Point Hope Wind Resource Report

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Point Hope met tower; D. Vaught photo

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Summary

The wind resource measured in Point Hope is very, very good, with measured wind power class 6 (outstanding). In addition to high average wind speeds and high wind power density, the site experiences very low turbulence and calculations indicate low extreme wind speed probability.

Met tower data synopsis

Data dates	June 16, 2009 to July 15, 2010 (13 months)
Wind power class	6 (outstanding)
Power density mean, 30 m	515 W/m^2
Wind speed mean, 30 m	7.12 m/s
Max. 10-min wind speed average	27.9 m/s
Maximum wind gust	32.2 m/s (Dec. 2009)
Weibull distribution parameters	k = 1.82, c = 7.92 m/s
Wind shear power law exponent	0.110 (low)
Roughness class	0.27 (rough sea)
IEC 61400-1, 3rd ed. classification	Class III-c (lowest defined and most common)
Turbulence intensity, mean	0.073 (at 15 m/s)
Calm wind frequency	20% (<3.5 m/s)

Community profile

Current Population:	713 (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

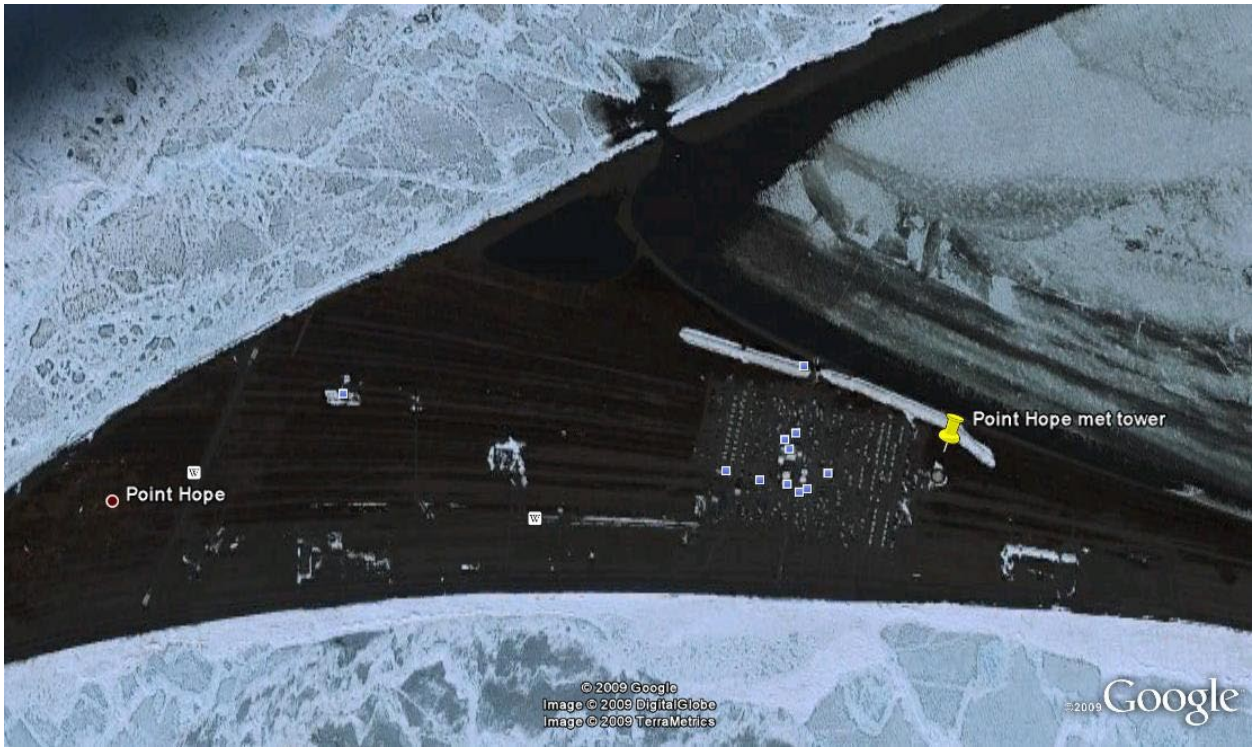
Test Site Location

Met tower was installed on the northeast corner of Point Hope, between the village water storage tank and a large snow fence. This site could be considered ideal for wind power development as it is also near the power plant and other existing electrical power infrastructure.

Site information

Site number	0221
Latitude/longitude	N 68° 20.974’ W 166° 43.146’, WGS 84
Site elevation	2 meters
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 34-meter tall tower, 152 mm diameter, erected to 30 m
Anchor type	2.5 m shaft, 0.7 m square metal plate, buried

Google Earth image



Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.755	0.38	178° T
2	NRG #40 anemometer	30 m (B)	0.758	0.37	274° T
3	NRG #40 anemometer	20 m	0.756	0.37	282° T
7	NRG #200P wind vane	29 m	0.351	359	359° 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

Datalogger weather box and PV panel; D. Vaught photo

Top of met tower; D. Vaught photo

Datalogger with snow in weather box; D. Vaught photo

Met tower and village edge; D. Vaught photo

Data Recovery

Data recovery to date in Point Hope was superior, with nearly 100 percent functionality of the anemometers and wind vane. This is remarkable anywhere in Alaska, but even more so on the Chukchi Sea coast of the North Slope with its intensely cold winter temperatures. Note that data loss from the relative humidity (RH) sensor was initially due to voltage drawdown of the iPack battery during the dark months of winter (the battery is recharged with photovoltaic panels). For unknown reasons, functionality of the RH sensor did not recover on return of daylight in springtime, even though the iPack battery recharged fully.

Near perfect anemometer and wind vane data recovery indicates the complete absence of rime icing conditions, which would not have been expected at a coastal elevation anyways, but also the absence of heavy hoarfrost conditions which plagued wintertime data recovery on the relatively nearby Wainwright and Atqasuk met towers.

