ALASKA ENERGY AUTHORITY

Wind Resource Assessment For

# King Cove

Date Last Modified: 8/6/2013

By: Rich Stromberg & Holly Ganser

## Site Summary

**Station ID:** 2857

**Latitude:** 55˚ 7’ 45.8” N

**Longitude:** 162˚ 16’ 10.6” W

**Tower Type:** 30 m NRG Tall Tower

**Sensor Heights:** Speed: 30m and 20m Dir: 27m Temp: 2m

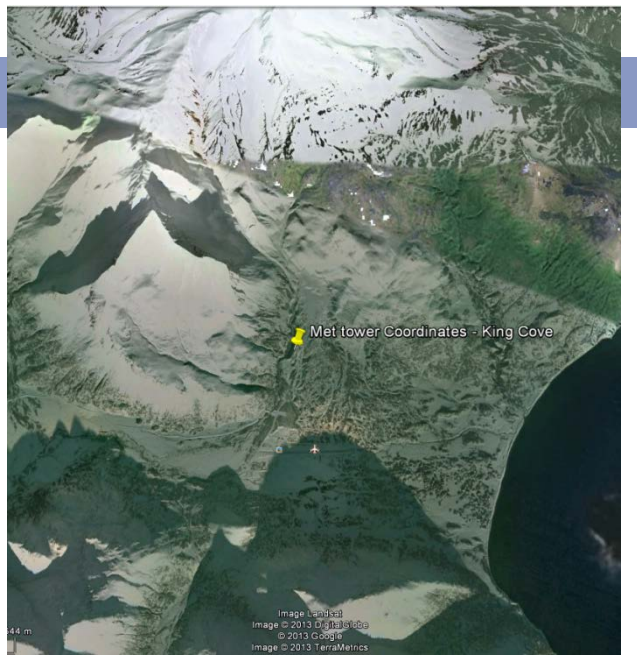
**Elevation:** 145m

**Monitor Start:** May 6, 2005

**Monitor End:** June 14, 2006


In August 2005, the Alaska Energy Authority, V3Energy, Aleutian/Pribilof Islands Association, and employees of the City of King Cove installed a 30-meter tall meteorological tower in King Cove. The purpose of this monitoring effort is to evaluate the feasibility of utilizing wind energy in the community. This report summarizes the wind resource data collected and the long-term energy production potential of the site.

## Wind Resource Summary




Annual Average Wind Speed (20m AGL): 7.387 m/s

Annual Average Wind Speed (30m AGL sensor A): 7.595 m/s

Annual Average Wind Speed (30m AGL sensor B): 7.548 m/s

Predicted by Wind Resource Model (30m AGL): 6.229 m/s

Annual Average Wind Speed (50m AGL calculated): 7.927 m/s – model under predicts

Average Wind Power Density (30 m height):713 W/m$^2$

Average Wind Power Density (50m AGL calculated): 842 W/m$^2$

Wind Power Class (range= 1 to 7): 7

Rating (Poor, Marginal, Fair, Good, Excellent, Outstanding, Superb): Superb

Prevailing Wind Direction: Northwest – model predicts E/ESE



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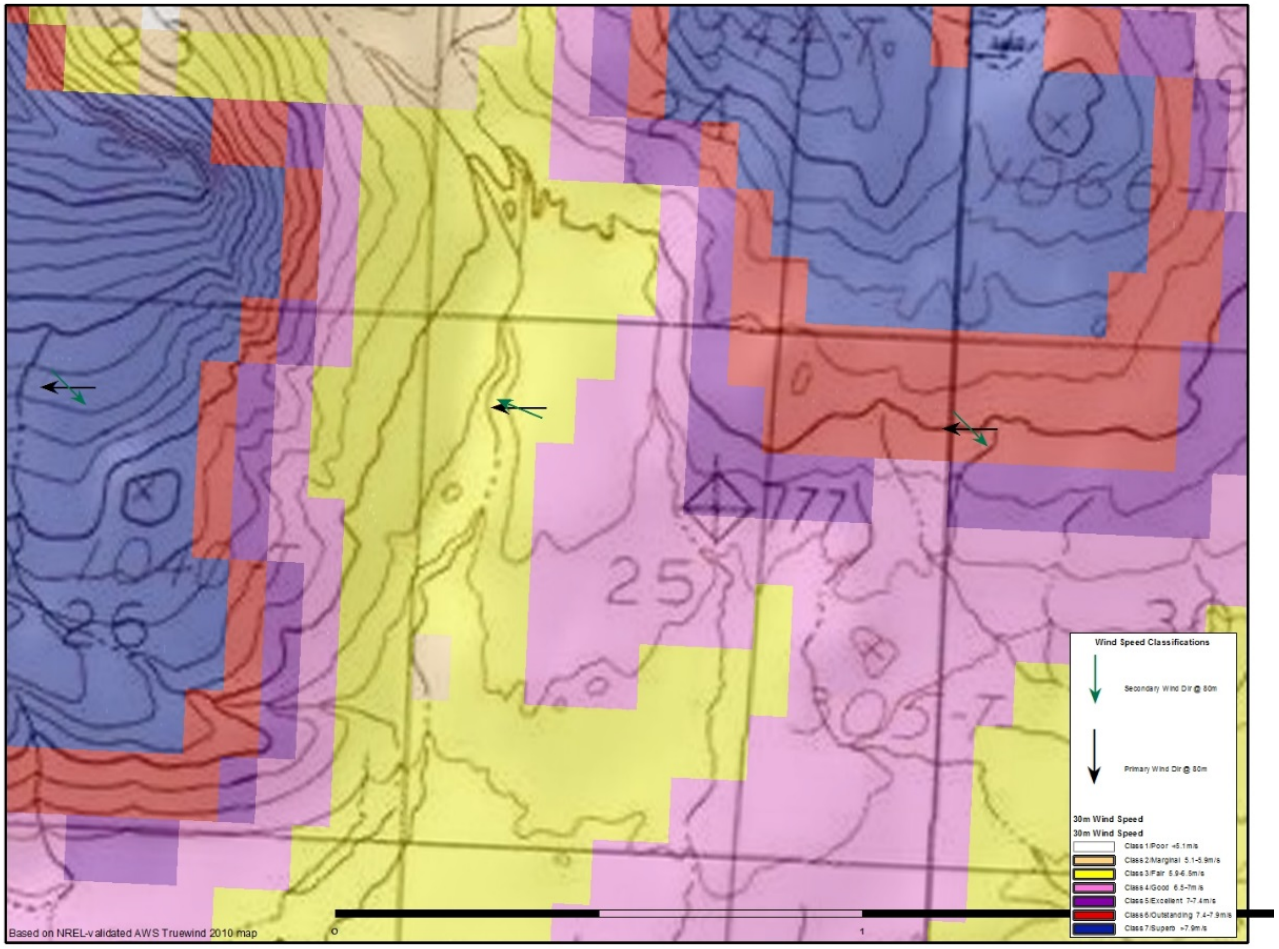
# Introduction

On initial review of the wind resource model, King Cove appears to be a “marginal” wind candidate. The wind resource map below indicates that the community lies in an area that experiences between Class 1 and Class 3 wind resources. Areas of Class 4 and higher are considered suitable for utility-scale wind power development. The site north of King Cove selected for measurement predicted wind classes between 3 and 7 out of the east. The actual winds measured were Class 7 out of the northwest. It has been observed that the more variable the terrain at a location, the more incorrect the wind resource map is. This exemplifies the need for met tower studies to verify the wind resource model. While a strong wind resource was found, turbulence at the met tower site is above desirable levels and that location is not recommended for wind energy development. Additional reconnaissance work should be conducted in the region to find a more suitable site.

King Cove Met Tower Site

AEA - Alaska Wind Speed Map



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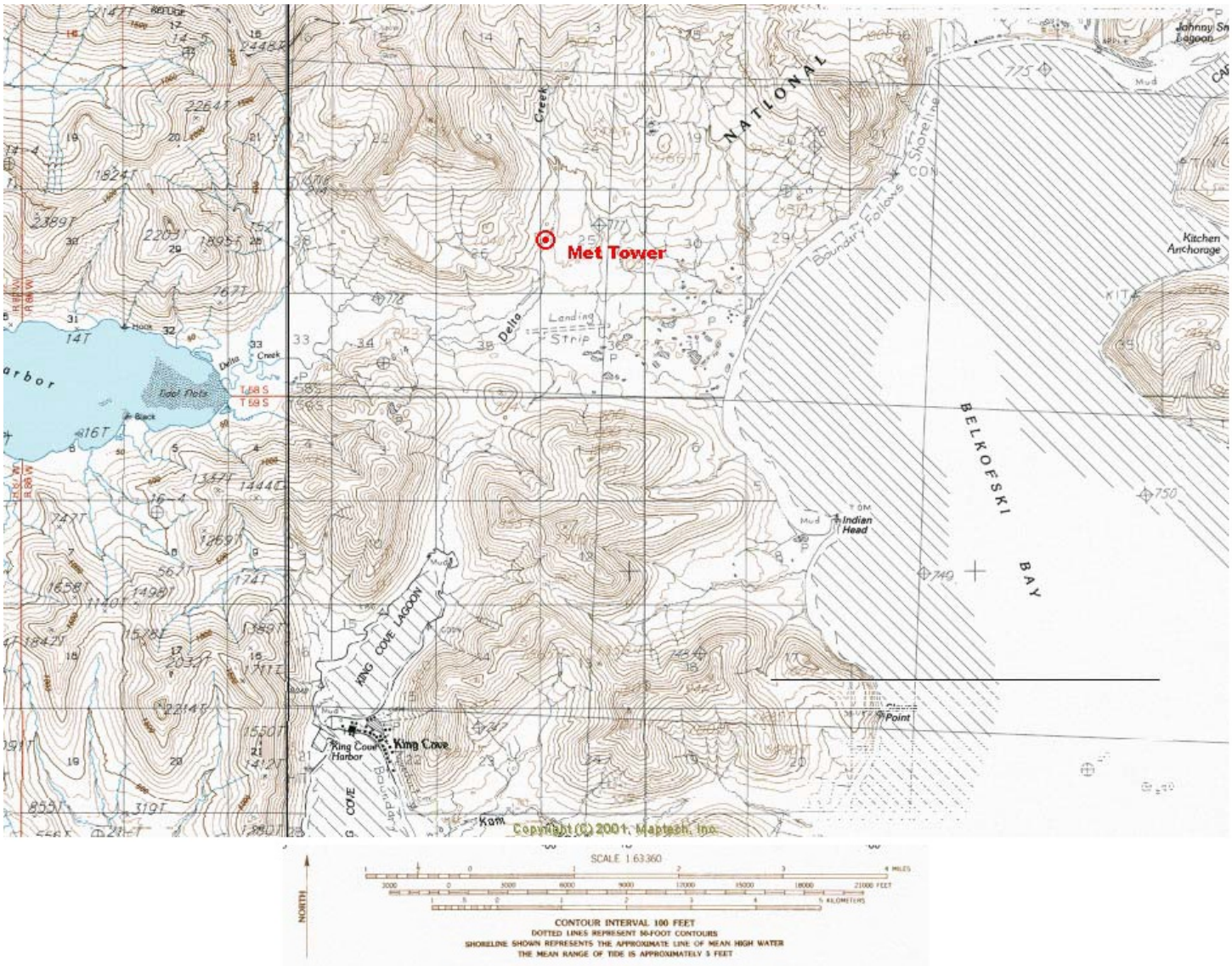
# Site Description

King Cove is located near the tip of the Alaska Peninsula on the south side, approximately 625 air miles southwest of Anchorage and 18 miles southeast of Cold Bay. The meteorological tower was placed at 55˚ 7’ 45.8” N, 162˚ 16’ 10.6” W approximately 1.5 miles north of the airport and 5 miles north of the city. Below is the location of the met tower on a topographical map and the following photograph shows the met tower site from the King Cove airstrip.




