Nightmute, Alaska Wind Resource Report

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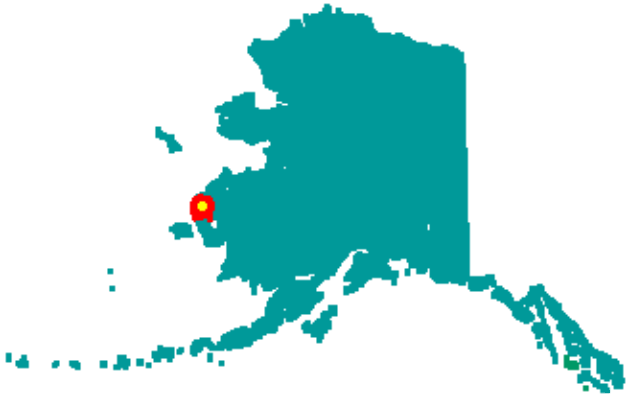
Date of report: June 26, 2008

Photo by Doug Vaught



Summary Information

Nightmute has an outstanding wind resource for wind power development, characterized by a high average wind speed, high wind power class, and low turbulence. Nightmute's wind resource is higher than other wind resources measured in the area, perhaps due to funneling of winds around the very high (839 ft elevation) Toksook hill immediately north and behind the village.

Meteorological Tower Data Synopsis

Wind power class	Class 6 – Outstanding
IEC wind classification	Class III C- (IEC standard 61400-1 ed. 3)
Wind speed annual average (at 30 meters)	7.37 m/s
Maximum wind gust (3 second)	33.6 m/s (January 2005)
Maximum wind (10 min average)	29.3 m/s (December 2004)
Mean wind power density (30 meters)	668 W/m^2 (measured)
Weibull distribution parameters	k = 1.48, c = 7.70 m/s
Roughness Class	0.59 (snow surface)
Power law exponent	0.114 (low wind shear)
Mean Turbulence Intensity	0.102
Data start date	June 25, 2004
Data end date	September 12, 2005

Community Profile

Current Population: 244 (2007 DCCED Certified Population)
Pronunciation/Other Names: (NITE-myoot)
Incorporation Type: 2nd Class City
Borough Located In: Unorganized
School District: Lower Kuskokwim Schools
Regional Native Corporation: Calista Corporation

Location

Nightmute is located on Nelson Island, in western Alaska. It is 18 miles upriver from Toksook Bay and 100 miles west of Bethel. It lies at approximately 60.479440° North Latitude and -164.723890° West Longitude. (Sec. 33, T005N, R088W, Seward Meridian.) Nightmute is located in the Bethel Recording District. The area encompasses 97.0 sq. miles of land and 4.6 sq. miles of water. Nightmute is influenced by a marine climate. Precipitation averages 22 inches, with 43 inches of snowfall annually. Summer temperatures range from 41 to 57; winter temperatures are 6 to 24.

History

Nelson Island has been inhabited by the Qaluyaarmiut, or "dip net people," for 2,000 years. The area was relatively isolated from outside contact, and has kept its traditions and culture. Umkumiut is the traditional fish camp. In 1964, several residents moved to Toksook Bay to obtain more cost-effective goods. The City was incorporated in 1974.

Culture

Nightmute is a traditional Yup'ik Eskimo village, active in subsistence. The sale, importation or possession of alcohol is banned in the village.

Economy

The economy is a mixture of both subsistence and cash-generating activities. Employment is primarily with the City, school, services, commercial fishing and construction. Trapping and crafts also provide income. Almost all families engage in either commercial or subsistence fishing, and most have fish camps. 31 residents hold commercial fishing permits for herring roe, salmon drift and net fisheries.

Facilities

The City of Nightmute provides a small water facility, which is the central watering point for residents to haul their own water. The City also provides water and sewer haul service. The city utility system has 37 residential units, 5 commercial/residential and 6 commercial units. The school has its own sewage lagoon. A washeteria is not available. The Nightmute Power Plant was acquired by AVEC in March 1998.

Transportation

A State-owned 1,650' long by 45' wide gravel airstrip is used by chartered and private aircraft. A seaplane landing area is also available. There are no docking facilities, although many residents use fishing boats or skiffs for local travel. Snow machines and ATVs are used during winter months. Winter trails are marked to Toksook Bay (20 mi.), Cak'caaq (25 mi.) and Baird Inlet (50 mi.). Cargo and supplies must be lightered up the Tuqsuk River.

Climate

Nightmute is influenced by a marine climate. Precipitation averages 22 inches, with 43 inches of snowfall annually. Summer temperatures range from 41 to 57; winter temperatures are 6 to 24.

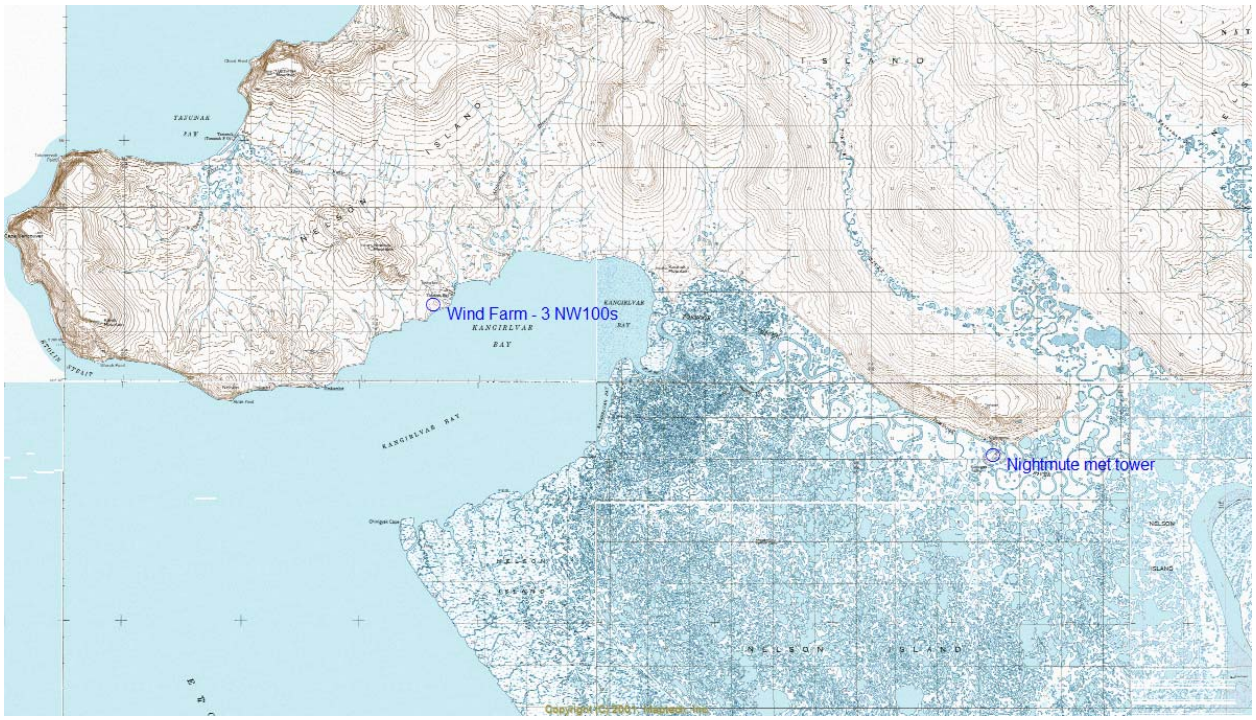
(Above information from State of Alaska Department of Commerce, Community, and Economic Development website, http://www.dced.state.ak.us/)