Data recovery summary table

Label	Units	Possible Records	Valid Records	Recovery Rate (%)
Speed 30 A	m/s	56,649	56,171	99.2
Speed 30 B	m/s	56,649	56,169	99.2
Speed 20	m/s	56,649	56,468	99.7
Direction 29	°	56,649	55,911	98.7
Temperature	°C	56,649	56,581	99.9
RH-5 Humidity %RH	%RH	56,649	22,397	39.5
iPack Voltmeter	volts	56,649	56,649	100.0

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	2,073	2,073	100.0	2,073	100.0	2,073	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	4,244	95.1	4,240	95.0	4,350	97.5
2009	Nov	4,320	4,263	98.7	4,241	98.2	4,320	100.0
2009	Dec	4,464	4,464	100.0	4,354	97.5	4,464	100.0
2010	Jan	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2010	Feb	4,032	4,032	100.0	4,032	100.0	4,032	100.0
2010	Mar	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2010	Apr	4,320	4,186	96.9	4,320	100.0	4,320	100.0
2010	May	4,464	4,464	100.0	4,464	100.0	4,464	100.0
2010	Jun	4,320	4,320	100.0	4,320	100.0	4,320	100.0
2010	Jul	2,016	1,949	96.7	1,949	96.7	1,949	96.7
All data		56,649	56,171	99.2	56,169	99.2	56,468	99.7

Wind Speed

Wind data collected from the met tower, from the perspective of both mean wind speed and mean power density, indicates an outstanding wind resource. The minor discrepancy in mean wind speed between the 30 m A and the 30 m B anemometer is due to the placement of the of the 30 m A anemometer at 178° T. With frequent northerly winds, the 30m A anemometer experienced some minor tower shadowing effects. The cold arctic temperatures of Point Hope contributed to the high wind power density, a key consideration of wind turbine performance.

Anemometer data summary

Variable	Speed 30 A	Speed 30 B	Speed 20
Measurement height (m)	30	30	20
Mean wind speed (m/s)	7.02	7.12	6.79
Max 10-min avg wind speed (m/s)	27.5	27.9	26.1
Max gust wind speed (m/s)	31.7	32.2	31.4
Weibull k	1.85	1.82	1.82
Weibull c (m/s)	7.83	7.92	7.57
Mean power density (W/m²)	487	515	452
Mean energy content (kWh/m²/yr)	4,268	4,515	3,955
Energy pattern factor	2.11	2.14	2.16
Frequency of calms (%)	19.6	19.7	21.7
1-hr autocorrelation coefficient	0.948	0.949	0.950
Diurnal pattern strength	0.033	0.032	0.034
Hour of peak wind speed	19	19	19

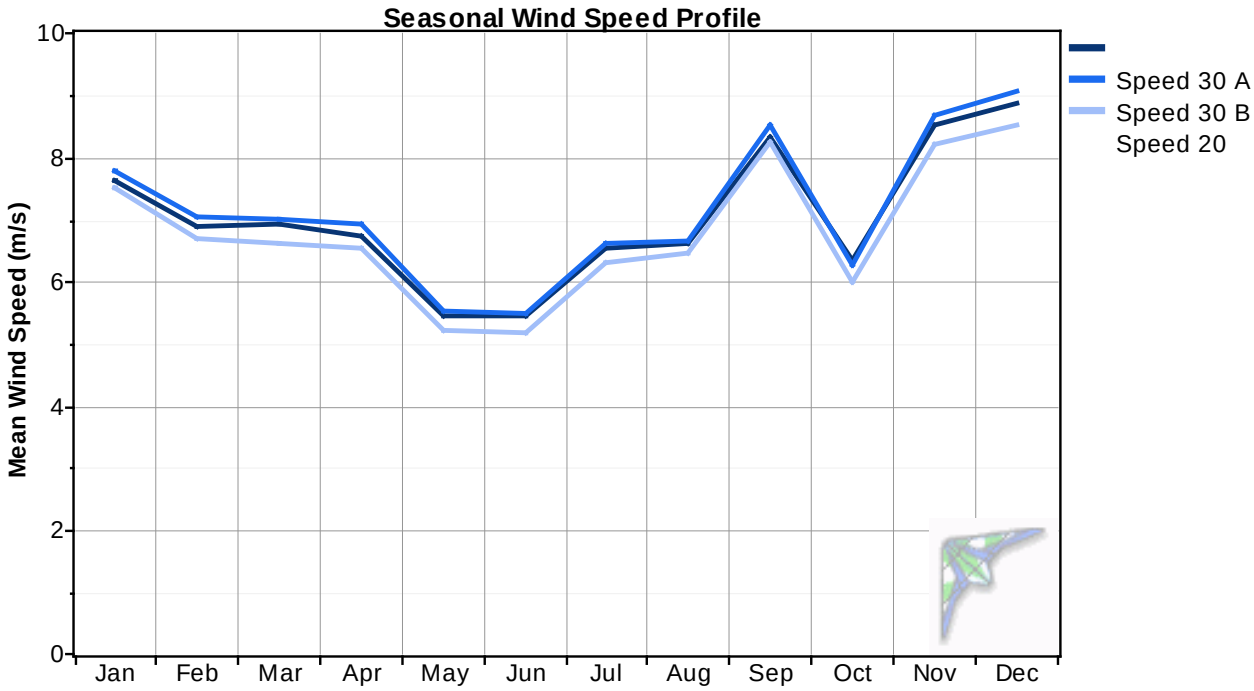
Time Series

Time series calculations indicate high wind speed averages throughout the year, even during summer. Although the October 2009 wind speed average was low compared to September and November, this is likely a statistical variation that would even out with multi-year data collection.

30m B data summary

Year	Month	Mean (m/s)	Max 10-min avg (m/s)	Max gust (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)
2009	Jun	6.41	15.4	18.2	3.14	2.14	7.23
2009	Jul	6.26	17.5	21.6	2.90	2.28	7.06
2009	Aug	6.64	19.9	23.5	3.57	1.92	7.47
2009	Sep	8.54	21.4	25.8	4.38	2.04	9.63
2009	Oct	6.28	15.9	18.6	3.35	1.97	7.10
2009	Nov	8.67	24.0	26.9	5.00	1.73	9.68
2009	Dec	9.05	27.9	32.2	4.64	2.03	10.20
2010	Jan	7.76	23.6	29.9	4.35	1.84	8.72
2010	Feb	7.03	22.8	24.6	3.66	2.00	7.92
2010	Mar	6.99	20.3	24.6	4.26	1.66	7.81
2010	Apr	6.91	19.0	23.9	3.45	2.09	7.79
2010	May	5.53	19.0	23.1	3.47	1.67	6.20
2010	Jun	5.04	15.7	18.9	2.90	1.82	5.68
2010	Jul	7.41	16.1	19.3	3.70	2.11	8.36
MMM Annual		7.12	27.9	32.2	4.02	1.82	7.92

