**Results of Wind Monitoring at Sand Point**
**24 June, 2009**

## Report Outline

Project Overview/Summary of Results
Project Location
Project Instrumentation
Discussion of Wind Resource
Appendix

## Project Overview/Summary of Results

As part of the NREL Native American Anemometer Loan Program an anemometers was installed near Sand Point, Alaska to assess the area's wind energy potential. This report describes the wind resource measured at this location. The monitoring period ran from 14 February 2004 to 6 July 2005.

The measured average power density and wind speed, measured at 20m (66ft), are 424 W/m$^2$ and 6.7 m/s (14.9 mph) respectively. This is consistent with the resource indicated by publically available wind maps. For example, the 3Tier wind map (Figure 4) (http://firstlook.3tiergroup.com/) estimates the average wind speed at the site (@ 20m AGL) at between 5.9 and 10.6 m/s. (13.1 mph – 23.6 mph)

The wind data for this site was processed using three different software packages. The first is a package, referred to as the NREL Package" that has been developed at NREL for internal use. The advantage of this software package it that it provides values for the power density. The values provided by this package will be used in the main body of the report. The next package, WindPro, has been the software used to provide the interim plots during the monitoring period. Windpro provides the capability to exclude zero's (for wind speed) when calculating the average wind speed and the analyzing the wind speed distribution. Finally, Windographer provides nice rose plots of both frequency versus wind direction and relative energy versus wind direction. The values provided by the NREL package will be used in the main body of the report, but occasionally, the Windpro and Windographer values will be provided as well. The Windpro plots are provided in the back of this report.

## Project Location

The monitoring site is located just north of Sand Point, AK (N 55.34567 °, W 160.48832 °) at an elevation of 52m (170 ft). See Figure 1 through Figure 3. Figure 1 and Figure 2 also show the location of the reference site which provides long term wind data. This can be used to determine how closely the collected data matches the long term mean wind resource.

## Project Instrumentation

The instrumentation consisted of an NRG Wind Explorer system. This included a cup anemometer, wind vane and data logger. The instruments were mounted at a height of 20m (66ft) on a tilt-up tubular tower. The collected data consisted of 10-minute average wind speed, including wind speed standard deviation and wind direction.

**Figure 1:** Project Location (Regional)

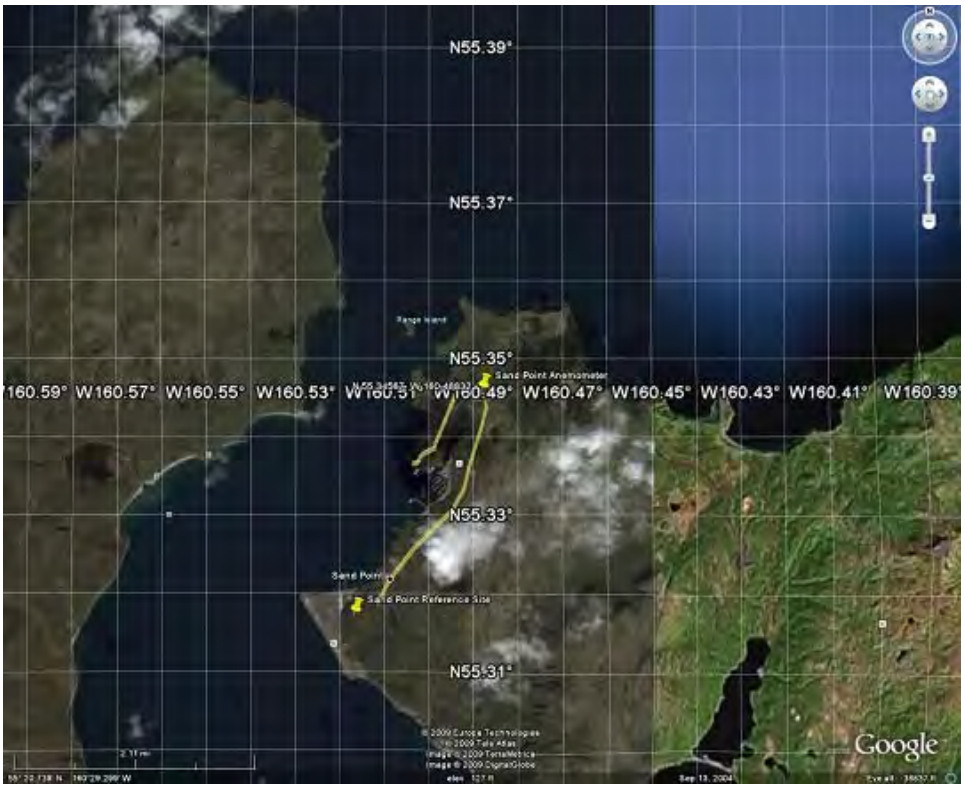


**Figure 2:** Project Location (Mid Scale)


**Figure 3:** Project Location (Close Up)

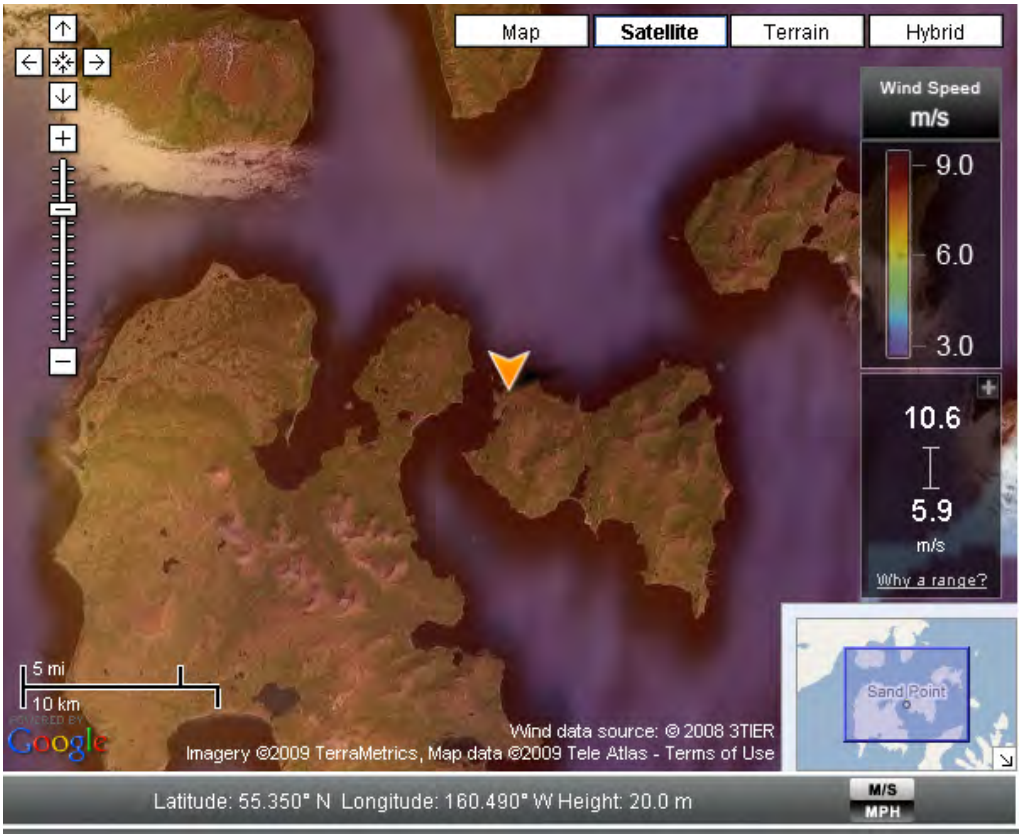



**Figure 4:** 3Tier Wind Map **(**Source: http://firstlook.3tiergroup.com/**)**

**Discussion of Wind Resource**

Figure 5 summarizes the collected wind data.

The values for the 50-meter wind speed and power density are conservative estimates using a wind shear factor of 0.15. The shear could well be higher in which case the average wind speed and power density (@ 50m AGL) will be higher.

| | Average Wind Speed (m/s) | Average Power Density (W/m^2) |
|---|---|---|
| Average Annual Wind Speed & power density | 6.7 m/s (14.9 mph) | 424 W/m$^2$ |
| Average wind speed & power density for best month (December) | 8.2 m/s (18.2 mph) | 694 W/m$^2$ |
| Average wind speed & power density for worst month (July) | 4.2 m/s (9.3 mph) | 101 W/m$^2$ |
| | | |
| Estimated Resource @ 50 meters | 7.6 m/s (16.9 mph) | 640 W/m$^2$ |