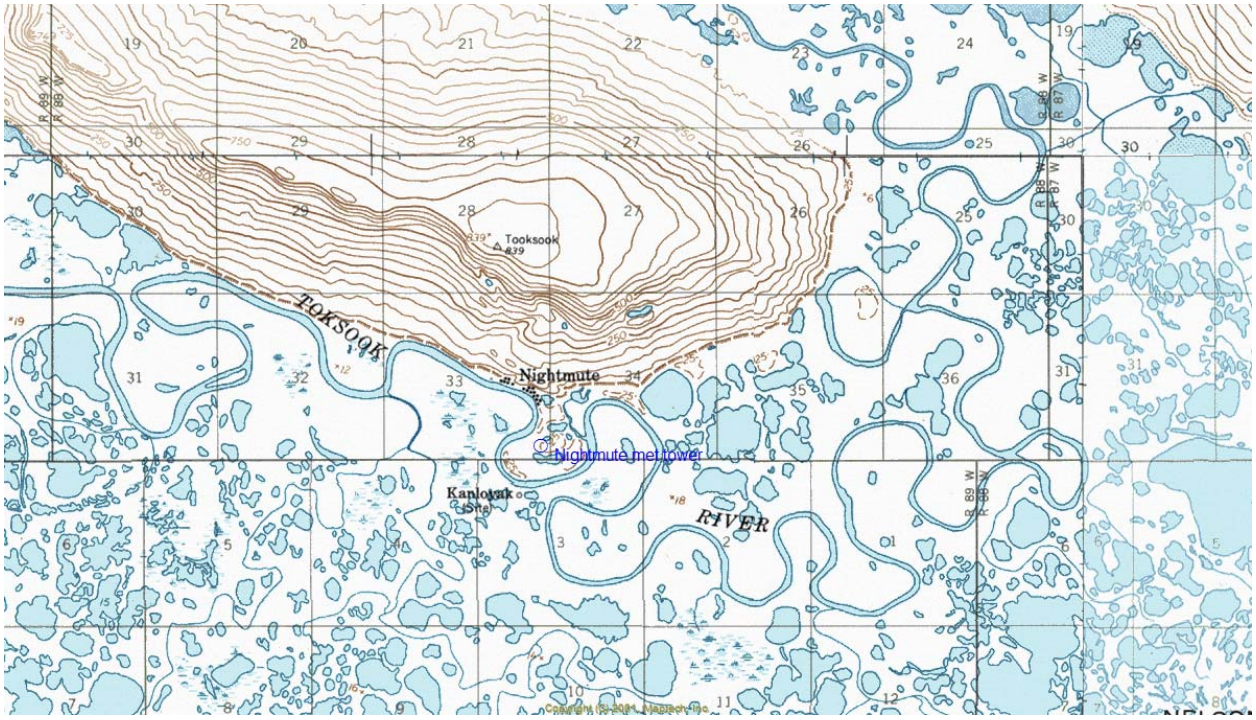
Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m	0.765	0.35	280°
2	NRG #40 anemometer	20 m	0.765	0.35	not rec.
7	NRG #200P wind vane	30 m	0.351	300°	120°
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Site Information and Location

Site number	0017
Site Description	Open tundra, immediately south of village and just north of wastewater lagoon
Latitude/longitude	N 60° 28.434’; W 164° 43.376’ (WGS 84)
Site elevation AMSL	3 meters
Datalogger type	NRG Symphonie, S/N 35262543
Tower type	NRG 30-meter tall tower, 152 mm (6-in) diameter


Wind Farm - 3 NW100s
Nightmute met tower
KANGIELVAK BAY
NELSON ISLAND


Tooksook
TOKSOOK
Nightmute
Nightmute met tower
Kanolzak Site
RIVER


Nightmute, AK
Nightmute met tower
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Data Quality Control

Data was filtered to remove presumed icing events that yield false zero wind speed data. Data that indicated flat or minimal sensor response, a standard deviation of 0, and temperatures of less than 3 degrees C were removed. Note that during the months of April through October little to no data was lost due to icing with some icing loss during the winter months. Because sensor icing was minimal, filtered data was not synthesized and replaced for analysis.

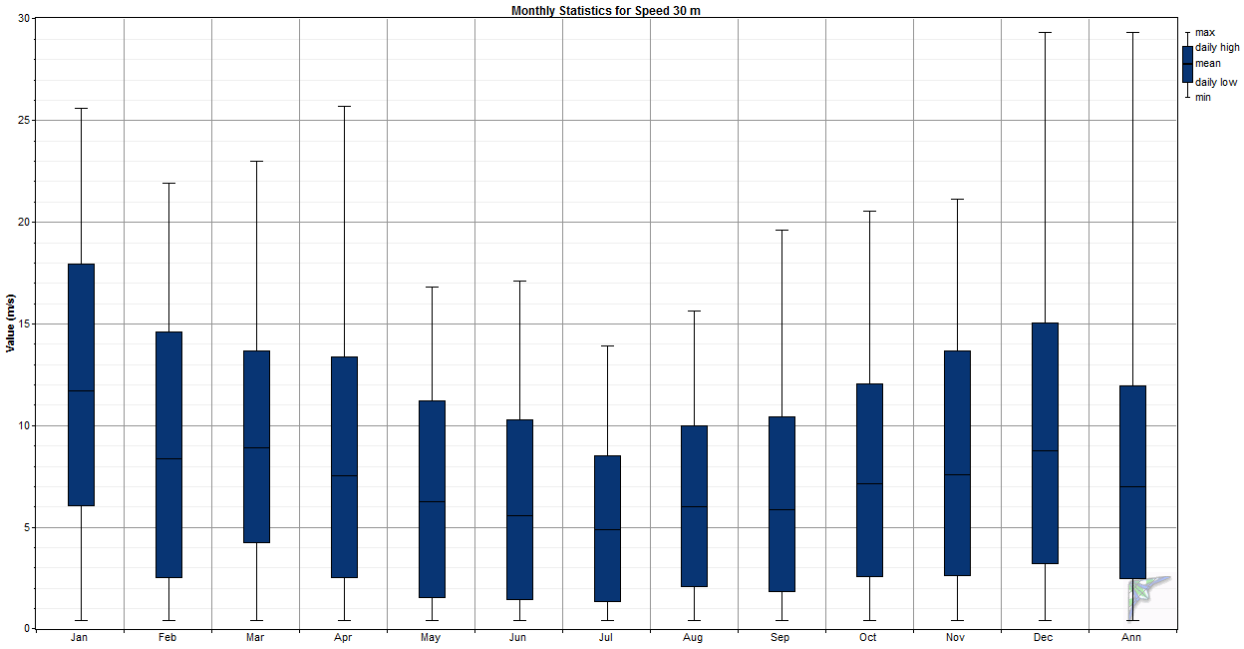
		Ch 1 (30 m speed)		Ch 2 (20 m speed)		Ch 7 (wind vane)		Ch 9 (temperature)	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2004	Jun	776	89.8	776	89.8	776	89.8	776	89.8
2004	Jul	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2004	Aug	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2004	Sep	4,320	100.0	4,320	100.0	4,320	100.0	4,320	100.0
2004	Oct	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2004	Nov	4,188	96.9	4,281	99.1	3,893	90.1	4,320	100.0
2004	Dec	4,387	98.3	4,353	97.5	3,559	79.7	4,464	100.0
2005	Jan	4,018	90.0	4,017	90.0	4,025	90.2	4,464	100.0
2005	Feb	3,955	98.1	3,955	98.1	1,826	45.3	4,032	100.0
2005	Mar	4,265	95.5	4,265	95.5	3,463	77.6	4,464	100.0
2005	Apr	4,320	100.0	4,320	100.0	3,311	76.6	4,320	100.0
2005	May	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2005	Jun	4,320	100.0	4,320	100.0	4,320	100.0	4,320	100.0
2005	Jul	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2005	Aug	4,464	100.0	4,464	100.0	4,464	100.0	4,464	100.0
2005	Sep	1,686	100.0	1,686	100.0	1,686	100.0	1,686	100.0
All data		63,019	98.4	63,077	98.5	57,963	90.5	63,950	99.9

Measured Wind Speeds

The 30 meter anemometer annual wind speed average for the reporting period is 7.37 m/s and the 20 meter anemometer annual wind speed average is 7.02 m/s, indicative of a strong wind resource.