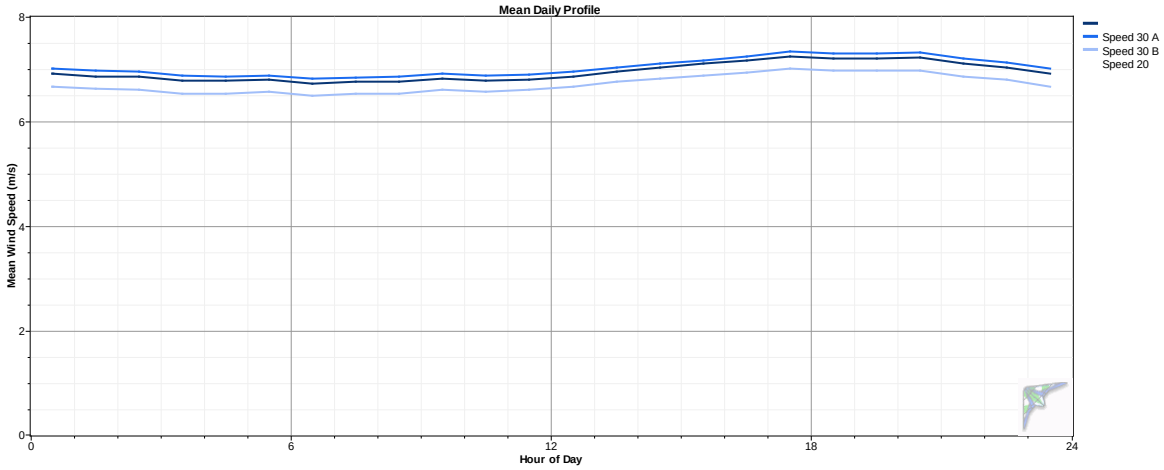
Time series graph



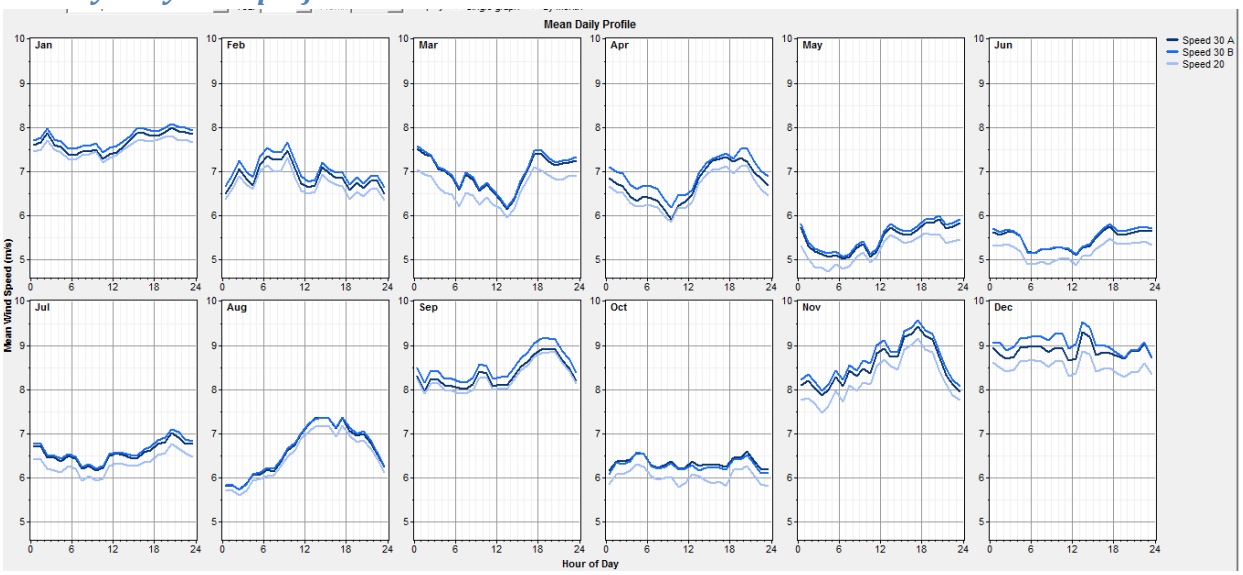
Daily Wind Profile

The daily wind profile indicates a minor variation 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 a bit when considering monthly views of daily profiles as more variation is observed.

