5-2012

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

Lake Michigan Offshore Wind Assessment Project

Lake Michigan Wind Assessment Project

Data Summary and Analysis

May 2012

Revised September 2012

Part I – Satellite Transmitted 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: May 8 through May 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, transmitted via satellite at the rate of one 10-minute average per hour

Number of Observations: 24 days at 24 observations per day = 576 observations

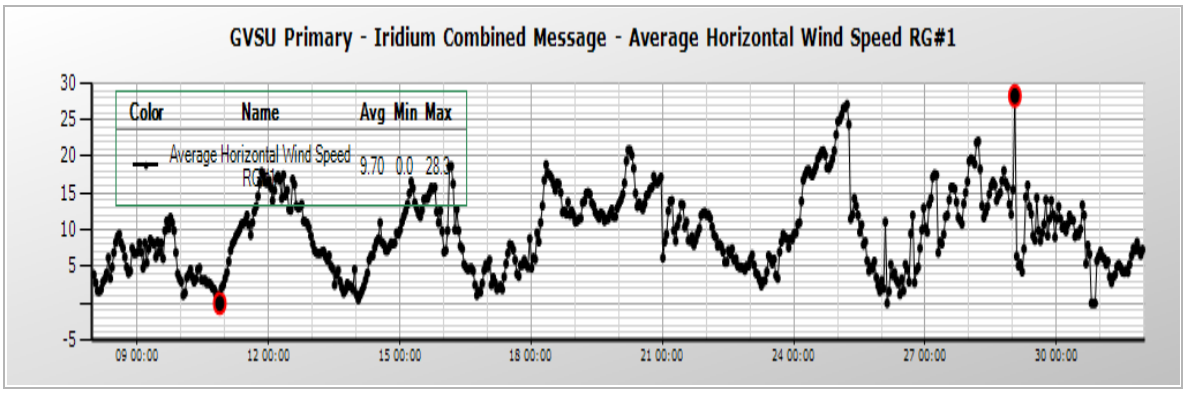
Missing Observations: None

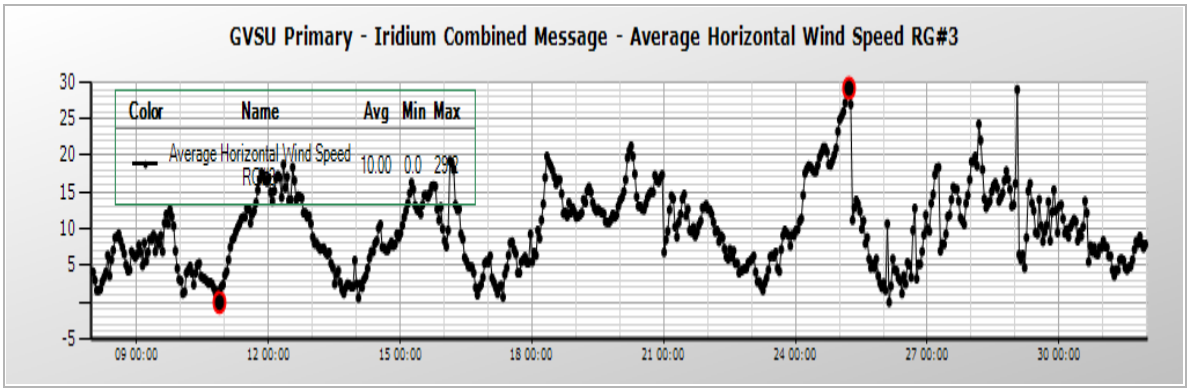
Good Observations: 576

Notes:

- Data for Range Gates 2 and 5 are available and stored on the buoy, but not transmitted (by choice) in the real-time 10 minute average data.
- 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.
- 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 6 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 RG#1
Color
Name
Avg Min Max
Average Horizontal Wind Speed
9.70 0.0 28.3
30
25
20
15
10
5
-5
09 00:00
12 00:00
15 00:00
18 00:00
21 00:00
24 00:00
27 00:00
30 00:00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Color
Name
Avg Min Max
Average Horizontal Wind Speed
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30
25
20
15
10
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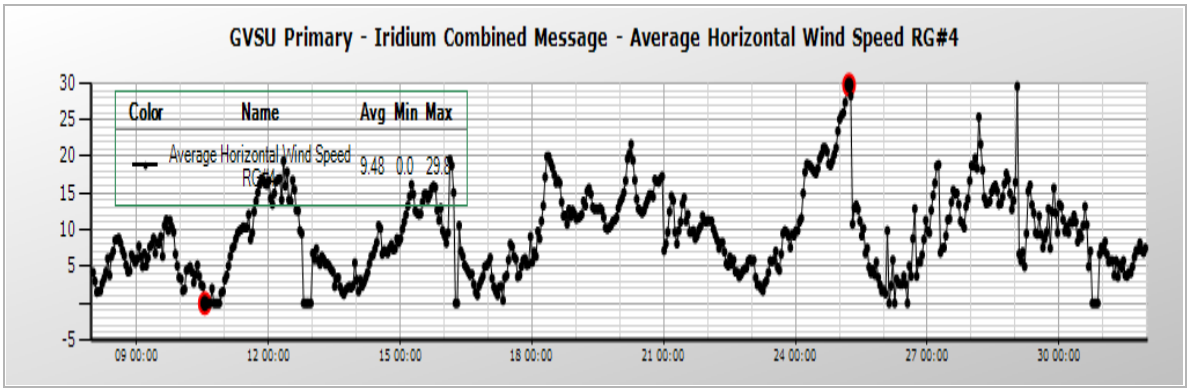
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Avg Min Max
Average Horizontal Wind Speed
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20
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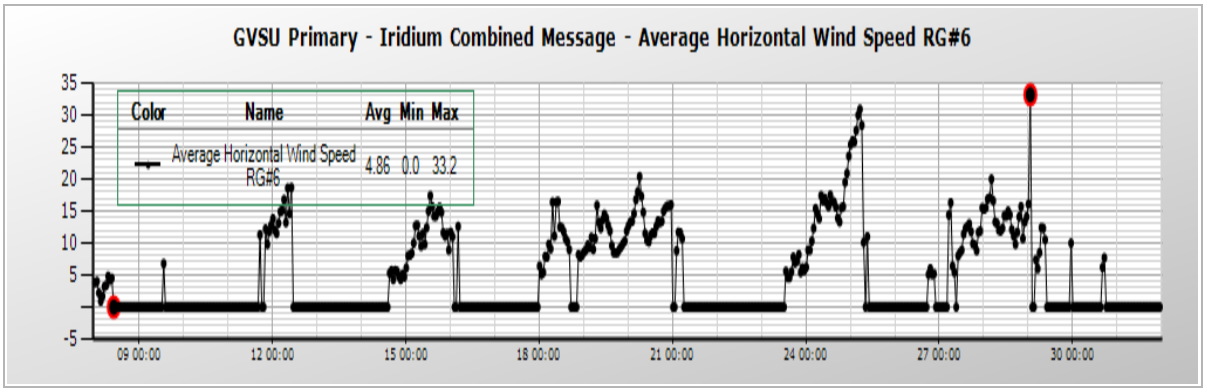
30 00:00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Color Name Avg Min Max
Average Horizontal Wind Speed RG#6 4.86 0.0 33.2
35
30
25
20
15
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5
-5
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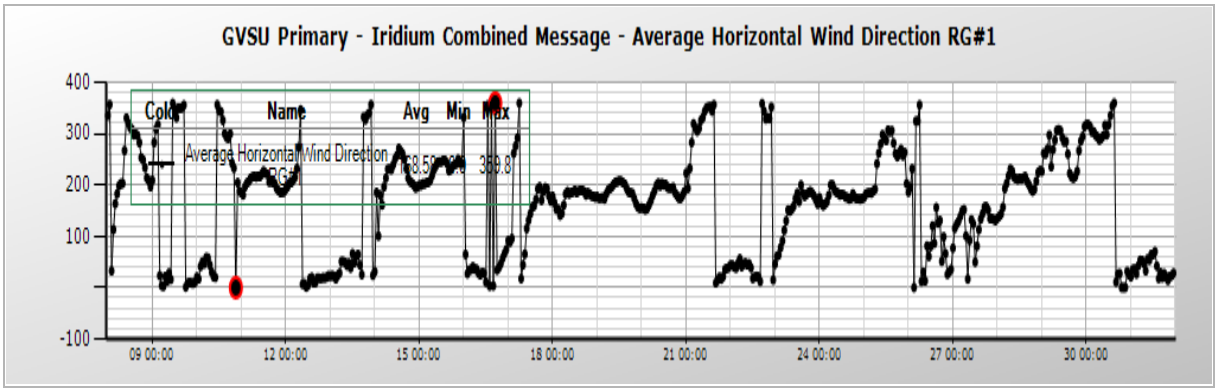
27 00:00
30 00:00


