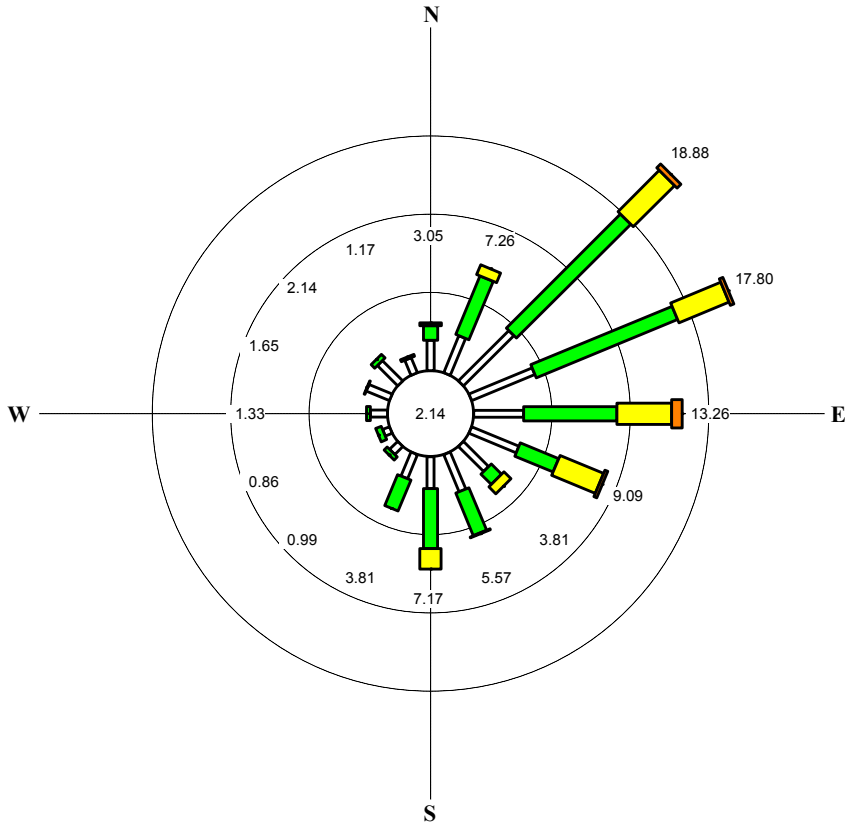


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_jul_98
N
W
E
S
18.50
23.42
20.32
17.41
3.00
4.26
5.05
2.12
0.72
0.52
0.25
0.27
0.50
0.20
0.20
1.31
1.94
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

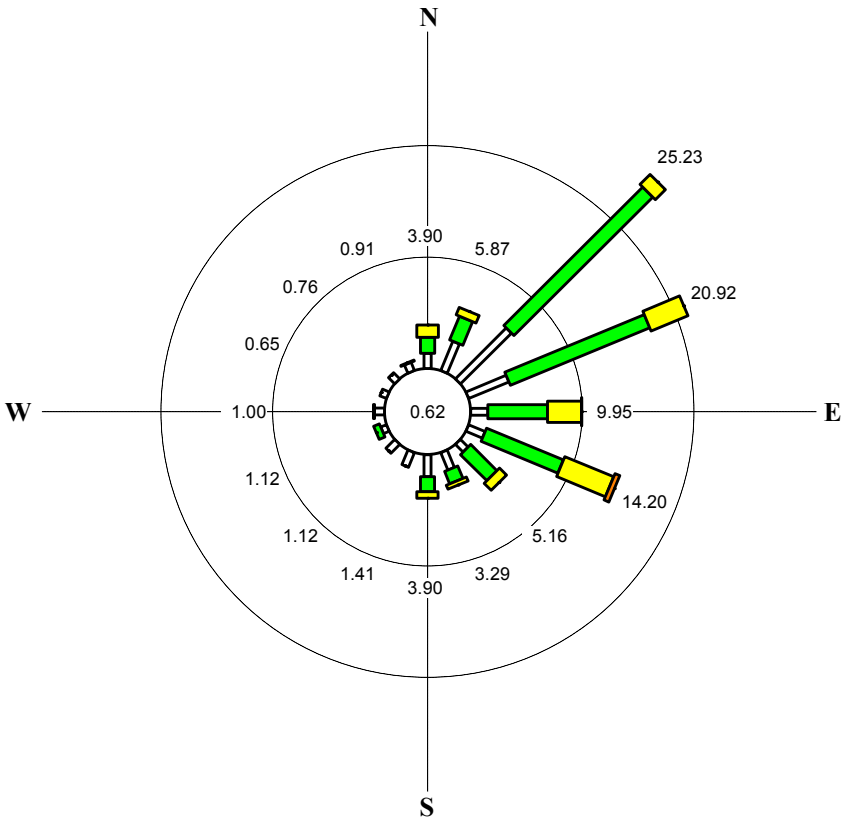
Joint Frequency Distribution
uh_aug_98



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

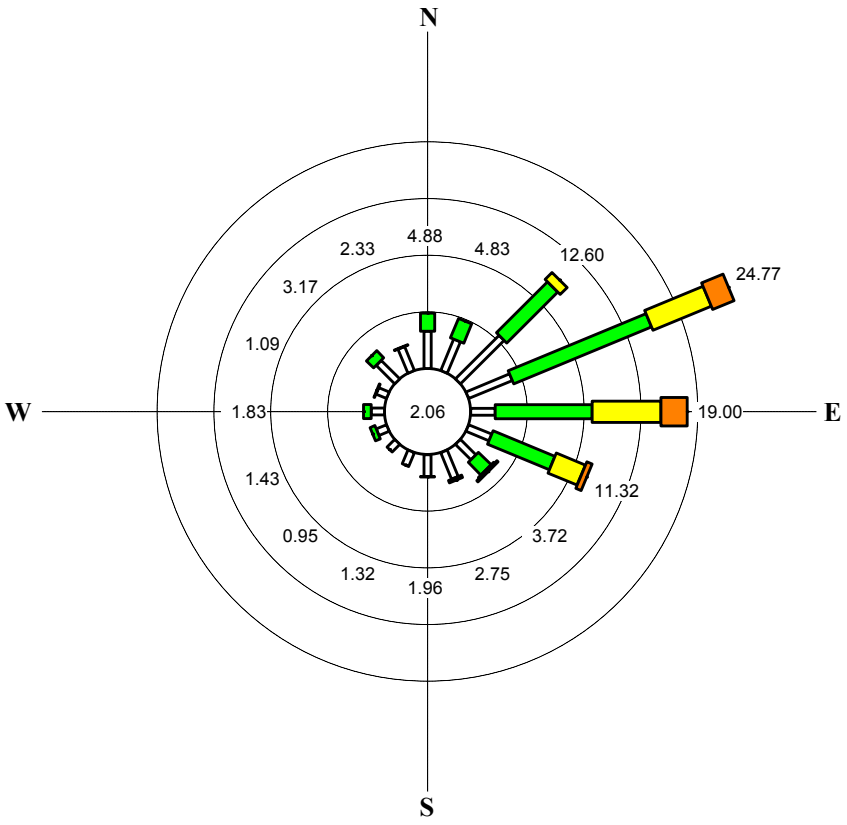
Joint Frequency Distribution
uh_sep_98



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

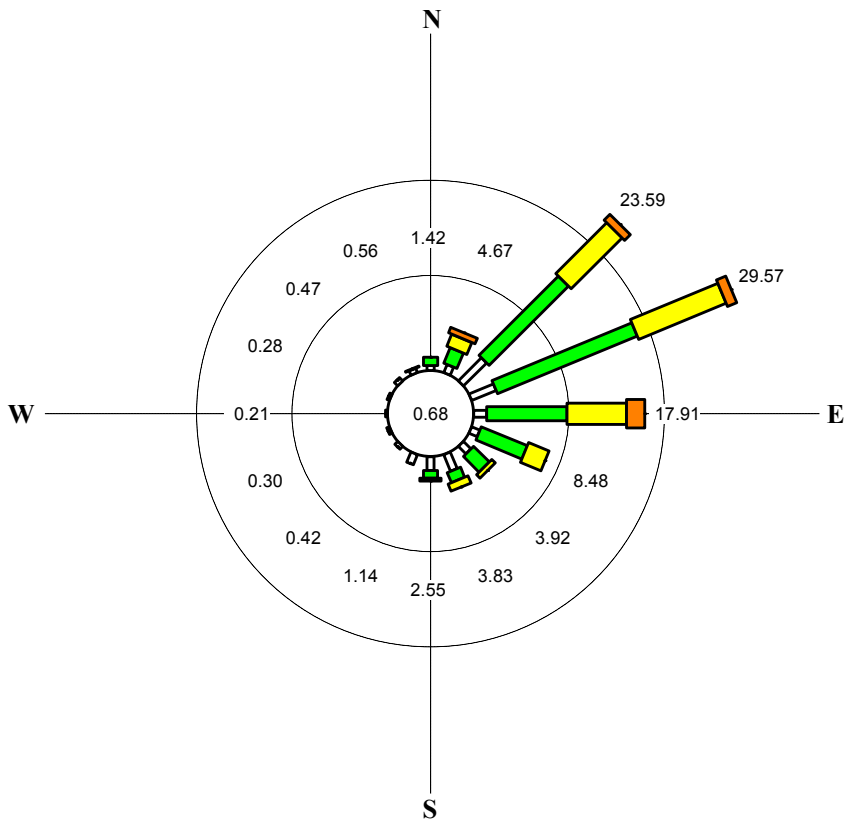
Joint Frequency Distribution
uh_oct_98



Wind Speed (Miles Per Hour)

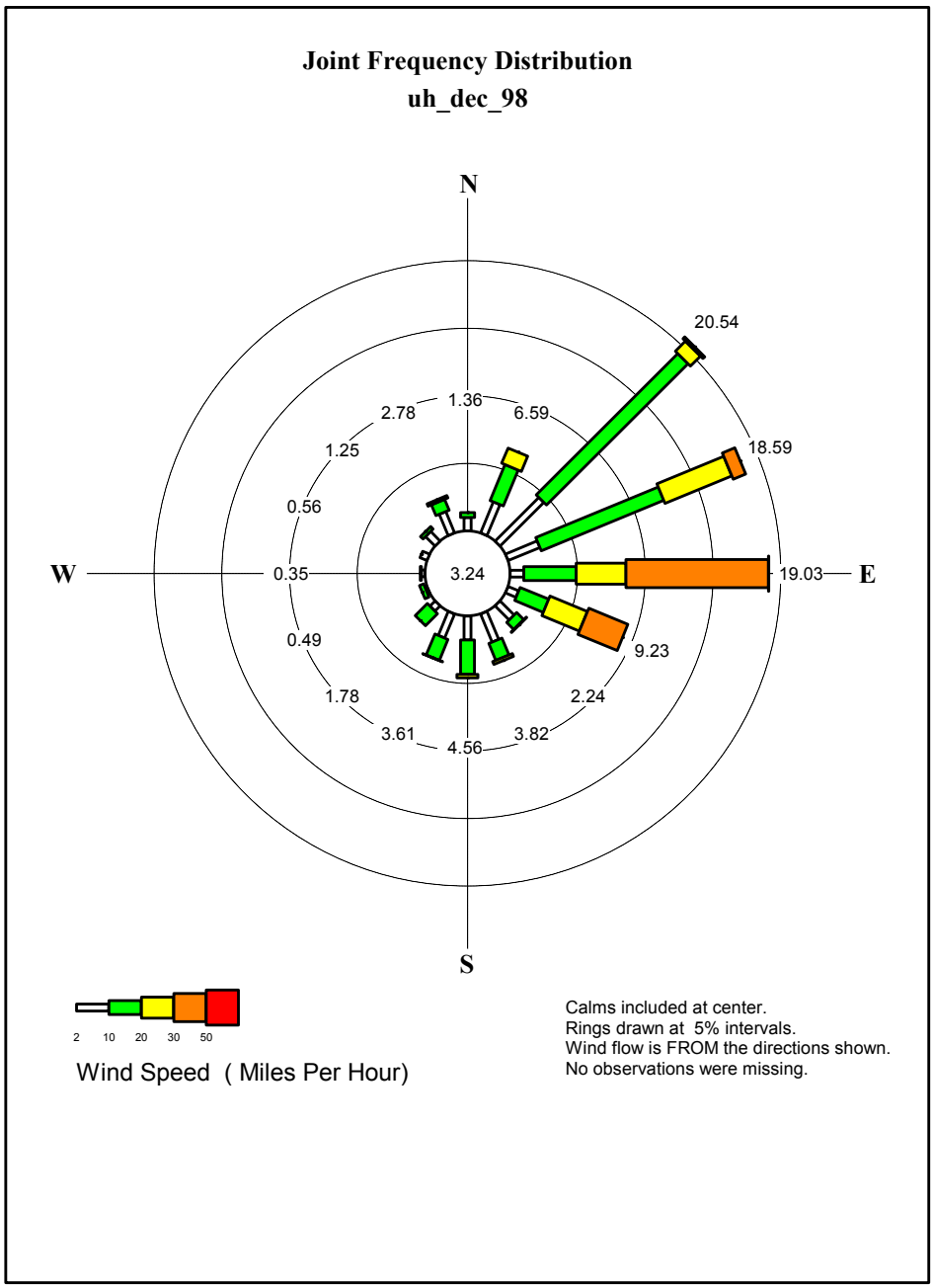
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_nov_98

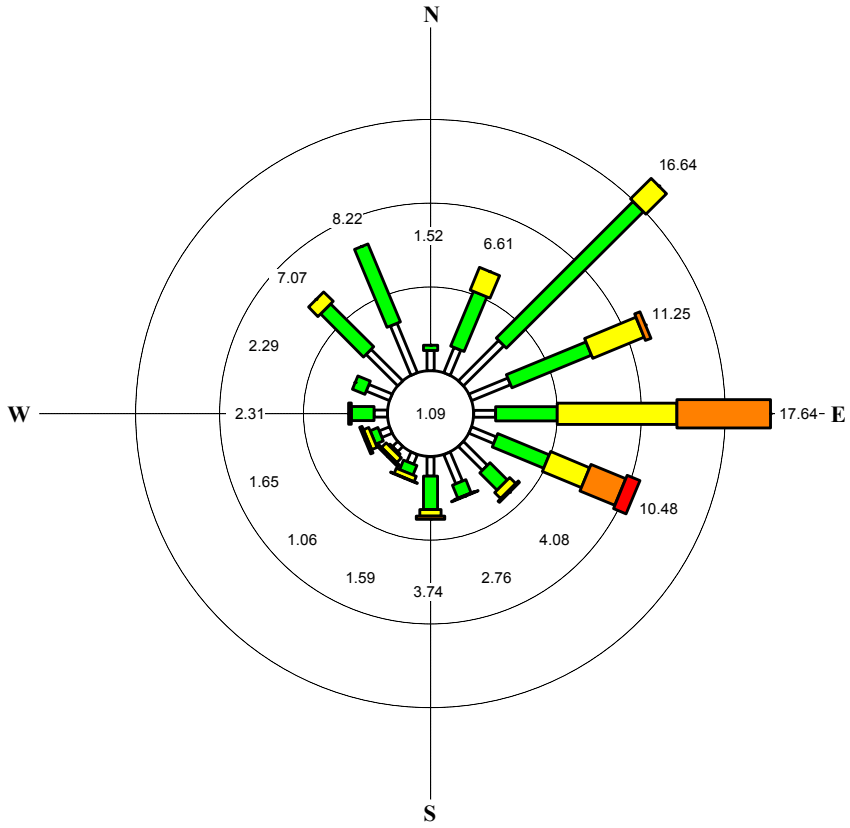


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_dec_98
N
W
E
S
20.54
18.59
19.03
9.23
2.24
3.82
4.56
3.61
1.78
0.49
0.35
0.56
1.25
2.78
1.36
6.59
3.24
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

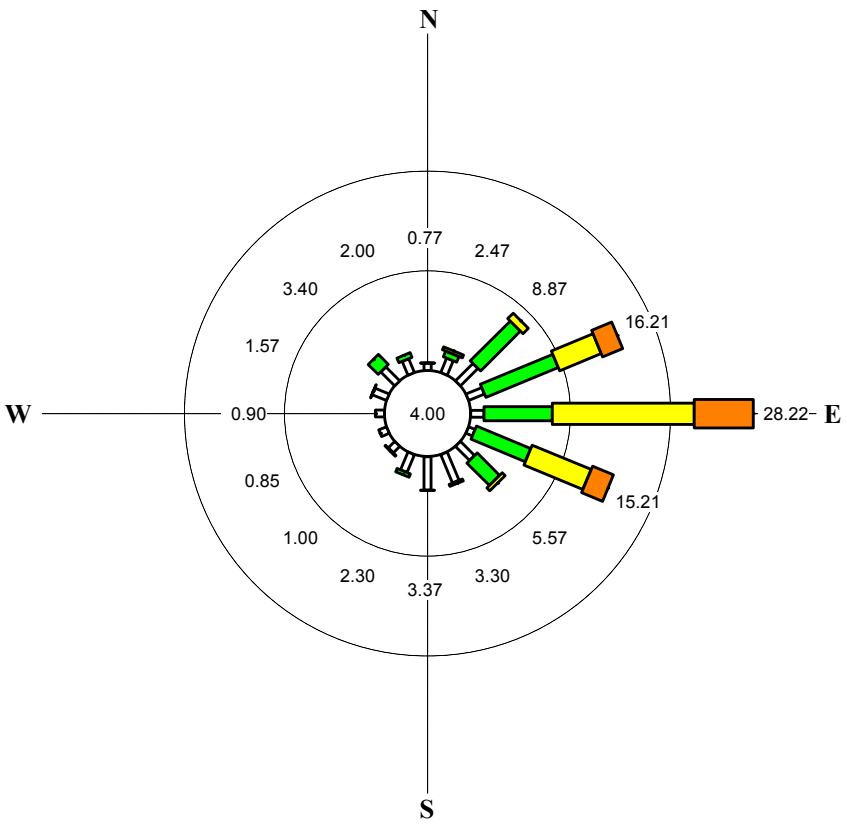
Joint Frequency Distribution
uh_jan_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