Annual daily wind profile

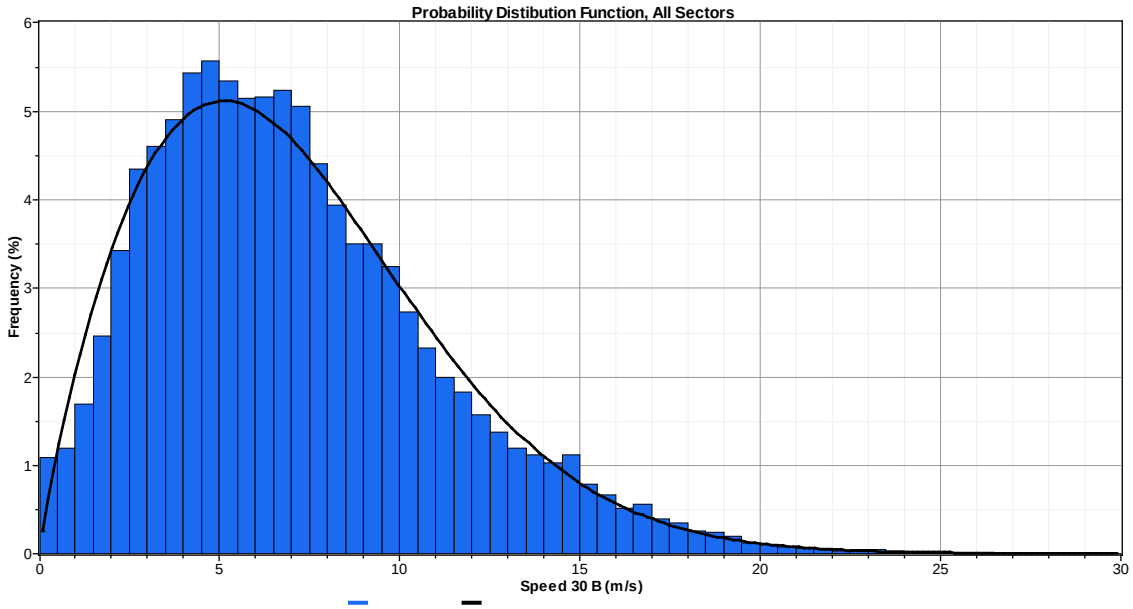


Monthly daily wind profile



Probability Distribution Function

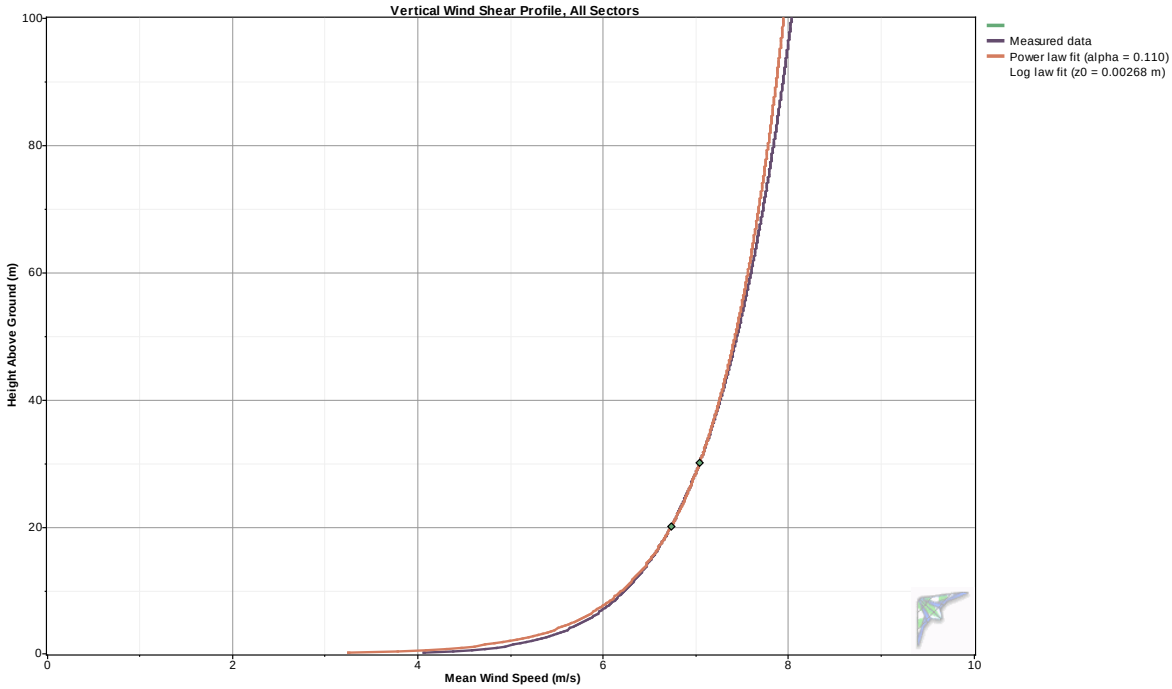
The probability distribution function (or histogram) of wind speed indicates a near-normal shape curve, defined as the Raleigh distribution (k=2.0), considered standard for wind power sites.



Wind Shear and Roughness

A wind shear power law exponent of 0.110 indicates very low wind shear at the site; hence turbine construction at a low hub height is feasible. Related to wind shear, a calculated surface roughness of 0.000789 meters (indicating the height above ground level where wind velocity would be zero) indicates moderately uneven terrain (roughness description: rough sea) surrounding the met tower, especially in the direction of the prevailing north-northwest winds.

Vertical wind shear profile



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	Surface Roughness (m)
348.75° - 11.25°	8,323	19.6%	9.91	9.45	0.081	0.0001
11.25° - 33.75°	4,374	10.3%	10.75	10.30	0.068	0.0000
33.75° - 56.25°	2,454	5.8%	8.51	8.08	0.108	0.0024
56.25° - 78.75°	1,564	3.7%	6.28	5.86	0.183	0.1047
78.75° - 101.25°	922	2.2%	6.52	5.91	0.274	0.6355
101.25° - 123.75°	1,238	2.9%	8.78	7.92	0.289	0.7712
123.75° - 146.25°	3,151	7.4%	8.99	8.51	0.164	0.0557
146.25° - 168.75°	2,744	6.5%	7.48	7.31	0.065	0.0000
168.75° - 191.25°	1,806	4.2%	7.24	7.19	0.007	
191.25° - 213.75°	338	0.8%	6.13	5.50	0.261	0.5313
213.75° - 236.25°	282	0.7%	5.52	5.06	0.225	0.2894
236.25° - 258.75°	207	0.5%	5.76	5.29	0.221	0.2626
258.75° - 281.25°	316	0.7%	6.11	5.65	0.211	0.2156
281.25° - 303.75°	1,028	2.4%	6.34	6.09	0.116	0.0044
303.75° - 326.25°	3,925	9.2%	6.50	6.27	0.067	0.0000
326.25° - 348.75°	9,870	23.2%	8.26	7.94	0.074	0.0000

Extreme Winds

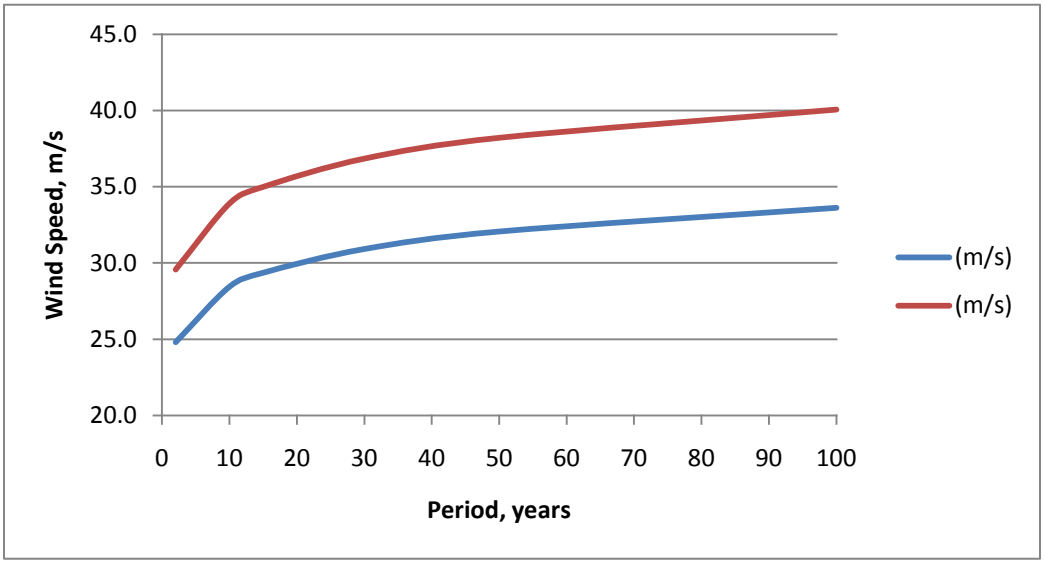
Although thirteen months of data is minimal for calculation of extreme wind probability, use of a modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, yields more realistic results. Extreme wind analysis indicates a highly desirable situation in Point Hope: high mean wind speeds combined with low extreme wind speed probabilities. This may be explained by particular climactic aspects of Point Hope which include prominent coastal exposure, offshore wind conditions, and due to the extreme northerly latitude, lack of exposure to Gulf of Alaska storm winds.

