Tall Tower Studies of Missouri Wind: Interim Data Report

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Executive Summary

This report is presented as a summary of work conducted on the Tall Tower Investigation of Missouri Wind Patterns Project. Herein we present the data collected to date and analyses of speed and power frequencies at each of six tall tower sites in Missouri encompassing a minimum six month period of data collection at each site. Analysis is presented of diurnal variations in wind speed, as well as wind shear observations. Initial investigations into the climatology of the low-level jet in Missouri are discussed. Plans for continued investigations can be found in many sections.

The major findings of the project to date are:

1. The observed wind speeds at the towers are consistently lower than the estimates presented in the AWS Truewind wind resource map of Missouri. Power density values are also overestimated by the map. There are many possible reasons for this that need further investigation. Primarily a longer data record is required to ascertain whether this is due to a bias in the model or the observational period to date being unrepresentative of the true climatology.

2. The observed wind speeds at the towers follow the rankings expected from previous studies, in that the tower expected to experience the strongest winds does so. This implies that the wind map accurately reflects the spatial pattern of relative power availabilities.

3. The diurnal variation in wind speed is as expected for the heights observed. However, this shows that the maximum wind power availability usually occurs during the overnight hours, with the weakest winds in the early part of the day. This has implications for energy production as it suggests that the majority of energy from a wind farm in this area would be produced between 2300 and 0400 CST, mostly in the night. As it is problematic to store energy produced by wind turbines, and power usage is generally low at these times there would be consequences for a power generator that relies on wind power from these areas.

4. Multi-level wind measurements show similar frequency distributions of wind shear as have been found in other studies. However, there appear to be some higher values of shear than have been observed at other sites in the Midwest. It is hypothesized that the sites in Missouri have a greater surface roughness than previously studied sites.

Much work needs to be done and definitive conclusions will not be possible before an entire year of data has been collected at each site. Further work will concentrate on extending the observations for that year (and beyond). Continuing investigations include addressing the following issues:

a. What is the source of the disparity between the observed winds and those presented in the AWS Truewind model wind map?

b. Does the wind map accurately represent the surface roughness of the areas in the vicinity of the towers?

c. How does the wind direction affect the wind speed and shear profile?

d. Are the Wiebull distributions of wind speed observed at the towers in accordance with those presented in the wind map?

e. How frequently does the low-level jet impact the wind speed and shear at the heights observed? What is its seasonal dependence? Are there preferential wind directions associated with the low-level jet?

The answers to most of these questions depend on the continued operation of the instrumentation on the towers and the planned incorporation of more towers into the dataset. It is likely that the issue of the disparity between the wind map and the observations will only be resolved conclusively by establishing a multi-year observational dataset.

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1. Background

The primary aim of the projects is to validate previously generated wind maps of the State using instruments placed on existing tall towers, such as communication towers. The advantage of using such towers is that measurements can be taken at heights where turbines operate, but observations are not commonly taken. Stand-alone towers up to 60m (197ft) tall are available, but the use of communications towers makes measurements from 70m (230ft) to 150m (494 ft) possible. The previously produced wind maps use modeled winds that are produced by extrapolating regular surface wind observations in combination with upper level wind data obtained from wind profilers and radiosondes. Both of these data sources are sparse (there is currently only one sonde site in Missouri and three profiler sites) and provide poor vertical resolution. Indeed, the profilers do not provide any information below about 500m. Therefore, by building up a network of tall tower sites we will be able to collect direct measurements of the winds at the most important heights for wind energy production.

The selection of towers has taken a number of factors into consideration. We are interested in providing a distribution of sites within Missouri, but with a greater concentration in the areas where the previous studies indicate a greater potential for wind power generation. Hence, we have a higher density of sites in northwestern MO. Other critical factors were naturally the availability of towers of a suitable height, and the willingness of the tower owners to allow us to place the instruments on their towers.

This interim report is in fulfillment of a commitment to provide information regarding the first six months of data collected on six towers. As the towers were instrumented at different times it was decided that the report would cover the period up to March 30, 2007. For some towers this meant that nine months of data were available at this time, and the most recently equipped tower included in this study had completed six months of data collection. The selection of towers is described in Section 2, descriptions of the sites and towers can be found in Section 3 and the extent of the data record at each site up to March 30, 2007 is in Section 4.

For the wind data analysis a variety of software was used. The raw data was initially processed using NRG Symphonie software. For the majority of the analyses hourly average data was used. The database facility was used to produce monthly files of hourly average wind speed which were examined in Microsoft excel and bad data removed by hand. The clean files were then read into Matlab and analysis completed and graphical products generated. The NRG software was used for the wind roses.

Not all the data is presented here. The volume of data is such that presenting it all, even in graphical and tabular would generate a voluminous and uninformative document. In general examples of data products are included to illustrate the nature of the data and support statements made within the report. The detailed data, processed for accessibility is available in a variety of forms on a dedicated website:

http://weather.missouri.edu/wind

Raw data in the form of excel spreadsheets, zipped text files and raw NRG format files will also be available through the website. Some of the data has already been provided to a number of users when requested.

This report will provide examples of the data that has been processed. In most cases we use the data from the Maryville tower, as this tower appears representative of the observations taken across the region and has the most complete data record. In Section 5 we detail the mean wind speeds found at each height on each tower on a monthly basis. Section 6 contains examples of wind direction information in the form of wind roses, and Section 7 has examples of monthly tables of hourly averages of wind speeds. The Sections up to this point in the report are similar to the information available on the website at this time and basically summarize the data collected to date.

From Section 8 onward we present results of analyses of the data. In that Section we examine the diurnal cycle of wind speeds. The bulk of the overall analysis can be found in Section 9. This extends the data record to date to estimate average annual wind speeds at each location based on the data collected to March 30, 2007. This Section looks at various means of extending the record to estimate annual wind speeds and also examines the wind power available at each location, on a projected annual basis. Also in Section 9 there is a preliminary comparison of the findings of wind speed and power to those provided by the AWS Truewind wind map. Limitations of the estimates are discussed along with the findings and further work that needs to be done to clarify issues arising from the findings to date.

Section 10 presents frequency distributions of wind speed and power at each site. Section 11 presents findings on the wind shear at turbine level observed at each site with some interpretation of the observations.

In Section 12 we discuss ongoing work into identifying and characterizing the low-level jet. There are a number of methodologies that we are pursuing in this regard and these are described. Once the basic climatology of the LLJ in Missouri has been established then its impact on wind speeds, shear patterns and power generation can be examined.

Section 13 relates some of the problems encountered to date. These concern the observational aspect of the project, the establishment of the tower network and its maintenance.

2. Tower selection

The locations of the towers were determined using several criteria. First, an Arc GIS wind map created by AWS Truewind Ltd.- commissioned by Missouri DNR was used to establish areas of strong winds. The map displays average wind speeds across the State of Missouri at heights of 30, 50, 70 and 100 m above ground level. After locating the areas of strong winds, corresponding towers were found as potential towers for the study. All the towers used in this study were pre-existing towers with heights between 100-150 m. The tall tower owners were then contacted for permission to place our equipment on their towers. This narrowed down the number of potential candidates as some owners were reluctant to allow us access to their towers. We settled on the following tower locations due to availability and location: Blanchard, Chillicothe, Maryville, Miami, Mound City and Raytown. All of the towers used in this study are located in the Northwestern portion of Missouri as the strongest winds are located in this area. The basic details of the towers are shown in table 2.1. A seventh tower, Santa Rosa, has also been instrumented for this project, but did not have a long enough data record for inclusion in this report.

Tower location	FCC #	Latitude	Longitude	Site Elevation (m)	Tower Height (m)	Overall height above MSL (m)
Blanchard	1003309	40-33-34	95-13-44	328	155	483
Maryville	1002208	40-22-33	94-51-26	353	151	505
Mound City	1007070	40-04-28	95-10-38	340	126	466
Miami	1029923	39-16-49	93-13-44	236	122	358
Chillicothe	1002160	39-48-48	93-35-26	244	152	396
Raytown	1230974	39-02-29	94-29-19.8	265	152	417

Table 2.1: Tower information including latitude, longitude, the elevation at the site, the tower height and the total height above mean sea level are provided.

2.1 Instrumental set-up

The aim of the project was to place equipment at three levels on each tower. In each case, the goal was to get instruments up on towers at the heights at which wind turbines operate. Therefore, we put up two anemometers and one wind vane at heights of 70m, 100m, and then somewhere above 100m. More specifically, each anemometer was mounted on a boom 113" long and weighing 17.3 lbs. Each set of two booms was placed at 180˚ to one another, either extending on the north and south sides of the tower or the northwest and southeast sides. This configuration was chosen to reduce the error that occurs with anemometers involving the effects of the tower, boom and other mounting arrangements on the wind flow. Since there were three instruments at each height three cables needed to be run down the tower from each height to a logger mounted at ground level. We originally planned to gather the data from the towers through a cell phone connection which would deposit the data into an e-mail account. This process has been employed with the Chillicothe and Raytown towers, but could not be carried out on the remaining four towers for various reasons. Thus the data from the remaining four towers has been collected manually.

The heights at which instruments were placed are constrained by the structure of the tower. It is also possible that other installations on the towers could interfere with the placement of the booms, but this has not been an issue on the towers used. The cables supplied for the lower two levels are 70 m and 100m in length, therefore the instruments need to be placed slightly lower than these heights to facilitate the attachment of the cables. Figure 2.1 shows an example of the instruments in place on one of the towers.

Figure 2.1: The Miami, MO tower with the sets of instruments visible at three heights.

3. Site descriptions

In this section we present details of the towers currently instrumented. Figure 3.1 shows the locations and distribution of the towers in operation. In each case the location of the tower is described and a table of the instrument set up referenced to the logger channels provided. Along with the six towers from which data is taken for use in this report, a seventh tower, Santa Rosa, is also described. This tower was instrumented on January 6, 2007 and therefore does not have a long enough data record to enable its inclusion herein. However, as an operational data source within the project at the time of this report its location as part of the observing network is worth noting.

Most of the towers are in rural locations, but for convenience they are designated by the city to which they are closest or are described by in the FCC registry. Some are a significant distance from their designated city. Photographs of the towers and their surroundings can be viewed on the website.

The following subsections detail the tower locations.

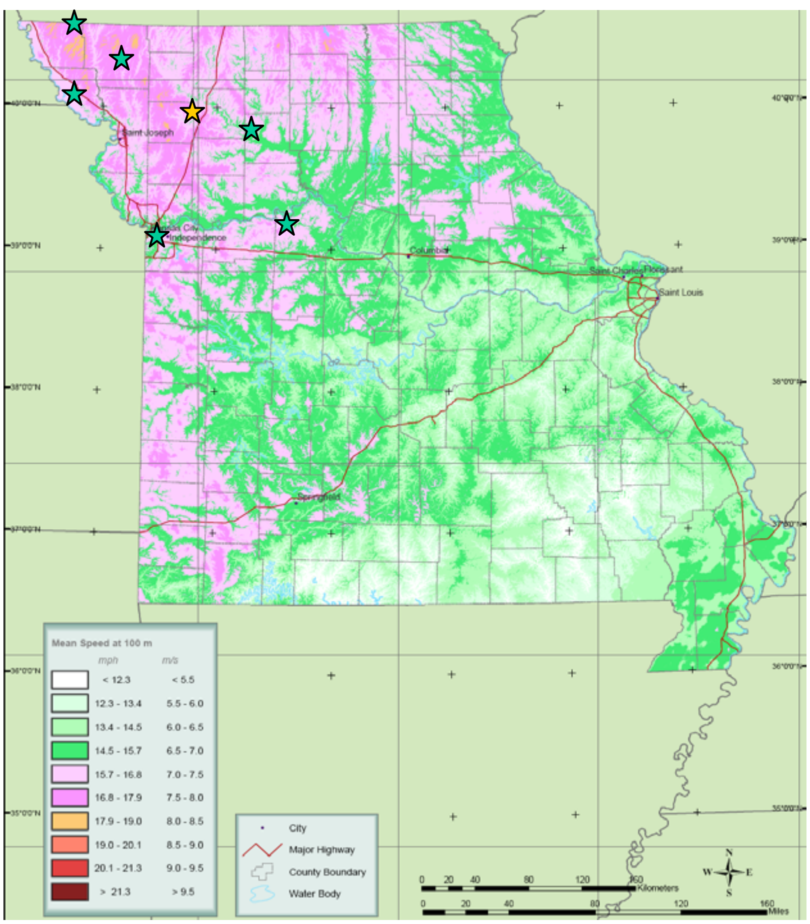


Figure 3.1: The locations of the towers used in this study. The green stars show the sites described. The yellow star shows the location of the Santa Rosa tower.

3.1 Maryville

Latitude: **40-22-33N**
Longitude: **94-51-26 W**
Elevation: **347.1 m**
Tower height: 127m
Owner: Northwest Missouri Cellular
FCC Registration #: 1006211

The Maryville tower is located on US 71 just northeast of Maryville, MO. It is in fairly open surroundings with some sparse low trees. There are some rolling hills and the tower is situated on a local high point. The highway runs north of the tower about 100m away. There is a second tower about 50m to the South. This is a shorter tower, about 70m tall.

The heights of the instruments installed on the tower is shown in Table 3.1.

Logger Channel	Instrument	Height (m)	Orientation
1	Anemometer	61	120°
2	Anemometer	61	300°
3	Anemometer	93	120°
4	Anemometer	93	300°
5	Anemometer	117	120°
6	Anemometer	117	300°
7	Wind vane	61	
8	Wind vane	93	
9	Wind vane	117	
11	Thermometer	1.5	

Table 3.1: Instrument heights and orientations for the Maryville tower.

3.2 Blanchard

Latitude: **40-33-34N**
Longitude: **93-13-44 W**
Elevation: **328.2 m**
Tower height: 152m
Owner: Northwest Missouri Cellular
FCC Registration #: 1003309

The Blanchard tower is located 2 km South of the IA state line on county road M. The nearest town to the tower is Blanchard which is actually across the state line in Iowa. The closest towns in Missouri are Elmo and Westboro, which are approximately equidistant to the east and west. The surroundings are very open and this is the most exposed site of those currently equipped. There are rolling hills and the tower is well elevated amongst them. There are few trees and the land is mostly agricultural corn and soy bean fields with some land apparently fallow.

Table 3.2 shows the heights of the instruments installed on the tower.

Logger Channel	Instrument	Height (m)	Orientation
1	Anemometer	61	120°
2	Anemometer	61	300°
3	Anemometer	97	120°
4	Anemometer	97	300°
5	Anemometer	137	120°
6	Anemometer	137	300°
7	Wind vane	61	
8	Wind vane	97	
9	Wind vane	137	
11	Thermometer	1.5	

Table 3.2: Instrument heights and orientations for the Blanchard tower.

3.3 Mound City

Latitude: **40-04-28N**
Longitude: **95-10-38 W**
Elevation: **437.9 m**
Tower height: 127m
Owner: Northwest Missouri Cellular
FCC Registration #: 1006209

The Mound City tower is on November Road, just south of Highway 159. It is about 1km east of I-29 and 5km south of Mound City. The tower is amongst the bluffs, so there are reasonable size hills. The tower base is not situated at the highest local point. The surroundings are mostly agricultural, with corn fields and some trees.

Logger Channel	Instrument	Height (m)	Orientation
1	Anemometer	61	120°
2	Anemometer	61	300°
3	Anemometer	99	120°
4	Anemometer	99	300°
5	Anemometer	117	120°
6	Anemometer	117	300°
7	Wind vane	61	
8	Wind vane	99	
9	Wind vane	117	
11	Thermometer	1.5	

Table 3.3: Instrument heights and orientations for the Mound City tower.

3.4 Chillicothe

Latitude: **39-48-48N**
Longitude: **93-35-26 W**

Elevation: **244.0 m**
Tower height: 152m
Owner: Northwest Missouri State University – KRNW radio
FCC Registration #: 1002160

The Chillicothe tower is just off of Old Highway 190, about 3km north west of the city of Chillicothe. The tower is on farm land, with a forested area to the south and significant farm buildings about 100m to the north. The tower is one of a cluster of five, all of similar height.

Logger Channel	Instrument	Height (m)	Orientation
1	Anemometer	61	120°
2	Anemometer	61	300°
3	Anemometer	93	120°
4	Anemometer	93	300°
5	Anemometer	117	120°
6	Anemometer	117	300°
7	Wind vane	61	
8	Wind vane	93	
9	Wind vane	117	
11	Thermometer	1.5	

Table 3.4: Instrument heights and orientations for the Chillicothe tower.

3.5 Miami

Latitude: **39-16-49 N**
Longitude: **93-13-44 W**
Elevation: **236.2 m**
Tower height: 122m
Owner: Kansas City Power & Light
FCC Registration #: 1029923

The Miami tower is on Highway 41 at the junction of route AD. It is about 4km south of Miami, MO and 10 km north of Marshall. The area around the tower is rolling farm land of soy and corn with some trees. The are some large silos in the vicinity. Table 3.5 shows the heights of the instruments installed on the Miami tower.

3.6 Raytown

Latitude: **39-02-29 N**
Longitude: **94-29-20 W**
Elevation: **264.9 m**
Tower height: 152 m
Owner: Mid-America Regional Council – Emergency Rescue
FCC Registration #: 1230974

The Raytown tower is the only one in an urban setting as it sits in the outskirts of Kansas City, MO. It lies close to a penitentiary in a well wooded area south of the large sports stadia. The trees are less than 10m tall and surround the tower except on the east where the penitentiary buildings is about 100m away.

