Saint Michael, Alaska Wind Resource Report

Saint Michael met tower site on extinct cinder cone in upper center, D. Vaught photo

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Summary

The wind resource measured at the Saint Michael met tower site 0021 is very good with measured wind power class 5 (excellent). In addition to high average wind speeds and high wind power density, the site experiences very low turbulence and initial calculations (based on relatively limited data to date) indicate low extreme wind speed probability.

Met tower data synopsis

Data dates	July 21, 2010 to July 9, 2011 (12 months), status: operational
Wind power class	5 (excellent)
Power density mean, 30 m	434 W/m^2
Wind speed mean, 30 m	6.85 m/s
Max. 10-min wind speed average	24.7 m/s
Maximum 2-sec. wind gust	29.8 m/s (Feb. 2011)
Weibull distribution parameters	k = 1.85, c = 7.71 m/s
Wind shear power law exponent	0.150 (low)
Roughness class	0.90 (fallow field)
IEC 61400-1, 3rd ed. classification	Undetermined at present
Turbulence intensity, mean	0.077 (at 15 m/s)
Calm wind frequency	25% (<4 m/s)

Community Description

St. Michael has a population of 401 people (2010 census) and is located on the east coast of St. Michael Island in Norton Sound. It lies 125 miles southeast of Nome and 48 miles southwest of Unalakleet. St. Michael has a subarctic climate with maritime influences during the summer. Summer temperatures average 40 to 60 °F; winters average -4 to 16 °F. Extremes from -55 to 70 °F have been recorded. Annual precipitation averages 12 inches, with 38 inches of snow. Summers are rainy, and fog is common. Norton Sound is ice free from early June to mid-November.

A fortified trading post called "Redoubt St. Michael" was built by the Russian-American Company at this location in 1833; it was the northernmost Russian settlement in Alaska. The Native village of "Tachik" stood to the northeast. When the Russians left Alaska in 1867, several of the post's traders remained. "Fort St. Michael," a U.S. military post, was established in 1897. During the gold rush of 1897, it was a major gateway to the interior via the Yukon River. As many as 10,000 persons were said to live in St. Michael during the gold rush. St. Michael was also a popular trading post for Eskimos to trade their goods for Western supplies. Centralization of many Yup'iks from the surrounding villages intensified after the measles epidemic of 1900 and the influenza epidemic of 1918. The village remained an important trans-shipment point until the Alaska Railroad was built. The city government was incorporated in 1969.

A federally-recognized tribe is located in the community -- the Native Village of Saint Michael. St. Michael's population is largely Yup'ik Eskimo today, and many residents are descendants of Russian

traders. Seal, beluga whale, moose, caribou, fish, and berries are important staples. The sale and importation of alcohol is banned in the village.

According to Census 2010, there were 117 housing units in the community and 96 were occupied. Its population was 92 percent American Indian or Alaska Native; 5.5 percent white; 2.5 percent of the local residents had multi-racial backgrounds. Additionally, 0.8 percent of the population was of Hispanic descent.

Water is derived from Clear Lake and is treated and stored in a 1.2 million-gallon tank. The system includes water delivery/holding tanks for homes, a piped gravity and vacuum sewer system with septic treatment, and household plumbing. Electricity is provided by AVEC. There is one school located in the community, attended by 172 students. Local hospitals or health clinics include Katherine Kobuk Memorial Clinic (St. Michael). Emergency Services have coastal air and floatplane access. Emergency service is provided by a health aide.

The St. Michael economy is based on subsistence food harvests supplemented by part-time wage earning. Most jobs are held in city government, the IRA council, the village corporation, schools, and local stores. In 2010, 14 residents held commercial fishing permits. The Stebbins/St. Michael Reindeer Corral Project was completed in 1993 for a herd on Stuart Island. The reindeer are essentially unmanaged.

Saint Michael is accessible by air and sea only. The state owns a 4,001' long by 75' wide gravel airstrip, and a seaplane base is available. Regular and charter flights are available from Nome and Unalakleet. It is near the Yukon River Delta and has a good natural harbor but no dock. Lighterage service is provided on a frequent basis from Nome. Saint Michael receives at least one annual shipment of bulk cargo. A 10.5-mile road exists to Stebbins.

