

9-2012

Lake Michigan Wind Assessment Project Data Summary and Analysis: September 2012

Lake Michigan Offshore Wind Assessment Project

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Lake Michigan Offshore Wind Assessment Project, "Lake Michigan Wind Assessment Project Data Summary and Analysis: September 2012" (2012). *Monthly Buoy Report*. 5.
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Lake Michigan Wind Assessment Project
Data Summary and Analysis

September 2012

This report summarizes the data collected by the Laser Wind Sensor (LWS) #8 with collection information as follows.

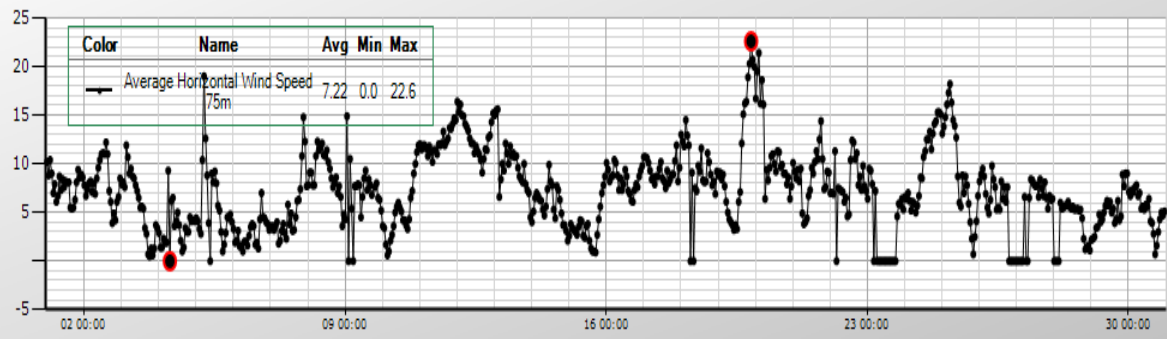
Location:	Lake Michigan – Mid-lake Plateau (4320.5105N 8707.1962W)
Date:	September 1 through September 30, 2012 (UTC)
Cup Anemometer:	3 meters mounted on the buoy
Range Gates 1-6:	75, 90, 105, 125, 150, 175 meters
Observations:	10-minute averages, transmitted via satellite at the rate of one 10-minute average per hour
Number of Observations:	30 days at 24 observations per day = 720 observations
Missing Observations:	1 – 18:10 on September 9
Good Observations:	719

Notes:

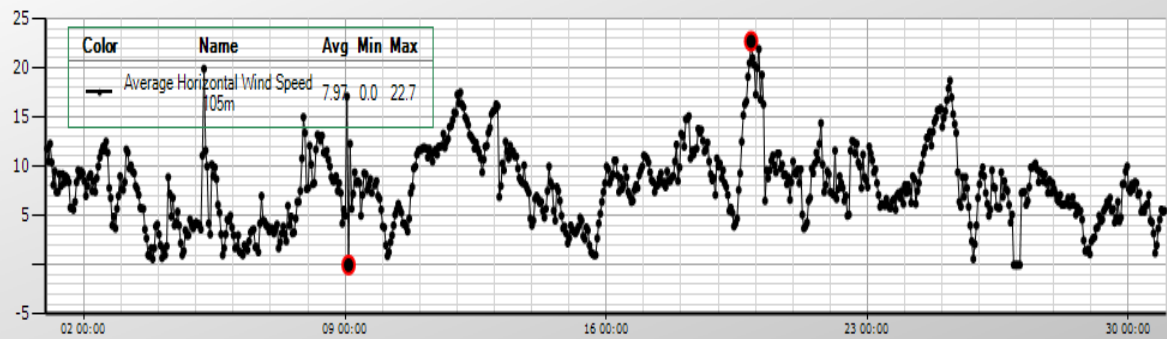
- o Data for Range Gates 2 and 6 are available and stored on the buoy, but not transmitted (by choice) in the real-time 10 minute average data.
- o Range Gate 6 (175 meters) is a test range gate to observe the performance of the sensor at the extreme operating height limit for this configuration. Thus, performance degradation was expected.
- o All high resolution 1 second data for all wind speeds is stored onboard the buoy and can be used for further detailed post processing as required.

Graphs for wind speed for ranges gates 1, 3, 4, and 5 as well as the cup anemometer follow. Graphs of the horizontal wind direction at the cup anemometer and range gate 1 are included as well.

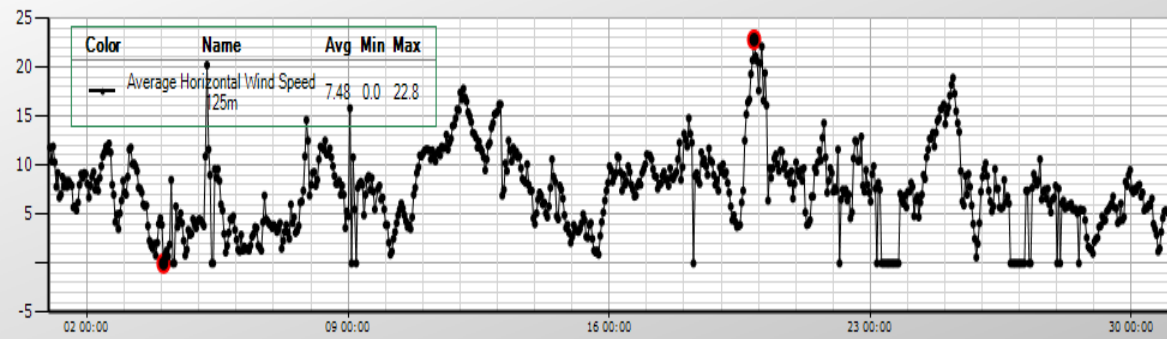
GVSU Primary
Iridium Combined Message
Average Horizontal Wind Speed 75m



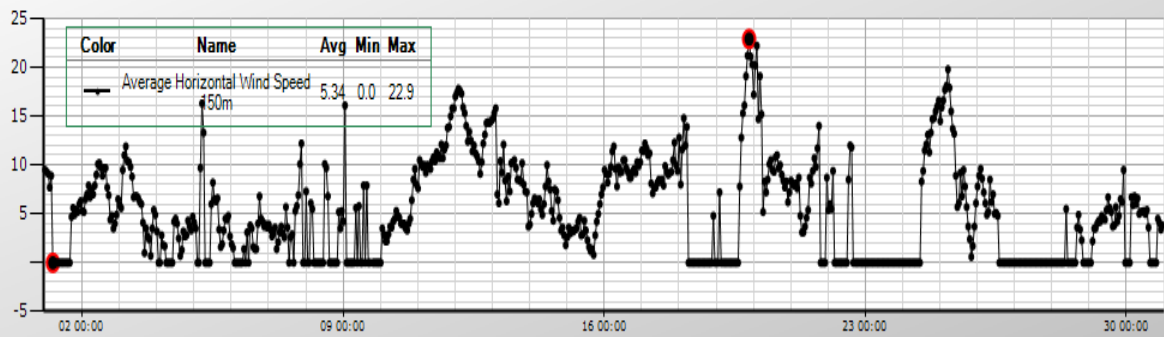
GVSU Primary
Iridium Combined Message
Average Horizontal Wind Speed 105m