GVSU Primary - Iridium Combined Message - Average Horizontal Wind Direction RG#1
Color Name Avg Min Max
Average Horizontal Wind Direction RG#1
400
300
200
100
-100
09 00:00
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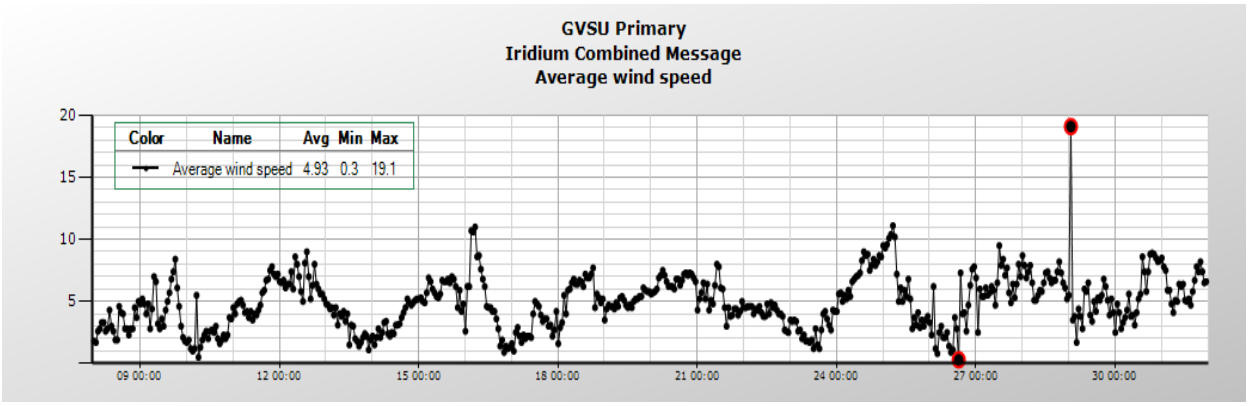
24 00:00
27 00:00
30 00:00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Iridium Combined Message
Average wind speed
Color Name Avg Min Max
Average wind speed 4.93 0.3 19.1
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5
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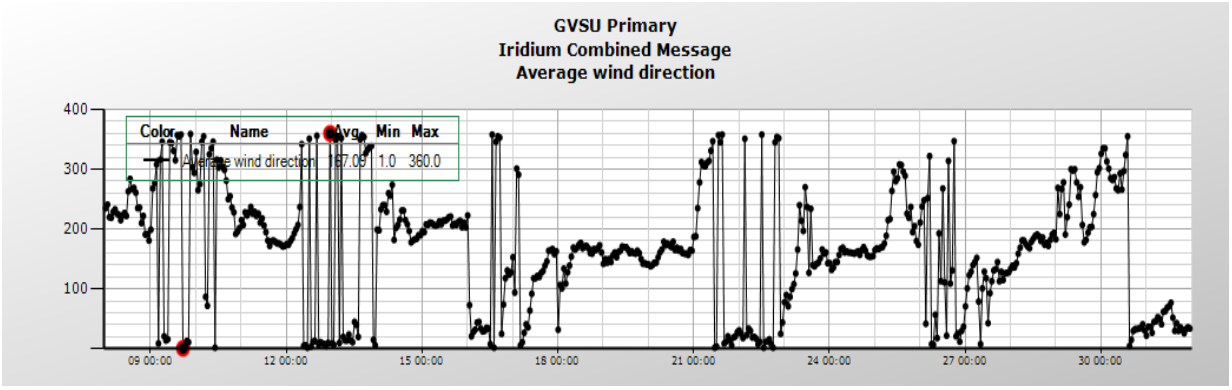
30 00:00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Iridium Combined Message
Average wind direction
Color Name Avg Min Max
Average wind direction 187.09 1.0 360.0
400
300
200
100
09 00:00
12 00:00
15 00:00
18 00:00
21 00:00
24 00:00
27 00:00
30 00:00

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 576 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	N001S009P088 Average Horizontal Wind Speed RG#6
Good Observations	576	558	565	522	199
% of Total (576)	100%	97%	98%	91%	35%
Average	4.9	9.9	10.1	10.1	12.1
Standard Deviation	2.1	5.4	5.4	5.5	5.0
Minimum	0.3	0.5	0.6	0.4	0.9
1st quartile	3.4	5.3	5.8	5.6	8.9
Median	4.9	9.5	9.6	9.7	11.9
3rd quartile	6.4	13.5	13.7	13.8	14.9
Maximum	19.1	28.3	29.2	29.8	30.9
99% CI for Mean – Lower Bound	4.7	9.3	9.5	9.4	11.2
99% CI for Mean – Upper Bound	5.2	10.5	10.7	10.7	13.0

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	N001S009P088 Average Horizontal Wind Speed RG#6
0-4	93.40%	14.72%	14.18%	14.62%	3.03%
4-8	6.42%	25.49%	25.53%	25.19%	14.65%
8-12	0.00%	25.85%	23.76%	24.62%	33.33%
12-16	0.17%	19.75%	22.16%	20.58%	33.84%
16-20	0.00%	10.77%	10.99%	11.54%	10.10%
20-24	0.00%	1.97%	1.77%	1.92%	1.52%
24-28	0.00%	1.26%	1.06%	0.96%	2.02%
28-32	0.00%	0.18%	0.53%	0.58%	1.52%

Table 3: Wind Direction Frequencies by Range Gate

Wind Direction Range (Degrees)	N001S009P089 Average Horizontal Wind Direction RG#1	N001S009P083 Average Horizontal Wind Speed RG#1
0 – 45 (NNE)	19.57%	7.8
45 – 90 (NE)	7.90%	5.3
90 – 135 (SE)	4.67%	9.2
135 – 180 (SSE)	13.64%	12.5
180 – 225 (SSW)	26.93%	12.7
225 – 270 (SW)	9.69%	9.9
270 – 315 (NW)	8.80%	9.4
315 – 360 (NNW)	8.80%	7.1

Notes:

1. The average wind speed appears to be equivalent for range gates 1, 3, 4 (75, 105, 125 meters).
2. The average wind speed appears to be greater for range gate 6 (175 meters). Further analysis showed this conclusion should not be drawn from the available data. For the 198 times when both range gate 4 and range gate 6 had a valid observation, the average difference in wind speed was 1.8 meters per second with range gate 4 being the higher.
3. The distribution of wind speeds appears to be equivalent for range gates 1, 3, 4.
4. The distribution of wind speeds for range gate 6 as well as the relatively small percent of good observations is consistent with the idea that range gate 6 needs high wind to measure the speed the majority of the time.
5. The most prevalent wind direction is 180 – 225 degrees (SSW). About forty percent of the time the wind direction is between 135 and 225 degrees (SW to SSW). The average wind speed in this direction exceeds the overall average. About twenty percent of the time the wind direction is between 0 and 45 degrees (NNE).

