Atqasuk Wind Resource Report

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Date of Report: August 26, 2010

Atqasuk met tower; D. Vaught photo

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Summary

The wind resource measured to date in Atqasuk appears to be promising for wind power development, but winter data recovery was very poor. Wind power class 3 (fair) is calculated but that with only one year of data characterized by poor winter data recovery, that classification may well be in error. With respect to other criteria, the Atqasuk site experiences very low turbulence conditions and apparent low extreme wind probability.

To improve confidence of measurement of the wind resource in Atqasuk, especially during the winter months, a met tower equipped with heated sensors (at least one anemometer and one wind vane) is strongly suggested.

Met tower data synopsis

Data dates	June 22, 2009 to July 16, 2010 (13 months)
Wind power class	Class 3 (fair)
Power density mean, 30 m	305 W/m^2 (QC'd data); 266 W/m^2 (with synthetic data)
Wind speed mean, 30 m	6.48 m/s (QC'd data); 6.07 m/s (with synthetic data)
Max. 10-min wind speed average	19.6 m/s
Maximum wind gust	23.1 m/s (Feb 2010)
Weibull distribution	k = 2.23, c = 7.15 m/s
Wind shear power law exponent	0.119 (moderate)
Roughness class	0.73 (lawn grass)
IEC 61400-1, 3rd ed. classification	Class III-c (lowest defined and most common)
Turbulence intensity, mean	0.075 (at 15 m/s)
Calm wind frequency	19% (<3.5 m/s)

Community profile

Current Population:	201 (2009 DCCED Certified Population)
Incorporation Type:	2nd Class City
Borough Located In:	North Slope Borough
Taxes:	Sales: None, Property: 18.5 mills (Borough), Special: None
Coastal Management District:	North Slope Borough

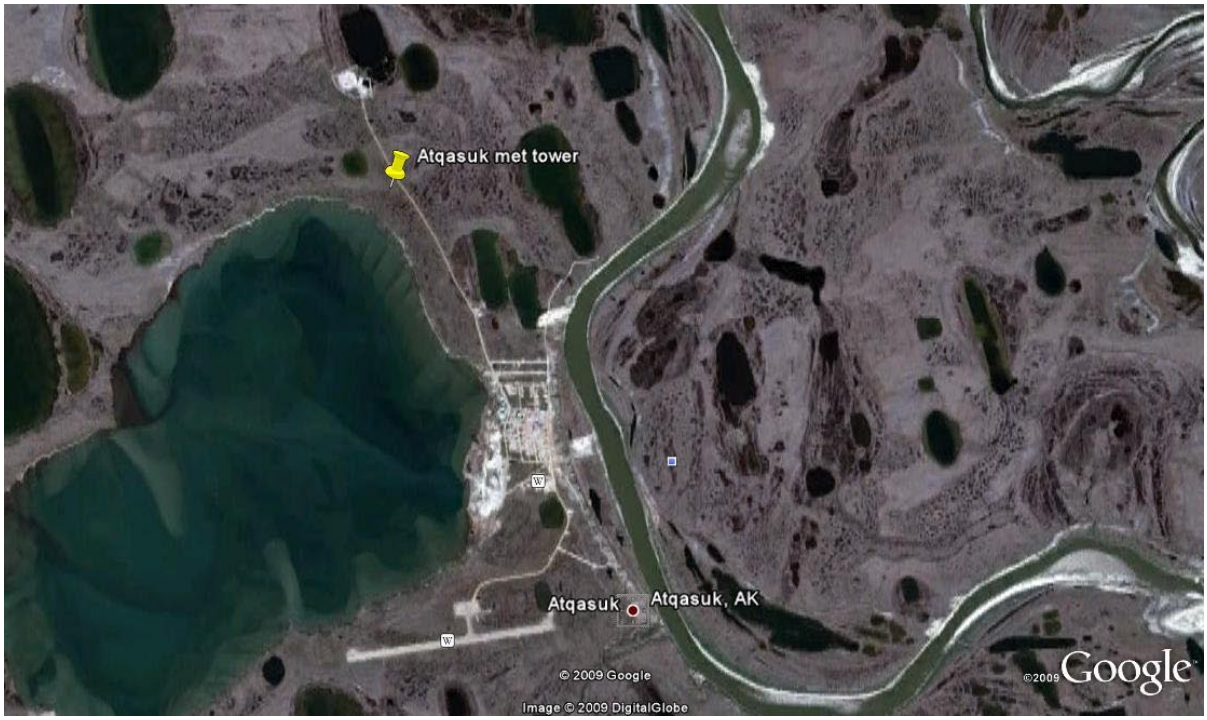
Test Site Location

The met tower was installed approximately 1,500 meters (4,800 ft) northwest of the village of Atqasuk, near a large lagoon and just south of the village landfill. This site is well exposed to winter winds with no upwind obstructions.

Site Information

Site number	0223
Latitude/longitude	N 70° 29.810' W 157° 26.826', WGS 84
Site elevation	23 meters (74 ft)
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 34-meter tall tower, 152 mm diameter, erected to 30 m
Anchor type	1.5 m screw-in

Google Earth image



Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.754	0.40	181° T
2	NRG #40 anemometer	30 m (B)	0.758	0.35	271° T
3	NRG #40 anemometer	20 m	0.753	0.41	272° T
7	NRG #200P wind vane	29 m	0.351	357	357° T
9	NRG #110S Temp C	3 m	0.136	-86.383	N
10	RH-5 relative humidity	2 m	0.098	0	S
12	Voltmeter	2 m	0.021	0	n/a

Photographs

Soft rice ice on guy wire; D. Vaught photo

Icing buildup on datalogger box; D. Vaught photo

Top of met tower; D. Vaught photo

Robert Akpik in Atqasuk; D. Vaught photo

Data Quality

Data recovery in Atqasuk was marginal with 63 to 73 percent data return from the anemometers and wind vane. The missing data represents the windier winter months when data recovery was extremely poor. This poor data recovery was due to soft rime ice (hoarfrost), beginning in October and lasting to early May (note a very similar data loss pattern was documented in Wainwright). Photographs taken in early February indicated heavy hoarfrost icing conditions which likely prevailed during the entire winter and were largely responsible for the poor data return. Note also that data loss from the relative humidity sensor is due to voltage drawdown of the iPack battery during the dark months of winter. Full operability of this sensor returned in early April when the PV panels recharged the iPack battery sufficiently to power it.

