

10-2012

Lake Michigan Wind Assessment Project Data Summary and Analysis: October 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: October 2012" (2012). *Monthly Buoy Report*. 4.
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Lake Michigan Wind Assessment Project
Data Summary and Analysis

October 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:** October 1 through October 31, 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, down sampled one per hour from data collected and stored on the buoy
- Number of Observations:** 31 days at 24 observations per day = 744 observations
- Missing Observations:**

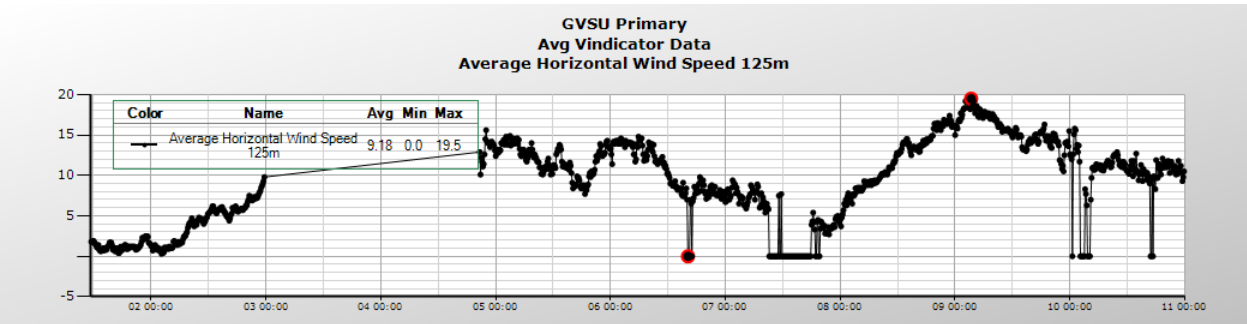
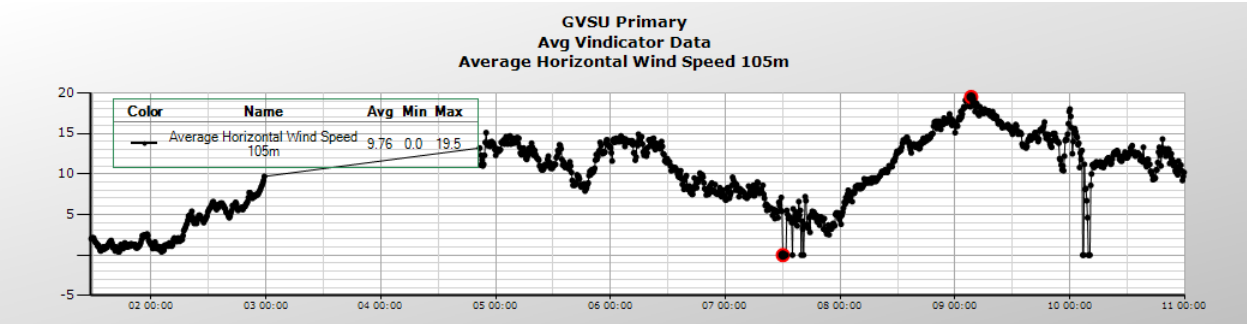
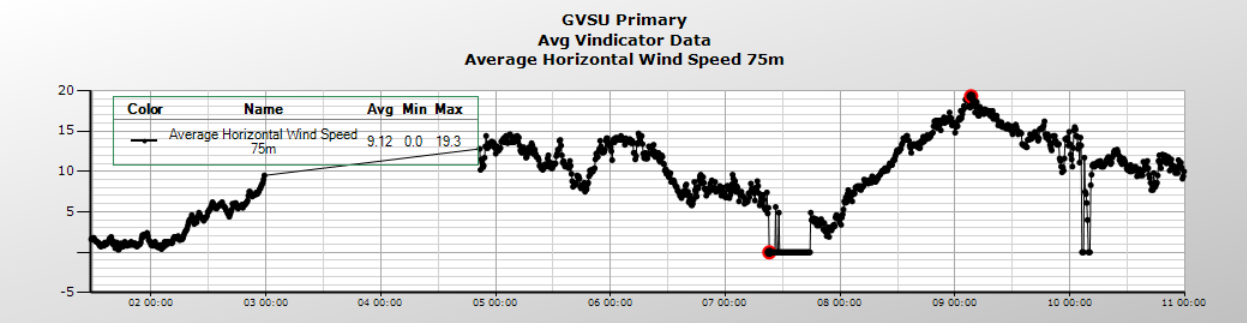
Start		End		Number Missing
Date	Time	Date	Time	
1-Oct	0:00	1-Oct	11:00	12
3-Oct	0:00	4-Oct	20:00	45
11-Oct	16:00	15-Oct	0:00	81

Good Observations: 606 (81.5%)

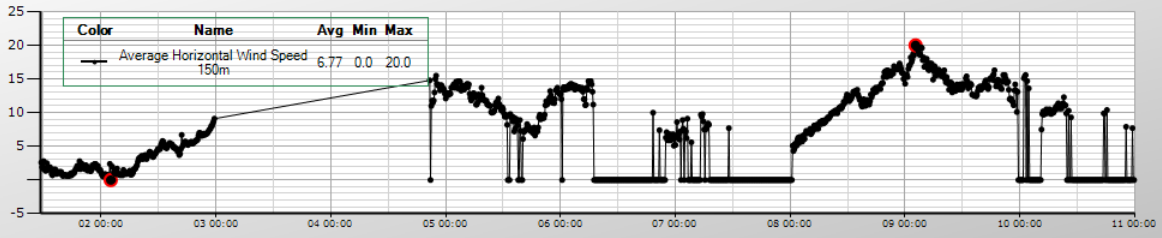
Notes:

- 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.

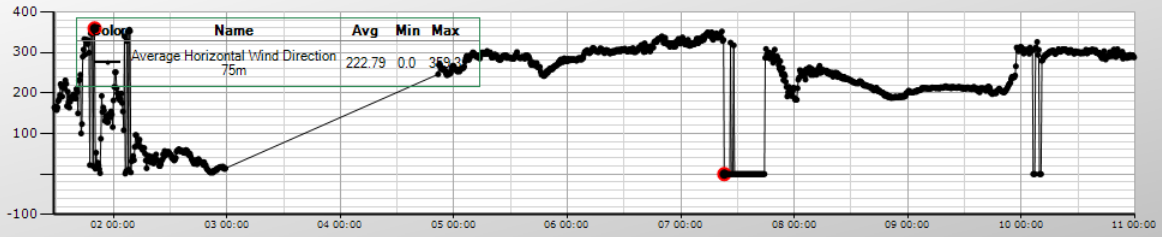
Graphs for wind speed for ranges gates 1, 3, 4, and 5 as well as the cup anemometer follow. Graphs of the horizontal wind direction at the cup anemometer and range gate 1 are included as well. The graphs are for October 1 through October 10.