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: May 8 through May 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: 24 days at 24 X 6 observations per day = 3456 observations

Missing Observations: As shown in table 4.

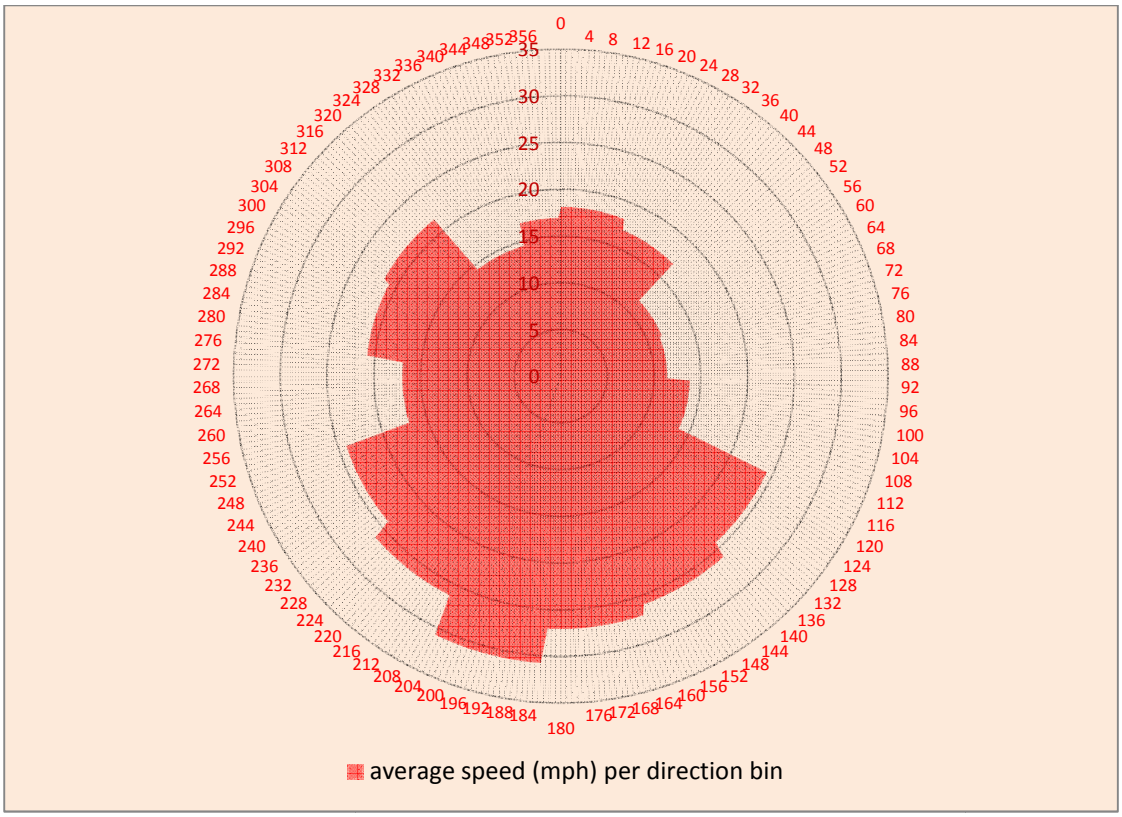
Good Observations: As shown in table 4.

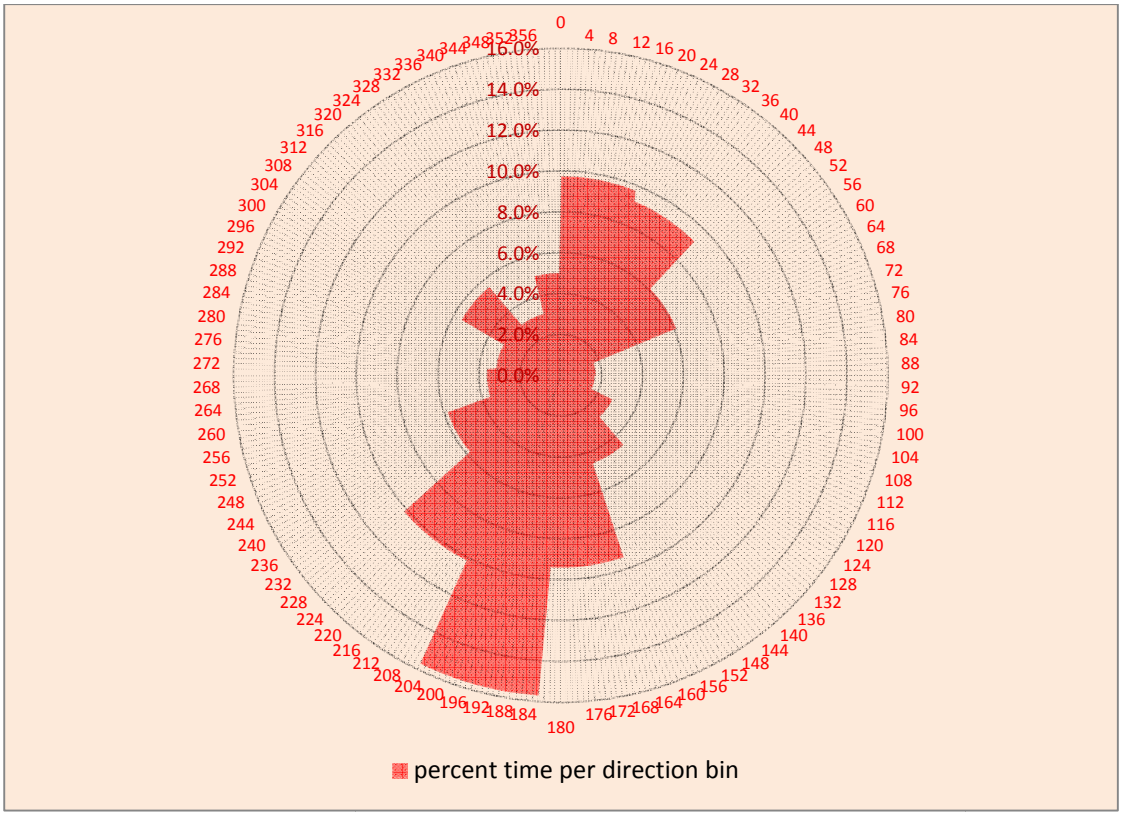
Table 4 shows information concerning the horizontal wind speed and the energy generated for each range gate. The amount of energy generated depends on the turbine employed in this case the Gamesa Elioca G58 850kW. The energy estimate was computed assuming that the turbine will always face the wind.

