False Pass Wind Resource Report

False Pass meteorological tower, view to the east, D. Vaught photo

January 27, 2012

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Summary

The wind resource as the False Pass met tower site is generally good with measured wind power class 4 by measurement of wind power density (Class 3 if considering only mean annual wind speed). Given the moderately cool temperatures of False Pass test site, air density is moderately higher than standard conditions. By other measures important for wind power analysis, the site has a low 50-year return period extreme wind probability but high turbulence; the latter apparently due to the high mountains that border Isantoski Strait and that are very near the met tower to the north, west and south. Turbulence intensity calculated from the met tower data indicates much higher than desirable turbulence conditions. This would require special care with turbine selection and operations.

It is not immediately clear if an alternate wind site that has good wind exposure and less turbulence exists in the near proximity of the village of False Pass. Siting restrictions include the obvious constraints of geography – mountains and Isantoski Strait – and the location and orientation of the False Pass airstrip. Computation fluid dynamics (CFD) modeling may lend insight into wind flow patterns at False Pass and would be a useful tool to investigate other wind turbine siting options.

Met tower data synopsis

Data dates	May 7, 2005 to August 19, 2005 and November 30, 2005 to September 4, 2007 (24 months); status: operational
Wind power class	Class 3 to 4 (fair to good)
Wind power density mean, 30 m	338 W/m^2
Wind speed mean, 30 m	6.11 m/s
Max. 10-min wind speed average	26.5 m/s
Maximum 2-sec. wind gust	39.0 m/s (January, 2007)
Weibull distribution parameters	k = 1.62, c = 6.76 m/s
Wind shear power law exponent	0.291 (high)
Roughness class	3.80 (suburban)
IEC 61400-1, 3rd ed. classification	Class III-S
Turbulence intensity, mean	0.173 (at 15 m/s)
Calm wind frequency (at 30 m)	35% (winds < 4 m/s)

Test Site Location

Wind measurement instrumentation (anemometers, wind vane, temperature sensor) was installed on a 30 meter tall, six-inch diameter NRG Systems Inc. tubular meteorological (met) test tower in an open area near the coast, approximately 2.4 km (1.5 miles) north of the village of False Pass. The tower (still standing and operational again in October 2011) is located on a grassy outwash plain immediately north of a moderately-sized stream that drains from the extensive mountain range immediately west of the site. This location had been the village's preferred site for wind turbines, but more recent thoughts are to locate wind turbines closer to the village.

Met tower installation was accomplished on May 6 and 7, 2005 by Doug Vaught of V3 Energy, LLC, Connie Fredenberg of Aleutian/Pribilof Islands Association, Mia Devine of Alaska Energy Authority, and George Jackson, power plant operator of the village of False Pass.

Site information

Site number	2399
Latitude/longitude	N 54° 52.443’ W 163° 24.646’, WGS 84
Site elevation	17 meters (54 ft)
Datalogger type	NRG Symphonie, 10 minute time step
Tower type	NRG 6-inch diameter tubular, 30 meter height

Tower installation photographs (May, 2005; D. Vaught photos)

C. Fredenberg and M. Devine heading to the site

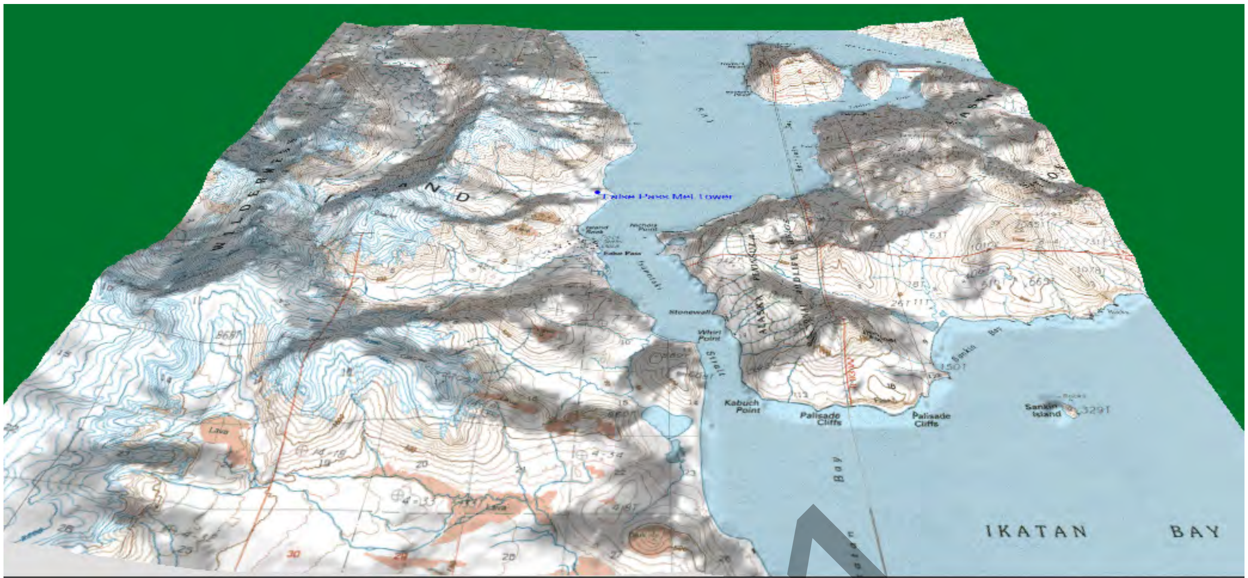
C. Fredenberg and G. Jackson assembling the tower

Lifting the met tower

M. Devine, G. Jackson, C. Fredenber wrapping up

Topographic maps, 2D views

Topographic map, 3D view



Tower sensor information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m (A)	0.765	0.35	~275° T
2	NRG #40 anemometer	30 m (B)	0.765	0.35	095° T
3	NRG #40 anemometer	20 m	0.765	0.35	240° T
7	NRG #200P wind vane	27 m	0.351	050	230° T
9	NRG #110S Temp C	3 m	0.138	-86.3	N

Met tower sensors photograph (view to the east)

Data Quality Control

Data quality is excellent with data recovery of all three anemometers at nearly 100 percent for the time periods of actual data recovery (8/19/05 to 11/30/05 excluded) and 87.5 percent with that time period included. On 8/19/05 a bear visiting the site ripped out the sensor wiring inputs to the datalogger; this damage was repaired on 11/30/05. Although False Pass is located in a cold climate where icing conditions might be expected, very few icing events were detected in the data. Note that the temperature sensor was not functional from initial tower installation on 5/7/05 until 11/30/05, the date that the bear damage to sensor wiring was repaired.