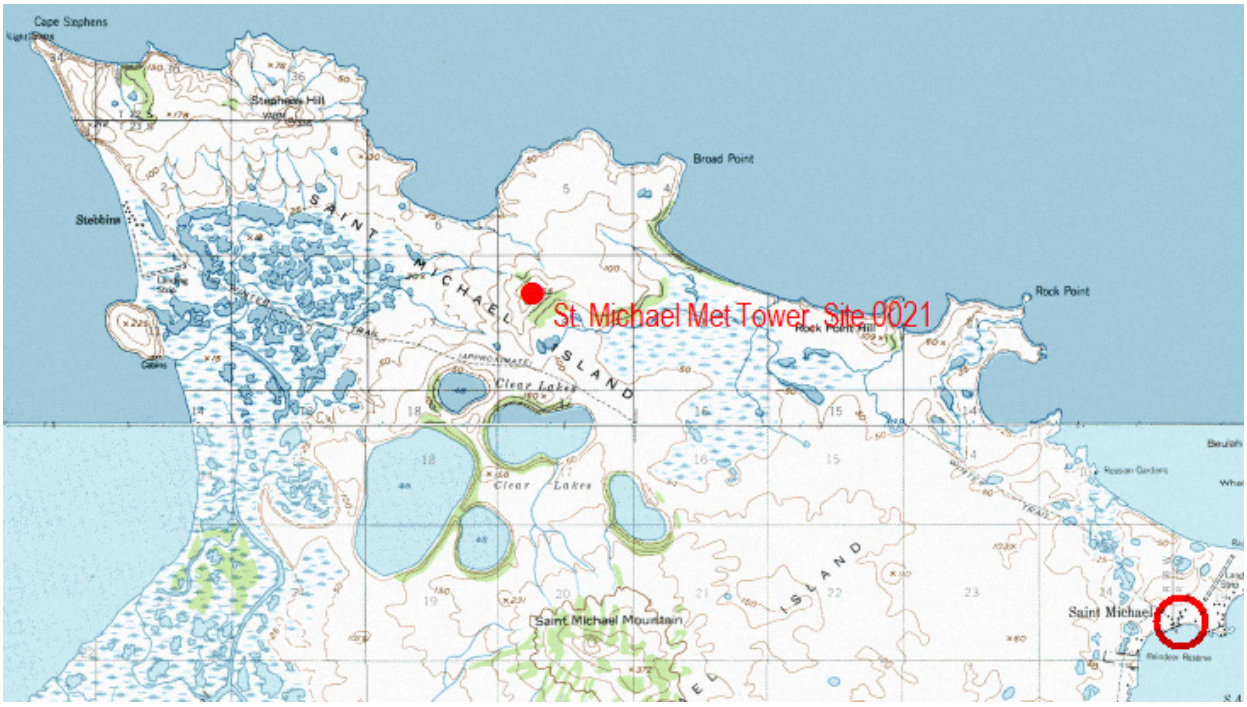
Test Site Location

The met tower is installed on an extinct cinder cone, located on Saint Michael Native Corporation land near the road that connects Saint Michael to the village of Stebbins to the west. The site is large enough to accommodate two to three wind turbines, but current land use planning by the corporation reserves the site area (the cinder cone) for mining of lava basalt for construction activities. Although the site is not at present near electrical distribution lines, near-term plans call for construction of an intertie adjacent to the road between Saint Michael and Stebbins, which would make wind development on the site more advantageous.

Site information

Site number	0021
Latitude/longitude	N 63° 30’ 44.4”’ W 162° 11’ 39.7”, WGS 84
Site elevation	80 meters (260 ft)
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 30-meter tall tower, 152 mm diameter
Anchor type	DB88 duckbill

Topographic maps



Google Earth images

Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.765	0.35	090° T
2	NRG #40 anemometer	30 m (B)	0.765	0.35	270° T
3	NRG #40 anemometer	21 m	0.765	0.35	090° T
7	NRG #200P wind vane	28 m	0.351	000	000° T
9	NRG #110S Temp C	3 m	0.138	-86.3	N

Data Quality Control

Data quality is generally very good with nearly 96 percent data recovery of the primary 30 meter A anemometer. Data recovery of the 30 m B anemometer though is less and data recover y of the 21 m anemometer significantly less. For the 30 m A anemometer and the wind direction vane, missing data is entirely attributable to winter-season icing events, which are characterized by non-variant output of the anemometer at minimum offset and by non-variant output of the direction vane at the last operable direction. It does appear though that for unknown reasons both the 30 m B and the 21 m anemometers failed on June 28. Additionally, also for unknown reasons, the 21 m anemometer was inoperative for two months from late August to late October 2010.

Data recovery summary table

Label	Units	Possible Records	Valid Records	Recovery Rate (%)
Speed 30 m A	m/s	50,886	48,720	95.7
Speed 30 m B	m/s	50,886	46,285	91.0
Speed 21 m	m/s	50,886	38,933	76.5
Direction 28 m	°	50,886	47,199	92.8
Temperature	°C	50,886	50,886	100.0

Anemometer data recovery

	30 m A anem.			30 m B anem.			21 m anem.		
Month	Possible Records	Valid Records	Recovery Rate (%)	Possible Records	Valid Records	Recovery Rate (%)	Possible Records	Valid Records	Recovery Rate (%)
Jul	1,584	1,584	100.0	1,584	1,584	100.0	1,584	1,584	100.0
Aug	4,464	4,464	100.0	4,464	3,782	84.7	4,464	3,600	80.7
Sep	4,320	4,320	100.0	4,320	4,102	95.0	4,320	0	0.0
Oct	4,464	4,464	100.0	4,464	4,464	100.0	4,464	775	17.4
Nov	4,320	3,631	84.1	4,320	3,544	82.0	4,320	3,585	83.0
Dec	4,464	3,907	87.5	4,464	3,894	87.2	4,464	4,382	98.2
Jan	4,464	4,464	100.0	4,464	4,464	100.0	4,464	4,464	100.0
Feb	4,032	3,645	90.4	4,032	3,645	90.4	4,032	3,645	90.4
Mar	4,464	4,464	100.0	4,464	4,464	100.0	4,464	4,464	100.0
Apr	4,320	3,787	87.7	4,320	3,949	91.4	4,320	4,041	93.5
May	4,464	4,464	100.0	4,464	4,464	100.0	4,464	4,464	100.0
Jun	4,320	4,320	100.0	4,320	3,929	91.0	4,320	3,929	91.0

Jul	1,206	1,206	100.0	1,206	0	0.0	1,206	0	0.0
	50,886	48,720	95.7	50,886	46,285	91.0	50,886	38,933	76.5

Wind Speed

Anemometer data collected from the met tower, from the perspectives of mean wind speed and mean wind power density, indicate an excellent wind resource. The slightly lower wind speed measured by the 30 m B anemometer compared to the 30 m A anemometer can be attributed by anemometer placement to 270° True. With occasional easterly winds, the 30 m B anemometer would experience some shadowing effects. Additionally, data recovery for the 30 m B anemometer is less, with apparent sensor failure on June 28, 2011. Curiously, the 21 meter anemometer also failed at the same time, although the 30 m A anemometer continues to operate normally. Cause of failure is unknown at present. Note though that cold temperatures contributed to a higher wind power density than otherwise might have been expected for the mean wind speeds.

Anemometer data summary

Variable	Speed 30 m A	Speed 30 m B	Speed 21 m
Measurement height (m)	30	30	21
Mean wind speed (m/s)	6.85	6.81	6.50
MMM wind speed (m/s)	6.83	6.69	6.35
Max 10-min wind speed (m/s)	24.6	24.7	22.7
Max gust wind speed (m/s)	29.8	29.8	29.1
Weibull k	1.85	1.82	1.80
Weibull c (m/s)	7.71	7.67	7.32
Mean power density (W/m²)	436	437	389
MMM power density (W/m²)	431	418	362
Mean energy content (kWh/m²/yr)	3,818	3,827	3,404
MMM energy content (kWh/m²/yr)	3,777	3,661	3,174
Energy pattern factor	2.11	2.15	2.18
Frequency of calms (%)	25.1	25.4	28.3
1-hr autocorrelation coefficient	0.932	0.928	0.932
Diurnal pattern strength	0.026	0.028	0.025
Hour of peak wind speed	20	20	17