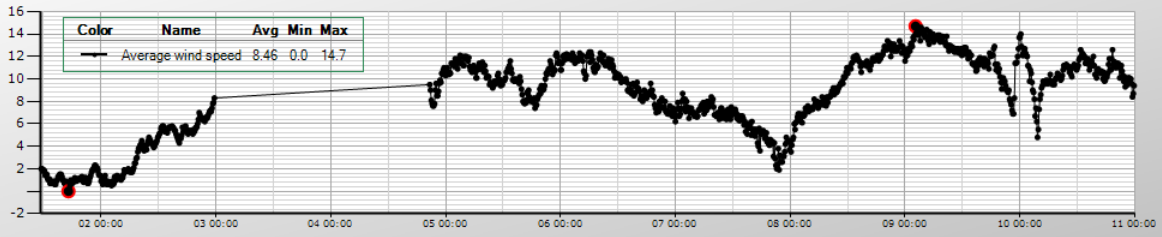
GVSU Primary
Avg Vindicator Data
Average Horizontal Wind Speed 150m

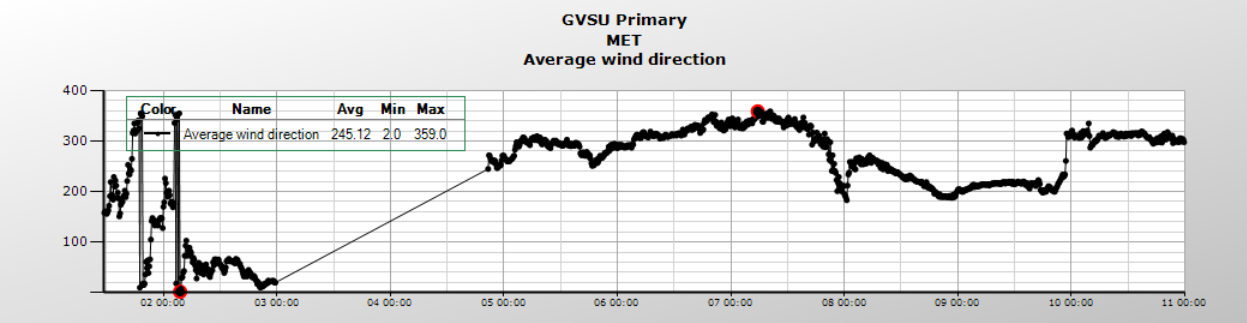


GVSU Primary
Avg Vindicator Data
Average Horizontal Wind Direction 75m



GVSU Primary
MET
Average wind speed





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 606 hours with one 10-minute average recorded.

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	606	536	573	506	341
% of Total (606)	100.0%	88.4%	94.6%	83.5%	56.3%
Average	8.5	11.0	11.5	11.4	11.7
Standard Deviation	3.9	5.6	5.7	5.8	6.0
Minimum	0.4	0.7	0.7	0.7	0.6
1st quartile	5.8	7.0	7.6	7.2	6.9
Median	8.4	10.5	10.9	10.7	11.7
3rd quartile	11.1	14.6	15.1	15.3	16.4
Maximum	19.2	25.5	26.7	26.9	27.1
99% CI for Mean – Lower Bound	8.1	10.4	10.9	10.7	10.9
99% CI for Mean – Upper Bound	8.9	11.6	12.1	12.0	12.6

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	12.7%	10.4%	9.2%	10.1%	10.3%
4-8	34.0%	24.4%	20.9%	22.7%	22.3%
8-12	36.3%	23.7%	26.7%	24.7%	19.1%
12-16	12.9%	22.0%	22.0%	20.4%	22.3%
16-20	4.1%	12.1%	12.2%	12.6%	16.7%
20-24	0.0%	6.2%	7.3%	8.3%	7.9%
24-28	0.0%	1.1%	1.6%	1.2%	1.5%
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)	9.9%	7.5
45 – 90 (NE)	2.4%	2.3
90 – 135 (SE)	0.9%	0.2
135 – 180 (SSE)	11.8%	9.5
180 – 225 (SSW)	27.8%	11.9
225 – 270 (SW)	9.3%	8.1
270 – 315 (NW)	14.2%	9.6
315 – 360 (NNW)	23.7%	9.3

Notes for October:

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, the 8-12m/sec range, and the 12-16m/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 2.8m/sec is statistically significant ($\alpha = 0.01$).
5. The most prevalent wind direction is 180 – 225 degrees (SSW). Almost 50% percent of the time, the wind direction is between 135 and 270 degrees (SSE to SW).
6. About 28% 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 11.0m/sec for range gate 1.

Notes comparing September and October:

1. The average October wind speed is significantly greater than the September wind speed. This is seen in the average, the median, the 1st quartile, and the maximum.
2. The variability of the wind seems to be higher in October than September, as seen in the standard deviation and in the frequencies.
3. Approximately 50% of the time in October 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 away from 0-135 degrees (NNE to SE) and toward 135-360 degrees (SSE to NNW) in October versus September. In September, about 30% of the time the wind direction was between 0-135. In October, about 13% 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.