	30 m speed (Ch 1)					20 m speed (Ch 2)		
Month	Mean (m/s)	Max 10 min (m/s)	Max gust (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max 10 min (m/s)	Max gust (m/s)
Jan	11.69	25.6	33.6	1.698	12.88	11.12	24.5	32.1
Feb	8.34	21.9	25.6	1.722	9.26	8.03	21.0	26.3
Mar	8.86	23.0	25.6	2.016	9.95	8.38	21.3	26.0
Apr	7.52	25.7	28.7	1.156	7.87	7.15	23.5	27.5
May	6.26	16.8	20.6	1.596	6.94	6.01	15.5	20.2

Jun	5.56	17.1	19.1	1.655	6.20	5.36	15.5	18.3
Jul	4.88	13.9	17.2	1.812	5.46	4.73	13.3	16.8
Aug	5.99	15.6	21.4	1.733	6.68	5.69	14.9	19.9
Sep	5.85	19.6	25.2	1.565	6.46	5.52	18.5	23.7
Oct	7.14	20.5	27.5	1.732	7.95	6.78	20.2	26.8
Nov	7.57	21.1	28.7	1.391	8.25	7.16	20.9	28.3
Dec	8.75	29.3	33.2	1.455	9.61	8.34	27.0	32.1
Annual	**7.37**	29.3	33.6	1.475	7.70	**7.02**	27.0	32.1



Extreme Winds

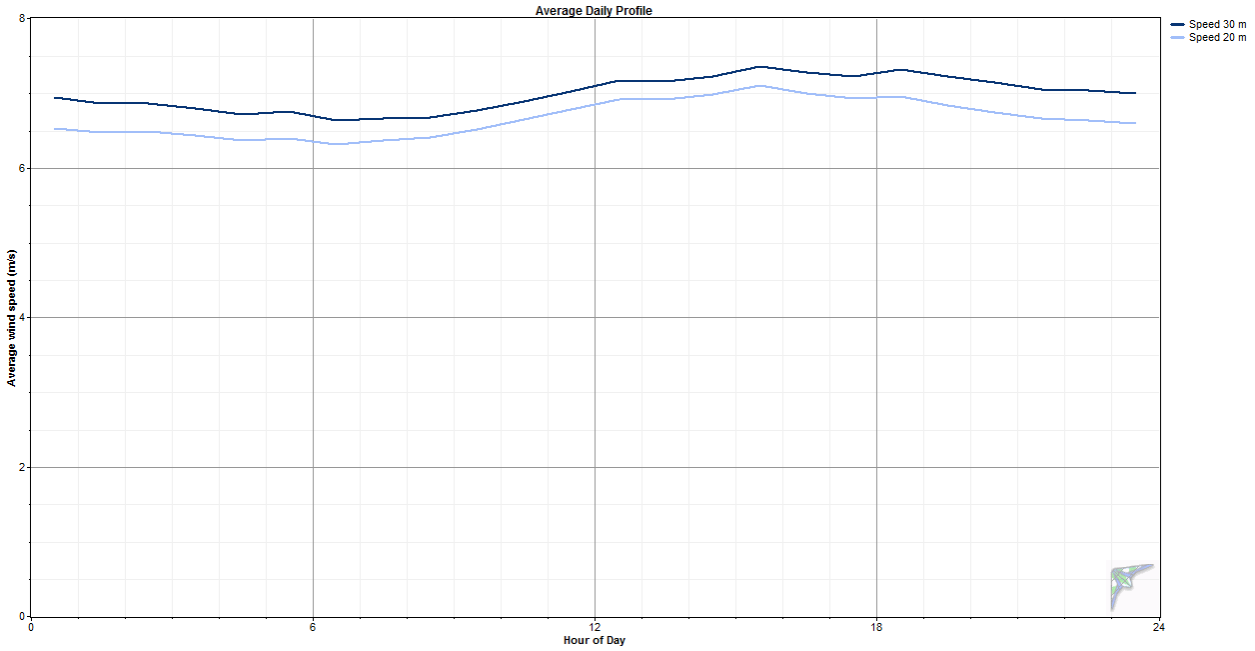
By use of a Gumbell distribution calculation modified to use monthly wind speed data instead of yearly data (this is necessary because the data set only included two calendar years, 2004 and 2005), estimated extreme wind speeds were calculated as shown below. For IEC classification and use in foundation design calculations, the 50 year design or reference wind speed (V_{ref}) is 34.9 m/s. This is a reasonable design wind speed and would classify the site as IEC Class III.

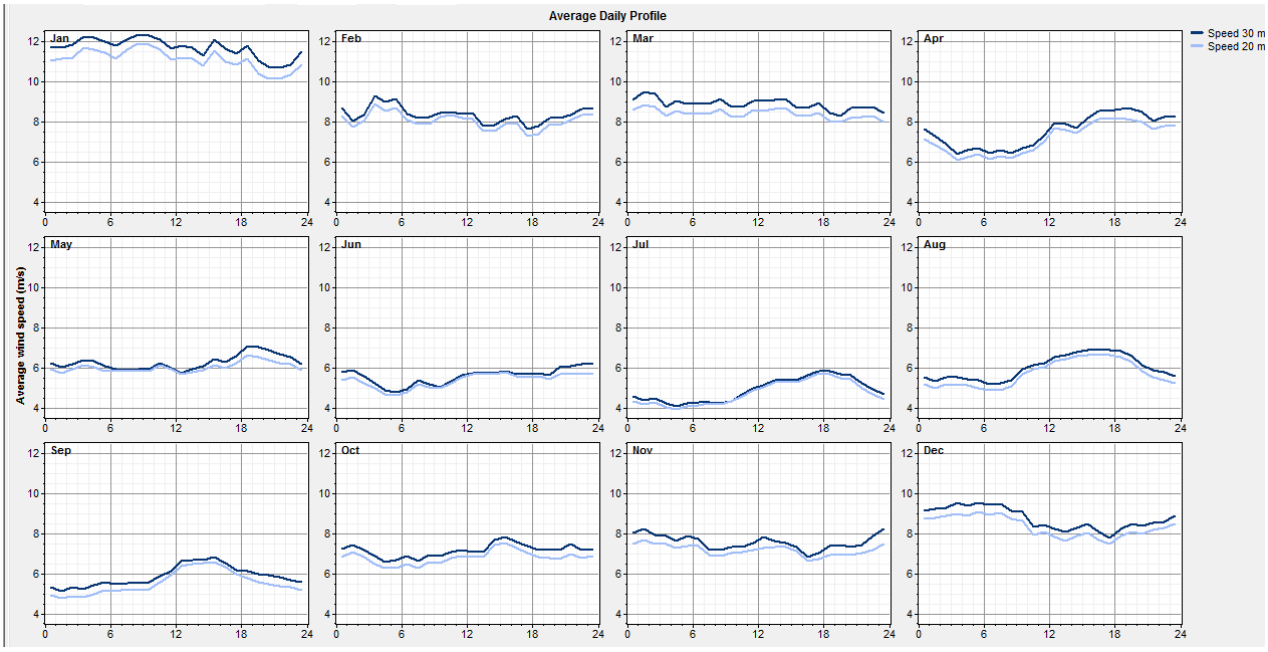
RETURN PERIOD SPEED — Average Gust Factor: 1.24

Nightmute	RETURN YR	V_{ref}, 10 min average wind speed, m/s	V_e, 3 sec gust, m/s
30 meter	2	25.7	31.8
	10	30.3	37.5
	15	31.5	38.9
	30	33.5	41.4
	50	34.9	43.2
	100	36.9	45.6