Logger Channel	Instrument	Height (m)	Orientation
1	Anemometer	67	120°
2	Anemometer	68	300°
3	Anemometer	93	120°
4	Anemometer	94	300°
5	Anemometer	114	120°
6	Anemometer	115	300°
7	Wind vane	67	
8	Wind vane	93	
9	Wind vane	114	
11	Thermometer	1.5	

Table 3.5: Instrument heights and orientations for the Miami tower.

Logger Channel	Instrument	Height (m)	Orientation
1	Anemometer	67	120°
2	Anemometer	68	300°
3	Anemometer	93	120°
4	Anemometer	94	300°
5	Anemometer	142	120°
6	Anemometer	142	300°
7	Wind vane	67	
8	Wind vane	93	
9	Wind vane	142	
11	Thermometer	1.5	

Table 3.6: Instrument heights and orientations for the Raytown tower.

3.7 Santa Rosa

Latitude: **39-57-28N**
Longitude: **94-06-56 W**
Elevation: **298.0 m**
Tower height: 124m
Owner: Shepperd Radio Group (KWKK)
FCC Registration #: 1005778

The Santa Rosa tower is on grazing land on highway 69, 1km north of its junction with I-35. The surroundings are very open, with rolling hills and sparse small trees which are all less than 10m tall. The tower is on a local high point. The interstate passes about 1 km to the east.

Due to concerns about the tower's structural strength only a single boom and set of instruments was installed ay each height.

Logger Channel	Instrument	Height (m)	Orientation
1	Anemometer	63	60°
2			
3	Anemometer	93	60°
4			
5	Anemometer	121	60°
6			
7	Wind vane	63	
8	Wind vane	93	
9	Wind vane	121	
11	Thermometer	1.5	

Table 3.7: Instrument heights and orientations for the Santa Rosa tower.

3.8 Summary

Table 3.8 shows a summary of the instrument heights on each tower. As can be seen six towers were instrumented within a period of three months. Each of the towers has one set of instruments between 60 and 70 m, and one set close to 100 m. The highest sets of instruments varies and on the Raytown tower the instruments are at 140 m.

Tower Site	**Date Equipped**	**CH 1 Height (m)**	**CH 2 Height (m)**	**CH 3 Height (m)**	**CH 4 Height (m)**	**CH 5 Height (m)**	**CH 6 Height (m)**
Blanchard	8/4/2006	61	61	97	97	137	137
Chillicothe	10/4/2006	61	61	97	97	137	137
Maryville	8/3/2006	61	61	97	97	117	117
Miami	7/2/2006	67	68	96	97	114	115
Mound City	8/6/2006	61	61	97	97	117	117
Raytown	8/4/2006	67	67	95	95	140	140

Table 3.8: Displays date tower was equipped with wind vanes and anemometers as well as the heights of the anemometers for the specified tower site.

4. Data record

This section details the installation date and observational record for each tower. In each case the period of record is noted along with any major interruptions to data collection. Apart from times when work has been being conducted on the towers, there have been two significant ice storms that have affected the towers. The first occurred on 29th November, 2006. The data interruption varied for each tower and ended at different times for different channels on the towers. The initial icing and subsequent melting of the ice depended upon the height of the instruments and orientation (exposure) of the booms. The second ice storm began on 15th January 2007. Due to persistent very low temperatures following this storm some of the instruments did not renew activity for almost two weeks.

4.1 Maryville

The Maryville tower was instrumented on 4th August 2006. This tower has produced an uninterrupted record with no problems with any instruments. The only issues with the data have been during the icing episodes.

4.2 Blanchard

The Blanchard tower was instrumented on 6th August 2006. This tower operated excellently until January. At this time there was a logger malfunction which meant that data was not recorded on channels 1, 3 and 5 until the logger was replaced on 27 March. This means that winds were continuously recorded at each height for the entire period, but there was no redundancy and if the operational anemometer was sheltered by the tower structure then no knowledge of this is available.

4.3 Mound City

The Mound City tower was equipped on 7th August 2006. However, due to a cabling issue, the wind vane at the middle level was not connected. This tower has also suffered a number of logger problems. Channels 1, 2 and 3 were not recorded between 22 September and 11 December. Therefore, there was no recording of wind speed at the lowest level throughout this time. On the latter date the problem was discovered and the channels were reorganized so that one of the lower anemometers (that on the same side – originally channel 2) was connected to channel 5 on the data logger. The logger was replaced on January 7th, 2007 and has operated well since that time.

4.4 Chillicothe

The tower at Chillicothe was instrumented on 4th October, 2006. It has collected data continuously since that time. This is one of two towers for which remote communication has operated, allowing data to be downloaded on a daily basis.

4.5 Miami

The Miami tower was instrumented on June 30th 2006. The instruments on the Miami tower worked well until the icing episode in January 2007. Since then the anemometer on channel 3 has not recorded any data.

4.6 Raytown

The Raytown tower was instrumented on July 2006. Some of the channels have been intermittent due to wiring problems, but there is a good data record for the period. This tower has working remote communications so data is retrieved on a daily basis.

4.7 Santa Rosa

The Santa Rosa tower was instrumented on January 7th, 2007. There have been some problems with the data. These have been due to the period of icing immediately following the installation and a subsequent logger malfunction.

4.8 Data Processing

Quality control was performed manually on the data to remove the erroneous wind speeds recorded by the instruments on the tower. At times when the equipment was not operating properly, work was being done on the tower or data was being collected from the instruments a value of 0.4 m s^{-1} was recorded. Thus these values needed to be replaced with NaN (not a number) so as to not distort or misrepresent the data when analyses were performed. A value of 0.4 m s^{-1} was also recorded in times of icing. Since data was collected during the winter months, icing was a major issue. There were several periods during which the wind vanes and anemometers were frozen and unable to record data. Even after the instruments had thawed the effects of the ice could still be seen through low or calm wind speeds. Thus the periods where ice prevailed needed to be removed from the dataset. Once this was completed we could proceed with the analysis using our clean dataset.

It should be noted that all times referred to within this report are in UTC (or GMT).

5. Monthly wind speed data

In this section we tabulate the monthly wind speeds observed on each channel of each tower. These are calculated from the hourly average data. In general it can be seen that wind speeds increase with height, and that different speeds are observed at the different locations. One can also see differences between the two observations at the same height on each tower, and in some instances, these are significant. It is assumed that these differences are due to sheltering effects of the tower structure when the wind comes from particular directions. By using the directional information (presented in the next section) we intend to clarify whether this is indeed the case.

5.1 Maryville

Month	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6
August 2006	4.96	5.04	5.73	5.74	6.09	6.03
September 2006	6.19	6.05	6.86	7.01	7.20	7.30
October 2006	6.70	6.54	7.51	7.64	7.98	8.04
November 2006	6.60	6.26	7.17	7.44	7.41	7.79
December 2006	6.80	6.49	7.52	7.80	8.04	8.21
January 2007	7.45	7.05	8.10	8.42	8.51	8.62
February 2007	6.71	6.57	7.35	7.44	7.72	7.71
March 2007	7.63	7.50	8.46	8.58	8.96	8.91

Table 5.1: Monthly average wind speed (in m s^{-1}) for each channel of the Maryville tower.

5.2 Blanchard

Channels 2, 4 and 6 of the Blanchard tower did not collect data in February or March due to a logger malfunction.

Month	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6
August 2006	5.63	5.60	6.40	6.30	6.78	6.77
September 2006	6.32	6.26	7.08	7.16	7.70	7.56
October 2006	7.12	7.07	7.92	7.97	8.64	8.48
November 2006	6.98	7.03	7.82	7.83	8.36	8.18
December 2006	7.02	6.92	7.79	8.00	8.67	8.37
January 2007	8.06	7.16	8.84	8.21	9.31	8.69
February 2007	N/A	6.70	N/A	7.52	N/A	7.82
March 2007	N/A	7.72	N/A	8.51	N/A	9.05

Table 5.2: Monthly average wind speed (in m s^{-1}) for each channel of the Blanchard tower.

5.3 Mound City

Channels 1, 2 and 3 of the Mound City tower failed to collect data in October and November due to logger problems. For channels 1 and 3 this continued through December. On December 11th the logger connection was switched from channel 5 to channel 2. Therefore the average speed for channel 5 for December is up to 11th of the month, while that for channel 2 is from the 11th onward. The averages for channels 1, 3 and 5 for January are from January 7th onward, when the logger was replaced.

Month	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6
August 2006	4.45	4.48	4.96	4.94	5.31	5.36
September 2006	5.05	5.43	5.96	5.67	6.10	6.56
October 2006	N/A	N/A	N/A	6.52	6.90	7.35
November 2006	N/A	N/A	N/A	5.88	6.15	6.92
December 2006	N/A	5.76	N/A	6.42	7.40	7.39
January 2007	5.82	6.71	7.24	6.56	7.68	7.13
February 2007	6.10	6.10	6.58	6.58	6.99	6.98
March 2007	6.77	6.90	7.42	7.33	7.90	7.78

Table 5.3: Monthly average wind speed (in m s^{-1}) for each channel of the Mound City tower.

5.4 Chillicothe

Month	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6
October 2006	5.52	5.56	6.21	6.25	7.01	6.96
November 2006	5.76	5.73	6.54	6.55	7.35	7.27
December 2006	5.82	5.88	6.67	6.61	7.53	7.53
January 2007	6.04	5.81	6.50	6.66	7.50	7.15
February 2007	5.84	5.81	6.39	6.43	7.12	7.01
March 2007	6.41	6.58	7.31	7.23	8.10	8.15

Table 5.4: Monthly average wind speed (in m s^{-1}) for each channel of the Chillicothe tower.

5.5 Miami

Channel 3 of the Miami tower has operated only intermittently since the icing episode in mid-January 2007. Therefore averages are not provided for this channel fro Febraury or March, while the record for January does not cover the same period for channel 3 as it does for channel 4.

Month	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6
July 2006	5.00	4.61	5.61	5.26	5.94	5.98
August 2006	5.17	4.93	5.80	5.56	6.09	6.28
September 2006	5.23	5.31	5.81	5.83	6.04	6.44
October 2006	6.30	6.21	7.08	6.94	7.43	7.80
November 2006	6.39	5.71	7.19	6.48	7.51	7.21
December 2006	6.82	6.80	7.72	7.57	8.09	8.54
January 2007	6.14	6.35	7.22	7.03	7.30	7.74
February 2007	6.35	6.54	N/A	7.14	7.16	7.65
March 2007	7.52	7.40	N/A	8.16	8.61	9.13

Table 5.5: Monthly average wind speed (in m s^{-1}) for each channel of the Miami tower.

5.6 Raytown

Month	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6
August 2006	4.10	4.13	4.79	4.78	5.56	5.64
September 2006	4.49	4.55	5.25	5.32	6.03	6.18
October 2006	4.93	5.00	5.90	5.94	6.86	6.99
November 2006	4.83	5.02	5.91	6.08	6.98	7.43
December 2006	5.17	5.31	6.36	6.35	7.51	7.35
January 2007	5.54	5.77	6.45	6.54	7.11	8.10
February 2007	5.26	5.48	6.06	6.13	6.82	7.25
March 2007	5.70	5.75	6.70	6.55	7.56	6.53

Table 5.6: Monthly average wind speed (in m s^{-1}) for each channel of the Raytown tower.

6. Wind roses

The wind roses were constructed using the function in the database section of the NRG Symphonie software. Those displayed here are for the Maryville tower and are arranged by height and month. The patterns at the other towers are similar and the roses for the other towers can be found on the website.

There is a clear monthly variation as the winds shift from more southerly and easterly directions during the summer to northerly and westerly winds in the winter. This may have implications for the wind speeds as the terrain to the south of Missouri is rougher than that to the north and west.

The directional information recorded at the towers has not been used in any of the analyses conducted to date. However there are a number of ways in which we intend to utilize this information. These include:

a) Wind direction data will be used as a quality control on wind speeds. When differences are observed between the two anemometers operating at the same height on a tower the most likely cause is interference by the tower structure. We intend to test this assumption.
b) Wind speed data at each tower will be stratified by direction to determine if there is a dependence of speed on direction.
c) Cases of low-level jet incidence will be correlated with direction. This will be done to determine whether the LLJ climatology found from model analyses is accurate.
d) Wind shear observations will be stratified by direction to determine if there is a directional dependence on shear. This could be the case if there are significant variations on topography and land cover characteristics for the various upwind directions at each tower.

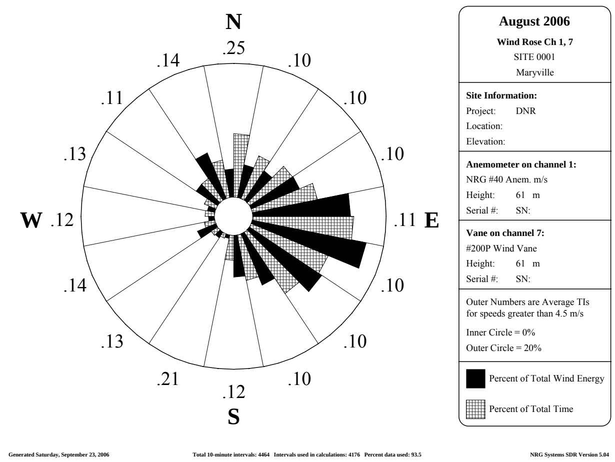


Figure 6.1a: Wind rose for Maryville tower 61-m vane for August 2006.

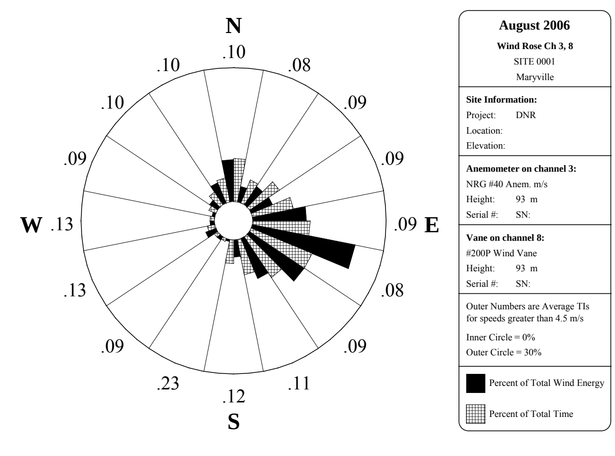


Figure 6.1b: Wind rose for Maryville tower 93-m vane for August 2006.

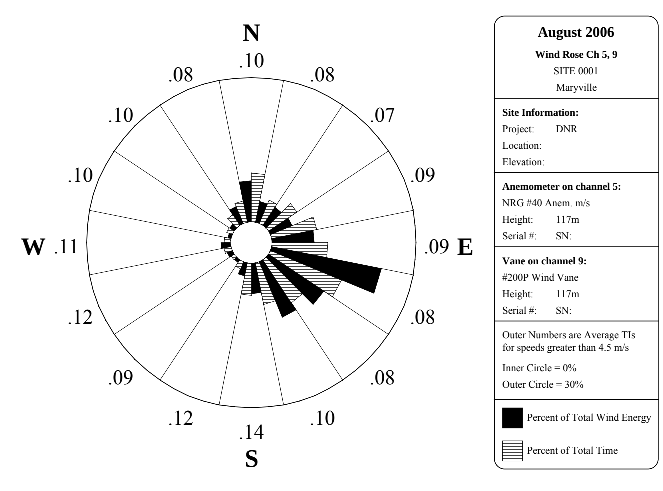


Figure 6.1c: Wind rose for Maryville tower 117-m vane for August 2006.

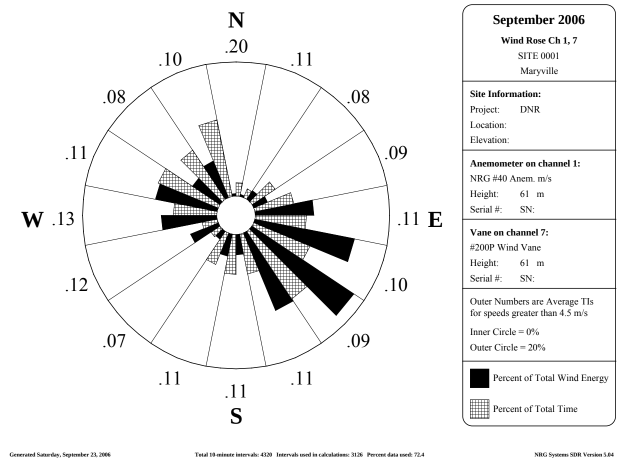


Figure 6.2a: Wind rose for Maryville tower 61-m vane for September 2006.

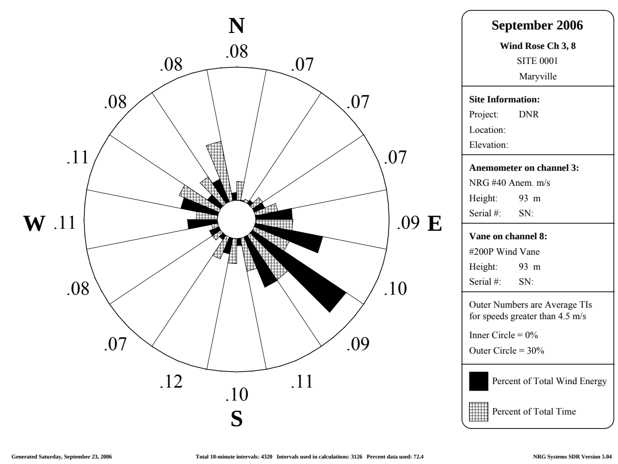


Figure 6.2b: Wind rose for Maryville tower 93-m vane for September 2006.