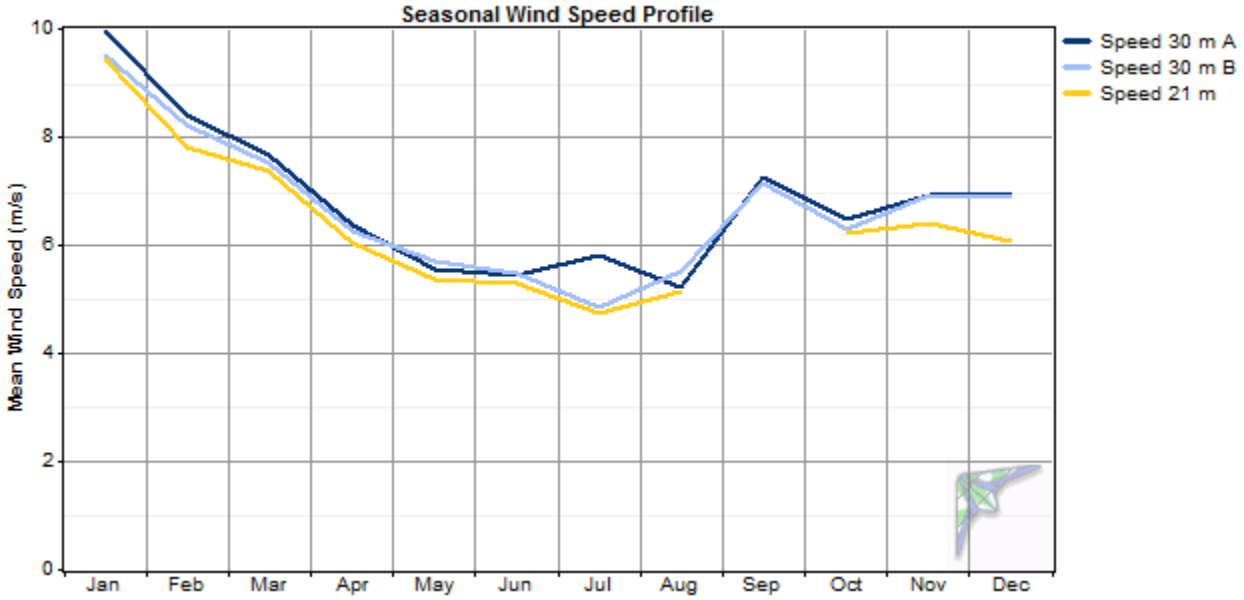
Time Series

Time series calculations indicate high mean wind speeds during winter with more moderate mean wind speeds during the summer months. This matches the village load profile where winter months have a high electric and heat demand and summer months a lighter demand.

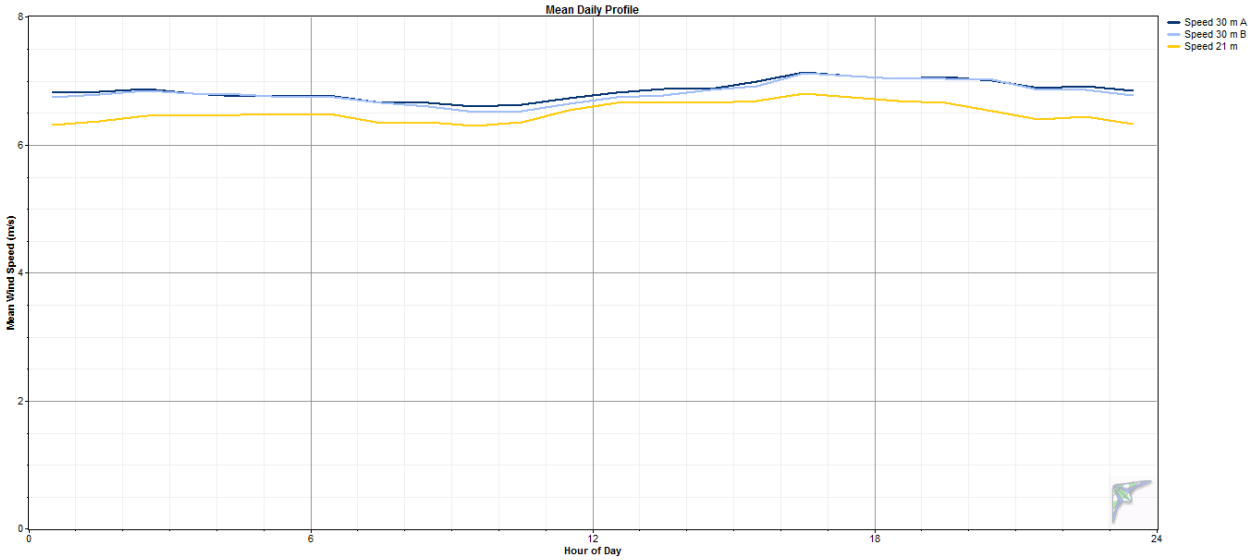
30 m A anemometer data summary

Year	Month	Mean (m/s)	Max (m/s)	Gust	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)
2010	Jul	5.01	12.7	15.6	2.28	2.29	5.64
2010	Aug	5.22	17.9	22.6	3.02	1.82	5.89
2010	Sep	7.24	19.3	22.9	3.86	1.98	8.19
2010	Oct	6.49	18.2	22.9	3.51	1.94	7.32
2010	Nov	6.93	16.2	18.7	3.37	2.15	7.81
2010	Dec	6.91	20.5	25.2	3.88	1.82	
2011	Jan	9.95	22.7	26.3	4.37	2.41	11.17
2011	Feb	8.40	24.6	29.8	5.63	1.48	9.27
2011	Mar	7.67	21.4	23.7	3.67	2.14	8.61
2011	Apr	6.38	23.1	28.7	3.45	1.95	7.21
2011	May	5.55	15.1	19.5	2.42	2.44	6.25
2011	Jun	5.44	14.5	17.6	2.50	2.30	6.13
2011	Jul	6.85	16.6	20.2	2.57	2.81	7.69
All data		6.85	24.6	29.8	3.86	1.85	7.71