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

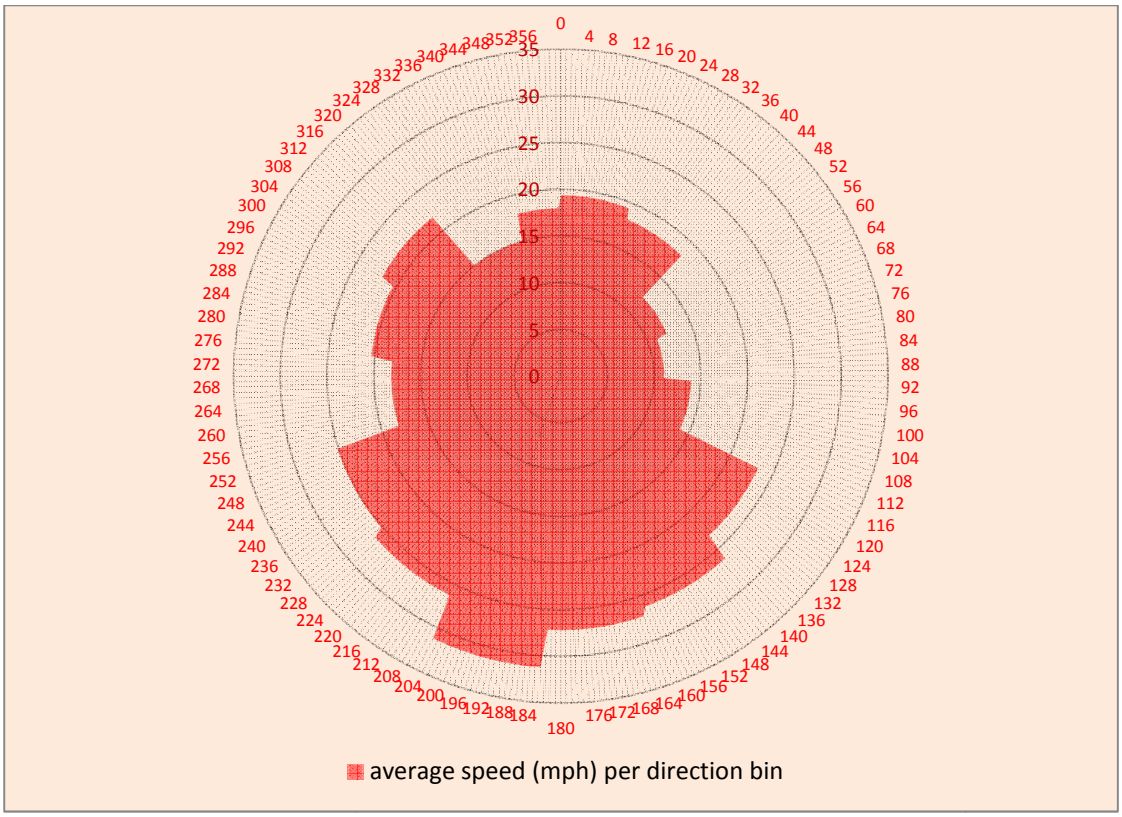
Table 4: Wind Speed (meters per second) and Energy (kWh/time unit) by Range Gate

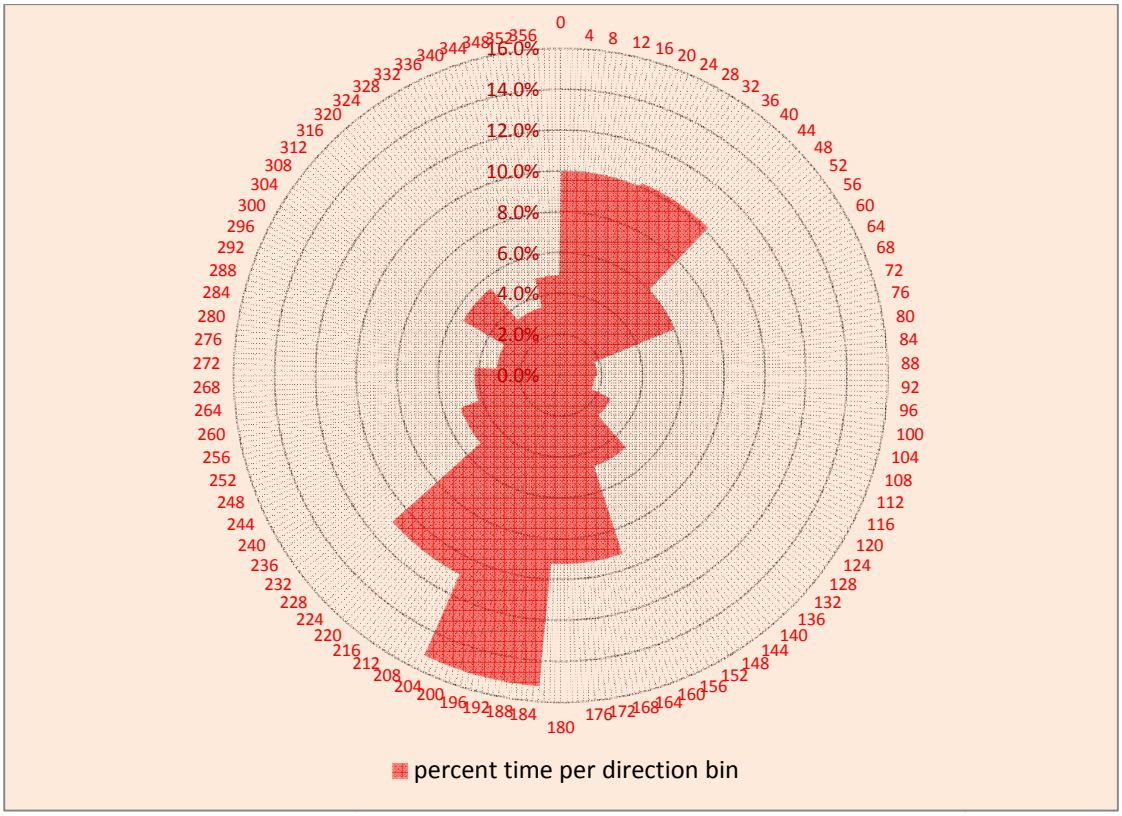
Range Gate	Number of Obs. (Possible = 3456)	% Good Obs.	Average Horizontal Wind Speed	Average Horizontal Wind Speed -- 1 Obs. per hour	Average Horizontal Wind Speed -- Difference	Average Power (MW)	Average Daily Energy (MWh)
1	3353	97.0%	9.9	9.9	0	0.484	11.616
2	3396	98.3%	10.1			0.496	11.904
3	3380	97.8%	10.1	10.1	0	0.497	11.928
4	3108	89.9%	10.1	10.1	0	0.492	11.808
5	1887	54.6%	11.7			0.567	13.608
6	1211	35.0%	12.1	12.1	0	0.624	14.976
Buoy Cup	3456	100.0%	4.9			0.125	3.000