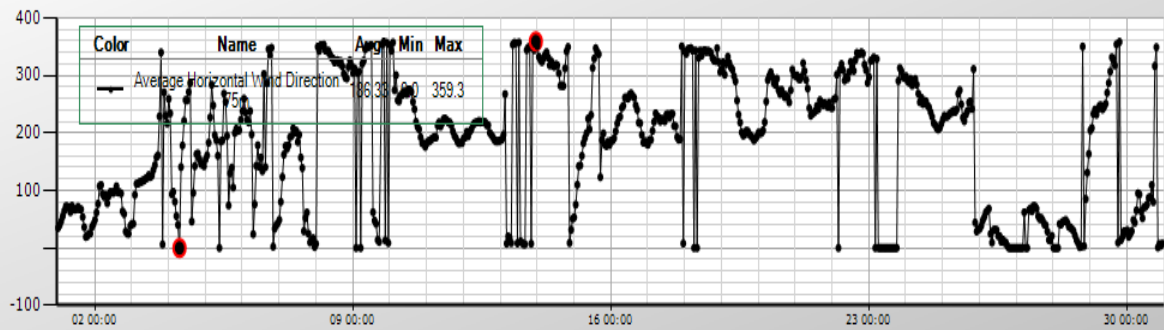
GVSU Primary
Iridium Combined Message
Average Horizontal Wind Speed 125m



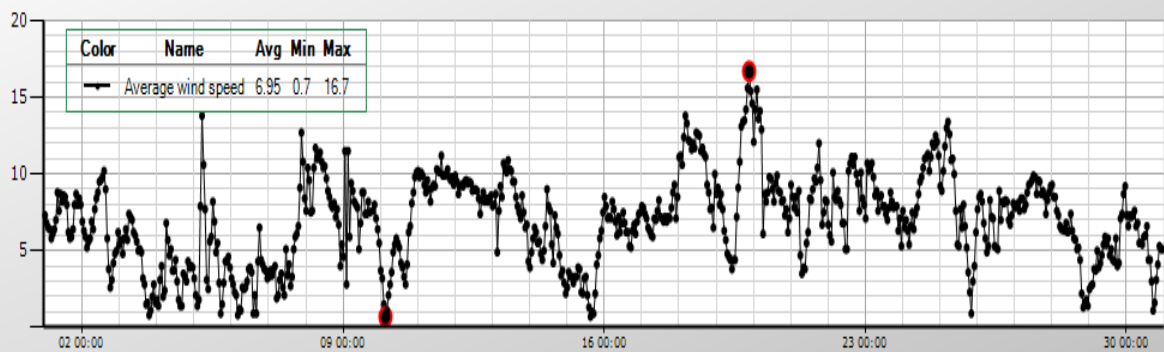
GVSU Primary
Iridium Combined Message
Average Horizontal Wind Speed 150m



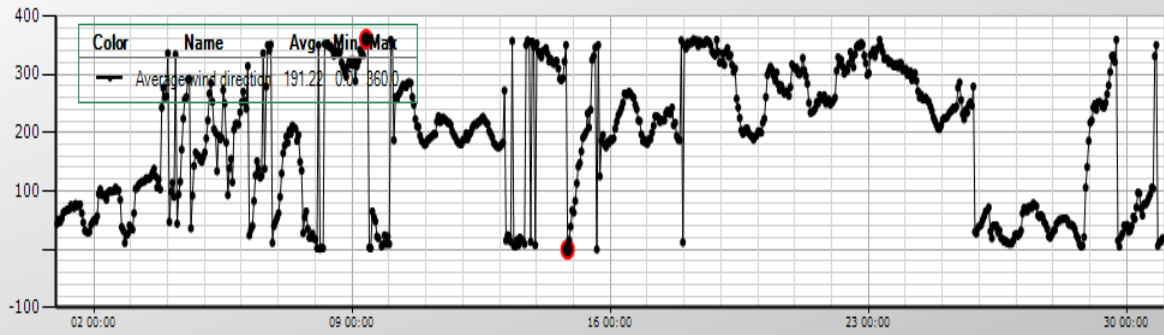
GVSU Primary
Iridium Combined Message
Average Horizontal Wind Direction 75m



GVSU Primary
Iridium Combined Message
Average wind speed



GVSU Primary
Iridium Combined Message
Average wind direction



Summary statistics for wind speed by range gate and for the cup anemometer are shown in the following tables. Good observations are 10-minute averages consisting of at least 300 one-second observations. There were 719 hours with one 10-minute average transmitted.

Table 1: Wind Speed (meters per second) Statistics by Range Gate

Statistic	N001S007P006 Average Wind Speed Cup Anemometer	N001S009P083 Average Horizontal Wind Speed RG #1	N001S009P085 Average Horizontal Wind Speed RG #3	N001S009P086 Average Horizontal Wind Speed RG #4	N001S009P087 Average Horizontal Wind Speed RG #5
Good Observations	719	642	683	629	421
% of Total (719)	100.0%	89.3%	95.0%	87.5%	58.6%
Average	6.9	7.7	8.2	8.0	8.0
Standard Deviation	2.9	3.8	3.9	4.0	4.3
Minimum	0.7	0.5	0.6	0.6	0.6
1st quartile	4.9	5.0	5.5	5.1	4.5
Median	7.2	7.6	8.1	7.8	7.7
3rd quartile	8.8	10.0	10.5	10.3	10.3
Maximum	16.7	22.6	22.7	22.8	22.9
99% CI for Mean – Lower Bound	6.7	7.3	7.8	7.6	7.4
99% CI for Mean – Upper Bound	7.2	8.1	8.5	8.4	8.5

Table 2: Wind Speed (meters per second) Frequencies by Range Gate

Wind Speed Range	N001S007P006 Average Wind Speed Cup Anemometer	N001S009P083 Average Horizontal Wind Speed RG #1	N001S009P085 Average Horizontal Wind Speed RG #3	N001S009P086 Average Horizontal Wind Speed RG #4	N001S009P087 Average Horizontal Wind Speed RG #5
0-4	19.1%	17.8%	15.7%	16.7%	21.1%
4-8	44.4%	38.6%	34.1%	36.9%	32.3%
8-12	32.5%	31.6%	36.6%	34.0%	31.6%
12-16	3.9%	8.9%	10.1%	8.3%	10.0%
16-20	0.1%	2.5%	2.8%	3.0%	3.6%
20-24	0.0%	0.6%	0.7%	1.1%	1.4%
24-28	0.0%	0.0%	0.0%	0.0%	0.0%
28-32	0.0%	0.0%	0.0%	0.0%	0.0%

Table 3: Wind Direction Frequencies and Average Speed by Range Gate

Wind Direction Range (Degrees)	N001S009P089 Average Horizontal Wind Direction RG#1	N001S009P083 Average Horizontal Wind Speed RG#1
0 – 45 (NNE)	14.2%	7.0
45 – 90 (NE)	9.5%	6.2
90 – 135 (SE)	5.9%	6.7
135 – 180 (SSE)	4.8%	4.1
180 – 225 (SSW)	20.9%	10.6
225 – 270 (SW)	16.4%	8.0
270 – 315 (NW)	12.0%	6.5
315 – 360 (NNW)	16.4%	7.6

Notes for September:

1. The average wind speed for ranges gates 1, 3, 4, and 5 appears to be equivalent. However, the average wind speed for range gate 1 may be slightly less. The difference in the averages between range gate 1 and range gate 3 of 0.5m/sec is statistically significant ($\alpha = 0.01$).
2. The same pattern indicating equivalent wind speed at range gates 1, 3, 4, and 5 is seen in the other summary statistics, as well as the distribution of wind speeds.
3. The distribution of the wind speeds shows more values in the 4-8m/sec range and the 8-12m/sec range together for all range gates.
4. Ranges gates 1, 3, 4, and 5 have higher average wind speeds than the cup anemometer. The difference in the averages between the cup anemometer and range gate 4 of 1.1m/sec is statistically significant ($\alpha = 0.01$).
5. The most prevalent wind direction is 180 – 225 degrees (SSW). Slightly more than 37% percent of the time, the wind direction is between 180 and 270 degrees (SSW to SW).
6. About 21% of the time, the wind direction is between 180 and 225 degrees (SSW) and the average wind speed in this direction appears to be higher than the overall average of 7.7m/sec for range gate 1.