**Figure 5:** Wind Data Summary

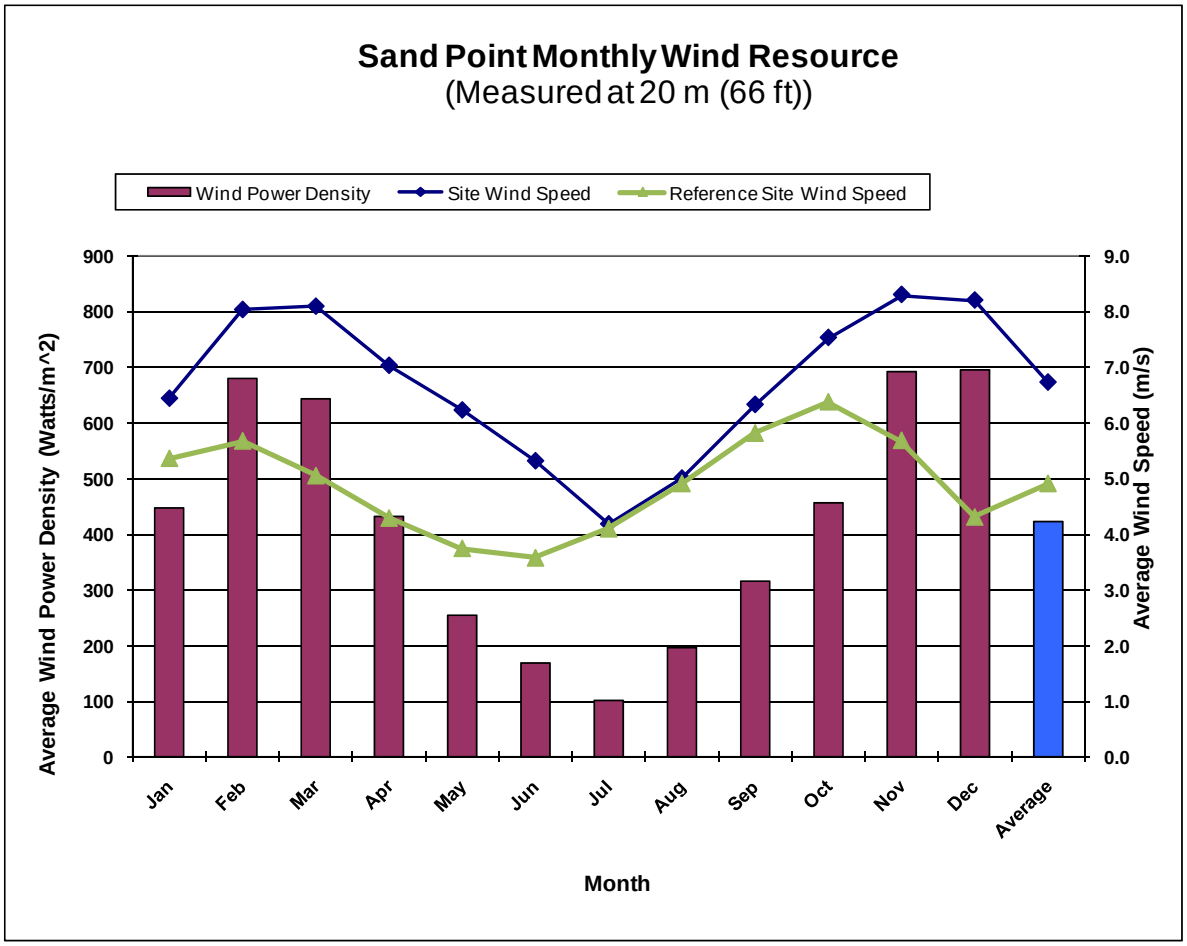



**Figure 6:** Monthly average and annual average wind power density and wind speed.

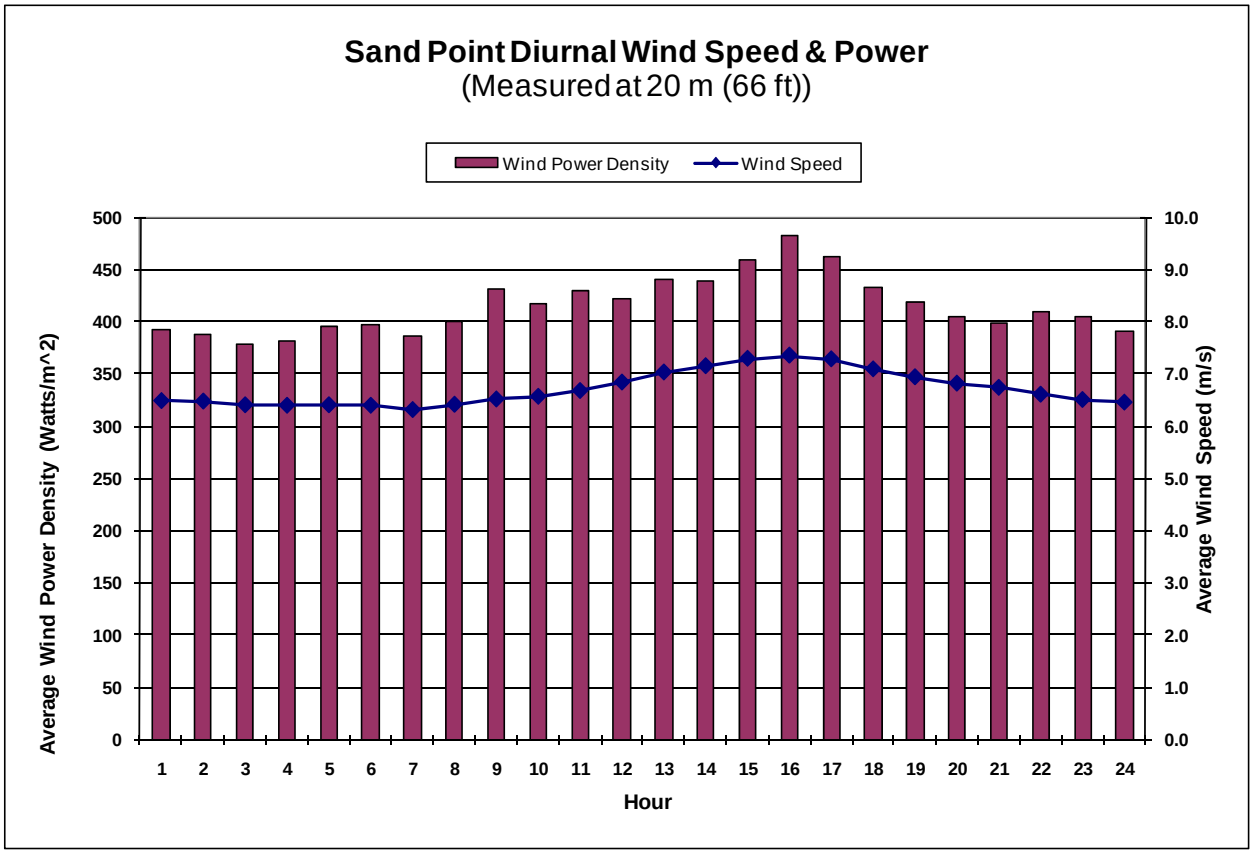


**Figure 7:** Average annual daily wind profile.

**Speed and Power by Month**

Figure 6 shows the monthly and annual average wind power density. The measured annual average power density is 424 W/m$^2$. The measured annual average wind speed is 6.7 m/s (14.9 mph). The winter months have the greatest wind resource while the early summer has the lowest wind resource. The wind resource at this site is extremely seasonal, with the average wind speed varying by a factor of two between the summer and winter and the average power density varying by a factor four. Figure 6 also shows the long term monthly average wind speeds for the reference site. This data usually gives a better indication of how the wind resource varies by season than does the collected data. In this case the measured data broadly follows the pattern of the reference site data. Compared to the long term data, the monitoring period data shows a more pronounced difference between the summer and winter wind speeds. Both the measured data and the reference data show a mid-winter dip in the monthly average wind speeds. For the measured data this dip occurs in January compared to December for the reference data. Finally, the lowest wind speed month in the collected data is July, compared to June for the reference site data.

**Speed and Power by Hour**

Figure 7 shows the annual average diurnal (daily) profile for the site. In general the winds are highest in the mid afternoon and weakest in the very early morning. (See Appendix B for monthly profiles). Compared to most other sites examined by this author, the diurnal profile at this site is weak. Be advised it is very possible that the diurnal profile may shift with increasing height.

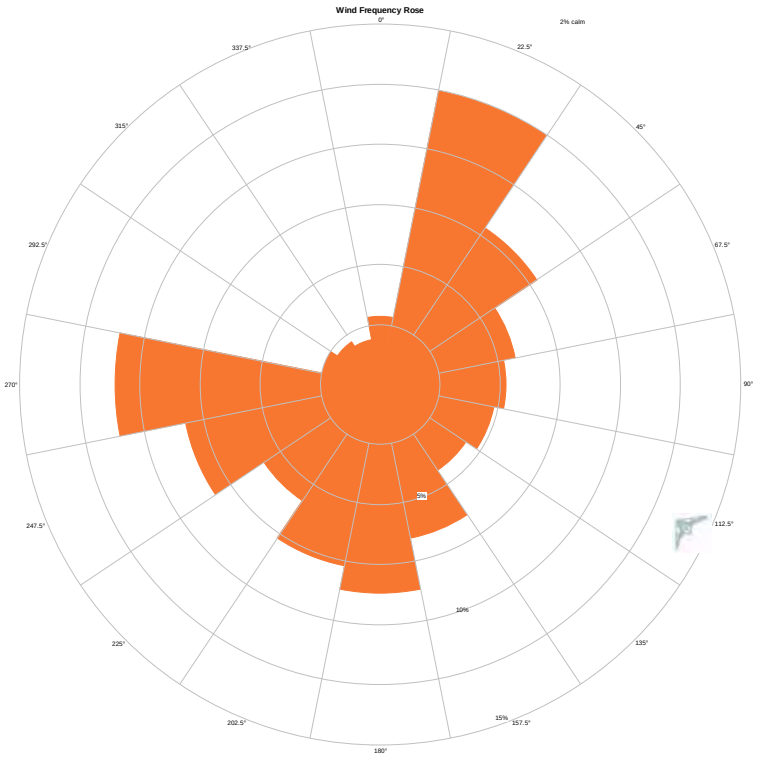



**Figure 8A:** Frequency by direction.

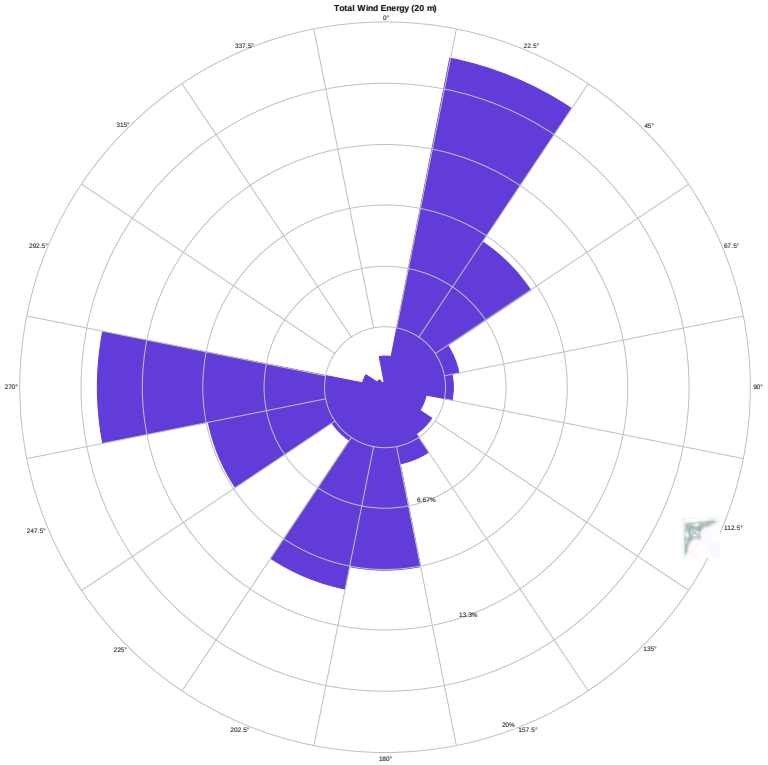



**Figure 8B:** Energy by direction.

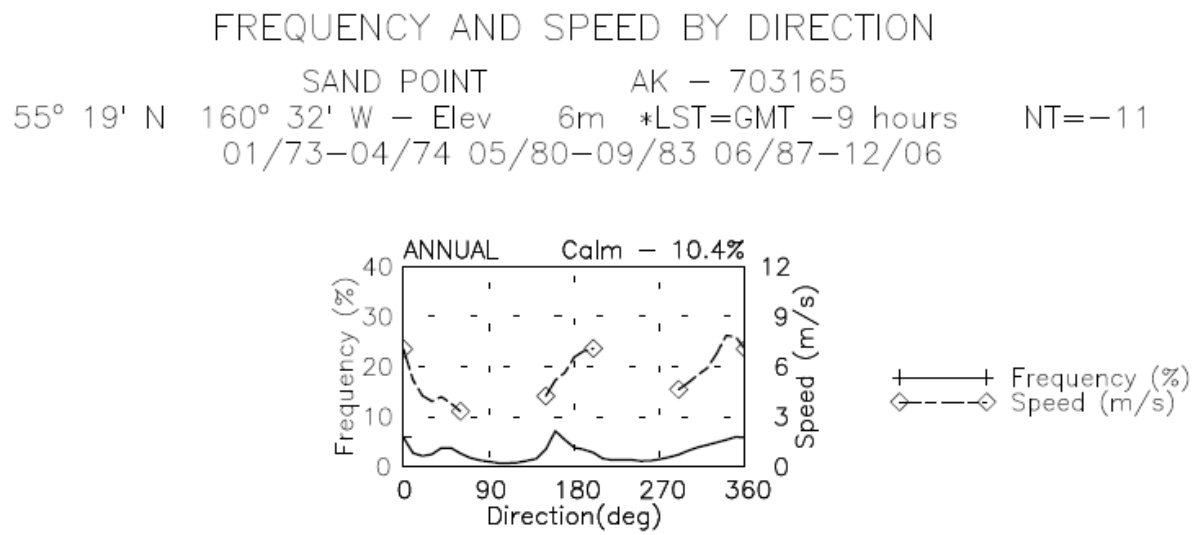



**Figure 8C:** Reference Site frequency and mean wind speed by direction

**Frequency and Speed by Direction**
Both Figure 8A and 8B show the prevailing & energetic winds coming from the NNE and the west. The most energetic winds come from NNE, with secondary peaks from the west and SSW. However, Figure 8C, which shows the frequency and mean wind speed rose for the long term reference site data, indicates that a significant portion of the winds come from the quadrant 270 – 360 degrees, (west – north). The lack of wind from this quadrant in the measured wind data is noteworthy to the NREL meteorologist who reviewed this report. A possible explanation for this observation is that the anemometer had poor exposure (for whatever reason) to the winds coming from this direction.

**Frequency of Speed and Percent of Power by Speed**
Figure 9 shows the annual frequency distribution of wind speed and power density. The line labeled PCTs shows the fraction of time that the wind falls within the specified bin. The line labeled PCTp shows the fraction of total annual energy contributed by winds of the indicated wind speed bin. On an annual basis, while over half of the time the wind speed is between 2 m/s and 9 m/s (61%), most of the wind energy is from winds with wind speeds from 7 to 15 m/s (64%). (See Appendix B).

The percentage of calms, 4.9%, while low, is a bit high for such a high wind speed site such as this one. This could be due to the strong seasonal wind profile of this site, with very strong fall, winter, & spring winds and light summer winds.

The best fit weibull distribution parameters for the measured data are k = 1.8 and c = 7.6. The k value indicates how widely the winds are distributed. The weibull k value of this site, at less than 2, is more typical of a continental inland site, than a coastal site such as this one. A possible explanation for the unusually low Weibull is the strong seasonal wind profile at this site.

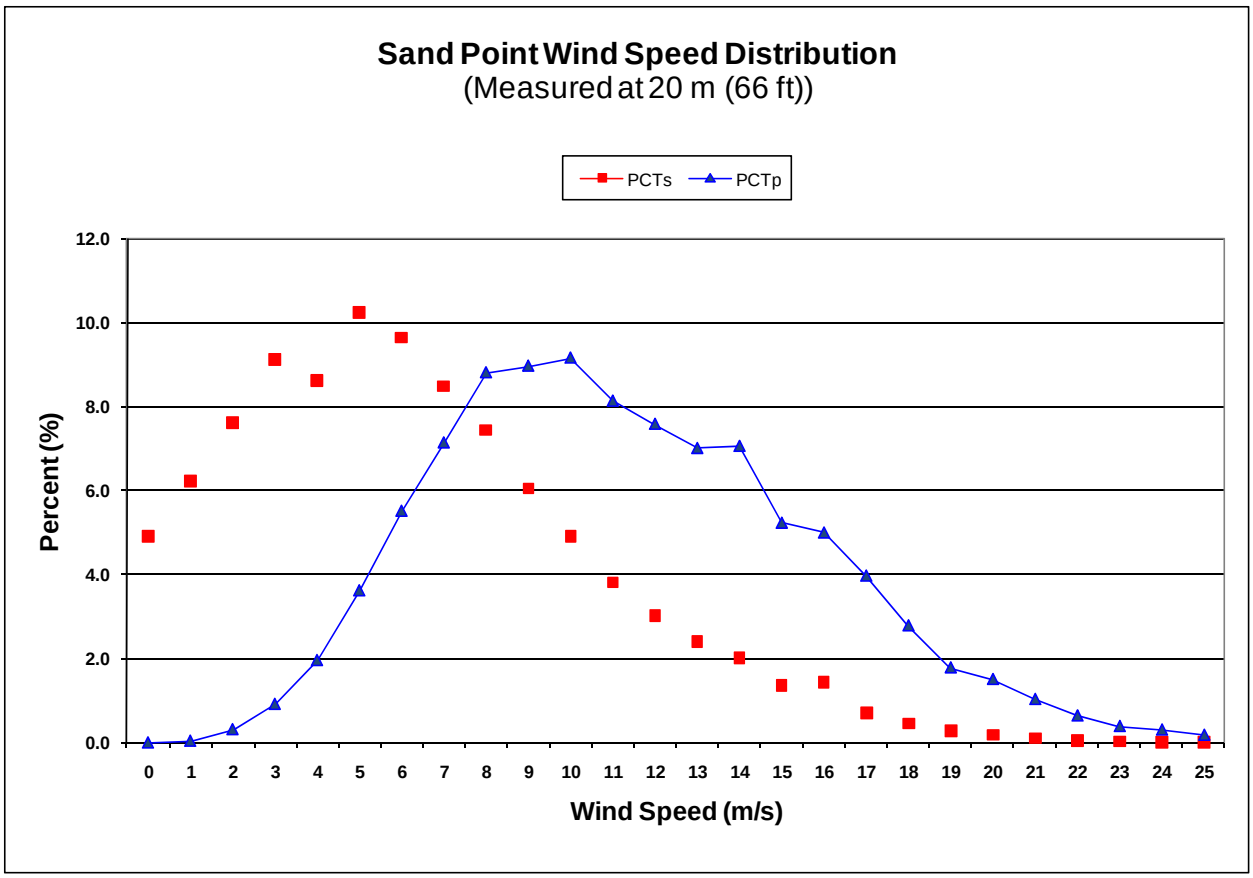



**Figure 9:** Annual wind and wind energy distribution.

**Comparison of anemometer data with long term average data**

An important consideration is the closeness with which the measured data reflects the long-term (multi-year) average wind resource. In other words, does the monitoring period data reflect a good year, a bad year or an average year? To answer this question long term data from a nearby reference site, Sand Point, was examined. For this site the multi year average wind speed was compared to the wind speed during the monitoring period. The results are given in the table and graph below.