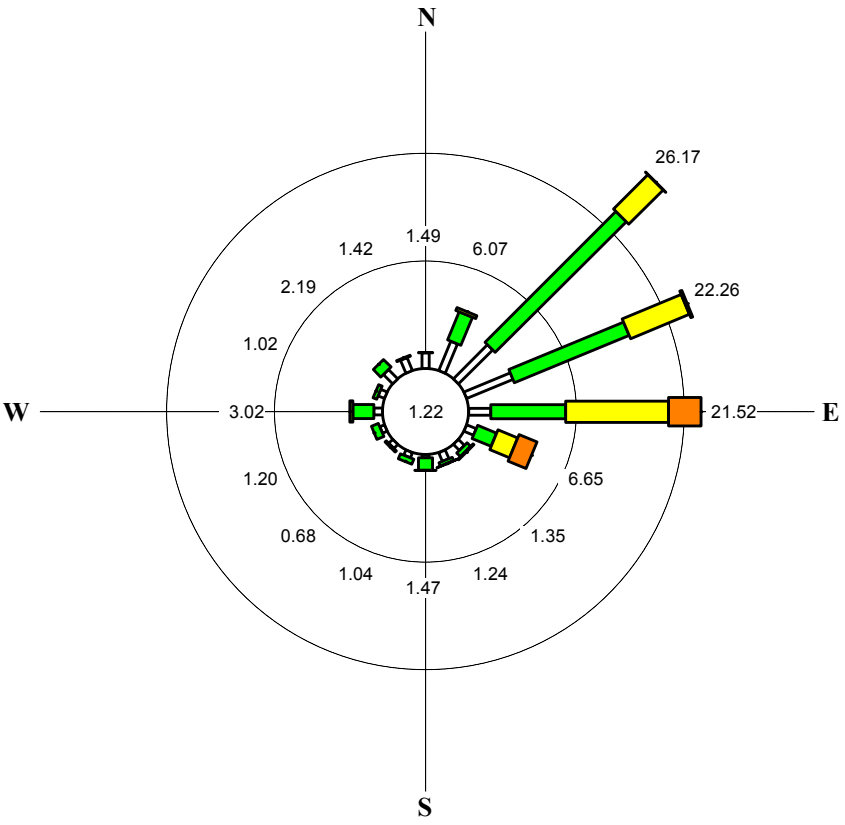
Joint Frequency Distribution
uh_feb_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

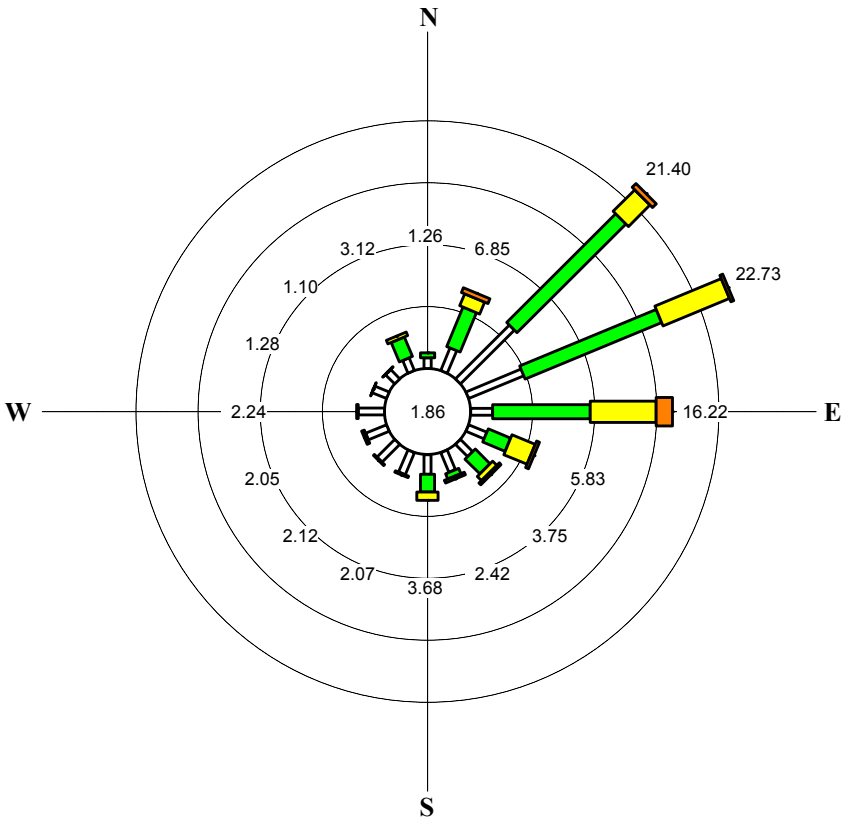
Joint Frequency Distribution
uh_mar_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

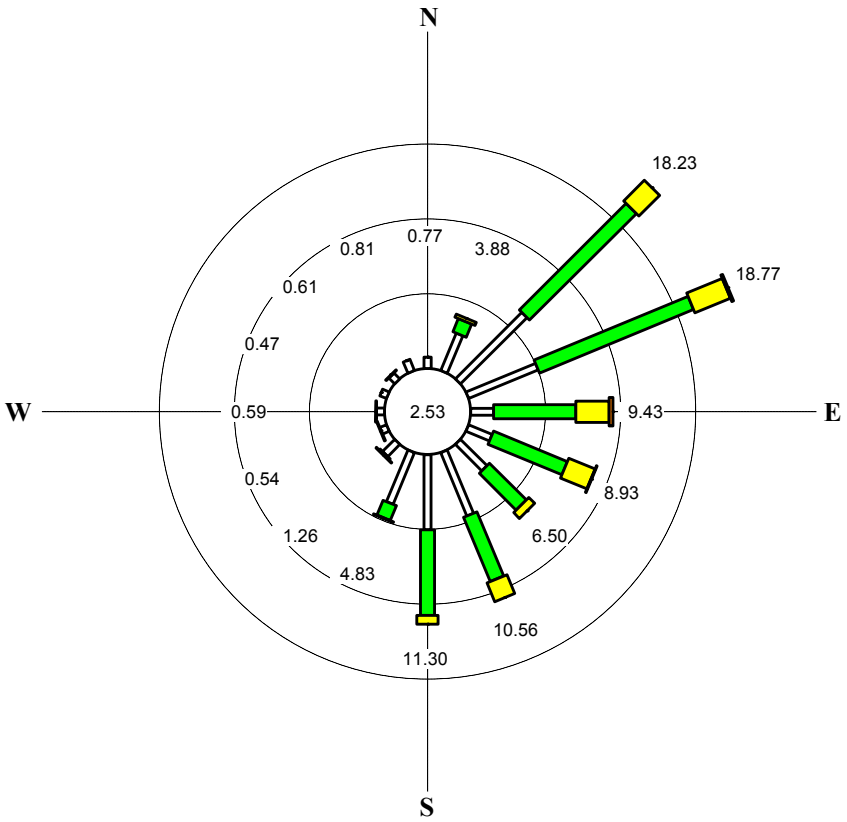
Joint Frequency Distribution
uh_apr_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

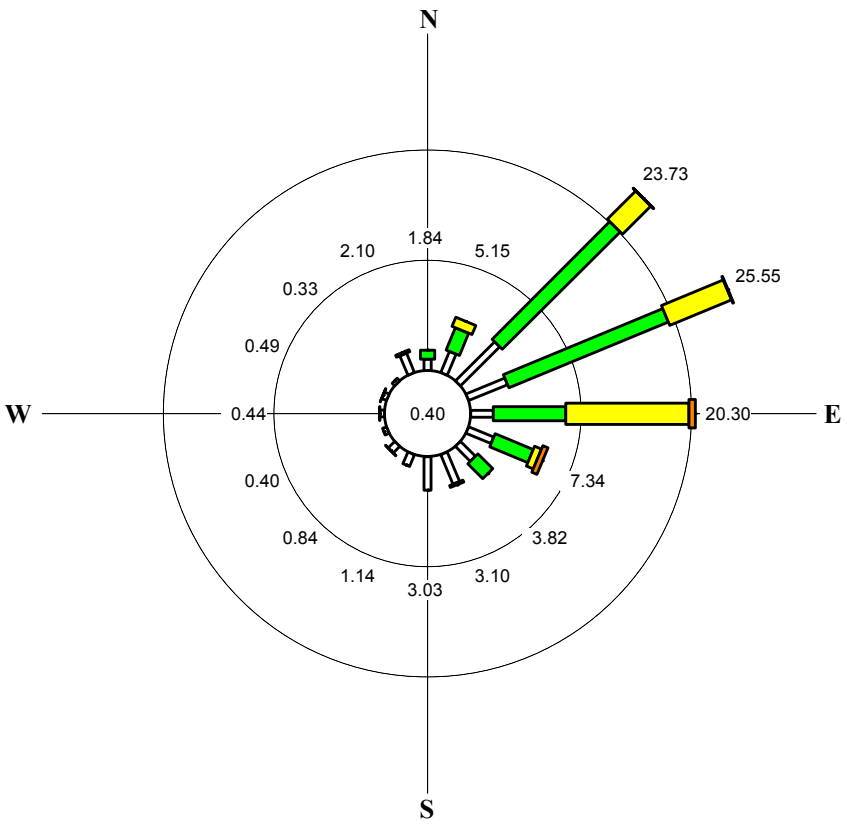
Joint Frequency Distribution
uh_may_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

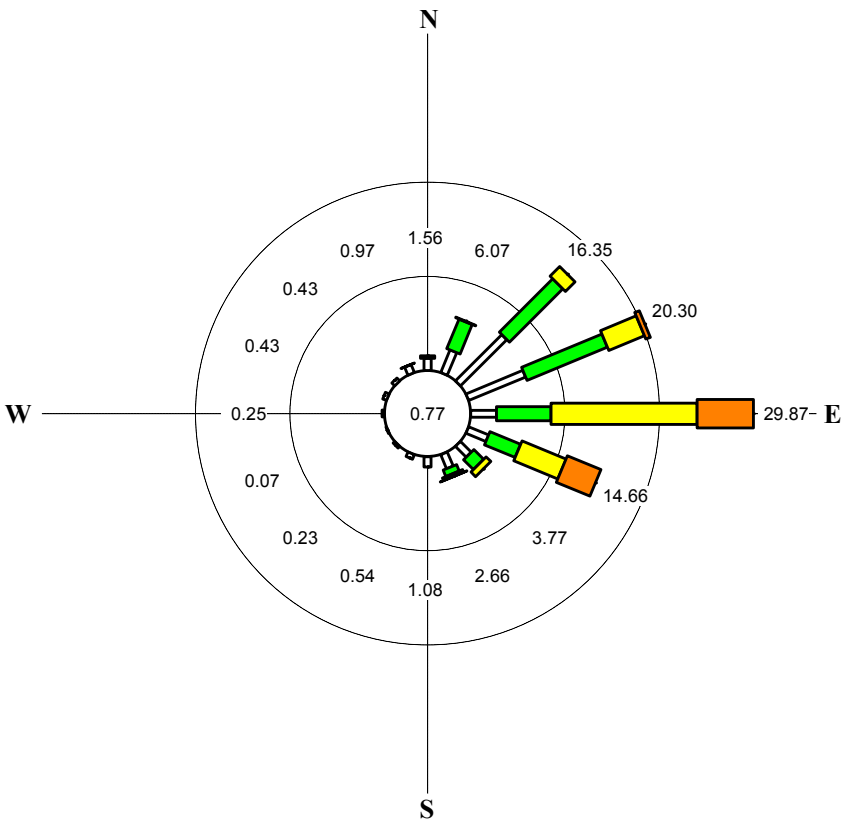
Joint Frequency Distribution
uh_jun_99



Wind Speed (Miles Per Hour)

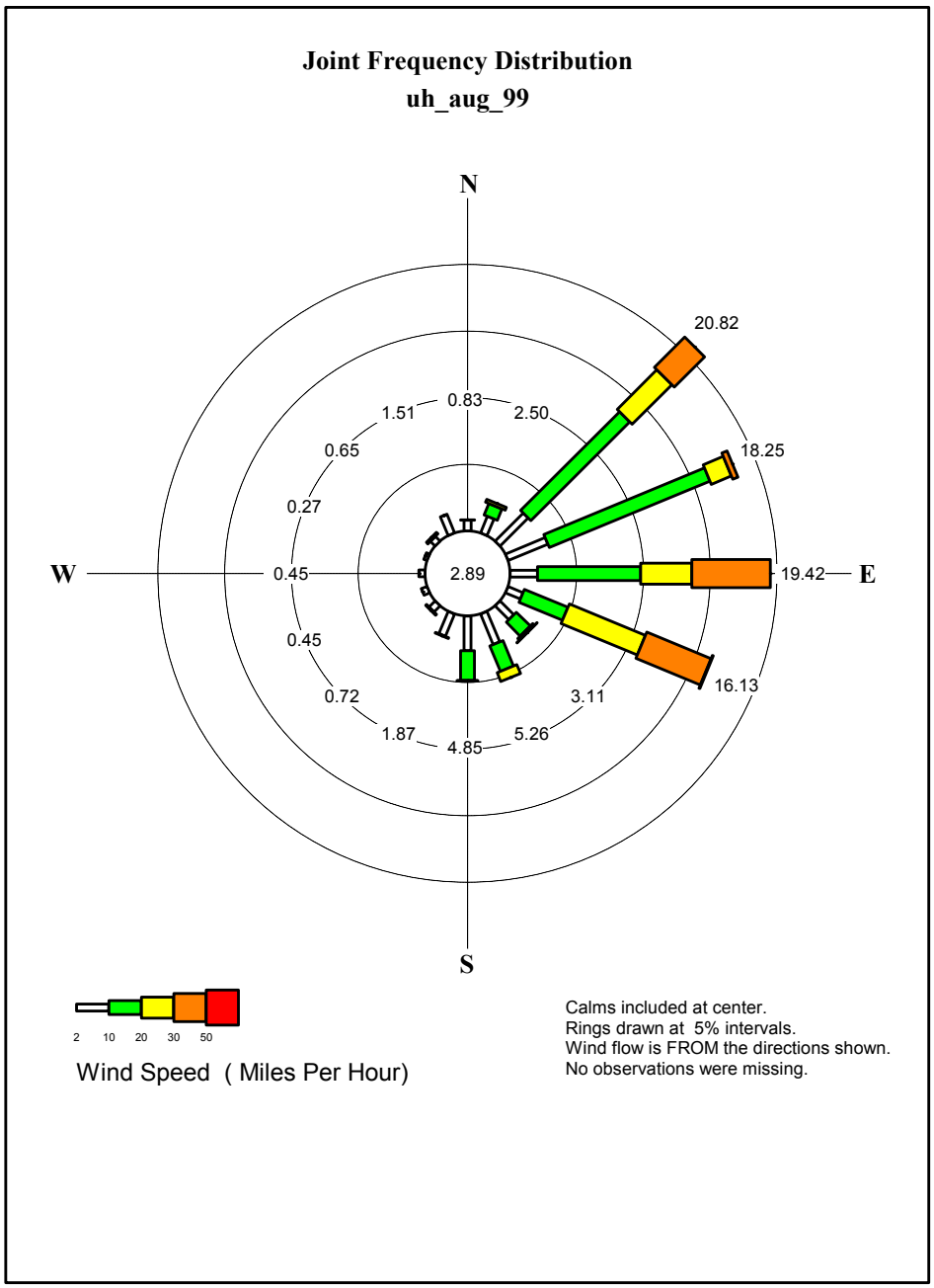
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_jul_99

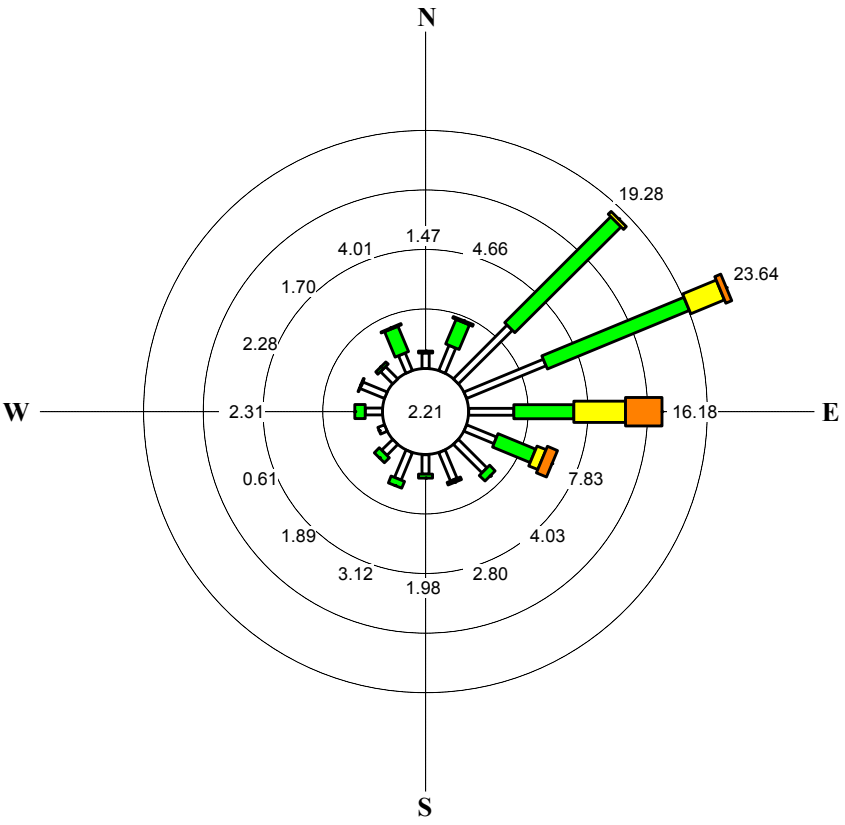


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_aug_99
N
E
S
W
20.82
18.25
19.42
16.13
3.11
5.26
4.85
1.87
0.72
0.45
0.27
0.65
1.51
0.83
2.50
0.45
2.89
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