Industry standard reference of extreme wind is the 50 year 10-minute average probable wind speed, referred to as V_{ref}. For Point Hope, this calculates to 32.1 m/s, below the 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

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. Class	V_{ref}, m/s
2	24.8	29.6	I	50.0
10	28.4	33.9	II	42.5
15	29.4	35.0	III	37.5
30	30.9	36.8	S	designer-specified
50	32.1	38.2		
100	33.6	40.1		
average gust factor:	1.19			

Extreme wind speed probability graph



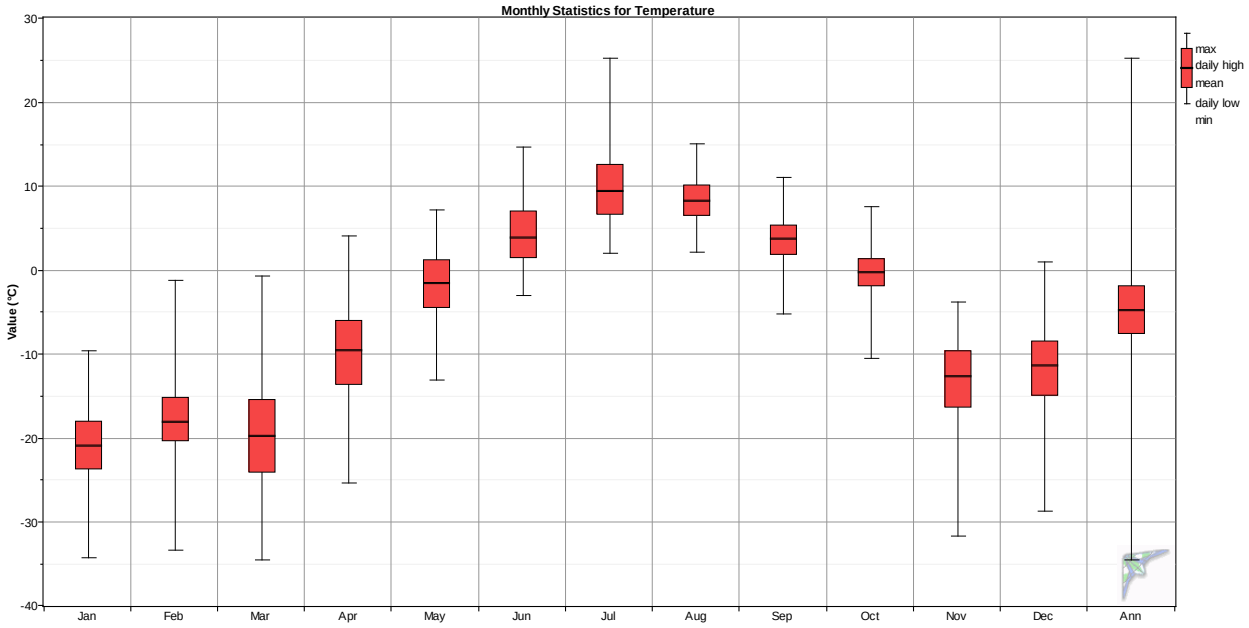
Temperature and Density

Point Hope experiences cool summers and very cold winters. The result is high air density. Calculated air density during the met tower test period exceeds standard air density for a sea level elevation (1.225 Kg/m^3) by eight percent. This is advantageous in wind power operations as wind turbines produce more power at low temperatures (high air density) than at standard temperature and density.

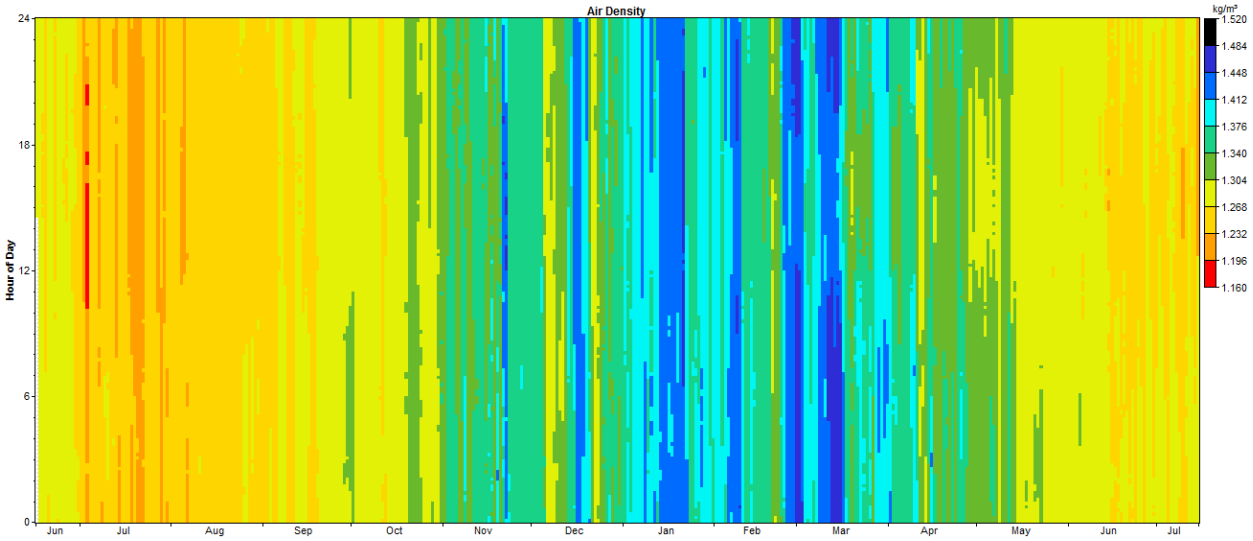
Temperature and density table

	Temperature			Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-20.8	-34.3	-9.7	1.399	1.339	1.477
Feb	-18.1	-33.4	-1.2	1.384	1.297	1.472
Mar	-19.7	-34.6	-0.8	1.393	1.295	1.479
Apr	-9.5	-25.4	4.0	1.339	1.273	1.424
May	-1.6	-13.1	7.1	1.299	1.259	1.357
Jun	3.9	-3.1	14.6	1.274	1.226	1.306
Jul	9.4	2.0	25.2	1.248	1.182	1.282
Aug	8.3	2.1	15.0	1.254	1.224	1.282
Sep	3.8	-5.3	11.0	1.274	1.242	1.317
Oct	-0.3	-10.5	7.5	1.293	1.257	1.343
Nov	-12.6	-31.7	-3.9	1.354	1.310	1.461
Dec	-11.4	-28.7	1.0	1.349	1.287	1.443
Annual	-5.7	-34.6	25.2	1.322	1.182	1.479