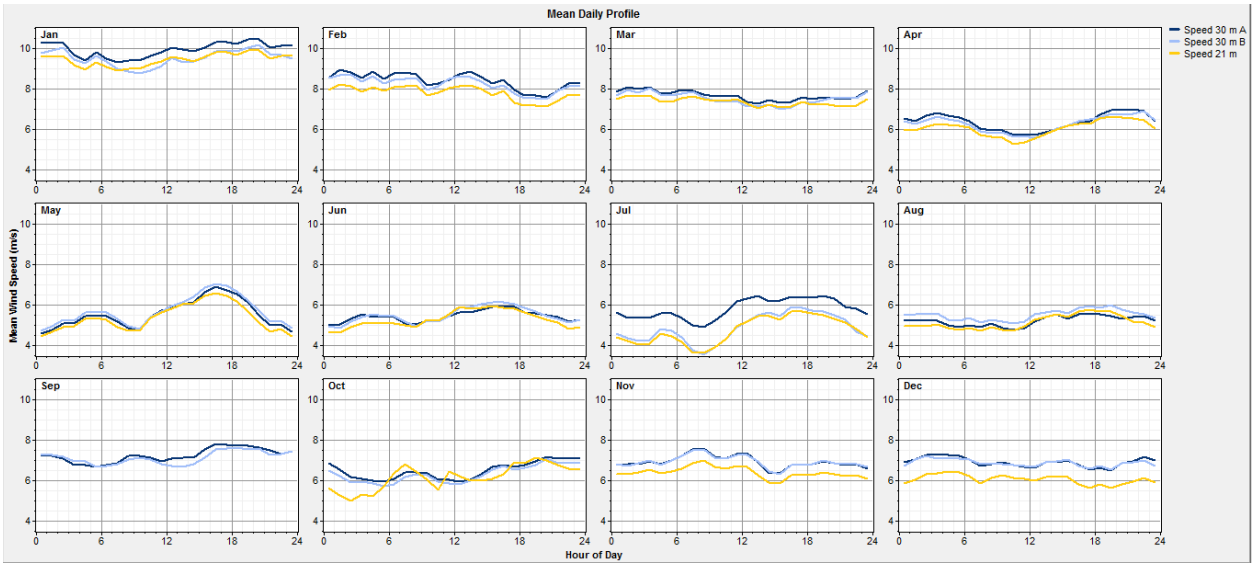
Time series graph



Annual daily wind profile

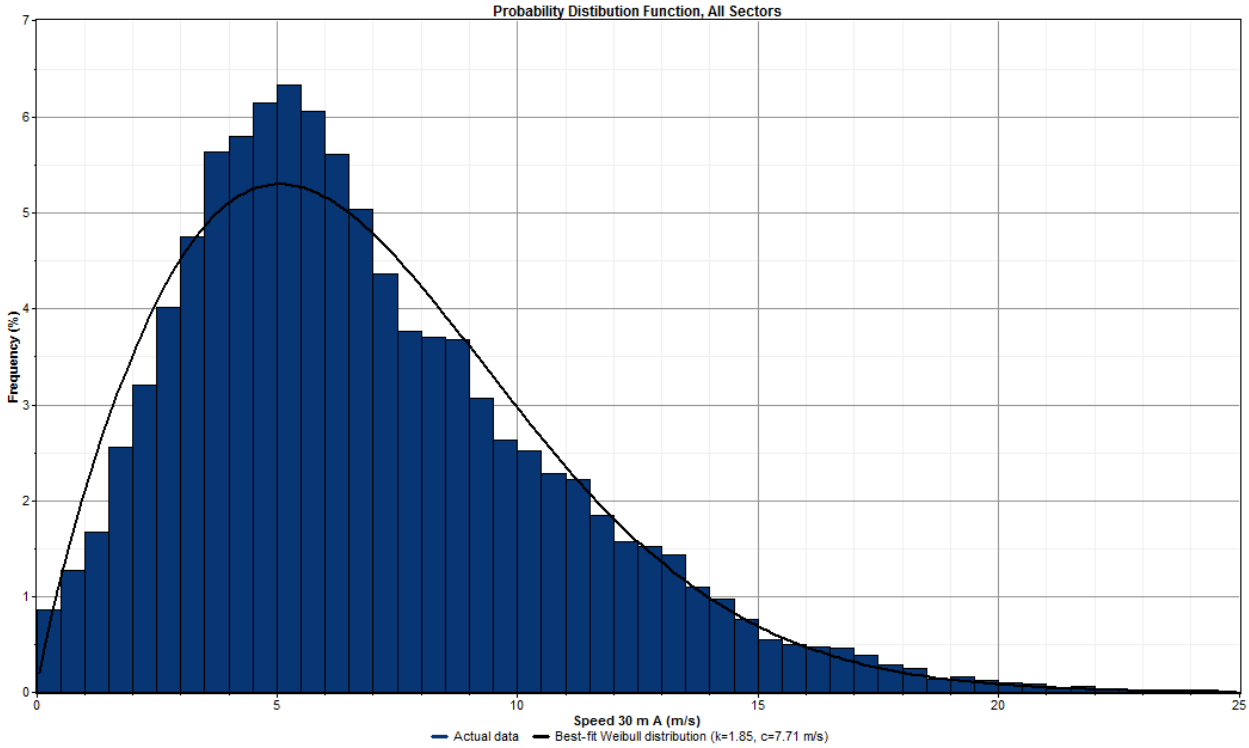


Monthly daily wind profile



Probability Distribution Function

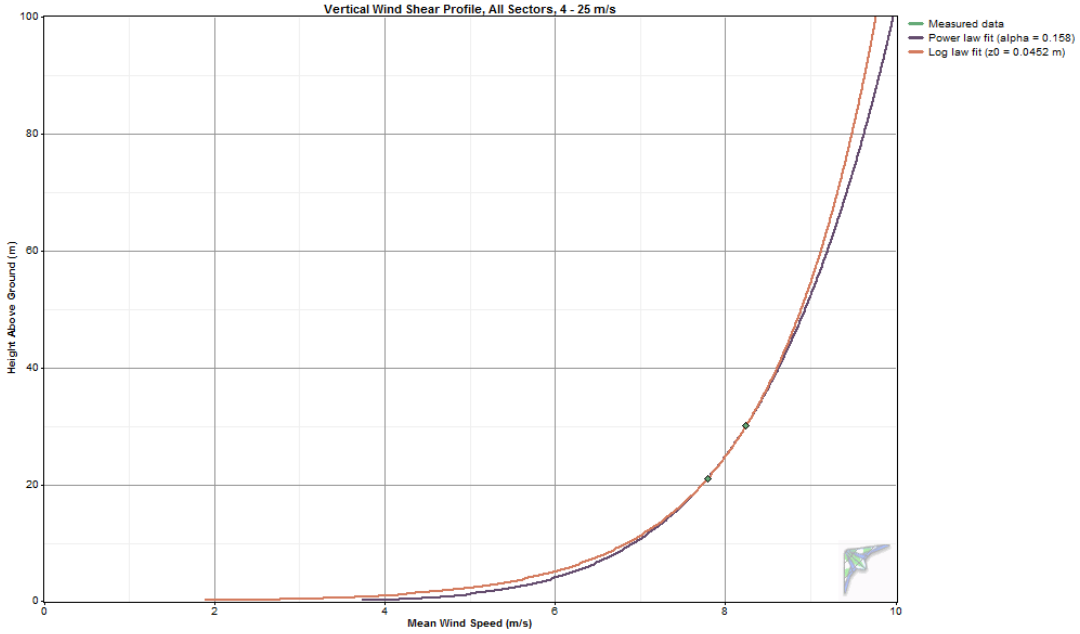
The probability distribution function (or histogram) of wind speed indicates a near-normal shape curve, defined as the Raleigh distribution (k=2.0), defined as standard for wind power sites.