Data recovery summary table

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)
Speed 30 A	m/s	30 m	56,088	39,791	70.9
Speed 30 B	m/s	30 m	56,088	40,649	72.5
Speed 20	m/s	20 m	56,088	40,924	73.0
Direction 29	°	29 m	56,088	35,258	62.9
Temperature	°C		56,088	55,907	99.7
RH-5 Humidity %RH	%RH		56,088	35,572	63.4
iPack Voltmeter	volts		56,088	55,944	99.7

Anemometer data recovery

			30 m A		30 m B		20 m	
Year	Month	Possible Records	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)	Valid Records	Recovery Rate (%)
2009	Jun	1,296	1,296	100.0	1,296	100.0	1,296	100.0
2009	Jul	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Aug	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2009	Sep	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2009	Oct	4,464	3,386	75.9	3,214	72.0	3,510	78.6
2009	Nov	4,320	1,147	26.6	1,274	29.5	1,225	28.4
2009	Dec	4,464	89	2.0	164	3.7	340	7.6
2010	Jan	4,464	1,190	26.7	1,190	26.7	1,190	26.7
2010	Feb	4,032	1,960	48.6	1,830	45.4	2,528	62.7
2010	Mar	4,464	3,124	70.0	3,719	83.3	2,737	61.3
2010	Apr	4,320	3,750	86.8	4,195	97.1	4,188	96.9
2010	May	4,464	4,071	91.2	4,073	91.2	4,132	92.6
2010	Jun	4,320	4,320	100.0	4,236	98.1	4,320	100.0
2010	Jul	2,232	2,210	99.0	2,210	99.0	2,210	99.0
All data		56,088	39,791	70.9	40,649	72.5	40,924	73.0

Wind Speed

Wind data collected from the met tower, from the perspective of both mean wind speed and mean power density, indicates a moderate wind resource, but loss of such a significant percentage of winter data reduces the certainty of this assessment. Because it is problematic analyzing wind data with significant concentrated data loss, synthetic data was inserted in the data gaps to create a more realistic wind speed data profile. To be sure, long segments of synthetic data introduce uncertainty to the data set, in this significantly, but missing data is uncertain as well. To overcome this uncertainty, improved data collection with heated sensors would be necessary and advisable for Atqasuk.

Anemometer summary

Variable	Original data set			Synthesized data set		
	Speed 30 A	Speed 30 B	Speed 20	Speed 30 A	Speed 30 B	Speed 20
Measurement height (m)	30	30	20	30	30	20
Mean wind speed (m/s)	6.48	6.21	5.95	6.07	6.07	5.77
Max wind speed (m/s) (10-min avg)	19.5	19.6	18.6	19.5	19.6	18.6
Max wind speed (m/s) (gust)	23.0	23.1	22.6			
Weibull k	2.23	2.17	2.18	2.15	2.14	2.11
Weibull c (m/s)	7.15	7.06	6.80	6.89	6.88	6.55
Mean power density (W/m²)	305	290	256	266	267	233
Mean energy content (kWh/m²/yr)	2,674	2,543	2,239	2,333	2,338	2,038
Energy pattern factor	1.71	1.75	1.75	1.76	1.77	1.79
Frequency of calms (%)	18.0	19.5	21.2	20.5	20.8	23.4
1-hr autocorrelation coefficient	0.943	0.946	0.947	0.940	0.940	0.941
Diurnal pattern strength	0.063	0.060	0.068	0.062	0.061	0.068
Hour of peak wind speed	18	18	18	18	18	17

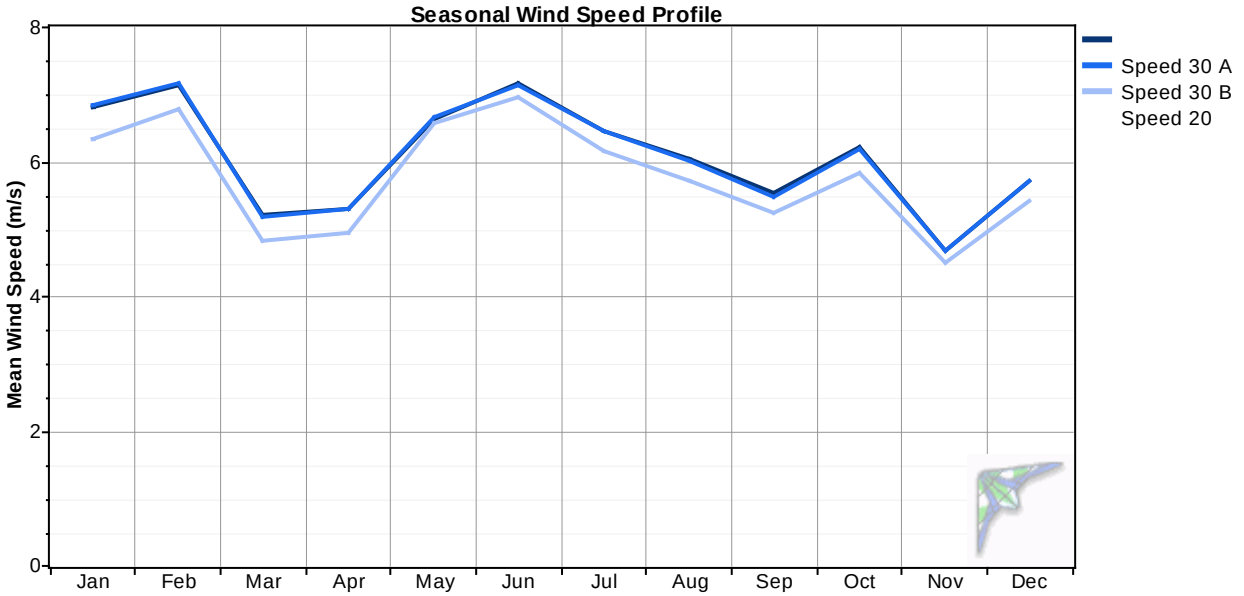
Time Series

Time series calculations indicated moderate wind speed averages throughout the year with lower winds measured in late winter and autumn. Poor data return, however, may have affected this analysis.