Monthly temperature boxplot



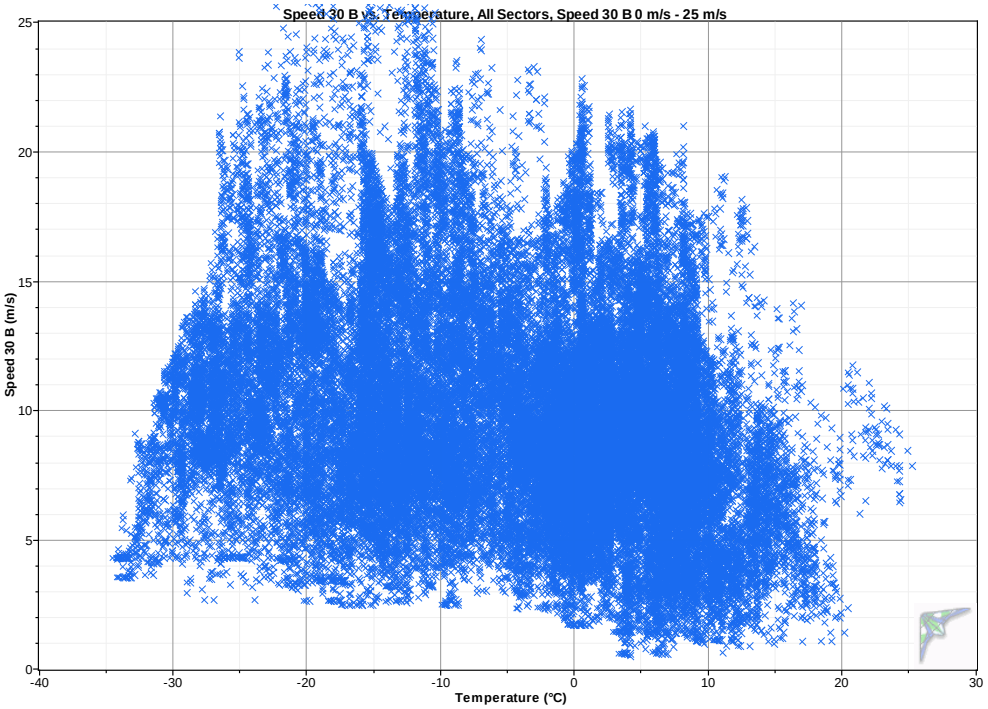
Air density DMap



Wind Speed Scatterplot

The wind speed versus temperature scatterplot below indicates that a substantial percentage of wind in Point Hope coincides with very cold temperatures, as one would expect give the location on the Chukchi Sea coast. However, during the met tower test periods, temperatures did not fall below -40°C. Other winters may see colder temperatures, but it is likely that temperatures colder than -40°C are infrequent and short duration in Point Hope. This compares to relatively nearby Wainwright which recorded a number of sub-minus 40°C temperature readings.

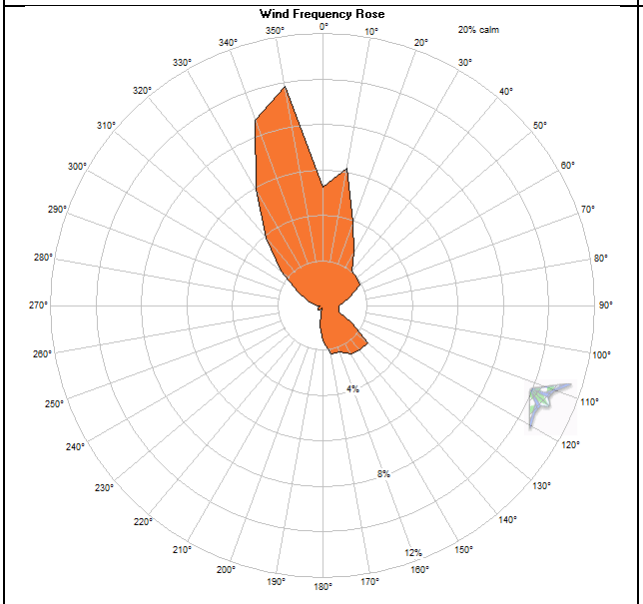
Wind speed versus temperature scatterplot



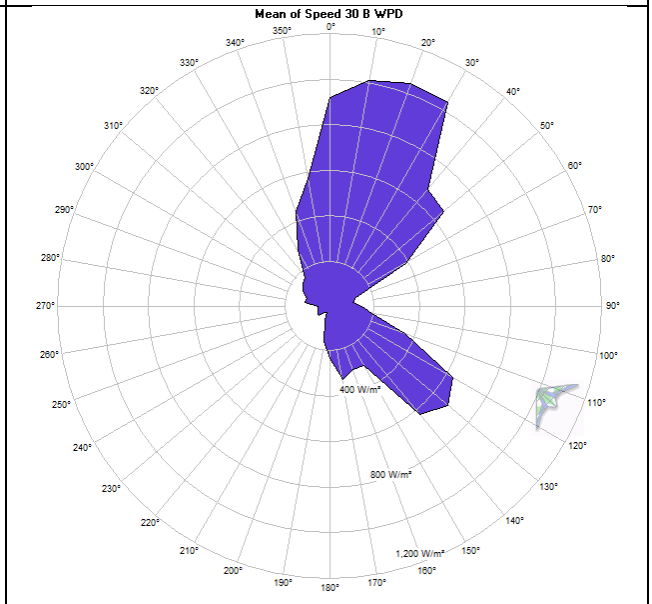
Wind Direction

Wind frequency rose data indicates highly directional winds from the north and southeast. Power density rose data (representing the power in the wind) indicates power winds are strongly directional, from 345°T to 025°T and to a lesser extent from 130°T. Calm frequency (percent of time that winds at the 30 meter level are less than 3.5 m/s) was 20 percent during the met tower test period.