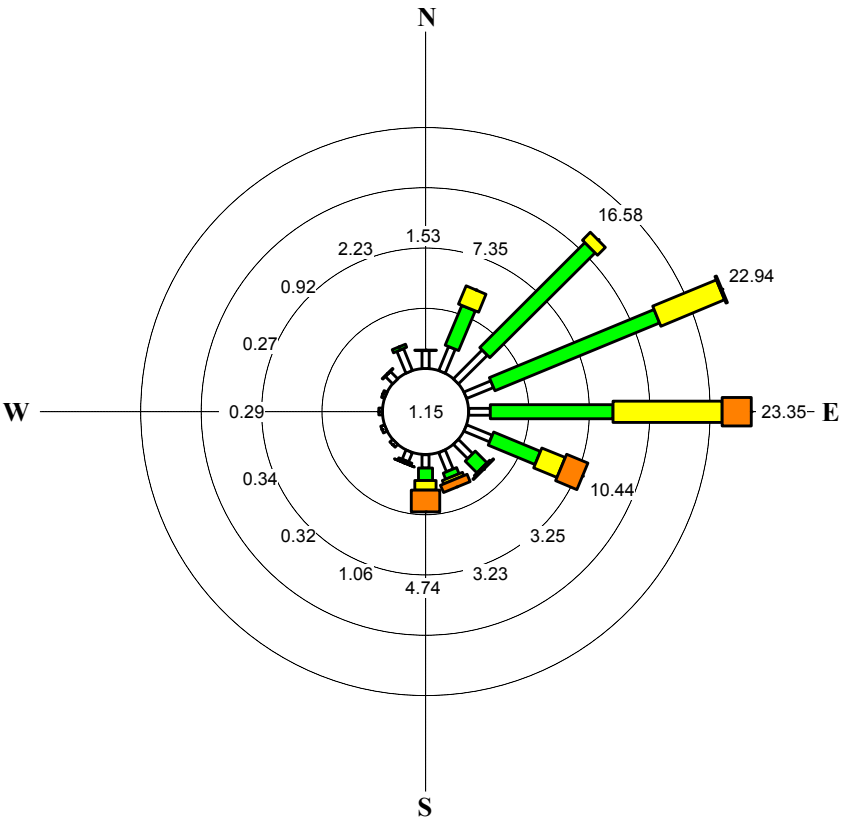
Joint Frequency Distribution
uh_sep_99



Wind Speed (Miles Per Hour)

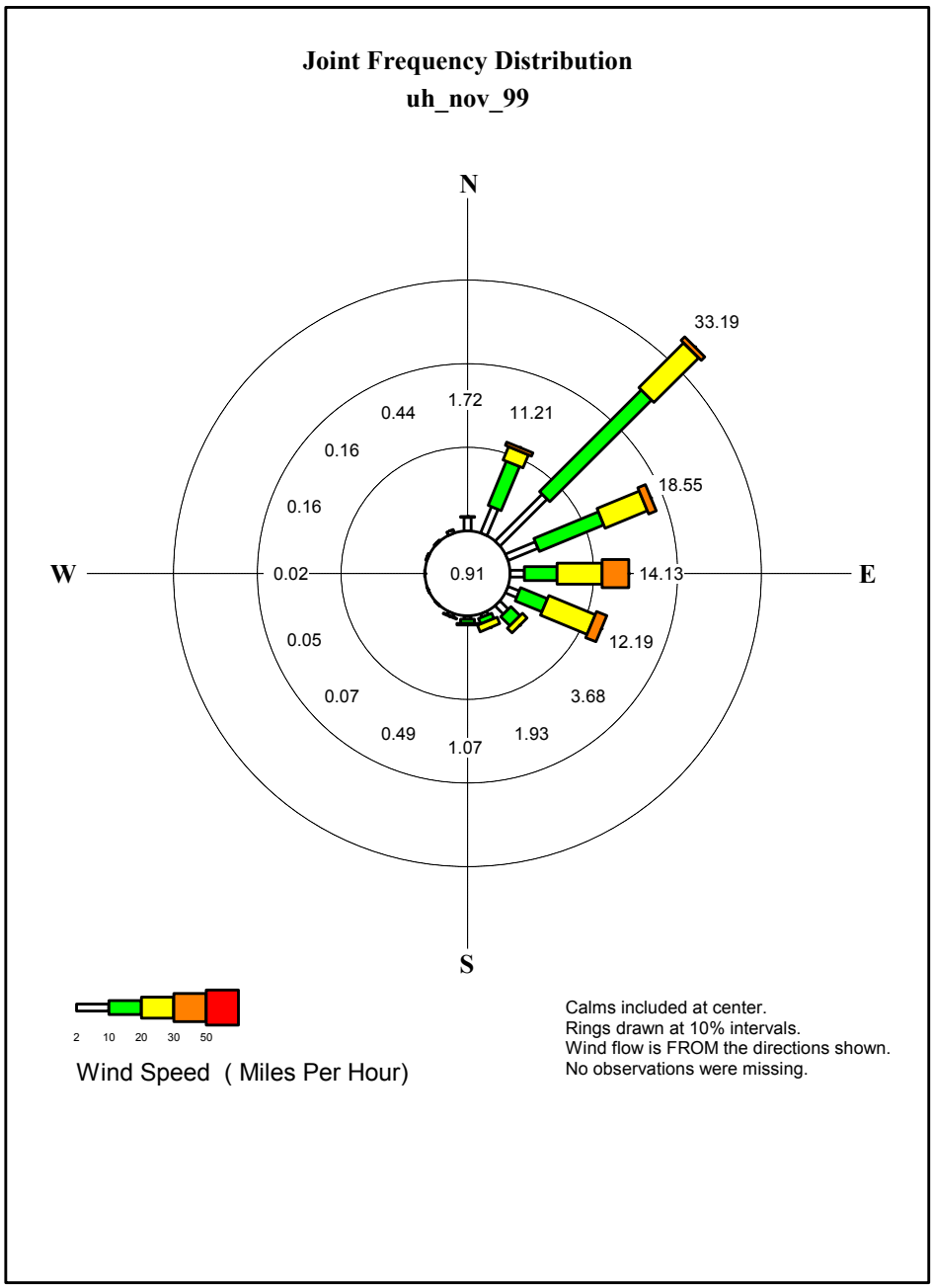
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_oct_99



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_nov_99
N
E
S
W
33.19
18.55
14.13
12.19
3.68
1.93
1.07
0.49
0.07
0.05
0.02
0.16
0.16
0.44
1.72
11.21
0.91
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

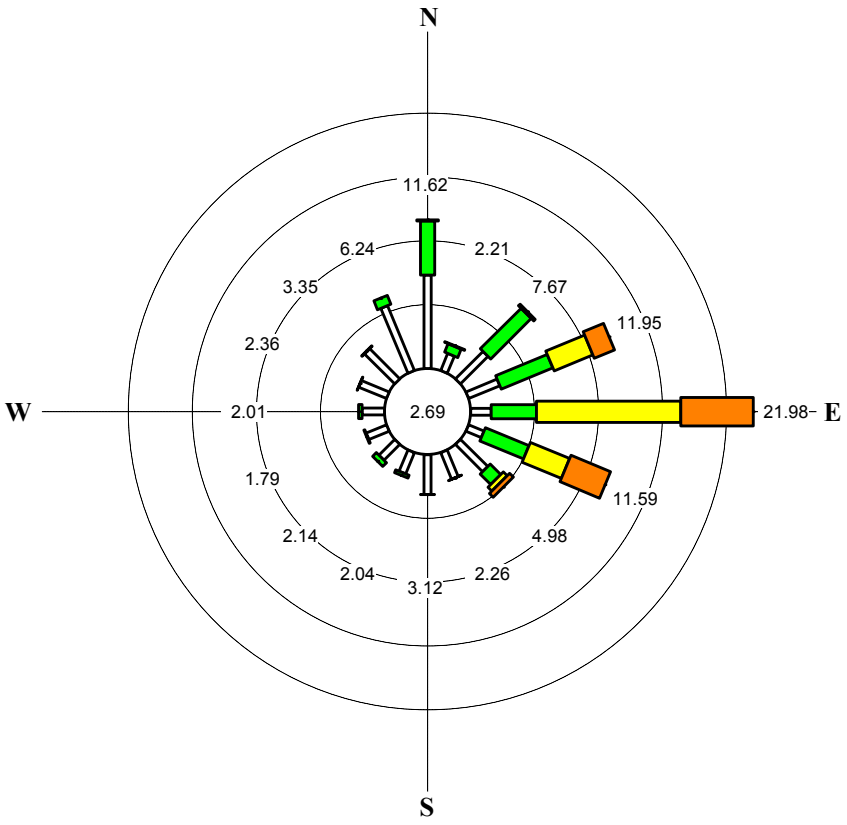
December 1999

(There is no data for this month.)

January 2000

(There is no data for this month.)

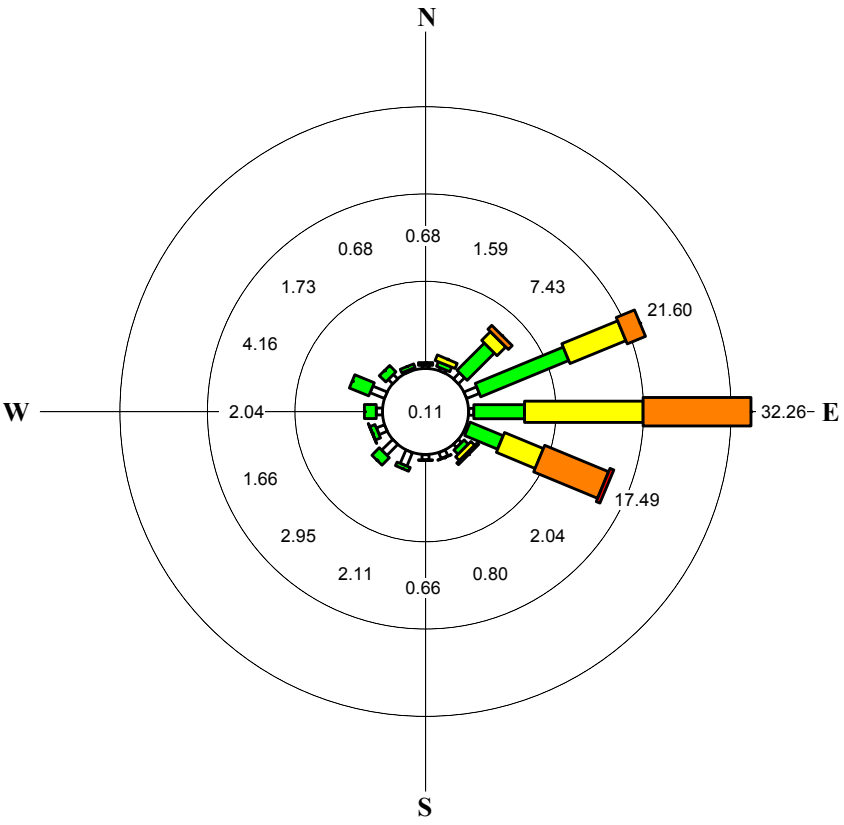
Joint Frequency Distribution
uh_feb_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

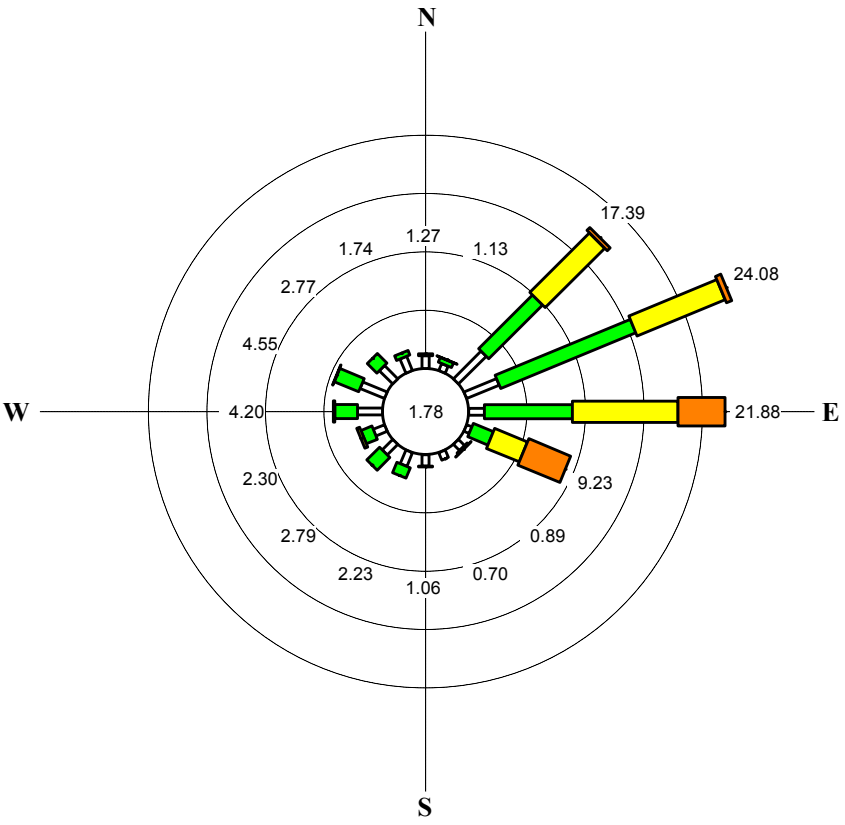
Joint Frequency Distribution
uh_mar_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

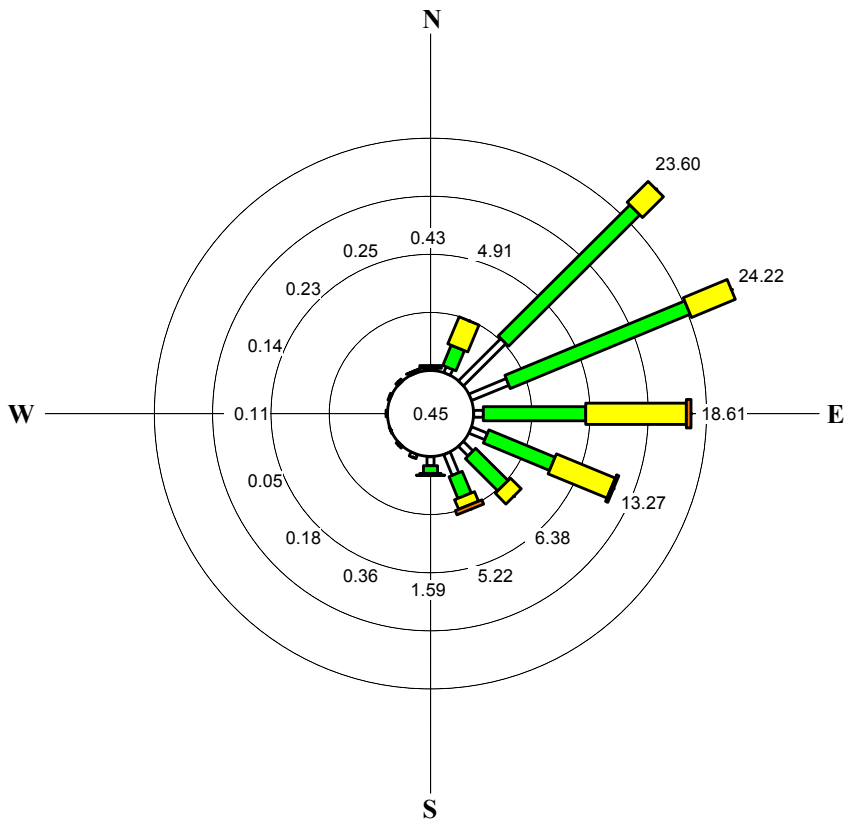
Joint Frequency Distribution
uh_apr_00



Wind Speed (Miles Per Hour)