Notes comparing August and September:

1. The average September wind speed seems greater than the August wind speed. This is seen in all summary statistics.
2. In September and August, the variability of the wind seems to be about the same, as seen in the standard deviation and in the frequencies.
3. Approximately 57% of the time in August the wind direction was between 135 and 270 degrees (SSW to SSW). In September, about 42% of the wind came from this direction.
4. There appears to be a shift in wind direction to the North in September versus August. In August, about 30% of the time the wind direction was between 270 and 45 degrees (NW to NNE). In September, about 42% of the wind came from this direction.

Part II – Buoy Stored Data

This report summarizes the data collected by the Laser Wind Sensor (LWS) #8 with collection information as follows.

Location: Lake Michigan – Mid-lake Plateau (4320.5100N 8707.2057W)

Date: September 1 through September 30, 2012 (UTC)

Range Gates 1-6: 75, 90, 105, 125, 150, 175 meters

Cup Anemometer: 3 meters mounted on the buoy

Observations: 10-minute averages, stored on the buoy and retrieved manually

Number of Observations: 30 days at 24 X 6 observations per day = 4320 observations

Missing Observations: As shown in table 4.

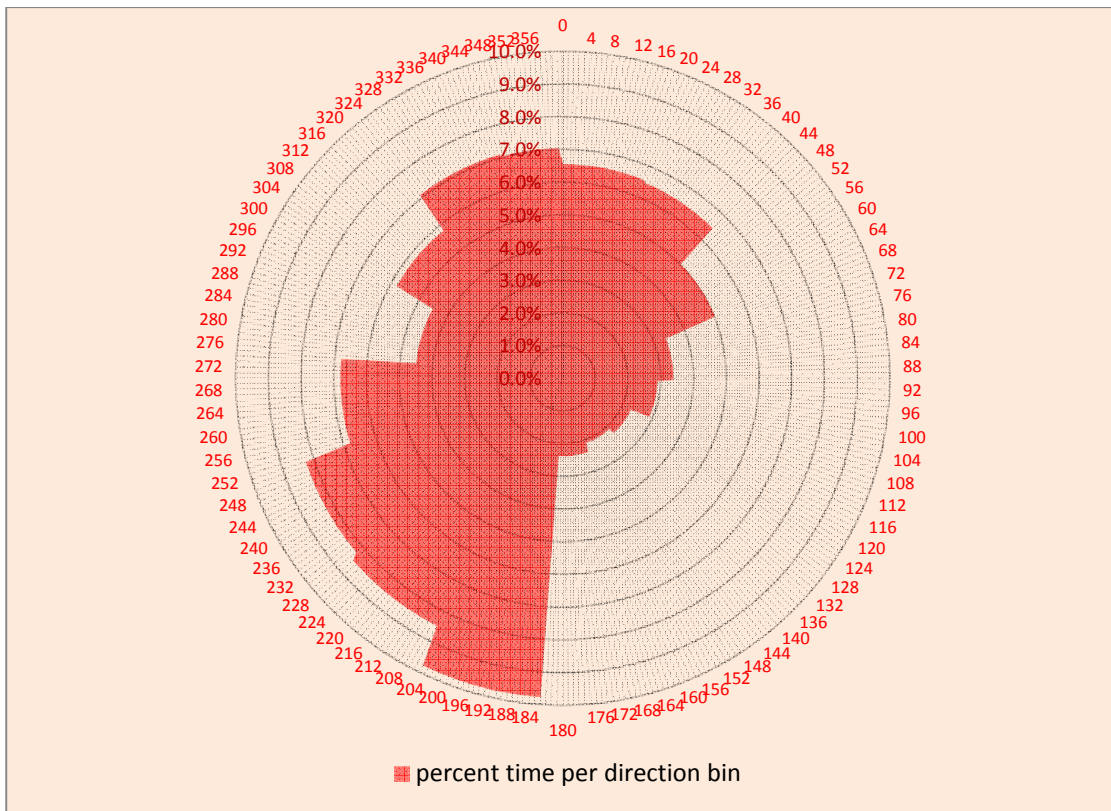
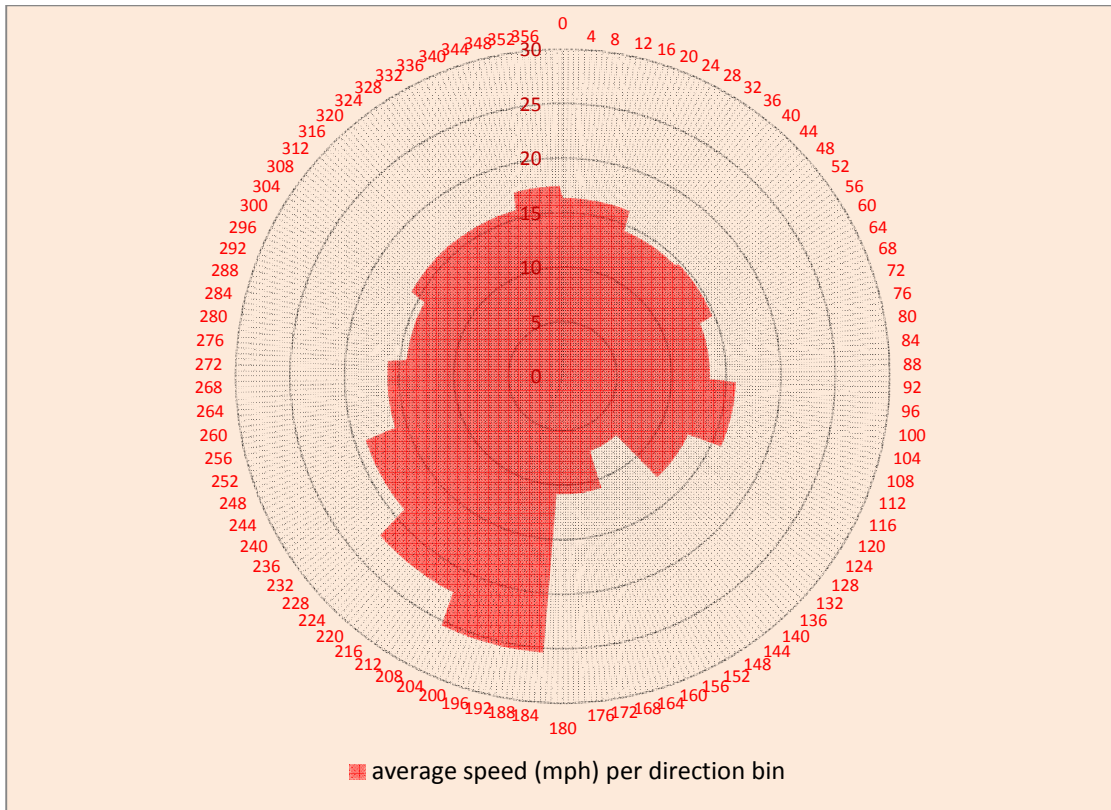
Good Observations: As shown in table 4.