30m A data summary

Year	Month	Original data			Synthesis data		
		Mean (m/s)	Max 10-min (m/s)	Max gust (m/s)	Mean (m/s)	Max 10-min (m/s)	Max gust (m/s)
2009	Jun	7.75	12.6	15.1	7.75	12.6	15.1
2009	Jul	6.21	13.5	16.2	6.21	13.5	16.2
2009	Aug	6.05	14.7	18.5	6.05	14.7	18.5
2009	Sep	5.54	16.2	20.7	5.54	16.2	20.7
2009	Oct	6.51	17.9	21.5	6.21	17.9	21.5
2009	Nov	5.79	13.0	17.0	4.67	13.0	17.0
2009	Dec	8.07	11.0	15.5	5.72	16.5	15.5
2010	Jan	6.65	13.1	15.9	6.81	16.2	15.9
2010	Feb	7.47	19.5	23.0	7.16	19.5	23.0
2010	Mar	5.84	12.7	15.1	5.23	12.7	15.1
2010	Apr	5.57	14.7	17.0	5.30	14.7	17.0
2010	May	6.74	14.9	17.0	6.64	14.9	17.0
2010	Jun	6.98	14.7	17.7	6.98	14.7	17.7
2010	Jul	6.94	14.4	17.0	6.96	14.4	17.0
MMM annual		6.48	19.5	23.0	6.07	19.5	23.0

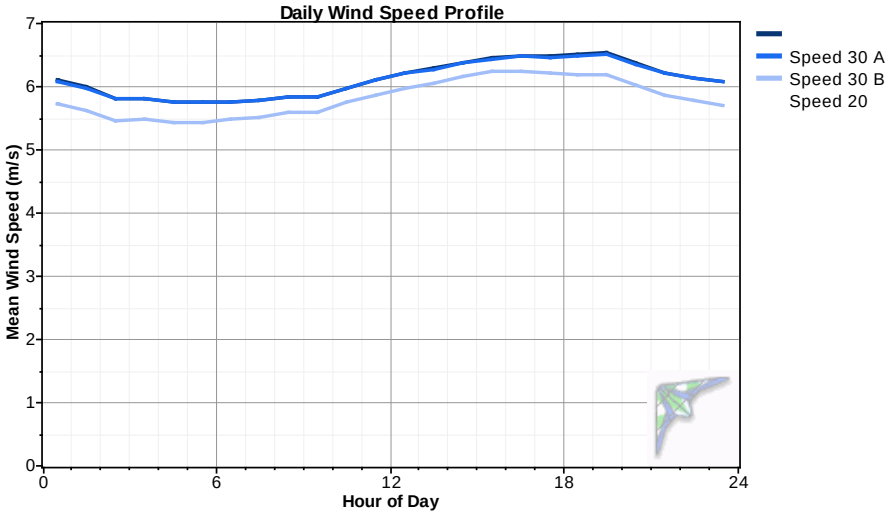
Time series graph (synth. data)



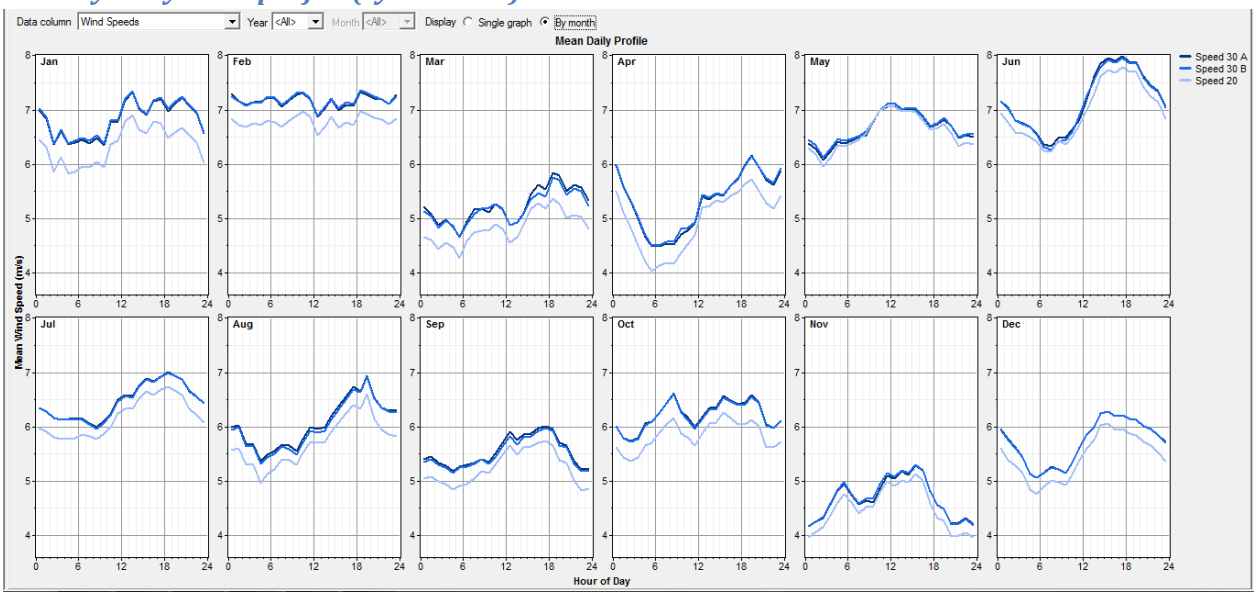
Daily Wind Profile

The daily wind profile indicates relatively high variation (for a cold climate location) of wind speeds throughout the day, with lowest wind speeds during the morning hours and highest wind speeds during late afternoon and early evening hours. This perspective changes somewhat when considering monthly views of daily profiles as considerably more variation is observed.