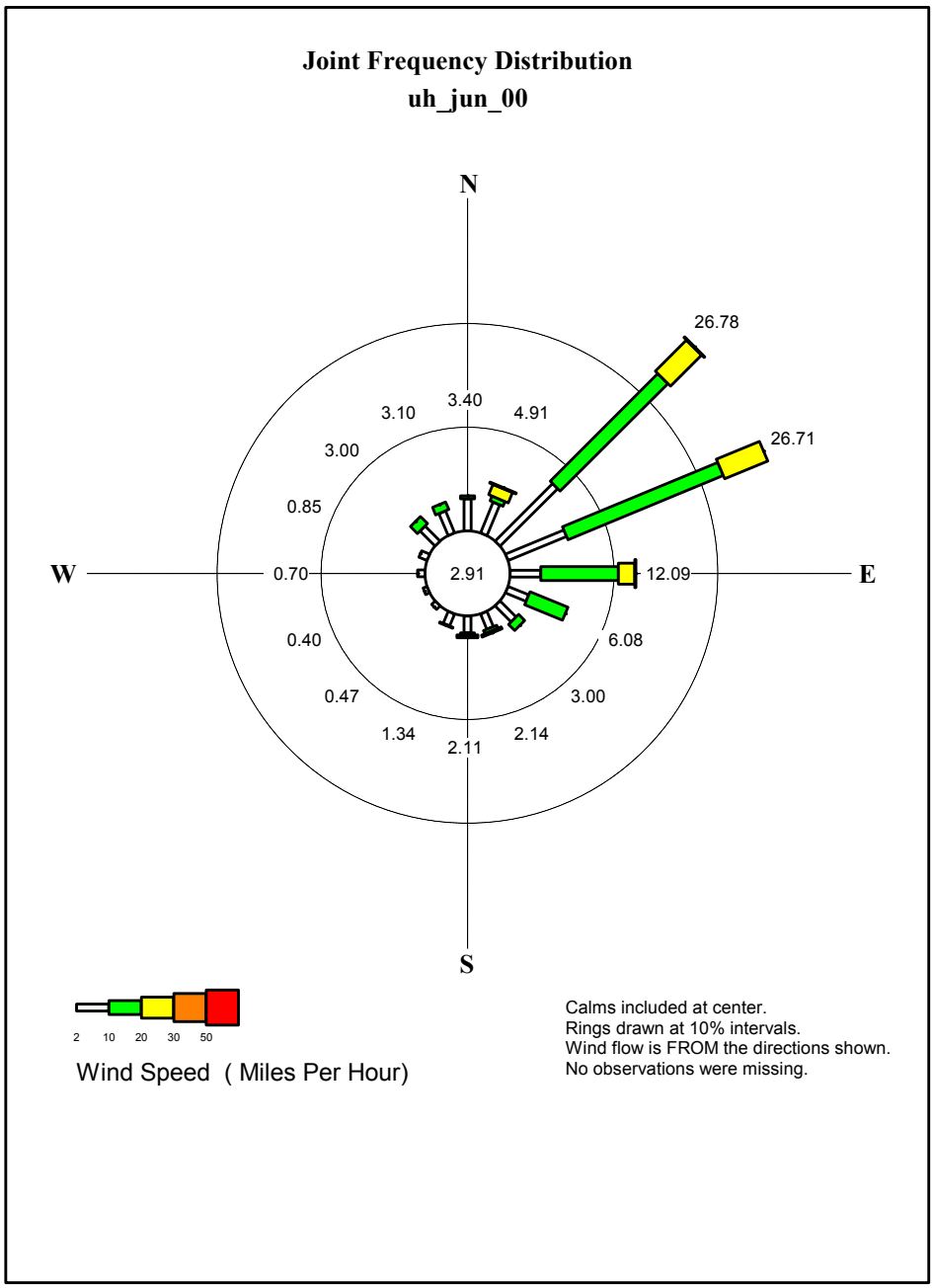
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

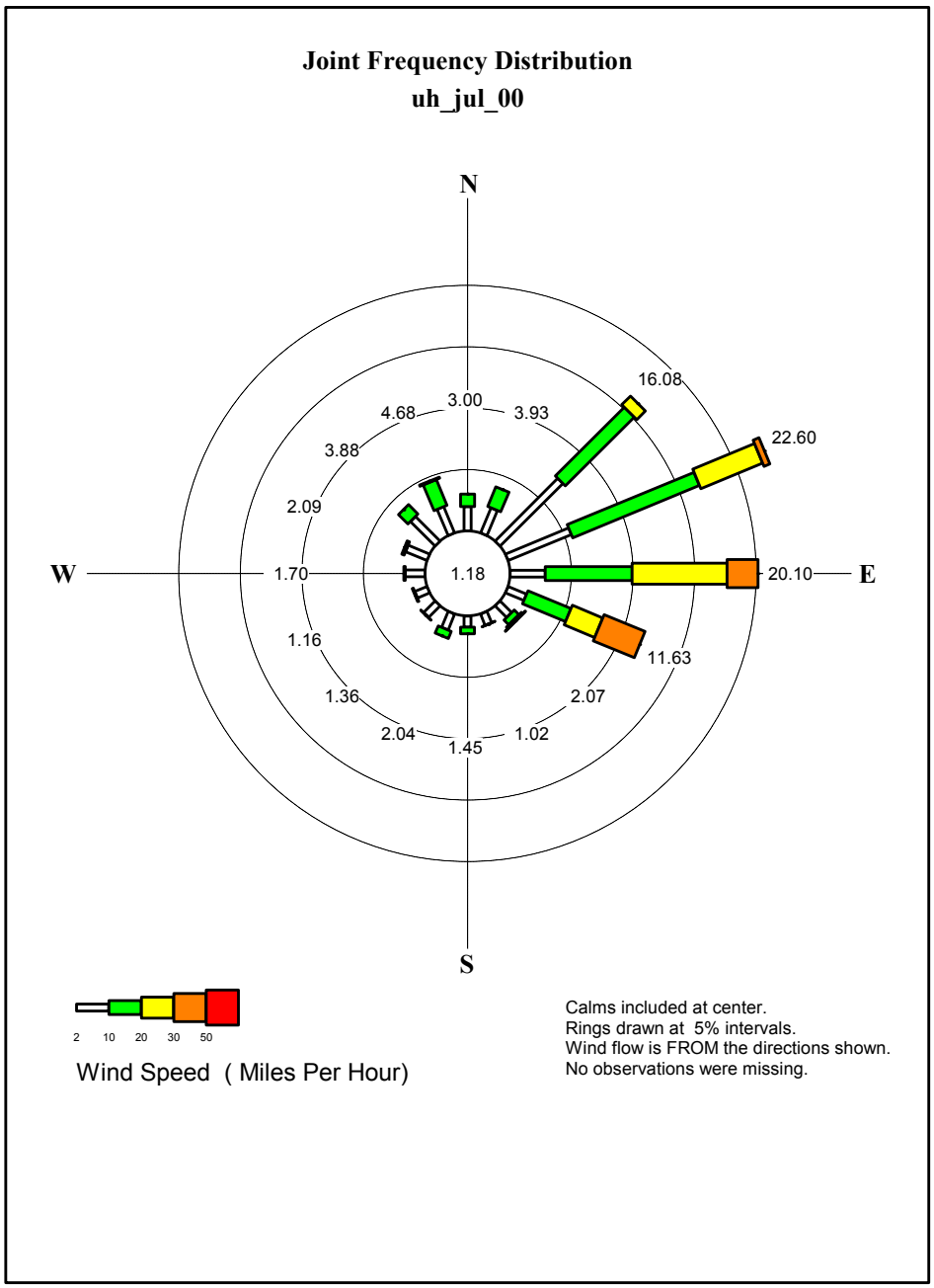
Joint Frequency Distribution
uh_may_00



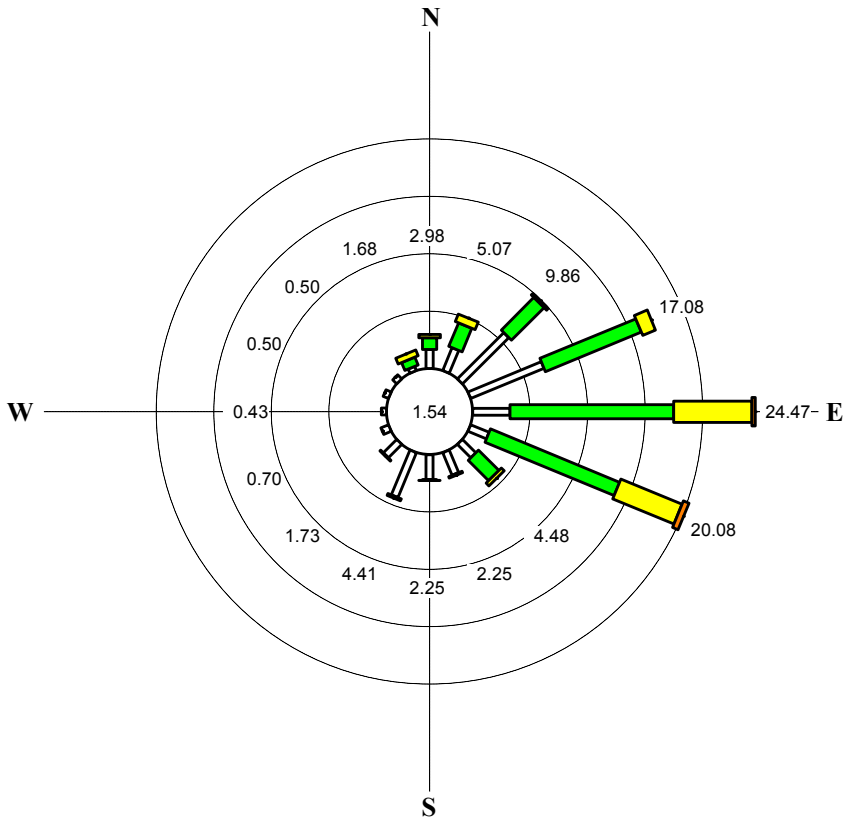
Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_jun_00
N
E
S
W
26.78
26.71
12.09
6.08
3.00
2.14
2.11
1.34
0.47
0.40
0.70
0.85
3.00
3.10
3.40
4.91
2.91
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

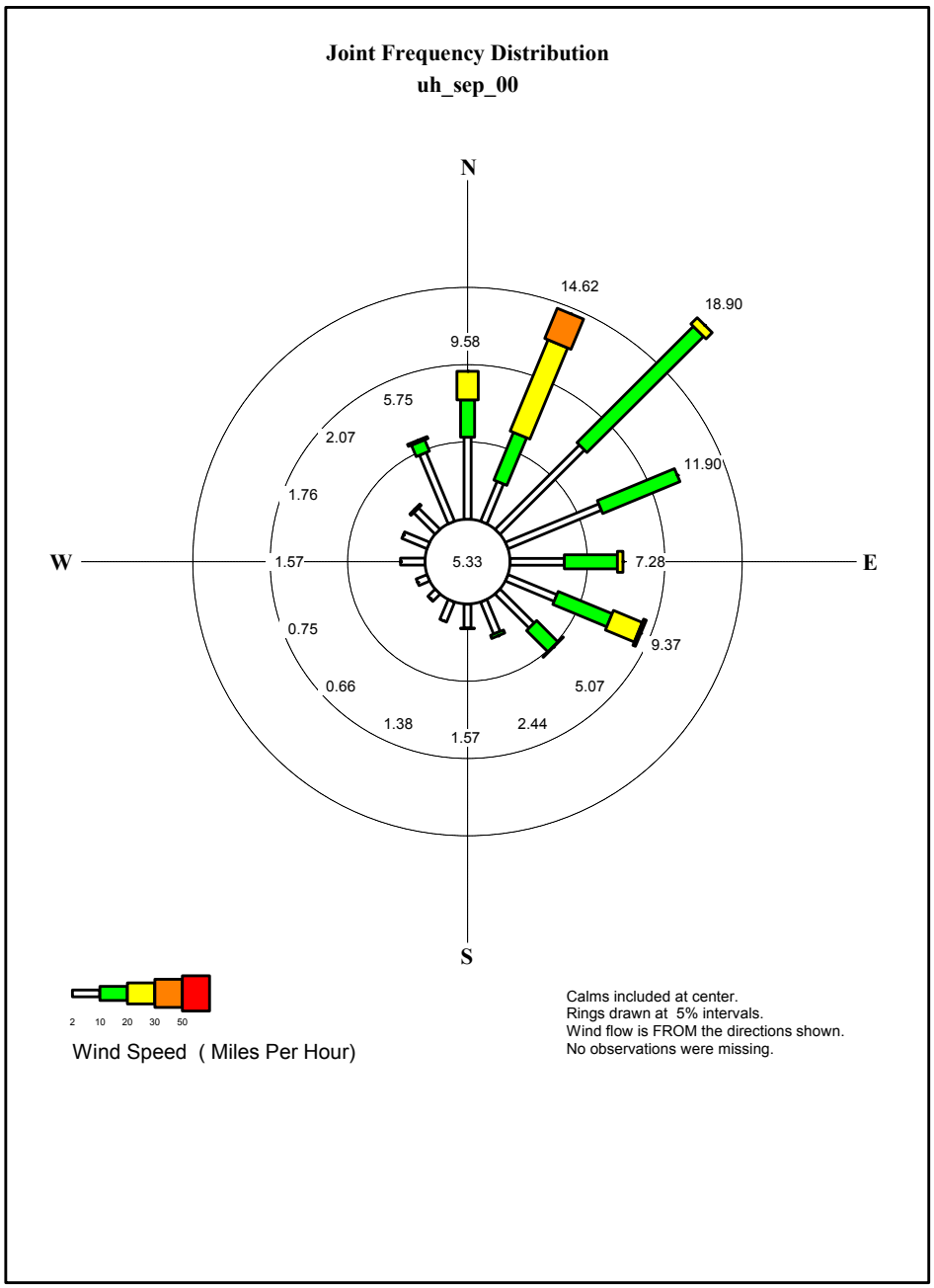

Joint Frequency Distribution
uh_jul_00
N
S
W
E
16.08
22.60
20.10
11.63
2.07
1.02
1.45
2.04
1.36
1.16
2.09
3.88
4.68
3.00
3.93
1.70
1.18
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

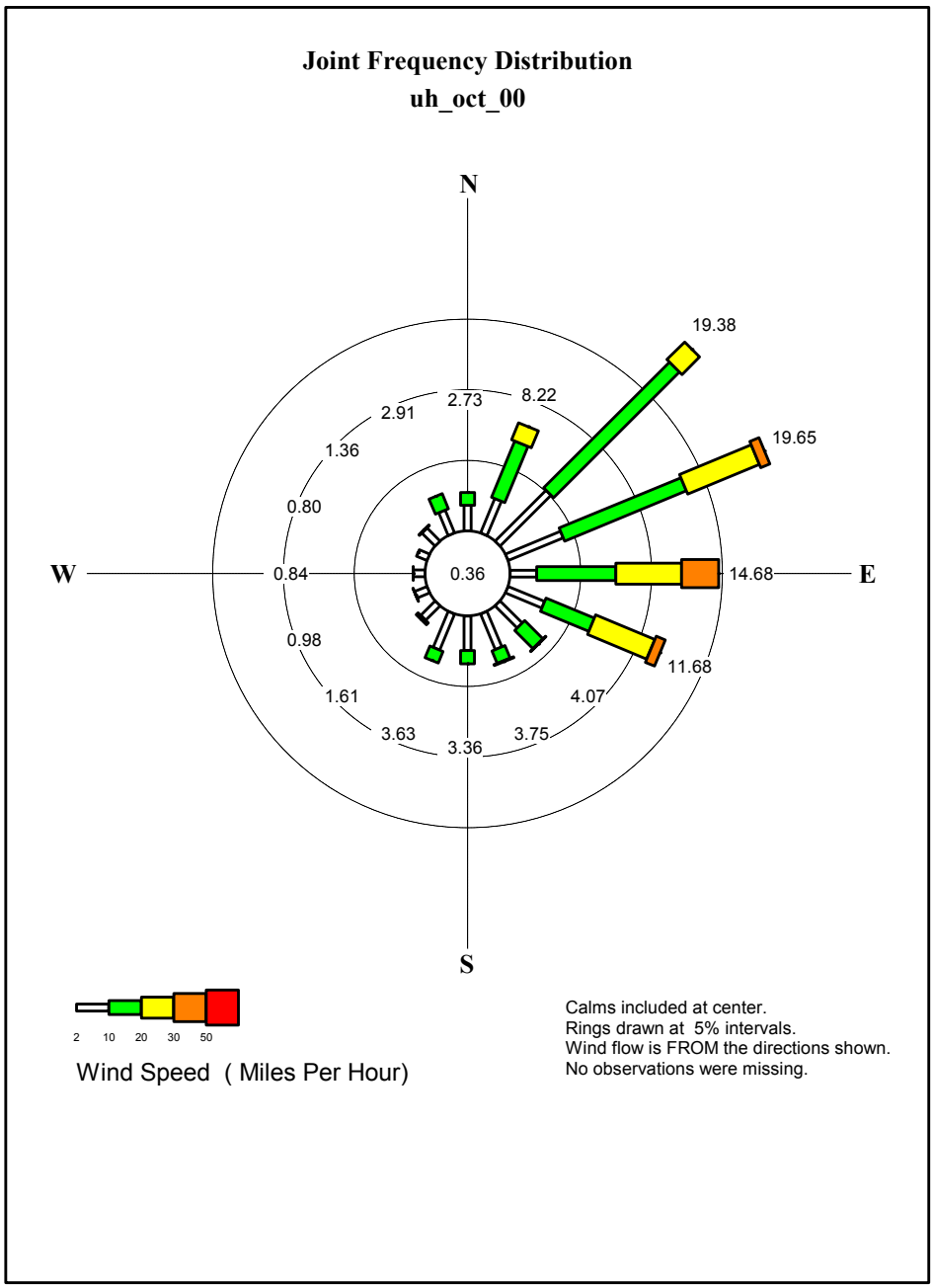
Joint Frequency Distribution
uh_aug_00



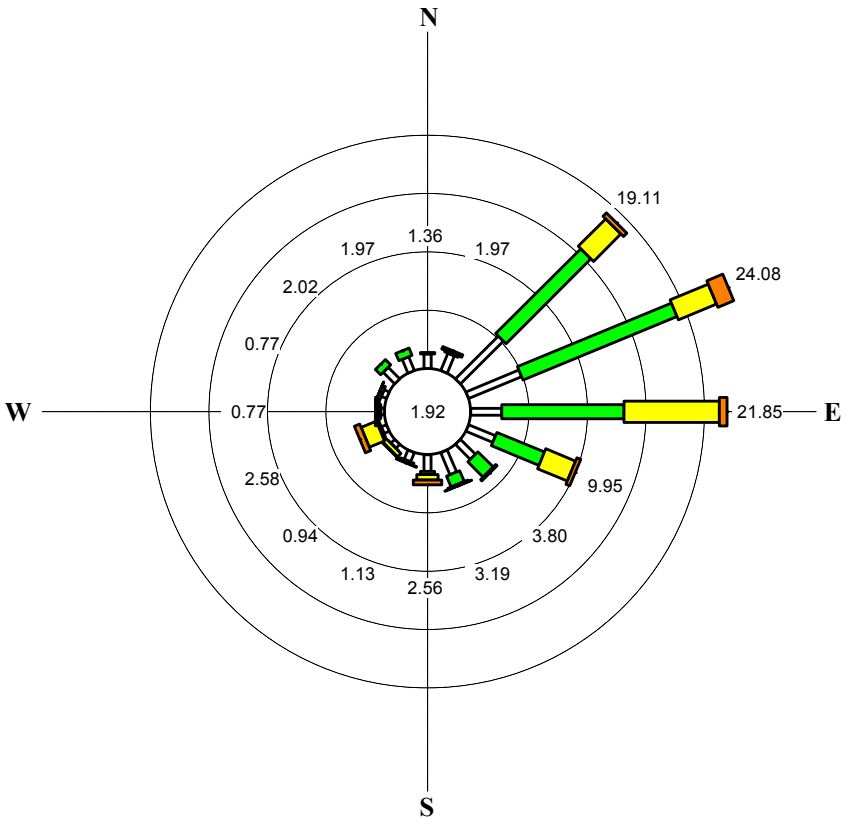
Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_sep_00
N
E
S
W
14.62
18.90
9.58
5.75
2.07
11.90
1.76
1.57
5.33
7.28
0.75
9.37
0.66
5.07
1.38
2.44
1.57
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_oct_00
N
E
S
W
19.38
19.65
14.68
11.68
4.07
3.75
3.36
3.63
1.61
0.98
0.84
0.80
1.36
2.91
2.73
8.22
0.36
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