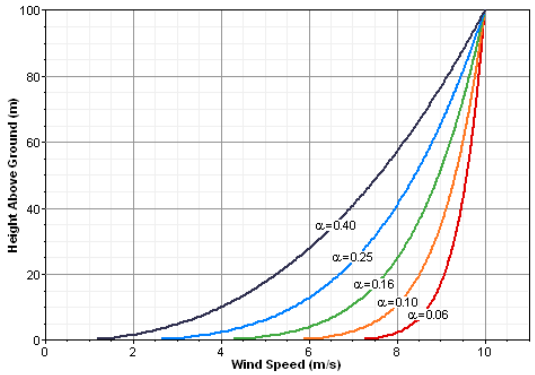
Wind Shear and Roughness

A wind shear power law exponent (α) of 0.158 indicates moderate wind shear at the site. Related to wind shear, a calculated surface roughness of 0.0183 meters (indicating the height above ground level where wind velocity would be zero) indicates relatively even terrain (roughness description: fallow field) surrounding the met tower, especially in the direction of the prevailing north-northwest wind.

Vertical wind shear profile



Comparative wind shear profiles



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

Direction Sector	Time Steps	Wind Sector (%)	Mean Wind Speed Speed 30 m A (m/s)	Mean Wind Speed Speed 21 m (m/s)	Power Law Exp (α)	Surface Roughness (m)
348.75° - 11.25°	2,499	9.0%	7.91	7.55	0.132	0.013
11.25° - 33.75°	5,338	19.1%	8.54	8.34	0.067	0.000
33.75° - 56.25°	3,703	13.3%	8.63	8.41	0.070	0.000
56.25° - 78.75°	2,392	8.6%	7.94	7.39	0.202	0.178
78.75° - 101.25°	2,021	7.2%	8.70	8.08	0.208	0.206
101.25° - 123.75°	1,464	5.2%	8.56	7.95	0.208	0.205
123.75° - 146.25°	1,697	6.1%	9.38	8.73	0.200	0.169
146.25° - 168.75°	1,635	5.9%	10.39	9.32	0.305	0.947
168.75° - 191.25°	1,682	6.0%	7.83	6.95	0.333	1.238
191.25° - 213.75°	1,399	5.0%	8.04	7.31	0.264	0.571
213.75° - 236.25°	1,105	4.0%	7.47	7.54	-0.025	
236.25° - 258.75°	737	2.6%	6.47	7.55	-0.432	
258.75° - 281.25°	590	2.1%	7.00	6.85	0.060	0.000
281.25° - 303.75°	277	1.0%	6.44	5.87	0.261	0.546
303.75° - 326.25°	575	2.1%	5.76	4.84	0.490	3.241
326.25° - 348.75°	790	2.8%	6.20	4.92	0.649	5.342

Extreme Winds

Extreme wind probability estimates will be included in the final wind resource report of this site, after receipt of all data at the conclusion of the met tower study.

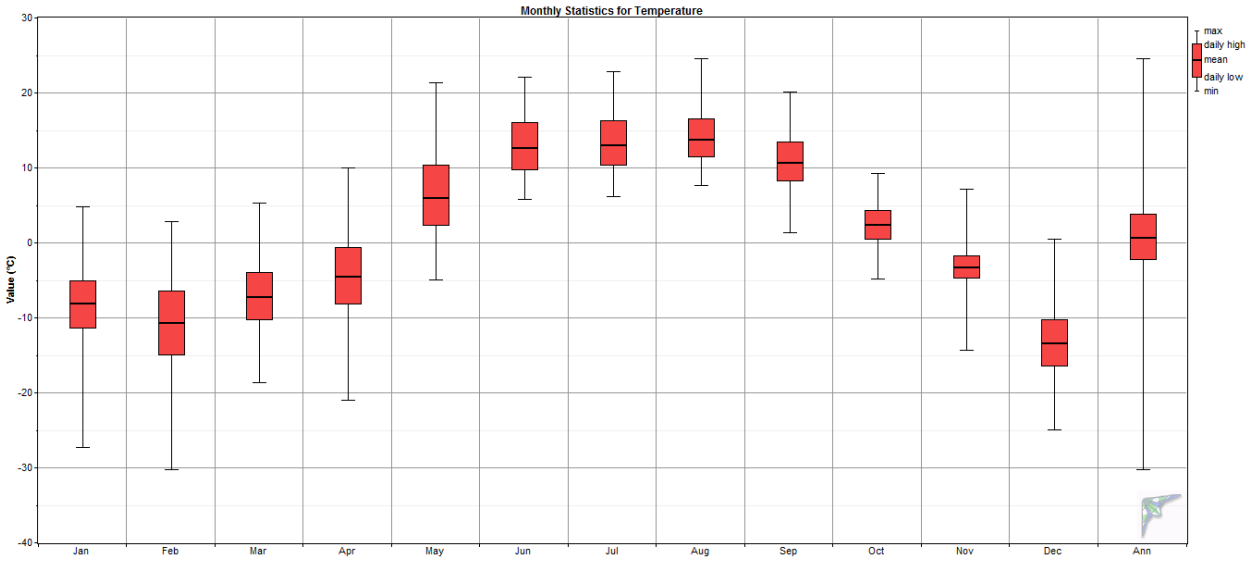
Temperature and Density

Saint Michael experiences cool summers and cold winters with resulting higher than standard air density. Calculated air density during the met tower test period exceeds standard air density for a sea level elevation (1.216 Kg/m^3) by five 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.