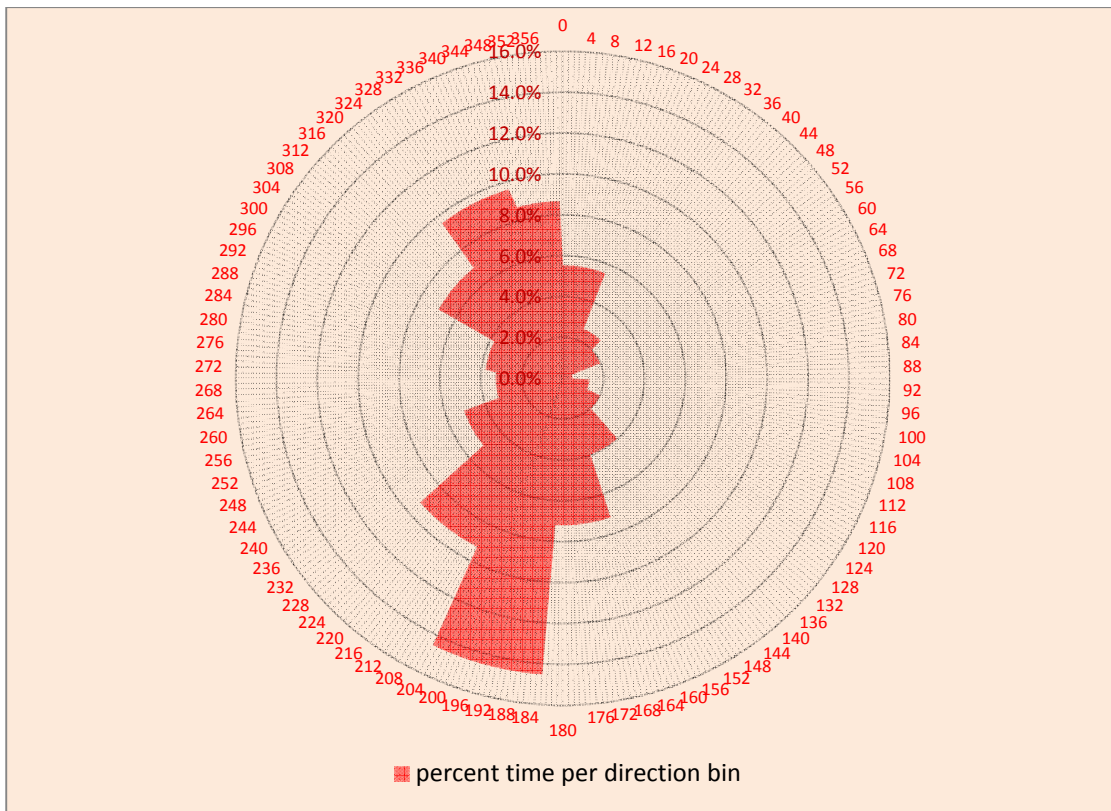
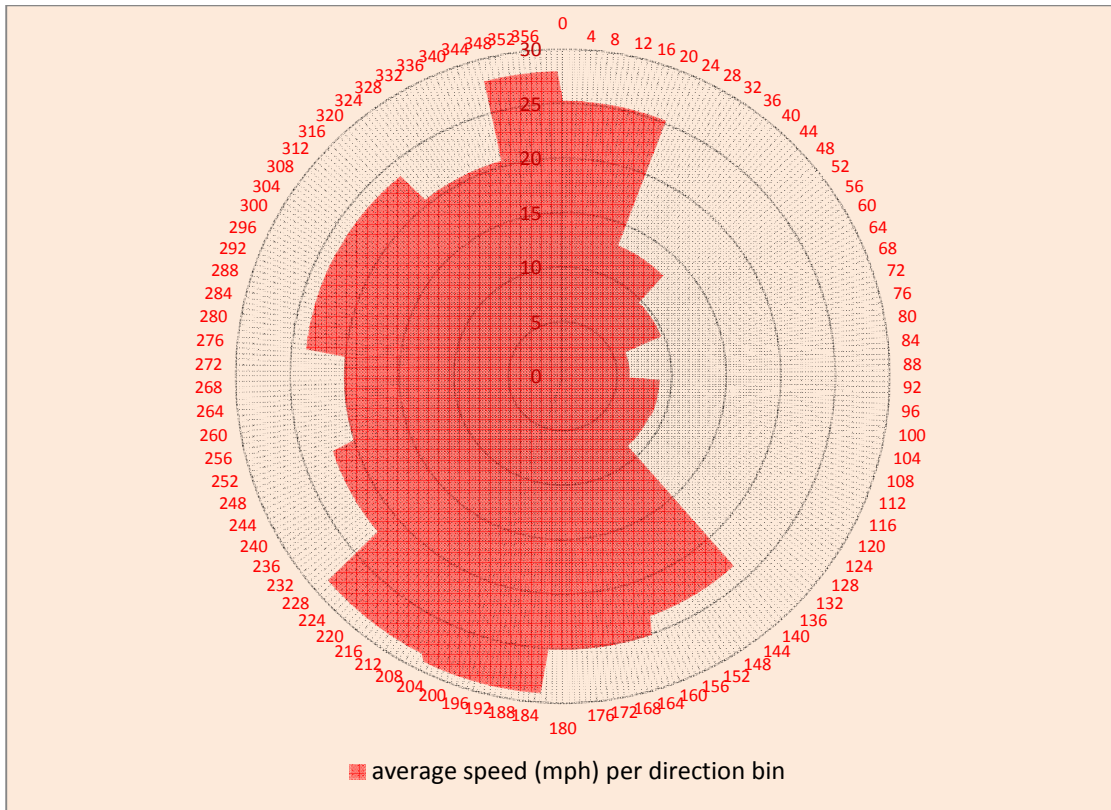
- Location:** Lake Michigan – Mid-lake Plateau (4320.5100N 8707.2057W)
- Date:** October 1 through October 31, 2012 (UTC)
- Range Gates 1-6:** 75, 90, 105, 125, 150, 175 meters
- Cup Anemometer:** 3 meters mounted on the buoy
- Observations:** 10-minute averages, stored on the buoy and retrieved manually
- Number of Observations:** 31 days at 24 X 6 observations per day = 4464 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.