*Topographical Map of King Cove Area*



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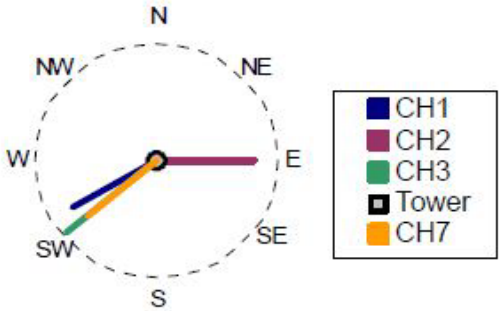
## Site Description- continued


*Met Tower Site from Airstrip*

Table 1 lists the data logger channels where each sensor is wired and the orientation that they are mounted on the tower. In August 2005, a bear chewed through the cables to the data logger. The damage was noted, but did not affect the data. The layout of the sensor booms on the tower is also shown below.

*Table 1 Data Logger Channels*

| Ch # | Sensor Type | Height | Offset | Boom Orientation |
|---|---|---|---|---|
| 1 | #40 Anemometer | 30m | NRG Standard | 225° True |
| 2 | #40 Anemometer | 30m | NRG Standard | 110° True |
| 3 | #40 Anemometer | 20m | NRG Standard | 130° True |
| 7 | #200P Wind Vane | 27m | 315° True | 135° True |
| 9 | #110S Temperature | 2m | NRG Standard | - |




*Layout of Sensor Booms*



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## Site Description- continued

The photos below illustrate the surrounding ground cover and any major obstructions, which could have an effect on how the wind flows over the terrain from a particular direction. As shown, the landscape surrounding the met tower site is free of obstructions.


North West of Tower Base


North of Tower Base


North East of Tower Base


West of Tower Base



East of Tower Base


South West of Tower Base


South of Tower Base


South East of Tower Base



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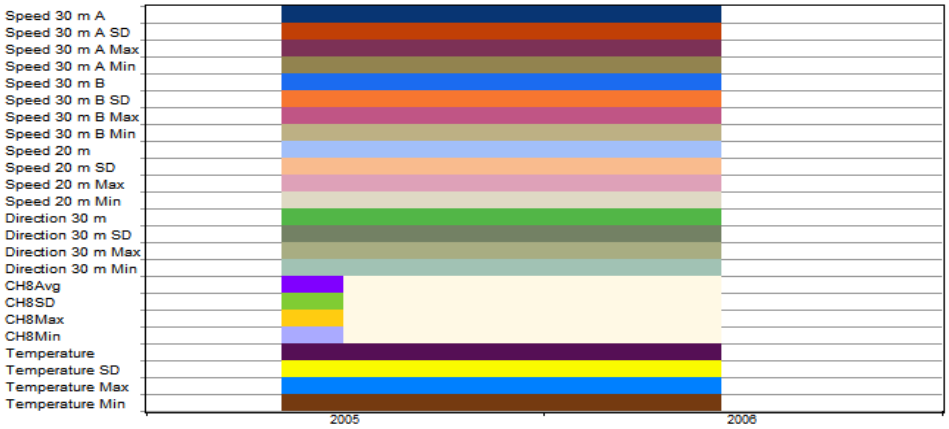
# Raw Wind Data Recovery




*Data Coverage Report*

Wind data for King Cove was measured from May 5th, 2005 to June 3, 2006. The data coverage report created by Windographer shows that a full 13 months of data was collected with no loss of data.

| | Label | Units | Height | Possible Data Points | Valid Data Points | Recovery Rate (%) | Mean | Min | Max | Std. Dev |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Speed 30 m A | m/s | 30 m | 58,034 | 58,034 | 100.00 | 6.949 | 0.400 | 36.400 | 5.021 |
| 2 | Speed 30 m A SD | m/s | 30 m | 58,034 | 58,034 | 100.00 | 1.444 | 0.000 | 7.600 | 0.970 |
| 3 | Speed 30 m A Max | m/s | 30 m | 58,034 | 58,034 | 100.00 | 10.751 | 0.400 | 52.000 | 7.171 |
| 4 | Speed 30 m A Min | m/s | 30 m | 58,034 | 58,034 | 100.00 | 3.613 | 0.400 | 25.200 | 3.246 |
| 5 | Speed 30 m B | m/s | 30 m | 58,034 | 58,034 | 100.00 | 6.913 | 0.400 | 36.400 | 4.879 |
| 6 | Speed 30 m B SD | m/s | 30 m | 58,034 | 58,034 | 100.00 | 1.450 | 0.000 | 7.600 | 0.986 |
| 7 | Speed 30 m B Max | m/s | 30 m | 58,034 | 58,034 | 100.00 | 10.730 | 0.400 | 51.600 | 7.051 |
| 8 | Speed 30 m B Min | m/s | 30 m | 58,034 | 58,034 | 100.00 | 3.572 | 0.400 | 25.200 | 3.111 |
| 9 | Speed 20 m | m/s | 20 m | 58,034 | 58,034 | 100.00 | 6.820 | 0.400 | 34.800 | 4.636 |
| 10 | Speed 20 m SD | m/s | 20 m | 58,034 | 58,034 | 100.00 | 1.473 | 0.000 | 7.900 | 1.002 |
| 11 | Speed 20 m Max | m/s | 20 m | 58,034 | 58,034 | 100.00 | 10.734 | 0.400 | 50.500 | 6.990 |
| 12 | Speed 20 m Min | m/s | 20 m | 58,034 | 58,034 | 100.00 | 3.469 | 0.400 | 22.900 | 2.861 |
| 13 | Direction 30 m | ° | 30 m | 58,034 | 58,034 | 100.00 | 321.6 | 0.0 | 359.0 | 108.5 |
| 14 | Direction 30 m SD | ° | 30 m | 58,034 | 58,034 | 100.00 | 17.0 | 0.0 | 127.0 | 15.8 |
| 15 | Direction 30 m Max | ° | 30 m | 58,034 | 58,034 | 100.00 | 217.3 | 0.0 | 359.0 | 111.4 |
| 16 | Direction 30 m Min | ° | 30 m | 58,034 | 58,034 | 100.00 | 315.0 | 315.0 | 315.0 | 0.0 |
| 17 | CH8Avg | | | 58,034 | 8,066 | 13.90 | 0 | 0 | 0 | 0 |
| 18 | CH8SD | | | 58,034 | 8,066 | 13.90 | 0 | 0 | 0 | 0 |
| 19 | CH8Max | | | 58,034 | 8,066 | 13.90 | 0 | 0 | 0 | 0 |
| 20 | CH8Min | | | 58,034 | 8,066 | 13.90 | 0 | 0 | 0 | 0 |
| 21 | Temperature | °C | 2 m | 58,034 | 58,032 | 100.00 | 5.7 | -86.4 | 24.7 | 6.4 |
| 22 | Temperature SD | °C | | 58,034 | 58,032 | 100.00 | 0.04 | 0.00 | 28.40 | 0.17 |
| 23 | Temperature Max | | | 58,034 | 58,032 | 100.00 | 5.94 | -86.40 | 54.90 | 6.45 |
| 24 | Temperature Min | | | 58,034 | 58,032 | 100.00 | 5.54 | -86.40 | 24.40 | 6.43 |
| 25 | Air Density | kg/m³ | | 58,034 | 58,034 | 100.00 | 1.244 | 1.164 | 1.334 | 0.027 |
| 26 | Speed 30 m A TI | | | 58,034 | 58,034 | 100.00 | 0.26 | 0.00 | 1.93 | 0.18 |
| 27 | Speed 30 m B TI | | | 58,034 | 58,034 | 100.00 | 0.25 | 0.00 | 1.40 | 0.17 |
| 28 | Speed 20 m TI | | | 58,034 | 58,034 | 100.00 | 0.25 | 0.00 | 1.39 | 0.15 |
| 29 | Speed 30 m A WPD | W/m² | | 58,034 | 58,034 | 100.00 | 635 | 0 | 31,614 | 1,628 |
| 30 | Speed 30 m B WPD | W/m² | | 58,034 | 58,034 | 100.00 | 606 | 0 | 31,614 | 1,575 |
| 31 | Speed 20 m WPD | W/m² | | 58,034 | 58,034 | 100.00 | 549 | 0 | 27,626 | 1,350 |

*Data Summary*



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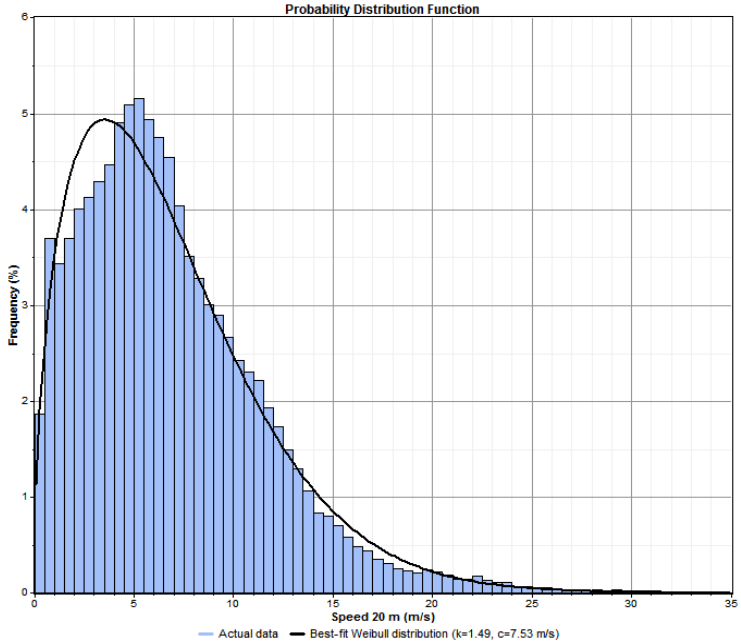
## Raw Wind Data Recovery - Continued

The wind speed summary and probability distribution function chart show the distribution of the raw data for each anemometer. At initial review the data for the 30 meter anemometers show higher frequencies of zero wind speeds. This indicates that there are areas in the data set that need to be filtered for icing conditions or other areas of invalid/questionable data.

| Variable | Speed 30 m A | Speed 30 m B | Speed 20 m |
|---|---|---|---|
| Measurement height (m) | 30 | 30 | 20 |
| Mean wind speed (m/s) | 6.949 | 6.914 | 6.820 |
| MoMM wind speed (m/s) | 6.986 | 6.939 | 6.849 |
| Median wind speed (m/s) | 6.100 | 6.100 | 6.000 |
| Min wind speed (m/s) | 0.400 | 0.400 | 0.400 |
| Max wind speed (m/s) | 36.400 | 36.400 | 34.800 |
| Weibull k | 1.322 | 1.380 | 1.487 |
| Weibull c (m/s) | 7.498 | 7.526 | 7.534 |
| Mean power density (W/m²) | 635 | 606 | 549 |
| MoMM power density (W/m²) | 640 | 610 | 553 |
| Mean energy content (kWh/m²/yr) | 5,561 | 5,312 | 4,812 |
| MoMM energy content (kWh/m²/yr) | 5,607 | 5,342 | 4,847 |
| Energy pattern factor | 3.014 | 2.925 | 2.761 |
| Frequency of calms (%) | 4.95 | 4.08 | 1.87 |
| Possible data points | 58,034 | 58,034 | 58,034 |
| Valid data points | 58,034 | 58,034 | 58,034 |
| Missing data points | 0 | 0 | 0 |
| Data recovery rate (%) | 100.00 | 100.00 | 100.00 |