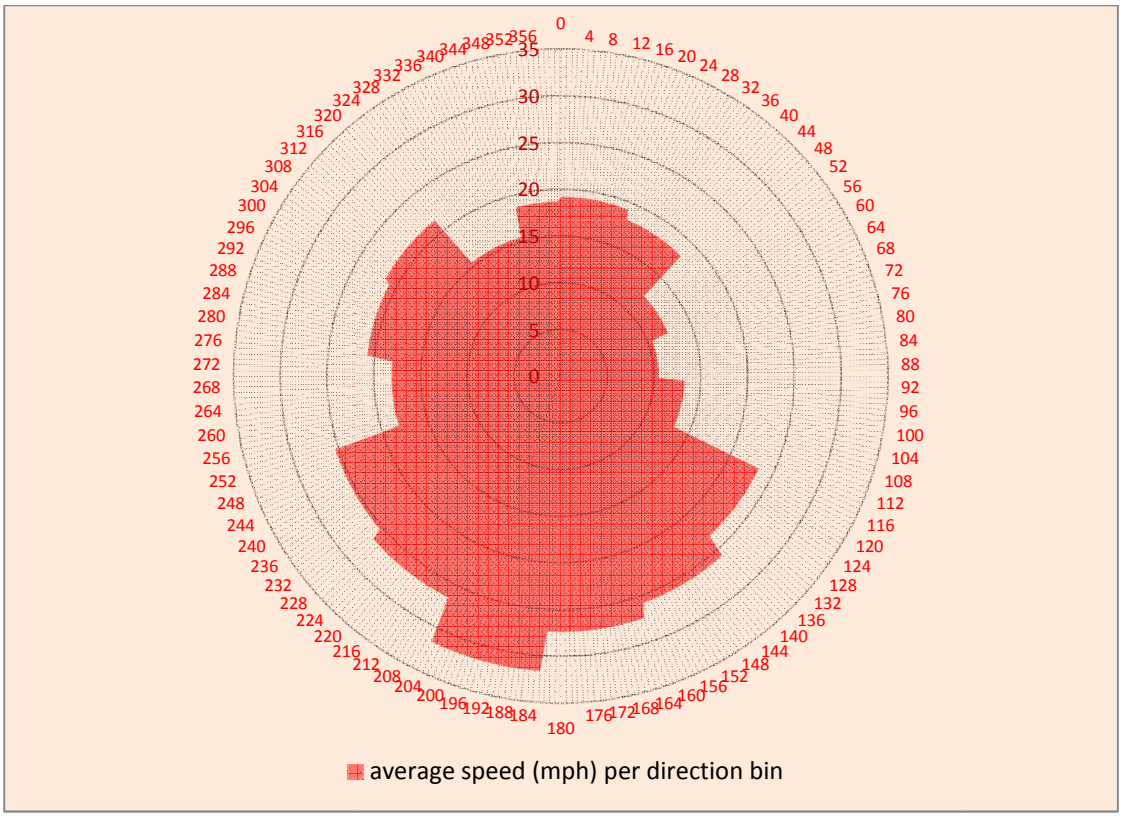


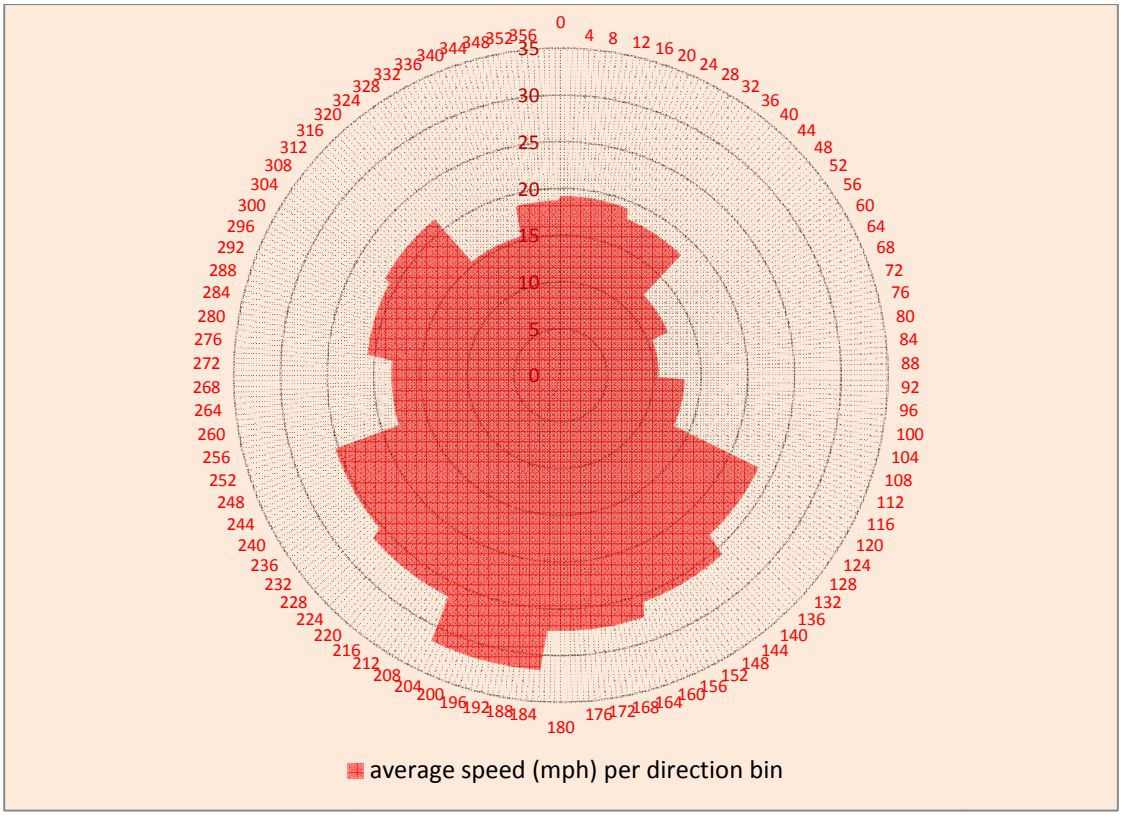
Range Gate 1: Average Wind Speed and Percent Time by Direction