Table 4 shows information concerning the horizontal wind speed and the energy generated for each range gate. The amount of energy generated depends on the turbine employed in this case the Gamesa Elioca G58 850kW. The energy estimate was computed assuming that the turbine will always face the wind.

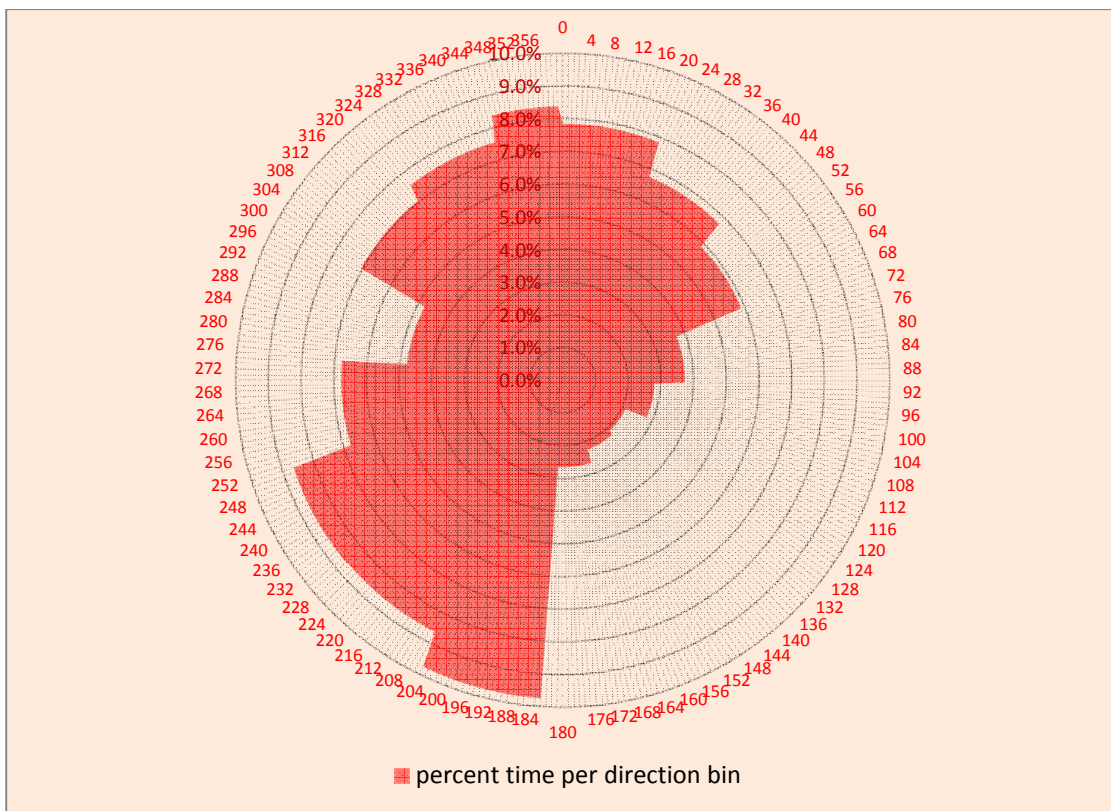
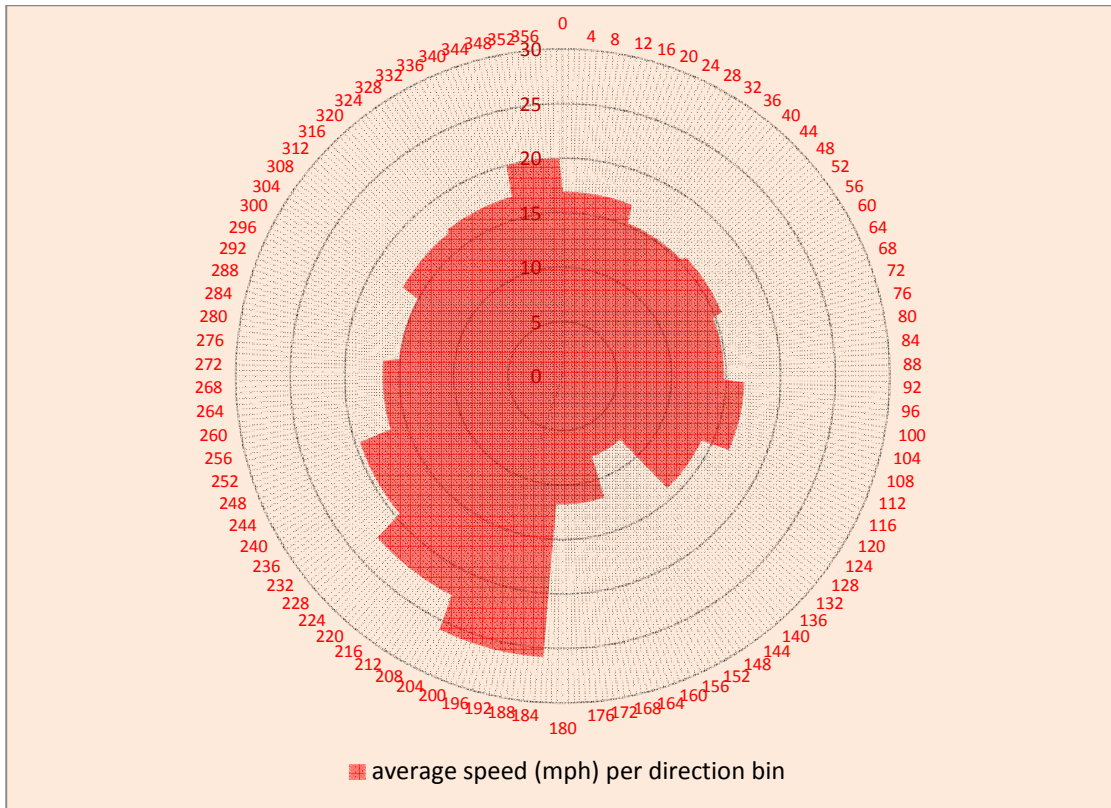
The wind rose graphs show the wind speed by direction as well as the percent of time the wind was blowing in each direction.