*Probability Distribution Function of the Speed 20m*



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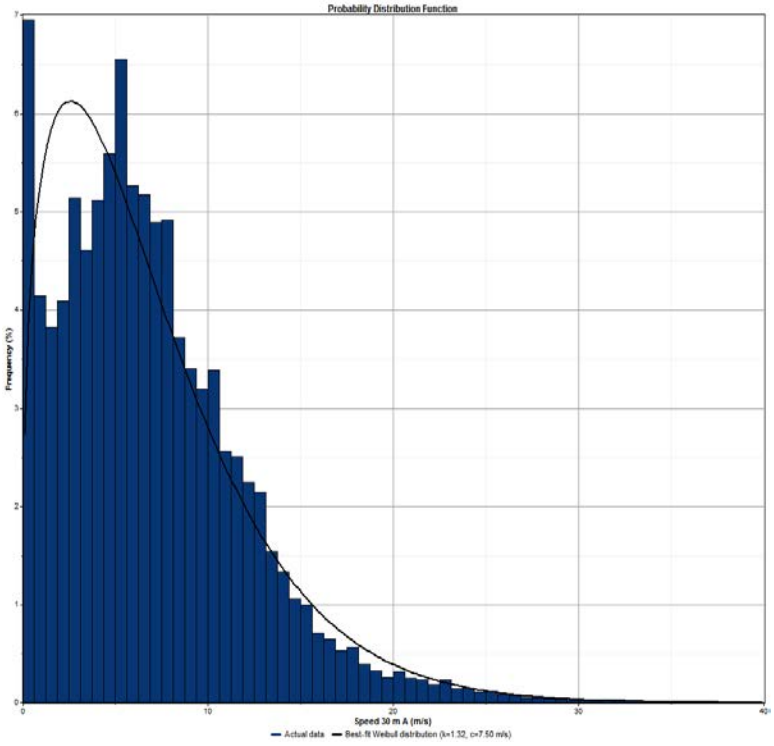
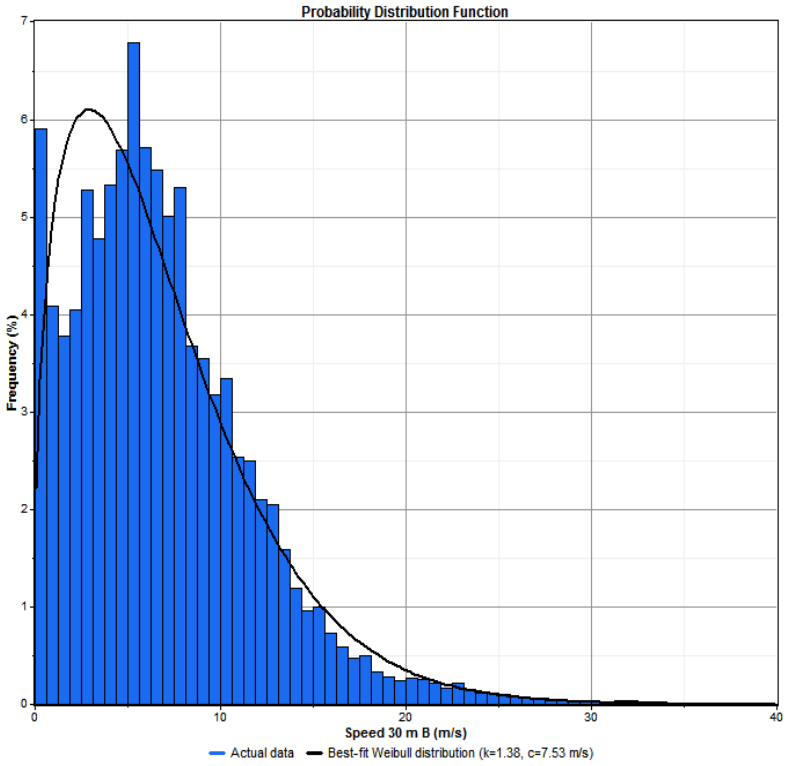
## Raw Wind Data Recovery - Continued




*Probability Distribution Function of the Speed 30m A anemometer*




*Probability Distribution Function of the Speed 30m B anemometer*



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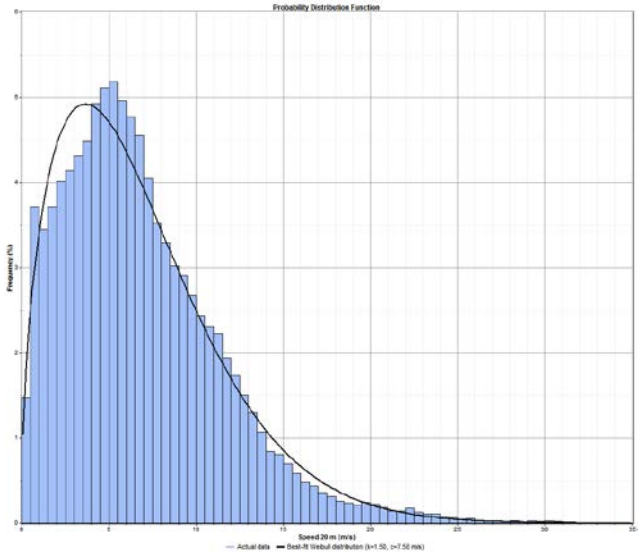
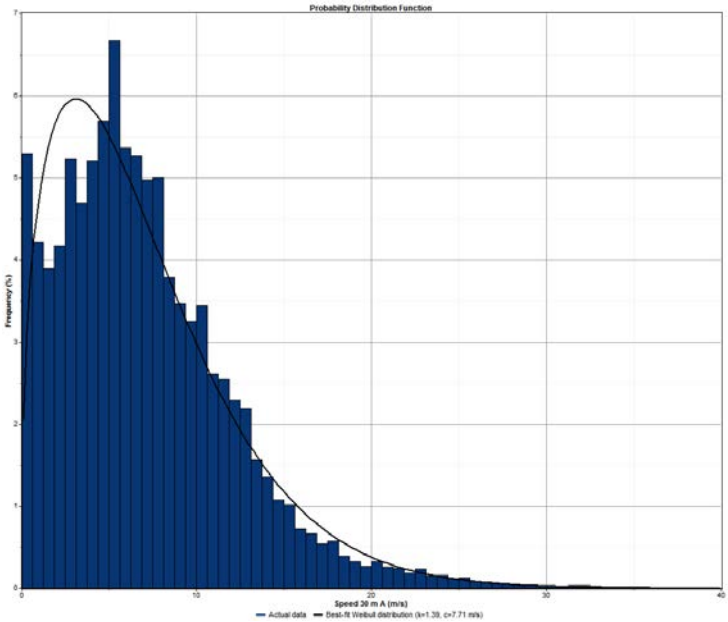
## Wind Speed Data – Flagging Data

Once the data set was filtered for invalid data points and icing occurrences, the high number of zero wind occurrences was reduced. Invalid data was indicated as temperatures that were impractical for King Cove. Rules were created to flag icing events. These rules included flagging the anemometer data anytime the temperature was below 4° C, the standard deviation of the anemometer was equal to zero and the speed was less than 0.5 m/s. Data was also marked as questionable when the speed for the 20m anemometer recorded values higher than the 30m anemometers, but these data values were not excluded in our analyses. After the icing rules were applied it was found that icing was flagged on the 30m A sensor 1.75%, 30m A 1.41%, and 20m 0.39% of the time it was recording data. The wind speed summary and the probability distribution functions for all three anemometers after the data was filtered can be found below.

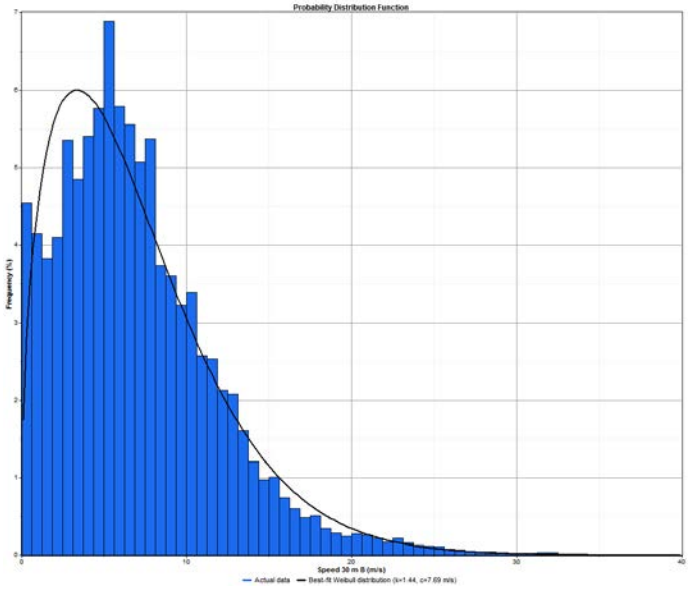
| Variable | Speed 30 m A | Speed 30 m B | Speed 20 m |
|---|---|---|---|
| Measurement height (m) | 30 | 30 | 20 |
| Mean wind speed (m/s) | 7.066 | 7.007 | 6.845 |
| MoMM wind speed (m/s) | 7.107 | 7.034 | 6.872 |
| Median wind speed (m/s) | 6.200 | 6.200 | 6.000 |
| Min wind speed (m/s) | 0.400 | 0.400 | 0.400 |
| Max wind speed (m/s) | 36.400 | 36.400 | 34.800 |
| Weibull k | 1.391 | 1.437 | 1.503 |
| Weibull c (m/s) | 7.711 | 7.690 | 7.577 |
| Mean power density (W/m²) | 646 | 615 | 551 |
| MoMM power density (W/m²) | 652 | 619 | 555 |
| Mean energy content (kWh/m²/yr) | 5,660 | 5,388 | 4,830 |
| MoMM energy content (kWh/m²/yr) | 5,711 | 5,421 | 4,865 |
| Energy pattern factor | 2.918 | 2.850 | 2.741 |
| Frequency of calms (%) | 3.26 | 2.70 | 1.48 |
| Possible data points | 58,034 | 58,034 | 58,034 |
| Valid data points | 57,017 | 57,213 | 57,808 |
| Missing data points | 1,017 | 821 | 226 |
| Data recovery rate (%) | 98.25 | 98.59 | 99.61 |