Data recovery summary table

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)
Speed 30 m A	m/s	30 m	122,386	107,093	87.5
Speed 30 m B	m/s	30 m	122,386	107,087	87.5
Speed 20 m	m/s	20 m	122,386	107,090	87.5
Direction 27 m	°	27 m	122,386	107,066	87.5
Temperature	°C	3 m	122,386	92,506	75.6

Anemometer and wind vane data recovery

Year	Month	Possible Records	Valid Records	30 m A Recovery Rate (%)	30 m B Recovery Rate (%)	20 m Recovery Rate (%)	Vane Recovery Rate (%)	Temp Recovery Rate (%)
2005	May	3,514	3,482	99.1	99.1	99.1	99.1	0.0
2005	Jun	4,320	4,320	100.0	100.0	100.0	100.0	0.0
2005	Jul	4,464	4,464	100.0	100.0	100.0	100.0	0.0
2005	Aug	4,464	2,740	61.4	61.4	61.4	61.4	0.0
2005	Sep	4,320	0	0.0	0.0	0.0	0.0	0.0
2005	Oct	4,464	0	0.0	0.0	0.0	0.0	0.0
2005	Nov	4,320	46	1.1	1.1	1.1	1.1	1.1
2005	Dec	4,464	4,335	97.1	96.9	97.8	91.6	100.0
2006	Jan	4,464	4,460	99.9	100.0	100.0	100.0	100.0
2006	Feb	4,032	4,032	100.0	100.0	99.1	100.0	100.0
2006	Mar	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2006	Apr	4,320	4,320	100.0	100.0	100.0	100.0	100.0
2006	May	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2006	Jun	4,320	4,320	100.0	100.0	100.0	100.0	100.0
2006	Jul	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2006	Aug	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2006	Sep	4,320	4,260	98.6	98.6	98.6	98.6	98.6
2006	Oct	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2006	Nov	4,320	4,320	100.0	100.0	100.0	100.0	100.0
2006	Dec	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2007	Jan	4,464	4,464	100.0	100.0	100.0	100.0	100.0

2007	Feb	4,032	3,833	95.1	95.1	95.1	100.0	100.0
2007	Mar	4,464	4,377	98.1	98.1	98.1	98.4	100.0
2007	Apr	4,320	4,320	100.0	100.0	100.0	100.0	100.0
2007	May	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2007	Jun	4,320	4,320	100.0	100.0	100.0	100.0	100.0
2007	Jul	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2007	Aug	4,464	4,464	100.0	100.0	100.0	100.0	100.0
2007	Sep	504	504	100.0	100.0	100.0	100.0	100.0
All data		122,386	107,093	87.5	87.5	87.5	87.5	75.6

Wind Speed

Anemometer data obtained from the met tower, from the perspectives of both mean wind speed and mean wind power density, indicate a very good wind resource. Mean wind speeds are greater at higher elevations on the met tower, as one would expect. Note that relatively cold temperatures contributed to 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 20 m
Measurement height (m)	30	30	20
Mean wind speed (m/s)	6.01	6.06	5.34
MMM wind speed (m/s)	6.06	6.11	5.38
Max 10-min avg wind speed (m/s)	26.2	26.5	22.4
Max gust wind speed (m/s)	39.0	38.6	37.1
Weibull k	1.59	1.62	1.55
Weibull c (m/s)	6.54	6.76	5.93
Mean power density (W/m²)	329	333	237
MMM power density (W/m²)	333	338	239
Mean energy content (kWh/m²/yr)	2,882	2,920	2,073
MMM energy content (kWh/m²/yr)	2,917	2,961	2,094
Energy pattern factor	2.40	2.38	2.46
Frequency of calms (%)	34.5	34.2	39.3
1-hr autocorrelation coefficient	0.863	0.864	0.859
Diurnal pattern strength	0.105	0.104	0.112
Hour of peak wind speed	16	16	16

MMM = mean of monthly means

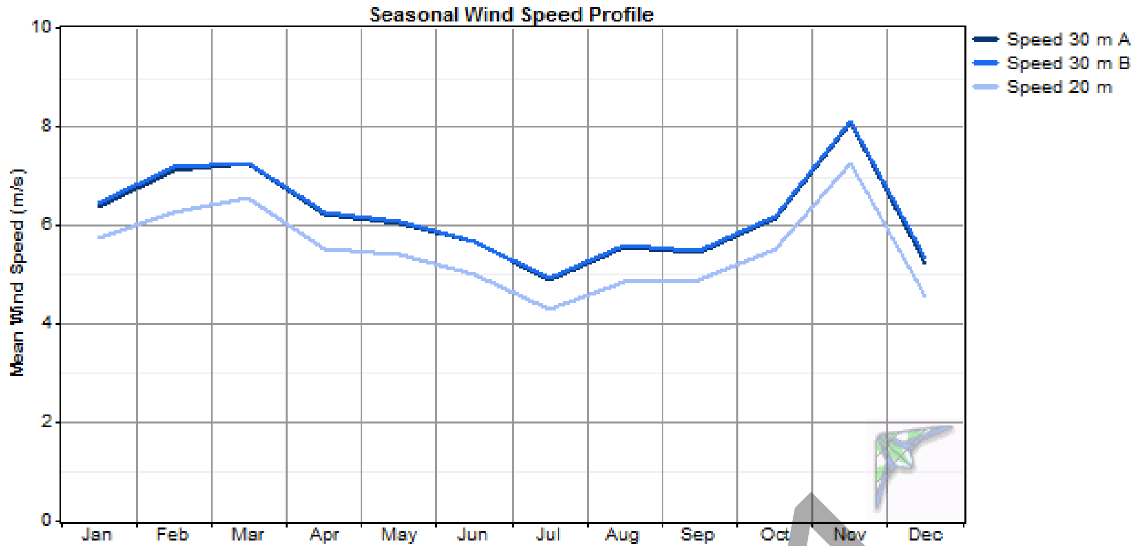
Time Series

Time series calculations indicate high mean wind speeds during the winter months with more moderate mean wind speeds during summer months. This correlates well with a typical village load profile of high electric and heat demand during the winter months and lower demand during summer months. The annual and monthly daily wind profiles indicate highest wind during the mid-afternoon hours.

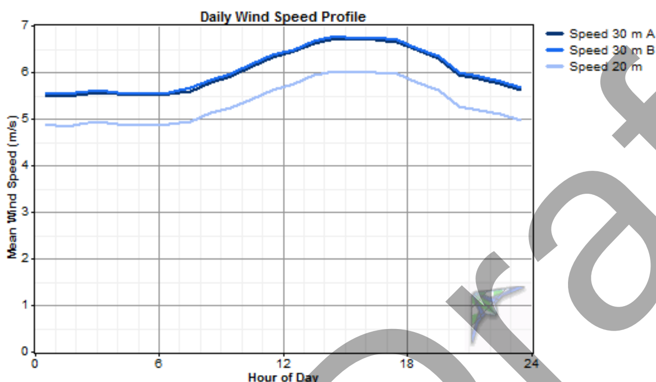
30 m B anemometer data summary

Year	Month	Mean (m/s)	Max (m/s)	Gust (m/s)	Std. Dev. (m/s)	Weibull k (-)	Weibull c (m/s)
2005	May	6.32	19.5	27.1	3.70	1.74	7.08
2005	Jun	5.89	16.9	23.3	3.47	1.66	6.55
2005	Jul	4.44	12.9	18.3	2.61	1.71	4.96
2005	Aug	7.02	17.6	23.3	4.08	1.62	7.76
2005	Sep						
2005	Oct						
2005	Nov						
2005	Dec	5.54	19.7	29.8	3.71	1.45	6.09
2006	Jan	5.73	16.5	27.9	3.13	1.81	6.40
2006	Feb	7.28	20.1	30.9	4.49	1.61	8.09
2006	Mar	6.37	22.2	32.4	4.09	1.51	7.03
2006	Apr	6.84	22.7	31.8	3.98	1.72	7.64
2006	May	6.49	23.1	29.8	4.61	1.35	7.05
2006	Jun	5.77	17.5	24.0	3.75	1.46	6.34
2006	Jul	5.80	17.9	23.7	3.26	1.75	6.47
2006	Aug	4.86	17.1	27.5	3.63	1.26	5.22
2006	Sep	5.34	24.2	35.9	3.88	1.33	5.80
2006	Oct	6.18	21.6	36.3	3.89	1.56	6.85
2006	Nov	8.16	20.6	36.3	3.89	2.17	9.18
2006	Dec	5.11	19.1	24.8	3.03	1.67	5.70
2007	Jan	7.17	26.5	38.6	4.60	1.55	7.96
2007	Feb	7.08	18.9	27.1	3.89	1.80	7.90
2007	Mar	8.17	19.3	30.2	3.92	2.17	9.18
2007	Apr	5.67	21.5	36.3	3.54	1.55	6.26
2007	May	5.50	17.5	24.0	3.89	1.33	5.95
2007	Jun	5.37	16.8	24.0	3.27	1.65	5.99
2007	Jul	4.58	13.8	21.8	3.12	1.40	5.00
2007	Aug	5.45	17.9	24.4	3.45	1.52	6.01
2007	Sep	6.63	16.5	27.5	3.82	1.69	7.37
All data		6.06	26.5	38.6	3.86	1.53	6.70
MMM		6.11			3.72	1.62	6.76