Annual daily wind profile (synth. data)

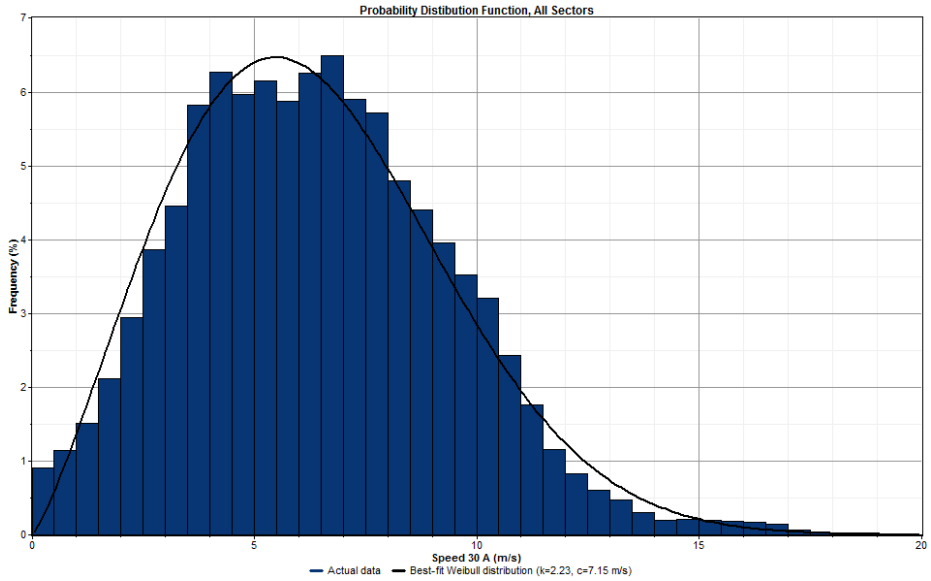


Monthly daily wind profile (synth. data)



Probability Distribution Function

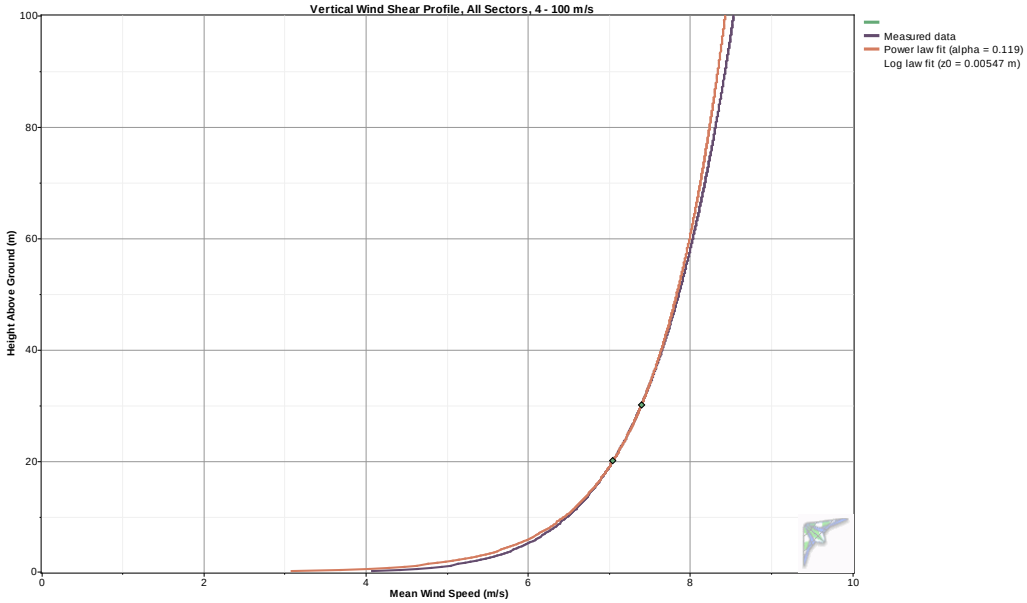
The probability distribution function (or histogram) of wind speed indicates a near-normal shape curve of wind speeds (defined as the Raleigh distribution, k=2.0).



Wind Shear and Roughness

A wind shear power law exponent of 0.119 indicates moderately low wind shear at the site; hence turbine construction at a low hub height is possibly a desirable option. Related to wind shear, a calculated surface roughness of 0.0078 meters (indicating the height above ground level where wind velocity would be zero) indicates relatively smooth terrain (roughness description: lawn grass) surrounding the met tower, especially toward the prevailing wind direction of northeast.

Vertical wind shear profile, wind speed > 4 m/s



Wind shear by direction sector table, wind speed > 4 m/s

Direction Sector	Time Steps	Sector Wind (%)	Mean Wind Speed (m/s) Speed 30 B	Speed 20	Best-Fit Power Law Exp	Best-Fit Surface Roughness (m)
348.75° - 11.25°	1,310	5.0%	6.34	6.08	0.101	0.0012
11.25° - 33.75°	3,067	11.6%	6.98	6.70	0.101	0.0013
33.75° - 56.25°	7,948	30.2%	7.69	7.47	0.073	0.0000
56.25° - 78.75°	5,030	19.1%	8.35	8.07	0.085	0.0002
78.75° - 101.25°	1,457	5.5%	6.99	6.38	0.223	0.2741
101.25° - 123.75°	507	1.9%	5.95	5.47	0.206	0.1915
123.75° - 146.25°	318	1.2%	6.36	5.72	0.259	0.5125
146.25° - 168.75°	549	2.1%	6.94	6.29	0.241	0.3866
168.75° - 191.25°	536	2.0%	7.17	6.61	0.198	0.1574
191.25° - 213.75°	1,017	3.9%	7.06	6.68	0.137	0.0166
213.75° - 236.25°	1,287	4.9%	6.72	6.27	0.172	0.0735
236.25° - 258.75°	1,237	4.7%	8.00	7.59	0.133	0.0131
258.75° - 281.25°	736	2.8%	6.80	6.41	0.145	0.0243
281.25° - 303.75°	425	1.6%	6.39	6.11	0.113	0.0035
303.75° - 326.25°	367	1.4%	5.81	5.56	0.107	0.0021
326.25° - 348.75°	551	2.1%	5.45	5.27	0.085	0.0002