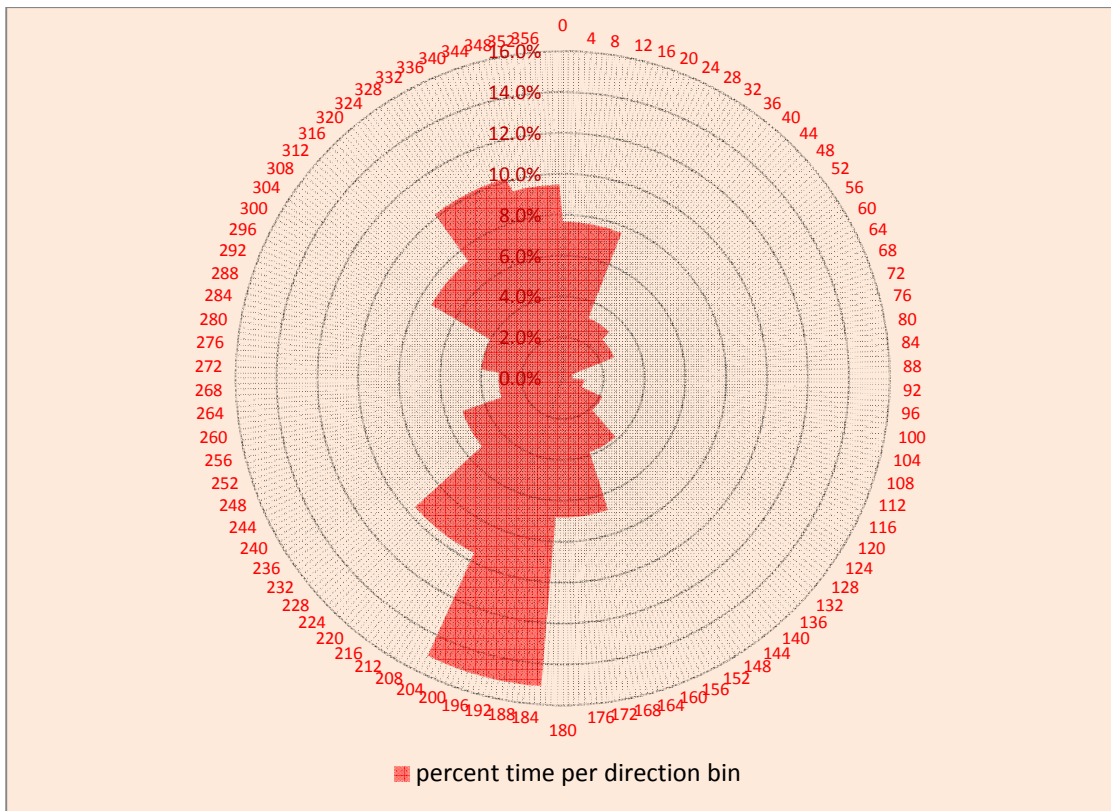
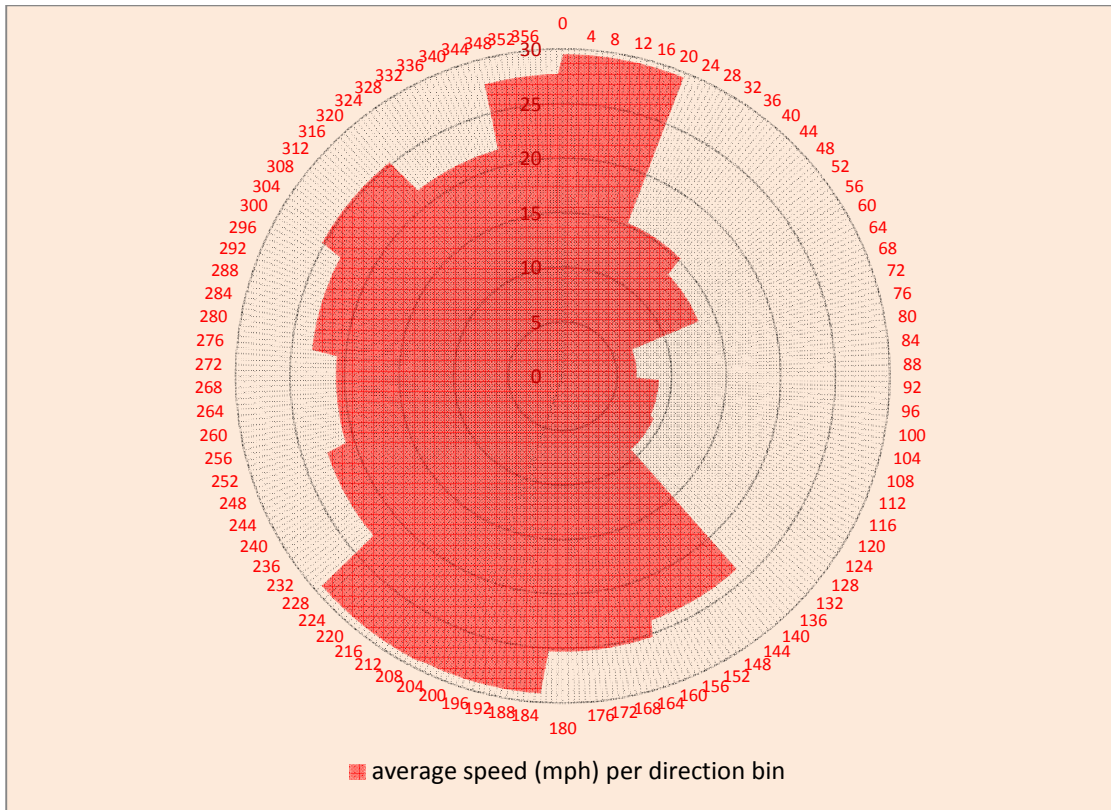
The wind rose graphs show the wind speed by direction as well as the percent of time the wind was blowing in each direction.