Daily Wind Profile

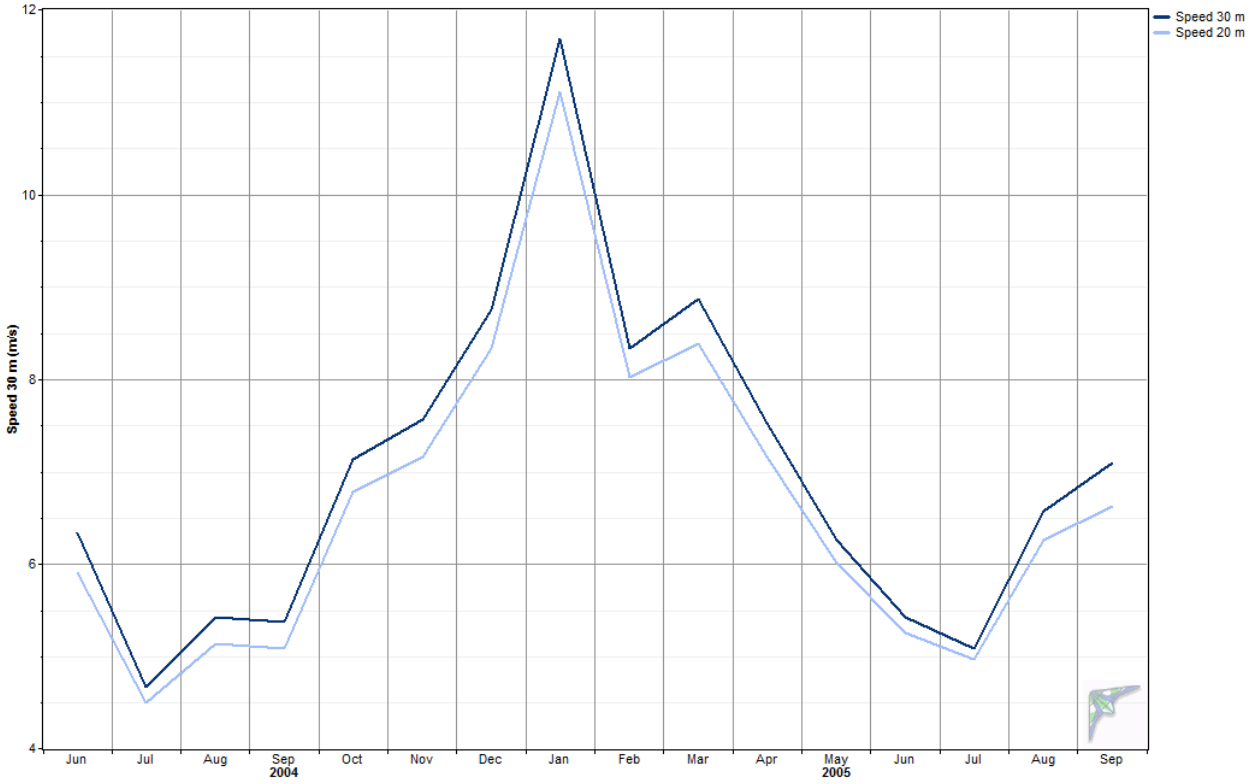
The daily wind profile indicates a minor annual daily variation of wind speeds with the lowest wind speeds occurring in the early morning hours of 4 a.m. to 9 a.m. and the highest wind speeds of the day occur during the afternoon and evening hours of 12 p.m. to 8 p.m. A monthly view of the average daily wind profile however yields somewhat more variability.

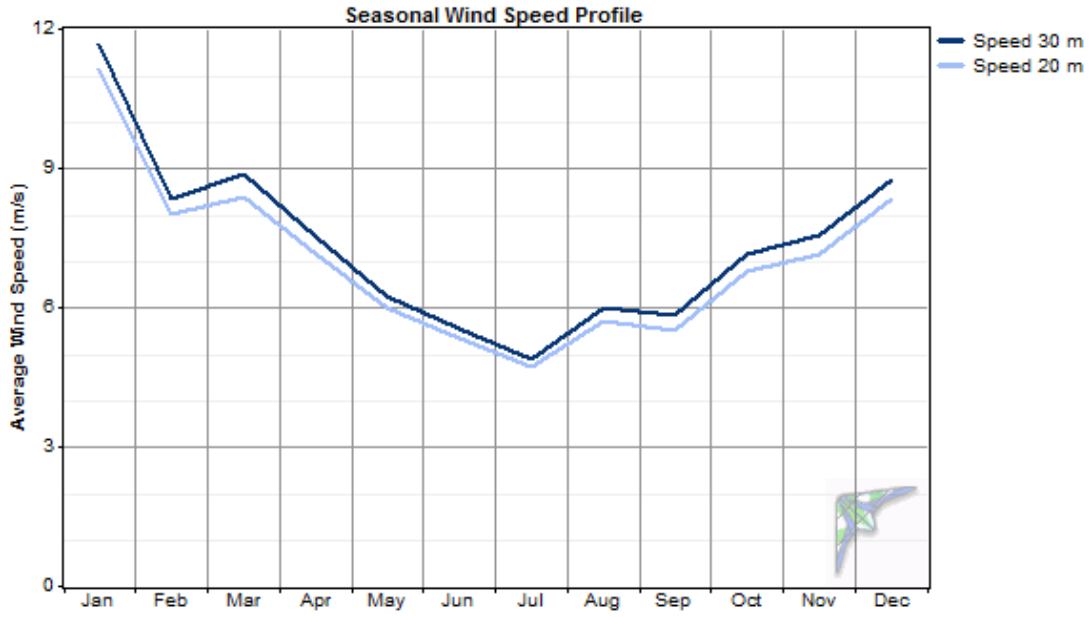




Time Series of Wind Speed Monthly Averages

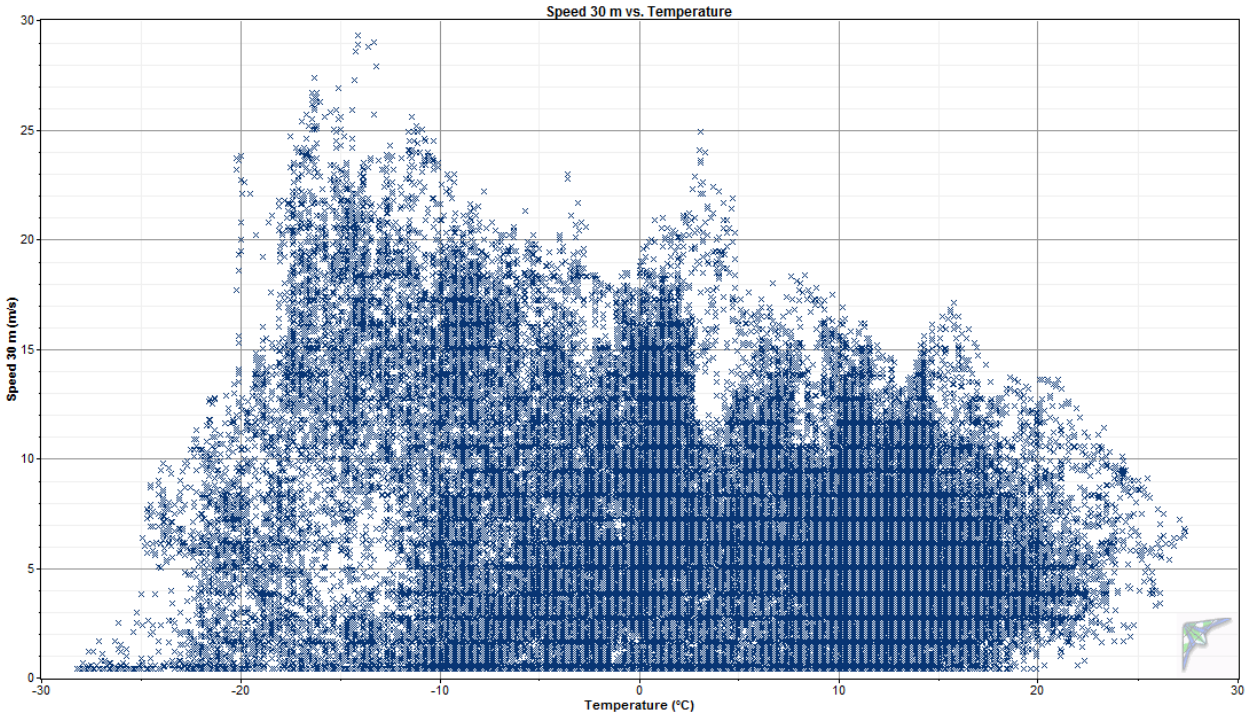
As expected, the highest winds occurred during the fall through spring months with relatively light winds during the late spring through autumn months of May through September. Note that the measured winds in January 2005 were extremely low. This will influence the measured wind resource and will be a high bias if normal January winds are not so energetic.