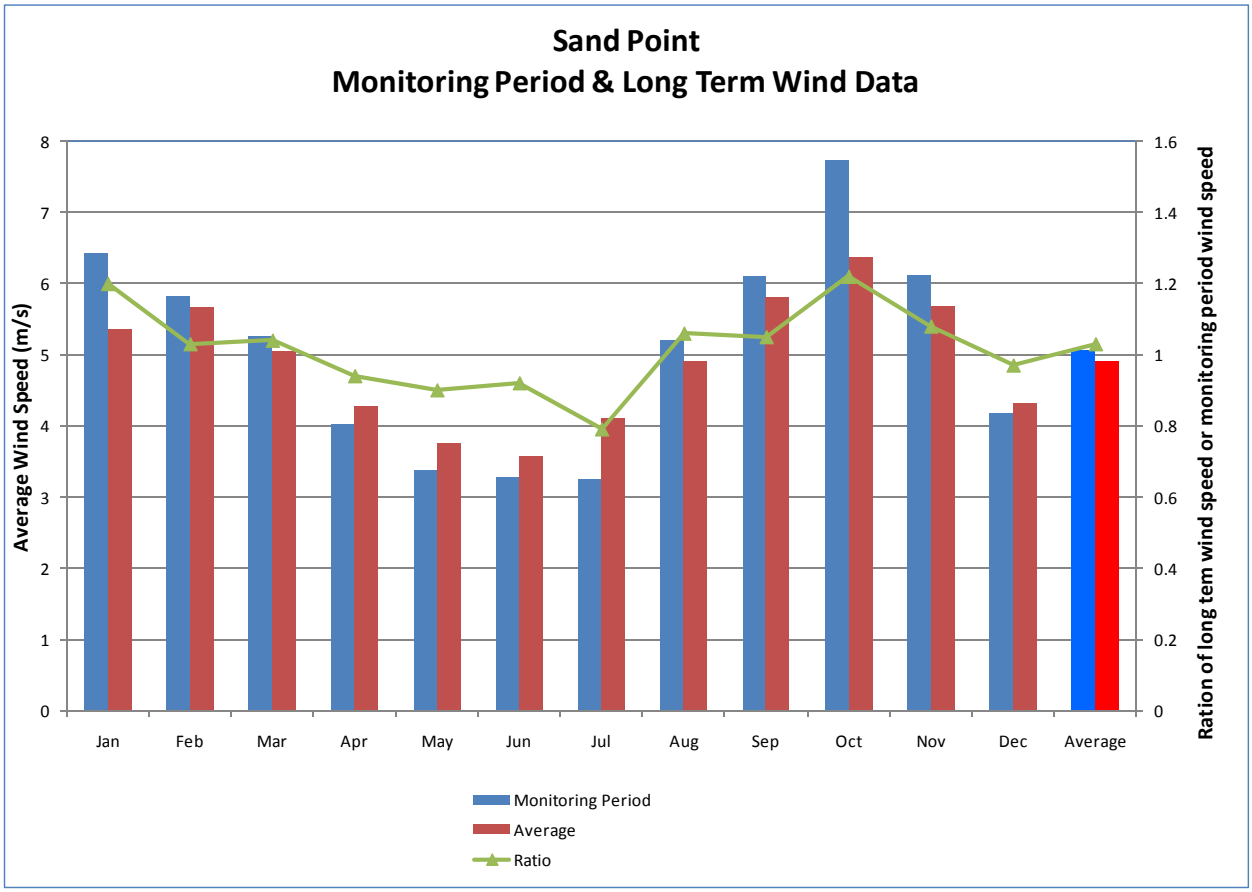



**Figure 11:** Comparison of long term data with monitoring period data

Figure 11 and Figure 12 show the monitoring period average wind speed compared to the long-term mean wind speed at the reference site. The data shows that during the monitoring period winds were higher than normal in the fall and winter and lower than normal in the spring and summer. The ratio of 1.03 indicates that overall, the monitoring period wind speeds at the reference station were slightly higher than the long-term mean wind speeds, however the difference is small (< 5%) This gives evidence that in general, the winds during the monitoring period are representative of the long term mean wind resource.

| | Lat | Long | Monitoring Period | Long Term | Ratio |
|---|---|---|---|---|---|
| Sand Point | 55.32 | 160.53 | 5.06 | 4.91 | 1.03 |
| Monitoring Site | 55.35 | 160.49 | | | |

**Figure 12:** Long term versus monitoring period wind data for reference stations.

**Appendix A: Wind Data in Tabular Form**

**Table A1:** Monthly average and annual average wind power density and wind speed.

| Month | Wind Speed (monitoring site) (m/s) | Wind Power (monitoring site) (W/m^2) | Wind Speed (Reference Site) (Long Term) (m/s) |
|---|---|---|---|
| Jan | 6.4 | 448 | 5.4 |
| Feb | 8.0 | 681 | 5.7 |
| Mar | 8.1 | 642 | 5.1 |
| Apr | 7.0 | 431 | 4.3 |
| May | 6.2 | 256 | 3.8 |
| Jun | 5.3 | 170 | 3.6 |
| Jul | 4.2 | 101 | 4.1 |
| Aug | 5.0 | 198 | 4.9 |
| Sep | 6.3 | 316 | 5.8 |
| Oct | 7.5 | 458 | 6.4 |
| Nov | 8.3 | 692 | 5.7 |
| Dec | 8.2 | 694 | 4.3 |
| Average | 6.7 | 424 | 4.9 |

**Table A2:** Average annual daily wind profile.

| Hour | Wind Speed (m/s) | Wind Power (W/m^2) |
|---|---|---|
| 1 | 6.5 | 393 |
| 2 | 6.5 | 388 |
| 3 | 6.4 | 379 |
| 4 | 6.4 | 382 |
| 5 | 6.4 | 395 |
| 6 | 6.4 | 398 |
| 7 | 6.3 | 387 |
| 8 | 6.4 | 401 |
| 9 | 6.5 | 431 |
| 10 | 6.6 | 418 |
| 11 | 6.7 | 429 |
| 12 | 6.8 | 421 |
| 13 | 7.0 | 440 |
| 14 | 7.2 | 439 |
| 15 | 7.3 | 460 |
| 16 | 7.4 | 482 |
| 17 | 7.3 | 462 |
| 18 | 7.1 | 433 |
| 19 | 6.9 | 419 |
| 20 | 6.8 | 406 |
| 21 | 6.7 | 398 |
| 22 | 6.6 | 410 |
| 23 | 6.5 | 404 |
| 24 | 6.5 | 392 |

**Table A3:** Frequency and Energy by direction.

| | F% | %Pwr |
|---|---|---|
| Calm | 4.9 | |
| 22.5 | 11.3 | 19.3 |
| 45 | 7.7 | 9.3 |
| 67.5 | 6.2 | 4.6 |
| 90 | 5.8 | 3.4 |
| 112.5 | 5.2 | 2.2 |
| 135 | 4.6 | 2.5 |
| 157.5 | 6.9 | 4.3 |
| 180 | 8.8 | 9.8 |
| 202.5 | 7.1 | 10.1 |
| 225 | 5.4 | 3.5 |
| 247.5 | 7.5 | 10.6 |
| 270 | 10.2 | 16.7 |
| 292.5 | 2.3 | 1.3 |
| 315 | 2.0 | 0.4 |
| 337.5 | 1.7 | 0.3 |
| 360 | 2.6 | 1.6 |

**Table A4:** Annual wind and wind energy distribution.

| Wind Speed (m/s) | PCTs | PCTp |
|---|---|---|
| 0 | 4.9 | 0.0 |
| 1 | 6.2 | 0.0 |
| 2 | 7.6 | 0.3 |
| 3 | 9.1 | 0.9 |
| 4 | 8.6 | 2.0 |
| 5 | 10.3 | 3.6 |
| 6 | 9.6 | 5.5 |
| 7 | 8.5 | 7.1 |
| 8 | 7.4 | 8.8 |
| 9 | 6.1 | 9.0 |
| 10 | 4.9 | 9.2 |
| 11 | 3.8 | 8.1 |
| 12 | 3.0 | 7.6 |
| 13 | 2.4 | 7.0 |
| 14 | 2.0 | 7.1 |
| 15 | 1.4 | 5.2 |
| 16 | 1.5 | 5.0 |
| 17 | 0.7 | 4.0 |
| 18 | 0.4 | 2.8 |
| 19 | 0.3 | 1.8 |
| 20 | 0.2 | 1.5 |
| 21 | 0.1 | 1.0 |
| 22 | 0.1 | 0.6 |
| 23 | 0.0 | 0.4 |
| 24 | 0.0 | 0.3 |
| 25 | 0.0 | 0.2 |

## Appendix B: Interpretation of the Wind Data Charts

### Introduction

This appendix is a guide to interpreting the wind data charts included in the report. Included are background information and an explanation of the meaning of the data in each chart.

The annual results given in the charts in this appendix will differ somewhat from the results given in the charts in the main body of the report. This is due to differences in how the data is processed. This is best described by using an example. Let us assume that 15 months of data was collected from a site, with the monitoring period running from 1 January 2003 to 31 March 2004. The annual average numbers given in the appendix simply provide the average of all the data collected. However this double counts the months of January, February & March. If these months tend to be windier than the rest of the year, then the wind resource will be over estimated.

The proper procedure is to average together the data from the double counted months before averaging the data to create annual averages. This is what has been done for the charts in the main body of the report.

The reason the software does not do this is that it was really designed to process multiyear data. If 9.5 years of data are processed, having 10 Januarys and 9 Julys creates negligible error. However, with only a little over a year of data, the double counted months can cause noticeable error.

### Power Density versus Wind Speed

Wind turbines convert the kinetic energy of moving air into useful mechanical or electrical energy. The power of a column of moving air is given by the equation below.

$$P = 0.5\rho A v^3 \qquad \text{(Equation B - 1)}$$

Where

| | | |
|---|---|---|
| $P$ | = | power in a column of air (watts) |
| $\rho$ | = | density of air ($kg/m^3$) (Roughly ~ 1 $kg/m^3$) |
| $A$ | = | cross sectional area of the column of air ($m^2$) |
| $v$ | = | velocity of the air (m/s) |

Thus the power a wind turbine can extract from the wind is proportional to the cross sectional area of the rotor, the density of the air, and the cube of the wind velocity. At a given location the air density typically doesn't change by more than 10%. Therefore the big variable is the wind speed. Annual average wind turbine production is very sensitive to the annual average wind speed.

A wind turbine cannot extract all the energy from the air stream moving past it. A wind turbine's extraction efficiency typically varies with wind speed. In their range of maximum conversion efficiency most of today's wind turbines extract about 40% - 50 % of the wind's energy.

Power density is simply the power divided by the cross sectional area. Power density is given in units of watts per meter squared. ($watts/m^2$)

$$\text{Power Density} = 0.5\rho v^3 \qquad \text{(Equation B - 2)}$$

The cubic dependence of wind power density upon velocity underscores the importance of accurately characterizing the wind at a given location. A small uncertainty in wind speed translates to a large uncertainty in wind turbine power production. For example a 5% uncertainty in wind speed leads to a 15% uncertainty in power output. The cubic relationship also makes it more difficult to predict the long-term performance of a wind turbine. More information is needed than simply the average wind speed. For example, imagine a location where the wind speed is a constant five meters per second. The average power density of a column of air with a 1m^2 cross section is then 0.5 * 1.0 $kg/m^3$ * 1.0 $m^2$ * 5 $(m/s)^3$ = 62.5 watts. Over a year the total energy of that column would be 547.5 kWh (this is found by multiplying the average power density by the number of hours in a year, then dividing by 1000 to convert to kilowatts). Now imagine a location where half the time the wind speed is 3 m/s and the other

half the time the wind speed is 7 m/s. The average wind speed is still 5 m/s but the average power density is now $0.5*1.0*1.0*(3^3 + 7^3)/2 = 92.5$ watts. This leads to an annual energy of 810 kWh.

Power density is listed in many of the graphs below because power density gives a better indication of wind turbine production than does wind speed alone. As can be seen from the graph titled "Speed and Power by Month," power density correlates to wind speed, but doesn't follow wind speed exactly.

**Wind Speeds/Wind Directions**
These first plots simply show the wind speed and direction for the monitoring period. Good data is shown with a solid line. Bad data is shown with a dotted line.

**Speed and Power by Month**
This graph gives the average wind speed and average power density for each month. This shows how the wind resource is distributed throughout the year.

**Observations by Month**
This graph shows the number of observations for each month. The greater the number of observations, the greater the probability the data is close to the long-term average resource.

**Speed and Power by Hour**
The top graph shows how the wind speeds and power densities are distributed by time of day over the whole year. The other 12 graphs show the same thing for each month. On top of each graph is an average wind speed and power density for the period in question.