*Probability Distribution Function of the Speed 20m anemometer*




*Probability Distribution Function of the Speed 30m A anemometer*




*Probability Distribution Function of the Speed 30m B anemometer*



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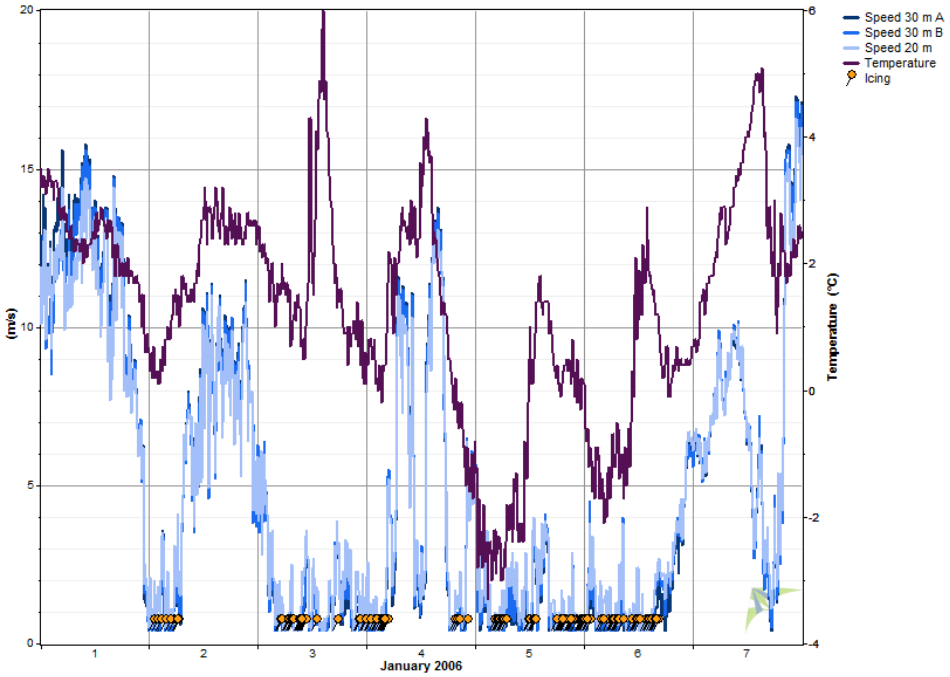
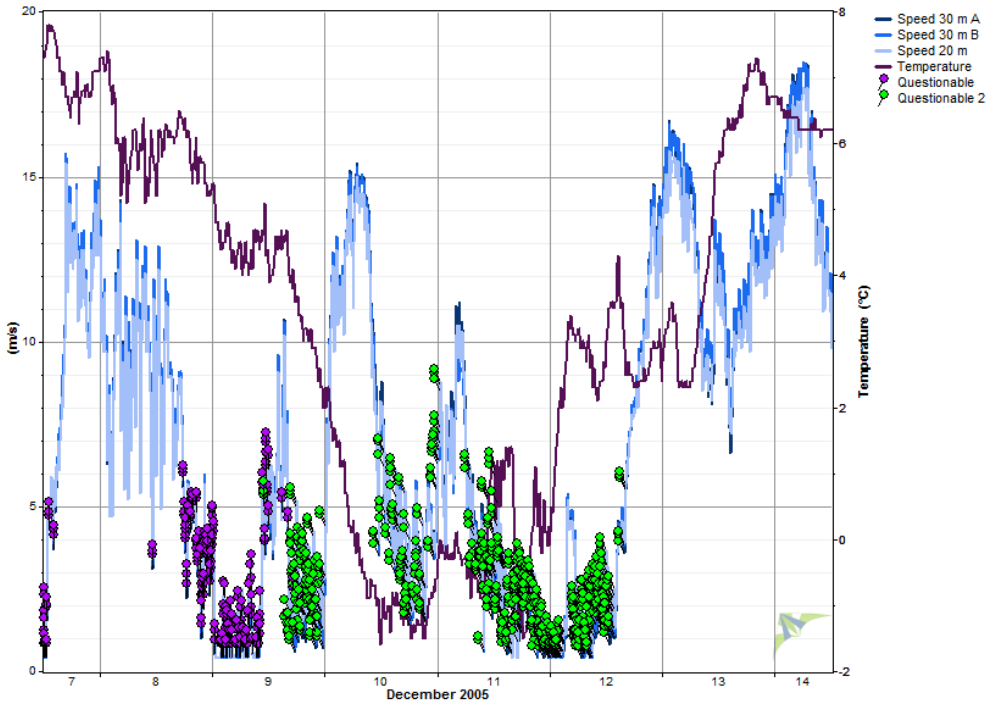
# Wind Speed Data – Flagging Data Continued




*Sample of the data that was flagged for icing conditions with temperature data.*




*Sample of the data that was flagged as questionable with temperature data. The purple flags are when temperature is above 4° C and the green flags are when temperatures are above 4°C.*



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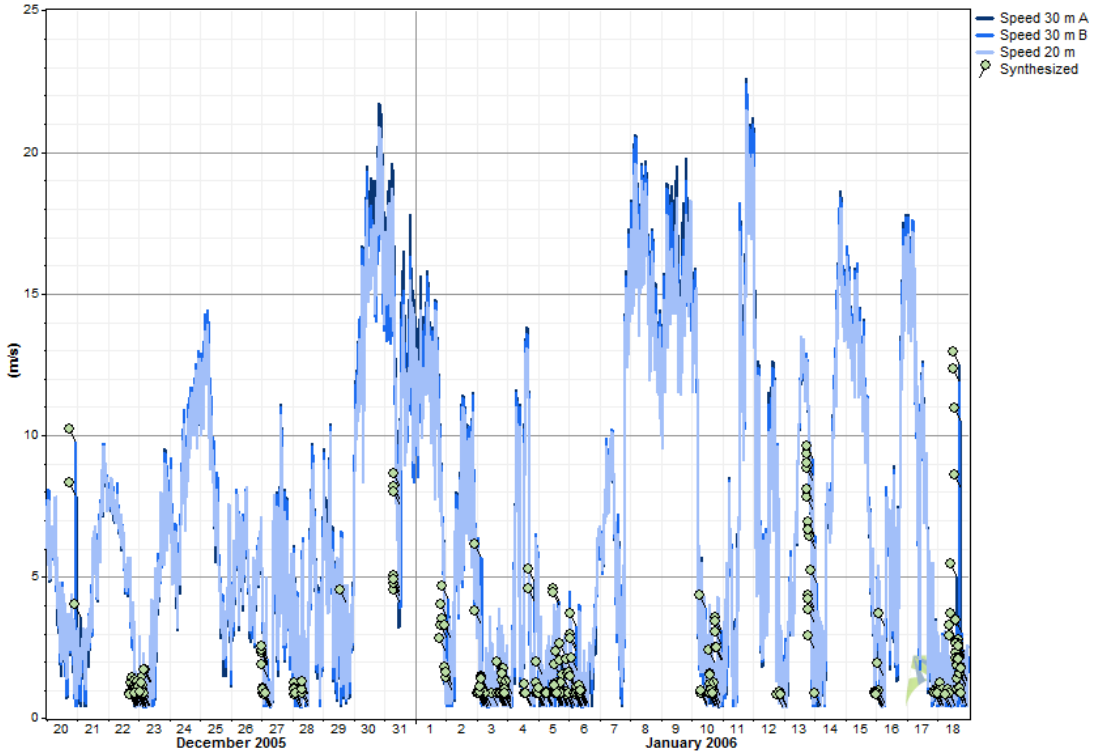
# Wind Speed Data – Synthesized Data

After the data was flagged for icing, it was deleted and synthesized to fill in the gaps. The resulting summary and probability distribution functions can be found below. The resulting mean wind speeds of each anemometer are higher than that of the flagged data. The synthesized data was not used in the analysis unless otherwise indicated.

| Variable | Speed 30 m A | Speed 30 m B | Speed 20 m |
|---|---|---|---|
| Measurement height (m) | 30 | 30 | 20 |
| Mean wind speed (m/s) | 8.128 | 8.092 | 7.902 |
| MoMM wind speed (m/s) | 8.108 | 8.069 | 7.883 |
| Median wind speed (m/s) | 7.200 | 7.200 | 7.000 |
| Min wind speed (m/s) | 0.365 | 0.366 | 0.353 |
| Max wind speed (m/s) | 36.400 | 36.400 | 34.800 |
| Weibull k | 1.653 | 1.713 | 1.749 |
| Weibull c (m/s) | 9.069 | 9.058 | 8.858 |
| Mean power density (W/m²) | 811 | 778 | 703 |
| MoMM power density (W/m²) | 804 | 771 | 697 |
| Mean energy content (kWh/m²/yr) | 7,105 | 6,815 | 6,156 |
| MoMM energy content (kWh/m²/yr) | 7,044 | 6,750 | 6,104 |
| Energy pattern factor | 2.406 | 2.339 | 2.270 |
| Frequency of calms (%) | 0.00 | 0.00 | 0.00 |
| Possible data points | 58,034 | 58,034 | 58,034 |
| Valid data points | 43,664 | 43,502 | 43,111 |
| Missing data points | 14,370 | 14,532 | 14,923 |
| Data recovery rate (%) | 75.24 | 74.96 | 74.29 |




*Sample of the synthesized data*



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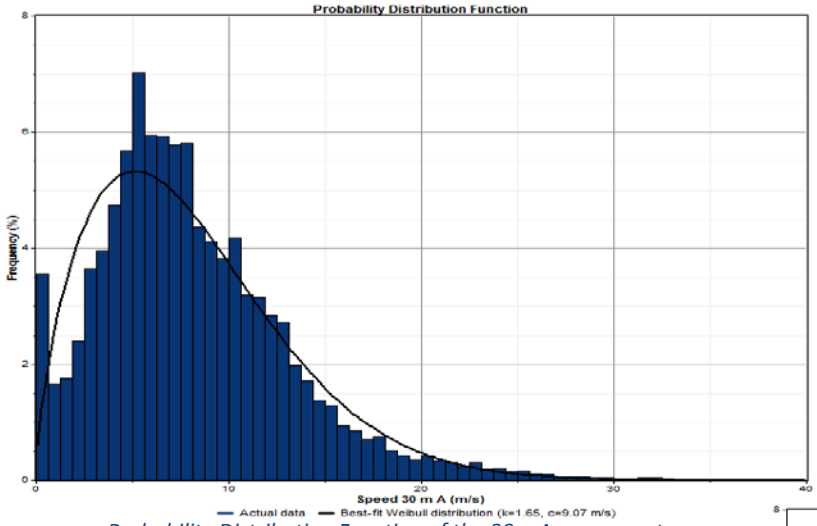
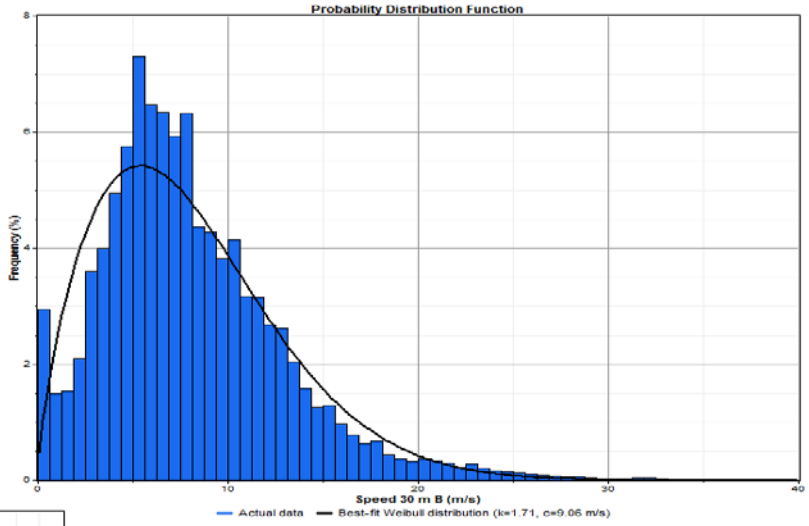
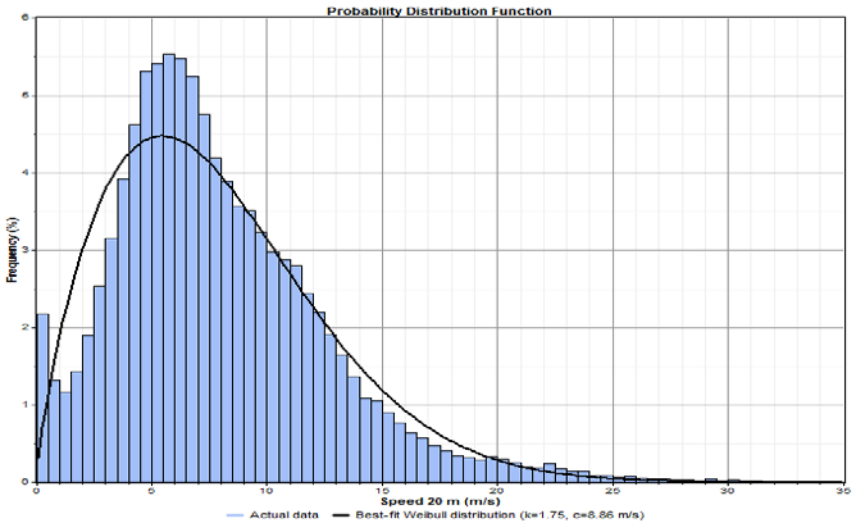
## Wind Speed Data – Synthesized Data