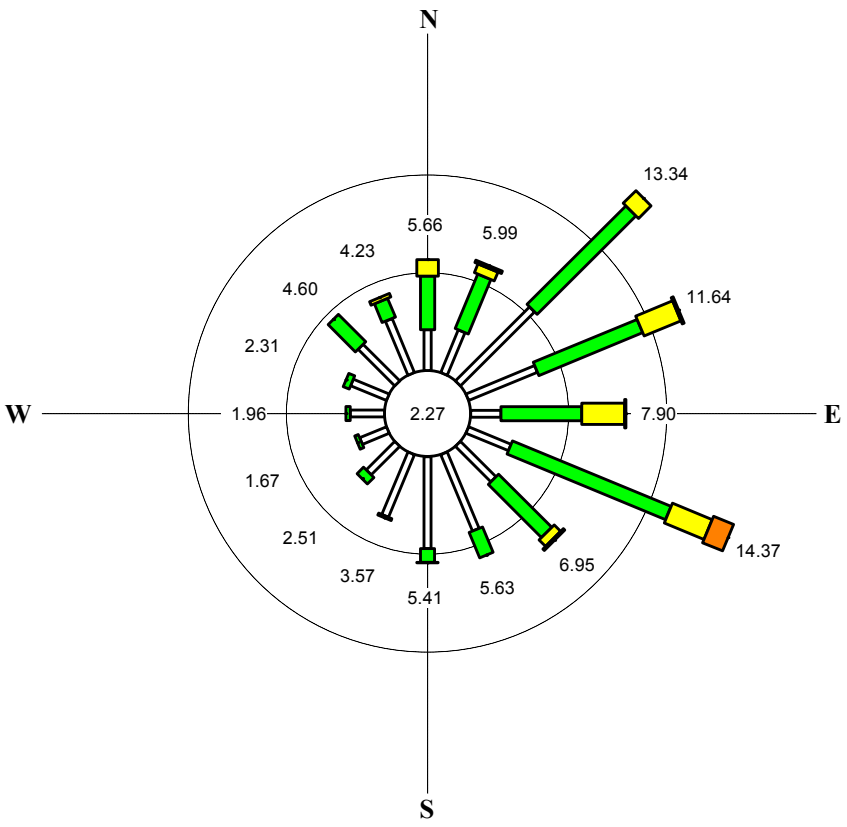
Joint Frequency Distribution
uh_nov_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

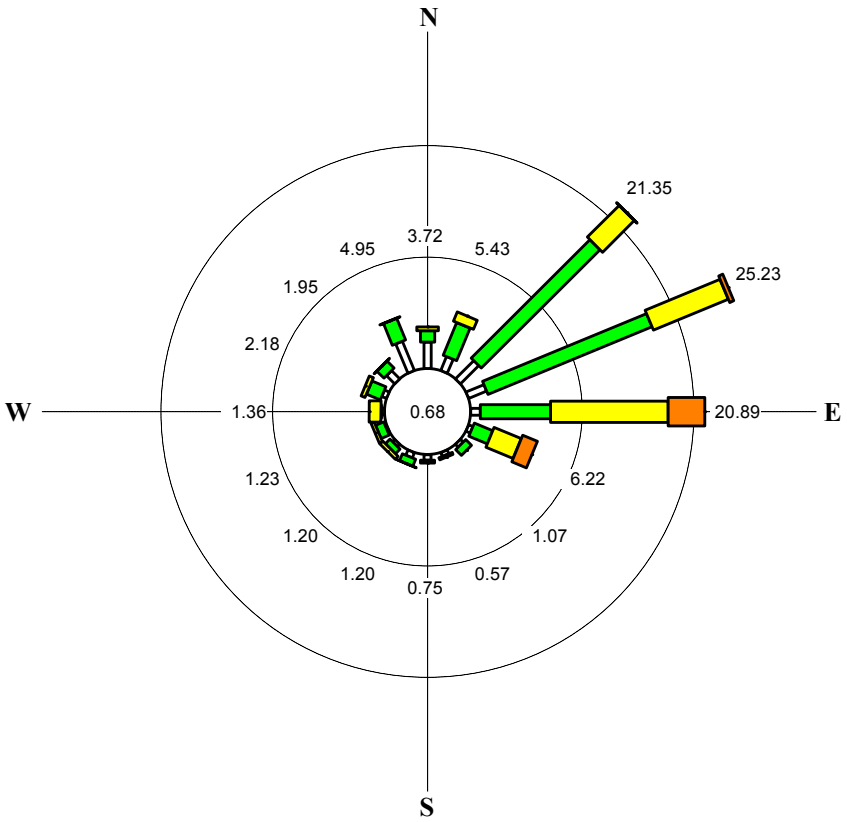
Joint Frequency Distribution
uh_dec_00



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

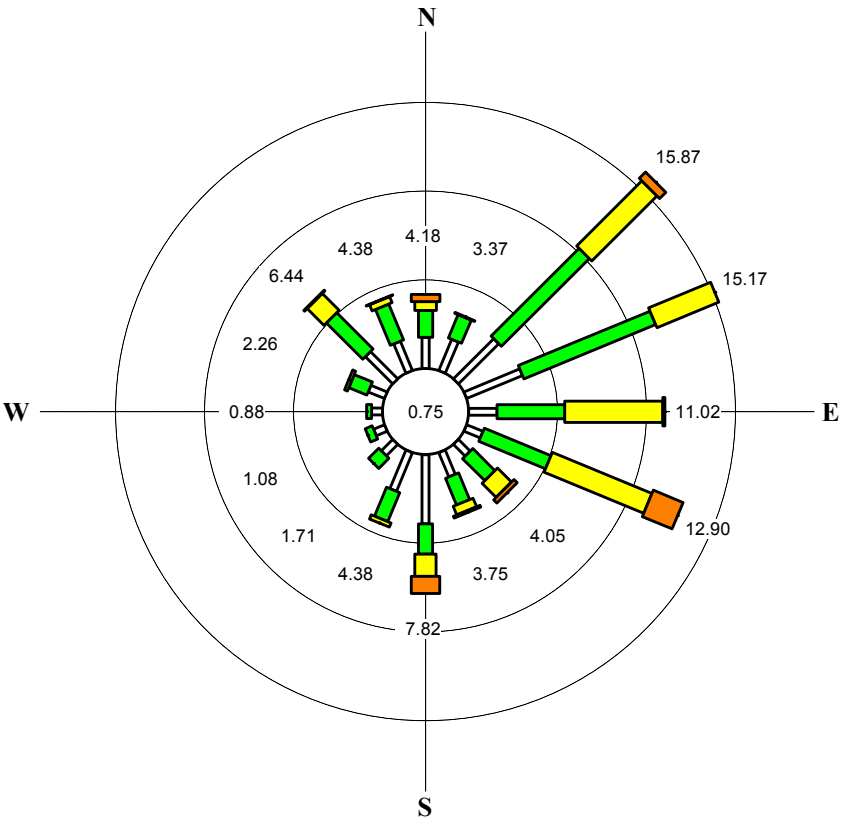
Joint Frequency Distribution
uh_jan_01



Wind Speed (Miles Per Hour)

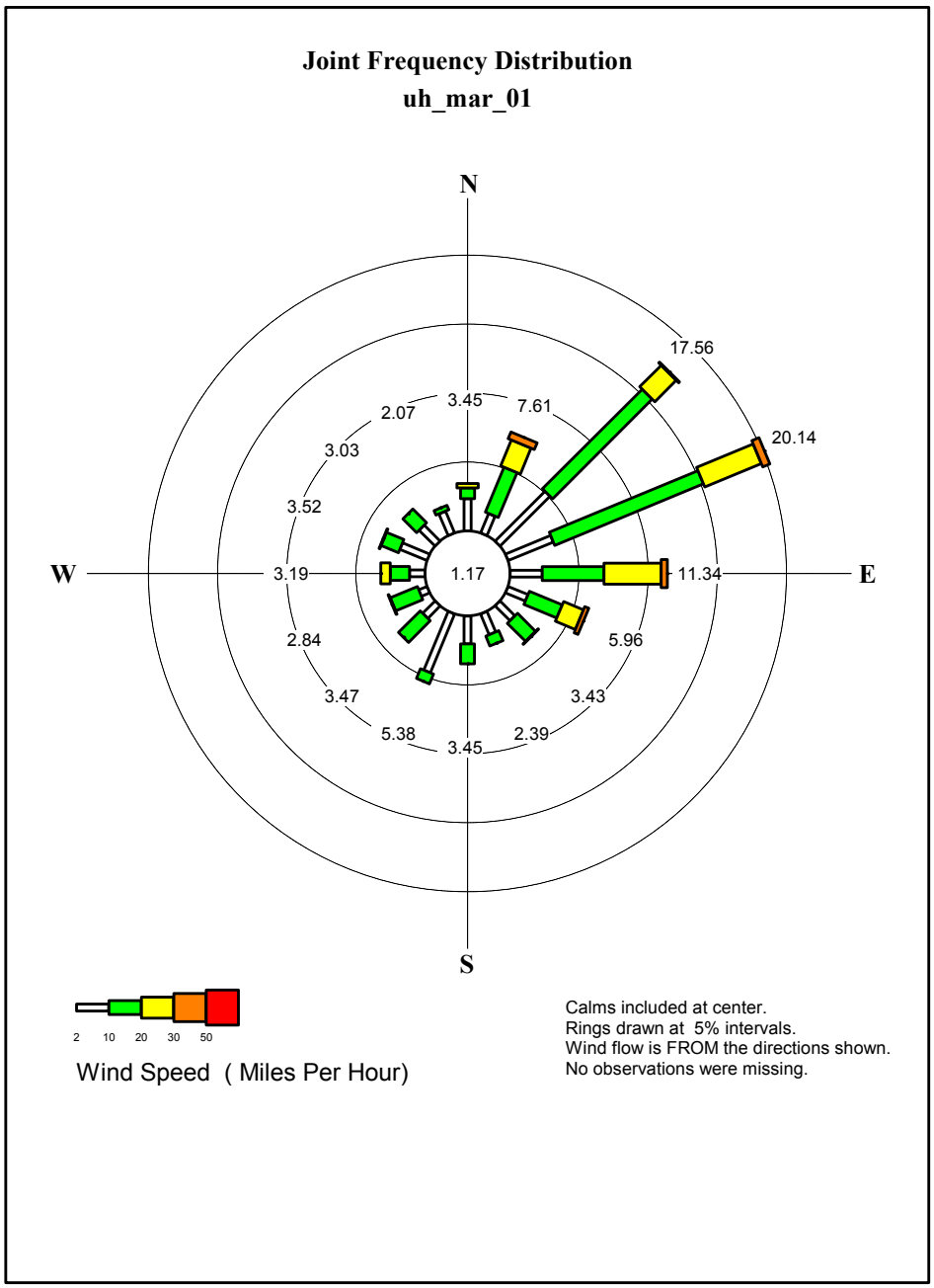
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_feb_01

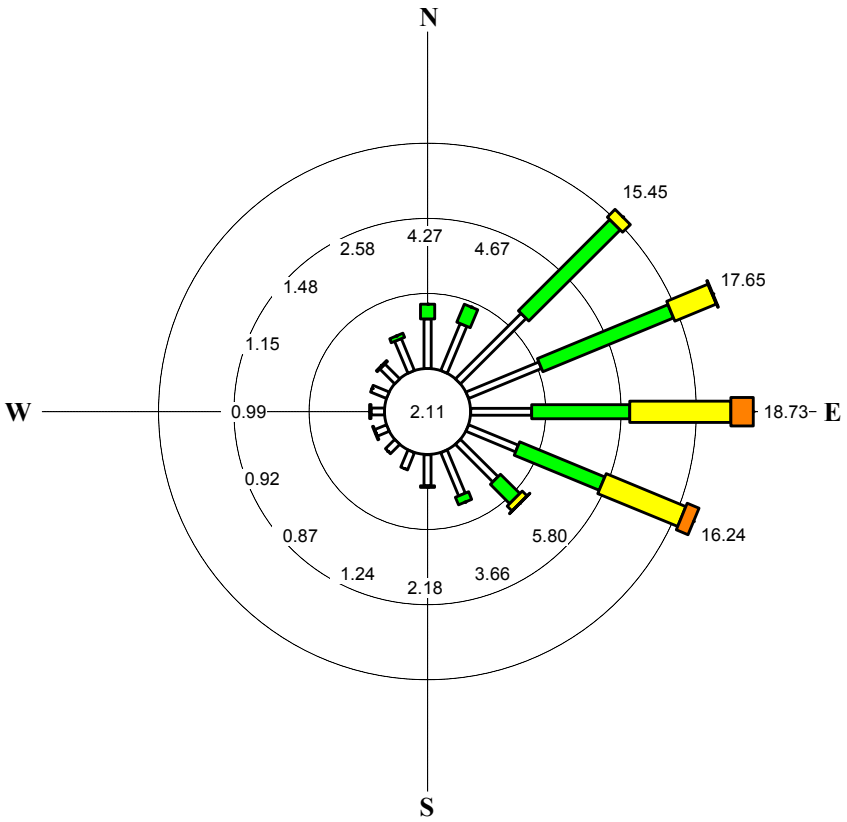


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_mar_01
N
E
S
W
17.56
20.14
11.34
5.96
3.43
2.39
3.45
5.38
3.47
2.84
3.19
3.52
3.03
2.07
3.45
7.61
1.17
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

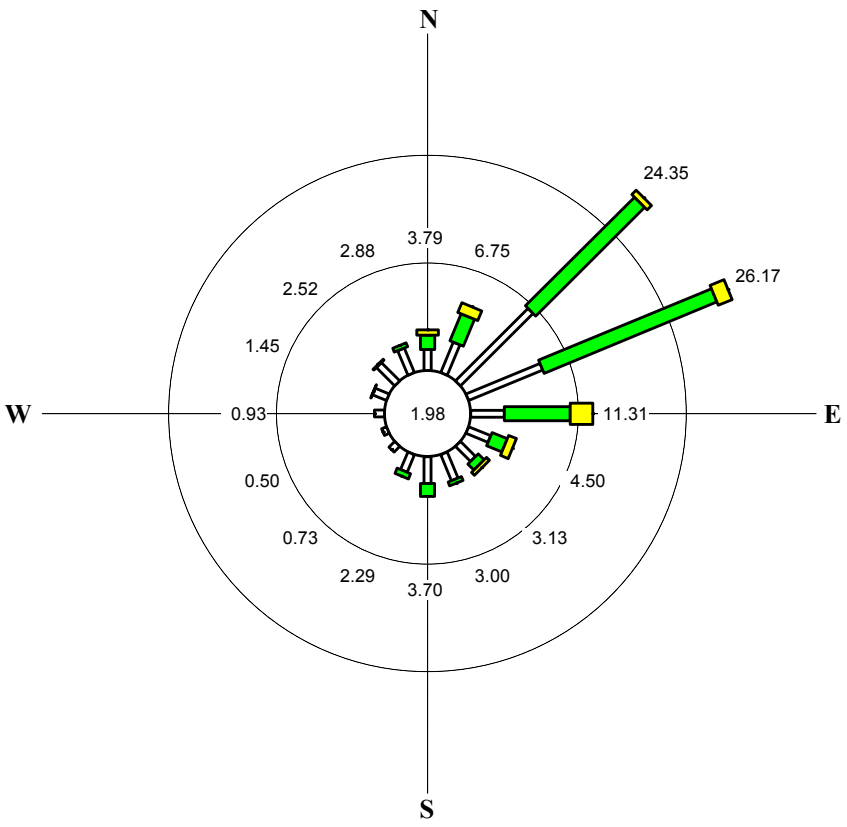
Joint Frequency Distribution
uh_apr_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