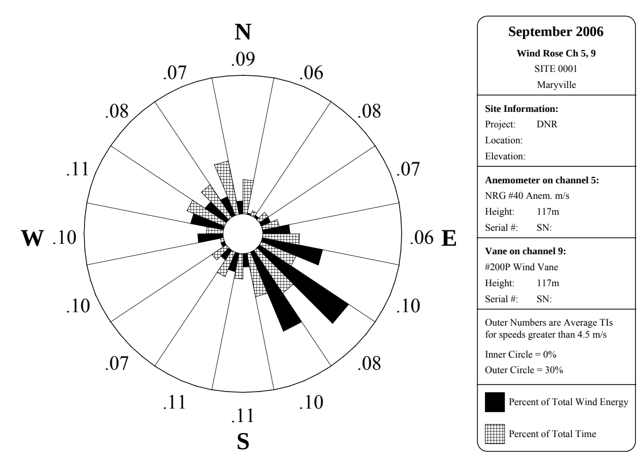


Figure 6.2c: Wind rose for Maryville tower 117-m vane for September 2006.

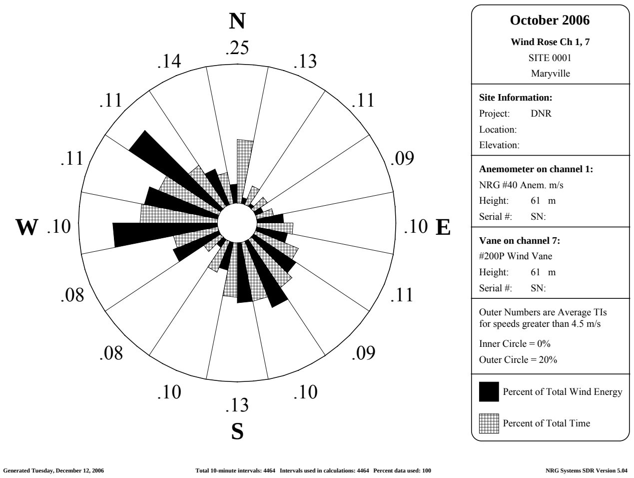


Figure 6.3a: Wind rose for Maryville tower 61-m vane for October 2006.

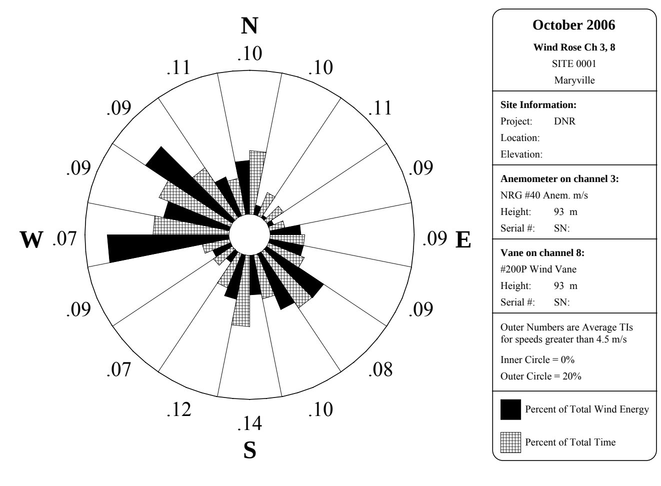


Figure 6.3b: Wind rose for Maryville tower 93-m vane for October 2006.

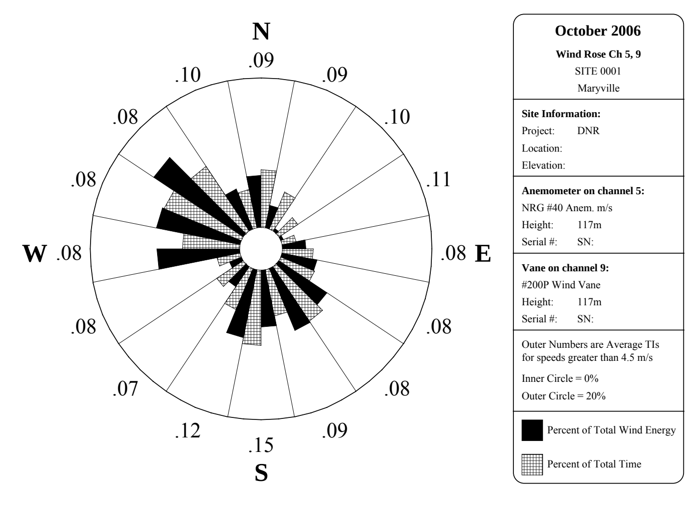


Figure 6.3c: Wind rose for Maryville tower 117-m vane for October 2006.

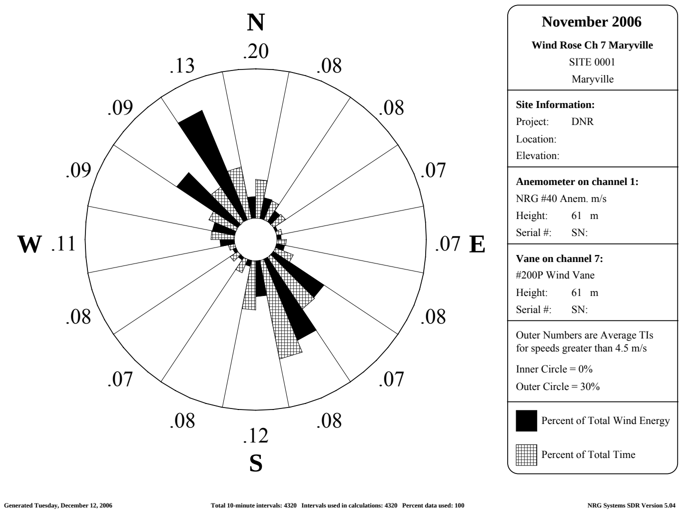


Figure 6.4a: Wind rose for Maryville tower 61-m vane for November 2006.

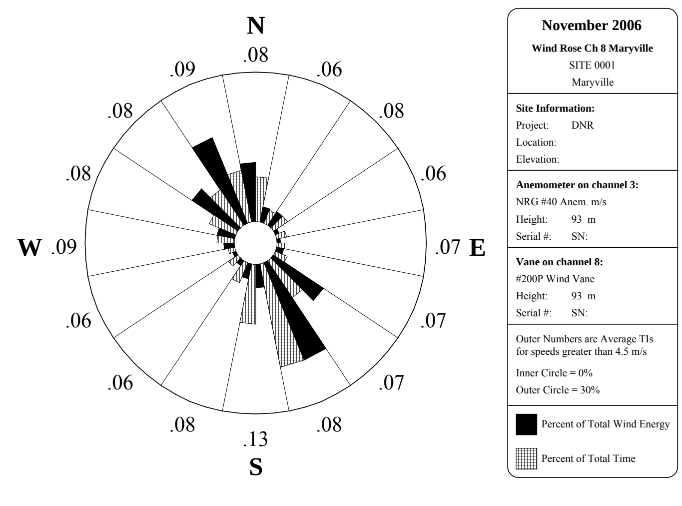


Figure 6.4b: Wind rose for Maryville tower 93-m vane for November 2006.

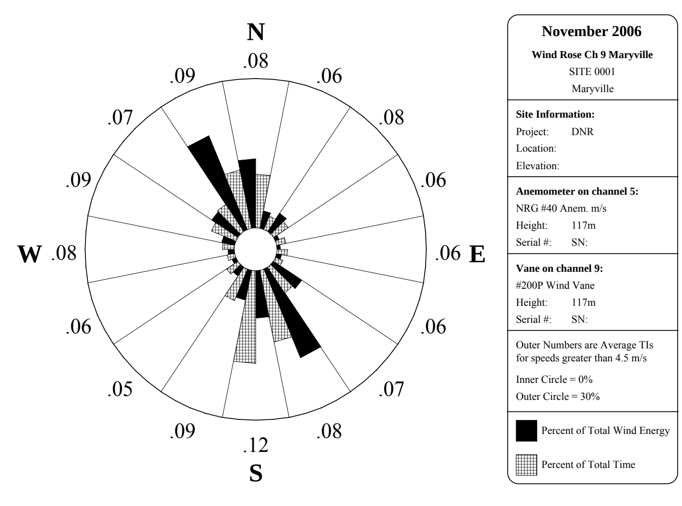


Figure 6.4c: Wind rose for Maryville tower 117-m vane for November 2006.

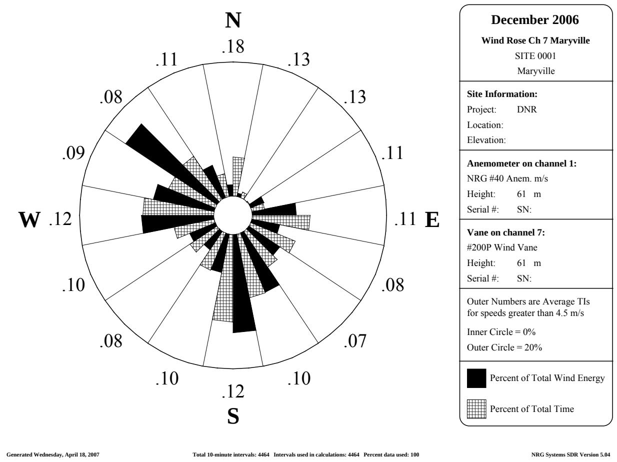


Figure 6.5a: Wind rose for Maryville tower 61-m vane for December 2006.

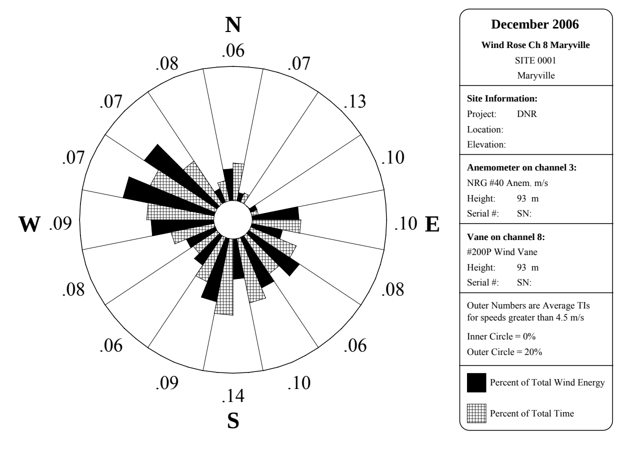


Figure 6.5b: Wind rose for Maryville tower 93-m vane for December 2006.

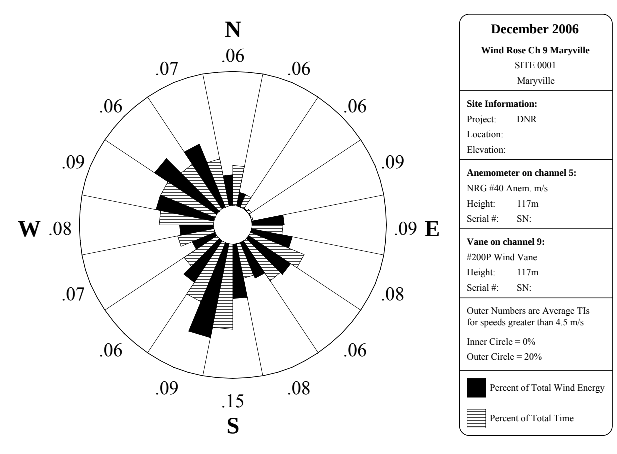


Figure 6.5c: Wind rose for Maryville tower 117-m vane for December 2006.

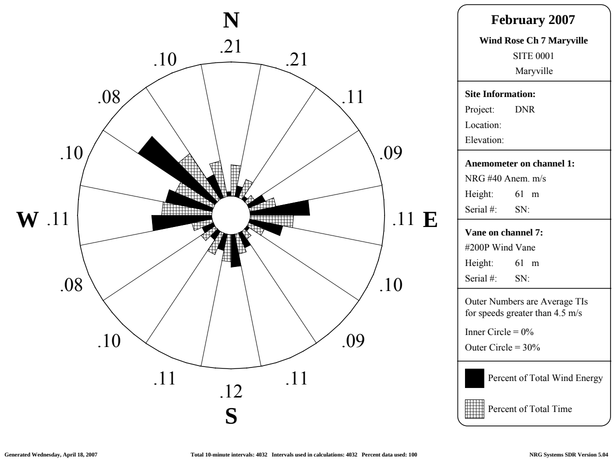


Figure 6.7a: Wind rose for Maryville tower 61-m vane for February 2007.

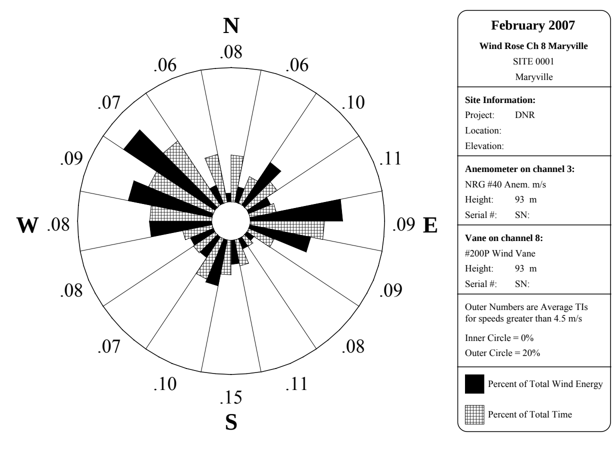


Figure 6.7b: Wind rose for Maryville tower 93-m vane for February 2007.

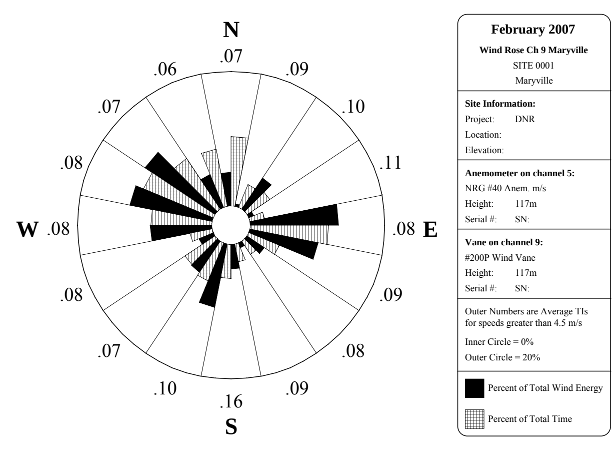


Figure 6.7c: Wind rose for Maryville tower 117-m vane for February 2007.

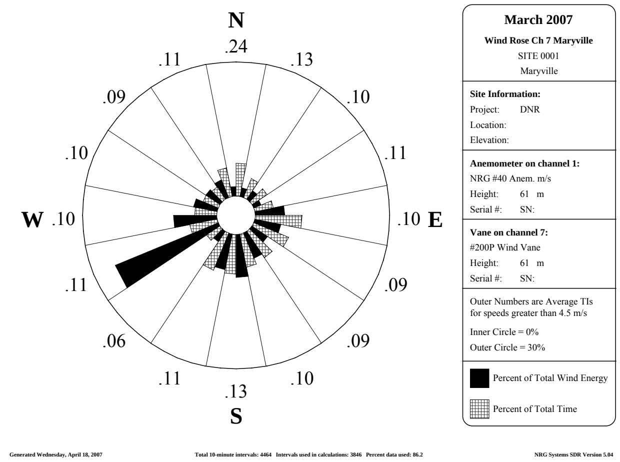


Figure 6.8a: Wind rose for Maryville tower 61-m vane for March 2007.

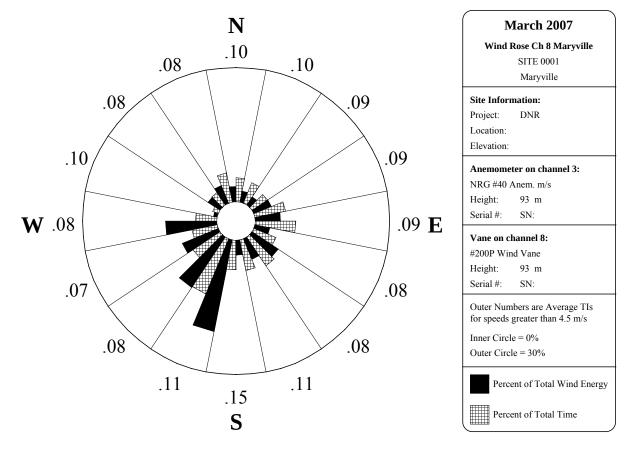


Figure 6.8b: Wind rose for Maryville tower 93-m vane for March 2007.

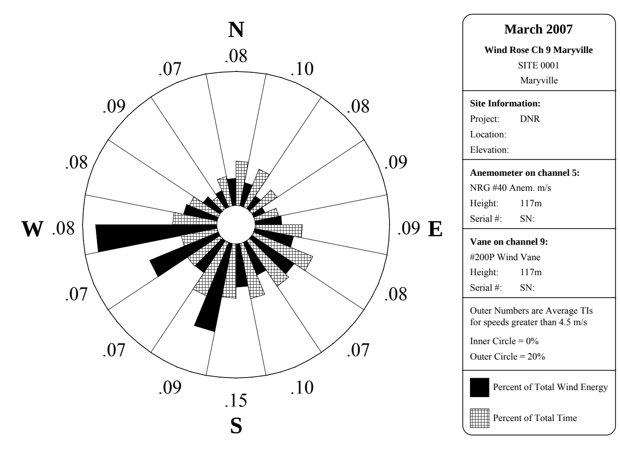


Figure 6.8c: Wind rose for Maryville tower 117-m vane for March 2007.

7. Hourly Averages

The tables in this section were produced by the NRG Symphonie software using the database function. These produce raw data values that are mean hourly wind speeds calculated from the 10-minute observations. Being raw data they include all times regardless of the quality of the data and no quality control of the data has been performed. Indeed quick looks of tehse tables provide a valuable guide to times when data may be corrupted and require attention. The tables also contain daily averages and averages for the month for each hour of the day. A complete set of these tables

In this section we present, as an example, some averages for the Maryville tower for one anemometer at each level and for one illustrative month. These demonstrate the utility of these tables. In figure 7.1, from August, one can see the missing data prior to the start of the operational period.