*Probability Distribution Function of the 30m A anemometer*




*Probability Distribution Function of the 30m B anemometer*




*Probability Distribution Function of the 20m anemometer*



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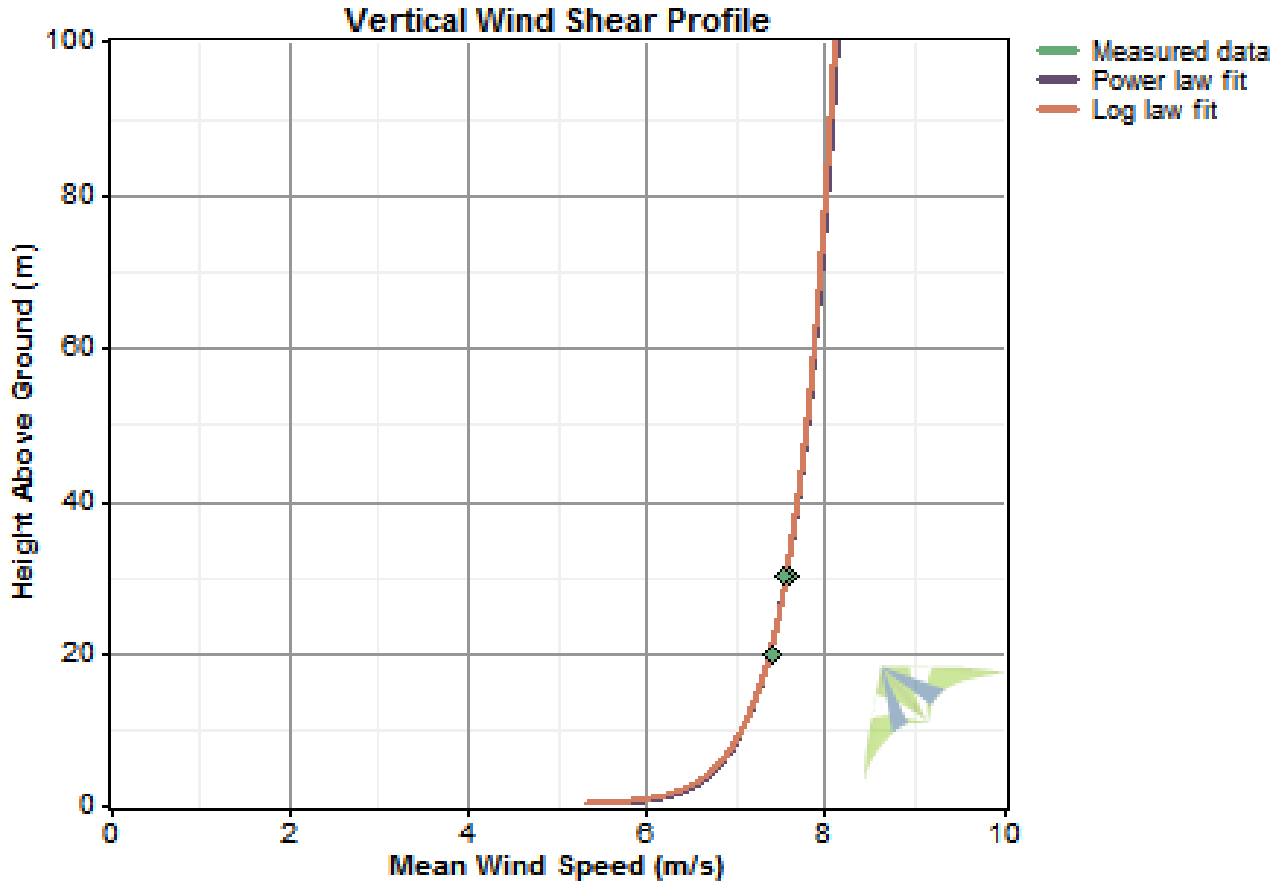
## Wind Speed Data – Analysis

The filtered data produced a power density at 50m of 842 W/m$^2$. At this density the wind power class is a low class 7 or superb winds. Windographer calculated a power law exponent of 0.0607 and a surface roughness of 0.0000017m. The wind shear is low when compared to a **typical** power law exponent value of 0.14. From this wind shear value, the mean wind speed for heights that were not measured can be estimated. The mean wind speed for heights up to 100m can be found below.

| Wind power coefficients | |
|---|---|
| Power density at 50m: | 842 W/m² |
| Wind power class: | 7 (Superb) |
| **Wind shear coefficients** | |
| Power law exponent: | 0.0607 |
| Surface roughness: | 0.0000017 m |
| Roughness class: | 0.00 |



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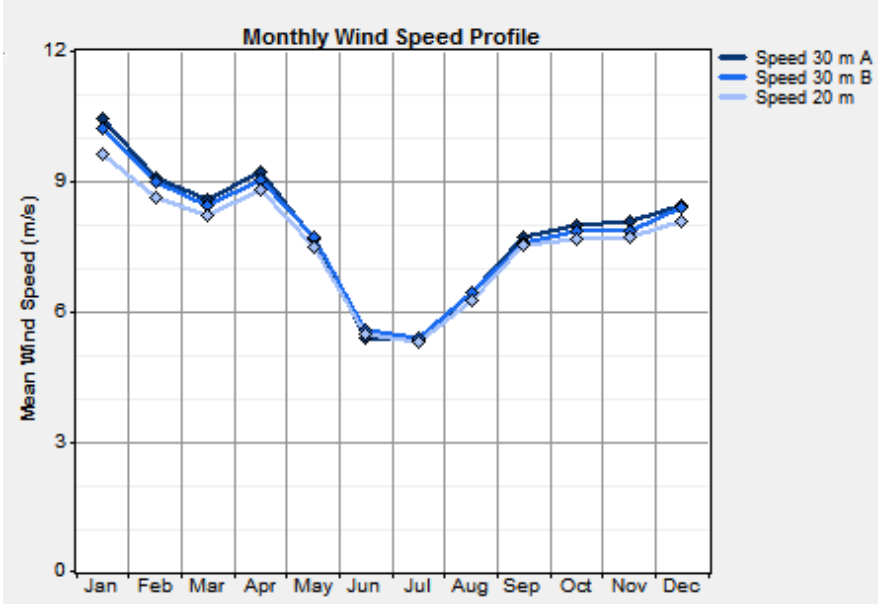
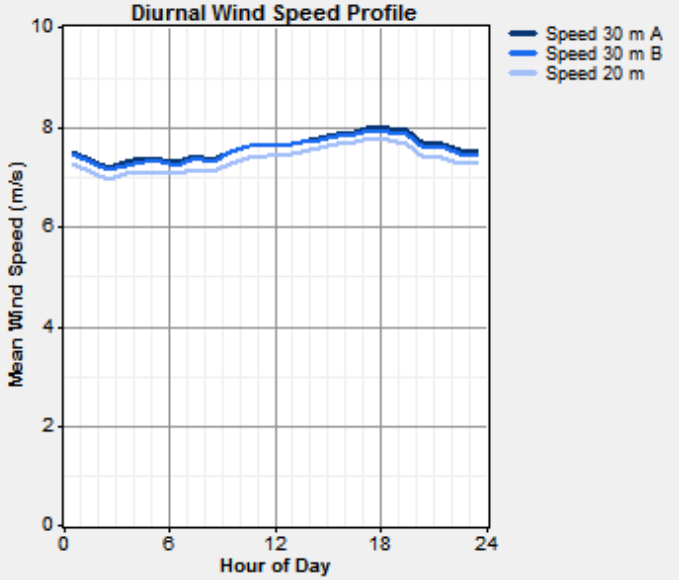
## Wind Speed Data – Analysis Continued

The monthly wind speed profile follows the common pattern of wind speeds that are higher in the winter months than the summer months. The diurnal wind speed profile indicates that King Cove experiences average wind speeds around 7 m/s in the morning which increase to speeds of 8 m/s at 6pm. This diurnal pattern is true up to 40m. At heights of 50m and higher the pattern may be inverted with stronger winds at nighttime. The wind shear analysis by month reveals instances in July and September when the calculated surface roughness is zero. The month with the highest roughness is in January which is also the month that has the highest mean wind speeds and power law exponent.




| Month | Time Steps | Mean Wind Speed (m/s) | | | Best-Fit | |
|---|---|---|---|---|---|---|
| | | Speed 30 m A | Speed 30 m B | Speed 20 m | Power Law Exp | Surface Roughness (m) |
| Jan | 2,830 | 10.440 | 10.291 | 9.894 | 0.115 | 0.004031 |
| Feb | 3,178 | 9.101 | 8.996 | 8.708 | 0.095 | 0.000623 |
| Mar | 3,058 | 8.574 | 8.433 | 8.307 | 0.058 | 0.000001 |
| Apr | 3,390 | 9.233 | 9.040 | 8.869 | 0.073 | 0.000029 |
| May | 7,426 | 7.659 | 7.704 | 7.482 | 0.065 | 0.000005 |
| Jun | 6,096 | 5.400 | 5.553 | 5.493 | -0.008 | |
| Jul | 4,464 | 5.352 | 5.386 | 5.295 | 0.034 | 0.000000 |
| Aug | 4,464 | 6.418 | 6.435 | 6.250 | 0.069 | 0.000011 |
| Sep | 4,320 | 7.694 | 7.584 | 7.527 | 0.037 | 0.000000 |
| Oct | 4,291 | 7.978 | 7.851 | 7.703 | 0.067 | 0.000008 |
| Nov | 3,599 | 8.095 | 7.850 | 7.763 | 0.066 | 0.000006 |
| Dec | 3,416 | 8.442 | 8.417 | 8.212 | 0.064 | 0.000004 |



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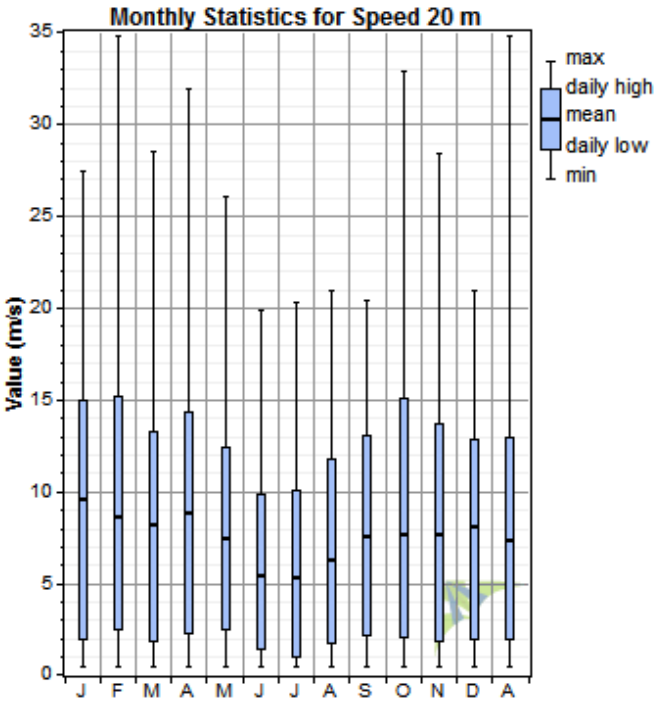
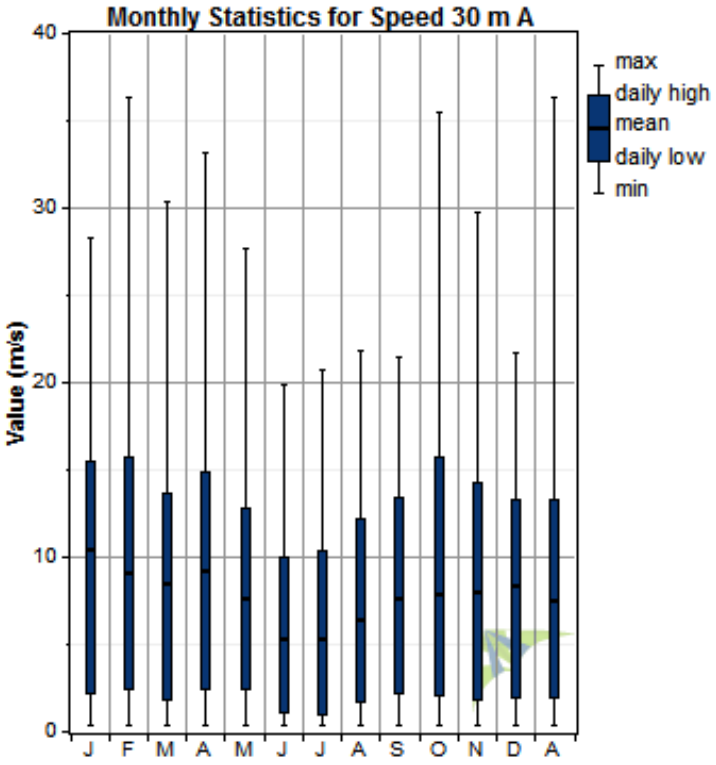
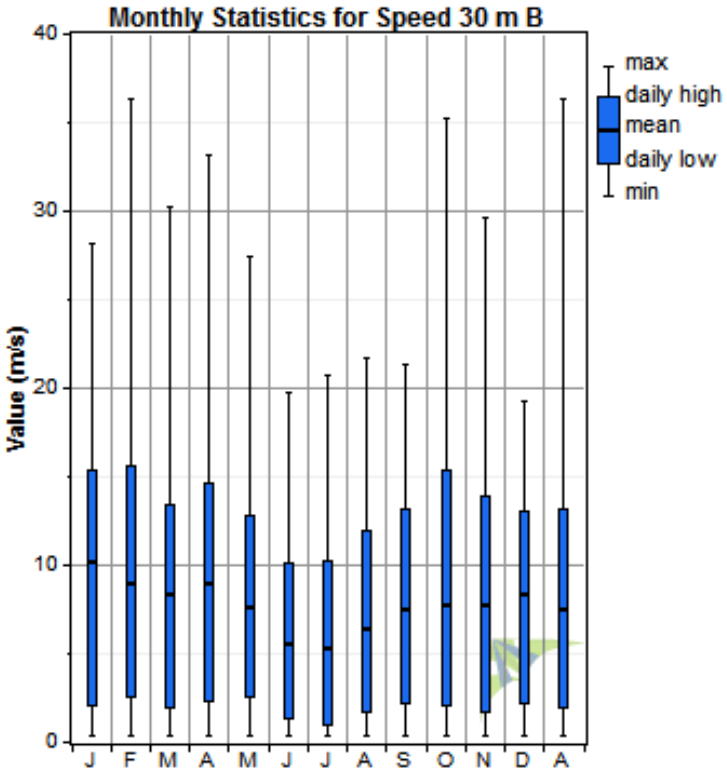
## Wind Speed Data – Analysis Continued