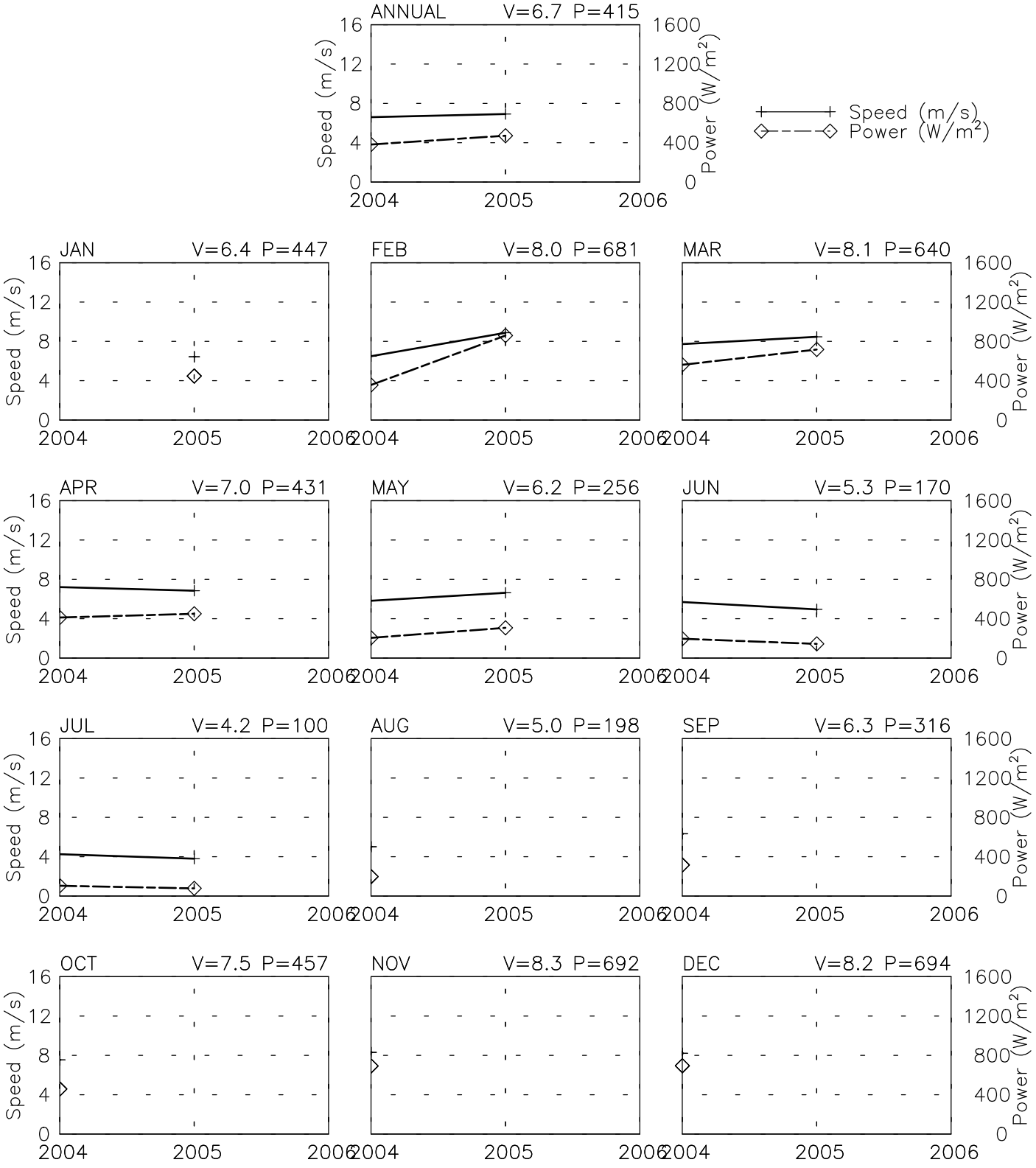
**Frequency and Speed by Direction**
These graphs show how the winds are distributed by direction. The solid line shows the fraction of time that the wind comes from a particular direction. The dotted line shows the average wind speed of the winds coming from a particular direction. Above each graph the fraction of time that the wind is calm (below 1.0 m/s) is given. These graphs indicate the directions from which the strongest winds come. Special care should be taken to ensure the wind turbines have good exposure to winds from these directions.

**Frequency of Speed and Percent of Power by Speed**
These graphs show the distribution of wind speeds and power densities. The solid line indicates the fraction of time that the wind has a particular velocity. The solid line indicates the fraction of the total wind power contributed by winds at each wind speed.

**Appendix C: Wind Data Graphs**
**NREL Software Package**

# SPEED AND POWER BY YEAR

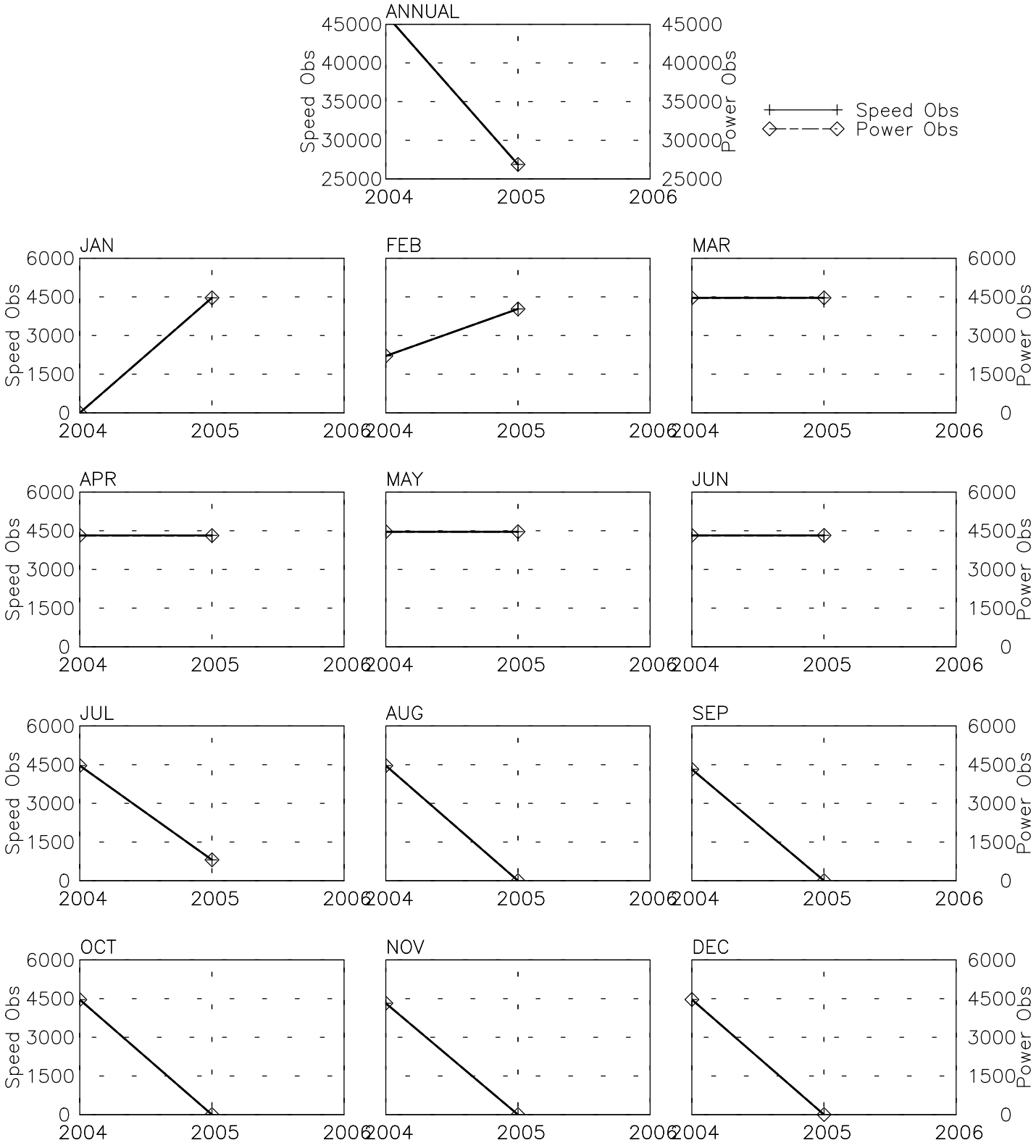
Sand Point 20m – 000291
55° 21' N 160° 29' W – Elev 52m LST=GMT+99 hours *NT=–11
02/04–07/05




Fri Apr 17 10:57:56 2009

# OBSERVATIONS BY YEAR

Sand Point 20m – 000291
55° 21' N 160° 29' W – Elev 52m LST=GMT+99 hours *NT=–11
02/04–07/05

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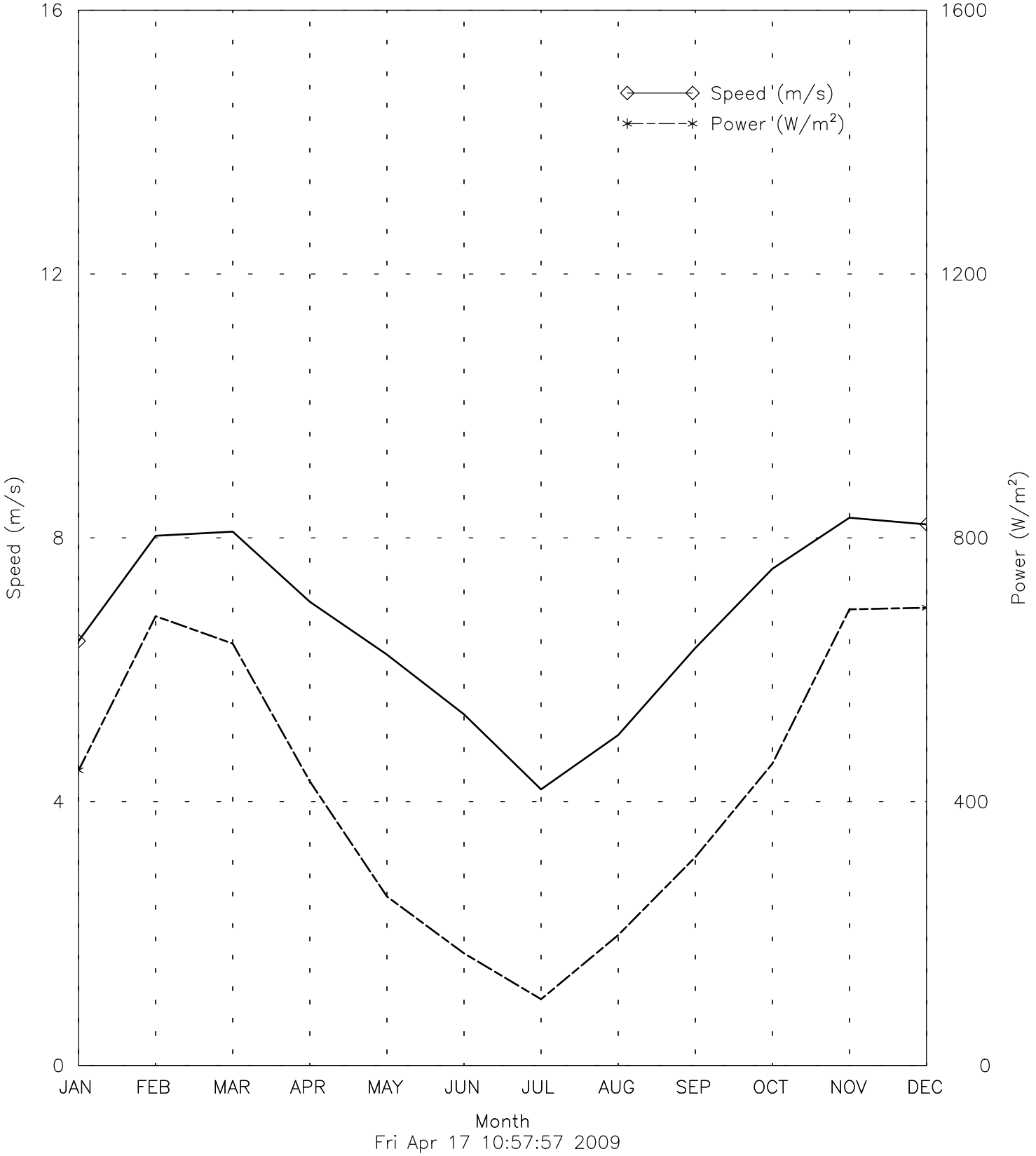
# SPEED AND POWER BY MONTH

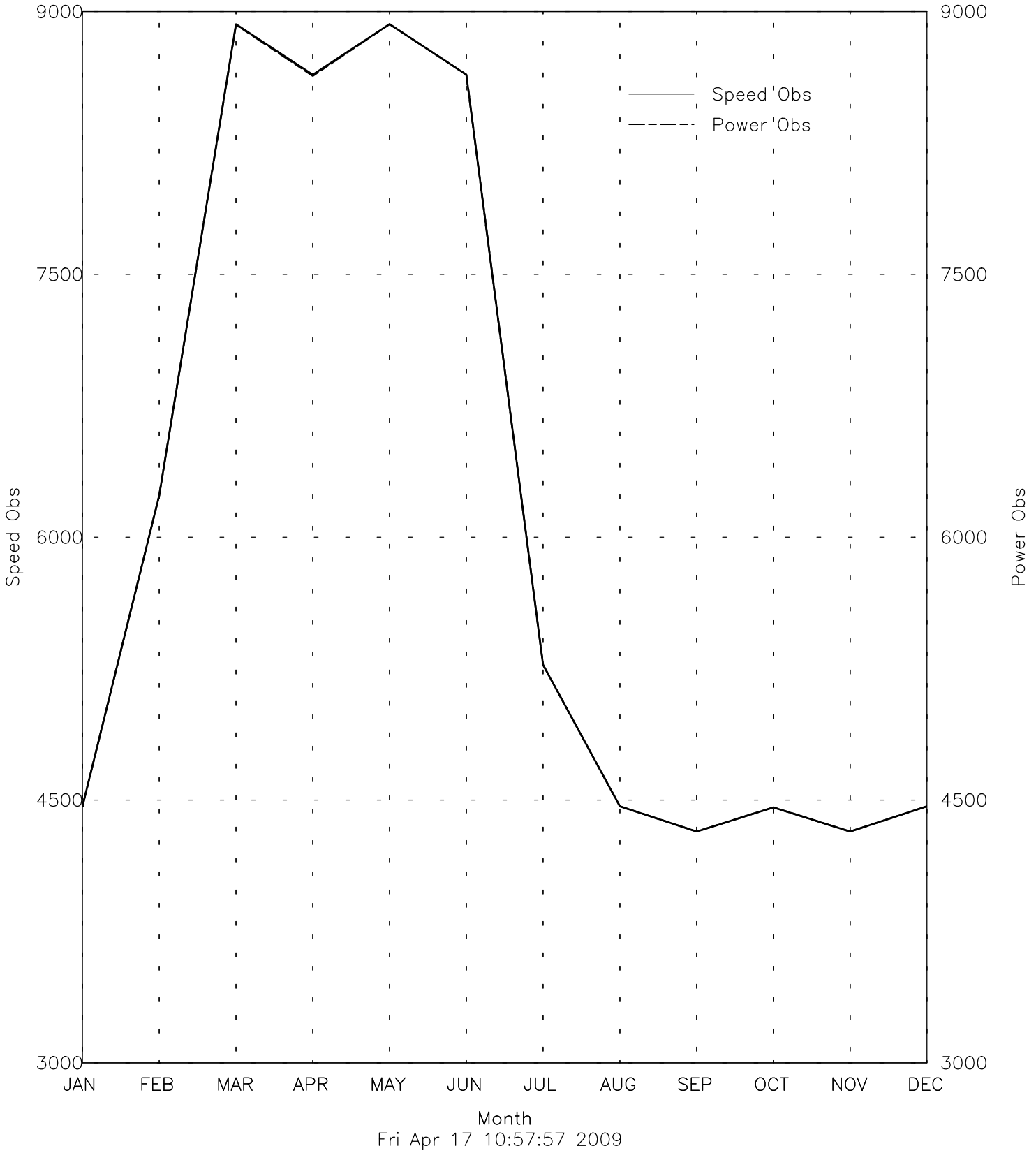
Sand Point 20m – 000291
55° 21' N 160° 29' W – Elev 52m LST=GMT+99 hours *NT=–11
02/04–07/05