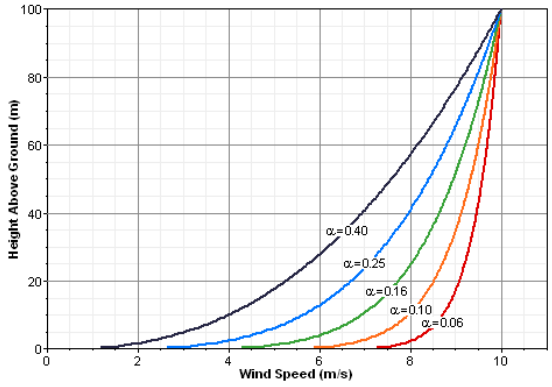
Wind Speed versus Temperature Scatterplot

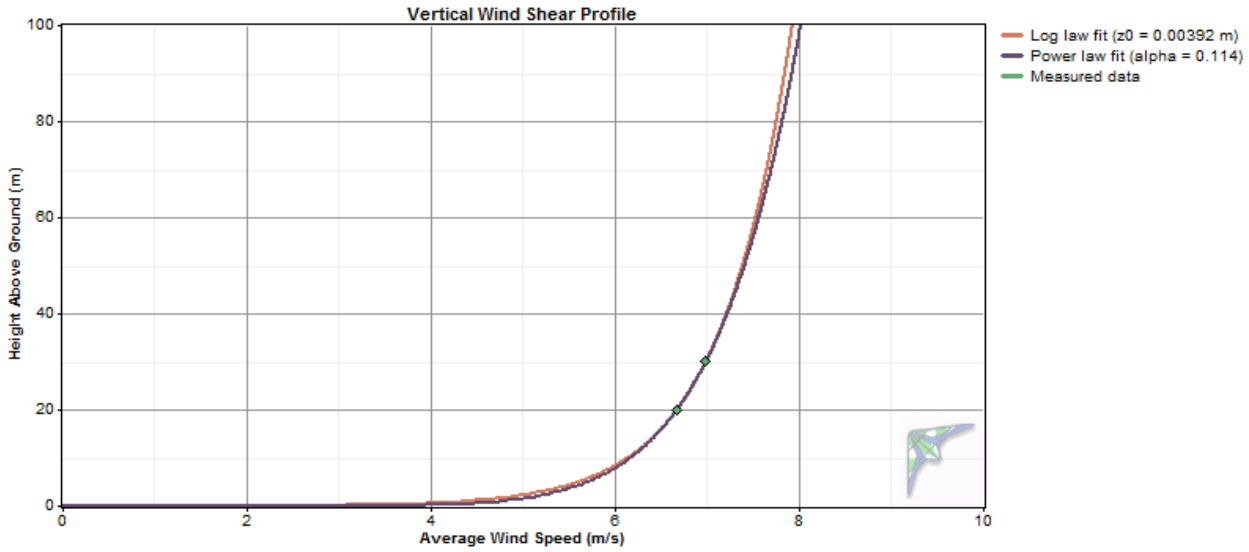
The graph below displaying a scatterplot of ten-minute average wind speeds measured at 30 meters versus temperature. As can be seen, a relatively minor amount of wind occurs when the temperature is less than -20° C; temperatures below -25° C are rare.

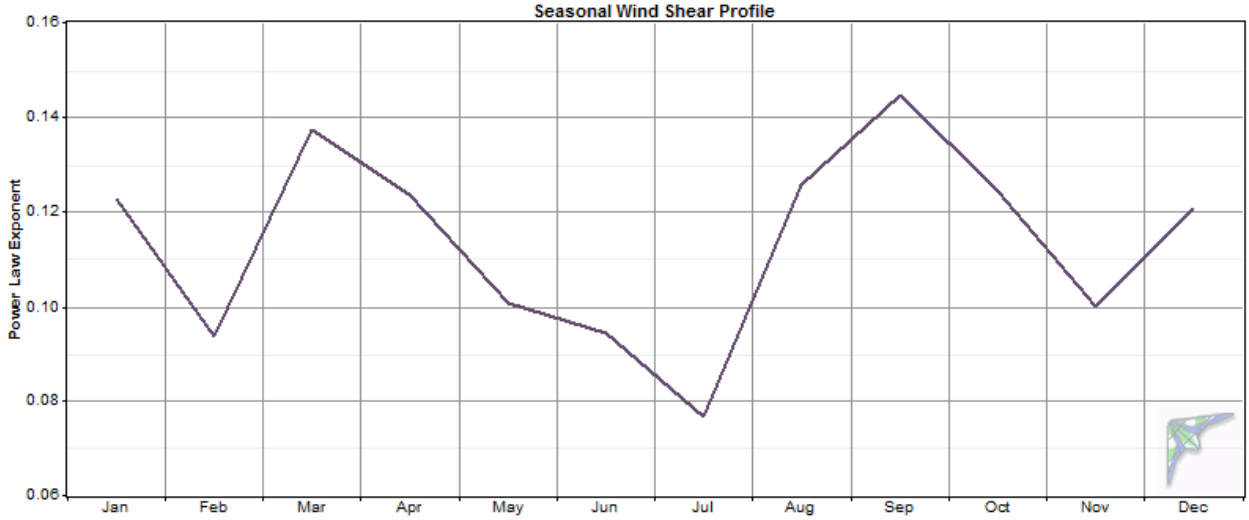


Wind Shear Profile

The average power law exponent was calculated at 0.114, indicating moderately low wind shear at the Nightmute met tower test site (first graph shows shear curves for representative shear coefficients). The practical application of this information is that a very high turbine tower height is not particularly advantageous at this site as there is not an appreciable marginal gain in average wind speed with height. Besides, the wind resource is very good even at low heights. However, a tower height/power recovery/construction cost tradeoff study would be advisable should a wind power project be initiated.