Extreme Winds

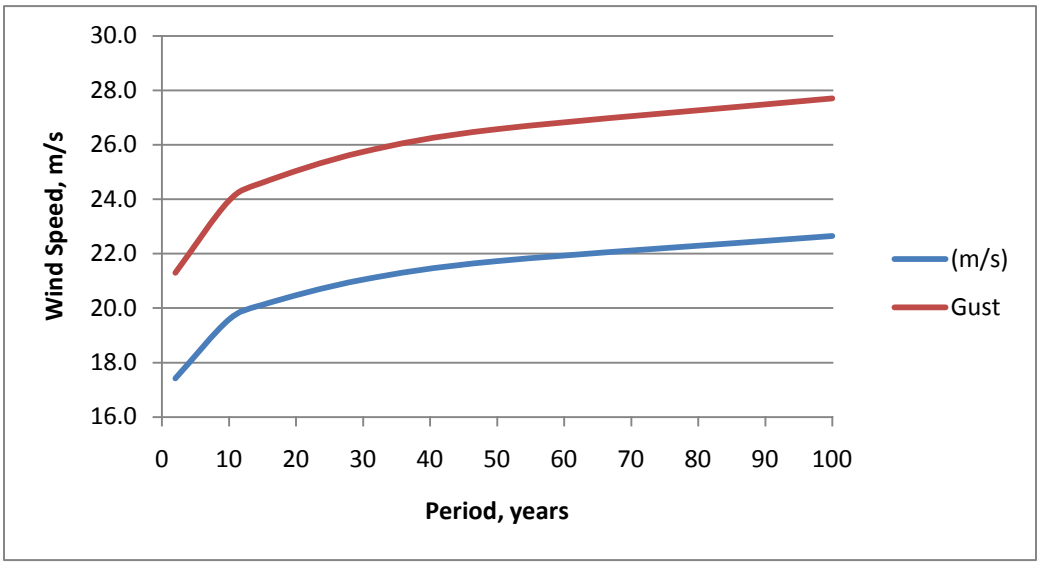
Although thirteen months of data is minimal for calculation of extreme wind probability, use of a modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, yields reasonably good results. Extreme wind analysis indicates a very low probability of extreme wind events, but one should be cautioned that the poor winter anemometer data return significantly reduces the confidence of this calculation. Even so, general aspects of Atqasuk, including distance from the coast, far northerly location and lack of exposure to Gulf of Alaska storm winds increases the likelihood that extreme wind events are uncommon and not highly energetic.

Industry standard reference of extreme wind is the 50 year, 10-minute average probable wind speed, referred to as V_{ref}. For Wainwright, this calculates to 21.7 m/s, well below the 37.5 m/s threshold of International Electrotechnical Commission (IEC) 61400-1, 3rd edition criteria for a Class III site. Note that Class III extreme wind classification is the lowest defined and all wind turbines are designed for this wind regime.

Extreme wind speed probability table (original data)

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. Class	V_{ref}, m/s
2	17.4	21.3	I	50.0
10	19.6	24.0	II	42.5
15	20.1	24.6	III	37.5
30	21.0	25.8	S	designer-specified
50	21.7	26.6		
100	22.7	27.7		
average gust factor:	1.22			

Extreme wind speed probability graph



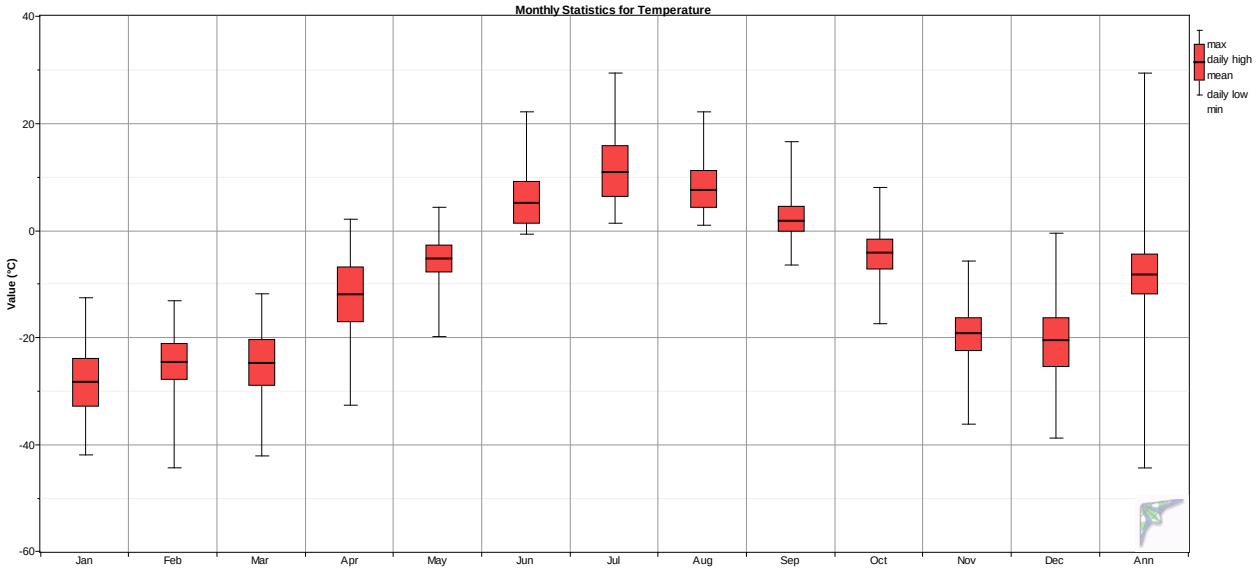
Temperature and density

Atqasuk experiences relatively warm summers (compared to the coast) and extremely cold winters with multiple recordings of sub negative 40 degree temperatures. The result is high air density; calculated air density exceeds standard air density for a 23 meter elevation (1.222 Kg/m^3) by nine percent. This is advantageous in wind power operations as most wind turbines produce more power at low temperatures (high air density) than at standard temperature and density.