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

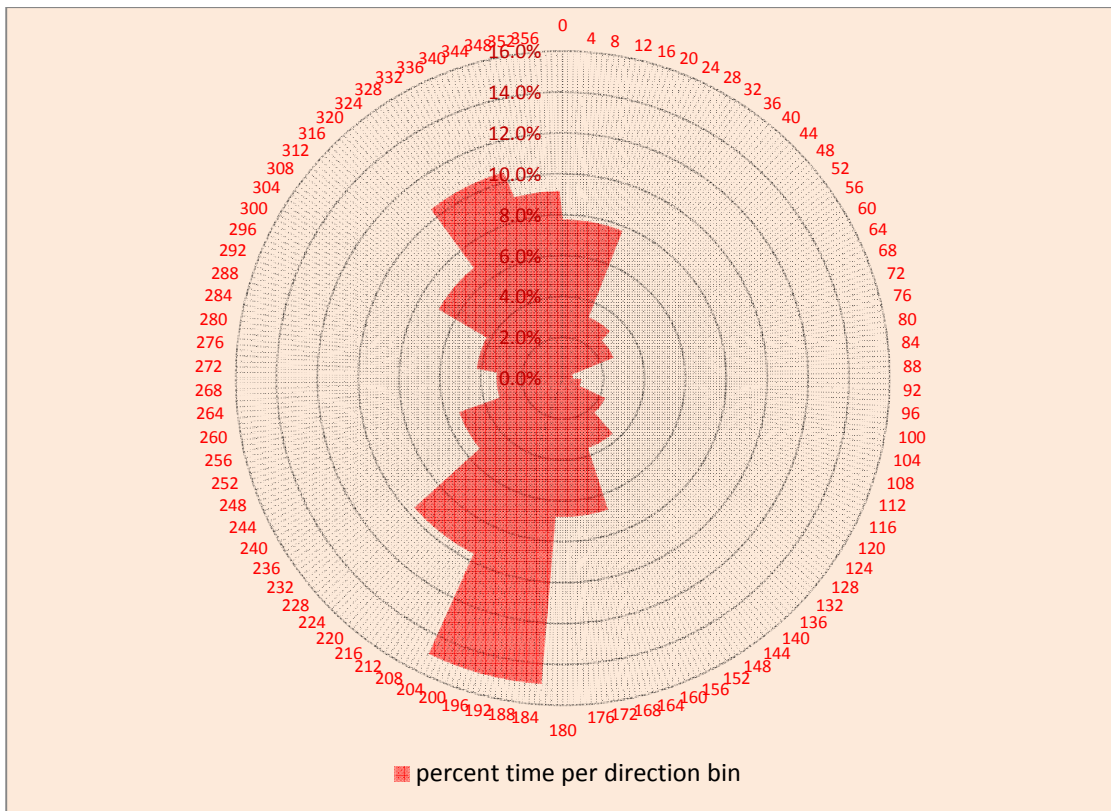
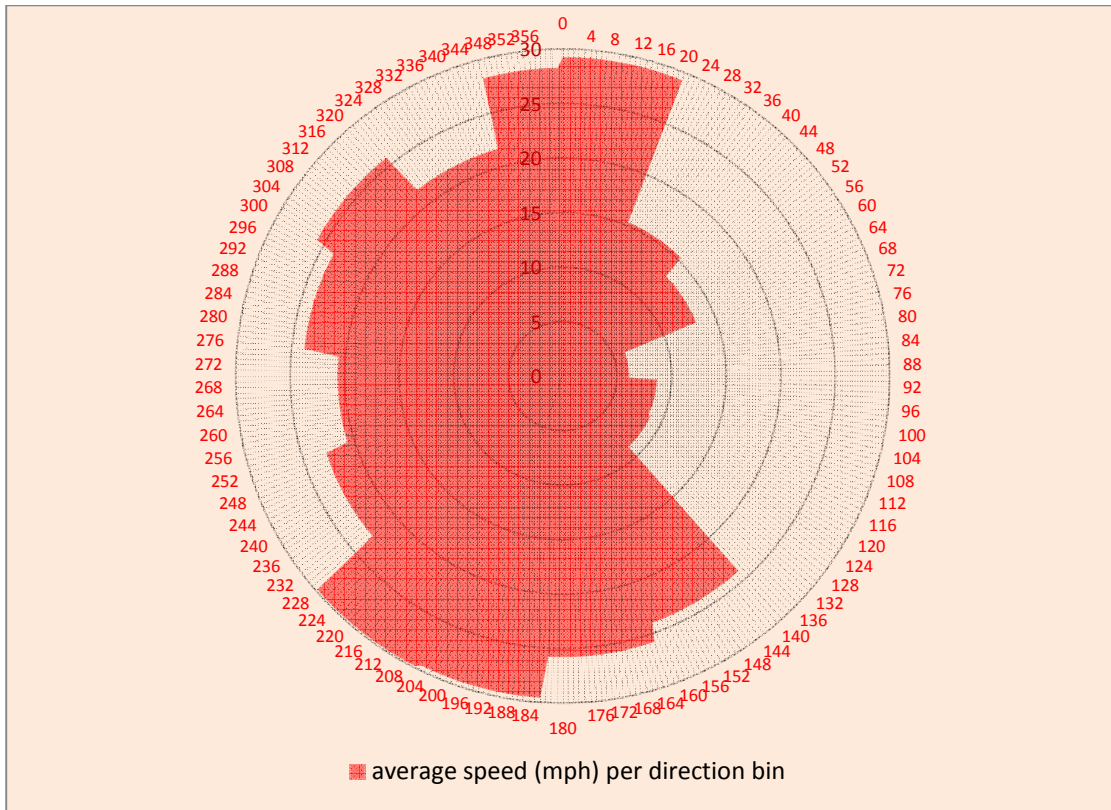
Range Gate	Number of Obs. (Possible = 4464)	% Good Obs.	Average Horizontal Wind Speed	Average Horizontal Wind Speed -- 1 Obs. per hour	Average Horizontal Wind Speed -- Difference	Average Power (kW)	Average Daily Energy (kWh)
1	3831	85.8%	10.7	11	0.3	510	12229
2	4093	91.7%	11.1			524	12573
3	4080	91.4%	11.2	11.5	0.3	521	12500
4	3620	81.1%	11.0	11.4	0.4	499	11965
5	2497	55.9%	11.5	11.7	0.2	521	12511
6	1628	36.5%	11.5			518	12432
Buoy Cup	4458	99.9%	8.5	8.3	-0.2	431	10346



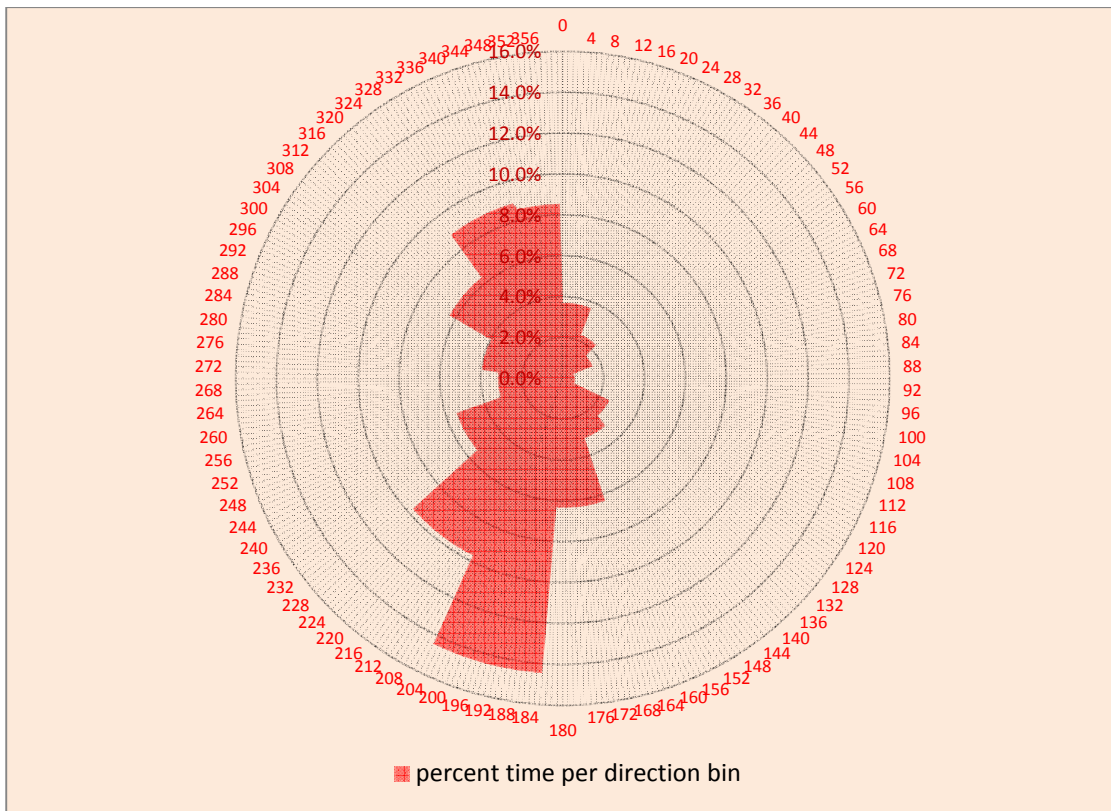
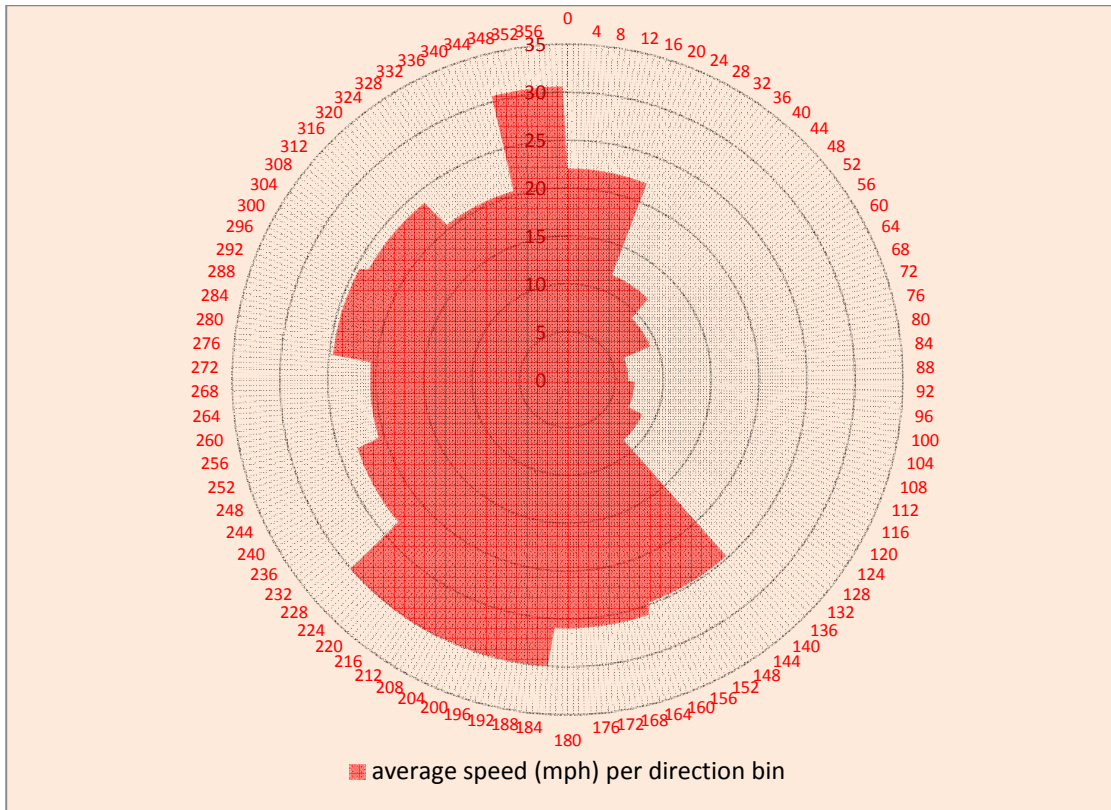
Range Gate 1: Average Wind Speed and Percent Time by Direction