In figure 7.2 the hourly averages for Chillicothe for January 2007 are shown. In these one can clearly see the period of icing, represented by the block of values of 0.4, on each sensor channel.

Site Information:
Project: DNR
Location:
Elevation:

Sensor on channel 2:
NRG #40 Anem. m/s
Height: 61 m Units: m/s
Serial #: SN:

August 2006
Hourly Averages Table Ch 2
SITE 0001
Maryville

Day \ Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3	6.5	5.7	9.6	3.6	1.3	2.5	4.8	3.5	4.1	4.4	4.7	5.1	4.9	3.9	4.1	5.1	5.7	6.0	6.0	4.8	4.1	4.0	4.0	4.2	4.7
4	4.6	4.8	4.8	4.9	4.5	5.7	6.6	6.7	6.0	6.0	6.0	5.7	4.8	3.8	3.0	4.3	5.5	5.3	5.1	5.8	5.7	5.4	5.2	5.4	5.2
5	6.2	7.2	6.9	6.7	6.8	7.3	6.9	7.4	8.2	7.9	7.3	7.3	7.1	4.5	7.1	9.0	9.2	8.9	9.1	8.6	8.8	8.1	6.7	6.7	7.5
6	6.4	7.3	6.7	7.5	7.9	7.7	8.8	8.4	6.0	1.8	2.2	1.8	2.9	3.7	3.1	2.6	1.8	1.4	1.9	3.0	3.6	6.5	7.1	7.5	4.9
7	7.9	8.3	7.8	5.8	5.7	7.6	3.5	7.1	5.0	4.8	2.2	3.3	5.9	5.9	4.6	4.4	4.9	3.7	3.9	3.9	3.4	3.9	5.9	6.3	5.2
8	6.3	5.5	5.2	5.8	5.2	6.8	5.9	5.8	8.5	9.6	6.2	4.5	4.1	3.2	3.9	5.2	5.8	5.7	4.8	4.6	5.9	5.5	5.1	5.4	5.6
9	5.9	6.0	6.0	6.0	6.7	7.3	7.3	7.5	7.3	6.8	6.6	6.8	5.1	4.3	5.0	5.0	6.0	5.4	5.6	6.9	6.9	6.6	6.1	5.7	6.2
10	5.7	6.9	6.6	7.1	4.9	6.4	5.1	6.7	5.6	6.4	8.6	10.2	7.9	6.7	8.3	7.2	7.6	3.8	5.6	5.7	6.0	4.7	4.5	4.0	6.3
11	4.4	4.4	4.3	3.9	4.2	4.9	5.1	3.9	5.0	5.2	4.7	6.4	5.2	5.8	6.3	5.4	4.7	4.6	4.0	4.2	4.5	4.8	4.8	5.3	4.8
12	6.6	7.2	6.5	4.9	5.3	5.1	5.3	5.7	6.7	6.3	7.8	6.0	6.0	5.8	5.5	5.5	5.3	5.0	5.5	5.7	6.1	6.0	6.8	7.2	6.0
13	6.1	6.3	7.2	7.2	7.2	7.2	7.2	6.5	6.9	7.5	7.8	7.5	8.2	8.1	7.2	4.7	3.9	4.8	4.9	3.9	3.8	8.6	2.7	2.4	6.2
14	1.1	1.8	2.4	1.6	3.8	4.1	3.3	4.2	5.2	7.0	7.8	5.3	7.2	7.0	6.3	5.7	6.4	5.6	5.9	6.1	5.9	5.3	4.2	4.3	4.9
15	3.0	2.3	1.8	1.6	0.5	0.4	1.5	2.0	1.9	2.7	2.8	2.6	2.4	1.9	0.8	1.1	2.4	2.8	4.4	4.9	4.7	5.1	4.7	4.4	2.6
16	4.1	5.6	6.2	6.1	6.9	7.3	7.2	7.1	7.8	8.0	7.6	7.0	6.8	7.1	5.8	5.5	7.0	8.2	9.3	8.8	8.4	8.1	9.0	7.3	7.2
17	5.9	6.7	7.0	7.2	6.8	7.5	8.3	8.7	4.4	4.7	3.9	2.5	4.7	4.0	5.3	4.8	2.8	3.6	4.3	4.3	3.0	2.6	3.2	3.8	5.0
18	4.0	4.2	4.5	5.0	5.0	4.4	6.7	5.1	4.3	3.8	1.8	2.8	3.9	5.2	5.7	4.5	3.6	5.4	5.1	5.9	5.0	4.9	2.9	3.9	4.5
19	5.0	4.4	2.1	1.2	5.4	8.1	3.2	1.5	2.2	4.5	5.2	4.7	6.2	6.4	5.5	4.8	4.6	3.2	5.0	3.1	2.7	3.8	3.7	4.5	4.2
20	5.4	6.3	6.3	4.2	3.9	4.4	4.1	4.0	5.1	4.8	5.1	4.6	4.8	3.4	2.7	2.6	3.3	3.8	3.9	3.7	3.1	3.1	3.0	2.5	4.1
21	2.9	3.9	4.7	5.2	4.8	4.8	4.1	4.0	4.1	5.5	5.1	4.8	4.0	2.0	1.5	1.2	1.3	2.1	1.4	1.2	0.7	0.6	0.8	1.0	3.0
22	0.6	1.1	1.6	0.8	0.7	1.5	2.0	2.2	2.4	3.0	4.0	3.4	3.5	1.7	1.2	1.5	2.0	2.3	1.7	2.4	2.6	3.1	2.7	1.7	2.1
23	2.7	3.4	4.5	5.0	5.9	7.0	7.7	8.7	8.3	7.9	6.9	7.1	6.7	5.6	3.9	2.8	3.1	3.9	4.4	4.7	5.0	5.5	5.3	3.4	5.4
24	3.0	4.1	6.4	6.0	4.6	5.4	5.1	5.1	5.3	5.0	4.7	4.4	4.1	3.7	3.5	4.4	4.4	4.6	4.7	6.2	6.6	6.6	7.4	6.6	5.1
25	6.4	6.5	7.7	6.9	6.6	6.1	6.9	5.1	4.1	8.1	8.9	5.3	4.0	2.2	2.5	3.3	1.8	0.8	1.3	3.3	3.8	4.0	6.2	6.1	4.9
26	7.2	8.6	7.3	7.2	7.1	5.7	9.3	8.1	4.2	5.7	4.3	3.3	4.6	3.9	2.9	2.0	0.8	1.9	3.5	5.0	4.6	3.9	3.9	3.6	4.9
27	3.4	3.1	3.8	4.8	4.3	5.3	5.2	4.7	3.7	4.0	4.3	4.6	4.2	4.7	5.3	4.7	6.2	6.2	5.5	4.0	4.1	4.0	3.7	4.1	4.5
28	4.6	4.2	4.2	3.6	2.4	5.6	4.1	4.4	3.6	6.3	5.5	5.3	6.5	5.9	5.5	5.7	5.6	5.7	5.8	6.3	6.9	6.2	7.1	5.3	5.3
29	5.5	5.3	6.2	6.5	4.7	4.0	5.2	5.4	4.7	4.0	4.3	4.6	4.7	4.0	4.4	4.2	3.7	4.6	5.0	5.4	5.7	6.2	6.0	5.6	5.0
30	4.4	4.0	5.2	6.1	6.0	6.7	6.5	5.5	4.8	5.6	6.4	6.0	5.4	4.1	2.3	3.2	2.5	3.0	3.4	3.5	3.3	4.2	4.6	5.6	4.7
31	5.9	6.6	7.5	6.2	5.4	5.5	5.0	4.7	5.2	5.3	6.2	6.0	5.4	3.2	3.3	4.0	4.5	6.1	6.0	5.6	5.5	5.5	5.9	5.4	5.4
AVG	4.9	5.2	5.6	5.1	5.0	5.6	5.6	5.5	5.2	5.6	5.5	5.1	5.2	4.5	4.4	4.3	4.4	4.4	4.7	4.9	4.8	5.1	4.9	4.8	5.0

Generated Saturday, September 23, 2006 **Total 10-minute intervals: 4464 Intervals used in calculations: 4176 Percent data used: 93.5** **NRG Systems SDR Version 5.04**

Figure 7.1a: Hourly averages for Channel 2 of the Maryville tower for August 2006.

Site Information:
Project: DNR
Location:
Elevation:

Sensor on channel 4:
NRG #40 Anem. m/s
Height: 93 m Units: m/s
Serial #: SN:

August 2006
Hourly Averages Table Ch 4
SITE 0001
Maryville

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3	7.4	6.7	10.7	4.5	1.3	2.6	5.0	4.5	4.5	5.4	5.7	6.4	6.3	4.7	4.5	5.6	6.3	6.6	6.0	4.3	4.1	3.7	3.7	3.8	5.2
4	5.0	5.8	5.8	5.5	5.6	6.9	7.5	7.1	6.7	7.1	7.2	6.7	6.0	5.2	3.3	4.3	5.5	5.2	5.2	6.0	5.9	5.5	5.4	5.9	5.8
5	6.7	8.7	9.1	9.3	9.4	9.8	9.0	9.2	9.9	9.2	8.4	8.1	8.0	4.6	8.0	9.4	9.1	8.8	8.9	8.6	8.8	8.6	6.9	7.1	8.5
6	7.0	8.1	7.6	8.5	8.8	8.9	10.2	9.6	7.0	2.8	2.8	1.9	2.9	5.1	4.8	3.4	2.0	1.2	1.9	3.0	3.6	5.8	5.7	8.2	5.5
7	9.8	10.6	9.0	6.6	6.1	8.7	4.5	7.4	5.6	4.7	1.6	3.2	6.9	6.7	5.6	5.3	5.1	4.0	4.3	4.3	3.9	4.6	6.6	7.7	5.9
8	7.9	7.0	6.7	7.4	6.4	8.3	7.0	7.0	8.7	10.4	7.1	5.2	4.6	4.0	4.9	6.5	6.4	5.9	4.9	4.9	6.3	5.7	5.5	5.9	6.4
9	6.5	6.8	6.9	6.9	7.5	8.1	8.0	8.0	8.0	7.3	7.1	7.7	6.4	4.7	5.2	5.0	5.9	5.4	5.5	6.9	7.4	6.9	6.3	6.3	6.7
10	6.5	8.1	8.2	10.1	9.9	10.3	9.6	10.7	8.5	8.6	10.4	12.3	8.5	7.8	9.1	7.3	7.8	3.7	5.7	5.8	6.1	4.8	4.6	4.4	7.9
11	5.4	5.7	5.9	5.7	5.7	6.3	6.6	4.9	6.0	6.3	5.2	7.0	6.4	6.2	6.6	5.6	4.7	4.6	4.1	4.3	4.6	4.9	4.9	5.7	5.6
12	7.2	8.1	7.5	6.1	6.4	6.2	6.2	6.9	7.5	6.7	7.9	6.4	6.1	5.9	5.5	5.6	5.3	4.9	5.5	5.8	6.1	6.1	7.0	7.4	6.4
13	6.6	7.2	8.7	8.7	8.5	8.3	8.3	7.5	8.0	8.6	8.8	8.4	8.9	8.6	7.6	5.6	4.3	5.9	6.1	5.3	5.5	9.8	2.4	2.7	7.1
14	1.1	2.2	2.5	1.5	3.9	4.2	2.9	4.0	6.8	8.6	6.4	5.2	7.9	5.9	5.5	5.0	6.1	5.6	5.9	5.4	5.2	4.2	3.5	3.3	4.7
15	3.3	2.9	2.2	2.1	0.6	0.4	0.9	1.6	1.8	2.7	3.0	3.3	2.6	1.8	0.9	1.1	2.6	3.1	4.4	4.9	4.8	5.1	4.7	4.8	2.7
16	4.4	6.7	8.0	8.2	9.3	10.0	9.7	9.6	10.2	10.3	9.4	8.8	8.1	7.7	6.3	6.0	7.2	8.3	9.3	8.9	8.8	8.3	9.2	8.2	8.4
17	7.0	8.2	8.4	8.4	7.8	8.7	9.2	9.6	6.6	7.0	5.8	4.5	5.1	4.6	5.6	5.1	3.5	3.6	4.3	4.3	2.7	2.5	3.2	3.9	5.8
18	4.2	4.5	5.5	5.9	5.8	5.5	8.9	5.9	3.2	3.1	2.1	2.7	4.4	6.4	6.5	4.8	3.9	5.7	5.6	6.1	4.9	4.9	2.9	3.7	4.9
19	5.5	5.1	3.3	1.2	5.7	8.5	4.0	2.0	3.5	5.6	6.0	5.9	7.6	7.9	5.5	4.0	4.2	3.4	4.9	3.1	2.5	2.9	3.6	4.9	4.6
20	4.4	4.8	5.1	3.9	4.6	5.1	5.2	5.4	7.0	6.8	7.0	6.9	7.1	4.8	2.9	2.8	3.5	3.9	4.0	3.9	3.1	3.3	3.1	2.8	4.6
21	3.4	4.3	5.2	6.1	5.5	5.7	5.4	5.3	5.5	7.3	7.0	6.1	5.0	2.7	2.0	1.6	1.7	2.4	1.5	1.1	0.8	0.7	1.0	1.2	3.7
22	0.7	1.2	1.8	1.0	1.1	1.6	1.8	2.1	2.3	2.7	3.9	3.4	3.6	3.1	2.3	2.0	2.4	2.5	1.9	2.5	2.9	4.3	3.1	1.8	2.3
23	2.8	3.3	4.5	4.9	6.0	8.5	9.9	10.4	10.6	10.9	9.9	11.0	8.9	7.2	5.2	4.1	3.4	4.0	5.5	6.8	6.8	7.6	7.2	5.7	6.9
24	6.0	7.1	7.8	8.2	9.5	9.9	10.5	9.8	9.1	8.9	8.4	8.3	7.7	6.5	5.0	5.5	7.3	7.5	7.5	7.9	7.2	7.3	7.7	6.9	7.8
25	7.1	7.8	9.0	8.3	7.9	7.1	8.0	7.6	6.4	11.0	9.9	7.1	6.3	4.2	3.1	3.9	2.6	1.3	1.2	3.4	3.5	2.9	4.5	4.5	5.8
26	5.3	6.8	6.3	6.6	8.0	6.3	10.5	9.1	3.4	4.2	3.6	3.4	5.3	4.3	3.0	1.9	1.0	2.2	3.8	4.8	4.1	3.5	3.7	3.2	4.8
27	4.2	4.4	5.2	5.9	5.3	6.6	6.6	6.0	4.8	4.9	5.0	5.4	5.1	5.3	5.8	5.2	6.4	6.3	5.7	4.2	4.2	4.3	4.0	4.5	5.2
28	5.1	5.0	5.2	4.5	3.2	6.8	5.7	5.1	3.9	6.6	5.8	5.5	6.8	6.5	6.1	5.2	4.2	5.5	5.8	5.8	5.9	5.2	5.7	5.0	5.4
29	6.6	6.5	6.5	7.5	5.1	5.1	7.0	6.6	5.8	5.3	5.4	5.8	5.8	5.2	4.8	4.5	4.0	4.8	5.3	5.8	6.2	6.8	6.8	6.5	5.8
30	5.1	4.6	6.5	5.3	4.1	4.2	7.5	6.0	4.9	5.8	5.7	5.3	4.8	5.0	3.1	3.1	2.6	3.0	3.4	3.6	3.2	4.3	4.6	6.0	4.6
31	6.8	8.0	9.0	8.6	7.4	7.5	6.8	6.2	6.7	6.8	7.4	7.8	7.3	3.6	3.3	4.0	4.5	6.2	6.1	5.7	5.6	5.7	6.0	5.7	6.4
AVG	5.5	6.1	6.5	6.1	6.1	6.8	7.0	6.7	6.3	6.7	6.3	6.2	6.2	5.4	4.9	4.6	4.6	4.7	5.0	5.1	5.0	5.2	4.9	5.1	5.7

Generated Saturday, September 23, 2006 Total 10-minute intervals: 4464 Intervals used in calculations: 4176 Percent data used: 93.5 NRG Systems SDR Version 5.04

Figure 7.1b: Hourly averages for Channel 4 of the Maryville tower for August 2006.