Fri Apr 17 10:57:57 2009

# OBSERVATIONS BY MONTH

Sand Point 20m – 000291
55° 21' N 160° 29' W – Elev 52m LST=GMT+99 hours *NT=–11
02/04–07/05




Fri Apr 17 10:57:57 2009

# SPEED AND POWER BY HOUR

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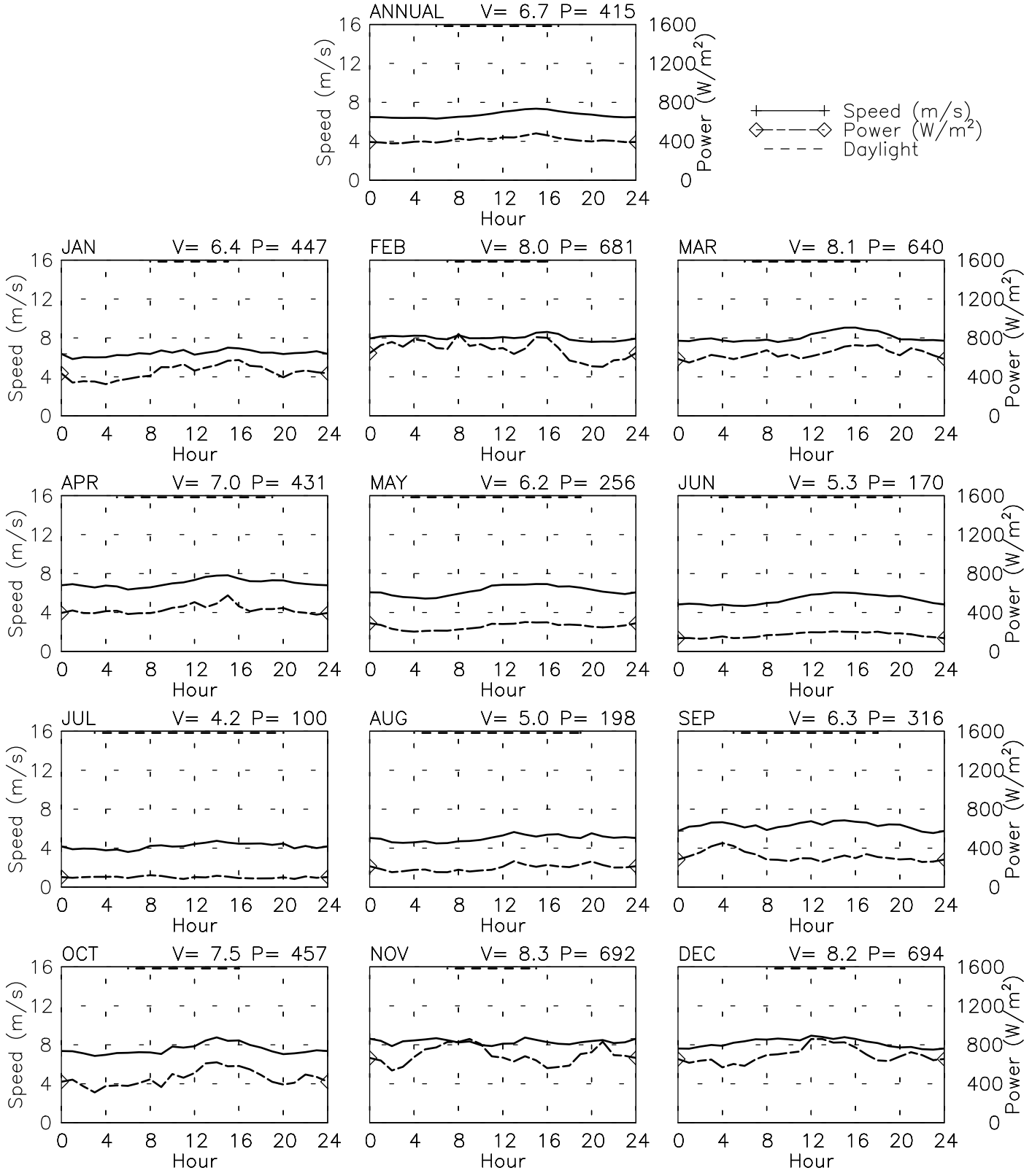
02/04–07/05

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# FREQUENCY AND SPEED BY DIRECTION

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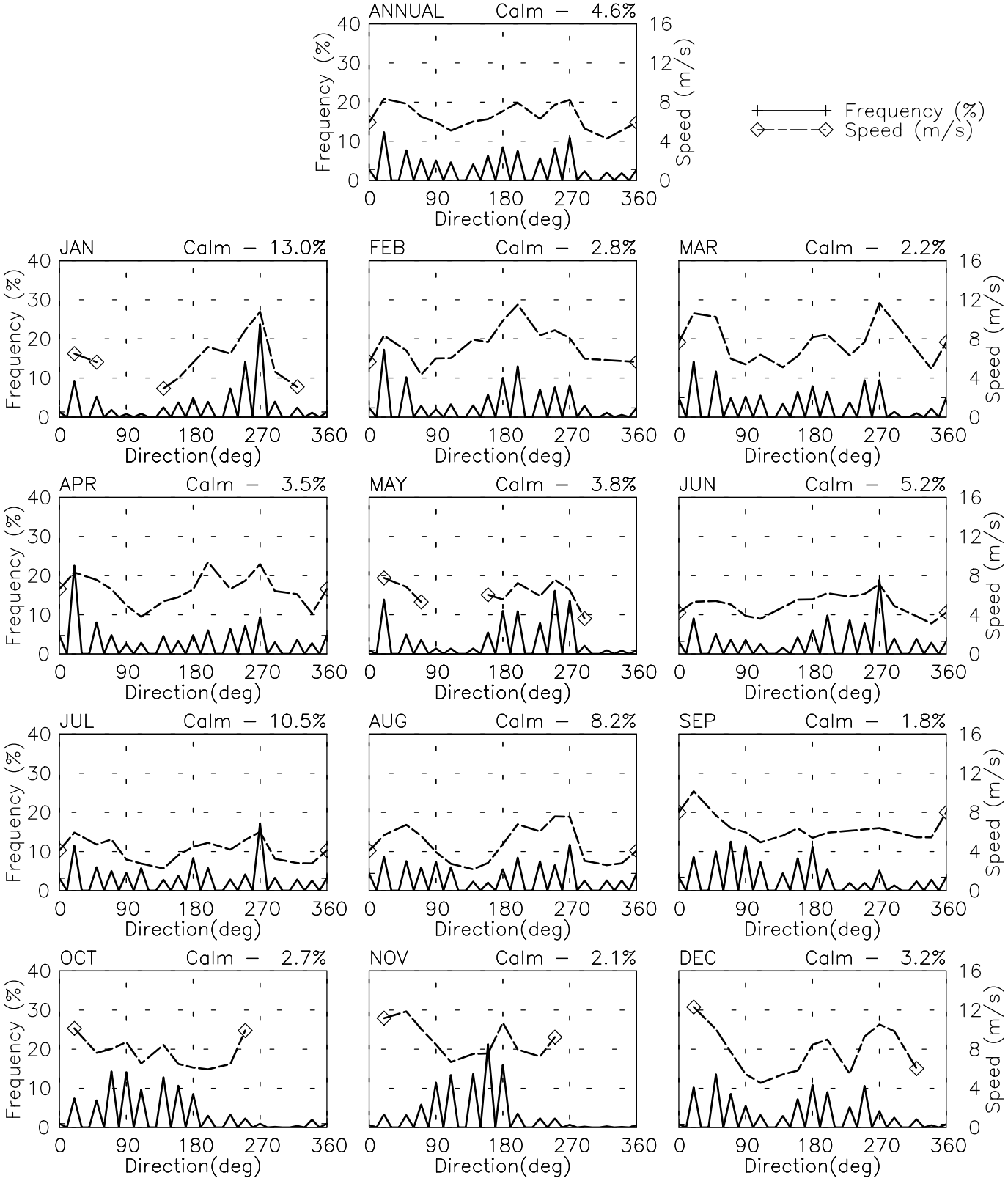
02/04–07/05

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# FREQUENCY OF SPEED & PERCENT OF POWER BY SPEED

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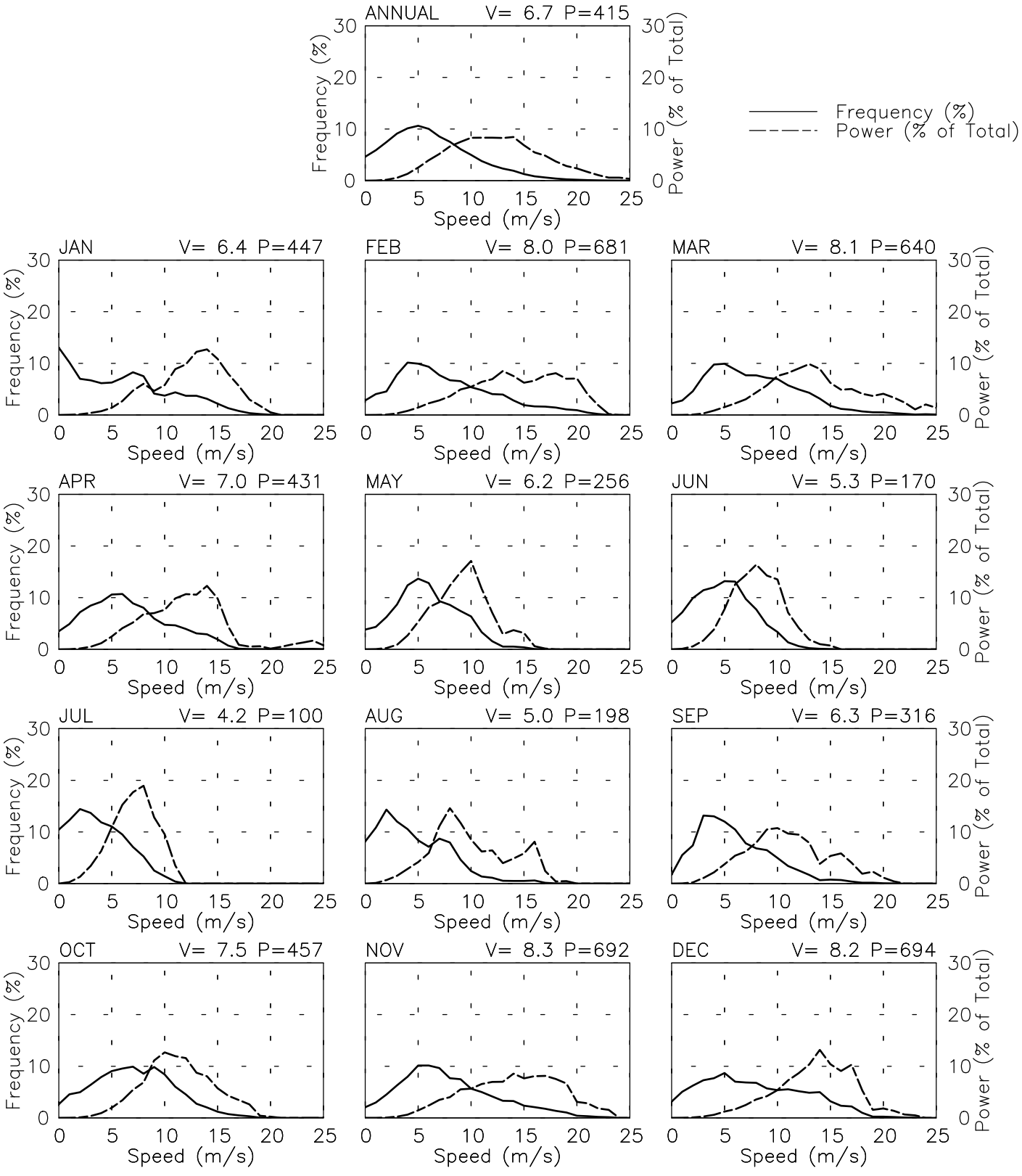
02/04–07/05

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# PREVAILING DIRECTION & SPEED BY HOUR