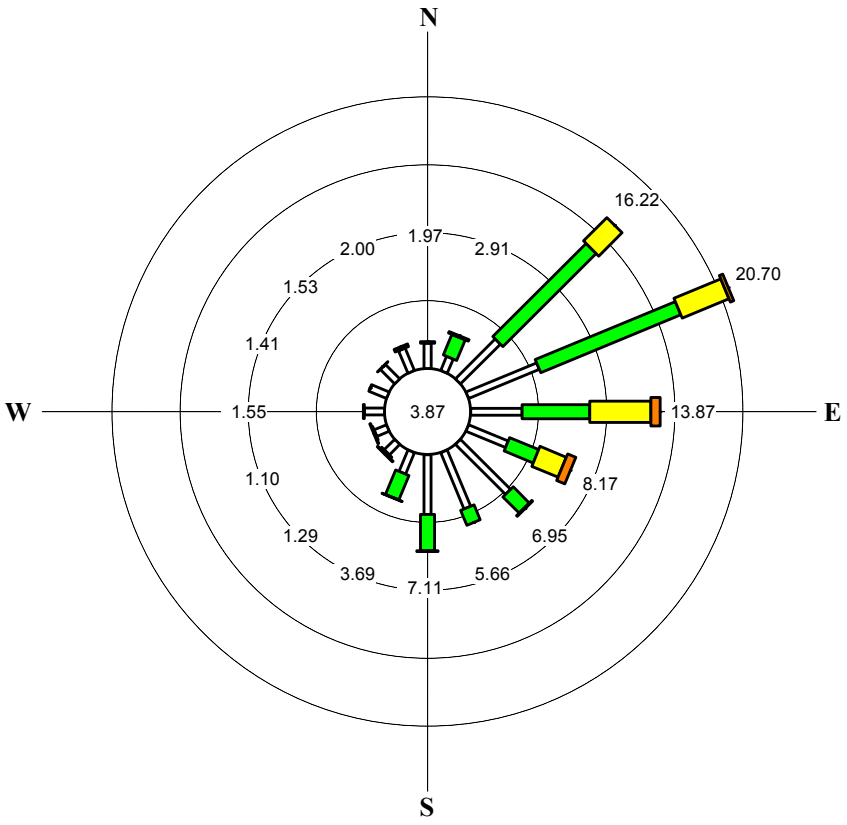
Joint Frequency Distribution
uh_may_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

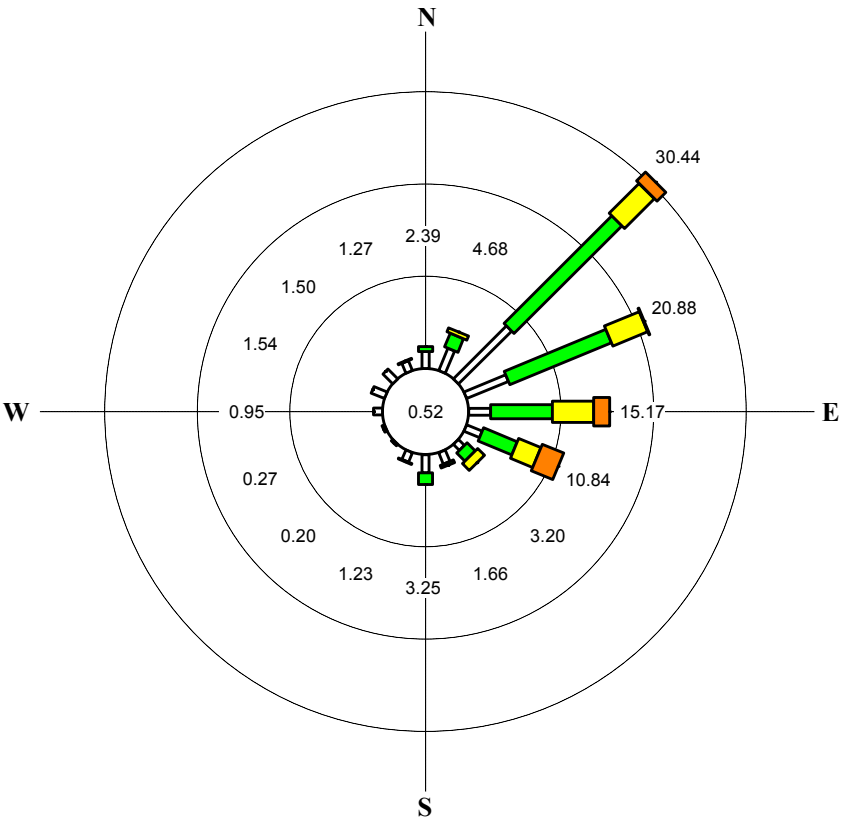
Joint Frequency Distribution
uh_jun_01



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

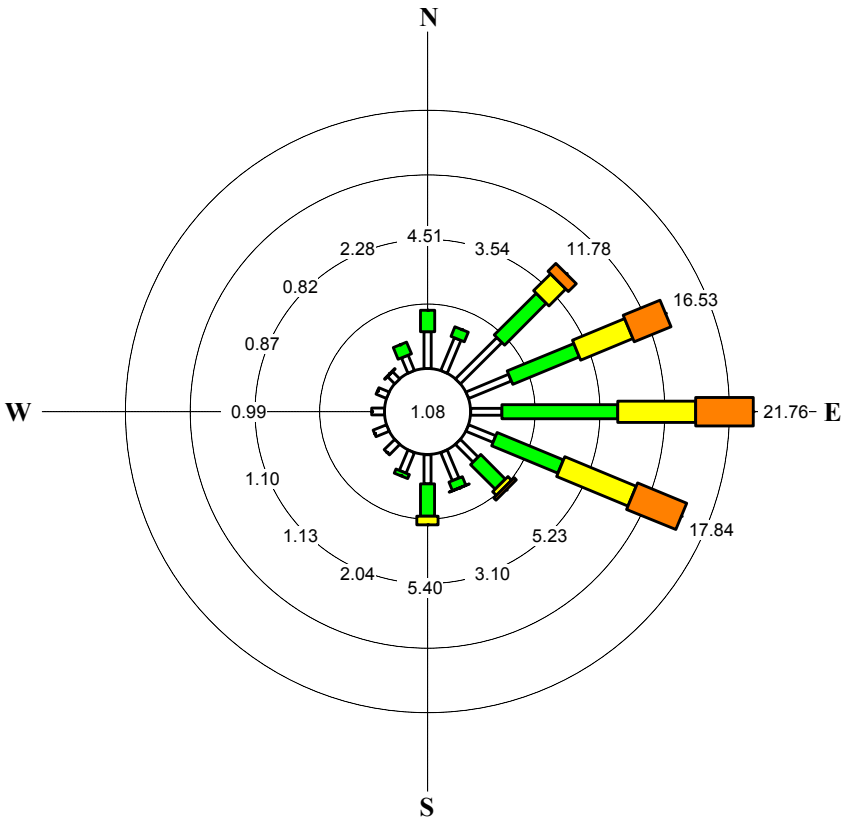
Joint Frequency Distribution
uh_jul_01



Wind Speed (Miles Per Hour)

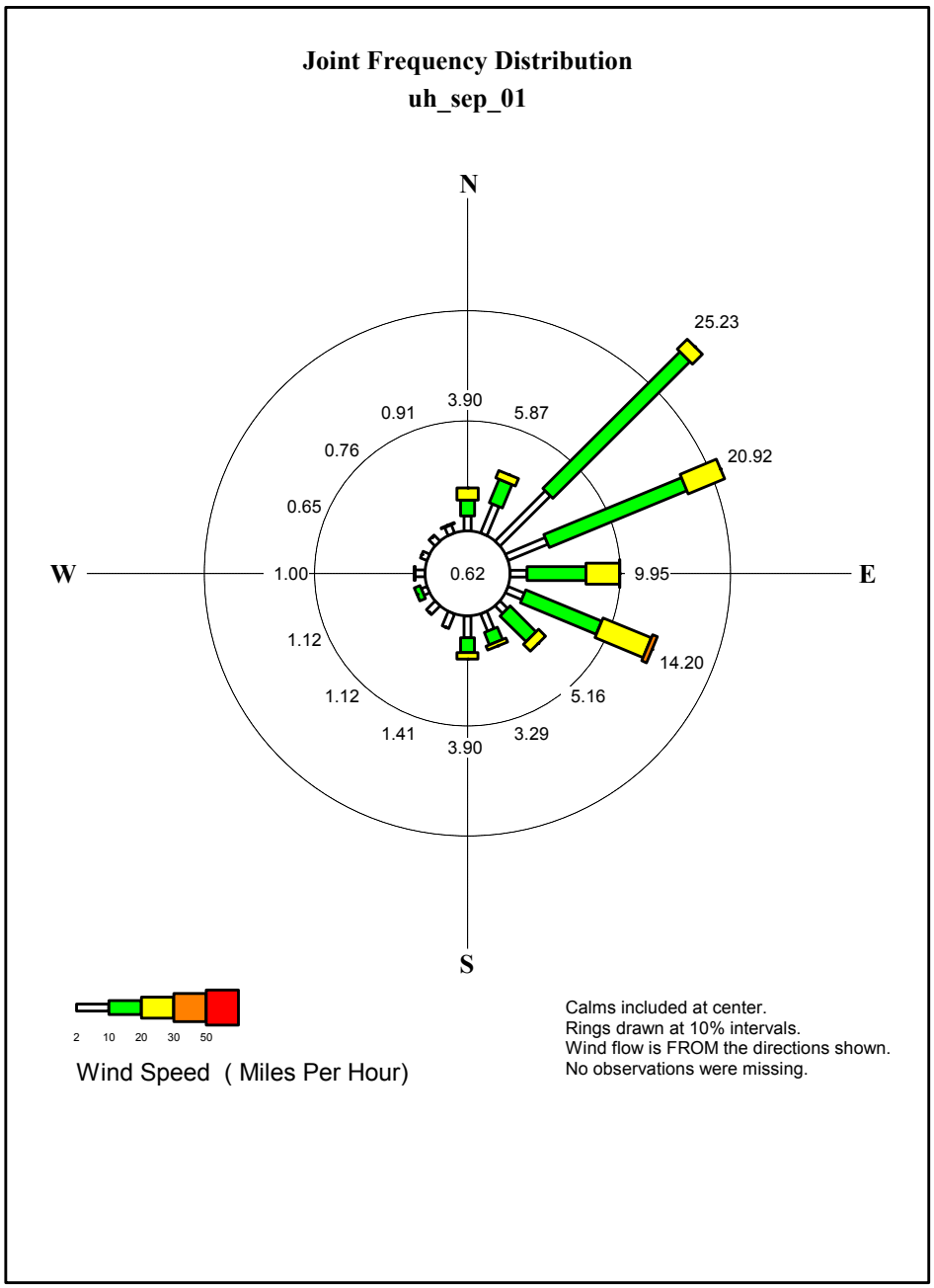
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_aug_01

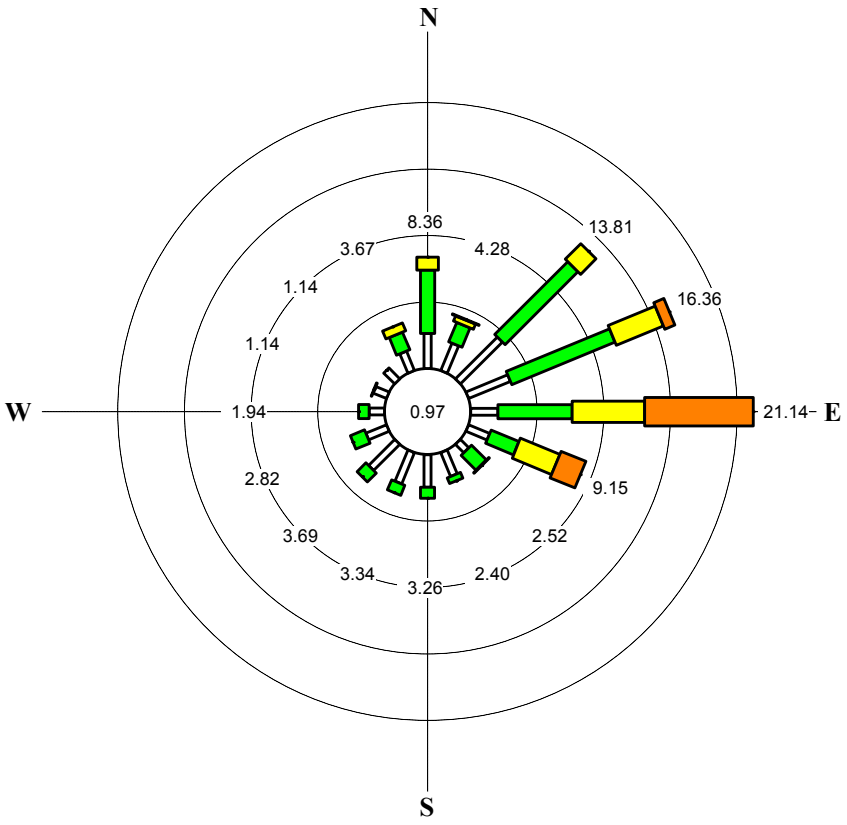


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

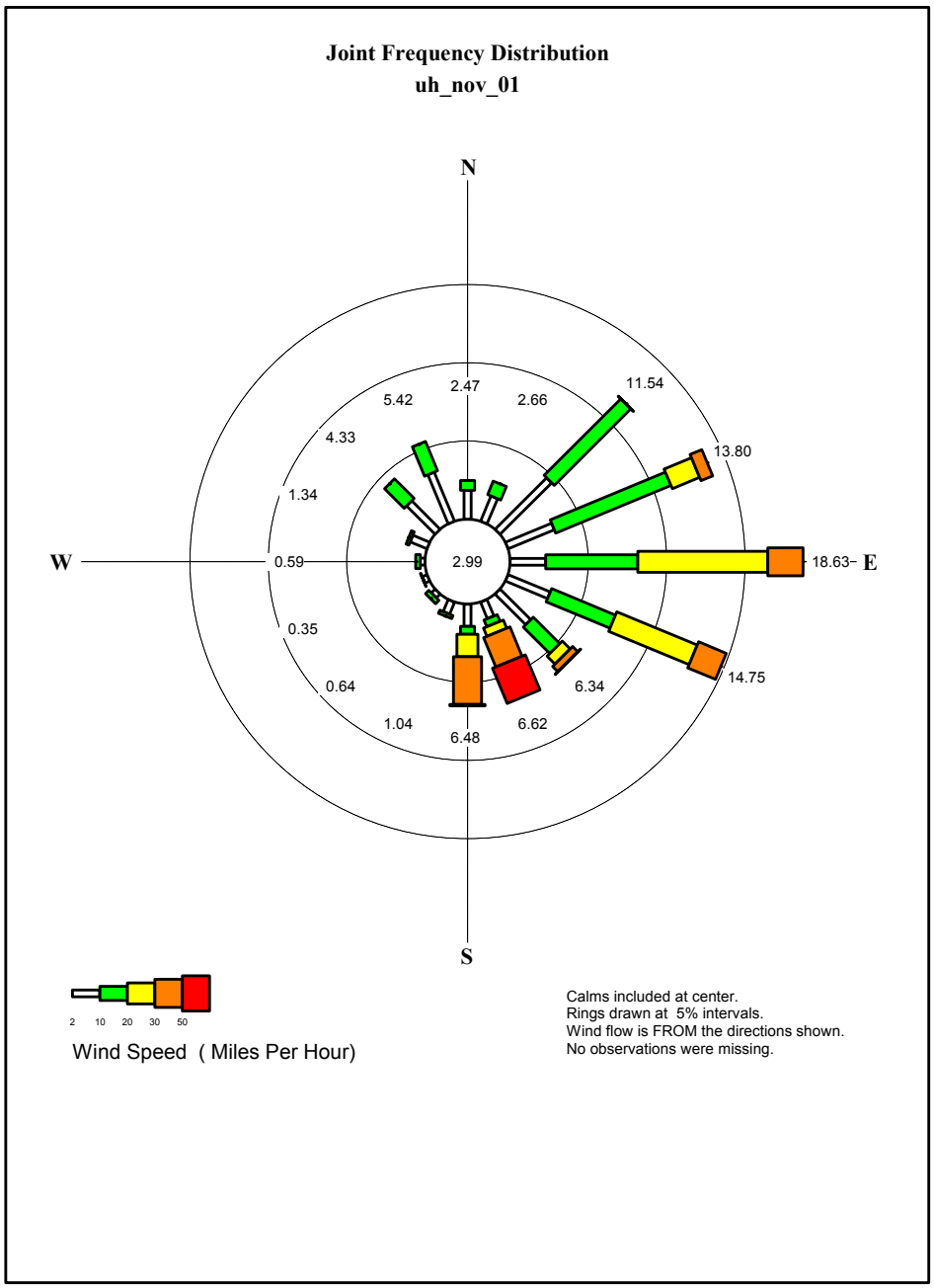

Joint Frequency Distribution
uh_sep_01
N
E
S
W
25.23
20.92
9.95
14.20
5.16
3.29
3.90
1.41
1.12
1.12
1.00
0.65
0.76
0.91
3.90
5.87
0.62
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_oct_01