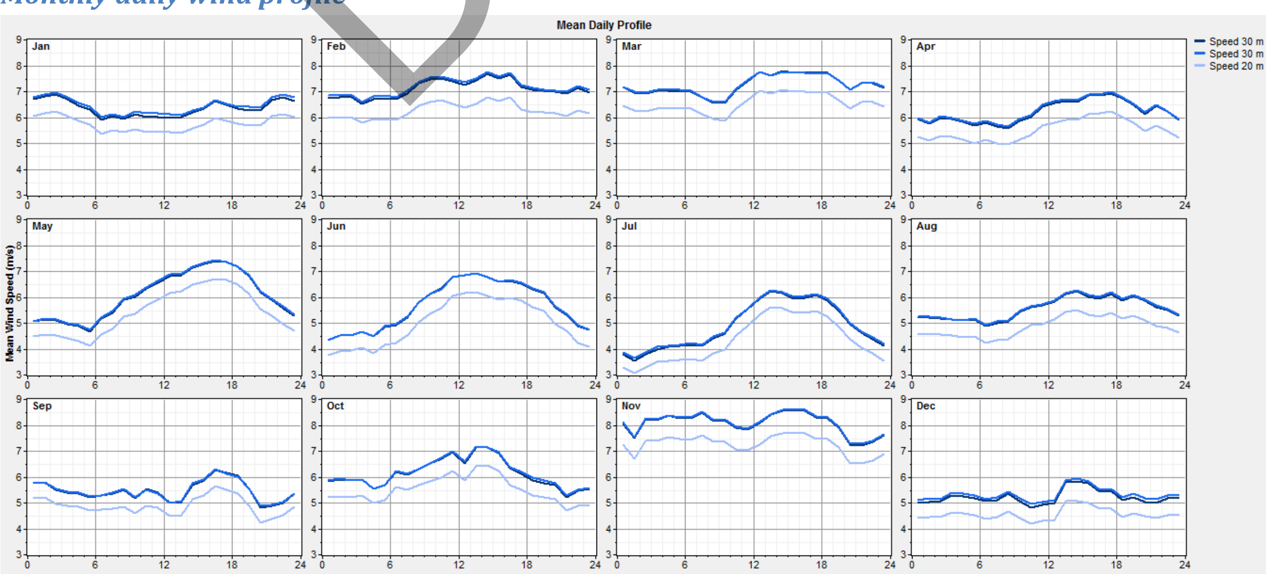
Seasonal time series graph



Annual daily wind profile



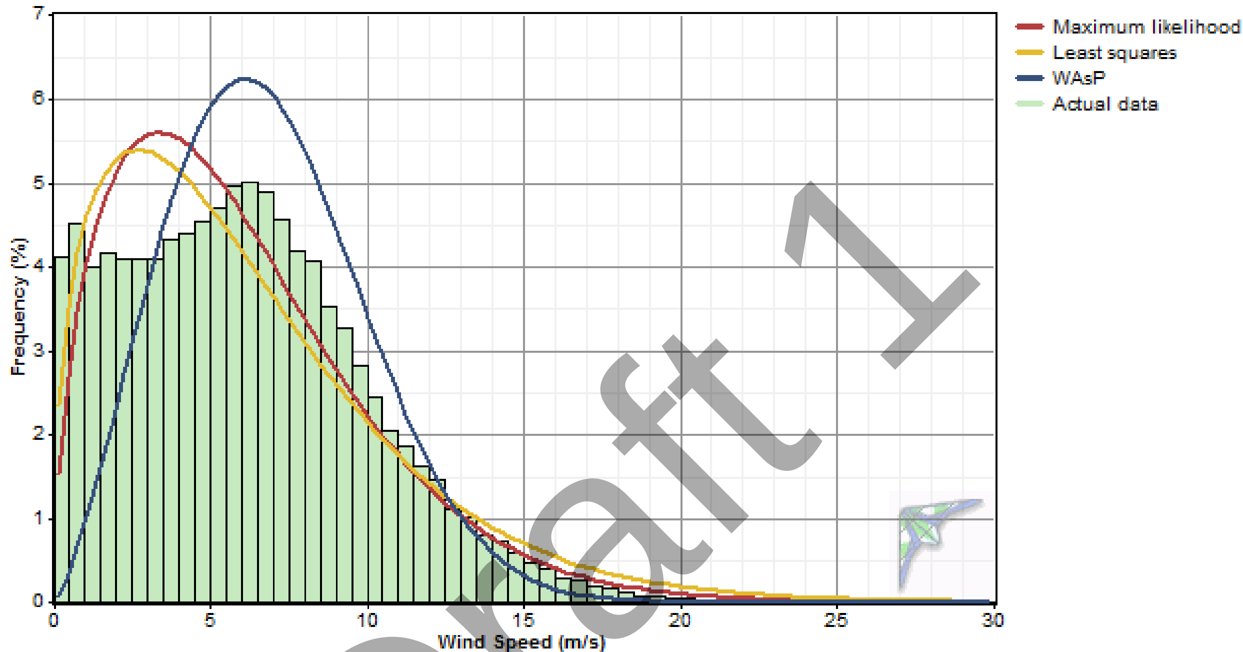
Monthly daily wind profile



Probability Distribution Function

The probability distribution function (PDF), or histogram, of the False Pass met tower site wind speed indicates a shape curve somewhat dominated by lower wind speeds, as opposed to a “normal” shape curve, known as the Rayleigh distribution (Weibull k = 2.0), which is defined as the standard wind distribution for wind power analysis. As seen in the PDF of the 30 m B anemometer, the most frequently occurring wind speeds are between 5 and 7 m/s with essentially no wind events exceeding 25 m/s (the cutout speed of most wind turbines; see following wind speed statistical table).