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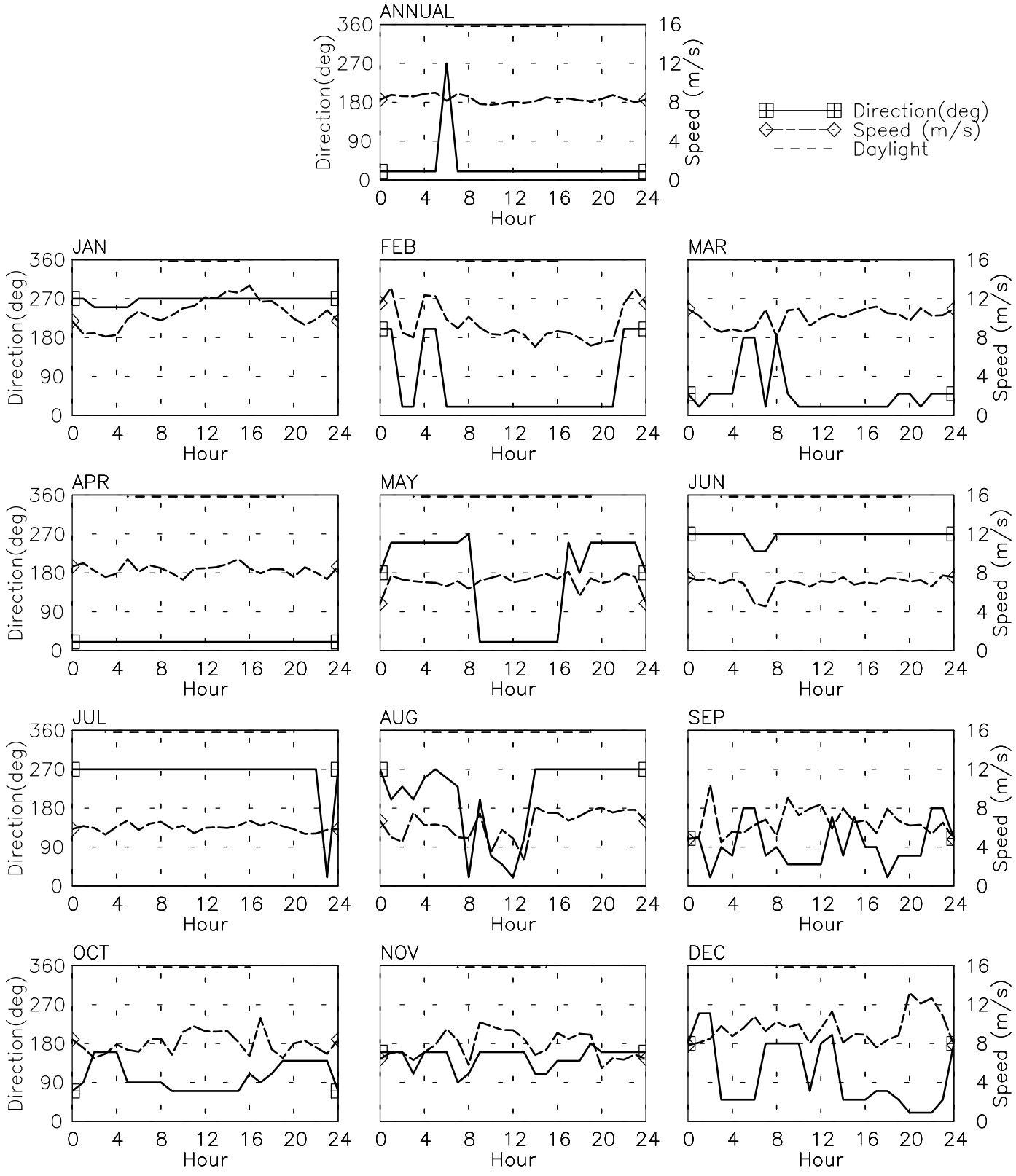
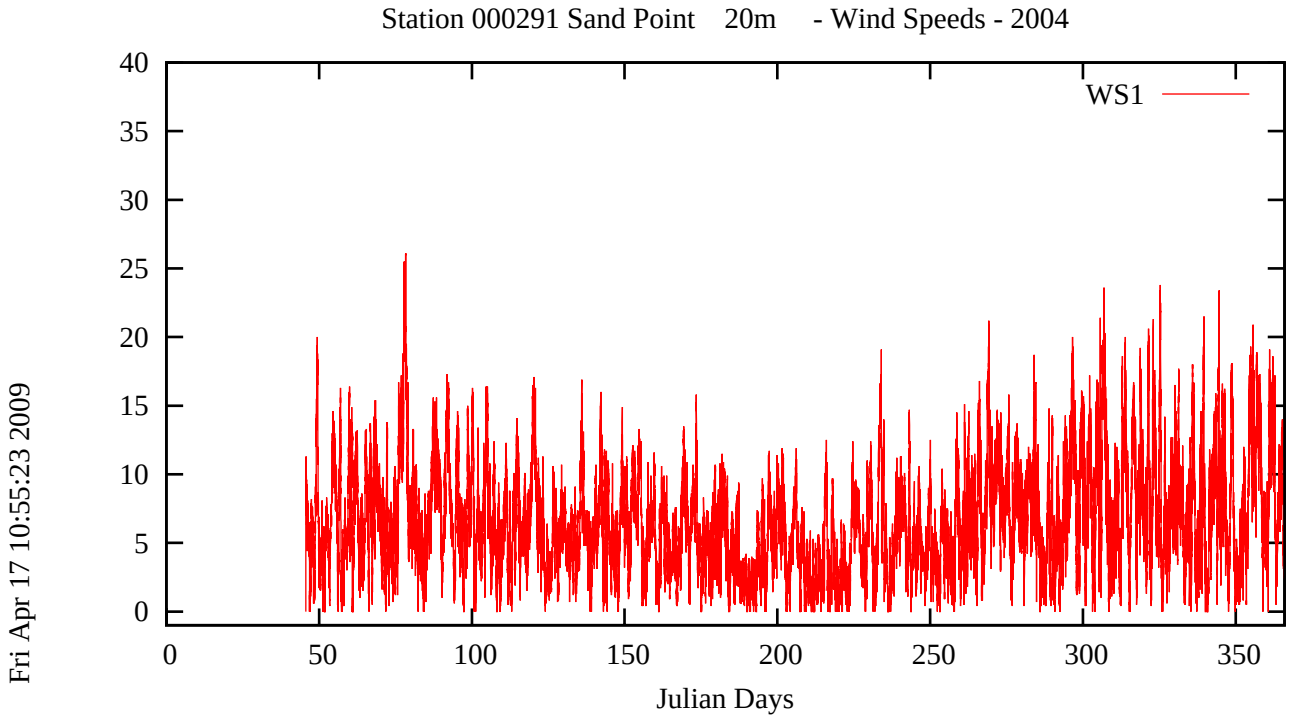
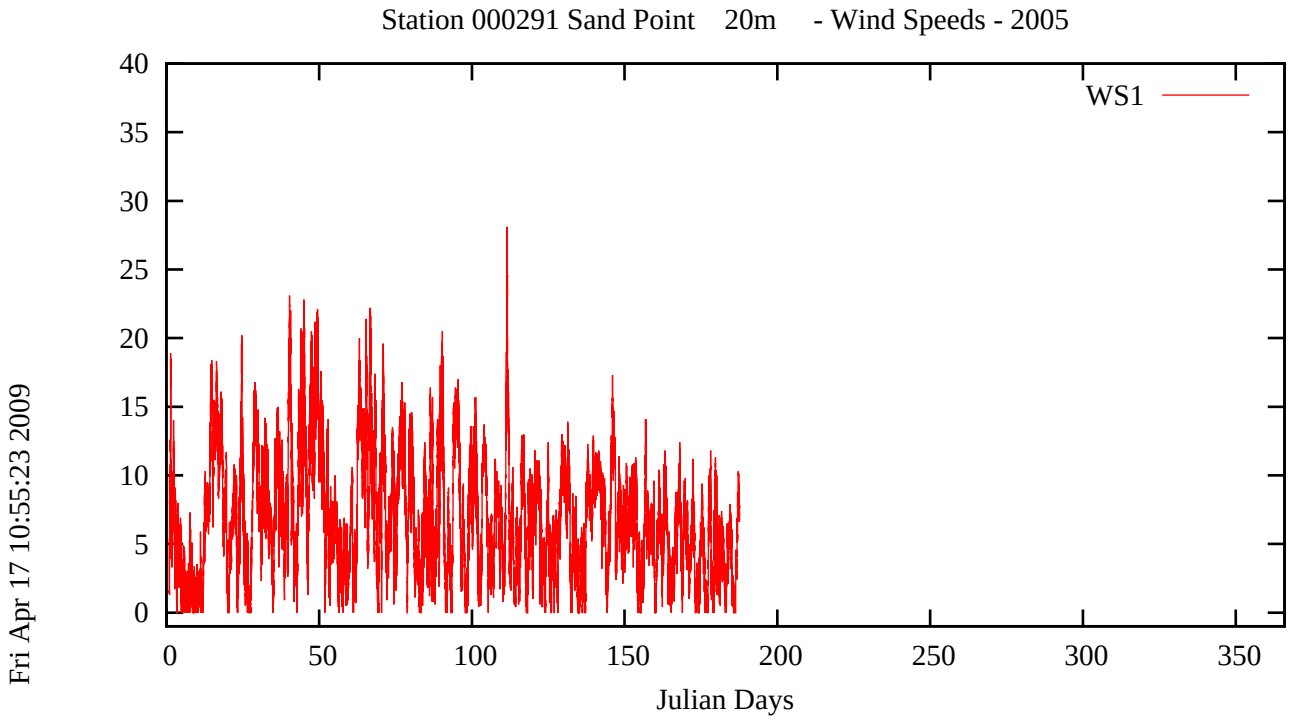
02/04–07/05

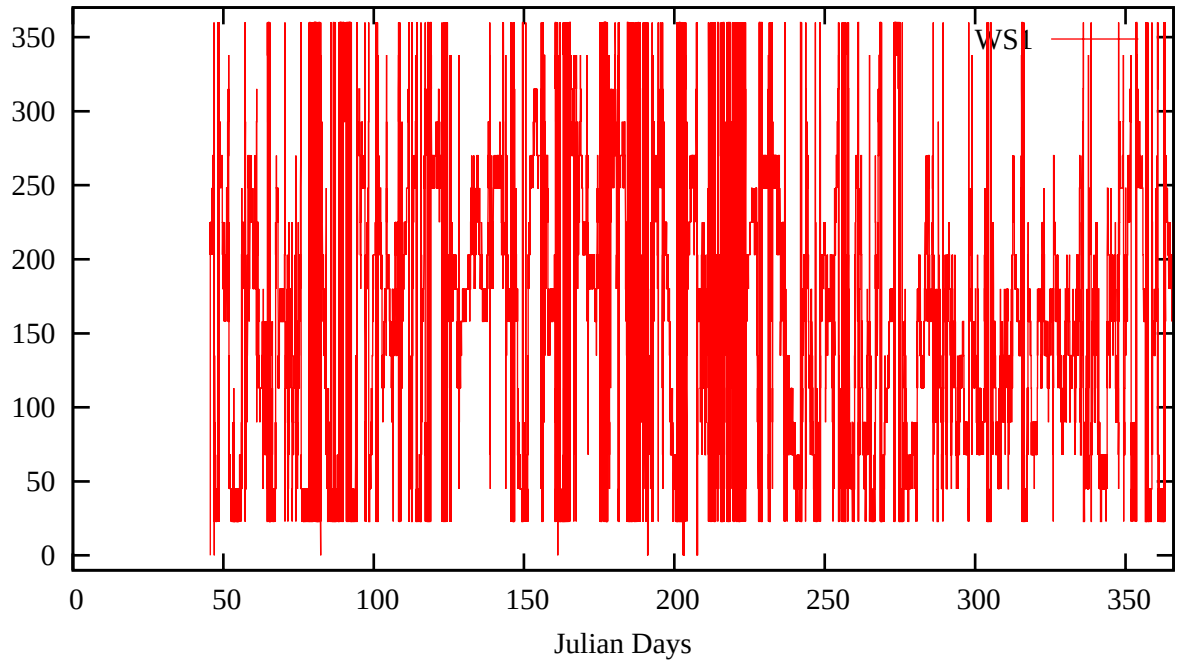



Fri Apr 17 10:57:58 2009


Station 000291 Sand Point 20m - Wind Speeds - 2004
WS1
Fri Apr 17 10:55:23 2009
Julian Days
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250
300
350

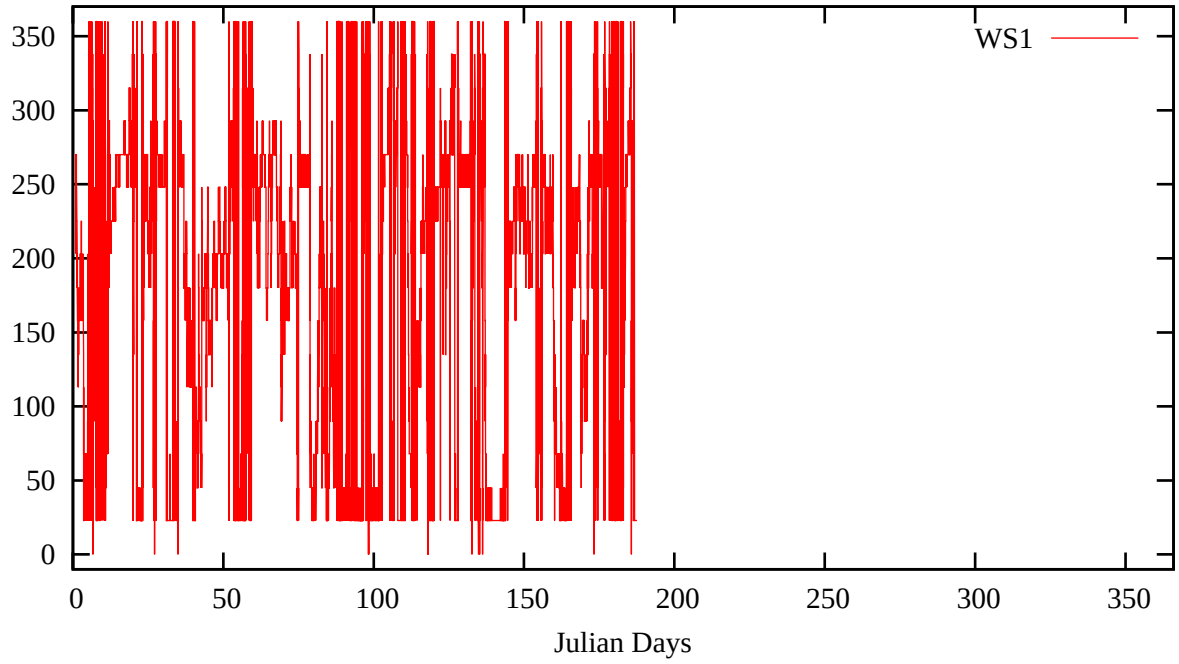

Station 000291 Sand Point 20m - Wind Speeds - 2005
WS1
Fri Apr 17 10:55:23 2009
Julian Days
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250
300
350

Station 000291 Sand Point 20m - Wind Directions - 2004




Fri Apr 17 10:55:33 2009

Station 000291 Sand Point 20m - Wind Directions - 2005




Fri Apr 17 10:55:33 2009

**Appendix D: Wind Data Graphs**
**WindPro**

Project:
**Sand Point - TDX**

Description:
Data from file(s)
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040315.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040214.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 041015.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 050223.csv