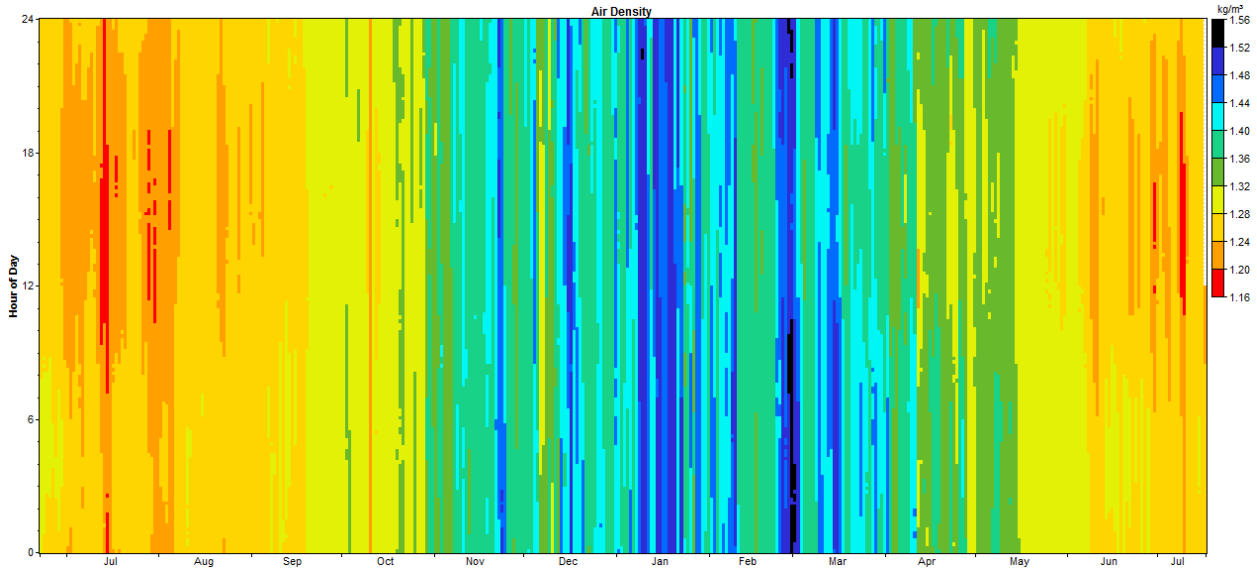
Temperature and density table

	Temperature			Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-28.1	-41.9	-12.6	1.438	1.351	1.522
Feb	-24.5	-44.4	-13.1	1.417	1.353	1.538
Mar	-24.7	-42.2	-11.8	1.417	1.347	1.524
Apr	-11.9	-32.7	2.0	1.347	1.222	1.464
May	-5.1	-19.8	4.3	1.313	1.268	1.389
Jun	5.3	-0.7	22.1	1.264	1.192	1.292
Jul	11.0	1.3	29.4	1.239	1.163	1.282
Aug	7.6	1.0	22.1	1.254	1.192	1.284
Sep	2.0	-6.5	16.6	1.279	1.215	1.320
Oct	-4.1	-17.5	8.1	1.305	1.222	1.377
Nov	-19.1	-36.3	-5.7	1.386	1.316	1.486
Dec	-20.5	-38.8	-0.6	1.394	1.291	1.502
Annual	-9.3	-44.4	29.4	1.338	1.163	1.538