PDF of 30 m B anemometer



Frequency distribution table

Algorithm	Weibull k	Weibull c (m/s)	Mean (m/s)	Proportion Above Mean	Power Density (W/m2)	R Squared
Maximum likelihood	1.53	6.70	6.03	0.427	354	0.896
Least squares	1.38	6.81	6.22	0.414	455	0.903
WAsP	2.35	7.72	6.84	0.471	324	0.751
Actual data	(107,087 time steps)		6.06	0.471	324	

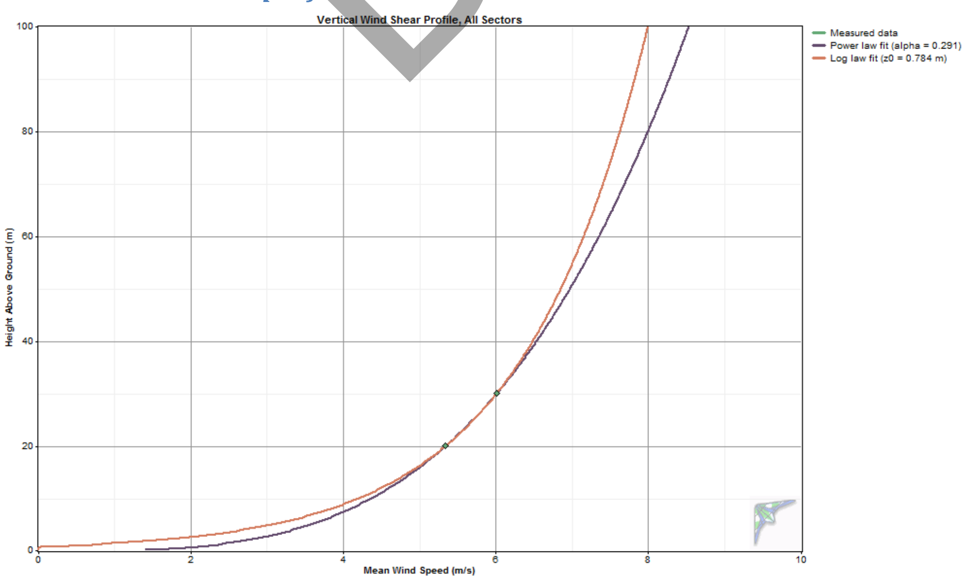
Occurrence by wind speed bin, 30 m B anemometer

Bin Endpoints (m/s)		Occurrences		Bin Endpoints (m/s)		Occurrences	
Lower	Upper	No.	Percent	Lower	Upper	No.	Percent
0	1	9,225	8.80%	15	16	923	0.88%
1	2	8,708	8.31%	16	17	588	0.56%
2	3	8,737	8.34%	17	18	365	0.35%
3	4	8,988	8.58%	18	19	195	0.19%
4	5	9,568	9.13%	19	20	104	0.10%
5	6	10,356	9.88%	20	21	77	0.07%
6	7	10,582	10.10%	21	22	44	0.04%
7	8	9,356	8.93%	22	23	8	0.01%
8	9	8,118	7.75%	23	24	6	0.01%
9	10	6,530	6.23%	24	25	4	0.00%
10	11	4,798	4.58%	25	26	0	0.00%
11	12	3,715	3.55%	26	27	1	0.00%
12	13	2,751	2.63%	27	28	0	0.00%
13	14	1,930	1.84%	28	29	0	0.00%
14	15	1,410	1.35%	29	30	0	0.00%

Wind Shear and Roughness

A wind shear power law exponent (α) of 0.291 indicates high wind shear at the site. Related to wind shear, a calculated surface roughness of 0.878 meters (indicating the height above ground level where wind velocity would be zero) indicates very rough terrain (roughness description: suburban). This is somewhat curious as the terrain surrounding the met tower is mostly comprised of low-lying grass and light brush and presumably snow cover during the winter months. The high wind shear measured at the site indicates that it would be advantageous to erect wind turbines at higher hub heights if possible.

Vertical wind shear profile



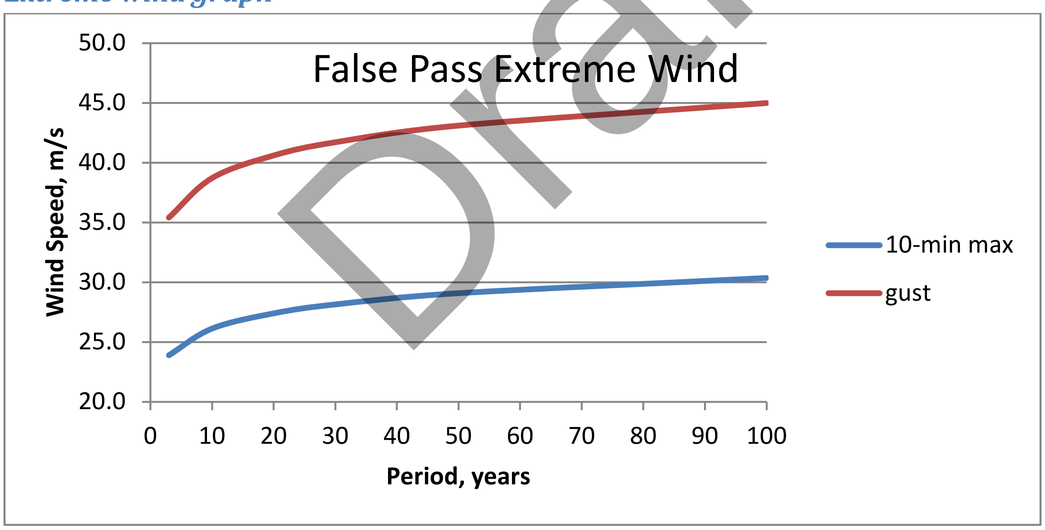
Extreme Winds

A modified Gumbel distribution analysis, based on monthly maximum winds vice annual maximum winds, was used to predict extreme winds at the False Pass met tower site. Note below that the extreme wind analysis shows relatively low extreme winds. Industry standard reference of extreme wind is the 50 year probable (50 year return period) ten-minute average wind speed, referred to as V_{ref}. For False Pass this calculates to 29.1 m/s (at 30 meters), which meets International Electrotechnical Commission (IEC) 61400-1, 3rd edition Class III criteria. All wind turbines are designed for IEC Class III extreme winds.

Extreme wind probability table, 30 m A data

Period (years)	V_{ref} (m/s)	Gust (m/s)	IEC 61400-1, 3rd ed. Class	V_{ref}, m/s
3	23.9	35.4	I	50.0
10	26.1	38.7	II	42.5
20	27.4	40.6	III	37.5
30	28.1	41.7	S	designer-specified
50	29.1	43.1		
100	30.4	45.0		
average gust factor:	1.48			

Extreme wind graph



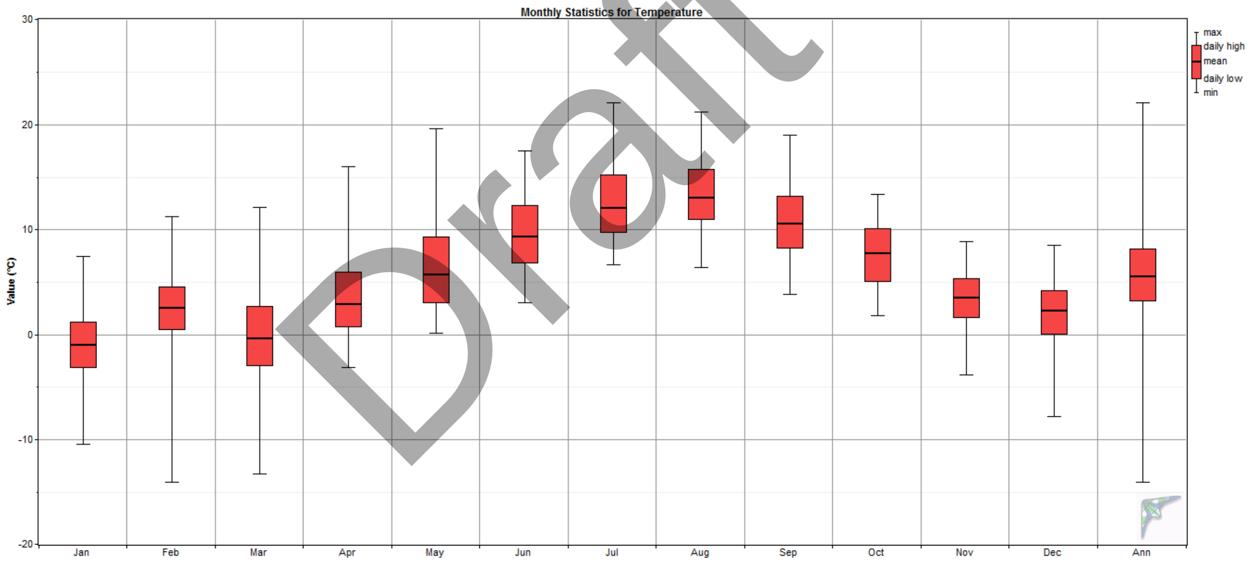
Temperature, Density, and Relative Humidity