Table 4: Wind Speed (meters per second) and Energy (kWh/time unit) by Range Gate

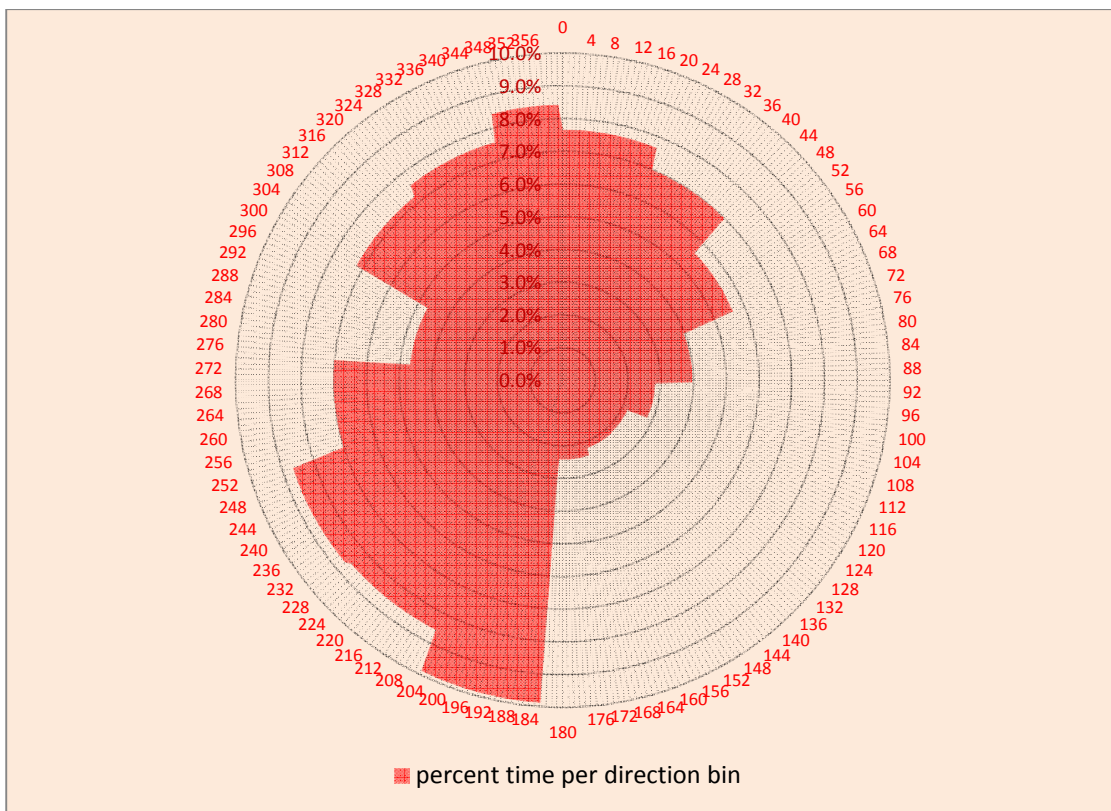
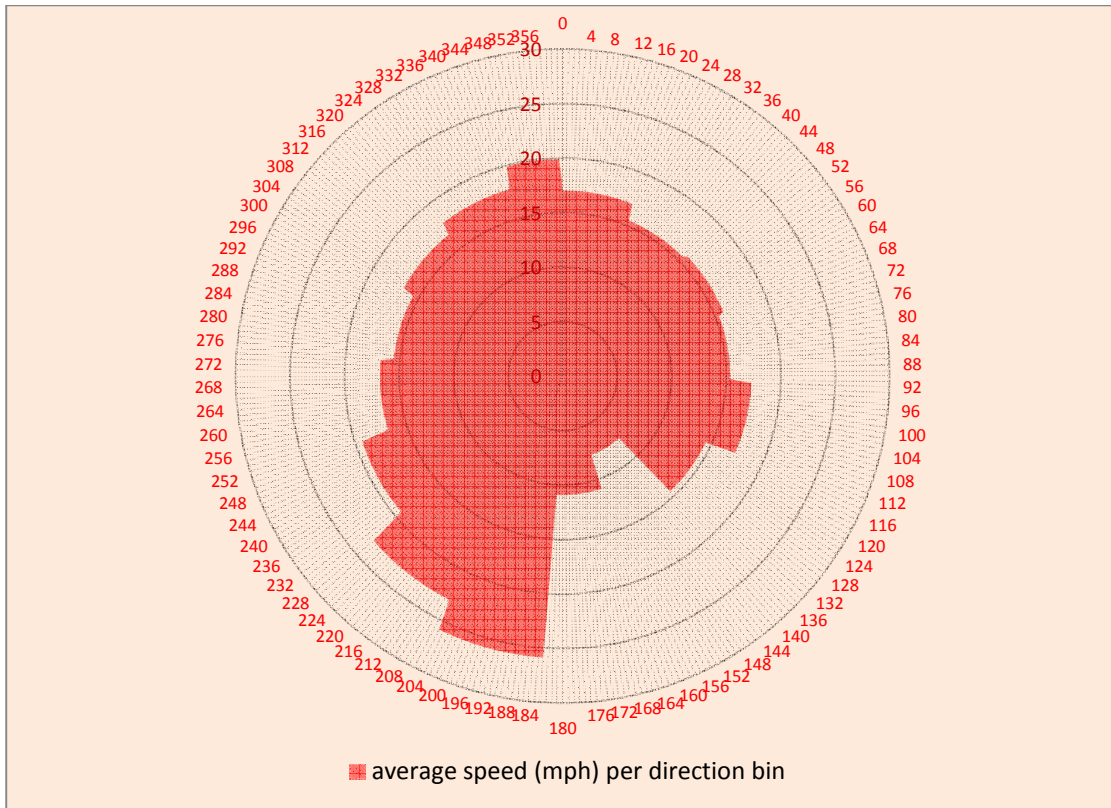
Range Gate	Number of Obs. (Possible = 4320)	% Good Obs.	Average Horizontal Wind Speed	Average Horizontal Wind Speed -- 1 Obs. per hour	Average Horizontal Wind Speed -- Difference	Average Power (kW)	Average Daily Energy (kWh)
1	3828	88.6%	7.7	7.7	0	364	8725
2	4111	95.2%	8.1			395	9487
3	4119	95.3%	8.2	8.2	0	401	9625
4	3772	87.3%	8.0	8.0	0	383	9192
5	2543	58.9%	8.0	8.0	0	376	9018
6	1176	27.2%	8.2			405	9730
Buoy Cup	4319	96.8%	7.0	6.9	0.1	311	7465