Monthly temperature boxplot



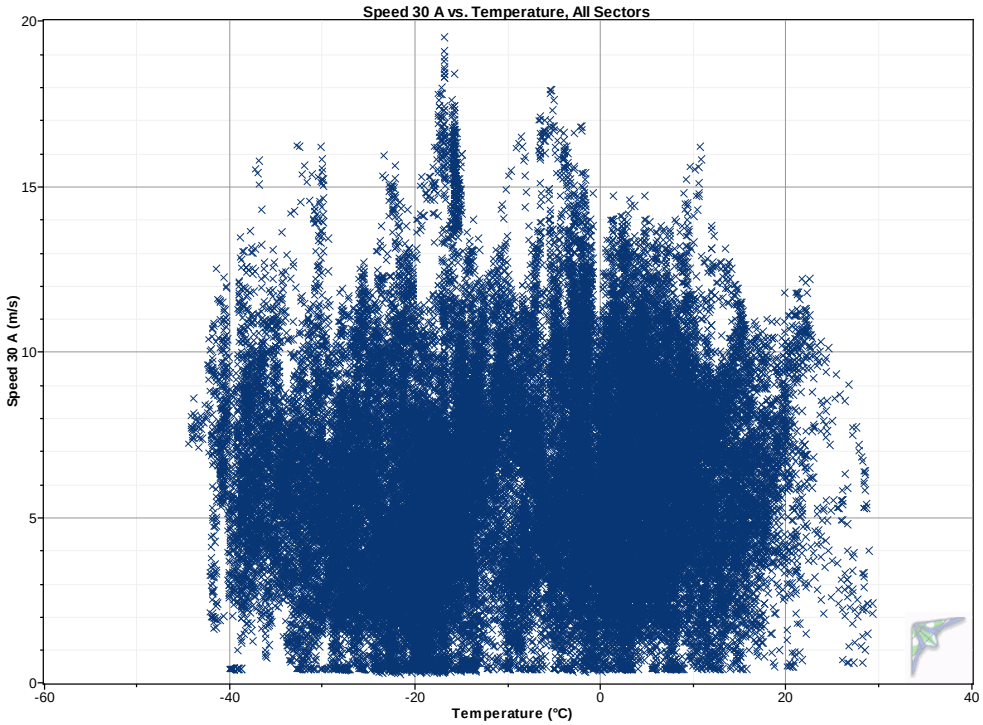
Air density DMap



Wind Speed Scatterplot

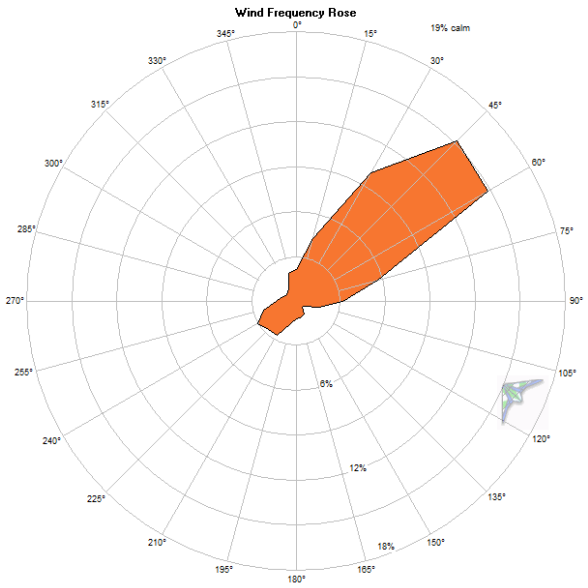
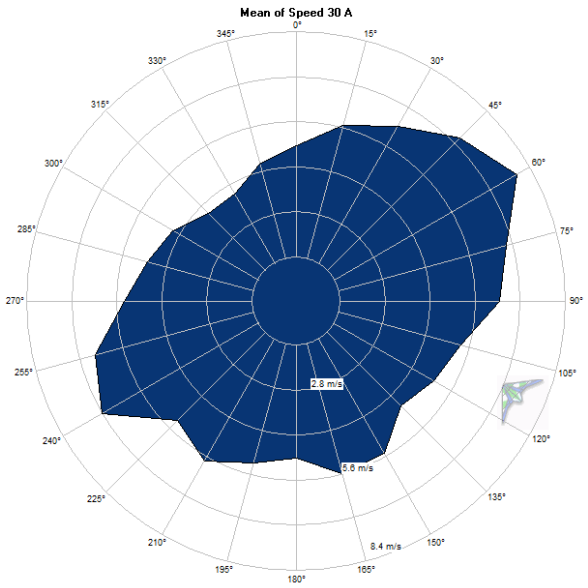
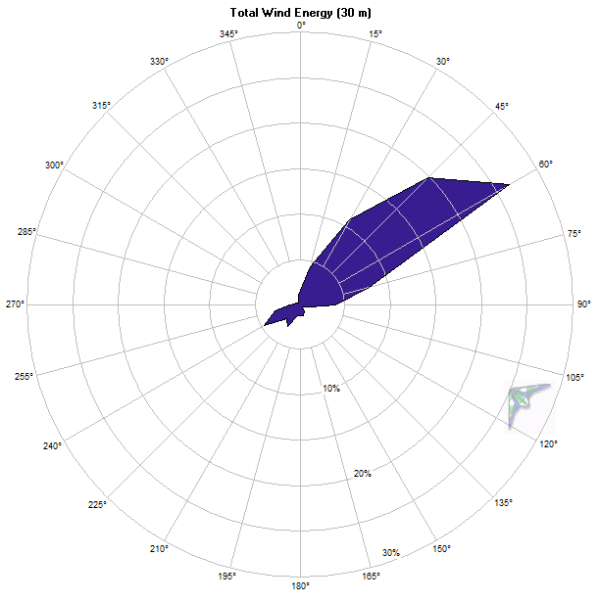
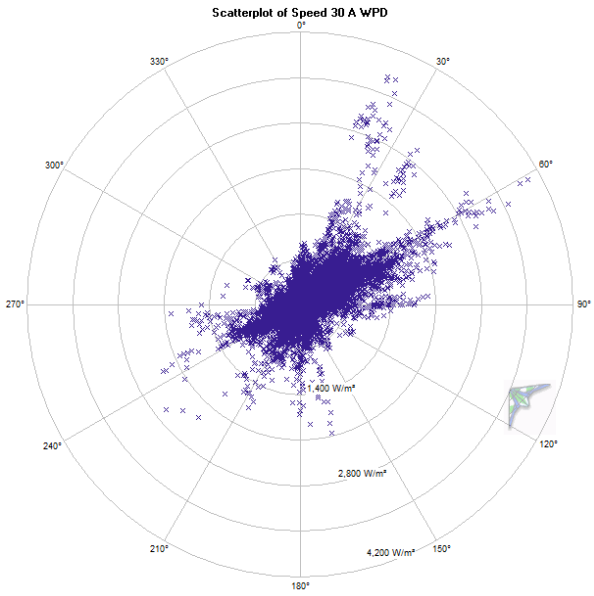
The wind speed versus temperature scatterplot below indicates that a substantial percentage of wind in Atqasuk coincides with very cold temperatures, as one would expect given its high arctic location. During the met tower test period, temperatures fell below -40°C on many occasions.

Wind speed versus temperature scatterplot (synth. data)

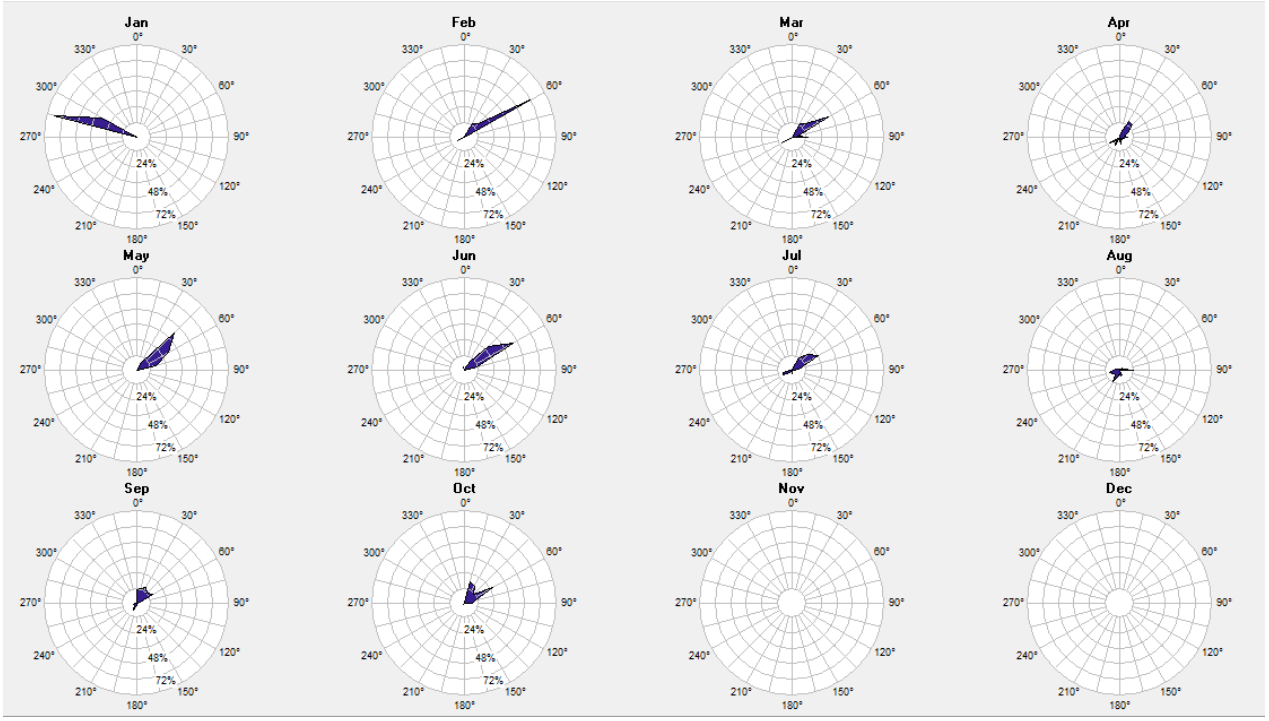


Wind Direction

Wind frequency rose data indicates highly directional winds from the northeast. Power density rose data (representing the power in the wind) indicates power winds are also strongly directional, from the northeast. Calm frequency (percent of time that winds at 30 meter level are less than 3.5 m/s) was 19 percent during the met tower test period. Note however that the wind vane had extremely poor data return during the winter months, so winter wind roses below should be evaluated with caution.