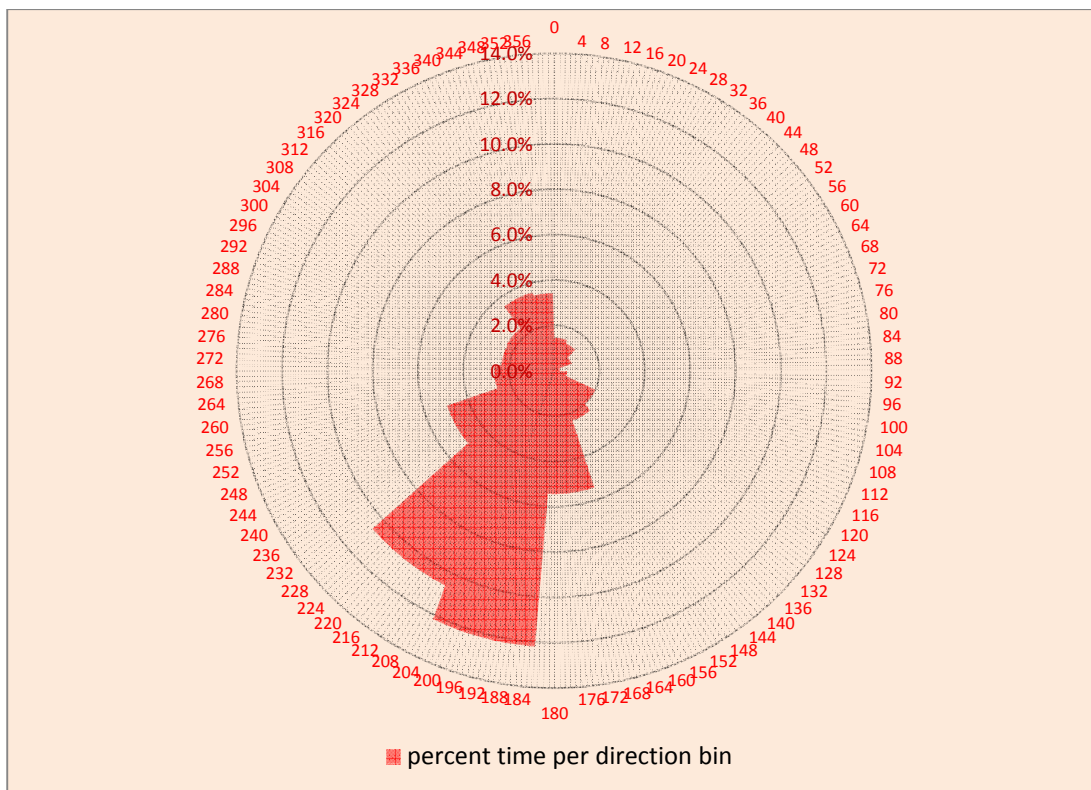
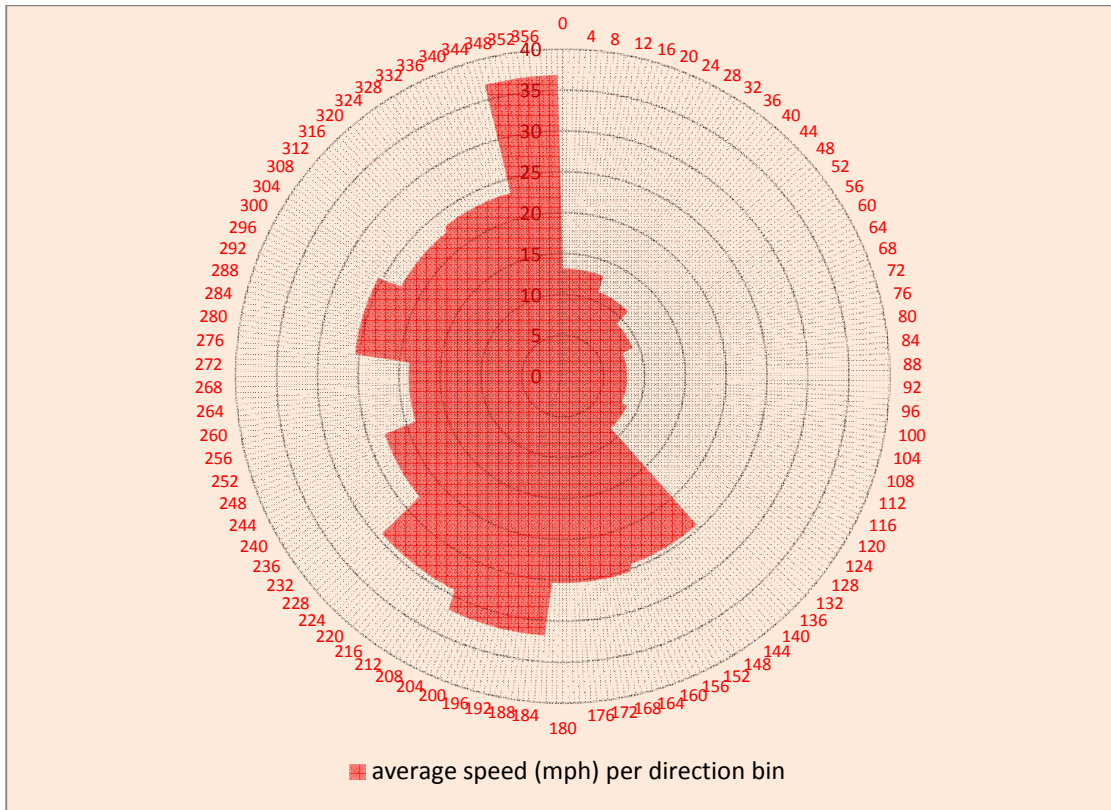
Range Gate 2: Average Wind Speed and Percent Time by Direction