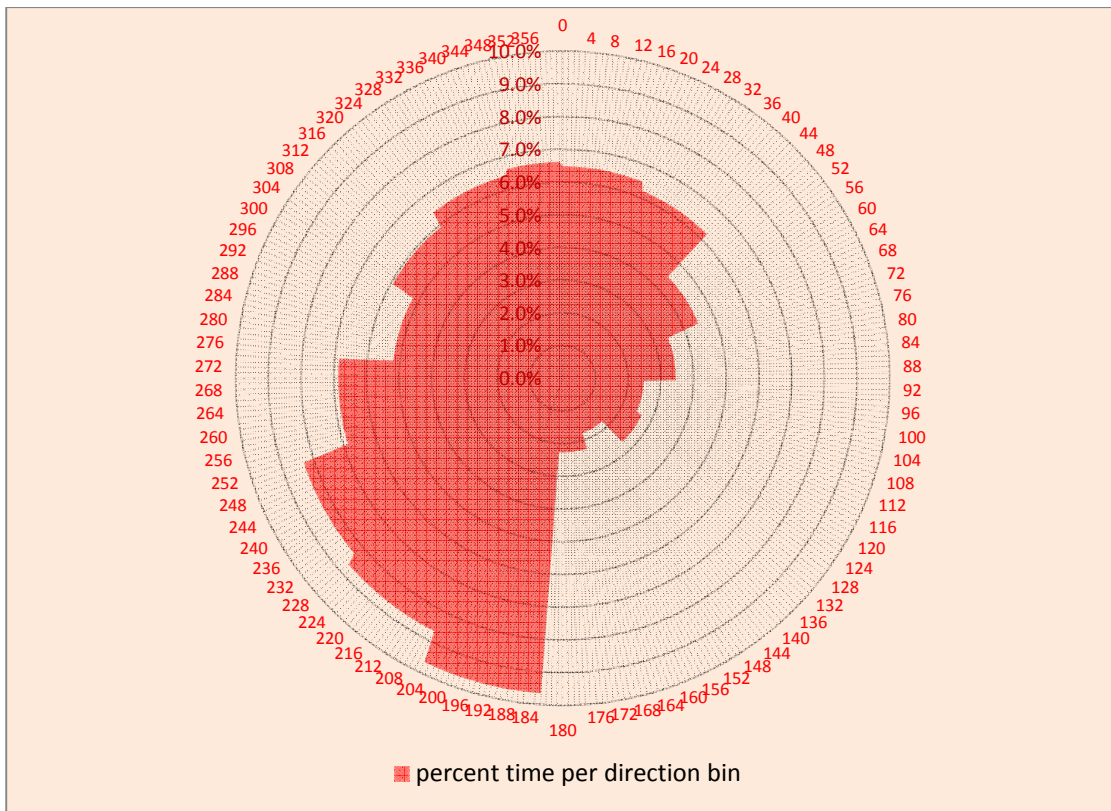
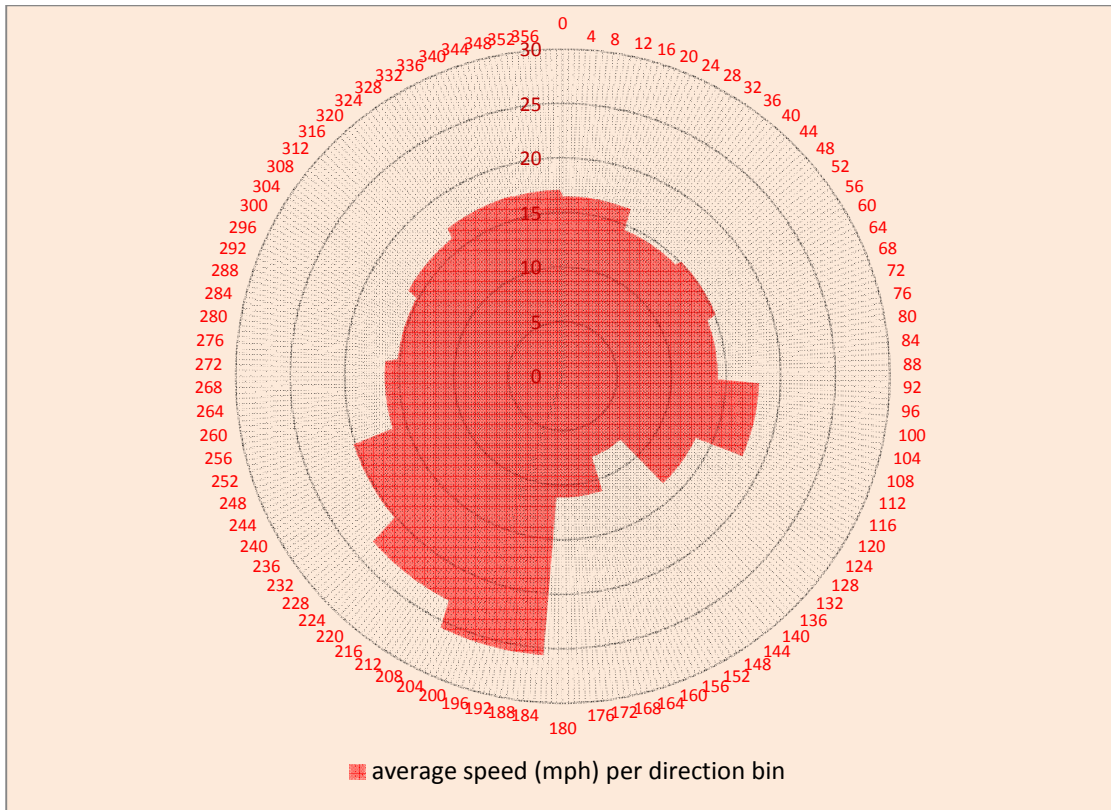
Range Gate 1: Average Wind Speed and Percent Time by Direction



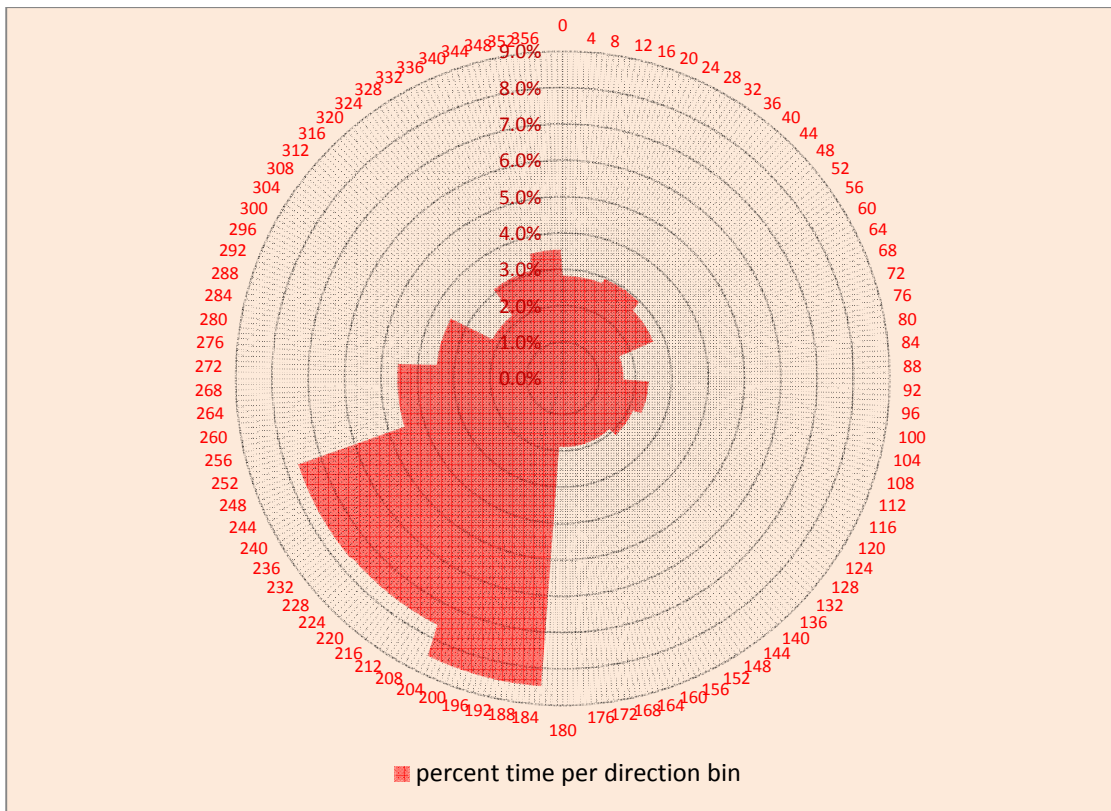
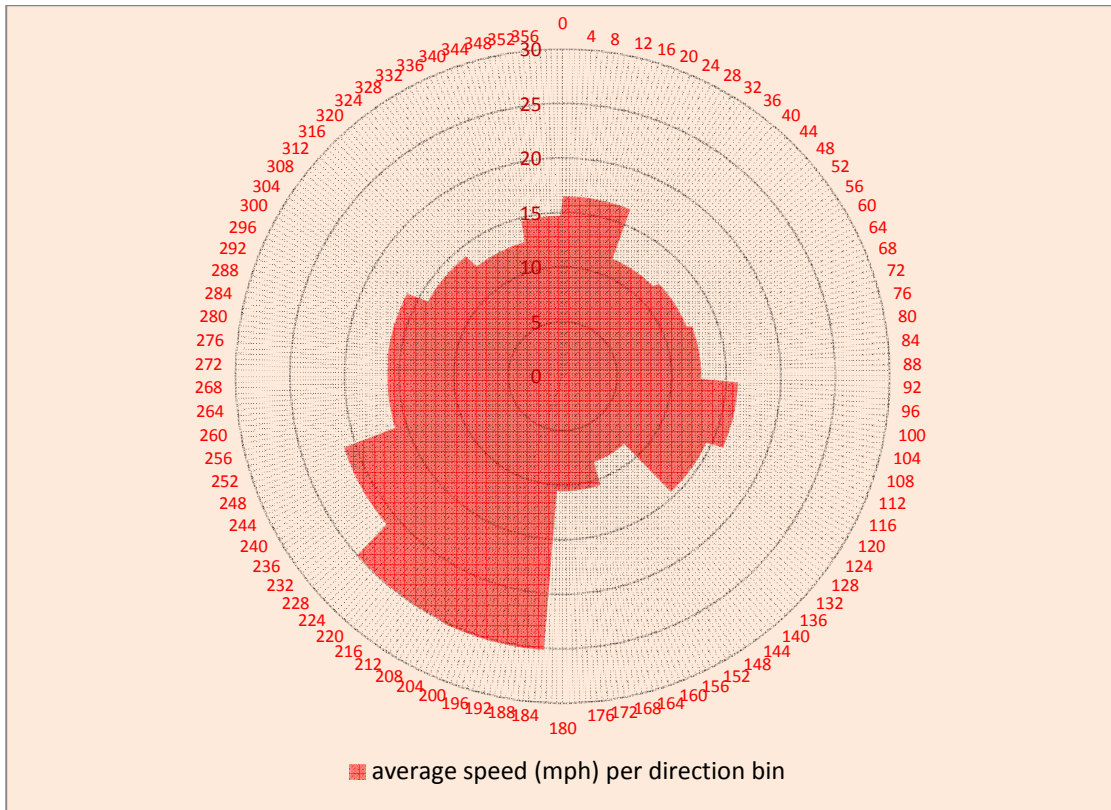
Range Gate 2: Average Wind Speed and Percent Time by Direction