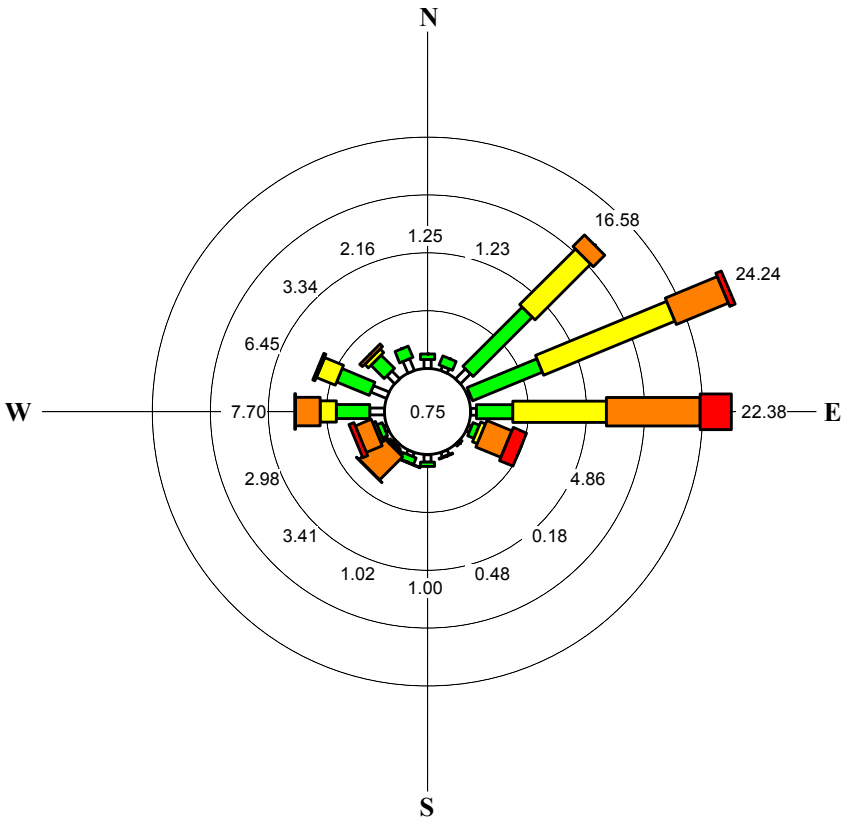


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

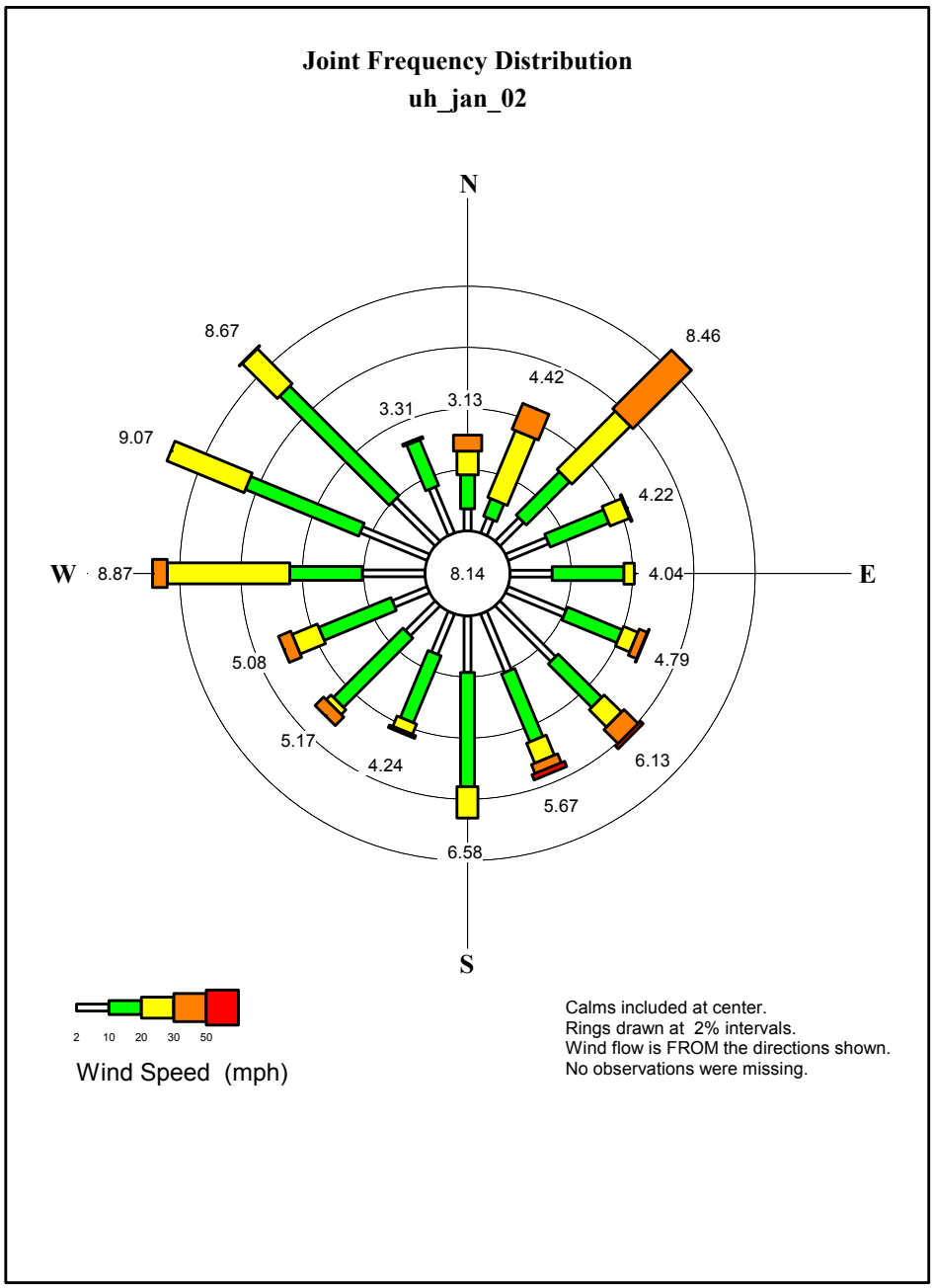

Joint Frequency Distribution
uh_nov_01
N
W
E
S
2.47
2.66
11.54
13.80
18.63
14.75
6.34
6.62
6.48
1.04
0.64
0.35
0.59
1.34
4.33
5.42
2.99
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_dec_01

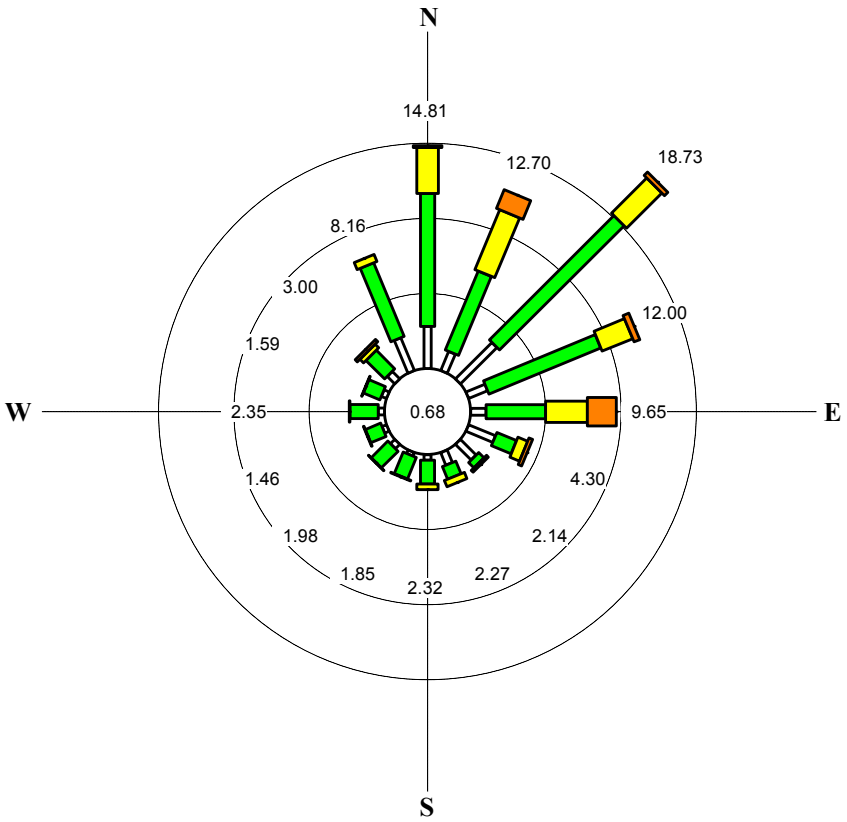


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_jan_02
N
E
S
W
8.67
8.46
9.07
8.87
4.04
5.08
4.79
5.17
6.13
4.24
5.67
6.58
3.31
3.13
4.42
4.22
8.14
2 10 20 30 50
Wind Speed (mph)
Calms included at center.
Rings drawn at 2% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

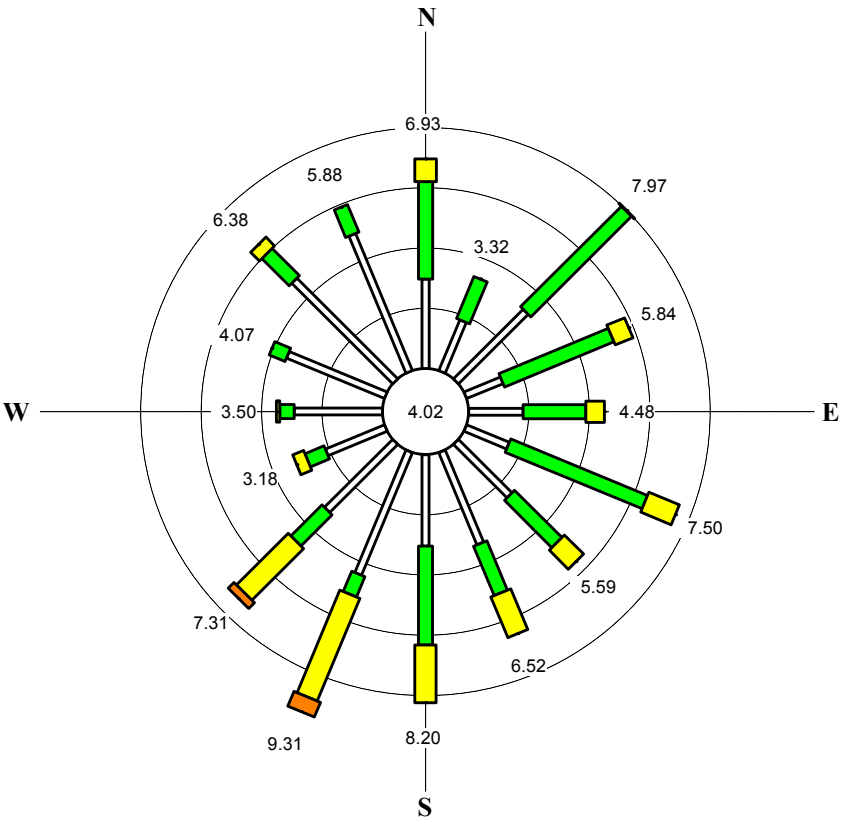
Joint Frequency Distribution
uh_feb_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

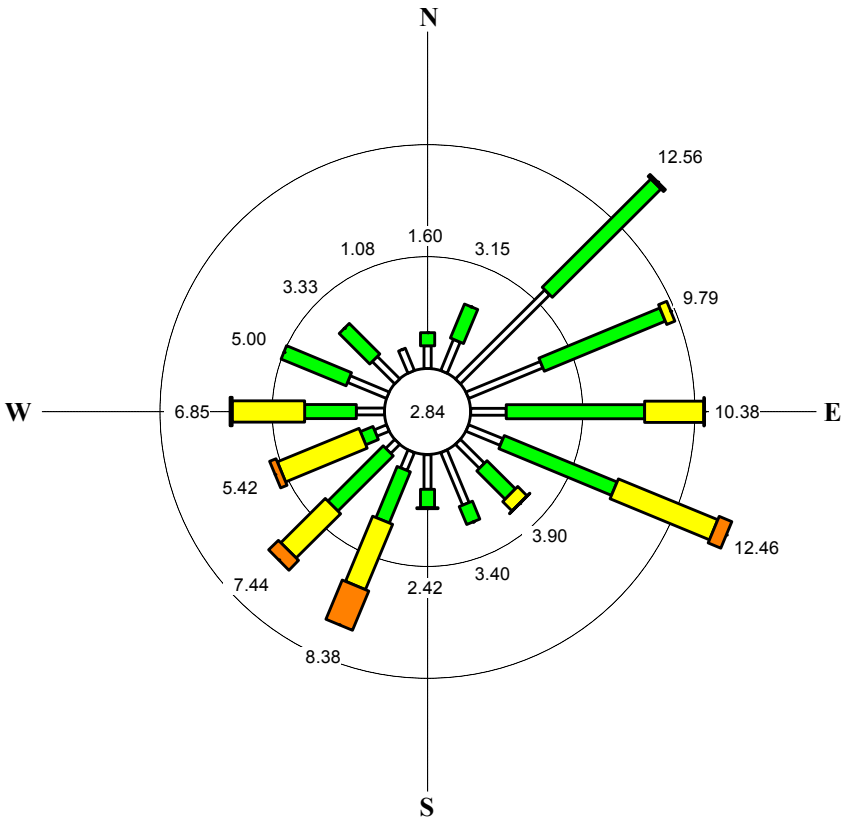
Joint Frequency Distribution
uh_mar_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 2% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

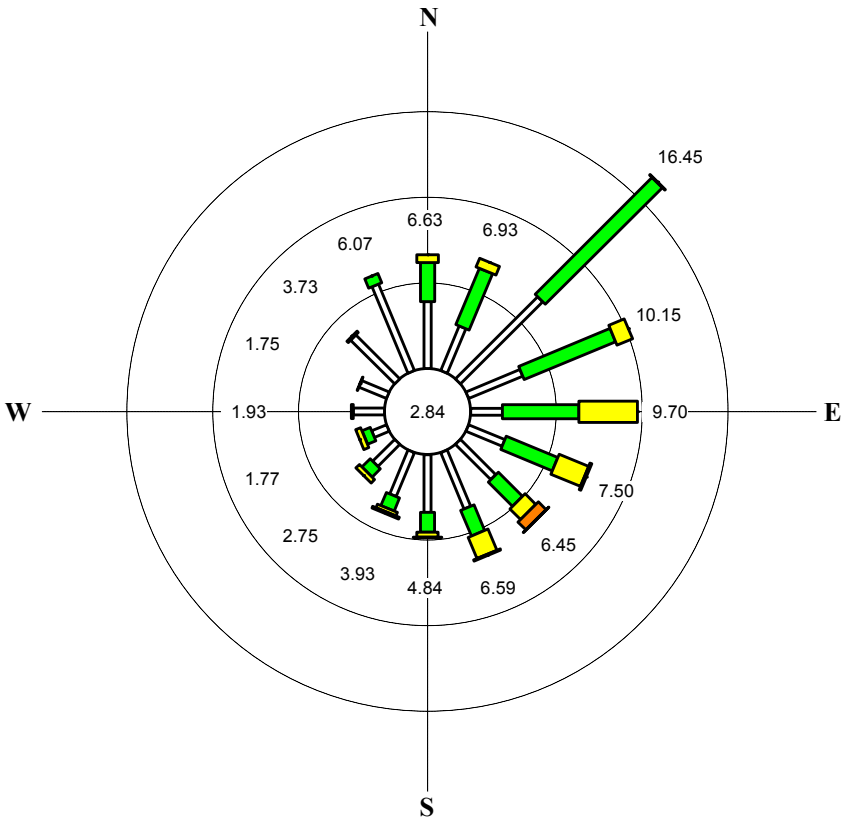
Joint Frequency Distribution
uh_apr_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

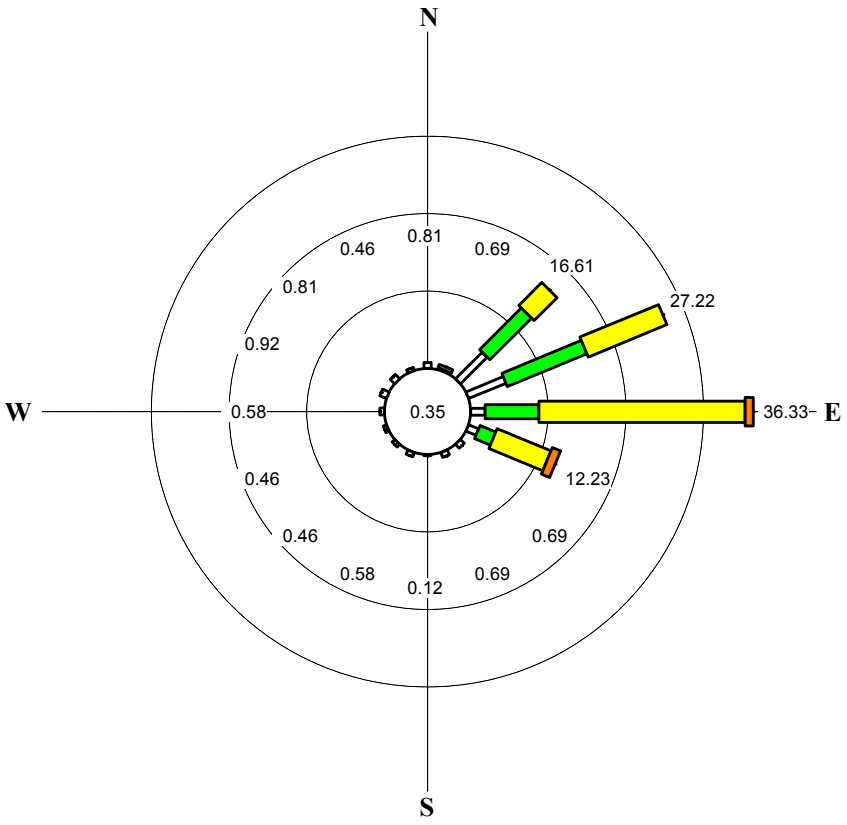
Joint Frequency Distribution
uh_may_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