Wind frequency rose	*Mean value rose*
	
Wind energy rose	*Scatterplot rose*
	

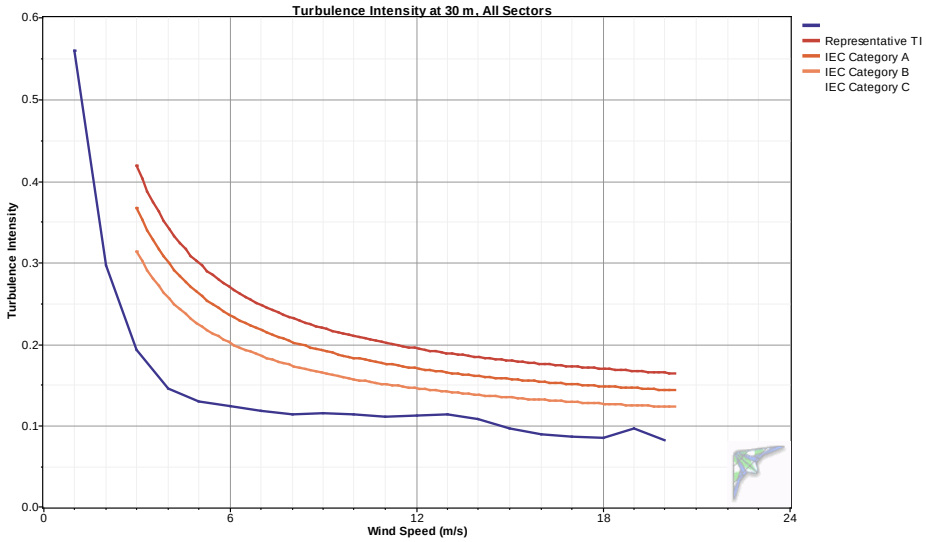
Wind density roses by month



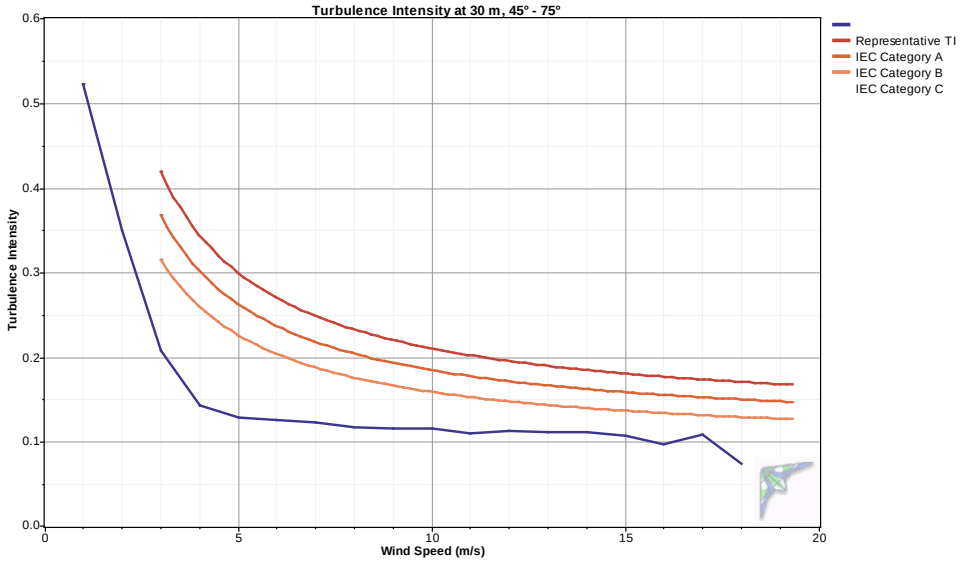
Turbulence

To date, the mean turbulence intensity of 0.075 at 15 m/s is within acceptable standards and classifies the site as IEC (International Electrotechnical Commission) 61400-1, 3rd edition (2005) turbulence category C (lowest).

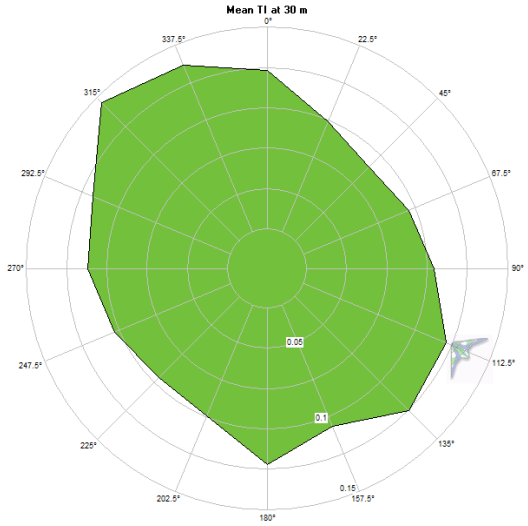
Turbulence intensity, all wind sectors



Turbulence intensity, northeast (prevailing) wind sector



Turbulence intensity by direction



Turbulence table

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records in Bin	Mean TI	Std Dev. of TI	Representative TI	Peak TI
1	0.5	1.5	1,057	0.362	0.154	0.559	0.857
2	1.5	2.5	2,010	0.177	0.093	0.296	1.190
3	2.5	3.5	3,306	0.118	0.059	0.193	0.594
4	3.5	4.5	4,808	0.094	0.040	0.145	0.425
5	4.5	5.5	4,819	0.084	0.035	0.129	0.667
6	5.5	6.5	4,820	0.084	0.031	0.123	0.386
7	6.5	7.5	4,924	0.082	0.028	0.117	0.288

8	7.5	8.5	4,184	0.082	0.025	0.113	0.227
9	8.5	9.5	3,324	0.084	0.024	0.115	0.234
10	9.5	10.5	2,679	0.083	0.024	0.114	0.505
11	10.5	11.5	1,667	0.082	0.023	0.111	0.175
12	11.5	12.5	789	0.085	0.021	0.112	0.200
13	12.5	13.5	429	0.089	0.020	0.114	0.236
14	13.5	14.5	202	0.086	0.017	0.108	0.148
15	14.5	15.5	165	0.075	0.016	0.096	0.138
16	15.5	16.5	140	0.073	0.012	0.089	0.115
17	16.5	17.5	84	0.073	0.010	0.086	0.114
18	17.5	18.5	15	0.070	0.012	0.085	0.098
19	18.5	19.5	5	0.077	0.015	0.096	0.099
20	19.5	20.5	1	0.082	0.000	0.082	0.082

Airport AWSS Data

Airport wind data has been requested of National Oceanic and Atmospheric Administration's Anchorage office but not yet received.