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+1 303-384-7027

Calculated:
10/7/2005 10:47 AM/

# Meteo data report, height: 66.0 Feet

Name of meteo object: Sand Point - TDX

Data from: 2/14/2004 4:10 PM Data to: 7/6/2005 2:30 PM Observations: 73137 Observations per day: 144 Recovery rate: 100%

| day | 02/04 | 03/04 | 04/04 | 05/04 | 06/04 | 07/04 | 08/04 | 09/04 | 10/04 | 11/04 | 12/04 | 01/05 | 02/05 | 03/05 | 04/05 | 05/05 | 06/05 | 07/05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | (142) | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 |
| 2 | | (124) | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 |
| 3 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (125) | 144 | 144 | (129) | 144 | 144 | 144 |
| 4 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (123) |
| 5 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (133) | 144 | (95) |
| 6 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (117) | 144 | 144 | 144 | 144 | (137) | 144 | (88) |
| 7 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 8 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (113) | 144 | (126) | |
| 9 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (115) | |
| 10 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 11 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 12 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 13 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 14 | (45) | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (135) | 144 | |
| 15 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (138) | 144 | 144 | 144 | 144 | 144 | 144 | (132) | 144 | |
| 16 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 17 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (133) | 144 | |
| 18 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 19 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (136) | 144 | 144 | 144 | |
| 20 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (103) | 144 | 144 | 144 | 144 | 144 | |
| 21 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 22 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (107) | |
| 23 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 24 | 144 | 144 | 144 | 144 | 144 | 144 | (128) | 144 | 144 | 144 | 144 | 144 | 144 | (136) | 144 | 144 | 144 | |
| 25 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | |
| 26 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (128) | 144 | 144 | 144 | 144 | (122) | |
| 27 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (141) | 144 | 144 | 144 | 144 | 144 | |
| 28 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | (110) | 144 | 144 | |
| 29 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | | 144 | 144 | 144 | 144 | |
| 30 | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | | 144 | 144 | 144 | 144 | |
| 31 | | 144 | | 144 | | (126) | 144 | | 144 | | 144 | 144 | | 144 | | 144 | | |
| % | (100) | (100) | 100 | 100 | 100 | (100) | (100) | 100 | (100) | 100 | (99) | (98) | 100 | (100) | (98) | (99) | (98) | (91) |

Project:
**Sand Point - TDX**

Description:
Data from file(s)
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040315.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040214.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 041015.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 050223.csv



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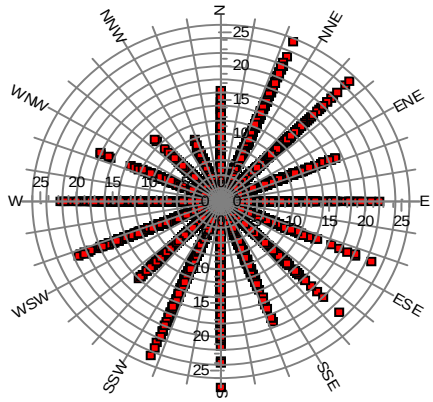
Calculated:
10/7/2005 10:47 AM/

# Meteo data report, height: 66.0 Feet

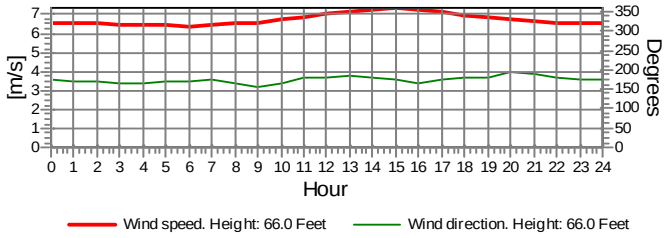
Name of meteo object: Sand Point - TDX

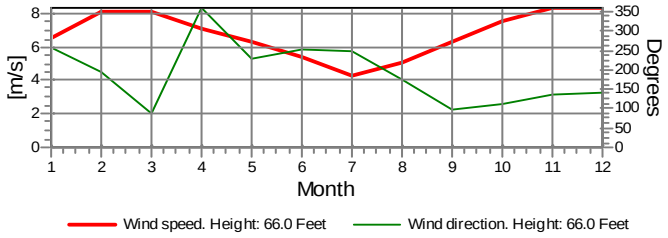



*Wind speed [m/s]*

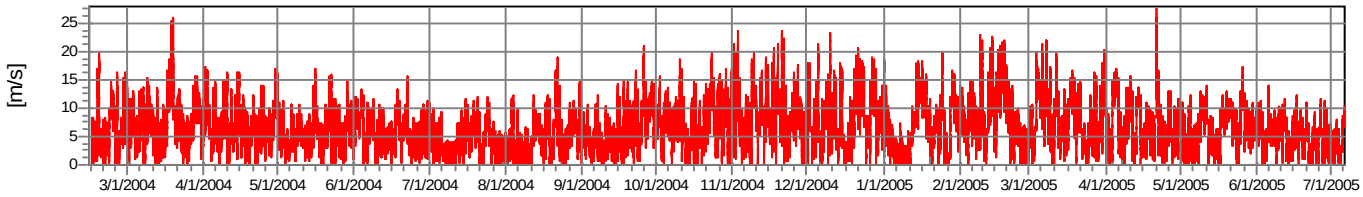
## Monthly mean values of wind speed in m/s

| Month | 2004 | 2005 | mean | mean of months |
|---|---|---|---|---|
| Jan | | 6.5 | 6.5 | 6.5 |
| Feb | 6.5 | 8.9 | 8.0 | 7.7 |
| Mar | 7.8 | 8.5 | 8.1 | 8.1 |
| Apr | 7.2 | 7.0 | 7.1 | 7.1 |
| May | 5.8 | 6.7 | 6.3 | 6.3 |
| Jun | 5.7 | 5.1 | 5.4 | 5.4 |
| Jul | 4.3 | 4.2 | 4.3 | 4.2 |
| Aug | 5.0 | | 5.0 | 5.0 |
| Sep | 6.3 | | 6.3 | 6.3 |
| Oct | 7.5 | | 7.5 | 7.5 |
| Nov | 8.3 | | 8.3 | 8.3 |
| Dec | 8.3 | | 8.3 | 8.3 |
| mean, all data | 6.6 | 7.0 | 6.8 | |
| mean of months | 6.6 | 6.7 | | 6.7 |

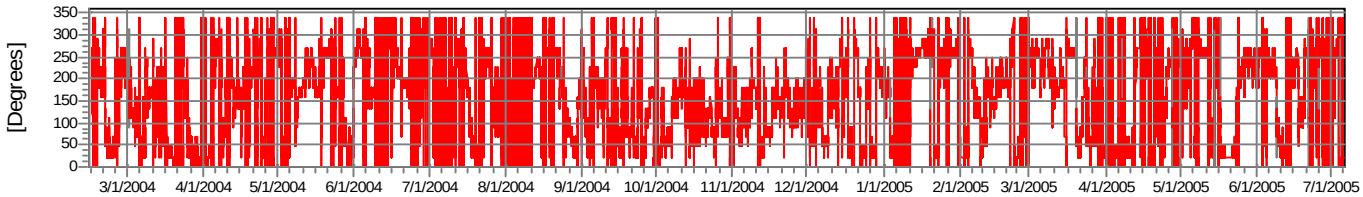


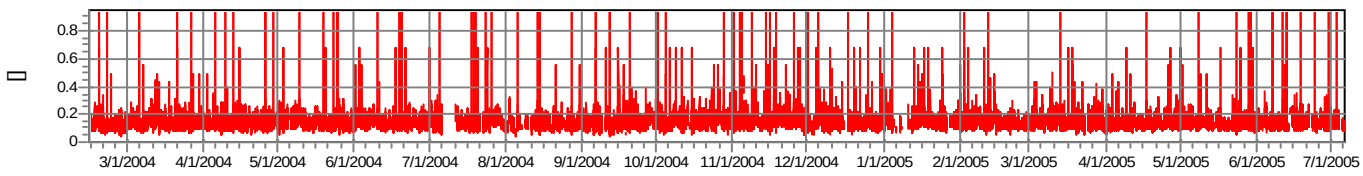

Wind speed




Wind direction




Turbulence intensity
V>4.0 m/s



Project:
**Sand Point - TDX**

Description:
Data from file(s)
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040315.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040214.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 041015.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 050223.csv

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Calculated:
10/7/2005 10:47 AM/

# Meteo data report, height: 66.0 Feet

Name of meteo object: Sand Point - TDX

## Frequency

| Wind speed | Sum | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 - 0.49 | 1,433 | 62 | 59 | 69 | 99 | 73 | 135 | 160 | 154 | 132 | 112 | 100 | 42 | 67 | 60 | 40 | 69 |
| 0.50 - 1.49 | 3,782 | 115 | 167 | 187 | 246 | 299 | 393 | 392 | 348 | 354 | 258 | 232 | 154 | 135 | 153 | 166 | 183 |
| 1.50 - 2.49 | 4,944 | 204 | 301 | 292 | 284 | 397 | 522 | 405 | 377 | 377 | 327 | 293 | 229 | 211 | 192 | 274 | 259 |
| 2.50 - 3.49 | 6,117 | 276 | 472 | 284 | 325 | 473 | 550 | 312 | 376 | 504 | 418 | 328 | 388 | 392 | 322 | 348 | 349 |
| 3.50 - 4.49 | 7,050 | 252 | 621 | 445 | 429 | 479 | 418 | 269 | 519 | 824 | 416 | 450 | 515 | 712 | 278 | 240 | 183 |
| 4.50 - 5.49 | 7,706 | 247 | 756 | 514 | 500 | 475 | 431 | 304 | 595 | 841 | 506 | 502 | 700 | 874 | 192 | 135 | 134 |
| 5.50 - 6.49 | 7,556 | 242 | 816 | 577 | 510 | 393 | 320 | 325 | 591 | 693 | 529 | 587 | 650 | 921 | 164 | 116 | 122 |
| 6.50 - 7.49 | 6,711 | 198 | 1,024 | 562 | 459 | 321 | 251 | 235 | 507 | 482 | 476 | 534 | 609 | 736 | 111 | 109 | 97 |
| 7.50 - 8.49 | 6,026 | 144 | 990 | 579 | 402 | 223 | 176 | 183 | 459 | 384 | 500 | 477 | 540 | 725 | 122 | 69 | 53 |
| 8.50 - 9.49 | 4,903 | 109 | 872 | 489 | 344 | 195 | 134 | 242 | 293 | 359 | 432 | 293 | 390 | 604 | 69 | 52 | 26 |
| 9.50 - 10.49 | 4,167 | 95 | 716 | 441 | 267 | 175 | 133 | 179 | 230 | 330 | 349 | 211 | 412 | 538 | 59 | 24 | 8 |
| 10.50 - 11.49 | 3,144 | 68 | 533 | 370 | 137 | 95 | 104 | 85 | 186 | 243 | 275 | 117 | 423 | 452 | 48 | 7 | 1 |
| 11.50 - 12.49 | 2,462 | 32 | 416 | 315 | 92 | 79 | 34 | 57 | 155 | 195 | 260 | 92 | 297 | 404 | 24 | 9 | 1 |
| 12.50 - 13.49 | 1,916 | 41 | 361 | 218 | 66 | 66 | 24 | 63 | 52 | 175 | 214 | 65 | 181 | 362 | 14 | 14 | 0 |
| 13.50 - 14.49 | 1,584 | 18 | 343 | 183 | 43 | 38 | 14 | 49 | 31 | 160 | 158 | 50 | 168 | 318 | 8 | 3 | 0 |
| 14.50 - 15.49 | 1,150 | 23 | 223 | 111 | 36 | 40 | 7 | 35 | 18 | 136 | 151 | 17 | 138 | 205 | 10 | 0 | 0 |
| 15.50 - 16.49 | 771 | 15 | 147 | 50 | 24 | 34 | 3 | 22 | 12 | 76 | 102 | 13 | 96 | 166 | 11 | 0 | 0 |
| 16.50 - 17.49 | 512 | 5 | 100 | 20 | 18 | 22 | 4 | 9 | 7 | 62 | 68 | 5 | 56 | 125 | 11 | 0 | 0 |
| 17.50 - 18.49 | 369 | 2 | 74 | 22 | 9 | 24 | 4 | 7 | 11 | 48 | 61 | 0 | 25 | 73 | 9 | 0 | 0 |
| 18.50 - 19.49 | 250 | 1 | 39 | 14 | 6 | 14 | 7 | 7 | 17 | 41 | 53 | 0 | 19 | 31 | 1 | 0 | 0 |
| 19.50 - 20.49 | 156 | 0 | 37 | 5 | 2 | 3 | 6 | 3 | 1 | 35 | 22 | 0 | 19 | 23 | 0 | 0 | 0 |
| 20.50 - 21.49 | 115 | 0 | 33 | 6 | 1 | 1 | 2 | 1 | 1 | 19 | 22 | 0 | 9 | 20 | 0 | 0 | 0 |
| 21.50 - 22.49 | 63 | 0 | 17 | 7 | 0 | 2 | 3 | 1 | 1 | 8 | 15 | 0 | 0 | 9 | 0 | 0 | 0 |
| 22.50 - 23.49 | 36 | 0 | 11 | 9 | 0 | 0 | 2 | 1 | 0 | 5 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23.50 - 24.49 | 17 | 0 | 3 | 5 | 0 | 0 | 4 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24.50 - 25.49 | 20 | 0 | 5 | 7 | 0 | 0 | 2 | 2 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25.50 - 26.49 | 9 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26.50 - 27.49 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27.50 - 28.49 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sum | 72,973 | 2,149 | 9,141 | 5,782 | 4,299 | 3,921 | 3,683 | 3,348 | 4,943 | 6,489 | 5,740 | 4,366 | 6,060 | 8,103 | 1,858 | 1,606 | 1,485 |