The monthly statistics boxplots for each anemometer indicate the mean, daily high, daily low, maximum, and minimum wind speeds for each month. While the monthly values differ for each anemometer, February had the highest recorded wind speed of approximately 37 m/s. October had the second highest recorded wind event of approximately 33 m/s, however January had the highest recorded mean wind speeds of approximately 10 m/s.



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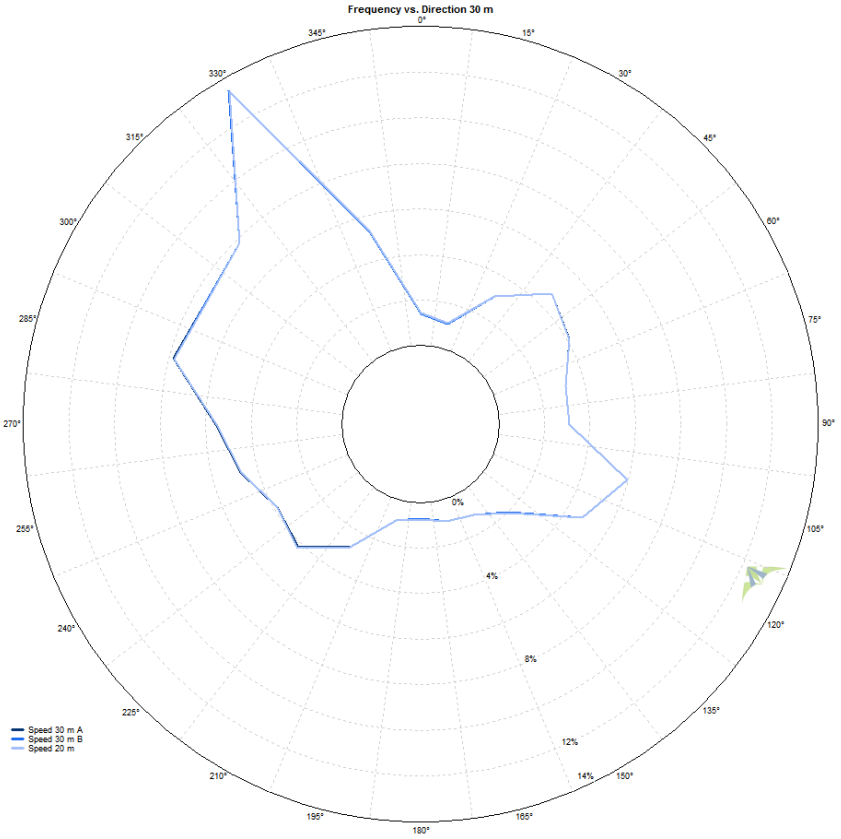
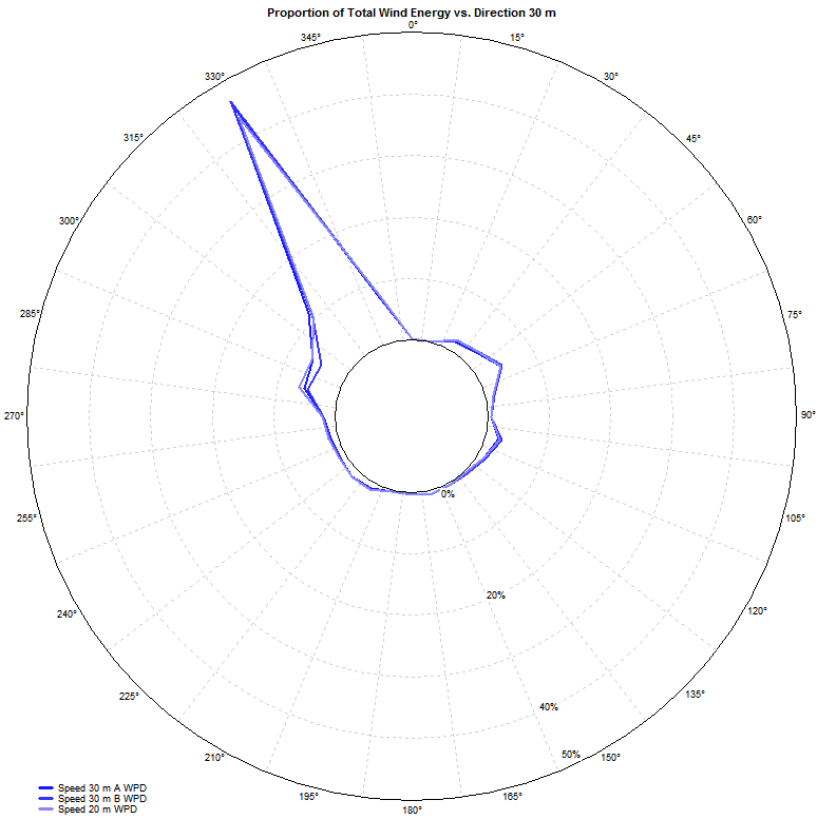
# Wind Direction and Energy Production




A wind frequency rose shows the percent of the time that the wind blows from each direction, while the wind power roses show the percent of total power that is available in the wind from each direction. The annual wind direction rose shows that the primary winds are in the northwest and west directions.




The wind energy rose shows the proportion of energy generated by the wind from each direction. The annual wind energy rose shows that most wind power available is generated from the northwest. Almost 50% of the total wind energy is generated from 330°.



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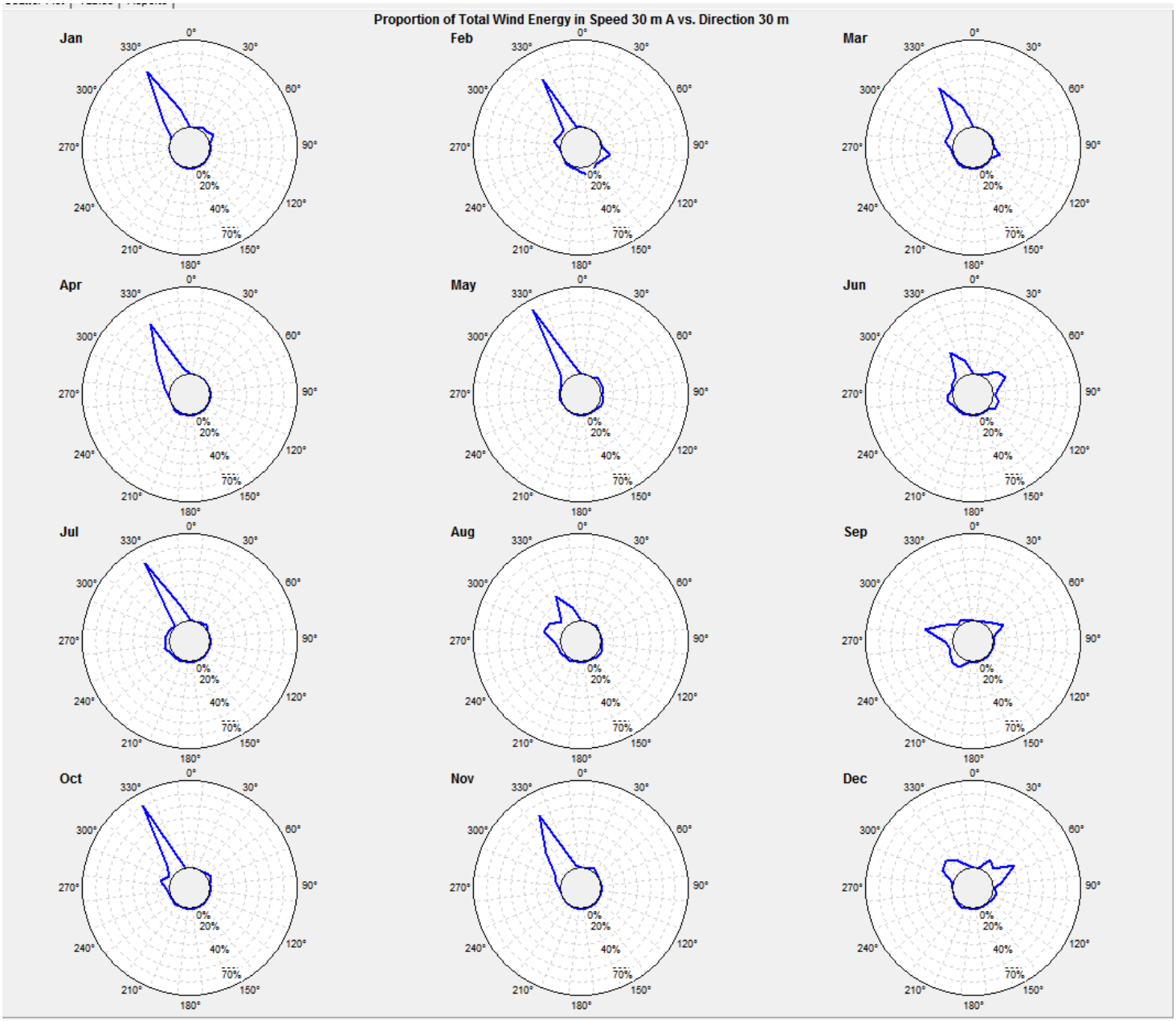
## Wind Direction and Energy Production Continued

The monthly wind energy charts show that for the majority of the year most of the wind energy is generated from 330°. June and August show more varied wind directions than the other months, however the primary direction is still from 330°. September and December also show a greater variation with primary winds coming from 315° and 60° respectively.