Site Information:
Project: DNR
Location:
Elevation:

Sensor on channel 6:
NRG #40 Anem. m/s
Height: 117m Units: m/s
Serial #: SN:

August 2006
Hourly Averages Table Ch 6
SITE 0001
Maryville

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3	7.3	6.7	11.1	4.9	1.2	2.9	5.3	4.8	4.6	5.9	6.0	6.7	6.5	4.8	4.5	5.6	6.3	6.6	6.0	4.4	4.1	3.7	3.7	3.9	5.3
4	5.1	5.9	5.8	5.8	5.7	7.1	7.3	6.9	6.8	7.1	7.1	6.7	6.2	6.0	3.7	4.3	5.6	5.3	5.2	6.0	5.9	5.6	5.6	6.1	5.9
5	6.9	9.6	10.1	10.1	10.0	11.1	10.4	10.6	11.2	10.1	9.2	8.8	8.8	4.9	8.2	9.7	9.2	9.0	9.1	8.8	9.0	8.7	7.3	7.4	9.1
6	7.4	8.8	8.4	9.5	9.6	9.8	11.1	10.6	7.5	3.3	2.8	1.9	2.8	5.3	4.9	3.4	2.1	1.2	2.0	3.0	3.6	5.8	6.0	8.3	5.8
7	10.1	11.1	9.7	6.5	5.9	9.4	5.2	7.4	5.6	4.6	1.3	3.2	7.0	6.9	5.9	5.7	5.3	3.9	4.2	4.2	3.9	4.5	6.9	8.0	6.1
8	8.6	7.6	7.4	8.1	7.1	8.9	7.5	7.4	9.0	10.4	7.5	5.5	4.6	4.3	5.4	7.3	6.7	5.9	5.0	4.8	6.5	5.8	5.8	6.1	6.8
9	6.8	7.3	7.5	7.4	7.9	8.6	8.5	8.4	8.4	7.8	7.7	8.5	7.4	5.0	5.3	5.1	5.8	5.4	5.7	7.0	7.7	7.2	6.7	6.8	7.1
10	7.1	9.0	9.4	11.5	11.6	11.6	11.1	12.1	9.7	9.6	10.9	12.8	8.9	8.3	9.5	7.5	8.0	3.4	5.8	5.8	6.2	4.9	4.6	4.5	8.5
11	5.7	6.5	6.7	6.5	6.4	6.8	7.5	5.6	6.3	6.4	5.0	6.7	7.0	6.4	6.6	5.7	4.8	4.6	4.2	4.4	4.6	5.0	5.0	5.9	5.8
12	7.4	8.6	8.2	6.8	7.1	7.0	6.8	7.6	8.0	7.1	8.1	6.6	6.3	6.1	5.7	5.6	5.3	4.9	5.6	5.8	6.2	6.2	7.1	7.5	6.7
13	6.8	7.8	9.6	9.7	9.3	9.2	9.1	8.3	8.8	9.3	9.6	9.2	9.7	9.1	7.9	5.7	4.4	6.1	6.2	5.5	5.8	10.1	2.4	2.9	7.6
14	1.1	2.2	2.2	1.5	3.8	3.9	2.7	3.7	7.5	9.0	6.9	5.4	7.9	6.1	5.5	4.9	6.0	5.6	6.0	5.4	5.3	4.4	3.6	3.7	4.8
15	3.5	2.8	2.4	2.2	0.7	0.4	0.7	1.6	1.7	2.7	2.9	2.9	2.1	1.6	1.2	1.0	2.7	3.3	4.5	5.0	4.9	5.2	4.9	5.0	2.7
16	4.7	7.1	8.4	8.6	9.7	10.9	11.4	11.4	12.0	12.1	10.7	10.1	9.1	8.2	6.7	6.3	7.5	8.5	9.5	9.2	9.3	8.5	9.4	8.8	9.1
17	7.7	9.1	9.3	9.2	8.6	9.6	10.0	10.3	7.3	7.4	6.2	5.1	5.5	5.1	5.8	5.4	3.9	3.8	4.3	4.5	2.8	2.6	3.2	3.9	6.3
18	4.2	4.6	5.9	6.6	6.5	6.3	9.8	6.3	3.2	2.8	2.6	2.5	4.4	6.6	6.8	5.0	4.1	6.0	5.9	6.3	4.9	4.8	2.8	3.7	5.1
19	5.6	5.4	3.8	1.0	5.1	8.8	4.4	1.8	3.2	5.5	5.9	6.2	7.9	8.2	5.7	4.2	4.4	3.3	4.4	3.0	2.2	2.9	3.6	4.9	4.7
20	4.4	4.8	5.2	4.2	4.8	5.6	6.1	6.6	7.9	7.7	7.8	7.7	7.5	5.2	2.6	2.8	3.5	3.9	4.0	3.8	3.1	3.3	3.1	2.8	4.9
21	3.5	4.4	5.3	6.3	5.6	5.9	6.2	6.1	6.3	8.4	8.2	6.9	5.7	2.9	2.1	1.5	1.8	2.5	1.4	1.1	0.9	0.7	0.9	1.2	4.0
22	0.6	1.0	1.6	0.5	0.5	0.9	1.3	1.8	1.9	2.3	3.7	3.3	3.4	3.2	2.6	2.1	2.4	2.6	1.9	2.5	3.0	4.4	3.2	1.9	2.2
23	2.9	3.4	4.6	5.0	6.0	8.4	10.1	10.4	11.8	12.4	11.5	12.7	10.5	8.4	6.0	4.6	3.5	4.0	5.6	7.0	7.0	7.8	7.5	6.2	7.4
24	7.0	7.8	8.0	8.7	10.7	11.1	11.6	10.9	10.2	10.2	9.7	9.7	8.8	7.2	5.4	5.7	7.5	7.7	7.7	8.0	7.4	7.5	8.0	7.3	8.5
25	7.7	8.6	10.0	9.4	9.0	7.9	8.9	8.8	7.3	11.6	10.0	7.6	6.9	5.2	3.6	3.9	2.7	1.5	1.2	3.3	3.5	2.9	4.6	4.7	6.3
26	5.7	7.4	7.0	7.3	8.3	6.9	11.1	9.8	3.5	5.2	3.6	3.9	5.5	4.5	3.1	2.3	1.1	2.1	3.8	4.7	4.0	3.4	3.8	3.5	5.1
27	4.5	4.9	5.7	6.2	5.6	7.0	7.2	6.5	5.3	5.2	5.3	5.8	5.3	5.6	5.9	5.3	6.4	6.4	5.8	4.2	4.1	4.5	4.1	4.6	5.5
28	5.3	5.2	5.5	4.9	3.4	7.4	6.1	5.3	4.2	6.7	6.0	5.6	7.0	6.9	6.3	5.3	4.4	5.5	5.8	5.8	5.9	5.4	6.1	5.2	5.6
29	6.7	6.7	6.9	7.5	5.1	5.5	7.3	6.8	5.9	5.4	5.8	6.2	6.2	5.7	4.9	4.4	3.8	4.8	5.3	5.8	6.2	6.7	6.8	6.4	5.9
30	5.1	4.5	6.4	4.7	4.3	4.5	7.2	5.7	5.3	5.1	4.8	4.5	4.1	4.3	3.3	3.0	2.4	3.0	3.4	3.5	3.2	4.3	4.6	6.2	4.5
31	7.2	8.3	9.3	9.2	8.6	8.8	8.2	7.2	7.6	7.3	7.1	7.9	8.4	4.0	3.3	4.0	4.5	6.2	6.2	5.8	5.6	5.8	6.1	5.9	6.8
AVG	5.7	6.4	6.9	6.5	6.5	7.3	7.6	7.3	6.8	7.2	6.7	6.6	6.6	5.7	5.1	4.7	4.7	4.7	5.0	5.1	5.1	5.3	5.1	5.3	6.0

Generated Saturday, September 23, 2006 Total 10-minute intervals: 4464 Intervals used in calculations: 4176 Percent data used: 93.5 NRG Systems SDR Version 5.04

Figure 7.1c: Hourly averages for Channel 6 of the Maryville tower for August 2006.

Site Information:
Project: New Project
Location:
Elevation:

Sensor on channel 1:
NRG #40 Anem. m/s
Height: 70 m Units: m/s
Serial #: SN:

January 2007
Hourly Averages Table Ch 1
SITE 0004
New Site

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
1	6.3	5.8	7.6	6.9	6.3	6.8	6.4	7.2	6.3	6.2	5.7	6.2	5.0	4.5	4.9	3.9	4.4	5.0	4.5	4.7	4.5	4.2	3.9	4.4	5.5
2	3.8	1.4	0.4	0.4	1.8	3.0	5.1	5.3	5.8	5.3	3.6	3.5	3.6	5.0	5.1	5.4	5.9	6.8	8.8	7.7	8.6	6.9	5.8	5.8	4.8
3	5.0	5.5	6.2	6.3	6.2	6.7	6.6	6.5	5.8	5.0	5.0	5.5	5.6	9.2	9.7	10.5	10.7	10.6	10.4	10.3	9.2	8.8	8.6	9.8	7.6
4	8.2	6.8	8.6	7.1	3.9	5.5	7.6	8.0	8.5	8.6	8.1	7.8	8.3	10.3	10.8	9.9	8.2	7.0	8.2	8.6	7.3	7.0	6.7	6.3	7.8
5	6.5	5.2	5.4	5.0	4.2	2.1	0.6	2.3	4.1	4.0	2.4	1.1	2.2	2.0	3.8	3.3	6.4	6.3	6.5	6.9	7.1	6.0	5.4	5.3	4.3
6	6.6	6.0	5.8	5.8	6.0	6.0	5.7	5.4	3.6	1.9	2.6	3.2	3.3	3.8	3.5	3.3	2.8	3.8	5.0	5.2	5.6	6.3	7.0	8.3	4.9
7	7.1	5.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6.2
8	7.1	6.3	5.9	5.9	5.9	5.9	6.2	6.0	6.3	6.8	9.6	8.5	9.4	8.6	8.6	8.5	7.2	7.8	7.9	7.9	8.2	8.4	8.8	8.5	7.5
9	10.7	12.0	10.4	9.2	9.8	8.9	10.8	10.6	9.8	9.4	9.6	9.0	7.5	7.1	7.1	6.3	5.4	4.8	4.4	3.6	3.6	4.0	4.0	3.4	7.6
10	3.0	4.7	6.1	7.0	7.6	8.1	7.5	7.8	7.9	7.1	9.7	9.8	10.4	13.6	11.7	12.3	11.5	10.2	9.3	9.7	9.4	9.2	9.3	9.3	8.8
11	8.8	7.1	6.0	7.1	7.9	9.2	9.0	9.7	8.2	7.1	7.2	6.4	5.1	6.3	6.9	7.2	7.2	7.6	7.1	7.3	7.1	6.4	8.8	8.5	7.5
12	7.0	7.0	6.3	6.0	6.4	6.6	7.1	7.0	7.3	7.1	6.6	6.7	6.0	6.4	5.9	5.9	5.1	5.2	6.1	6.0	5.9	6.4	6.1	7.1	6.4
13	7.2	6.1	6.5	6.7	6.6	5.9	5.6	5.6	4.5	4.3	5.6	5.2	3.6	4.0	3.6	4.5	4.4	4.5	4.1	3.3	3.4	3.5	3.2	3.6	4.8
14	4.1	4.3	3.2	2.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.9
15	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
16	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
17	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	8.1	7.0	5.8	6.1	6.3	6.5	6.4	6.0	5.9	2.7
19	6.1	5.0	5.0	5.9	6.8	6.5	5.8	5.9	6.4	4.4	4.5	5.7	6.5	6.5	7.3	6.3	5.4	5.4	5.5	5.0	4.3	2.8	3.6	3.5	5.4
20	2.4	3.5	3.0	3.3	4.0	6.4	5.7	4.0	4.3	3.7	4.2	4.5	4.5	4.7	4.6	4.3	3.9	3.7	4.1	5.1	6.5	6.8	7.3	7.9	4.7
21	9.0	8.3	6.8	5.8	4.9	4.3	4.0	3.3	2.6	2.2	1.8	1.5	2.4	4.0	5.3	4.5	4.5	4.7	5.8	5.3	4.0	4.3	4.8	4.3	4.5
22	4.4	4.3	4.2	4.7	4.3	3.3	3.8	4.6	3.7	3.4	3.5	4.2	5.3	5.2	4.9	5.1	5.8	4.8	5.7	6.0	6.2	7.2	5.8	5.4	4.8
23	6.2	6.4	6.4	6.2	5.8	6.2	7.3	6.0	4.1	2.7	3.4	3.4	4.3	4.2	3.6	3.7	3.0	5.0	4.3	3.5	4.9	3.3	4.0	3.9	4.7
24	4.1	4.8	3.8	3.8	3.2	0.9	2.6	3.2	3.7	4.3	4.3	4.2	4.5	4.7	6.0	5.9	6.3	5.0	6.2	6.7	7.1	6.9	6.3	4.2	4.7
25	3.7	5.3	5.0	4.2	3.4	3.9	4.2	3.2	3.1	2.4	1.4	1.0	1.9	2.4	3.7	4.0	3.8	4.3	4.4	5.8	6.8	7.3	7.5	6.5	4.1
26	6.8	6.7	6.3	6.2	6.3	6.3	6.2	6.7	7.3	7.3	7.5	8.0	8.8	8.5	9.0	11.2	8.4	7.3	7.7	6.8	6.3	6.1	7.2	6.3	7.3
27	7.6	6.8	7.5	6.7	6.3	6.3	5.4	4.7	4.2	6.9	7.9	9.9	10.7	9.9	10.0	10.6	9.4	9.2	10.4	9.3	8.2	7.4	7.0	6.8	7.9
28	6.3	6.6	7.4	7.5	7.2	6.9	6.8	6.9	6.9	6.6	5.5	4.7	4.1	4.4	4.4	4.7	4.2	4.5	4.1	5.1	5.2	6.1	6.9	8.1	5.9
29	7.3	6.8	6.2	6.2	5.3	5.7	6.4	6.5	5.9	3.0	3.9	5.5	8.1	8.7	9.8	11.3	9.4	9.7	10.6	9.0	10.0	9.9	7.2	7.9	7.5
30	7.6	8.2	8.5	8.0	7.4	7.3	7.1	6.5	8.0	8.9	7.4	7.7	7.2	7.0	6.9	5.9	5.7	4.5	4.0	4.2	4.4	3.8	2.3	1.3	6.2
31	2.6	3.1	4.0	4.6	5.0	4.7	5.3	5.3	6.2	6.1	6.6	7.7	6.6	6.3	5.9	5.2	4.5	5.1	4.7	4.0	3.6	3.0	3.1	3.4	4.9
AVG	5.4	5.2	5.1	5.0	4.8	4.8	5.0	5.0	4.9	4.6	4.7	4.8	4.9	5.3	5.5	5.8	5.4	5.3	5.6	5.5	5.5	5.3	5.3	5.2	5.2

Generated Thursday, April 19, 2007 **Total 10-minute intervals: 4464 Intervals used in calculations: 4331 Percent data used: 97** **NRG Systems SDR Version 5.02**

Figure 7.2a: Hourly average wind speeds for Chillicothe for January 2007 for channel 1.

Site Information:
Project: New Project
Location:
Elevation:

Sensor on channel 3:
NRG #40 Anem. m/s
Height: 100 m Units: m/s
Serial #: SN:

January 2007
Hourly Averages Table Ch 3
SITE 0004
New Site

Day	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
1	5.9	5.8	7.1	6.2	5.8	6.7	5.9	6.6	5.9	5.4	5.0	5.4	4.2	3.8	4.2	3.3	4.0	5.3	4.8	4.7	4.1	4.2	4.8	5.6	5.2
2	5.2	2.7	1.2	0.9	2.0	3.3	5.0	7.2	7.9	6.1	4.1	3.5	3.7	5.1	5.4	6.0	6.7	7.5	9.9	9.2	10.2	8.4	7.1	7.2	5.6
3	6.4	6.9	7.6	7.6	7.5	8.0	7.6	7.4	6.5	5.7	5.1	5.4	5.8	9.5	10.0	11.0	11.4	11.6	11.4	11.4	10.3	9.9	9.9	10.9	8.5
4	9.1	8.0	9.7	8.2	4.9	6.3	8.6	8.6	9.3	9.3	8.5	8.2	8.6	10.7	11.1	10.4	9.1	7.8	9.1	9.6	8.2	7.9	7.8	7.4	8.6
5	7.4	5.8	6.0	5.9	5.1	2.2	0.6	1.8	4.4	4.2	2.2	0.7	2.0	1.8	3.9	3.5	7.0	6.9	7.3	7.7	7.9	6.7	5.9	5.8	4.7
6	6.8	5.8	5.4	5.1	6.2	6.0	6.0	5.4	4.2	1.9	2.6	3.0	3.2	3.8	3.3	3.3	2.9	4.0	5.7	6.0	5.8	7.1	7.9	9.1	5.0
7	8.8	6.9	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7.8
8	8.9	8.1	7.6	7.4	7.1	7.1	7.4	7.2	7.3	7.9	10.4	9.3	10.3	9.4	9.3	9.4	8.5	9.5	9.5	7.9	7.8	7.7	7.7	8.1	8.4
9	9.7	10.4	9.2	8.3	9.1	8.2	9.7	9.4	9.1	9.8	10.0	9.3	7.7	6.3	6.2	5.6	5.0	5.2	5.2	4.3	3.5	4.5	5.1	4.0	7.3
10	3.2	3.8	6.5	8.5	9.0	9.1	8.7	8.8	8.9	8.3	10.4	10.3	10.8	14.2	12.3	13.0	12.4	11.2	10.4	10.8	10.5	10.1	10.4	10.4	9.7
11	9.8	8.4	7.0	8.4	9.2	10.4	10.2	10.7	8.9	7.9	7.9	7.5	6.7	7.5	7.5	8.1	8.4	8.6	8.2	8.9	8.6	6.0	8.9	9.3	8.5
12	7.8	7.7	6.8	6.5	7.0	7.3	7.7	7.6	8.0	7.7	7.2	7.2	6.4	6.8	6.3	6.3	5.5	5.6	6.6	6.5	6.4	6.9	6.6	7.8	6.9
13	8.0	6.8	7.2	7.3	7.3	6.4	6.0	5.9	4.8	4.6	6.0	5.6	3.8	4.2	3.8	4.9	4.9	5.0	4.6	3.5	3.8	3.8	3.4	3.9	5.2
14	4.4	4.5	2.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.8
15	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
16	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
17	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	4.8	6.1	7.5	10.2	8.9	7.3	6.3	7.0	7.2	7.2	7.1	6.6	6.8	4.1
19	6.9	6.2	6.4	7.5	9.1	9.7	7.5	7.7	8.4	5.4	5.0	6.2	7.2	7.0	7.9	7.0	5.2	6.2	4.2	4.7	4.3	3.4	4.1	3.8	6.3
20	3.3	3.8	4.0	4.4	5.0	6.8	7.7	6.5	6.4	5.1	5.2	5.4	5.5	5.5	5.7	5.6	5.3	4.5	4.7	5.6	7.1	7.4	8.0	8.5	5.7
21	9.7	9.1	8.9	7.9	6.9	6.2	5.7	4.8	3.9	3.5	2.6	2.1	2.9	3.8	5.2	4.5	3.8	5.1	6.5	6.1	4.5	4.7	5.4	4.5	5.3
22	4.3	4.0	4.0	5.1	4.4	3.0	3.8	4.8	3.7	3.3	3.6	4.5	5.8	5.3	5.3	5.5	6.1	5.4	6.3	6.9	7.0	8.0	6.6	6.1	5.1
23	7.4	7.5	7.4	7.4	6.7	7.5	8.8	7.1	5.1	3.3	3.7	3.5	4.6	4.5	3.8	4.0	3.2	5.6	4.3	3.4	5.4	3.9	4.4	4.6	5.3
24	4.2	4.7	3.6	3.5	3.0	0.8	2.3	3.6	4.6	4.5	4.4	4.5	5.0	4.7	5.3	5.7	6.4	5.4	6.7	7.2	7.9	7.6	7.0	5.0	4.9
25	4.4	4.5	5.6	4.4	3.7	3.8	4.0	2.8	2.8	2.5	1.3	1.0	1.8	2.2	3.6	4.0	3.8	4.6	4.7	6.1	7.7	8.3	9.1	7.8	4.4
26	8.1	8.0	7.7	7.4	7.6	7.9	8.1	8.5	8.8	8.7	8.7	8.7	9.7	9.4	10.0	12.5	9.5	8.8	9.4	7.3	6.8	6.1	8.1	7.0	8.4
27	8.5	7.6	8.5	7.8	7.5	6.8	5.9	5.2	4.3	6.5	8.2	9.9	11.1	9.4	9.5	9.9	8.4	8.4	10.6	9.9	8.7	8.1	6.4	6.5	8.0
28	5.6	6.2	7.1	7.3	7.1	6.8	6.6	7.2	6.7	5.6	4.9	4.2	3.9	4.3	4.6	5.0	4.6	4.9	4.8	5.8	6.0	7.2	8.1	9.2	6.0
29	8.2	7.6	7.1	7.2	6.4	6.8	8.1	7.7	6.3	3.4	4.3	6.0	8.8	9.5	9.2	10.6	8.5	8.8	9.6	8.4	9.7	9.5	6.4	7.1	7.7
30	7.1	7.9	8.4	7.5	6.7	6.5	6.2	5.7	7.3	8.0	7.0	6.9	7.0	6.3	6.1	5.4	5.1	4.1	3.7	3.2	4.0	4.0	2.5	1.1	5.7
31	2.3	3.0	3.6	5.0	5.8	5.9	6.5	6.5	7.3	6.7	6.9	8.0	6.7	6.5	6.1	5.4	4.8	5.6	5.1	4.3	4.0	3.6	3.6	4.0	5.3
AVG	5.9	5.6	5.6	5.5	5.4	5.4	5.6	5.6	5.4	4.9	4.9	5.1	5.3	5.7	5.9	6.0	5.6	5.8	6.1	5.9	6.0	5.8	5.8	5.8	5.6