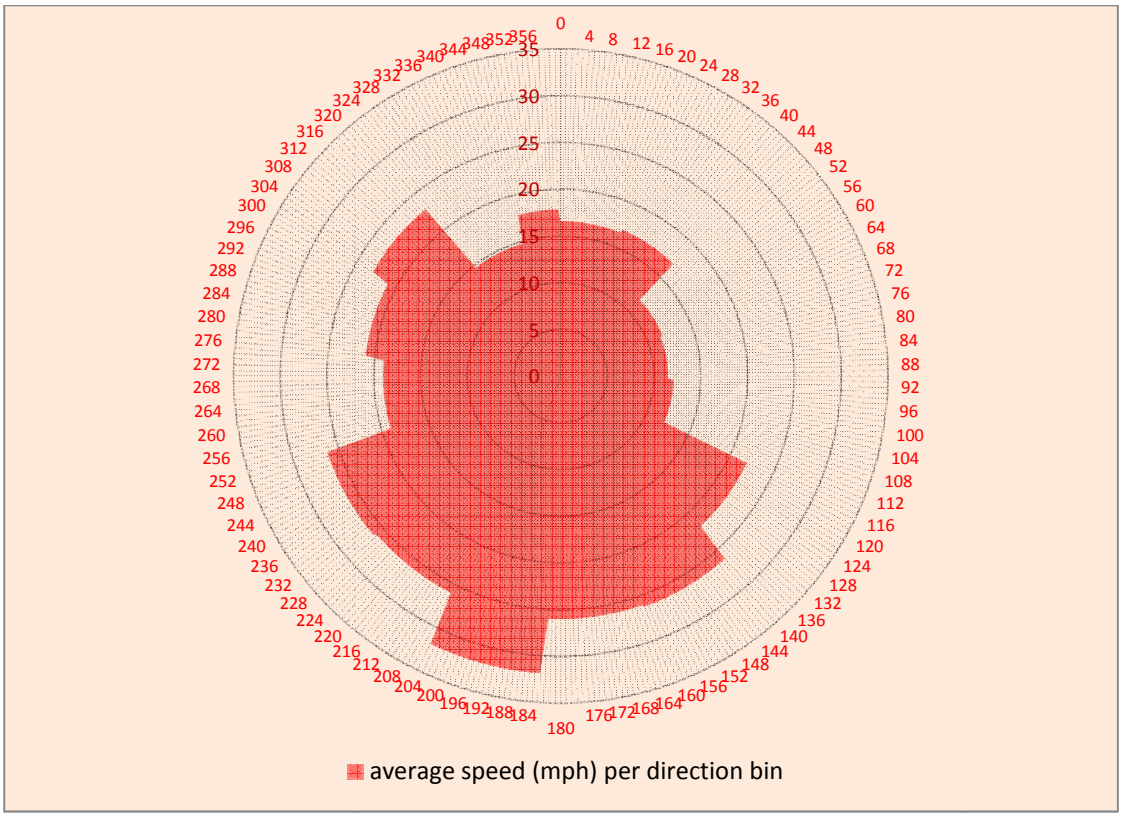


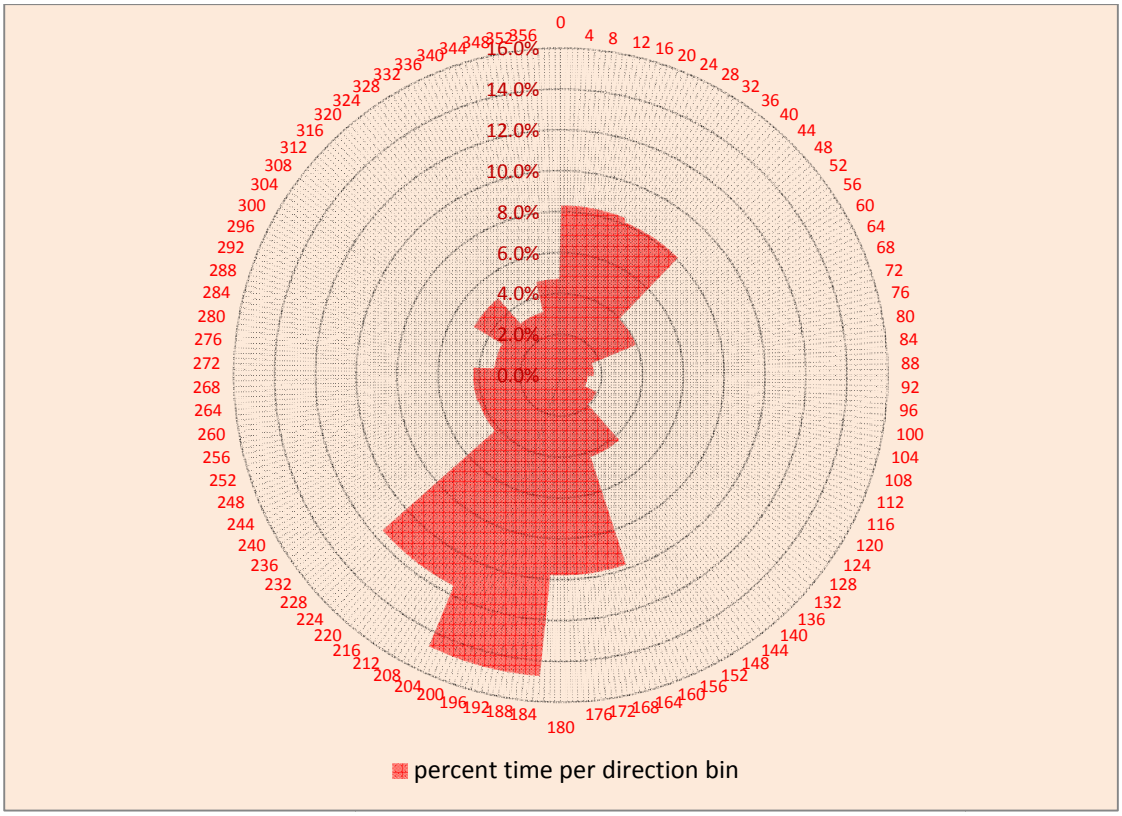
Range Gate 2: Average Wind Speed and Percent Time by Direction