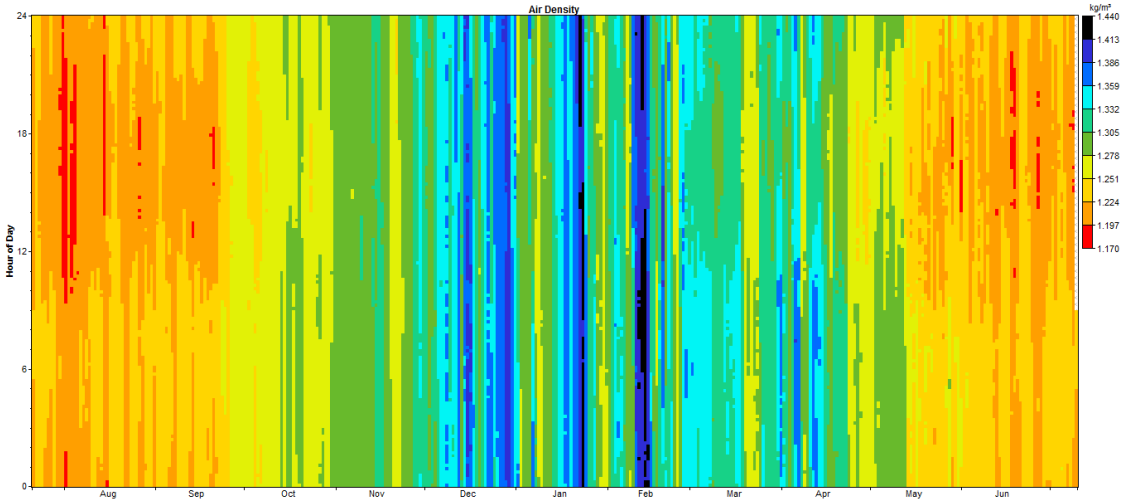
Temperature and density table

Month	Temperature Mean (°C)	Temperature Min (°C)	Temperature Max (°C)	Air Density Mean (kg/m³)	Air Density Min (kg/m³)	Air Density Max (kg/m³)
Jan	-8.0	-27.3	4.8	1.320	1.258	1.422
Feb	-10.6	-30.2	2.9	1.333	1.266	1.439
Mar	-7.2	-18.6	5.3	1.315	1.255	1.373
Apr	-4.4	-21.0	10.0	1.302	1.235	1.386
May	6.1	-4.9	21.4	1.252	1.187	1.303
Jun	12.7	5.8	22.1	1.223	1.184	1.253
Jul	13.1	6.2	22.9	1.221	1.181	1.251
Aug	13.8	7.6	24.6	1.218	1.174	1.245
Sep	10.7	1.4	20.1	1.232	1.192	1.273
Oct	2.4	-4.8	9.3	1.269	1.238	1.303
Nov	-3.2	-14.3	7.1	1.295	1.247	1.351
Dec	-13.4	-25.0	0.5	1.346	1.278	1.409
Annual	1.1	-30.2	24.6	1.277	1.174	1.439

Temperature boxplot



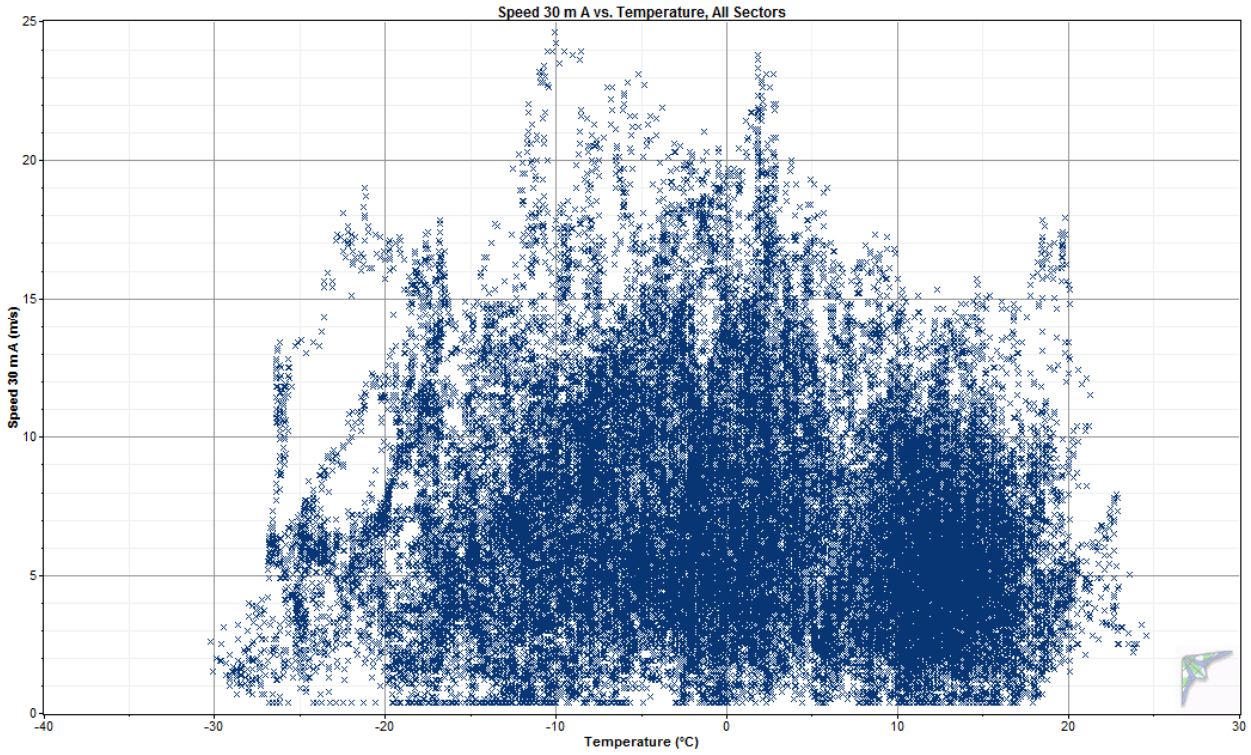
Air density DMap



Wind Speed Scatterplot

The wind speed versus temperature scatterplot below indicates that a substantial percentage of wind at the Saint Michael met tower site coincides with cold temperatures, as one would expect. However, during the met tower test periods, temperatures did not fall below -40°C, minimum operating temperature for arctic-capable wind turbines, and barely fell below -30°C on just a few occasions. Colder temperatures may occur during particular severe winters, but it is likely that temperatures colder than -40°C are extremely rare at the site.