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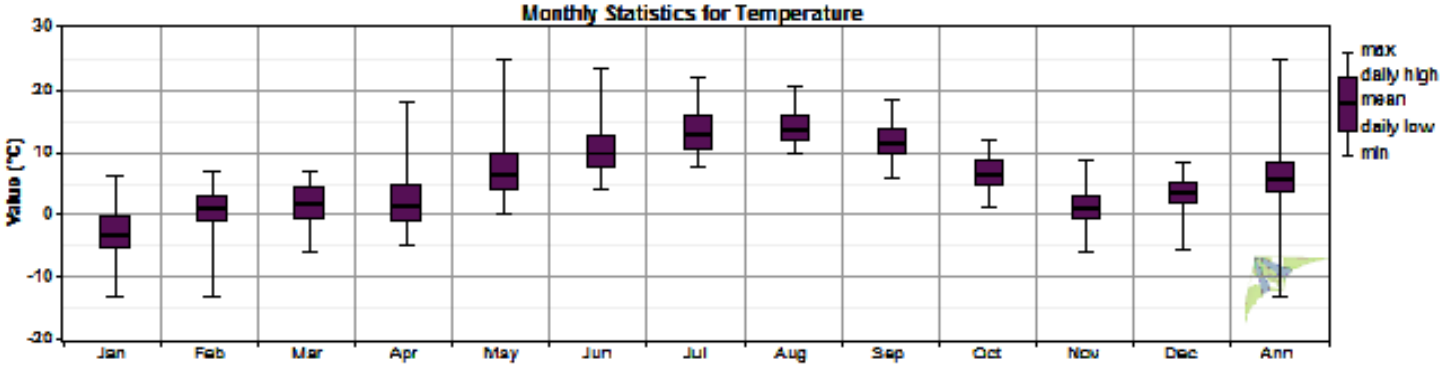
## Temperature

Temperature was measured over the entire monitoring period. A box plot of the monthly averages with each month's maximum and minimum can be found below. The mean for the 13 months of observation was 5.78°C (42.4°F). The mean air pressure is 99.56 kPa and the mean air density is 1.244 kg/m$^3$, which is 1.05% denser than the standard of 1.225 kg/m$^3$.




## Extreme Winds

The 50 year wind extreme ($V_{ref}$) was calculated using the 10 minute mean wind speed. Three different algorithms were used to calculate the $V_{ref}$, the Periodic Maxima (using 1 month maximums), the Method of independent Storms, and the European Wind Turbine Standards II (EWTS II) algorithm. The resulting $V_{ref}$ for each algorithm can be found in the table below. This would require an IEC Class I wind turbine. It is important to note that extreme winds are best calculated using multiple years' worth of data. Continued monitoring of wind sites is recommended to calculate more accurate extreme winds.

| Method | Vref (50 yr) (m/s) |
|---|---|
| Periodic Maxima | 60.297 |
| Method of Independent Storms | 39.272 |
| EWTS II (Exact) | 47.150 |
| EWTS II (Gumbel) | 47.707 |
| EWTS II (Davenport) | 50.966 |

| IEC Wind Turbine Classes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wind Speed Parameters for Wind Turbine Classes | | | | | | | | |
| | I | II | III | IV | | | | |
| Reference Wind Speed, $U_{ref}$ (m/s) | 50 | 42.5 | 37.5 | 30 | | | | |
| Annual Average Wind Speed $U_{ave}$ (m/s) | 10 | 8.5 | 7.5 | 6 | | | | |
| 50-year Return Gust Speed, 1.4 $U_{ref}$ (m/s) | 70 | 59.5 | 52.5 | 42 | | | | |
| 1-year Return Gust Speed, 1.05 $U_{ref}$ (m/s) | 52.5 | 44.6 | 39.4 | 31.5 | | | | |
| Notes: 10-minute averages, hub height wind speed. Air density: 1.225 kg/m3. | | | | | | | | |
| Turbulence Intensity Classes | I | | II | | III | | III | IV |
| | A | B | A | B | A | B | A | B |
| $I_{15}$ (Turbulence Intensity at 15 m/s) | 18% | 16% | 18% | 16% | 18% | 16% | 18% | 16% |
| a | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| $I_u$ (Turbulence Intensity) | 0.210 | 0.180 | 0.226 | 0.191 | 0.240 | 0.200 | 0.270 | 0.220 |
| $I_u$ (Turbulence Intensity) = $I_{15}(a=15/U_{ave})/(a+1)$ | | | | | | | | |
| Source: IEC 61400-1; cited in Wind Energy Handbook, Tony Burton, et al, John Wiley & Sons UK), 2001, ISBN: 0-471-48997-2, p. 210. | | | | | | | | |
| Caution: Verify with current IEC 61400-1 for all parameters and criteria. | | | | | | | | |



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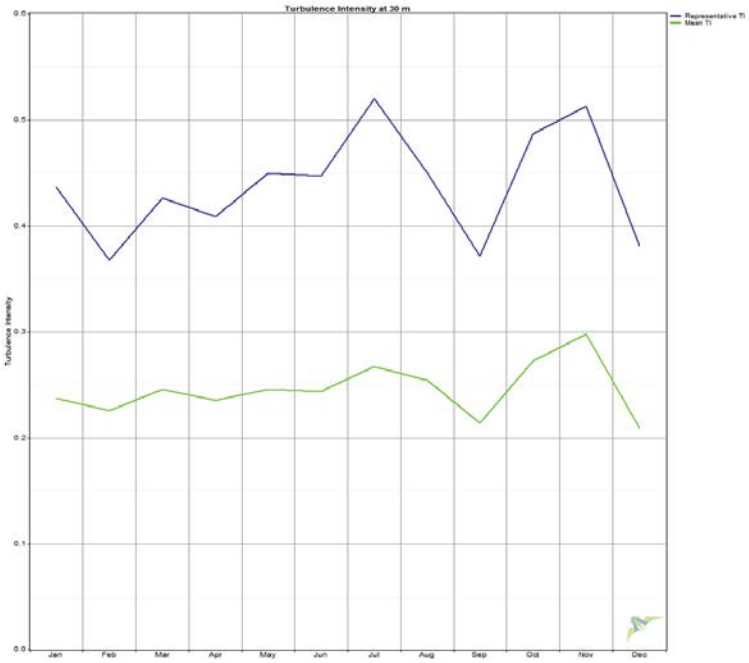
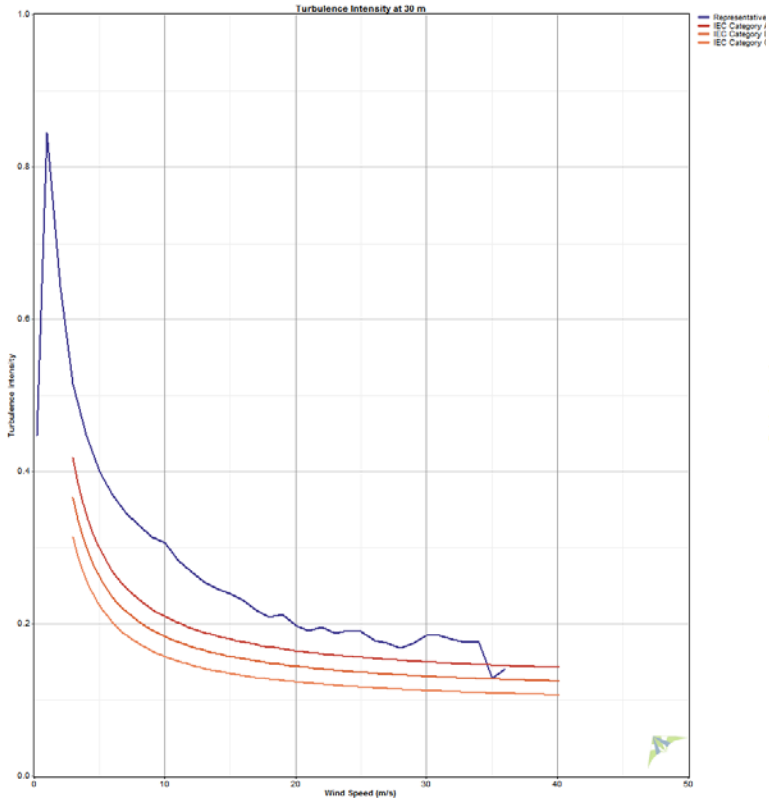
# Wind Turbulence

Analysis of the turbulence intensity (TI) indicated that the met tower was in a location that exceeds IEC standard 61200-1 3rd ed. (IEC3) turbulence category A. It would be difficult to find a manufacturer that would allow their turbine to be sited here; AEA does not recommend development of this site.

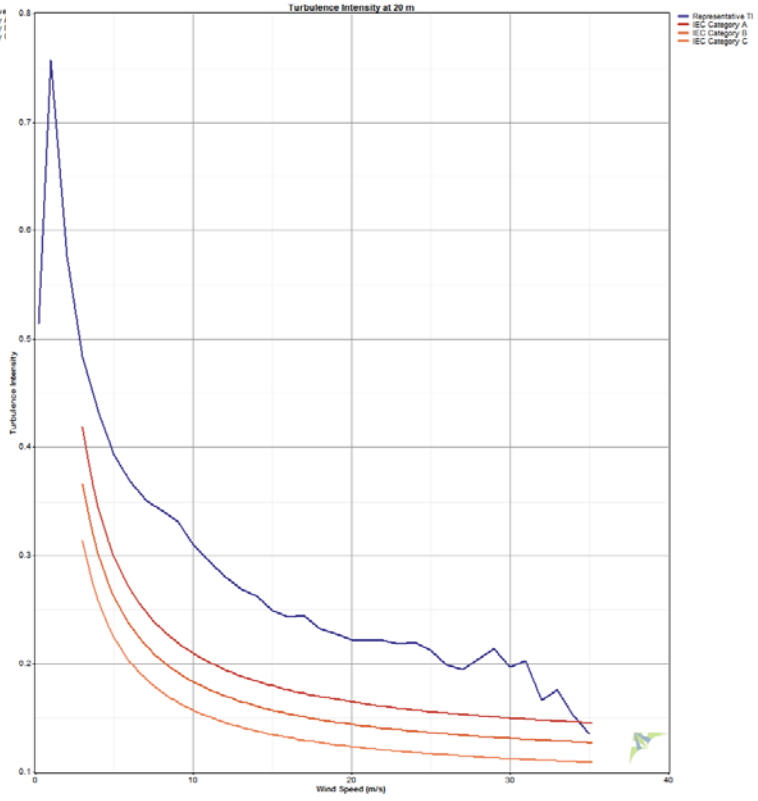
| Quantity | Value |
|---|---|
| Data points in 15 m/s bin | 928 |
| Mean TI at 15 m/s | 0.17 |
| Representative TI at 15 m/s | 0.24 |
| IEC3 turbulence category | S |




*30m Turbulence Intensity by Month*




*30m Turbulence Intensity and Wind Speed*




*20m Turbulence Intensity and Wind Speed*



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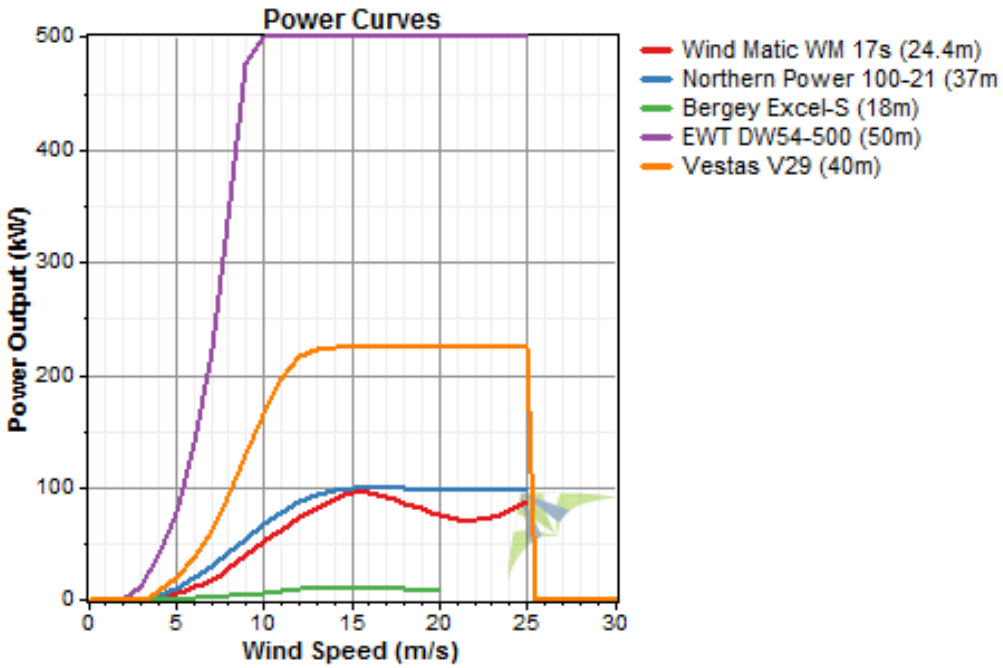
## Estimated Turbine Outputs