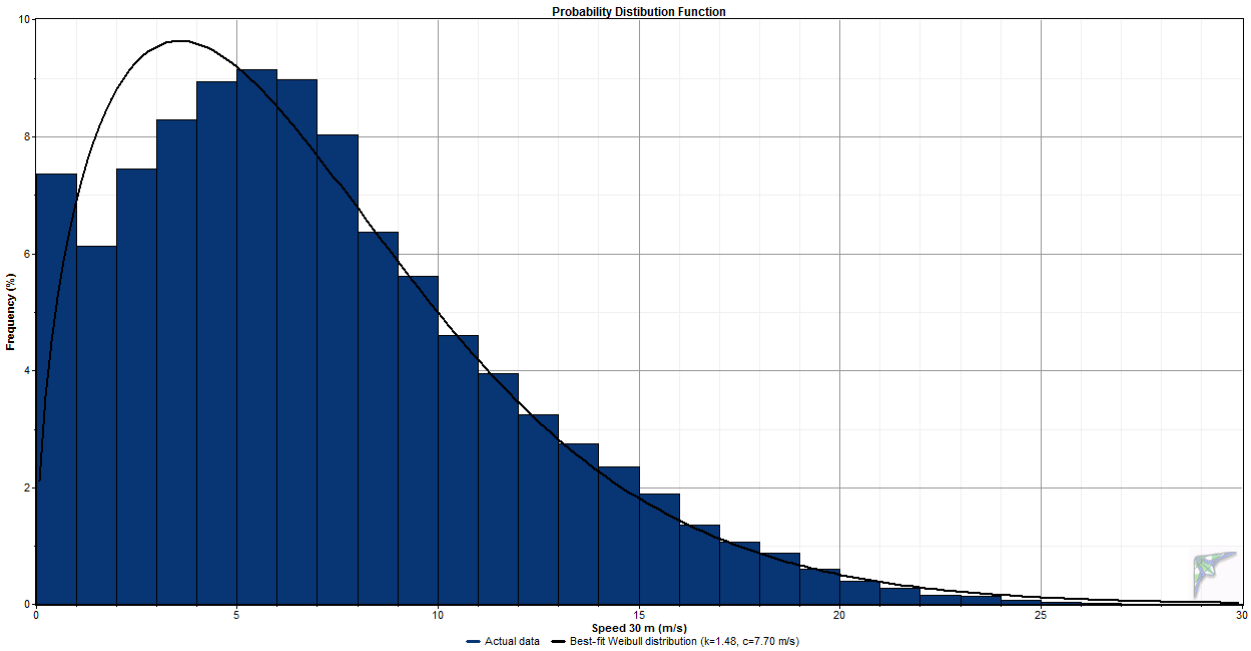


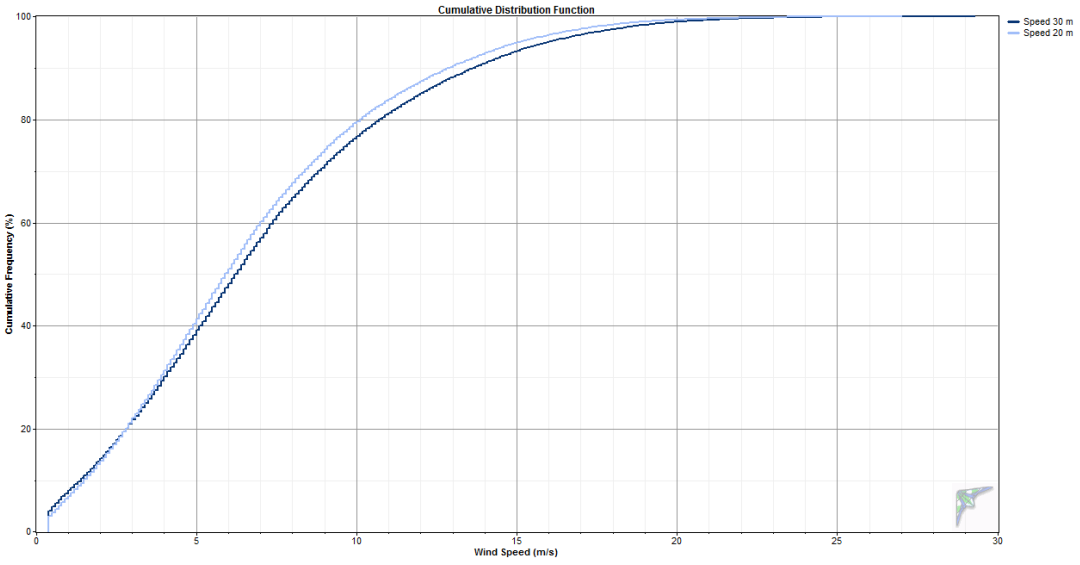
Probability Distribution Function

The probability distribution function (PDF) provides a visual indication of measured wind speeds in one meter per second "bins". Note that most wind turbines do not begin to generate power until the wind speed at hub height reaches 4 m/s, also known as the *cut-in* wind speed. The black line in the graph is a "best fit" Weibull distribution. At the 30 meter level, Weibull parameters are k = 1.48 (indicates a low distribution of wind speeds) and c = 7.70 m/s (scale factor for the Weibull distribution; in this case relatively high).

The Cumulative Distribution Function (CDF, second graph) is another way of displaying PDF information. It is interpreted by noting the percent frequency for any given wind speed. For instance, at 15 m/s, the

CDF at 30 meters is 94%. This means that the winds in Nightmute blow at less than 15 m/s 94 percent of the time.





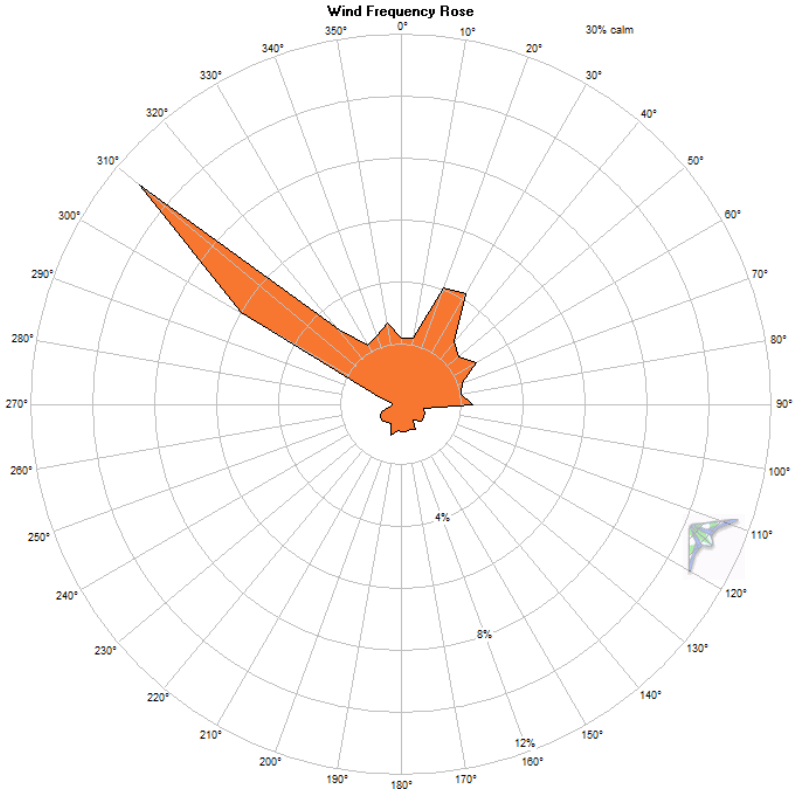
Wind Roses

Nightmute's winds are strongly bi-directional with the most frequent winds from the northwest and to a lesser extent northeast. This data observation, however, changes somewhat upon consideration of the power density rose (second wind rose). As one can see, the power producing winds are primarily northeast with northwest winds slightly less so. This is very interesting and somewhat different from the more variably wind rose measure in nearby Toksook Bay. The reason for this would appear to be

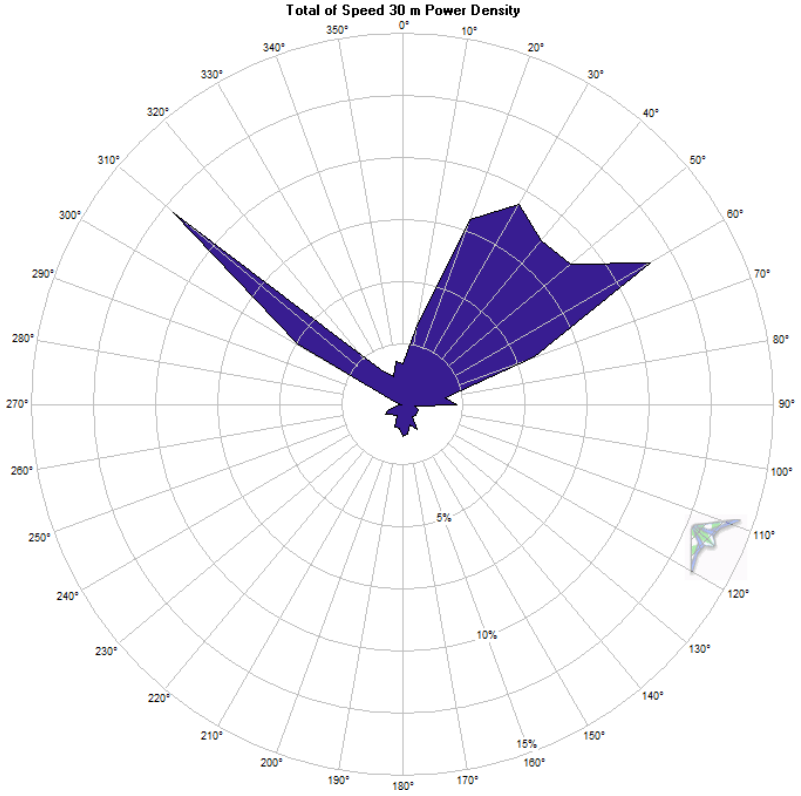
the presence of the massive Toksook Hill towering above the village. This hill effectively prevents any northerly winds from approaching Nightmute directly; northerly winds from west to east are forced to wrap around the hill and are squeezed directionally in somewhat of a venturi effect, narrowing the directionality of the winds and possibly also increasing the wind velocity. The practical application of this information is that multiple turbines must be carefully spaced to avoid downwind wake effects from both northwest and northeast winds. Note that as a practical matter, southerly type winds are virtually nonexistent in Nightmute.