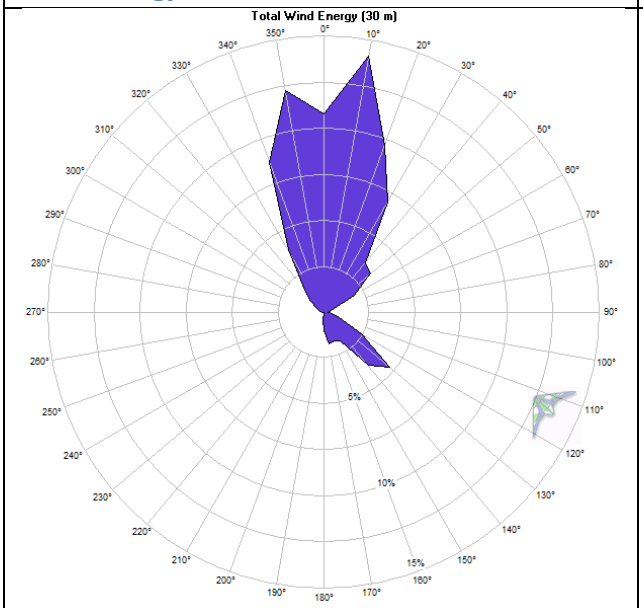
Wind frequency rose



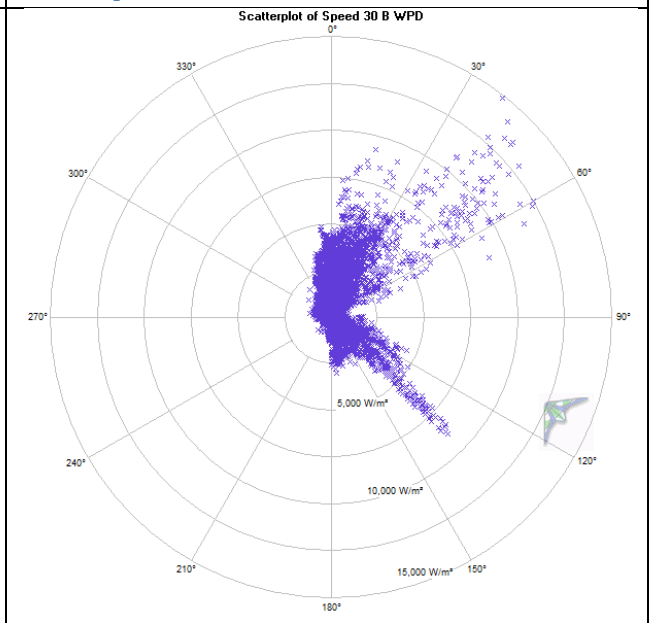
Mean value rose



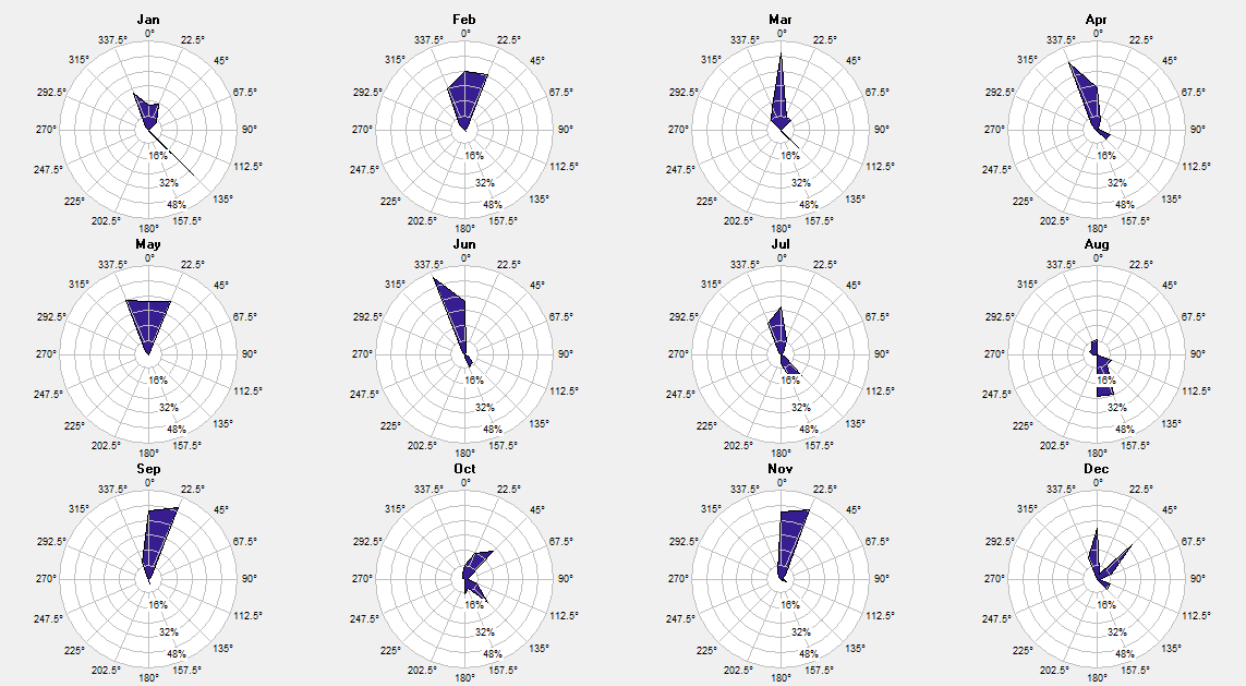
Wind energy rose



Scatterplot rose



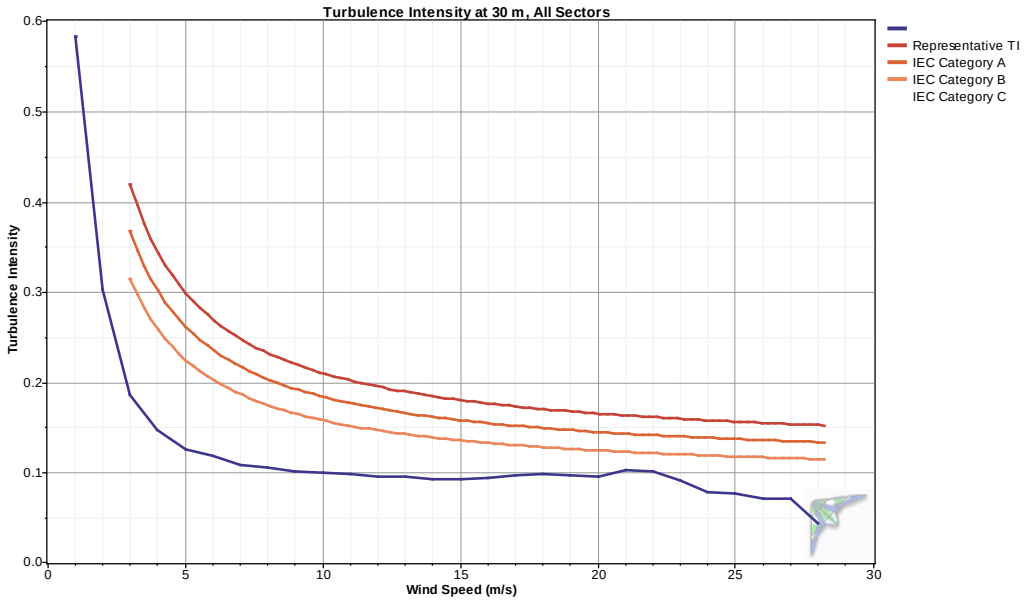
Wind density roses by month



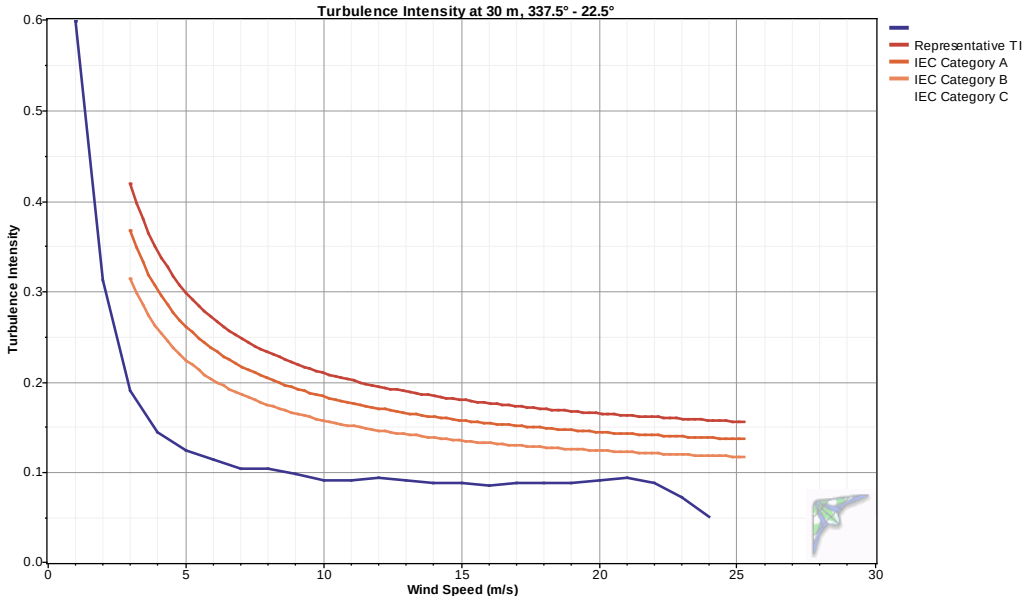
Turbulence

Turbulence intensity at the Point Hope test site is well within acceptable standards with an IEC 61400-1, 3rd edition (2005) classification of turbulence category C, which is the lowest defined.

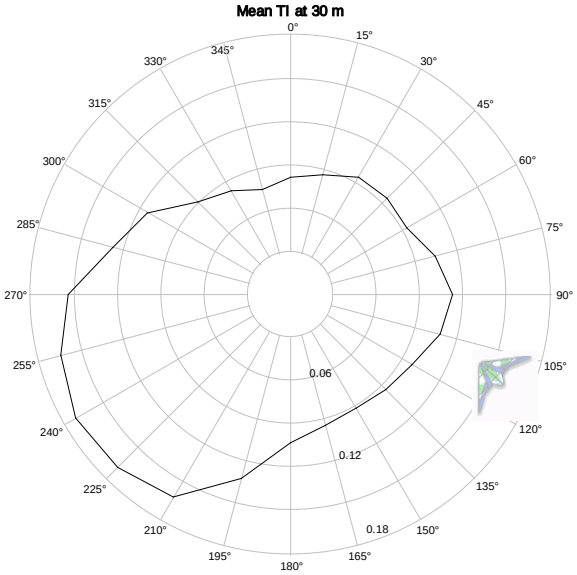
Turbulence intensity, all wind sectors



Turbulence intensity, north (prevailing) wind sector



Turbulence intensity by direction



Turbulence table

Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records In Bin	Mean TI	Standard Deviation of TI	Representative TI	Peak TI
1	0.5	1.5	1,613	0.371	0.165	0.583	1.000
2	1.5	2.5	3,307	0.180	0.095	0.301	0.895
3	2.5	3.5	5,016	0.116	0.055	0.186	0.593
4	3.5	4.5	5,796	0.091	0.043	0.147	0.475

5	4.5	5.5	6,124	0.079	0.036	0.125	0.673
6	5.5	6.5	5,779	0.075	0.033	0.118	0.633
7	6.5	7.5	5,779	0.072	0.028	0.107	0.412
8	7.5	8.5	4,680	0.071	0.027	0.105	0.360
9	8.5	9.5	3,924	0.072	0.023	0.101	0.309
10	9.5	10.5	3,349	0.071	0.021	0.099	0.414
11	10.5	11.5	2,421	0.072	0.020	0.097	0.390
12	11.5	12.5	1,906	0.072	0.018	0.095	0.198
13	12.5	13.5	1,438	0.073	0.017	0.095	0.244
14	13.5	14.5	1,207	0.073	0.014	0.092	0.188
15	14.5	15.5	1,062	0.073	0.015	0.093	0.230
16	15.5	16.5	662	0.073	0.016	0.094	0.151
17	16.5	17.5	533	0.074	0.017	0.096	0.211
18	17.5	18.5	343	0.076	0.017	0.097	0.196
19	18.5	19.5	250	0.076	0.016	0.096	0.128
20	19.5	20.5	130	0.074	0.016	0.094	0.114
21	20.5	21.5	75	0.080	0.017	0.102	0.116
22	21.5	22.5	52	0.082	0.015	0.101	0.111
23	22.5	23.5	48	0.071	0.016	0.091	0.104
24	23.5	24.5	28	0.065	0.010	0.078	0.087