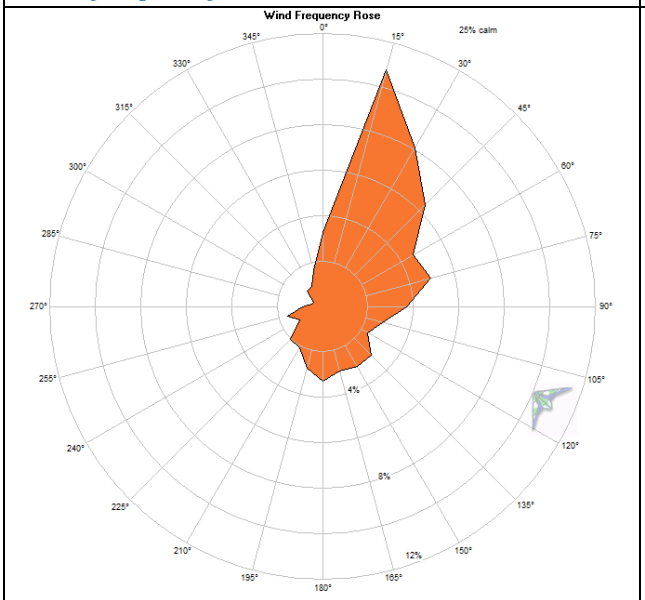
Wind speed/temperature



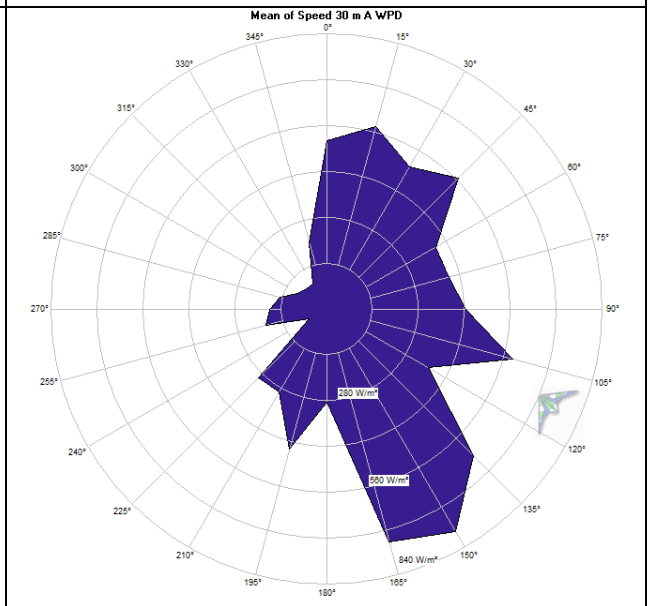
Wind Direction

Wind frequency rose data indicates highly directional winds principally from the north-northeast with easterly and southeasterly winds to a lesser extent. The mean value rose indicates that southeasterly winds, when they do occur, are of high energy and hence are storm winds. The wind energy rose indicates that for wind turbine operations the majority of power-producing winds will be north-northeast to northeast. Calm frequency (percent of time that winds at the 30 meter level are less than 4 m/s) was 25 percent during the met tower test period.