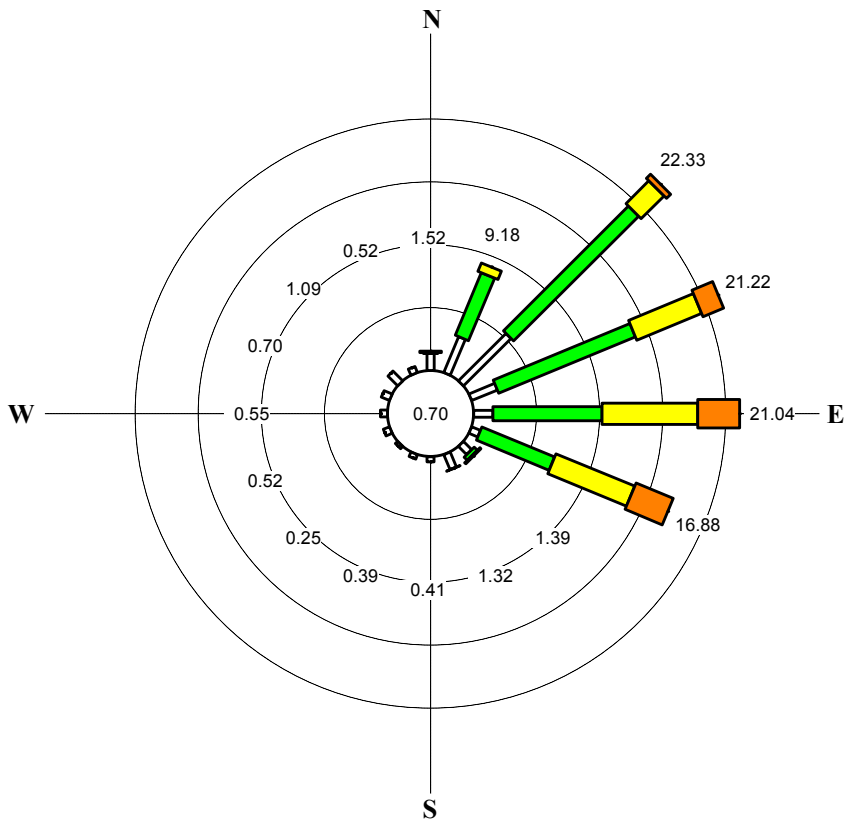
Joint Frequency Distribution
uh_jun_02



Wind Speed (Miles Per Hour)

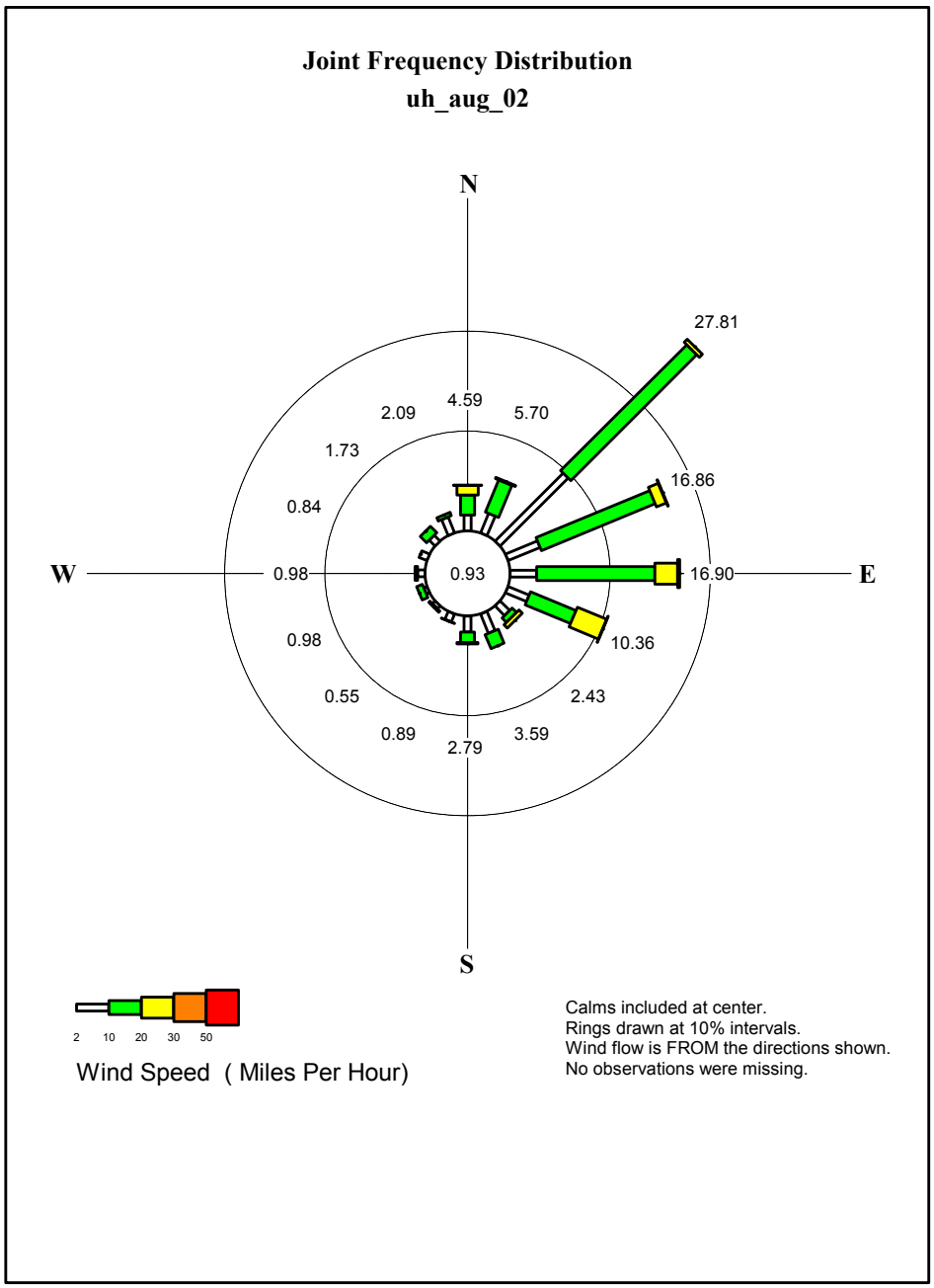
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_jul_02

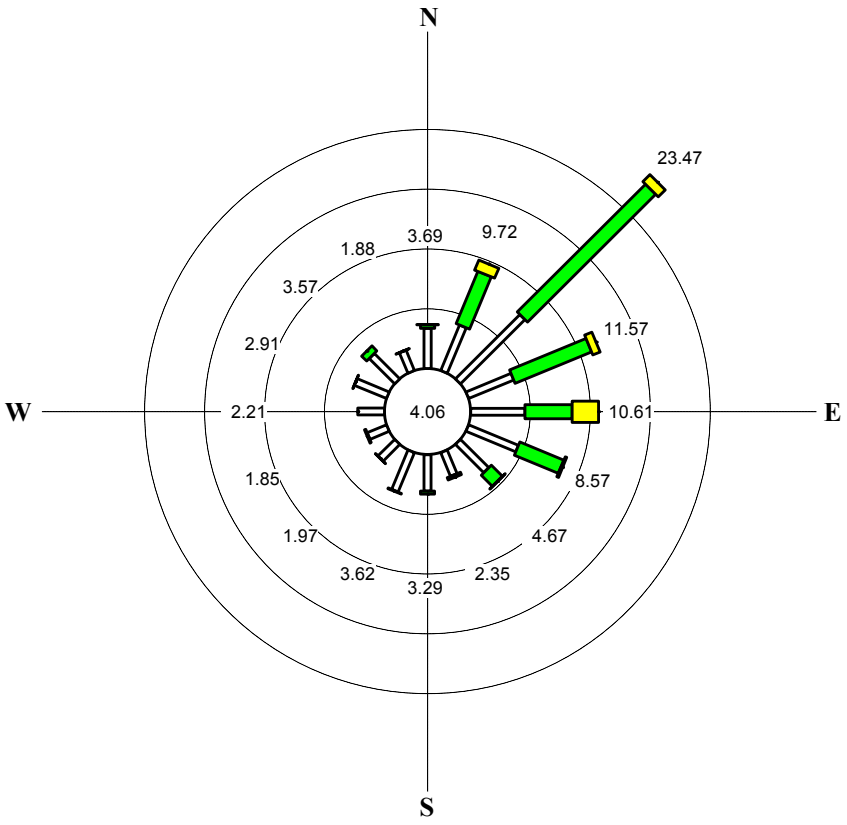


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_aug_02
N
E
S
W
27.81
16.86
16.90
10.36
2.43
3.59
2.79
0.89
0.55
0.98
0.84
1.73
2.09
4.59
5.70
0.93
0.98
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 10% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

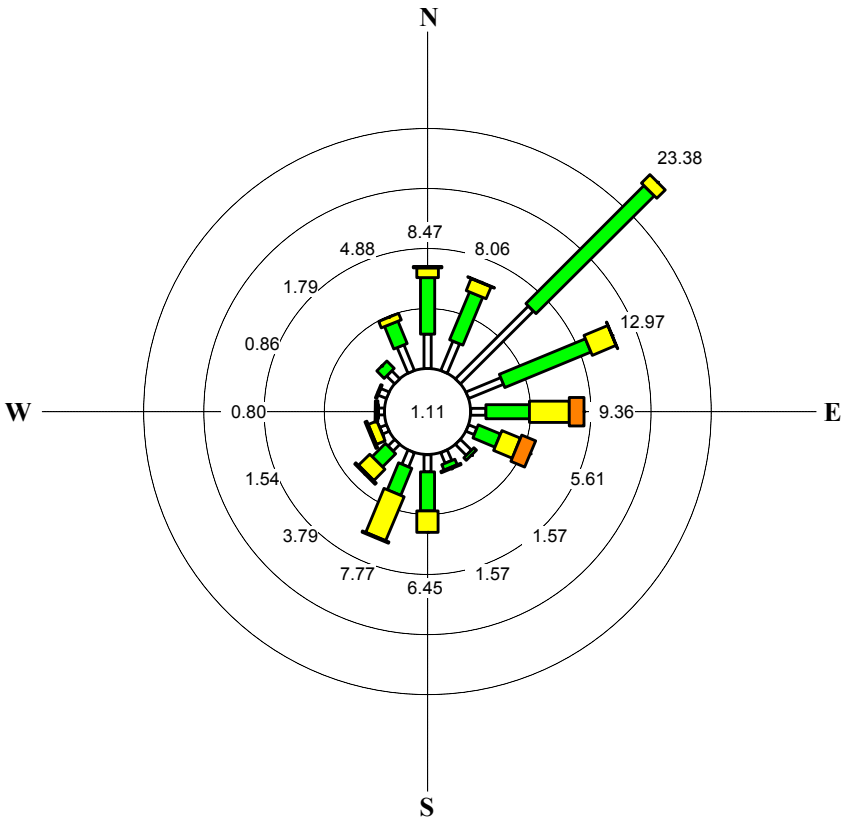
Joint Frequency Distribution
uh_sep_02



Wind Speed (Miles Per Hour)

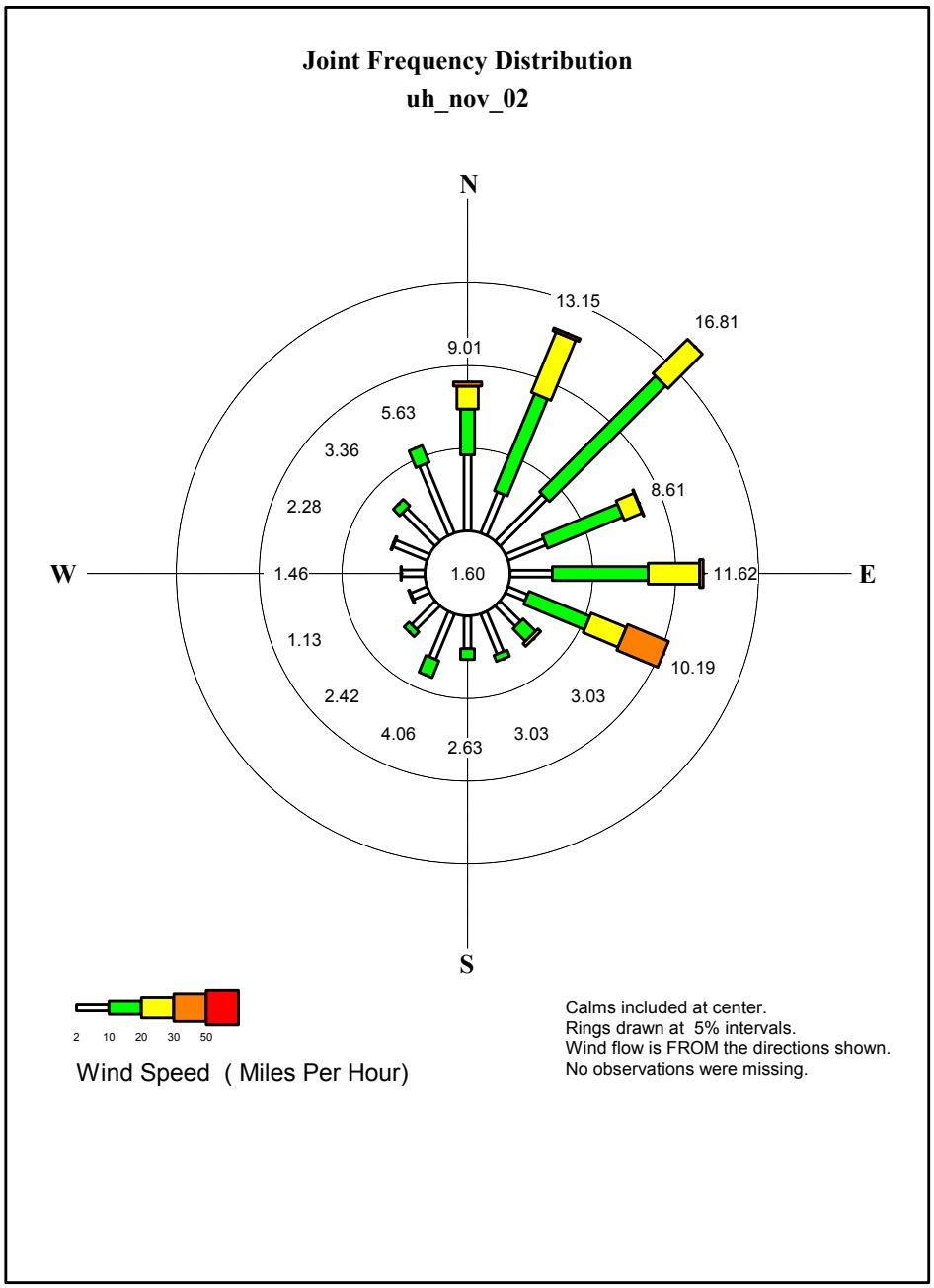
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_oct_02

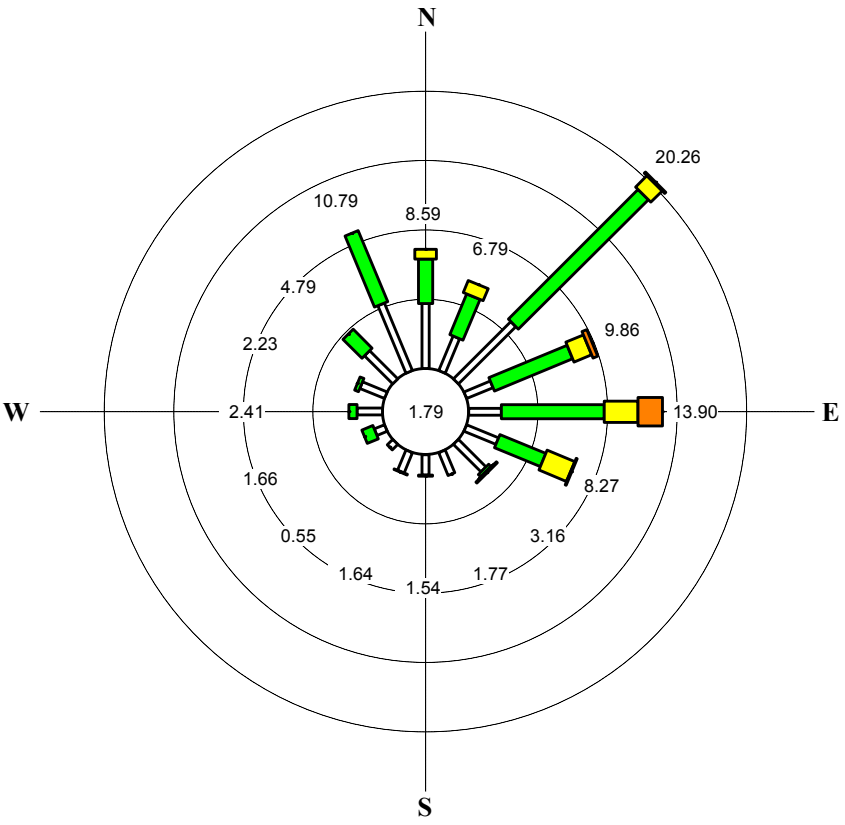


Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.


Joint Frequency Distribution
uh_nov_02
N
E
S
W
13.15
16.81
9.01
5.63
3.36
2.28
1.46
1.60
8.61
11.62
10.19
3.03
3.03
2.63
4.06
2.42
1.13
2 10 20 30 50
Wind Speed (Miles Per Hour)
Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.

Joint Frequency Distribution
uh_dec_02



Wind Speed (Miles Per Hour)

Calms included at center.
Rings drawn at 5% intervals.
Wind flow is FROM the directions shown.
No observations were missing.