Generated Thursday, April 19, 2007 **Total 10-minute intervals: 4464 Intervals used in calculations: 4331 Percent data used: 97** **NRG Systems SDR Version 5.02**

Figure 7.2b: Hourly average wind speeds for Chillicothe for January 2007 for channel 3.

Site Information:
Project: New Project
Location:
Elevation:

Sensor on channel 5:
NRG #40 Anem. m/s
Height: 120 m Units: m/s
Serial #: SN:

January 2007
Hourly Averages Table Ch 5
SITE 0004
New Site

Day	Hour 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
1	7.9	7.4	9.3	8.5	8.1	8.8	8.3	9.3	7.9	7.3	6.2	6.5	5.2	4.7	5.0	4.1	4.9	6.2	6.3	7.1	6.8	6.0	5.5	6.5	6.8
2	6.1	4.0	2.8	2.8	2.5	3.6	5.9	8.0	9.4	7.2	4.8	3.8	3.9	5.3	5.7	6.8	7.5	8.6	11.7	11.1	12.3	10.3	9.0	8.8	6.8
3	8.3	8.9	9.3	9.3	9.1	9.6	9.2	8.9	7.9	6.9	5.9	5.9	6.4	10.1	10.8	11.8	12.6	12.9	12.9	13.0	11.7	11.5	11.8	12.4	9.9
4	10.4	9.5	11.3	9.6	6.2	7.3	9.8	9.8	10.7	10.5	9.4	8.9	9.3	11.2	11.8	11.3	10.0	8.6	10.2	10.6	9.0	8.7	8.5	7.9	9.6
5	7.9	6.1	6.4	6.9	5.6	2.7	0.7	2.3	4.6	4.5	2.6	1.2	2.5	2.2	4.1	3.8	7.2	7.4	7.8	8.1	8.4	7.0	6.3	6.5	5.1
6	7.9	7.3	7.3	7.4	7.9	7.6	7.4	7.2	5.8	2.5	2.8	3.2	3.5	4.0	3.7	3.6	3.3	4.4	6.6	6.3	6.1	7.7	8.4	9.1	5.9
7	9.2	8.0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	8.6
8	9.9	9.3	9.0	8.7	8.2	8.2	8.8	8.6	8.3	8.6	10.5	9.3	10.2	9.3	9.7	10.1	9.1	10.3	10.9	10.9	10.7	10.6	10.6	10.9	9.6
9	13.0	14.3	12.9	11.4	12.3	10.7	13.0	12.5	11.5	10.9	10.8	10.0	8.5	7.8	7.7	7.1	6.2	6.1	5.8	4.9	4.0	4.4	4.2	3.6	8.9
10	3.5	4.4	7.2	9.5	11.0	10.6	10.3	10.5	10.7	9.4	11.8	11.1	11.7	15.1	13.3	14.1	13.8	12.7	11.9	12.6	12.2	11.7	11.9	12.0	11.0
11	11.6	10.5	8.8	10.4	11.3	12.2	12.0	12.2	10.1	9.3	9.2	8.4	7.5	8.8	8.7	9.7	10.0	9.9	9.5	10.8	10.1	7.4	9.9	9.7	9.9
12	8.0	7.8	7.0	6.8	7.2	7.4	7.9	7.7	8.1	7.9	7.3	7.2	6.4	6.8	6.3	6.3	5.7	5.7	6.9	6.6	6.6	7.1	6.8	7.9	7.1
13	8.3	7.1	7.5	7.6	7.7	6.4	6.2	6.0	5.0	4.5	6.1	5.6	3.9	4.3	3.9	5.2	5.2	5.2	4.9	3.5	4.0	4.0	3.3	3.7	5.4
14	4.3	4.3	3.1	3.2	1.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	1.0
15	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
16	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
17	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
18	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	4.0	10.2	8.6	8.9	9.2	11.8	11.5	9.7	8.7	9.4	9.9	9.8	9.9	9.3	9.4	6.0
19	9.5	8.3	7.5	7.9	10.4	11.8	8.6	9.2	9.8	6.5	5.3	6.1	7.2	7.1	8.1	7.6	6.3	6.6	6.2	6.2	5.8	4.8	4.6	4.1	7.3
20	3.4	3.7	4.8	5.2	5.4	7.0	8.5	6.6	6.9	5.2	4.8	5.0	5.0	5.1	5.2	5.1	5.1	4.7	5.1	6.3	8.2	8.9	9.2	9.8	6.0
21	11.3	10.0	8.4	7.3	6.1	5.5	5.3	4.8	4.2	3.9	3.8	3.1	3.4	4.5	5.8	5.3	5.2	5.8	6.9	6.4	4.9	5.3	5.8	5.3	5.8
22	5.5	5.2	5.3	5.8	5.5	4.6	5.3	6.0	4.9	3.6	3.8	4.5	5.7	5.4	5.4	5.6	6.4	5.8	6.5	7.2	7.0	8.1	6.9	6.6	5.7
23	8.2	8.3	8.2	8.3	7.8	8.8	10.1	7.8	6.1	4.1	3.7	3.6	4.5	4.4	3.8	4.0	3.2	6.0	5.6	4.6	5.8	4.4	5.4	5.1	5.9
24	5.9	6.4	4.5	4.5	4.1	2.0	2.4	3.9	5.4	5.0	4.6	4.4	5.2	5.3	6.9	6.8	7.4	6.2	7.4	8.1	8.4	7.9	7.3	5.5	5.7
25	4.8	5.7	5.7	4.0	3.3	2.9	3.7	2.4	2.9	2.9	1.3	1.2	2.0	2.3	3.8	4.2	4.1	5.0	5.2	7.3	8.8	10.1	10.9	9.6	4.8
26	9.7	9.5	9.4	8.8	9.3	9.8	9.9	10.1	10.5	10.2	9.8	9.7	10.4	10.1	10.5	13.1	10.1	9.7	10.3	9.3	8.7	8.4	10.1	8.4	9.8
27	9.4	8.5	9.1	8.6	8.5	8.6	7.5	6.7	6.0	8.3	8.9	11.2	12.2	11.5	11.5	12.6	10.9	10.8	12.0	10.8	9.3	8.5	8.3	8.2	9.5
28	7.5	8.2	8.8	8.8	8.5	8.3	8.2	8.2	7.7	7.1	5.8	5.1	4.3	4.6	4.7	5.0	4.6	5.1	5.3	6.2	6.7	8.8	10.0	11.0	7.0
29	9.7	8.9	8.2	8.0	7.6	8.2	9.3	10.1	8.3	4.6	4.5	6.2	9.0	9.8	11.5	13.4	10.9	11.6	12.5	10.8	12.0	11.7	8.8	9.5	9.4
30	9.1	9.9	10.2	9.5	8.9	8.7	8.4	7.6	9.3	10.0	8.0	8.4	7.9	7.5	7.3	6.5	6.3	5.4	4.9	5.1	5.3	3.8	2.2	1.2	7.1
31	2.0	3.5	4.1	5.4	7.3	7.6	7.9	7.9	9.0	7.5	7.2	8.4	7.0	6.8	6.2	5.7	5.2	5.8	5.3	4.5	4.5	4.0	4.1	4.3	5.9
AVG	6.9	6.7	6.6	6.5	6.4	6.4	6.6	6.5	6.4	5.8	5.7	5.6	5.8	6.2	6.5	6.7	6.4	6.5	7.0	7.0	7.0	6.7	6.7	6.6	6.5

Generated Thursday, April 19, 2007 Total 10-minute intervals: 4464 Intervals used in calculations: 4331 Percent data used: 97 NRG Systems SDR Version 5.02

Figure 7.2c: Hourly average wind speeds for Chillicothe for January 2007 for channel 5.

8. Diurnal variations

The interpretation of wind profiles in a day to day manner may not represent the true diurnal variations due to changing synoptic conditions and variations in the surface energy balance. But, when the profiles are averaged over a period of time, such as a month or longer, the diurnal variations can be seen. Figure 1 shows the diurnal variation of winds at a range of levels above the surface for a classic historical case. This confirms the hypothesis that wind speeds are generally stronger in the daytime as opposed to the evening hours, but just for the levels closest to the surface. This is the case because the surface is more susceptible to energy transfer from the sun. Once the surface heats up with the sun there is a more rapid and efficient transfer of momentum from aloft through the evolving unstable planetary boundary layer in the daytime. In the levels above 98 m winds are actually stronger in the evening hours and the diurnal wave is 180˚ out of phase.

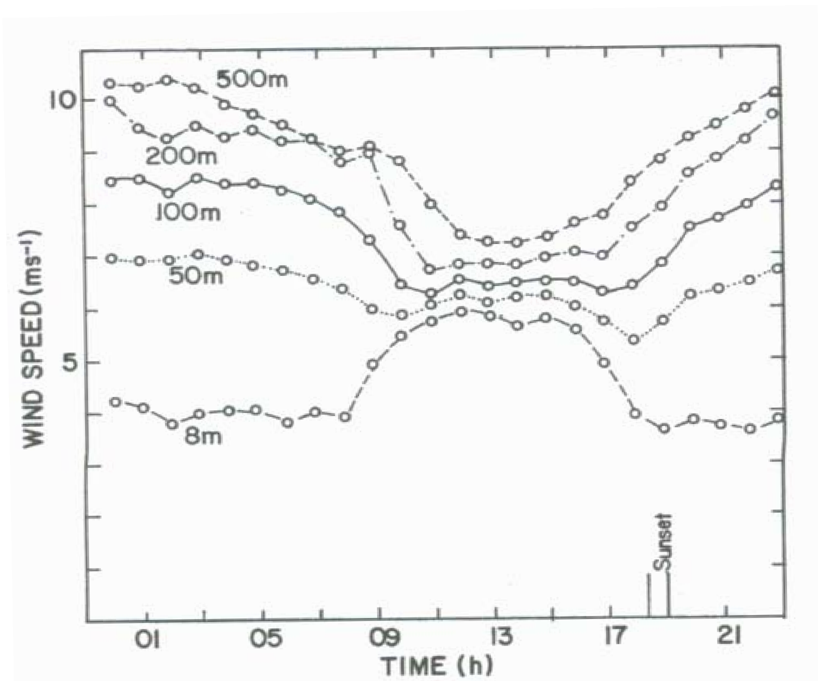


Figure 8.1: Diurnal variations observed during the Wangara experiment for different heights above the surface (from Arya, 1998).

Matlab was utilized to create diurnal variation plots to confirm the presence of a pattern within our data. These plots were made for each month at each tower for each of the six channels. All six channels were plotted on the same graph to best view the diurnal variation. Examples are shown below. Note that in each case the times are in UTC, such that sunset occurs around 00 Z or where the origin appears on the x-axis.

Figure 8.2 shows examples from four of the sites of the diurnal variations observed for the month of October 2006. In each case the diurnal variations observed appear consistent with the previously established cycles. In particular, the variation is more evident at the higher levels. The weakest winds are generally seen between 15 Z and 17 Z (or 0900 to 1100 CST). The peak winds generally occur overnight with the peak between 05 Z and 10 Z.

This has implications for energy production as it suggests that the majority of energy from a wind farm in this area would be produced between 2300 and 0400 CST, mostly in the night. As it is problematic to store energy produced by wind turbines, and power usage is generally low at these times there would be consequences for a power generator that relies on wind power from these areas. It is notable that most of the times of day when the wind averages above 7 m s^{-1} (a value often quoted as the minimum for viable utility scale wind power generation) occur in the overnight during the times of year for which we have observations.

Figure 8.3 shows similar plots for the Blanchard and Maryville towers for the month of October 2006. These show that the patterns observed in December were not significantly different in October. Similarly, figure 8.4 shows the same pattern at Maryville in March 2007, while figure 8.5 shows the consistency at Miami in July 2006.

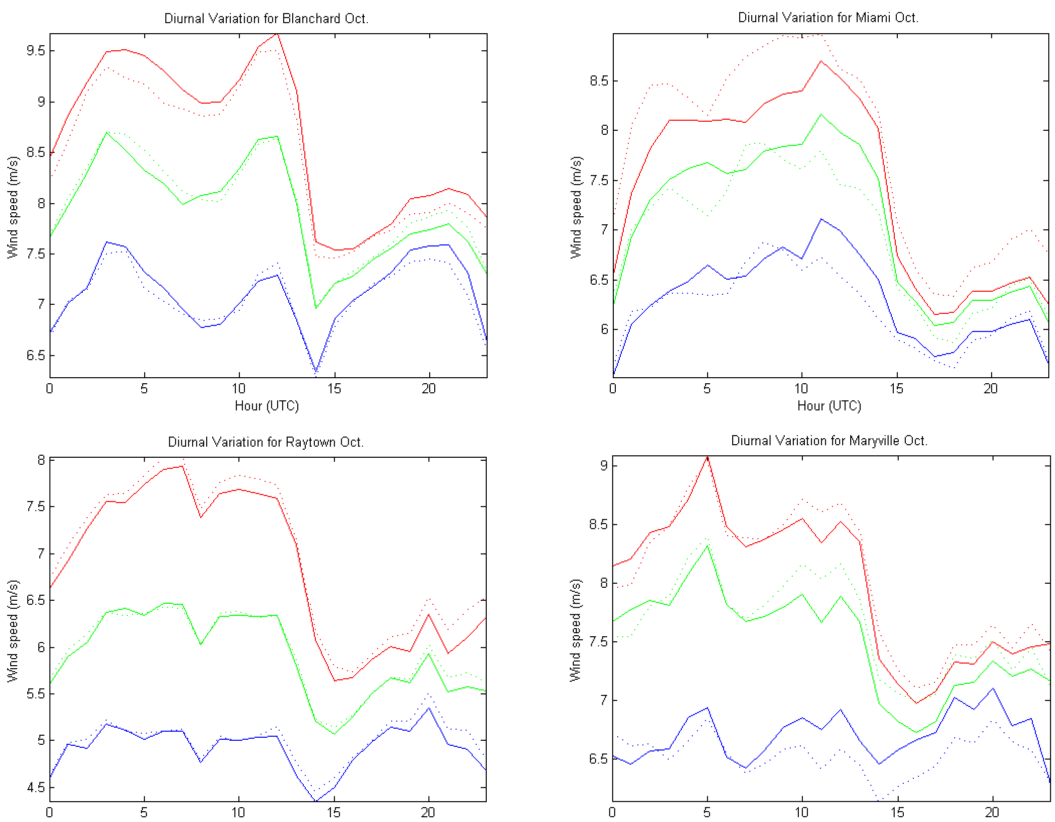


Figure 8.2: Diurnal variations for the month of October 2006 for the towers at Blanchard (top left), Miami (top right), Raytown (bottom left) and Maryville (bottom right). In each case the red lines represent the winds observed at the upper level, the green lines show the middle level, and the blue lines are for the lower level of instruments.