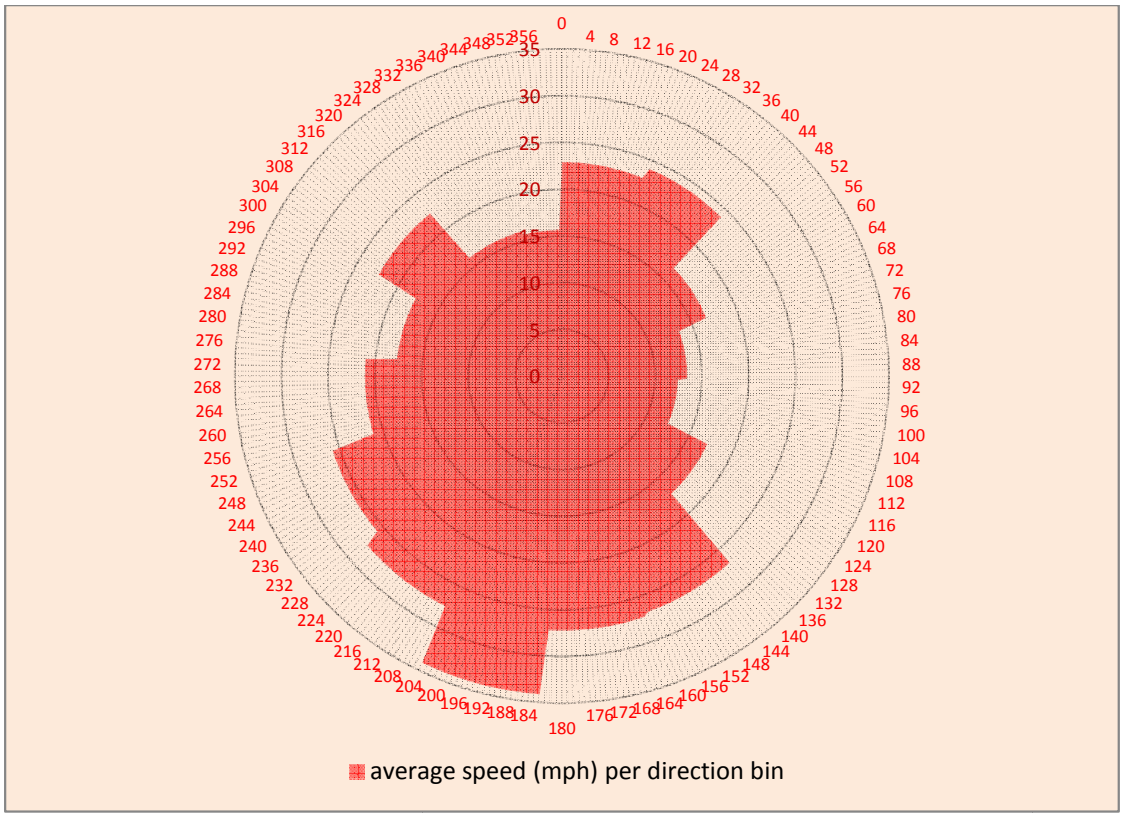


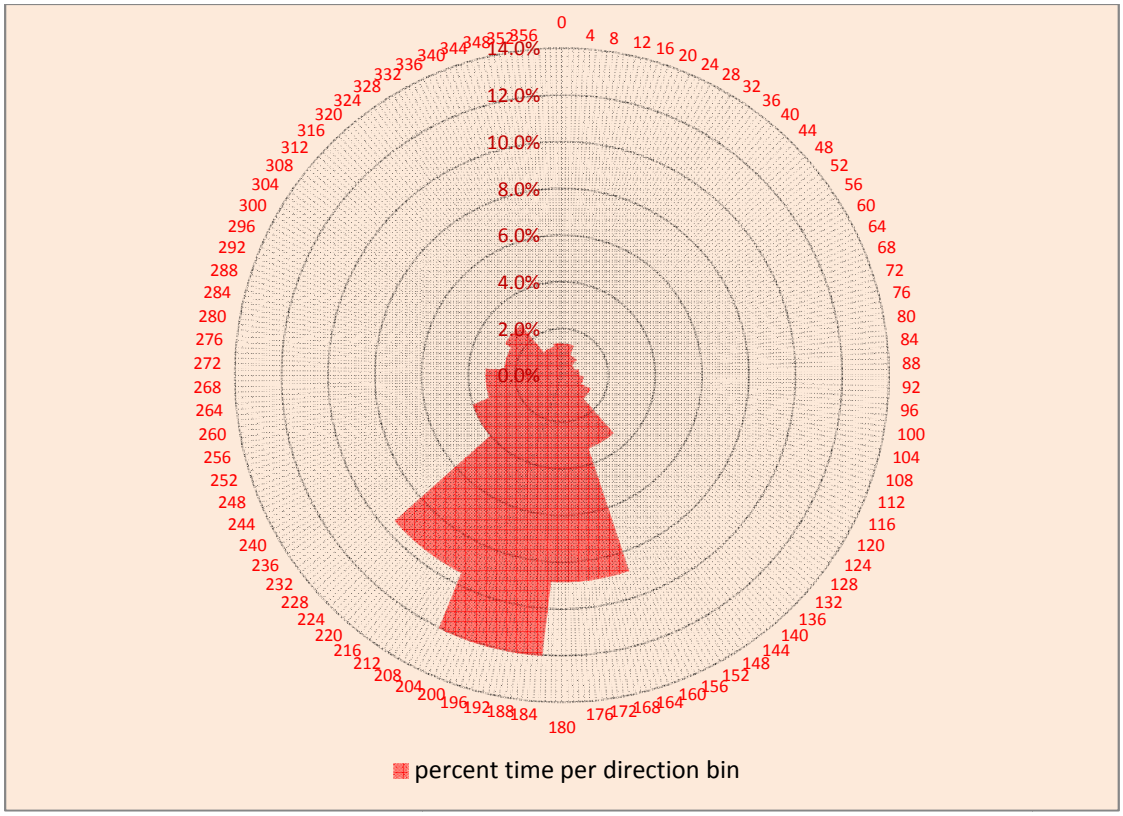
Range Gate 3: Average Wind Speed and Percent Time by Direction



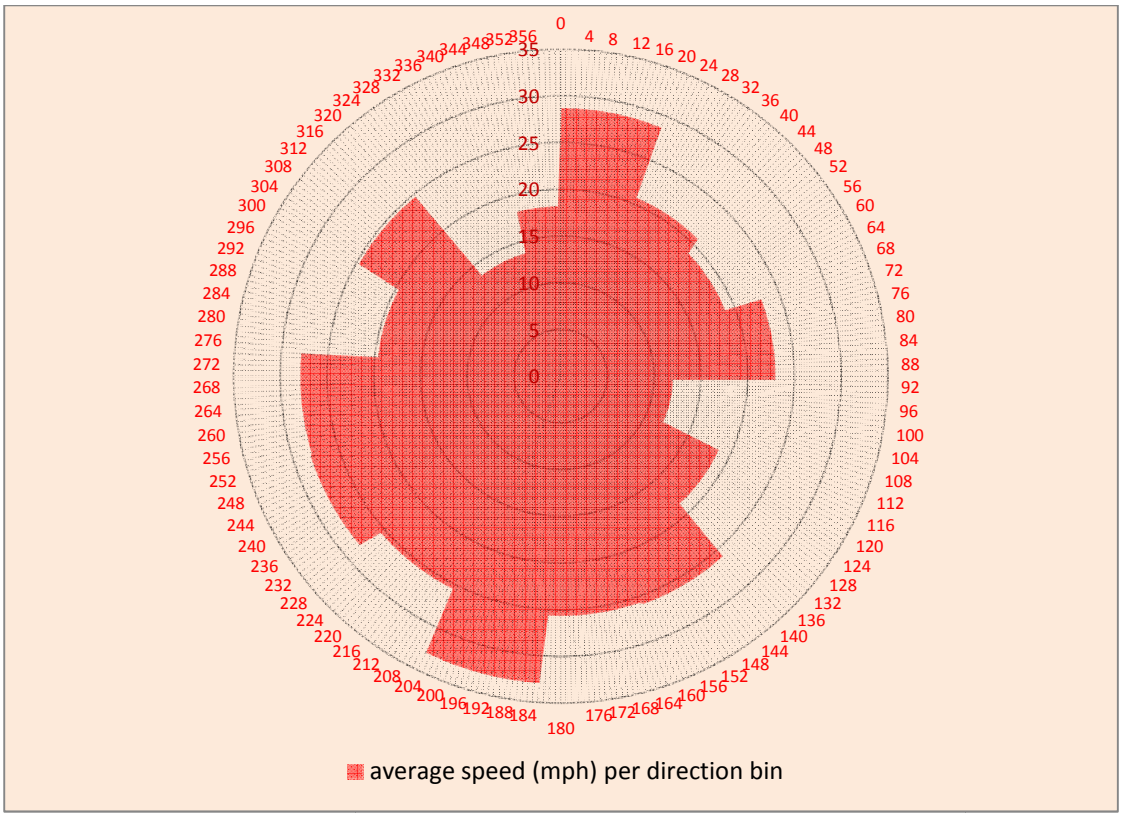


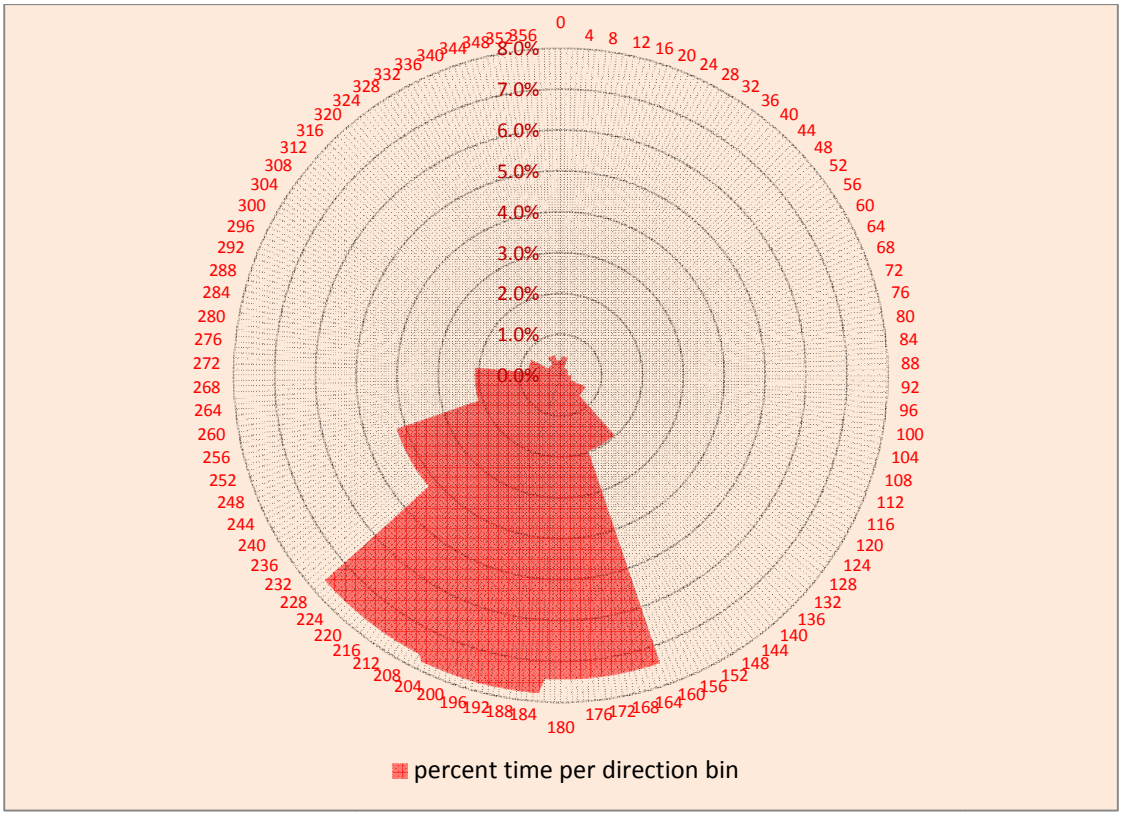
Range Gate 4: Average Wind Speed and Percent Time by Direction