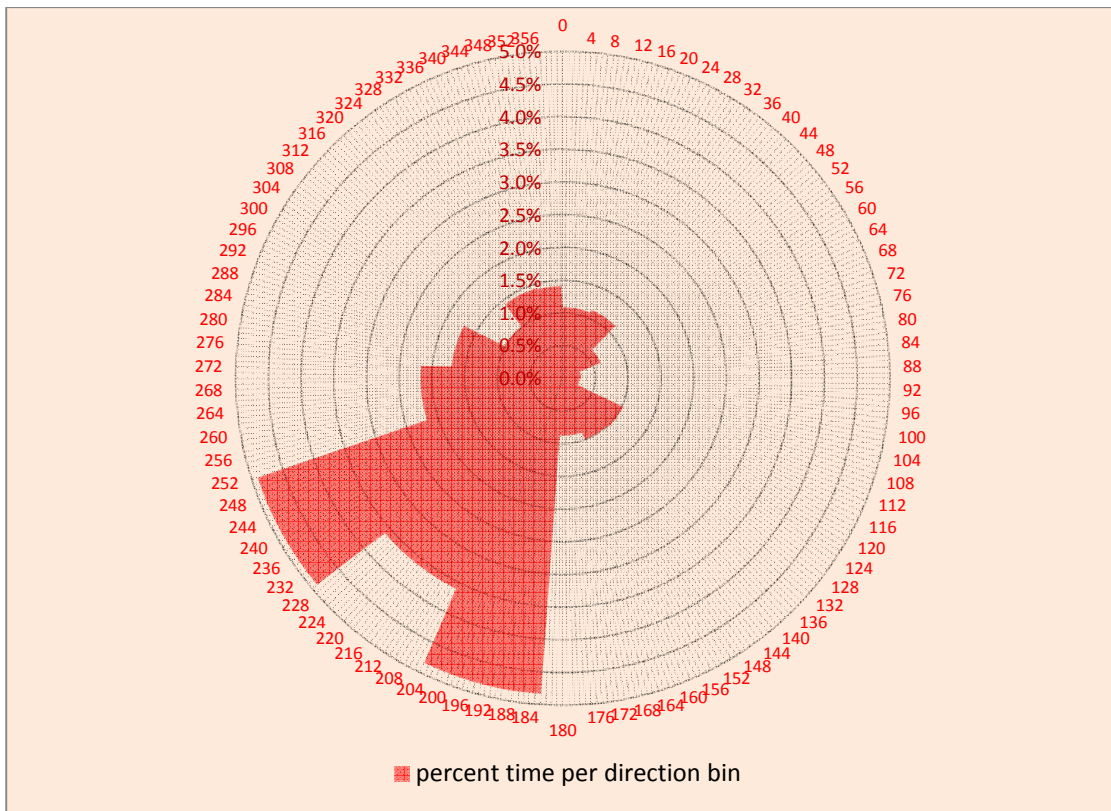
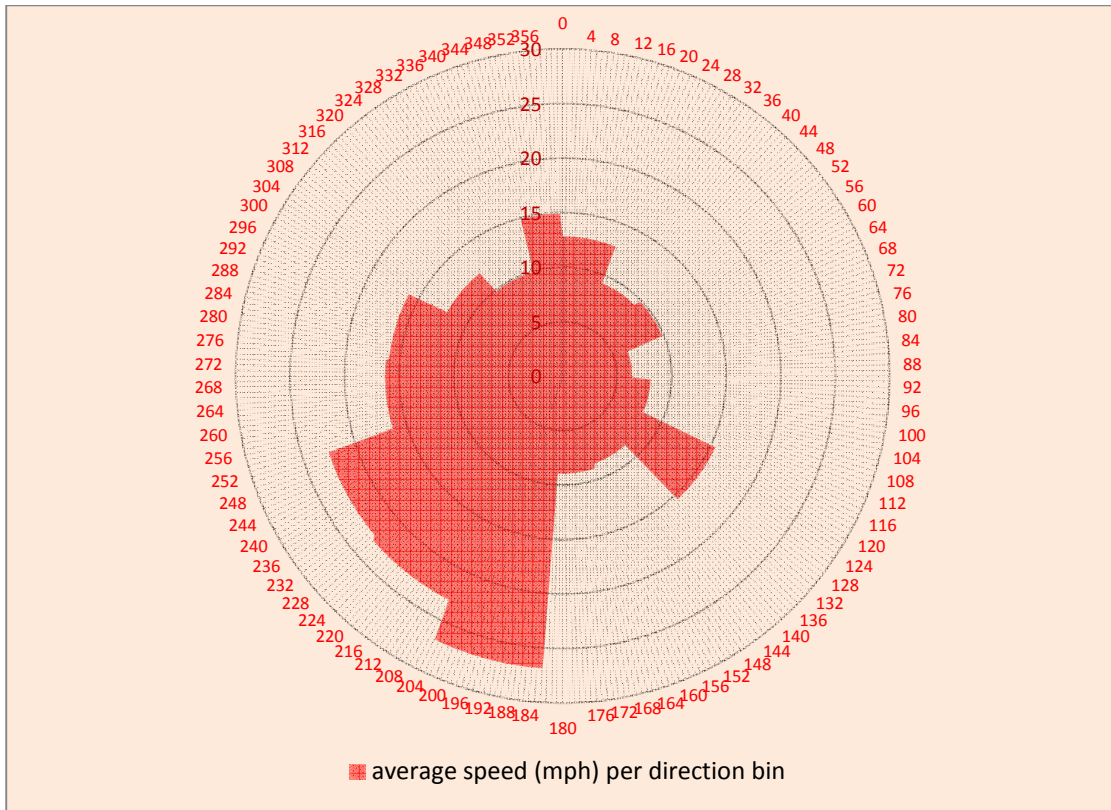
Range Gate 3: Average Wind Speed and Percent Time by Direction