Also note also that a wind threshold of 4 m/s was selected for the definition of calm winds. This wind speed represents the cut-in wind speed of most wind turbines. By this definition Nightmute experiences calm conditions 30 percent of the time (see wind frequency rose below).

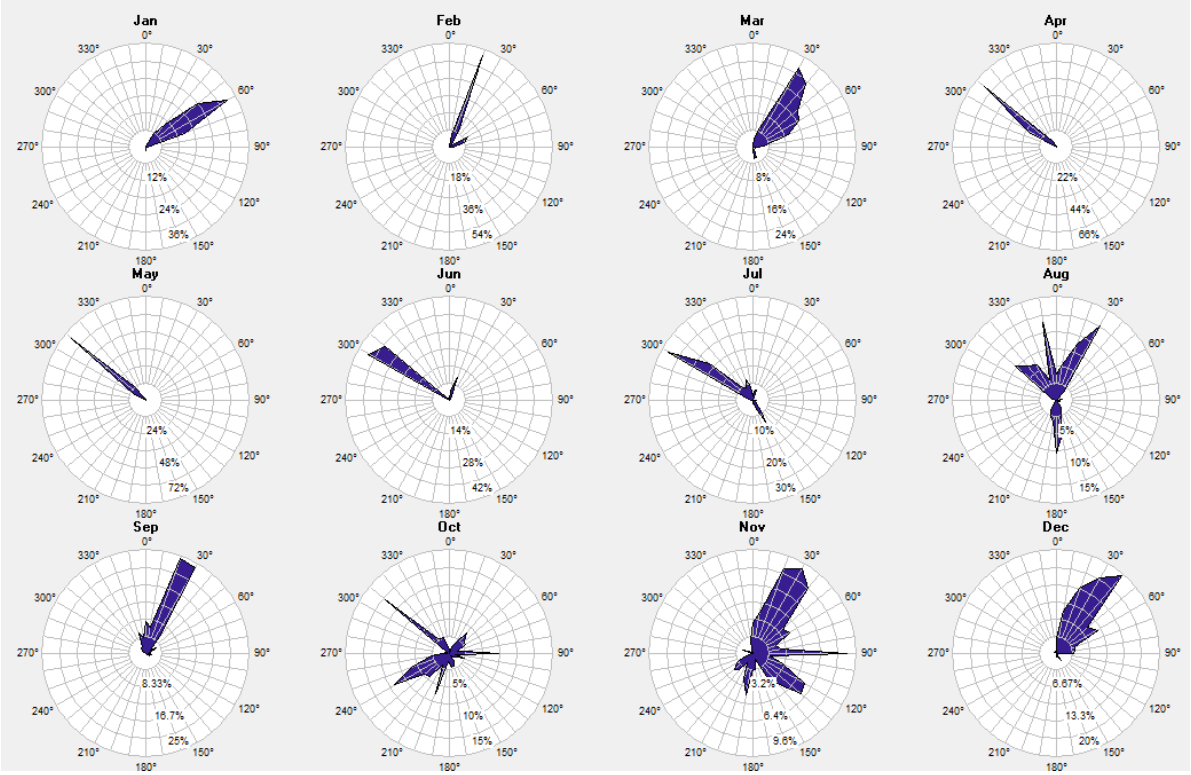
Wind frequency rose (30 meters)



Power Density Rose (30 meters)



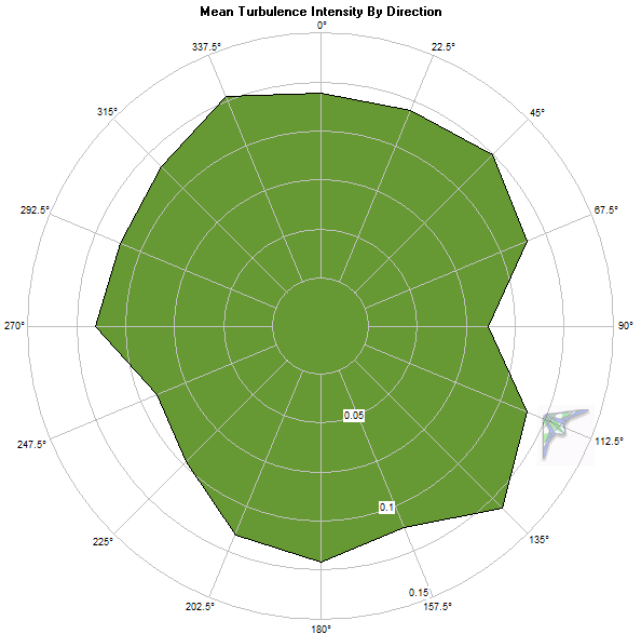
Wind Power Density Rose by Month (30 meters), scale is not common



Turbulence Intensity

The turbulence intensity at 30 meters in Nightmute is quite acceptable for the most frequent wind directions with mean turbulence intensity (all directions) of 0.102 (at 15 m/s) for all wind above the threshold wind speed is 4 m/s. This indicates an acceptable degree of turbulence for wind power development. Turbulence intensities for all southerly directions, although not of concern, are somewhat unimportant as winds rarely blow from these sectors.

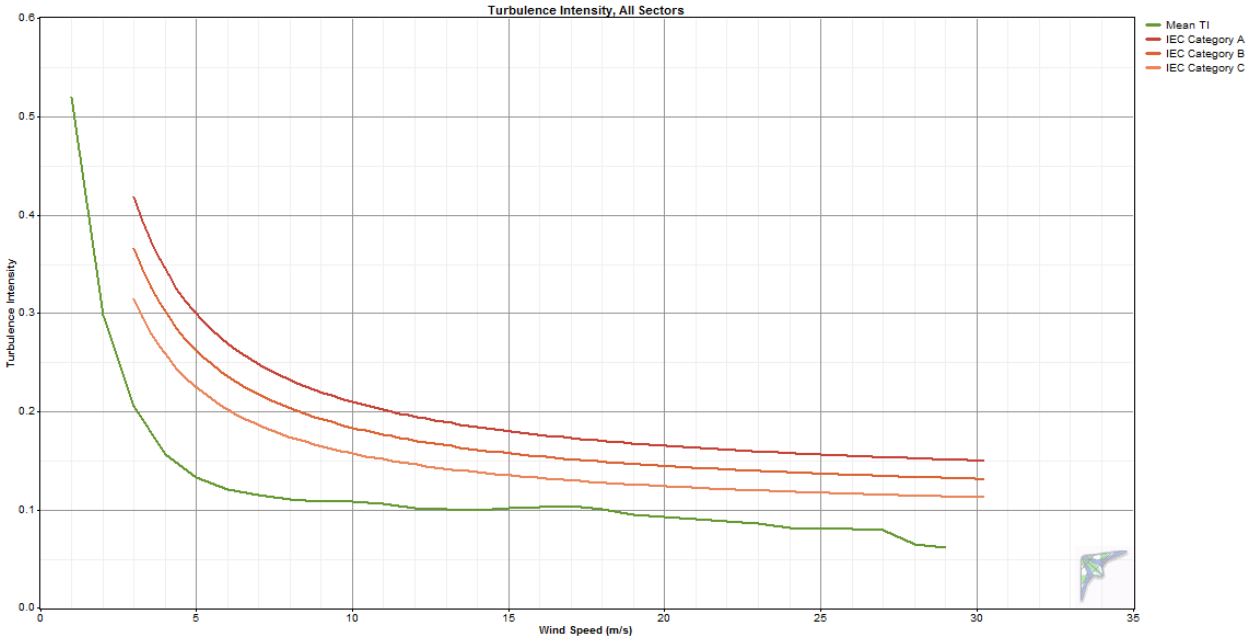
Turbulence Intensity Rose – 30 meter vane, 30 meter anemometer