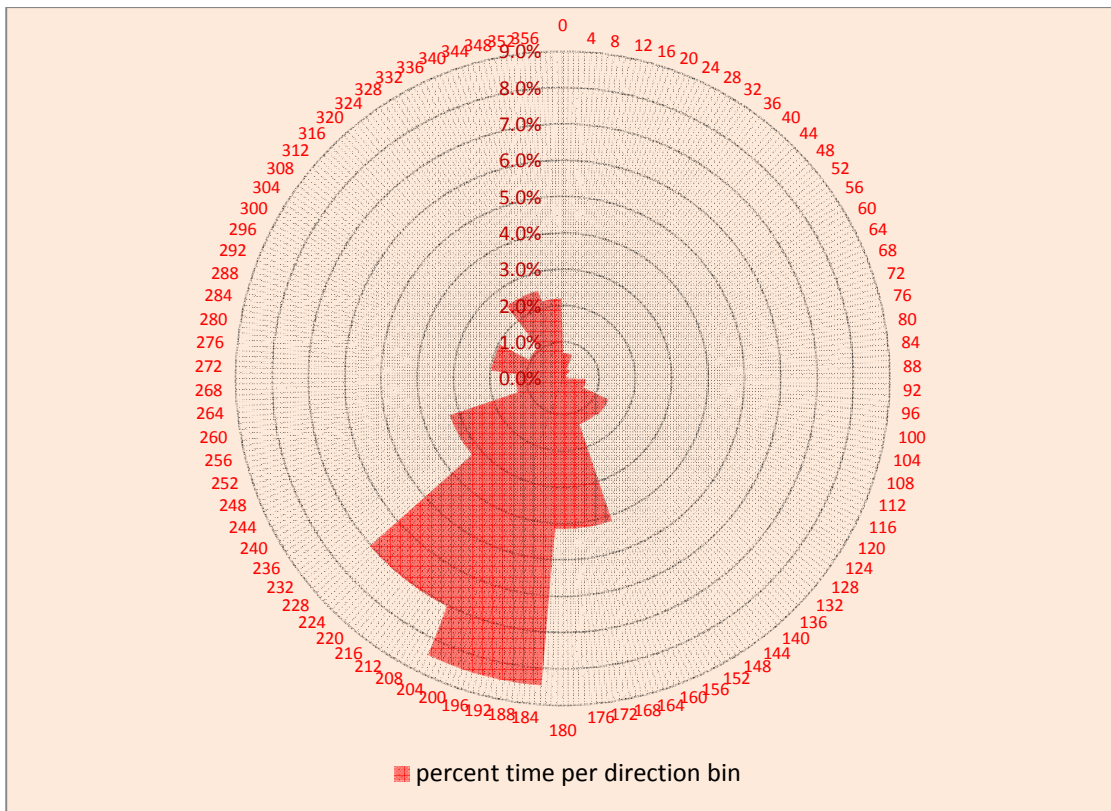
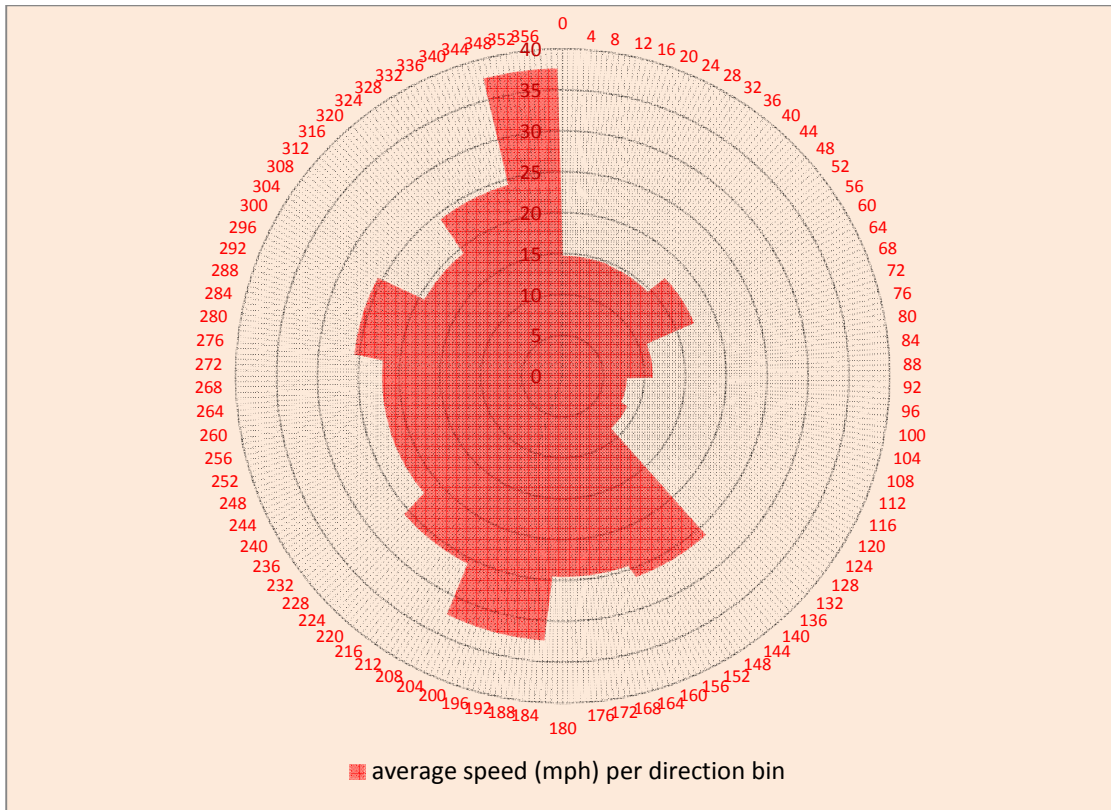
Range Gate 3: Average Wind Speed and Percent Time by Direction