False Pass experiences cool summers and moderately cold winters with resulting higher than standard air density. Calculated mean-of-monthly-mean air density during the met tower test period exceeds the 1.223 kg/m^3 standard air density for a 17 meter elevation by approximately three 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.

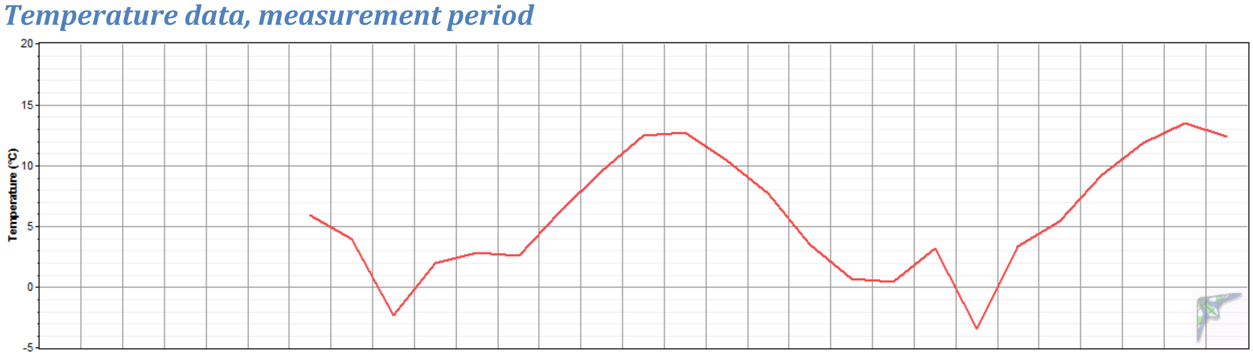
Temperature and density table

	Temperature				Air Density		
Month	Mean (°C)	Mean (°F)	Min (°C)	Max (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-0.9	30.3	-10.5	7.4	1.294	1.255	1.341
Feb	2.6	36.6	-14.1	11.2	1.278	1.239	1.359
Mar	-0.3	31.4	-13.3	12.1	1.291	1.235	1.355
Apr	2.9	37.3	-3.2	16.0	1.276	1.218	1.305
May	5.8	42.4	0.1	19.6	1.251	1.203	1.289
Jun	9.4	48.8	3.0	17.5	1.239	1.212	1.275
Jul	12.1	53.9	6.6	22.1	1.231	1.193	1.259
Aug	13.1	55.5	6.4	21.2	1.228	1.196	1.260
Sep	10.6	51.1	3.8	19.0	1.232	1.205	1.272
Oct	7.7	45.9	1.8	13.3	1.238	1.223	1.281
Nov	3.5	38.3	-3.9	8.8	1.248	1.223	1.308
Dec	2.3	36.1	-7.8	8.5	1.279	1.250	1.327
Annual	5.7	42.3	-14.1	22.1	1.257	1.193	1.359