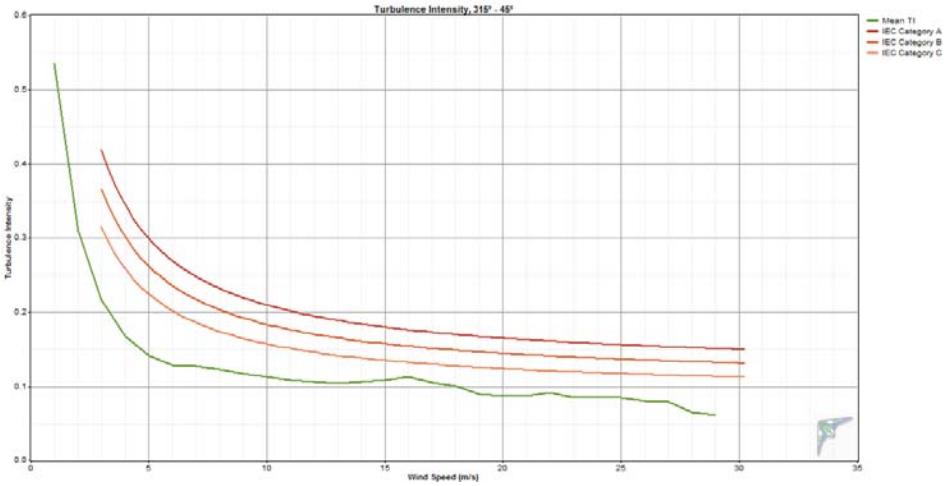
IEC Turbulence Intensity Standards

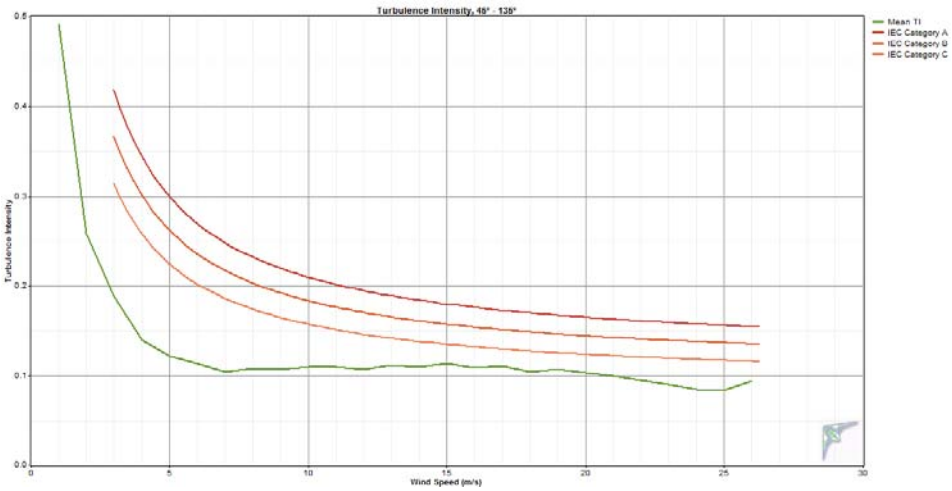
Under IEC standard 61400-1 edition 3 criteria, Nightmute classifies as category C-. These are shown graphically below for all sectors and by four 90 degree sectors.

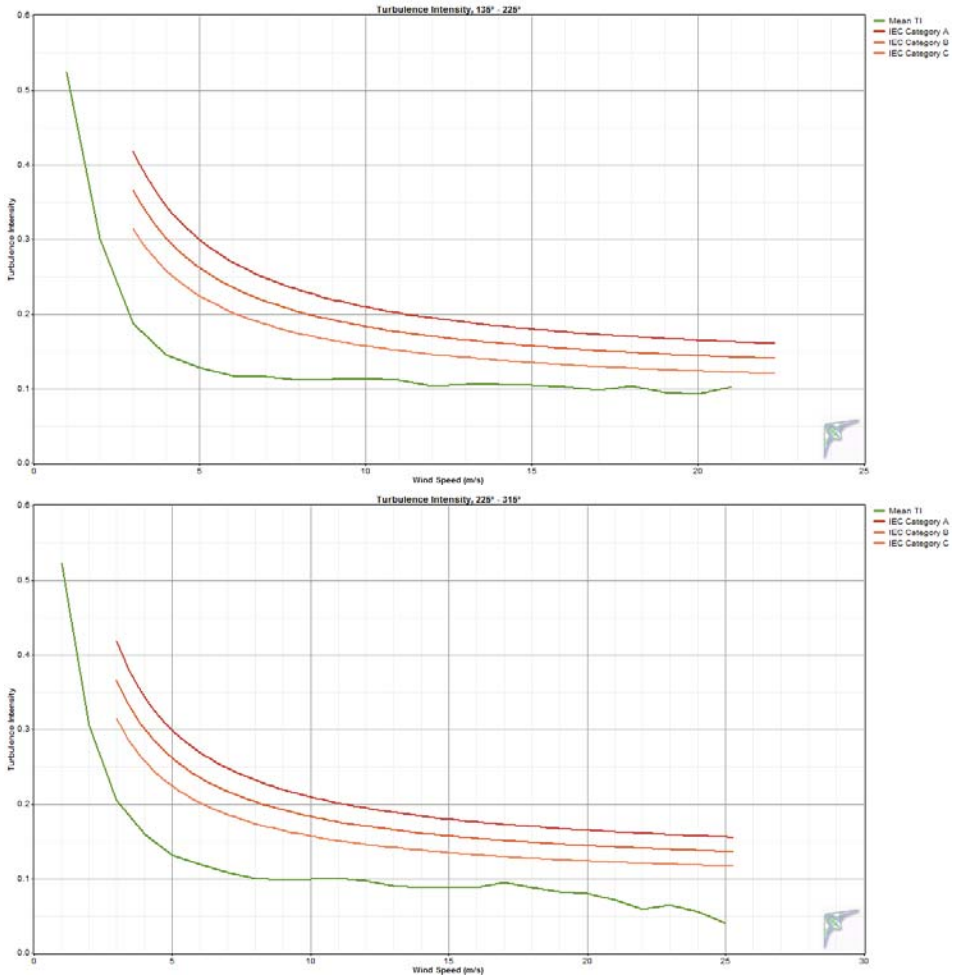
Quantity	Value
Records in 15 m/s bin	1,347
Mean TI at 15 m/s	0.102
Representative TI at 15 m/s	0.141
Turbulence category - IEC 3rd ed.	C-



IEC Turbulence Intensity Standards by 90 degree sector







Air Temperature and Density

Over the reporting period, Nightmute had an average temperature of 1.6° C. The minimum recorded temperature during the measurement period was -28.2° C and the maximum temperature was 27.4° C, indicating a cool temperate environment for wind turbine operations. Consequent to Nightmute's cool temperatures, the average air density of 1.286 kg/m^3 is five percent higher than the standard air density of 1.225 kg/m^3 (at 15.0° C temperature and 101.25 kPa pressure at 3 meters elevation). Practically, this means that a stall-controlled wind turbine will have a higher power output in Nightmute than it would in a warmer climate proportional to the density ratio actual:standard. The same is also true for a pitch-controlled wind turbine, but to a lesser extent.

	Temperature (Ch 9)			Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-8.2	-20.2	3.1	1.332	1.277	1.395
Feb	-8.8	-28.2	3.1	1.336	1.277	1.440
Mar	-6.3	-24.1	4.0	1.323	1.273	1.416

Apr	-6.4	-23.6	13.8	1.324	1.229	1.414
May	5.8	-3.7	16.7	1.265	1.217	1.309
Jun	13.2	2.6	27.4	1.232	1.174	1.279
Jul	13.7	4.5	24.8	1.230	1.184	1.270
Aug	13.6	5.1	23.4	1.230	1.189	1.268
Sep	8.3	-2.8	16.9	1.254	1.216	1.305
Oct	3.5	-7.3	11.3	1.275	1.240	1.327
Nov	-2.7	-16.0	4.2	1.305	1.272	1.372
Dec	-7.0	-25.2	2.0	1.326	1.282	1.423
Annual	**1.6**	-28.2	27.4	**1.286**	1.174	1.440