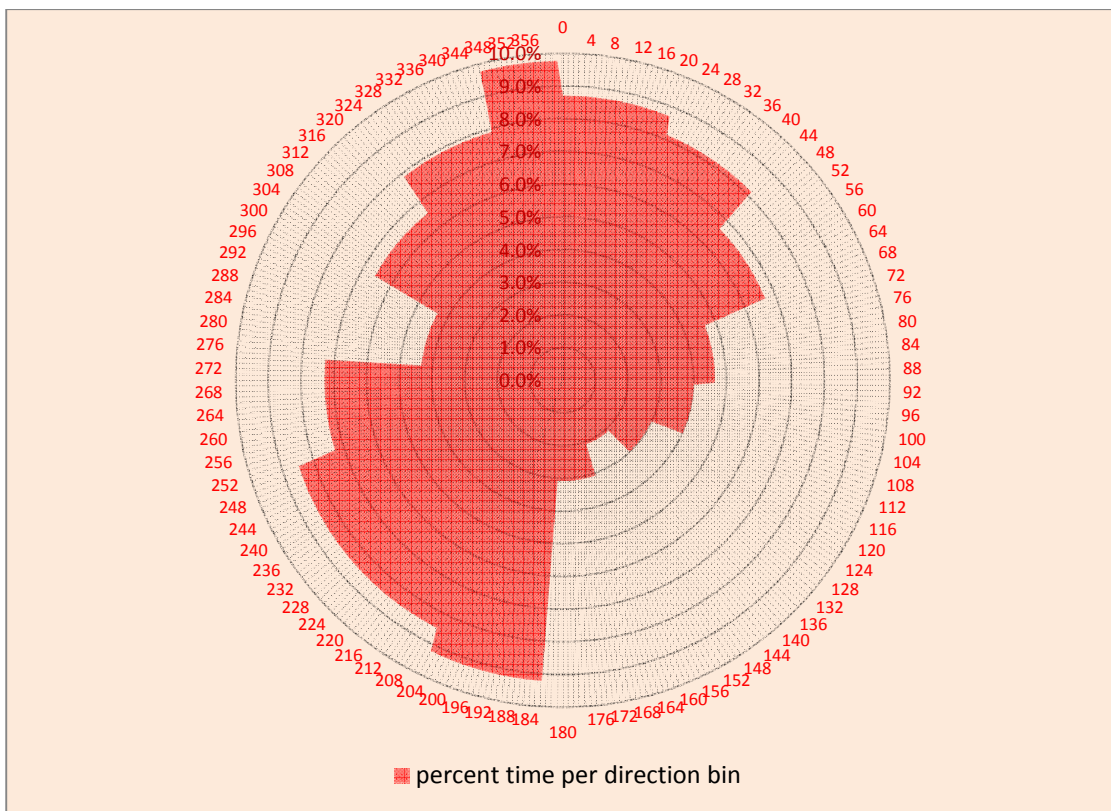
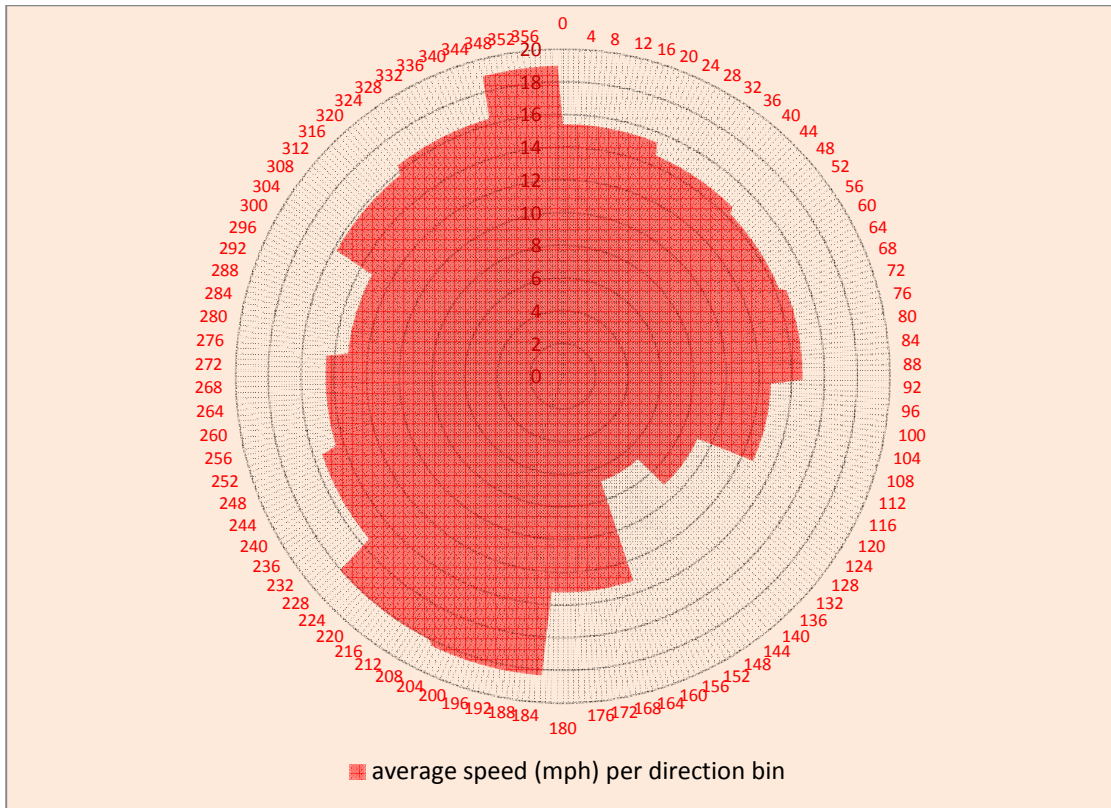
Range Gate 4: Average Wind Speed and Percent Time by Direction



Range Gate 5: Average Wind Speed and Percent Time by Direction



Range Gate 6: Average Wind Speed and Percent Time by Direction



Buoy Cup Anemometer: Average Wind Speed and Percent Time by Direction

Notes:

1. Based on the percent of good observations in Table 4, performance appears to be degraded for range gates 5 and 6. This was expected for range gate 6 which is experimental. To demonstrate reliability, the results for range gate 5 need further investigation.
2. Energy potential ranges from 9.1 to 9.7 megawatts hours per day, about 2 megawatts hours per day higher than in August.
3. The energy potential of the wind at the surface as measured by the cup anemometer on the buoy is about 80% of the energy potential at the higher elevations. The wind speed is about 85% of that at the higher elevations.
4. The average wind speed estimated by six 10-minute averages per hour and one 10-minute average per hour are the equivalent. Differences in variability estimates are yet to be explored.
5. The highest average wind speed is in the southwest direction, which is the same direction from which the greatest percent of the wind comes.