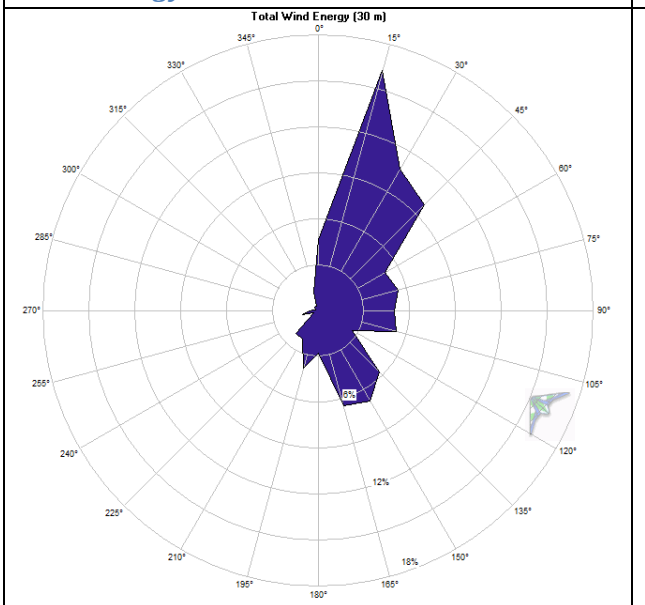
Wind frequency rose



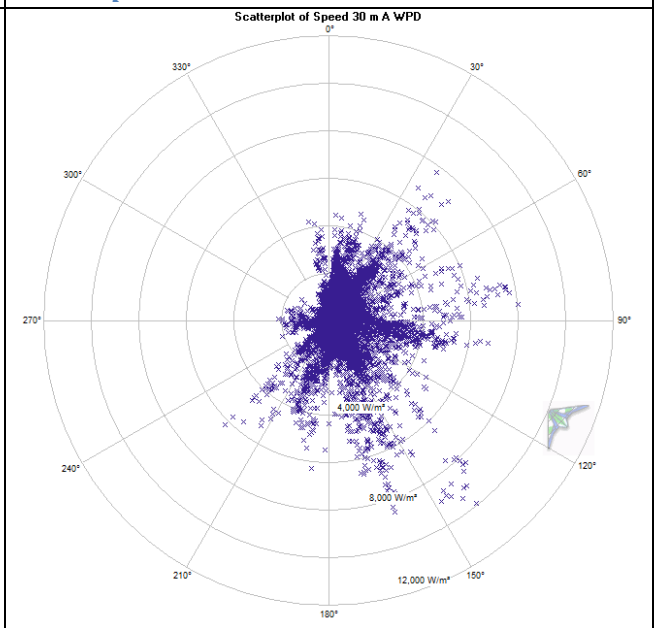
Mean value rose



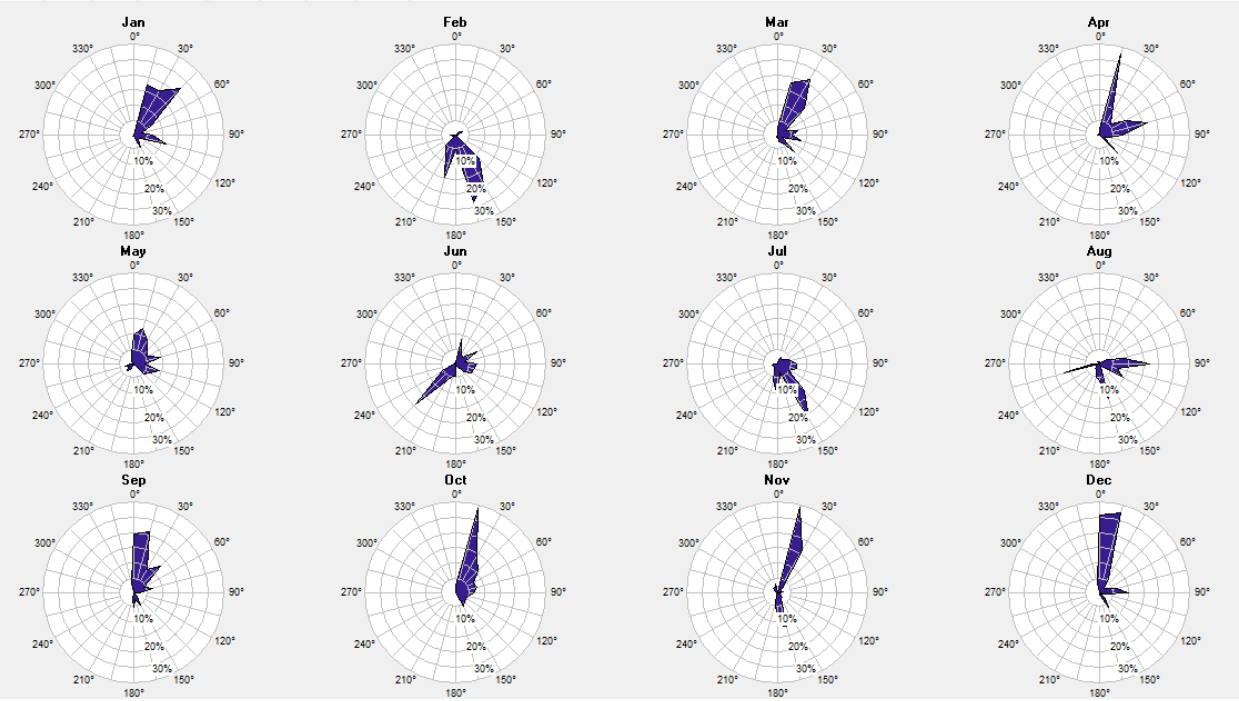
Wind energy rose



Scatterplot rose



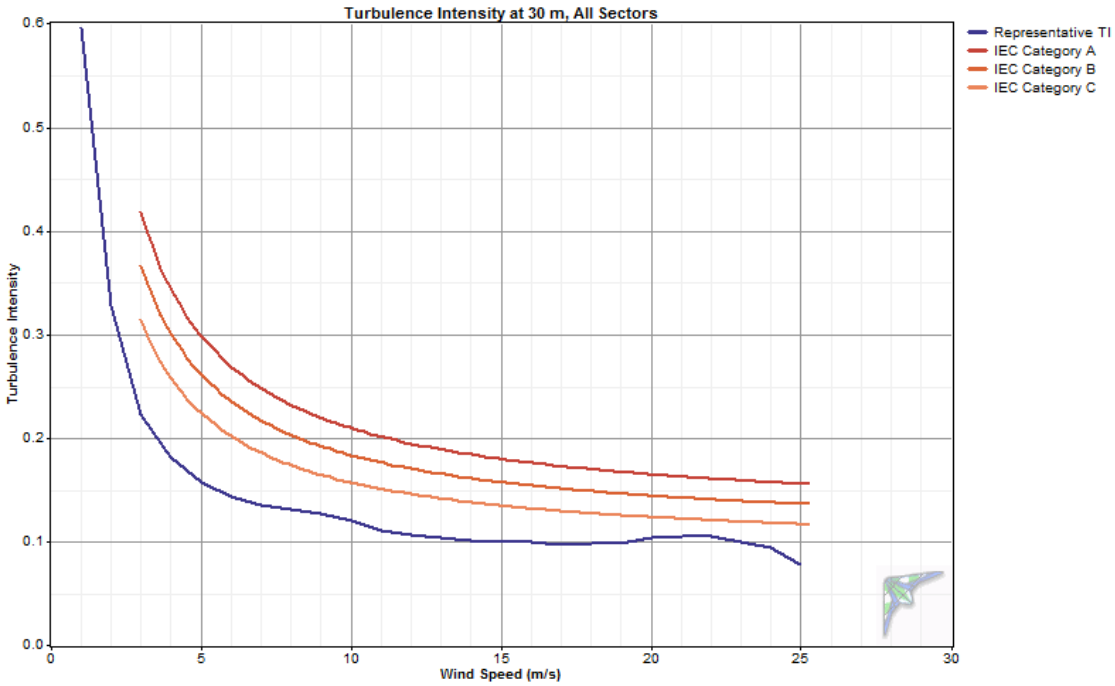
Wind density roses by month



Turbulence

Turbulence intensity at the Saint Michael met tower 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, 30 m, all direction sectors



Turbulence table, 30 m A data

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Upper (m/s)	Records in Bin	Mean TI	Standard Deviation of TI	Representative TI	Peak TI
1	0.5	1.5	1,434	0.396	0.157	0.596	0.909
2	1.5	2.5	2,807	0.201	0.099	0.328	1.000
3	2.5	3.5	4,268	0.138	0.066	0.223	0.655
4	3.5	4.5	5,562	0.111	0.055	0.182	0.553
5	4.5	5.5	6,069	0.096	0.047	0.157	0.511
6	5.5	6.5	5,685	0.089	0.042	0.143	0.413
7	6.5	7.5	4,571	0.086	0.038	0.135	0.408
8	7.5	8.5	3,635	0.086	0.035	0.131	0.303
9	8.5	9.5	3,280	0.085	0.033	0.127	0.275
10	9.5	10.5	2,507	0.082	0.029	0.120	0.235
11	10.5	11.5	2,190	0.077	0.026	0.110	0.223
12	11.5	12.5	1,662	0.075	0.024	0.106	0.342
13	12.5	13.5	1,437	0.077	0.021	0.104	0.194
14	13.5	14.5	1,007	0.077	0.019	0.101	0.196
15	14.5	15.5	643	0.077	0.018	0.100	0.160
16	15.5	16.5	475	0.078	0.017	0.100	0.136
17	16.5	17.5	412	0.076	0.017	0.097	0.149
18	17.5	18.5	261	0.075	0.018	0.098	0.125
19	18.5	19.5	145	0.079	0.015	0.099	0.118
20	19.5	20.5	114	0.081	0.018	0.104	0.124
21	20.5	21.5	63	0.084	0.016	0.105	0.131
22	21.5	22.5	41	0.086	0.015	0.105	0.113
23	22.5	23.5	23	0.086	0.011	0.099	0.111
24	23.5	24.5	10	0.084	0.007	0.094	0.097
25	24.5	25.5	1	0.077	0.000	0.077	0.077