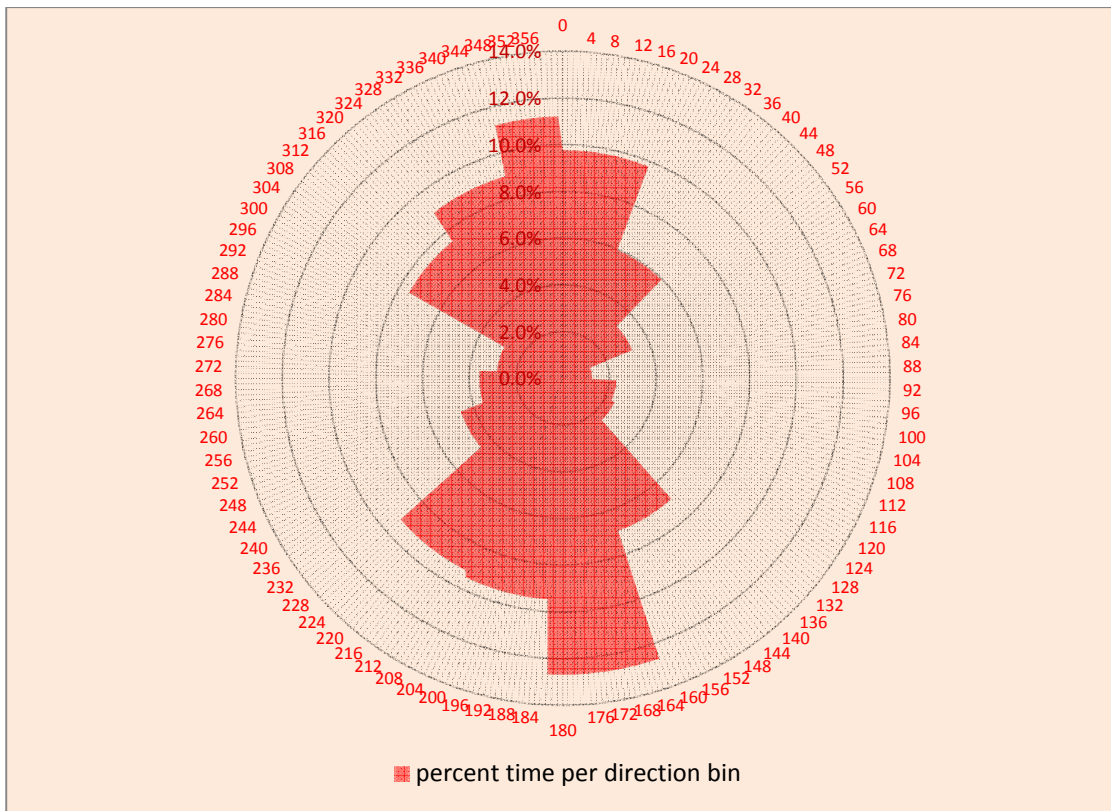
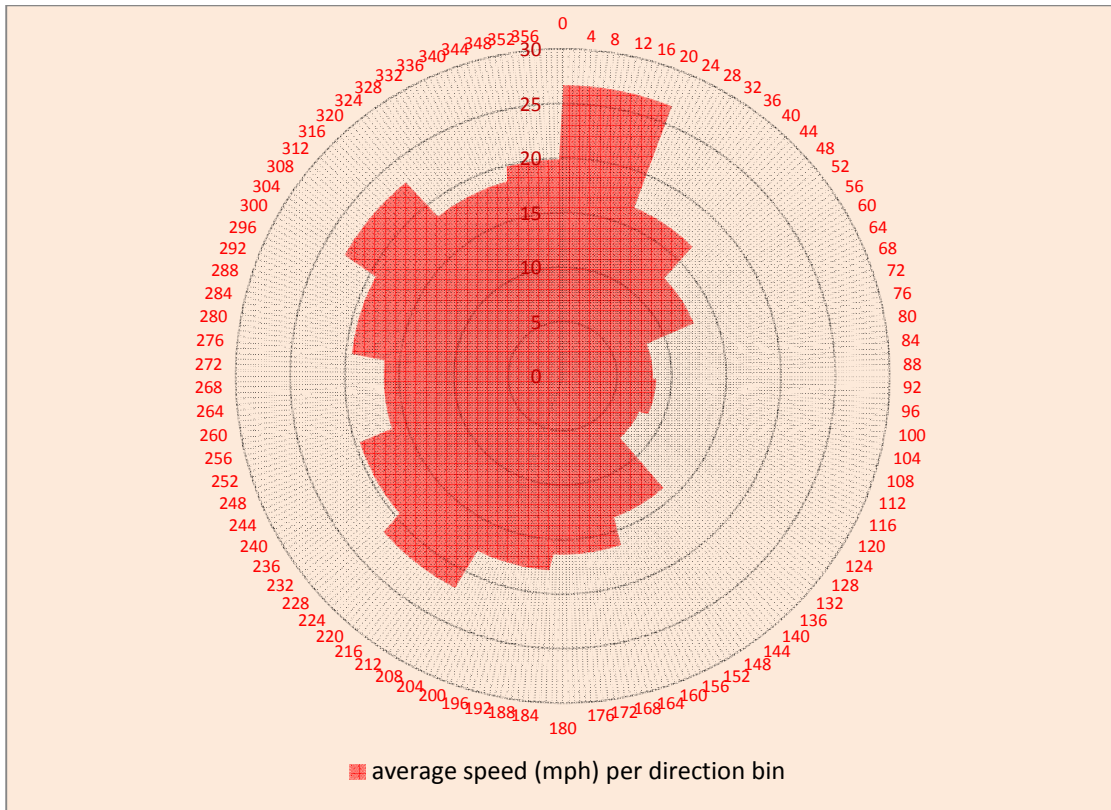
Range Gate 4: Average Wind Speed and Percent Time by Direction



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 12.0 to 12.6 megawatts hours per day, about 1/3rd more megawatts hours per day than in September.
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 average wind speed is about 2/3rds 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. The maximum difference is about 0.4 m/s about 4%. 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.