25	24.5	25.5	19	0.065	0.009	0.076	0.082
26	25.5	26.5	12	0.057	0.010	0.070	0.076
27	26.5	27.5	6	0.055	0.012	0.070	0.074
28	27.5	28.5	1	0.043	0.000	0.043	0.043

Airport ASOS Data

In 2005, Alaska Energy Authority (AEA) analyzed the wind resource at all Automated Weather Observing Station (AWOS) and Automated Surface Observing System (ASOS) sites in Alaska. At most stations, AWOS/ASOS data has been collected for twenty-five or more years. The Point Hope Airport (ICAO station identifier: PAPO) AWOS has been in place since 1990.

The AEA report documents data from the AWOS sensor, which is 10 meters above ground level. To compare this data to the met tower upper sensor height of 30 meters, the data was extrapolated with a power law exponent value of 0.110. Compared to the met tower 30 meter B anemometer, the AWOS data predicts an annual wind speed average approximately six percent higher. There may be a number of reasons for this discrepancy, including the more exposed location of the airport to northerly winds with less upwind terrain (that will cause some wind speed decrease due to drag) and extrapolation errors in translating the ten meter airport data to thirty meters. Comparison discrepancies aside, the Point Hope airport data confirms the robust wind resource recorded by the met tower.

Airport/met tower data comparison

Point Hope Airport

	AWOS, 10 m sensor (m/s)	Data adjusted to 30 m (m/s)	Met tower data, 30m B anem. (m/s)	Met tower/AWOS adj. data (%)
Jan	6.90	7.79	7.76	99.7%
Feb	6.80	7.67	7.03	91.6%
Mar	6.10	6.88	6.99	101.5%
Apr	5.90	6.66	6.91	103.8%
May	5.60	6.32	5.53	87.5%
Jun	5.60	6.32	5.49	86.8%
Jul	6.00	6.77	6.61	97.6%
Aug	6.90	7.79	6.64	85.2%
Sep	7.60	8.58	8.54	99.5%
Oct	7.90	8.91	6.28	70.4%
Nov	7.70	8.69	8.67	99.7%
Dec	7.40	8.35	9.05	108.4%
Annual	6.70	7.56	7.12	94.2%