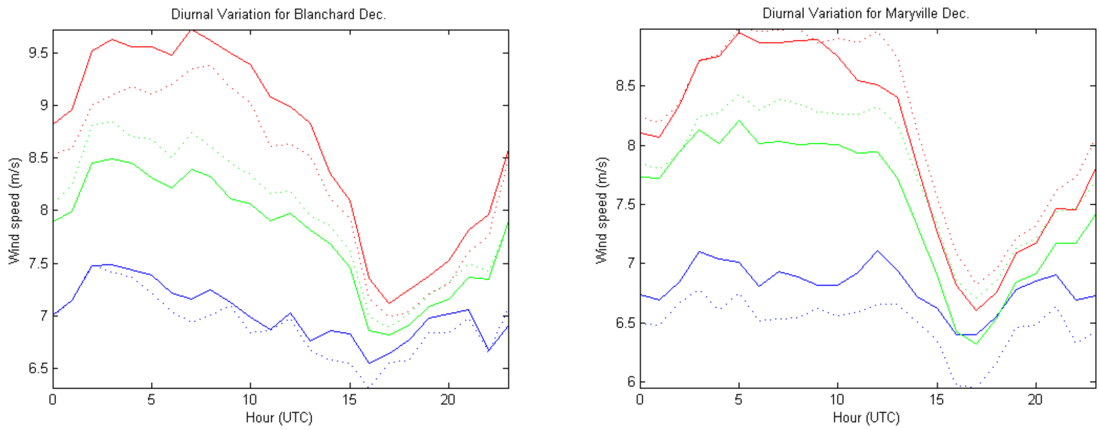


Figure 8.3: Diurnal variations for the month of October 2006 for the towers at Blanchard (left), and Maryville (right). In each case the red lines represent the winds observed at the upper level, the green lines show the middle level, and the blue lines are for the lower level of instruments.

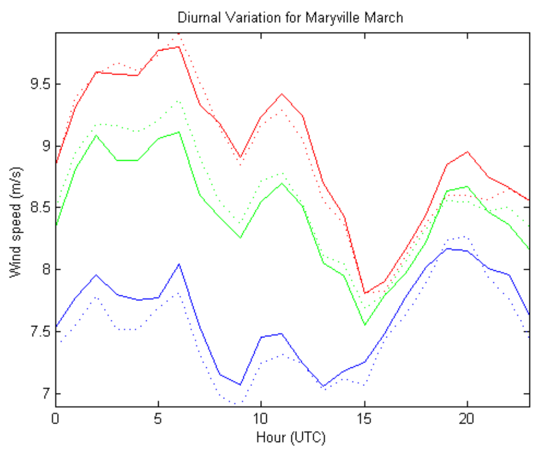


Figure 8.4: Diurnal variations for the month of March 2007 for the tower at Maryville. The red lines represent the winds observed at the upper level, the green lines show the middle level, and the blue lines are for the lower level of instruments.

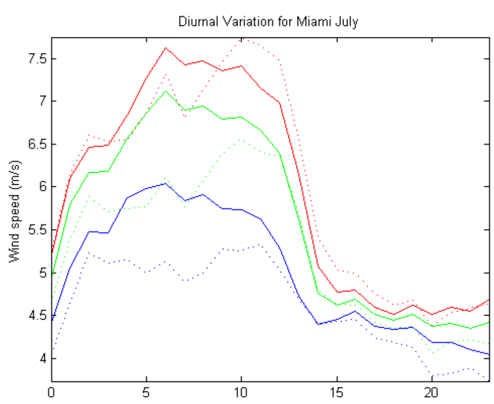


Figure 8.5: Diurnal variations for the month of July 2006 for the tower at Miami. The red lines represent the winds observed at the upper level, the green lines show the middle level, and the blue lines are for the lower level of instruments.

9. Annual Data

The data retrieved from the six towers was analyzed using Matlab and Microsoft Excel. Microsoft Excel was used to determine the average monthly wind speed for each channel. These averages were used to create one average wind speed for each tower location over the period that the towers were recording data.

Three different methods were used here in an attempt to estimate what the annual mean wind speeds at each location might be from the data collected so far. As we have no knowledge of what the winds will be for the remainder of the year, the first guess is simply the mean wind speed found to date. This is the equivalent of a linear projection, which in this case uses a linear regression model (e.g., see Neter et al., 1988).

$$\hat{Y} = b_o + b_1 x_i \qquad (9.1)$$

In (9.1), x is the predictor (independent variable), in this case time, and $\hat{Y}$ is the predictand (dependent variable), or our tower wind speeds. This will be defined as model 1.0. The other variables b_o and b_1 are regression coefficients which can be derived from the covariance matrix (see discussion below), which correlates the observations (dependent variable) and, in this case, time (independent variable).

However, this simplistic approach ignores the known seasonal variations in temperatures and other meteorological quantities such as relative humidity, pressure, and wind speed and direction. As these will follow an annual cycle in the mid-latitude regions (e.g., Hurrell et al., 1995) on this planet, which includes the midwest and southern plains of the United States, the second and third methods will estimate the winds using a curved fit to the model.

One of these methods involves constructing a higher order regression model, such as a "quadratic" or "cubic" model. In the linear model above, the coefficient b1 represents the slope of the line, or the rate of increase or decrease in the predictor. A quadratic estimate involves calculating a coefficient b2, which represents a 'curvature' term, and these coefficients can be derived from a system of equations from which the co-variance matrix is extracted and solved. In order to derive a quadratic model using a statistical approach, we use the same set of n-dimensional equations used to derive a multiple linear regression model (n-independent variables):

$$\begin{aligned}
\sum Y_i &= nb_o + b_1 \sum x_{i1} + b_2 \sum x_{i2} + \ldots.. \\
\sum Y_i x_{i1} &= b_o \sum x_{i1} + b_1 \sum x_{i1}{}^2 + b_2 \sum x_{i2} x_{i1} + \ldots.. \\
\sum Y_i x_{i2} &= b_o \sum x_{i2} + b_1 \sum x_{i1} x_{i2} + b_2 \sum x_{i2}{}^2 + \ldots..
\end{aligned} \qquad (9.2)$$

where $x_{i,1}$, and $x_{i,2}$ are two different independent variables, Y is the dependent variable, and their products represent a quantity called covariance. This system can be solved for the b coefficients to construct the line;

$$\hat{y} = b_o + b_1 x_1 + b_2 x_2 + ... \quad (9.3)$$

where $\hat{y}$ is a projected value of some dependent quantity based on some independent quantities. In deriving a quadratic model, we can replace $x_{i,2}$ with $x^2_{i,1}$ in (9.2) and solve for the b-coefficients similar to (9.3) to get:

$$\hat{y} = b_o + b_1 x_1 + b_2 x_1^2 + ... \quad (9.4)$$

and additional terms beyond the square-term are omitted. This will be defined as model 2.0. A "cubic" model would involve adding one more term and equation to the system of equations (9.2), and one more term in (9.3) and (9.4). The "cubic" model will not be shown here since the outcomes are similar to the quadratic and in the interest of brevity. These regression models are preferable to use here over quadratic interpolations or cubic splines (Kreysig, 1998) since such methods are used generally to interpolate values between two end points rather than to fit a model to set of observations. Fitting a model to observations then allows for limited extrapolation forward (forecasting) or backward (hindcasting) more readily than the interpolations discussed above.

The other method will simply fit a sine function to the data record to represent the shape of that annual cycle based on "symmetry" and calculate the average from this model. The annual cycle represents one maximum and a minimum point, or is wave-like. A sine function in a trigonometric function that represents the shape of a wave;

$$g(t) = \sin\left(\frac{2n\pi}{L}t + \phi\right) \quad (9.5)$$

where t is time, n is the wave number, L is our interval length, ϕ is the "phase shift" of the wave, and π is a natural constant value. The function g(t) will define the shape of the model. Then our model is defined as:

$$y(t) = A \cdot g(t) + C \quad (9.6)$$

where A is an amplitude function, defined in this study as the mean of the data set. The constant C is an "offset" term which will adjust the final value of y by some user defined amount. In our work we will use C = 0 (model 3.1), and C = model 2.0 – model 3.1, and this will be called model 3.2.

These function fitting methods also allow us to determine the frequency of any cycles in the wind speed that may occur. For instance, if there is a cycle of higher wind speeds indicative of low-level jet occurrence then this may be identifiable using this methodology. It is also cautioned that these results here will be based on projections of a data set whose length is less than one-year. Thus, the results presented here can only be interpreted as being representative of the year 2006-2007 for each tower. Significant interannual variations due to the El Nino profoundly impact the weather and climatolology of mid-Missouri and Midwest in general (e.g., Lupo et al., 2007). Additionally, interdecadal variations then impact the degree of El Nino-type variability

(Lupo et al., 2007), and climate change may also play a role in our annual cycle (e.g., Houghton et al. 2001).

9.1 Statistical reliability

Simple means and correlations were calculated and analyzed for each of six wind towers in Northwest Missouri, and the length of each data set is described in Table 9.1. Each tower was equipped with 6 anemometers, two at each of three levels. These anemometers are referred to here as channels (e.g., channel 1 and 2 represent the lowest level). Only the Mound City wind tower was missing data, and these were supplemented using standard procedures. The mean wind speeds for each tower were tested for significance using a simple two-tailed z-score test, assuming the null hypothesis (e.g., Neter et al., 1988). Annual distributions were also tested using a χ^2 statistical test. These distributions were tested using the total sample climatology as the expected frequency and each model as the observed frequency. It is hypothesized that using the climatological frequency as the "expected" frequency is more appropriate than using an "approximated" distribution since such analytical distributions (e.g., Poisson distribution) may not adequately represent real-world distributions (e.g., Lupo et al., 1997). Additionally, in this case, we are testing the reliability of statistical models to approximate "reality". It should be cautioned that while statistical significance reveals strong relationships between two variables, it does *not* imply cause and effect. Conversely, relationships that are found to be strong, but not statistically significant may still have underlying causes due to some atmospheric forcing process or mechanism.

Tower	**Period of observed record**
Raytown	August 2006 – March 2007
Blanchard	August 2006 – January 2007 (Channel 1,3,5) August 2006 – March 2007 (Channel 2,4,6)
Mound City	August 2006 – March 2007 (missing data noted in narrative)
Miami	July 2006 – March 2007 (All except Channel 3, which went to January 2007)
Maryville	August 2006 – March 2007
Chillicothe	October 2006 – March 2007

Table 9.1: The six towers used and the period of time for which monthly observations are available.

9.2 Results

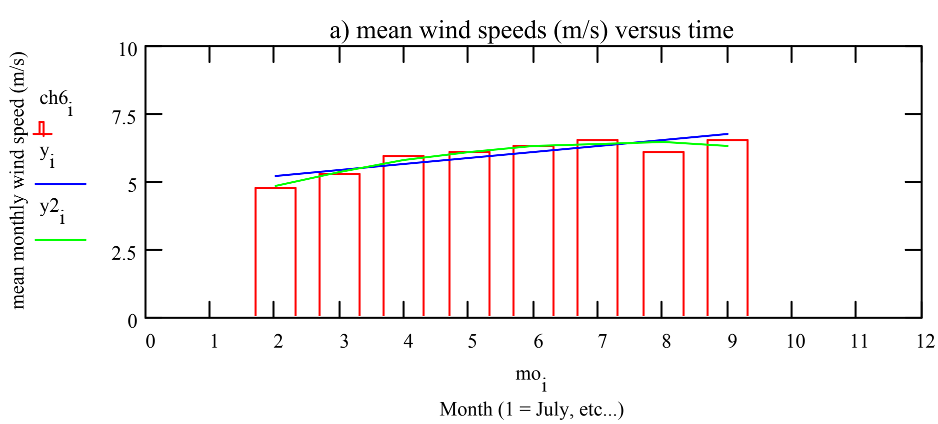
The results of each projection are shown, for example, in Tables 9.2-9.7. Each model assumes that the annual cycle follows a curve that would be at a minimum in June and July and a maximum in December and January (Fig. 9.1). An examination of each table reveals that there was no statistically significant difference between the current mean-to-date and each derived model. There was also no statistically significant difference between each model at commonly accepted levels of statistical confidence (defined as 90% or greater). However, the linear model tends to project higher values for the remaining months (April – June), and higher than currently observed. Model 3.1 is consistently lower and this result is significant at the 70% confidence level which indicates that there is a "likely" relationship which can be defined by stating that the difference may be due to some systematic cause and not just random chance. In this case, it is due to using the mean as the maximum value for the chosen sinusoidal model which will underestimate the total wind. Also, for the Blanchard tower (Table 9.3), there was no considerable difference between channels 1,3,5; and channels 2,4,6 for models 2.0 and 3.2, in spite of missing data (Table 9.1) ore two fewer months available for the projection. This indicates that the models chosen are not overly sensitive to the amount of data available. But for both towers, the linear model tends to project higher values for the remaining months (April – June), and higher than currently observed. These results indicate that for the 2006-2007 year, a sinusoidal curve may not provide the best model (Fig. 9.2), for many cases, due to higher springtime wind speeds than those in the fall.

Raytown Tower	Observed	Model 1.0	Model 2.0	Model 3.1	Model 3.2
67 m	5.00 / 5.13	5.21 / 5.35	5.08 / 5.15	4.50 / 4.61	5.08 / 5.15
95 m	5.93 / 5.96	6.16 / 6.18	5.85 / 5.76	5.33 / 5.36	5.85 / 5.76
137 m	6.80 / 6.93	7.03 / 7.11	6.57 / 6.19	6.12 / 6.23	6.57 / 6.19

Table 9.2: The monthly mean wind speeds (m s^{-1}) for the Raytown tower and each height. For this tower there are two measurements for each level and these are displayed as X/X.

Blanchard Tower	Observed	Model 1.0	Model 2.0	Model 3.1	Model 3.2
67 m	6.86 / 6.81	7.66 / 7.01	7.36 / 6.73	6.16 / 6.12	7.36 / 6.73
95 m	7.64 / 7.69	8.46 / 7.90	8.16 / 7.46	6.87 / 6.91	8.16 / 7.46
137 m	8.24 / 8.12	9.12 / 8.33	8.21 / 7.98	7.41 / 7.30	8.21 / 7.98

Table 9.3: As in Table 9.2, except for the Blanchard tower.



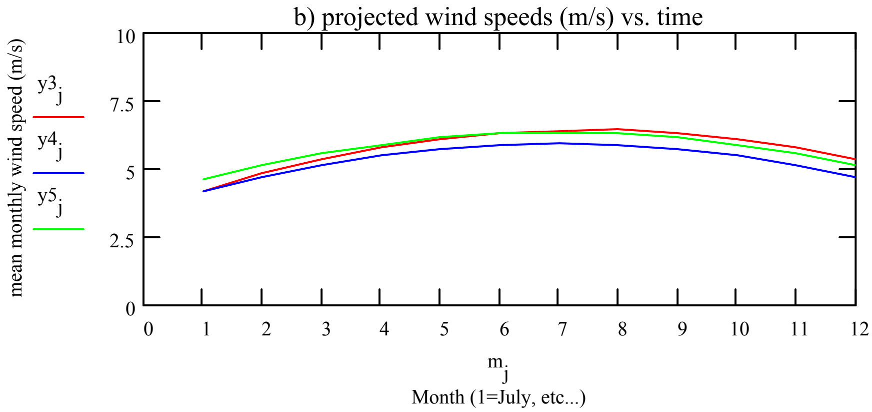


Figure 9.1: The Raytown tower (mid-level) mean monthly wind speeds (m s^{-1}) for the a) observed winds (red bars), linear regression (blue dotted), and quadratic regression (green dashes), and b) the projected annual cycle for model 2.0 (red), model 3.1 (blue), and model 3.2 (green dashes).

The Mound City tower (Table 9.4) presented a few problems in that there were missing data in the middle of the data set, even though the time period covered is the same as that of the Raytown Tower. The missing data for Channels 3 and 1 (October – December 2006) were assigned the same as that of channels 4 and 2, respectively, since there has been little difference throughout the datasets between pairs of channels. Channel 2 had missing data for October and November, and as such, a linear interpolation was performed since this is a commonly used technique (e.g., Kreysig, 1988) for interpolation. However, this would favor the linear models for the two lower channels at Mound City. We also speculate that models 3.1 and 3.2 would be desirable in this case for modeling years where there data are intermittent. This speculation is supported by the fact that model 2.0, 3.1, and 3.2 yielded similar results to the other towers and channels when comparing the differences (Tables 9.2 – 9.7). Additionally, for channels 1, 2 and 4, the quadratic models had the smallest curvature terms, and channel 4 did not have missing data. This yielded projections similar to those in Fig. 9.3. The Miami and Maryville towers showed distinctly less curvature as well, and these models look similar to Fig. 9.3.

Mound City Tower	Observed	Model 1.0	Model 2.0	Model 3.1	Model 3.2
67 m	5.64 / 5.82	5.91 / 6.11	5.82 / 5.96	5.07 / 5.23	5.82 / 5.96
95 m	6.37 / 6.24	6.65 / 6.50	6.50 / 6.40	5.73 / 5.61	6.50 / 6.40
137 m	6.80 / 6.93	7.12 / 7.16	6.86 / 6.74	6.12 / 6.23	6.86 / 6.74

Table 9.4: As in Table 9.2, except for the Mound City, MO tower.