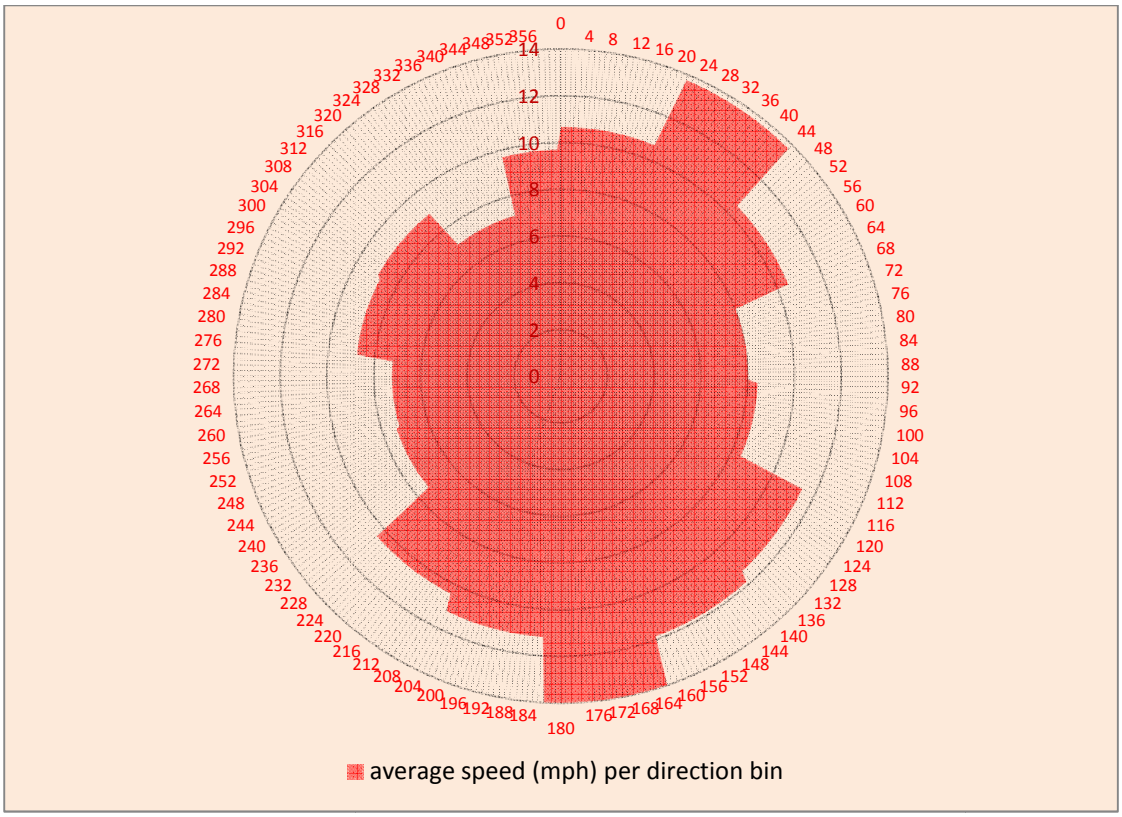


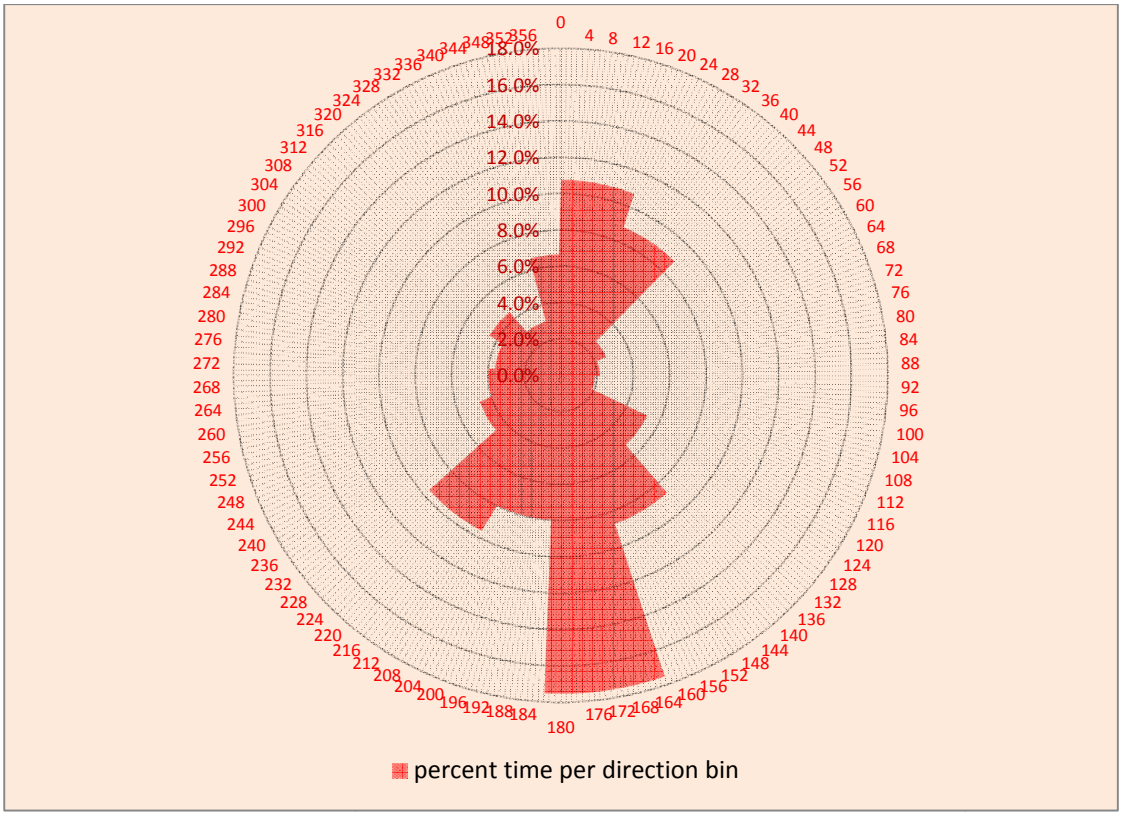
Range Gate 5: Average Wind Speed and Percent Time by Direction





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 11.6 to 12.0 kilowatt hours per day.
3. The energy potential of the wind at the surface as measured by the cup anemometer on the buoy is about 25% of the energy potential at the higher elevations. The wind speed is about 50% 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 same. Differences in variability estimates are yet to be explored.
5. The highest average wind speed for each LWS range gate is in the southwest direction, which is the same direction from which the greatest percent of the wind comes.
6. The highest average wind speed for the cup anemometer is in the southeast direction, which is the same direction from which the greatest percent of the wind comes.