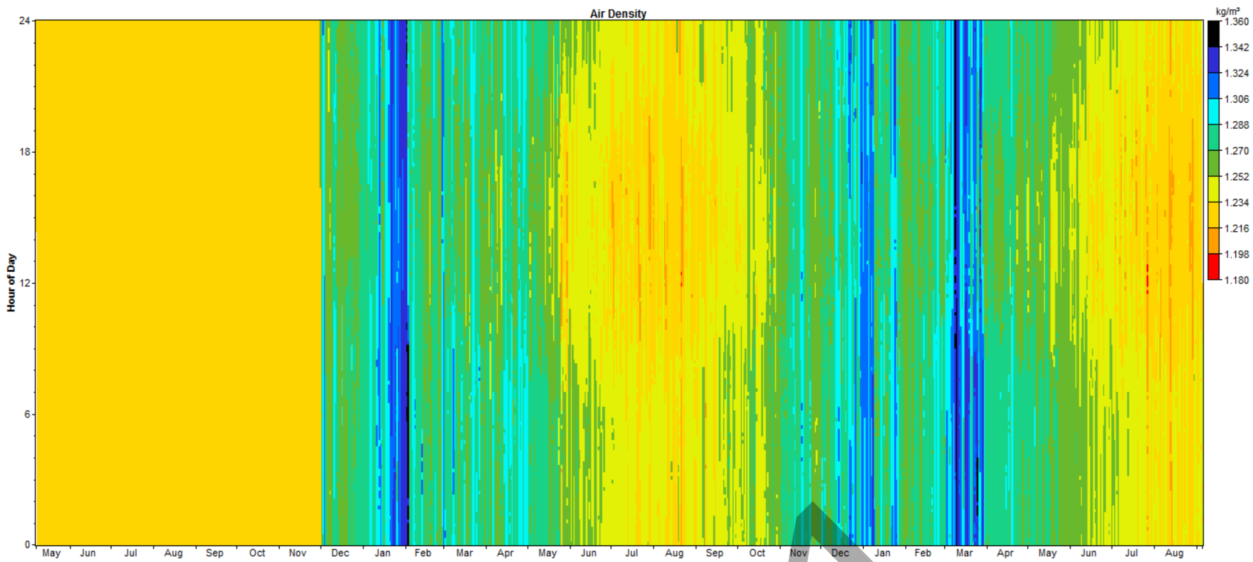
Annual temperature boxplot



Temperature data, measurement period



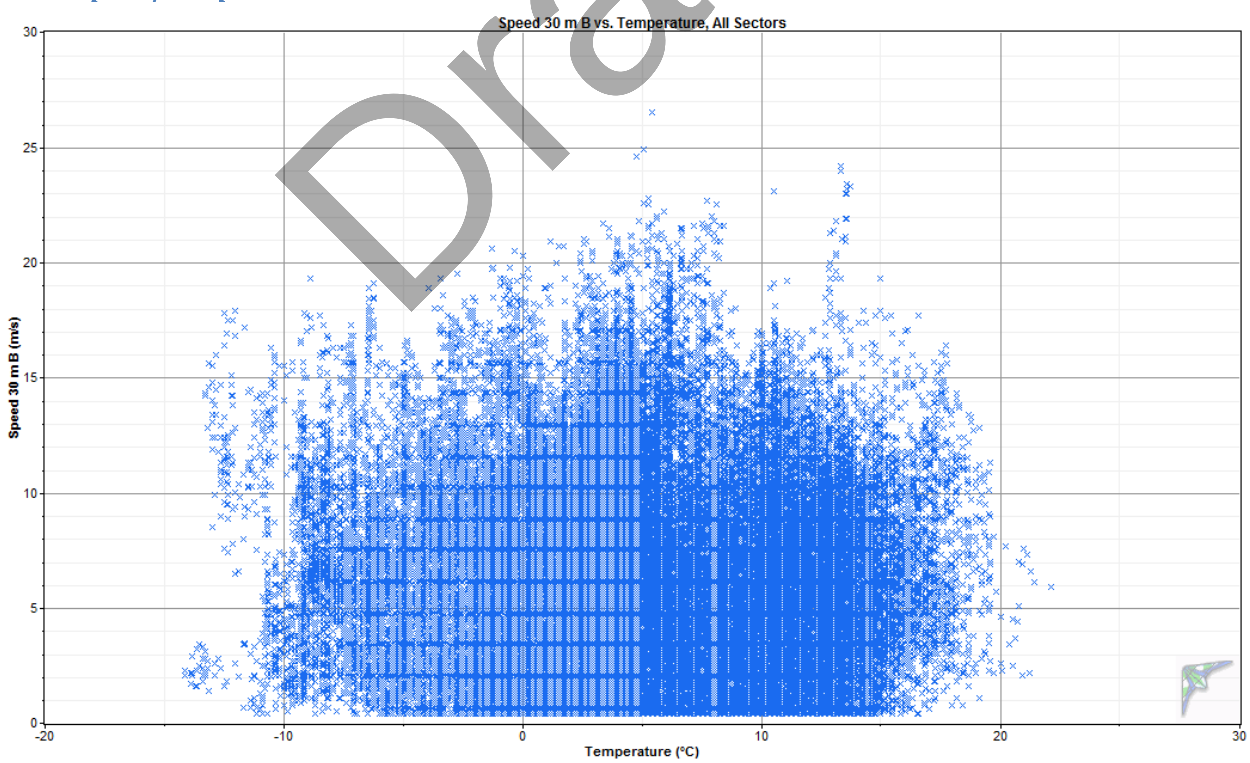
Air density DMap



Wind Speed Scatterplot

The wind speed versus temperature scatterplot for the False Pass wind site indicates a relatively even percentage of wind events across all temperatures. The minimum temperature is relatively warm by Alaska standards at -14°C (7° F). It is not likely that arctic-capable wind turbines with special low temperatures lubricants and heaters would be necessary for False Pass.

Wind speed/temperature

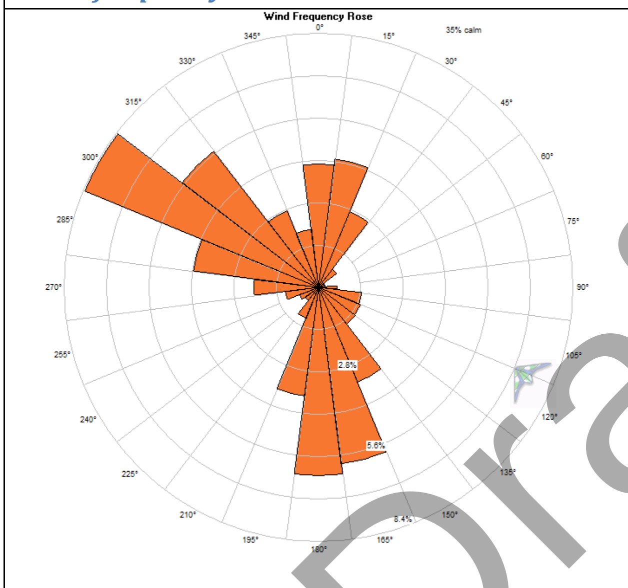


Wind Direction

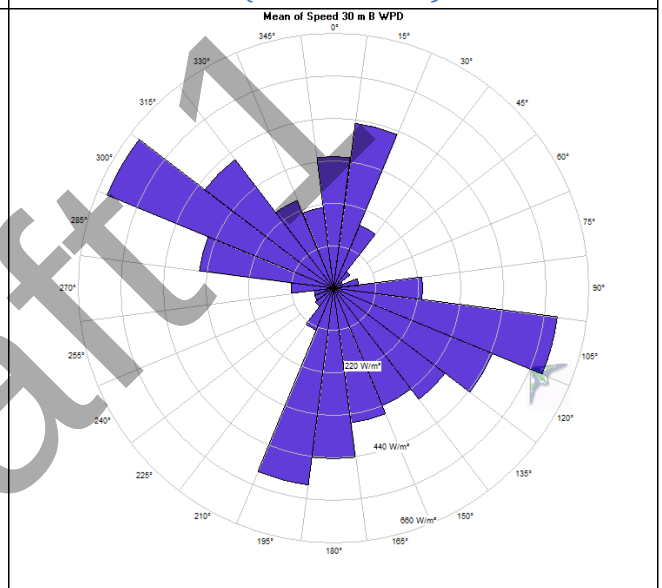
Wind frequency rose data indicates that winds at False Pass are primarily northwest and south with a lesser component of north winds. The mean value rose indicates that the primary and secondary frequency winds occur in strength proportional to their occurrence, but interestingly, when infrequent east-southeast winds occur, they are very strong. Combining these roses into a wind energy rose, one can see that the power-producing winds at the False Pass met tower site are predominately northwest and south, with a lesser degree of northerly winds. Calm frequency (percent of time that winds at the 30 meter level are less than 4 m/s) was a moderately high 35 percent during the test period.

Observing winds on a monthly basis indicates that northwesterly winds mostly occur during the spring and summer months while northerly and southerly winds mostly occur during the winter months.

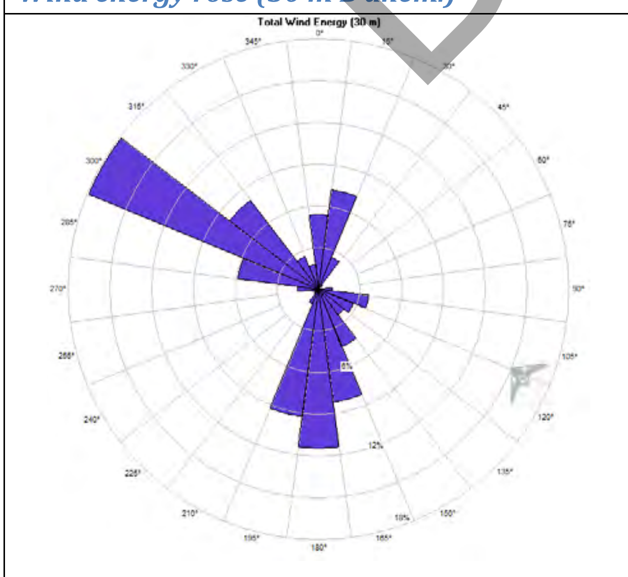
Wind frequency rose



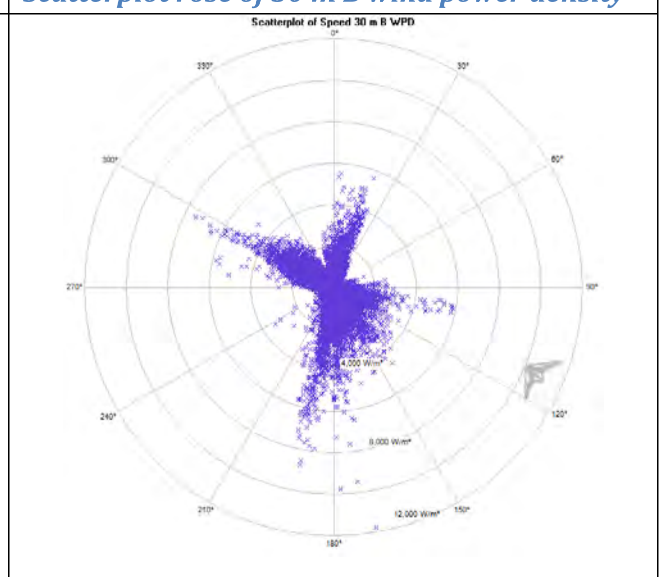
Mean value rose (30 m B anem.)