## Turbulence

| Wind speed | Sum | N | NNE | NE | ENE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 - 0.49 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.50 - 1.49 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1.50 - 2.49 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2.50 - 3.49 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3.50 - 4.49 | 0.152 | 0.154 | 0.141 | 0.143 | 0.140 | 0.145 | 0.169 | 0.176 | 0.191 | 0.167 | 0.140 | 0.136 | 0.132 | 0.145 | 0.153 | 0.149 | 0.149 |
| 4.50 - 5.49 | 0.146 | 0.147 | 0.139 | 0.131 | 0.129 | 0.134 | 0.160 | 0.183 | 0.180 | 0.165 | 0.139 | 0.129 | 0.138 | 0.139 | 0.150 | 0.143 | 0.146 |
| 5.50 - 6.49 | 0.148 | 0.147 | 0.137 | 0.136 | 0.130 | 0.135 | 0.157 | 0.178 | 0.182 | 0.168 | 0.135 | 0.143 | 0.142 | 0.140 | 0.148 | 0.140 | 0.167 |
| 6.50 - 7.49 | 0.141 | 0.143 | 0.126 | 0.125 | 0.123 | 0.146 | 0.161 | 0.178 | 0.177 | 0.163 | 0.134 | 0.129 | 0.140 | 0.135 | 0.154 | 0.146 | 0.159 |
| 7.50 - 8.49 | 0.138 | 0.137 | 0.124 | 0.124 | 0.119 | 0.131 | 0.159 | 0.182 | 0.177 | 0.165 | 0.127 | 0.128 | 0.135 | 0.136 | 0.148 | 0.145 | 0.153 |
| 8.50 - 9.49 | 0.141 | 0.148 | 0.125 | 0.127 | 0.122 | 0.130 | 0.167 | 0.181 | 0.184 | 0.164 | 0.133 | 0.139 | 0.137 | 0.141 | 0.165 | 0.141 | 0.152 |
| 9.50 - 10.49 | 0.136 | 0.128 | 0.121 | 0.123 | 0.117 | 0.134 | 0.157 | 0.173 | 0.174 | 0.162 | 0.125 | 0.126 | 0.132 | 0.136 | 0.155 | 0.129 | 0.144 |
| 10.50 - 11.49 | 0.137 | 0.122 | 0.120 | 0.124 | 0.126 | 0.139 | 0.153 | 0.183 | 0.179 | 0.164 | 0.122 | 0.124 | 0.138 | 0.139 | 0.151 | 0.140 | 0.179 |
| 11.50 - 12.49 | 0.134 | 0.117 | 0.121 | 0.117 | 0.122 | 0.132 | 0.148 | 0.181 | 0.172 | 0.156 | 0.120 | 0.128 | 0.136 | 0.141 | 0.146 | 0.137 | 0.108 |
| 12.50 - 13.49 | 0.137 | 0.129 | 0.123 | 0.122 | 0.126 | 0.134 | 0.155 | 0.171 | 0.176 | 0.159 | 0.123 | 0.130 | 0.136 | 0.151 | 0.154 | 0.144 | |
| 13.50 - 14.49 | 0.136 | 0.116 | 0.122 | 0.118 | 0.134 | 0.131 | 0.164 | 0.176 | 0.180 | 0.150 | 0.119 | 0.134 | 0.141 | 0.148 | 0.163 | 0.136 | |
| 14.50 - 15.49 | 0.134 | 0.120 | 0.118 | 0.116 | 0.147 | 0.148 | 0.152 | 0.180 | 0.176 | 0.150 | 0.124 | 0.131 | 0.131 | 0.143 | 0.211 | | |
| 15.50 - 16.49 | 0.132 | 0.119 | 0.114 | 0.115 | 0.143 | 0.142 | 0.157 | 0.172 | 0.177 | 0.144 | 0.118 | 0.119 | 0.134 | 0.141 | 0.164 | | |
| 16.50 - 17.49 | 0.137 | 0.119 | 0.126 | 0.121 | 0.142 | 0.150 | 0.186 | 0.166 | 0.183 | 0.146 | 0.124 | 0.136 | 0.132 | 0.144 | 0.155 | | |
| 17.50 - 18.49 | 0.135 | 0.133 | 0.122 | 0.108 | 0.121 | 0.151 | 0.151 | 0.173 | 0.177 | 0.147 | 0.118 | | 0.128 | 0.147 | 0.157 | | |
| 18.50 - 19.49 | 0.134 | 0.103 | 0.119 | 0.108 | 0.124 | 0.138 | 0.136 | 0.185 | 0.170 | 0.141 | 0.122 | | 0.132 | 0.145 | 0.124 | | |
| 19.50 - 20.49 | 0.132 | | 0.123 | 0.107 | 0.124 | 0.125 | 0.165 | 0.177 | 0.181 | 0.135 | 0.118 | | 0.128 | 0.150 | | | |
| 20.50 - 21.49 | 0.130 | | 0.119 | 0.116 | 0.117 | 0.193 | 0.150 | 0.171 | 0.155 | 0.139 | 0.125 | | 0.124 | 0.146 | | | |
| 21.50 - 22.49 | 0.126 | | 0.122 | 0.110 | | 0.102 | 0.156 | 0.159 | 0.145 | 0.134 | 0.118 | | | 0.144 | | | |
| 22.50 - 23.49 | 0.122 | | 0.115 | 0.112 | | | 0.153 | 0.147 | | 0.125 | 0.128 | | | | | | |
| 23.50 - 24.49 | 0.136 | | 0.110 | 0.139 | | | 0.155 | | | 0.131 | 0.137 | | | | | | |
| 24.50 - 25.49 | 0.122 | | 0.109 | 0.112 | | | 0.140 | 0.142 | 0.131 | | 0.139 | | | | | | |
| 25.50 - 26.49 | 0.114 | | 0.105 | 0.117 | | | | | 0.116 | | 0.135 | | | | | | |
| 26.50 - 27.49 | 0.125 | | | | | | | | | 0.125 | | | | | | | |
| 27.50 - 28.49 | 0.106 | | | | | | | | | 0.106 | | | | | | | |
| Sum | 0.141 | 0.141 | 0.127 | 0.126 | 0.126 | 0.137 | 0.160 | 0.179 | 0.180 | 0.162 | 0.129 | 0.132 | 0.137 | 0.141 | 0.153 | 0.143 | 0.155 |

Project:
**Sand Point - TDX**

Description:
Data from file(s)
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040315.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040214.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 041015.N04
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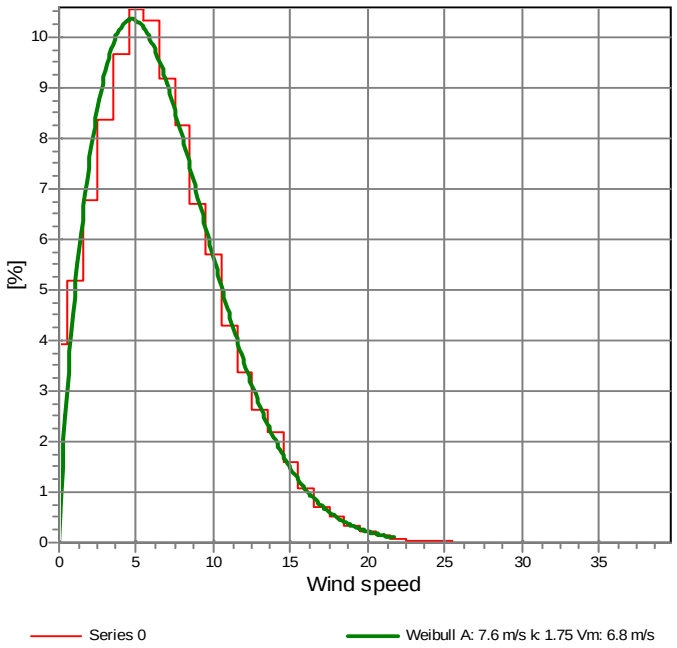
Calculated:
10/7/2005 10:47 AM/

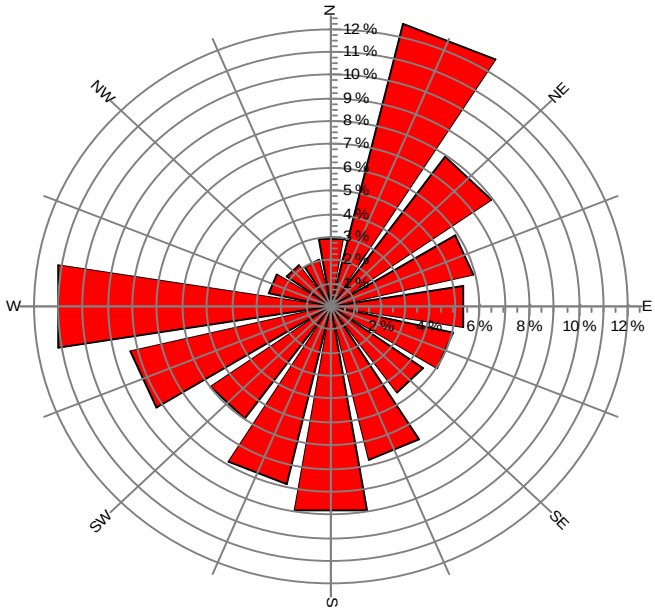
# Meteo data report, height: 66.0 Feet

Name of meteo object: Sand Point - TDX

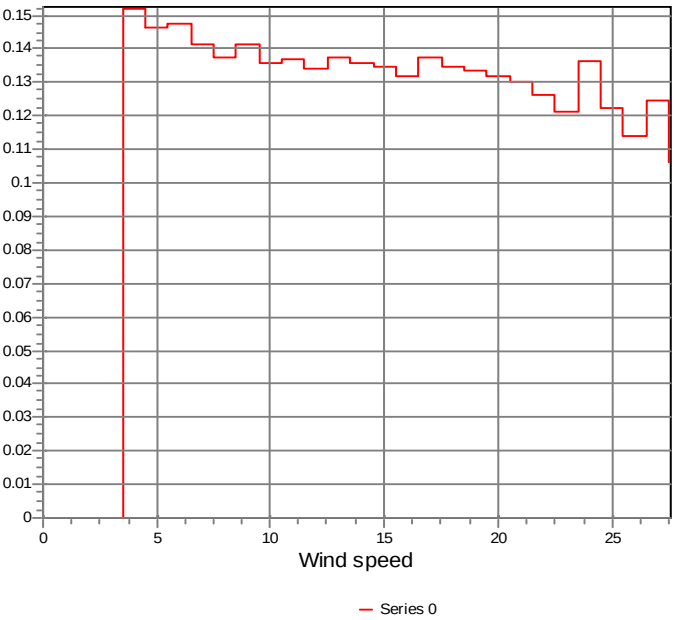
Frequency



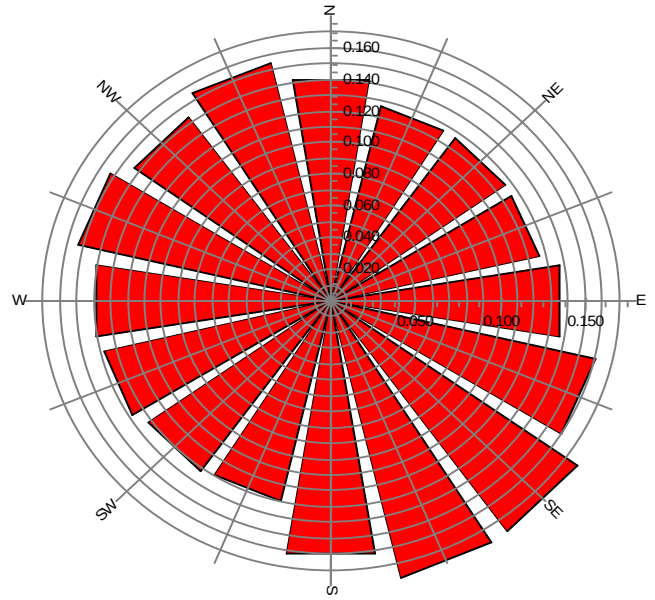

Frequency




Turbulence
V>4.0 m/s




Turbulence
V>4.0 m/s



Project:
**Sand Point - TDX**

Description:
Data from file(s)
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040315.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 040214.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 041015.N04
Y:\5000\shared\Anemometer_Loan_Programs\WPA.NA.Loans\Sand Point - AK\wind data\Sand Point 050223.csv



Licensed user:
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Calculated:
10/7/2005 10:47 AM/

# Meteo data report, height: 66.0 Feet

Name of meteo object: Sand Point - TDX

## Weibull Data

k-parameter correction: 0.0080/m

| Sector | A- parameter [m/s] | Mean wind speed [m/s] | k- parameter | Frequency | Frequency [%] | Wind shear |
|---|---|---|---|---|---|---|
| 0-N | 6.44 | 5.73 | 1.754 | 2.94 | 2.9 | 0.00 |
| 1-NNE | 9.29 | 8.23 | 2.082 | 12.53 | 12.5 | 0.00 |
| 2-NE | 8.82 | 7.81 | 2.154 | 7.92 | 7.9 | 0.00 |
| 3-ENE | 7.23 | 6.41 | 2.033 | 5.89 | 5.9 | 0.00 |
| 4-E | 6.36 | 5.72 | 1.542 | 5.37 | 5.4 | 0.00 |
| 5-ESE | 5.40 | 4.89 | 1.474 | 5.05 | 5.0 | 0.00 |
| 6-SE | 6.43 | 5.76 | 1.607 | 4.59 | 4.6 | 0.00 |
| 7-SSE | 6.88 | 6.10 | 1.944 | 6.77 | 6.8 | 0.00 |
| 8-S | 7.36 | 6.64 | 1.510 | 8.89 | 8.9 | 0.00 |
| 9-SSW | 8.79 | 7.81 | 1.823 | 7.87 | 7.9 | 0.00 |
| 10-SW | 7.04 | 6.23 | 2.250 | 5.98 | 6.0 | 0.00 |
| 11-WSW | 8.52 | 7.55 | 1.982 | 8.30 | 8.3 | 0.00 |
| 12-W | 9.05 | 8.02 | 1.988 | 11.10 | 11.1 | 0.00 |
| 13-WNW | 5.51 | 4.99 | 1.469 | 2.55 | 2.5 | 0.00 |
| 14-NW | 4.42 | 3.98 | 1.531 | 2.20 | 2.2 | 0.00 |
| 15-NNW | 3.96 | 3.54 | 1.649 | 2.03 | 2.0 | 0.00 |
| mean | 7.65 | 6.81 | 1.747 | 100.00 | 100.0 | 0.00 |