Five wind turbines were used in the comparison of the estimated wind turbine output. The wind turbines were selected because of their previous success in Alaska. In order to calculate the outputs at the individual turbine hub heights, Windographer used synthesized wind speed data calculated from the wind shear value for each time step in the data set. The resulting outputs can be found below. The power curves for each of the 5 compared turbines can also be found below. The net capacity factor assumes total turbine losses of availability, icing, array effects and other factors to be 18 percent. Thus, the net CF is 82% of the gross CF.

| Turbine | Valid Time Steps | Hub Height Wind Speed (m/s) | Percentage Of Time At Zero Power | Percentage Of Time At Rated Power | Simple Mean Net Power (kW) | Simple Mean Net AEP (kWh/yr) | Simple Mean NCF (%) | Mean of Monthly Means Net Power (kW) | Mean of Monthly Means Net AEP (kWh/yr) | Mean of Monthly Means NCF (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Wind Matic WM 17s (24.4m) | 50,825 | 7.43 | 16.37 | 2.93 | 23.1 | 202,732 | 24.36 | 23.5 | 205,939 | 24.75 |
| Northern Power 100-21 (37m) | 50,825 | 7.69 | 10.50 | 6.77 | 31.1 | 272,507 | 31.11 | 31.6 | 276,626 | 31.58 |
| Bergey Excel-S (18m) | 50,825 | 7.26 | 11.65 | 7.63 | 2.7 | 23,537 | 26.87 | 2.7 | 23,944 | 27.33 |
| EWT DW54-500 (50m) | 50,825 | 7.88 | 10.65 | 26.86 | 205.0 | 1,796,078 | 41.01 | 208.1 | 1,822,549 | 41.61 |
| Vestas V29 (40m) | 50,825 | 7.74 | 10.47 | 9.70 | 71.8 | 628,830 | 31.90 | 72.9 | 638,456 | 32.39 |



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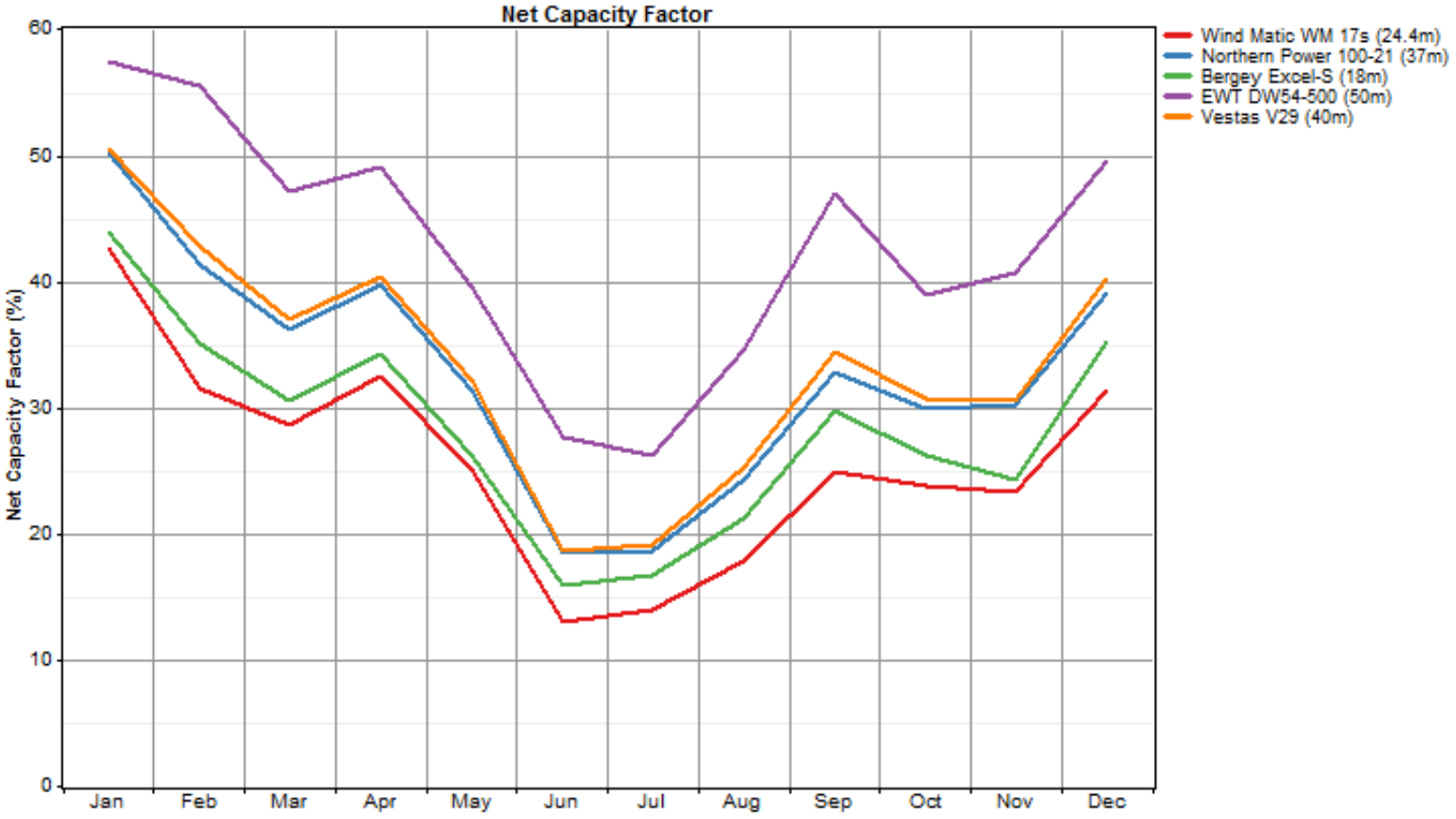
## Estimated Turbine Outputs Continued

The net capacity factor graph shows the estimated monthly capacity factor of each of the 5 compared turbines.



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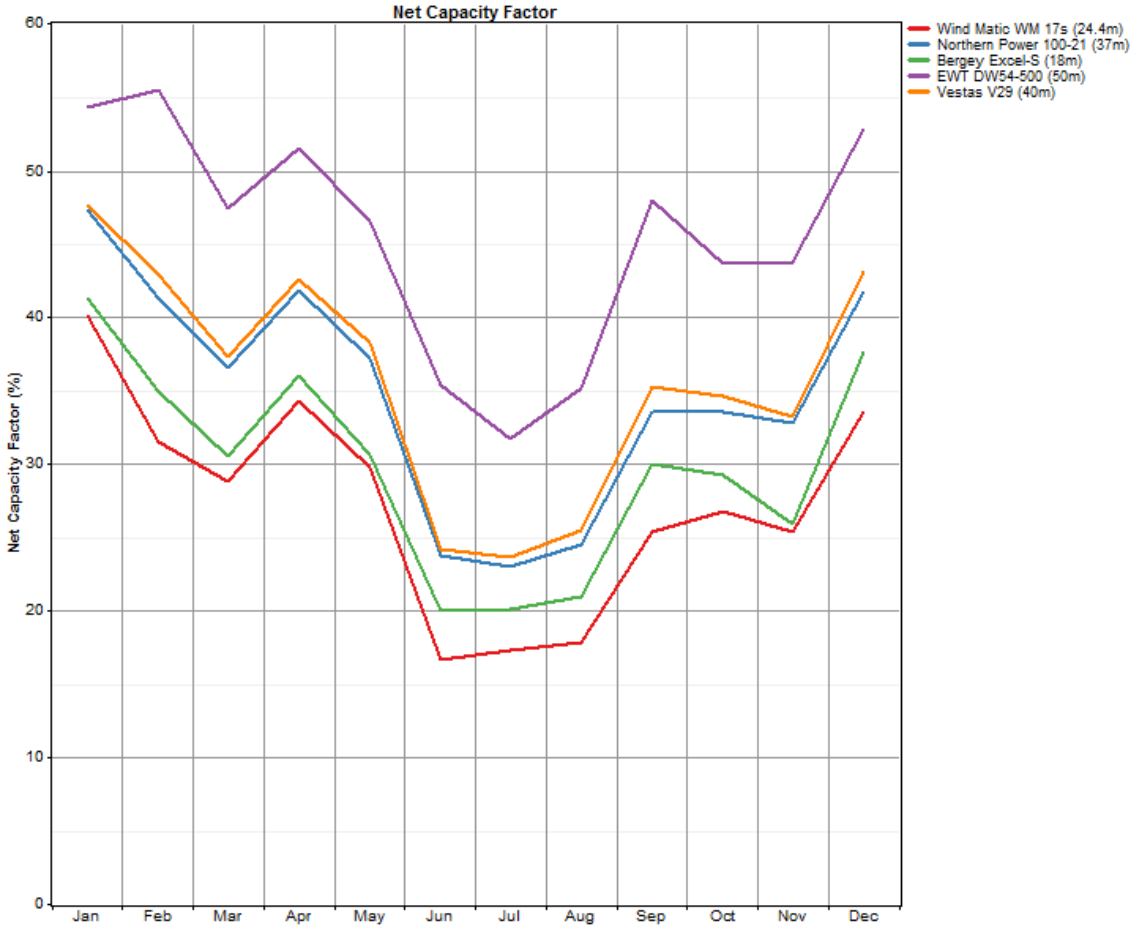
## Estimated Turbine Outputs Continued

The output for the five turbines was estimated again using the synthesized data. This allows for a comparison between the outputs with icing and without icing. The same turbines and conditions were used in each estimate. It can be noted that the net capacity factors for the synthesized data is slightly higher than the net capacity factors of the flagged data. While the percentage of time a zero power is lower for the synthesized data than that of the flagged data.

| Turbine | Valid Time Steps | Hub Height Wind Speed (m/s) | Percentage Of Time At Zero Power | Percentage Of Time At Rated Power | Simple Mean Net Power (kW) | Simple Mean Net AEP (kWh/yr) | Simple Mean NCF (%) | Mean of Monthly Means Net Power (kW) | Mean of Monthly Means Net AEP (kWh/yr) | Mean of Monthly Means NCF (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Wind Matic WM 17s (24.4m) | 43,731 | 7.95 | 12.45 | 3.38 | 25.6 | 224,576 | 26.99 | 25.5 | 223,695 | 26.88 |
| Northern Power 100-21 (37m) | 43,731 | 8.26 | 8.04 | 7.84 | 34.4 | 301,548 | 34.42 | 34.3 | 300,659 | 34.32 |
| Bergey Excel-S (18m) | 43,731 | 7.73 | 9.60 | 8.61 | 2.9 | 25,792 | 29.44 | 2.9 | 25,753 | 29.40 |
| EWT DW54-500 (50m) | 43,731 | 8.50 | 8.15 | 30.53 | 225.7 | 1,977,000 | 45.14 | 225.4 | 1,974,635 | 45.08 |
| Vestas V29 (40m) | 43,731 | 8.32 | 7.99 | 11.20 | 79.6 | 697,205 | 35.37 | 79.3 | 695,086 | 35.27 |



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## Summary

The met tower in King Cove, Alaska measured average wind speeds of 7.595 m/s at a 30 meter height. The winds measured at this site generated a wind power density of 842 W/$m^2$ at 50 meters, making this site a wind class 7. The extreme winds calculated would require an IEC Class 1 turbine. Low levels of icing were observed on the instrumentation at this site. However, the location experiences turbulence higher than an IEC Class A. AEA does not recommend building at this location.

The 13 month study revealed a wind class that was higher than predicted with the wind resource map. Because the wind class is so high at the tower location King Cove, AEA recommends additional reconnaissance work using multiple 10-meter meteorological towers to find the optimal site for a wind turbine and to further verify the wind resource model.



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