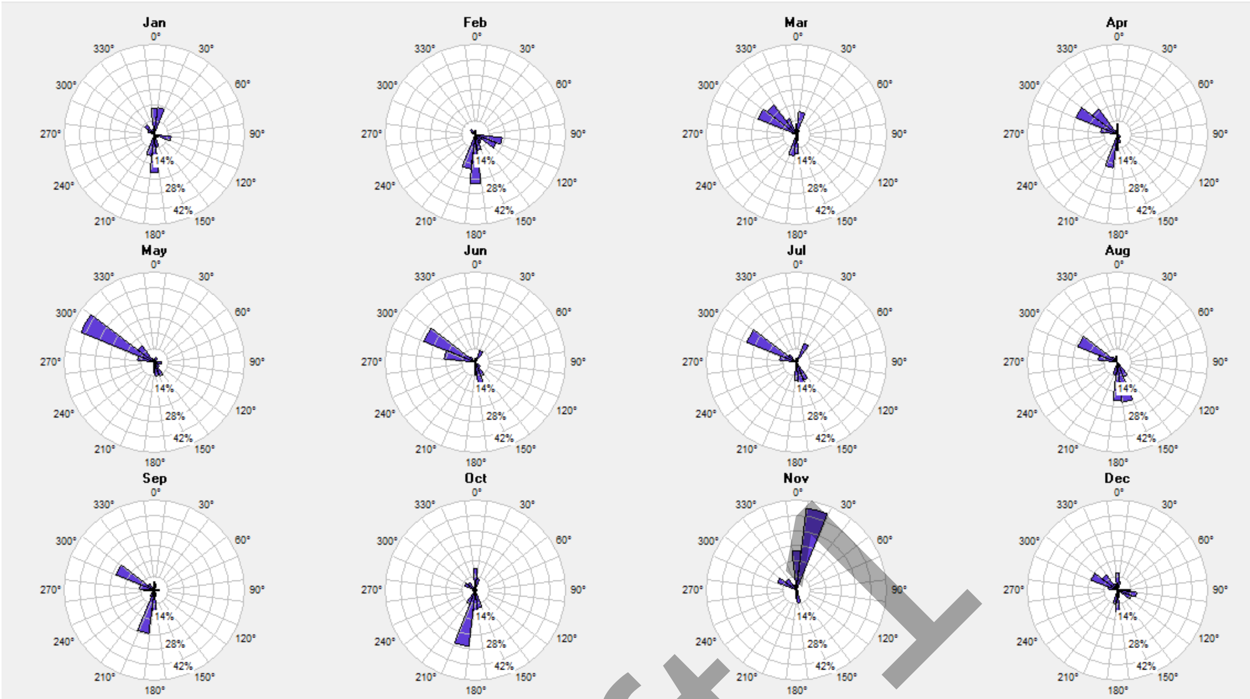
Wind energy rose (30 m B anem.)



Scatterplot rose of 30 m B wind power density



Wind density roses by month (common scale)



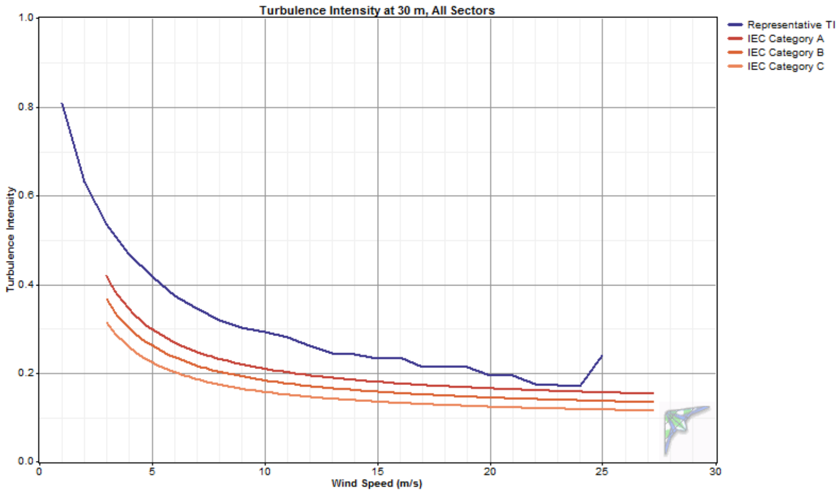
Turbulence

Turbulence intensity (TI) at the False Pass met tower site indicates unexpectedly turbulent conditions that are well above IEC 61400-1, 3rd edition (2005) turbulence category A criteria, which is the most turbulent defined category. This can be seen in the TI graph of anemometer 30 m B at all directions sectors, and also in TI graphs of isolating the north, south, and northwest direction sectors that represent the power-producing winds at the site.

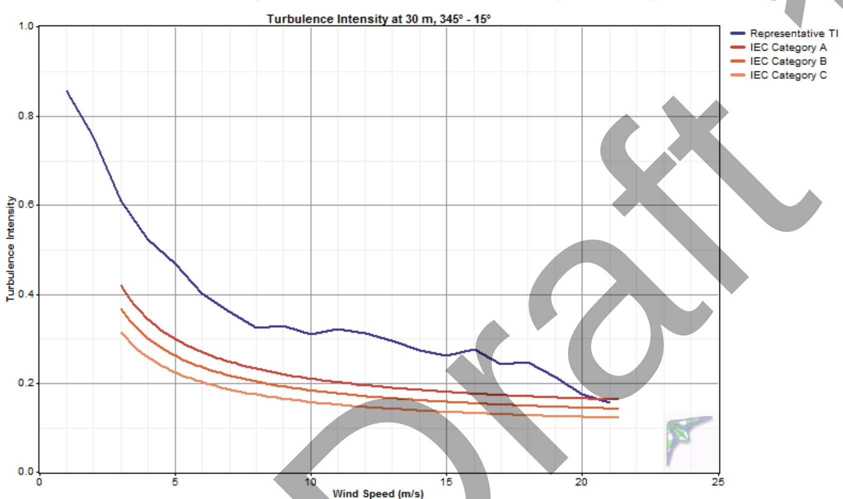
With the high turbulence, the False Pass site classifies by IEC 61400-1, 3rd Edition, criteria as Category S, or special conditions. The 30 meter B anemometer mean TI at 15 m/s is 0.173 and the representative TI at 15 m/s is 0.232, both of which are quite high and considered generally undesirable for wind turbine operations.

High turbulence at the met tower test site is almost certainly due to the high mountains that border Isantoski Strait and that are very near the met tower to the north, west and south. It's likely that air flowing more through the center of Isantoski Strait is less turbulent that at the margins near the mountains, which is the location of the met tower, but that is an academic consideration as it would be impractical from a wind power siting perspective. Insight into turbulent airflow in the False Pass area could be aided by use of computational fluid dynamics analysis to predict airflow patterns.

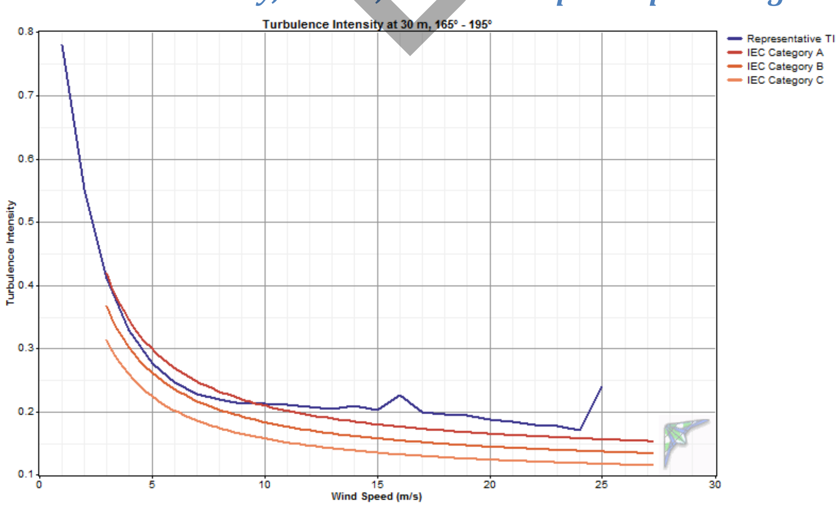
Turbulence intensity graph, 30 m B, all direction sectors



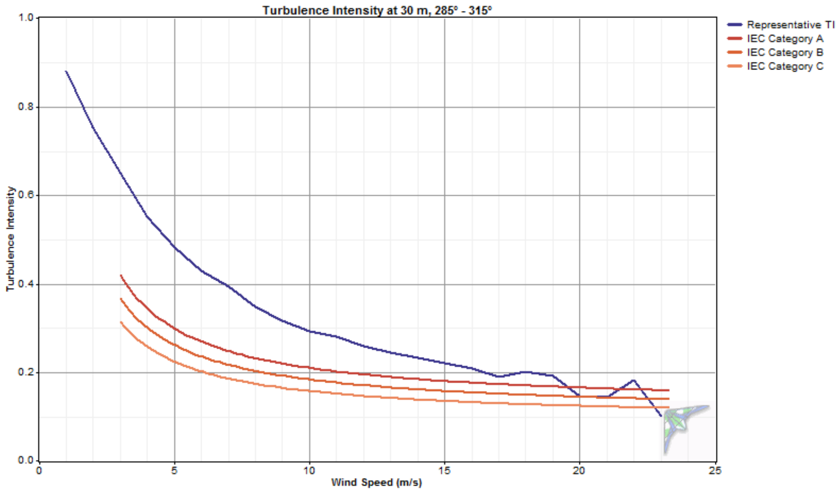
Turbulence intensity, 30 m B, north sector power-producing winds



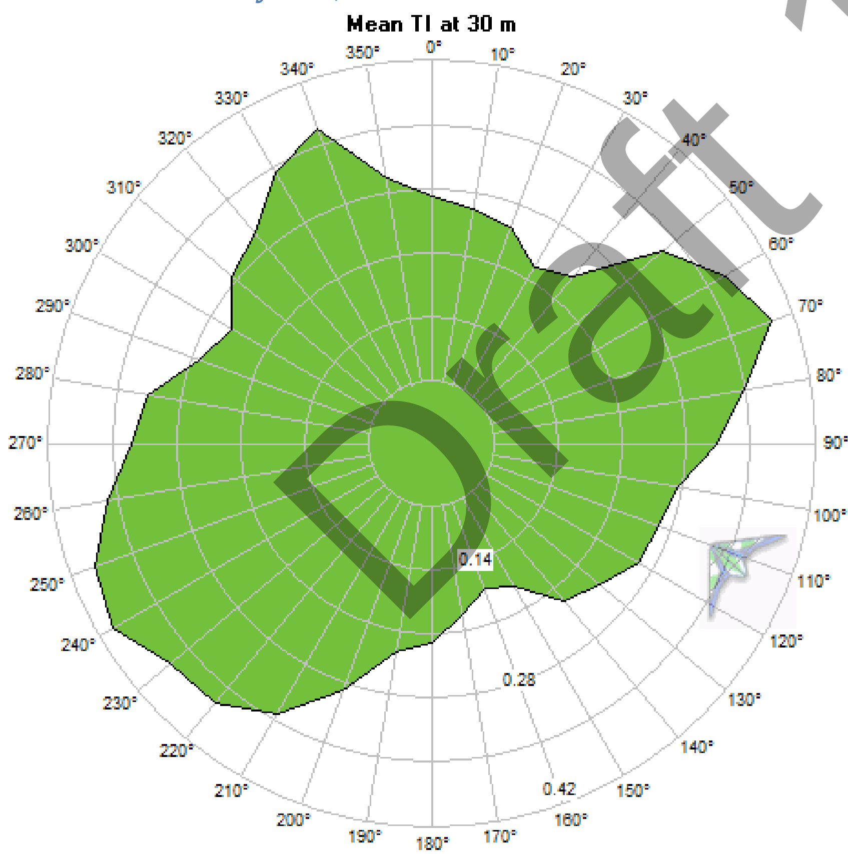
Turbulence intensity, 30 m B, south sector power-producing winds



Turbulence intensity, 30 m A, northwest sector power-producing winds



Turbulence intensity rose, 30 m B



Turbulence table, 30 m B data, all wind sectors

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Upper (m/s)	Records in Bin	Mean TI	SD of TI	Representative TI	Peak TI
1.0	0.5	1.5	9,100	0.583	0.176	0.808	1.571
2.0	1.5	2.5	8,810	0.395	0.185	0.631	1.300
3.0	2.5	3.5	8,736	0.327	0.162	0.534	1.346
4.0	3.5	4.5	9,327	0.287	0.141	0.468	0.972
5.0	4.5	5.5	9,898	0.262	0.121	0.418	0.844
6.0	5.5	6.5	10,680	0.238	0.107	0.374	0.732
7.0	6.5	7.5	10,107	0.221	0.098	0.346	0.682
8.0	7.5	8.5	8,823	0.209	0.086	0.319	0.603
9.0	8.5	9.5	7,264	0.199	0.080	0.301	0.547
10.0	9.5	10.5	5,643	0.196	0.074	0.291	0.510
11.0	10.5	11.5	4,172	0.193	0.068	0.280	0.458
12.0	11.5	12.5	3,287	0.186	0.059	0.262	0.475
13.0	12.5	13.5	2,266	0.181	0.051	0.246	0.418
14.0	13.5	14.5	1,635	0.180	0.050	0.243	0.424
15.0	14.5	15.5	1,135	0.173	0.046	0.232	0.360
16.0	15.5	16.5	732	0.173	0.048	0.235	0.364
17.0	16.5	17.5	475	0.163	0.040	0.214	0.374
18.0	17.5	18.5	280	0.166	0.039	0.215	0.290
19.0	18.5	19.5	143	0.167	0.035	0.212	0.265
20.0	19.5	20.5	86	0.158	0.029	0.195	0.228
21.0	20.5	21.5	53	0.158	0.027	0.193	0.227
22.0	21.5	22.5	26	0.146	0.022	0.175	0.200
23.0	22.5	23.5	11	0.136	0.028	0.172	0.177
24.0	23.5	24.5	2	0.168	0.002	0.171	0.169
25.0	24.5	25.5	2	0.212	0.022	0.240	0.228
26.0	25.5	26.5	0				
27.0	26.5	27.5	1	0.185	0.000	0.185	0.185