Miami Tower	Observed	Model 1.0	Model 2.0	Model 3.1	Model 3.2
67 m	6.10 / 5.98	6.50 / 6.45	6.44 / 6.36	5.49 / 5.38	6.44 / 6.36
95 m	6.63 / 6.66	7.53 / 7.14	6.98 / 7.02	5.96 / 5.99	6.98 / 7.02
137 m	7.13 / 7.42	7.56 / 7.92	7.41 / 7.81	6.41 / 6.67	7.41 / 7.81

Table 9.5: As in Table 9.2, except for the Miami, MO tower.

Maryville Tower	Observed	Model 1.0	Model 2.0	Model 3.1	Model 3.2
67 m	6.63 / 6.44	6.91 / 6.69	6.54 / 6.48	5.96 / 5.79	6.54 / 6.48
95 m	7.34 / 7.51	7.62 / 7.80	7.32 / 7.35	6.60 / 6.75	7.32 / 7.35
137 m	7.74 / 7.83	8.04 / 8.12	7.77 / 7.63	6.96 / 7.04	7.77 / 7.63

Table 9.6: As in Table 9.2, except for the Maryville, MO tower.

Chillicothe Tower	Observed	Model 1.0	Model 2.0	Model 3.1	Model 3.2
67 m	5.90 / 5.90	5.90 / 5.89	6.00 / 6.29	5.30 / 5.30	6.00 / 6.29
95 m	6.60 / 6.62	6.60 / 6.62	6.95 / 6.84	5.94 / 5.95	6.95 / 6.84
137 m	7.45 / 7.35	7.45 / 7.35	7.67 / 7.78	6.69 / 6.60	7.67 / 7.78

Table 9.7: As in Table 9.2, except for the Chillicothe, MO tower.

Only for channel 1 in Raytown does this provide an appropriate model (Fig. 9.2). Again, it should be cautioned that this may not represent a typical year in this part of the country. Additionally, when testing the distributions of each model, these are not different from the observed values, and for all of these models the confidence level is greater than 90%, and in most cases 99%. Thus, we are sure that our projection / prediction techniques are appropriate for most cases.

However, there was one case (Chillicothe tower) where the distribution produced by model 2.0 was not successful (Fig. 9.4). This model was different from models 3.1 and 3.2 at a statistically significant level (90%) of confidence. Again, models 3.1 and 3.2 follow the natural annual cycle, and can thus be interpreted as being closer to the true wind. Model 2.0 reversed the curvature (higher extrapolated values) in the fall and spring simply because of the high values in March and that the tower did not start recording data until October 2006. The Chillicothe model 2.0 only demonstrates that modeling with fewer data points can be dangerous. The addition of April and May 2007 data would likely change the curvature term from positive to negative (as in the other five towers).

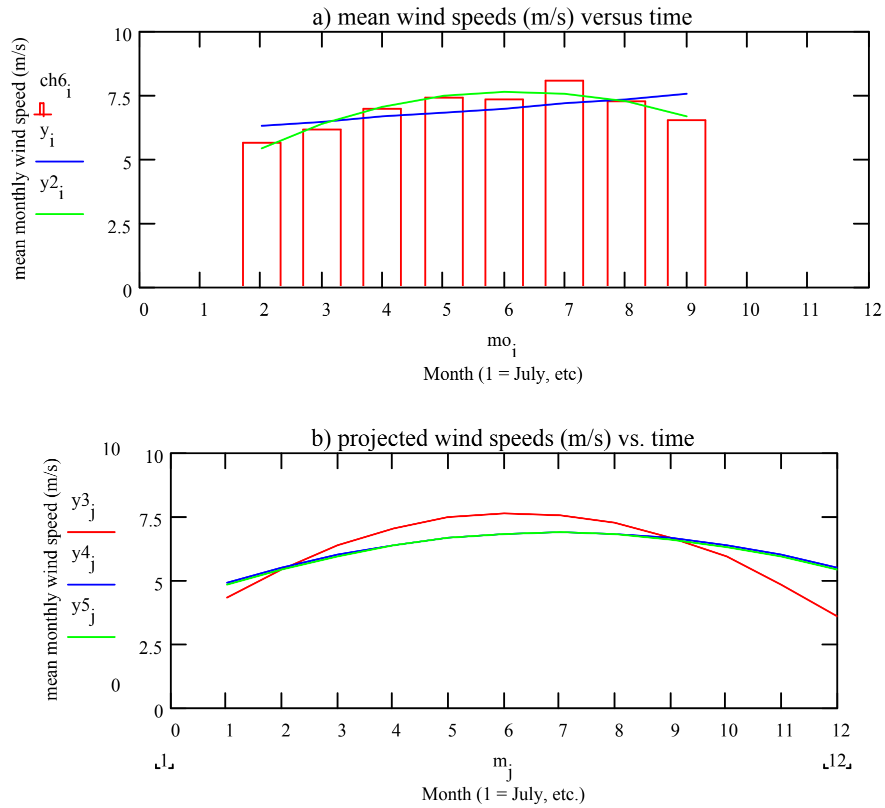


Figure 9.2: As in Fig. 9.1, expect for the Raytown tower (upper-level).

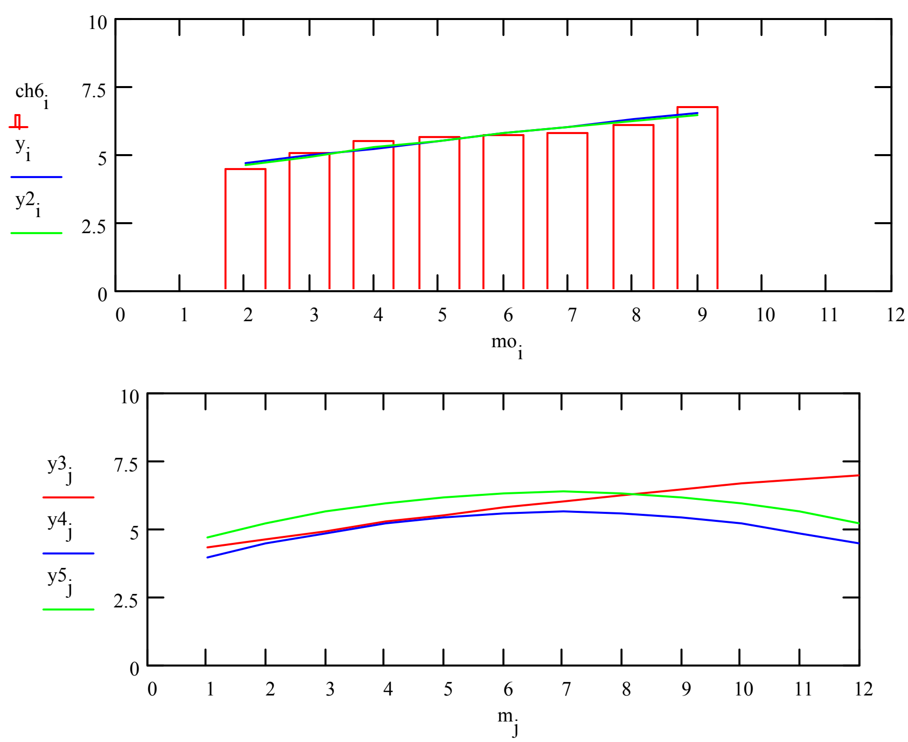
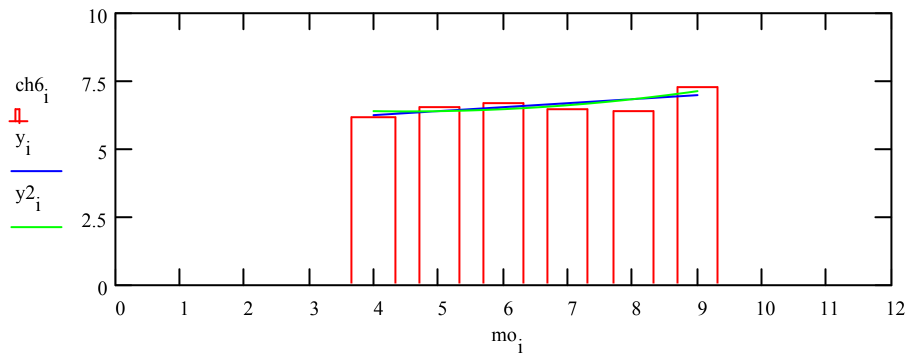


Figure 9.3: As in Fig. 9.1, expect for the Mound City tower (upper-level).

In summary, it is recommended here that model 2.0 or model 3.2 be used to fit an annual wind speed distribution to towers in order to forecast wind speed and power for one to two seasons ahead. These methods are not significantly different from long range forecasting techniques used in meteorology (Kung and Chern, 1995; Anderson, 1999). Model 3.2 would be ideal for use in determining the power generated when wind data from the tower when the data are intermittent, or the projection for an entire year may be needed and this would be based on an annual mean. Further research is needed to determine if the reliability of these models vary from year-to-year or if there are significant differences in the annual means from one year to another due to the influence of ENSO.



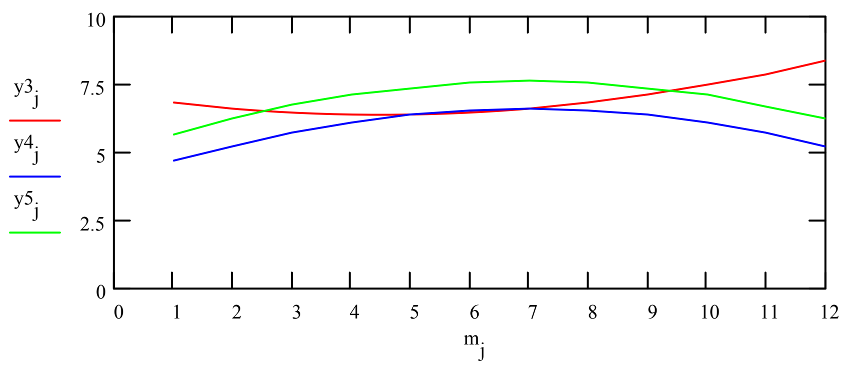


Figure 9.4: As in Fig. 9.1, expect for the Chillicothe tower (channel 1; upper-level).

Finally, an investigation for estimating wind power was carried out in order to determine if there was a significant difference in calculating power based on using the annual mean wind speed versus estimating the power month-by-month and summing up these values (in effect integrating the area under the curves in Figs. 9.1a – 9.4a). Wind power density is related to wind speed as a cubic function, e.g.,

$$P_{wind} \propto \left\|\vec{V}\right\|^3 \qquad (9.7)$$

where V represents the wind vector. The differences due to wind speed alone were 3% or less in all cases here. However, this does not take into effect density differences due to temperature (see discussion in section X).

9.3 Comparisons with wind map

Each tower's average was then compared to the corresponding wind speed taken from the Arc GIS wind map created by AWS Truewind Ltd.- commissioned by Missouri DNR to see how well the speeds match up. The wind speeds from the towers were compared to the wind maps in a general fashion to determine if the wind maps are a good representation of Missouri's wind resources.

As shown in section 9 there is uncertainty as to whether the data collected to date provides a good representation of the annual average wind speed that is provided by the wind map. The wind map also employs a much longer climatology covering forty years of data. Therefore there is a question of whether the particular period for which in situ data has been collected is typical of the wind climatology.

In these comparisons we use another version of the average wind speed. In this case the observed maximum wind speed at each level was used. This was achieved by finding which anemometer at each level was observing the higher wind speed at each time interval. This is done to exclude data where one sensor was sheltered by the tower structure and recorded a reduced wind speed. Note that this data will replace that used in the earlier part of this section at a later date, however the differences are not great and would not affect the conclusions drawn at this stage.

In table 9.8 we show comparisons between the speeds observed at the lower two instrument levels on each tower compared to the speeds retrieved from the wind map at the 70 m and 100 m heights which are close to the instrument heights on each tower.

Tower	**Mean speed at low level**	**Wind map 70 m wind**	**Mean speed at mid level**	**Wind map 100 m wind**	**Rank from wind map**	**Rank from observations**
Blanchard	**6.92**	7.30	**7.77**	7.90	1	**1**
Maryville	**6.83**	7.19	**7.68**	7.86	2	**2**
Miami	**6.42**	6.82	**7.14**	7.37	4	**3**
Mound City	**6.30**	6.85	**6.81**	7.46	3	**4**
Chillicothe	**6.07**	6.56	**6.80**	7.22	5	**5**
Raytown	**5.19**	6.25	**6.11**	6.95	6	**6**

Table 9.8: Comparison of wind speeds observed at each location with modeled values found in the AWS Truewind wind map. All speeds are in m s^{-1}.

In terms of where the strongest winds are found the map is in reasonable agreement with the observations. It should be remembered that the instruments on the different towers are at slightly different heights, but the ranking displayed is based on the mid-level instrumentation. In this case all towers are recording at between 95 m and 97 m. However there is a slight change in the ranking. Remember also, that the period of record for each site is different and this may well affect the mean speed recorded.

It can be seen from the table that in every case the wind map overestimates the wind at the location. There are a number of possible reasons for this which need further exploration.

1. The data record for the part of the year is not representative of the entire year.
2. The instruments are slightly lower than the heights the map uses.
3. The period we have observed to date is not representative of the longer term climatology.
4. The model representation of surface roughness and the near surface wind profile at specific locations is inaccurate.
5. The model contains a bias toward high wind speeds.

To address which of these issues is responsible for the disparity requires further work. In particular the first point should be addressed once a complete year of data has been collected at each location. In the future the tower observations will be adjusted to match the 70 m and 100 m heights. This will address point 2, but will not account for the magnitude of the differences seen.

Calculations of surface roughness will be made to see if the assumptions made in the model (based on land use type) are appropriate at each area. The model uses a limited number of land types with fixed surface roughness. However, the land surface is complex with great variability of topography and usage. This is, admittedly, extremely difficult to model accurately, but we can assess the accuracy of the roughness parameters used. Also, the roughness would be expected to vary in some locations throughout the year as vegetation state changes. There may even be a dependence on wind direction as the upwind fetch varies and this will be investigated.

The frequency of wind direction, as shown by the wind roses in section 5, may be an indicator of climatological regime. Therefore comparisons of directional frequency observed with that found in the wind map may indicate how representative the period of observation is of the general climate. On the other hand it is likely that the issue of the disparity between the wind map and the observations will only be resolved conclusively by establishing a multi-year observational data set.

9.4 Wind power

Wind power was calculated on an hourly basis using the equation:

$$P = \frac{1}{2}\rho v^3 \tag{9.8}$$

Where v is the wind velocity and ρ is the density of the air. The latter is adjusted for temperature and altitude using

$$\rho = 1.225e^{-h/7290}\frac{273}{273+T} \tag{9.9}$$

In which the standard density of air at sea level (1.225 kg m^{-3}) is reduced for a tower elevation, h (in meters), and adjusted for a temperature, T (in °C). The latter is time-varying and temperature data recorded at each tower was used in the calculation.

The power was calculated for each height at each tower on a monthly basis and for the complete period available for each tower. Frequency distributions for each tower were also produced and the annual mean power was estimated using similar methods to those in section 9. Therefore for each height on each tower we present the mean power density and frequency distributions of power density.

Table 9.9 shows the mean power density observed. This uses the hourly wind speed observations, but selects, at each height for each hour, the observation of higher wind speed form the two anemometers.

Tower	Power density at lowest level	Power density at middle level	Power density at highest level	Rank
Maryville	265	375	438	2
Blanchard	279	394	500	1
Mound City	230	286	352	4
Chillicothe	185	256	359	5
Miami	234	323	440	3
Raytown	125	198	315	6

Table 9.9: Observed mean power densities in W m^{-2}, at the level of the bottom, middle and top instrument heights on each tower.

The rank, in this case, is based upon the power density observed at the middle level as at this level all the towers observe at almost the same height. This level is also similar to the 100m wind power density estimates provided by the wind map. Table 9.10 shows the comparison between the mean wind power density found from the observations at the towers and that of the wind map.

Tower	100m power density from tower observations	100m power density from wind map	Rank from tower	Rank from windmap
Maryville	375	445	2	2
Blanchard	394	458	1	1
Mound City	286	397	4	3
Chillicothe	256	348	5	5
Miami	323	395	3	4
Raytown	198	321	6	6

Table 9.10: Comparison of wind power density found from tower observations and the wind map. All figures are in W m^{-2}.

In line with the comparison of the observed velocities, in each case the wind map estimates a higher power availability than the observations provide. As the power density is a direct function of the velocity the same reasons for the disparity as were given in the previous section apply. However, as the power scales with the cube of the velocity, the differences are magnified such that a small difference in velocity translates to a large difference in available wind energy at a given location. This emphasizes the need to discover if the difference between the observed winds and the modeled ones is real or not, and what the reason for the differences are.

10. Frequency Distributions

10.1 Wind Speed

Frequency distributions for each tower were produced on a monthly basis and for the complete data set to March 31, 2007. The monthly distributions are available on the website. These are produced from the NRG software and have not been subjected to the rigorous quality checking that is performed later. We intend to replace those figures with corrected versions at a later date.

In this report we show the overall distributions for channels 1, 3 and 5. In this case we are using the quality controlled data and the figures are generated using Matlab software. This also allows greater analysis and flexibility of figure production. The frequency distributions are of hourly average winds. Again, the different towers have different length data records and channel 5, in particular, represents different heights on each tower.

In most cases the distributions appear fairly symmetrical or normal around the mean value. This explains why the mean annual power models return similar projected values whether one uses average annual velocity or actually model the power, even though the power density is proportional to the cube of the velocity. Naturally, in each case there is a tail of high velocity values. This makes the frequency distributions take on the classic Wiebull distribution of observed velocity values.

Questions that arise, but have not been addressed to date include:

a. Are the higher wind speed values associated with low-level jet occurrence?
b. Do the Wiebull parameters that will be determined from the distributions in agreement with those provided by the wind map?
c. Is the overall distribution representative of the entire year and the general multi-annual climatology?

10.1.1 Maryville

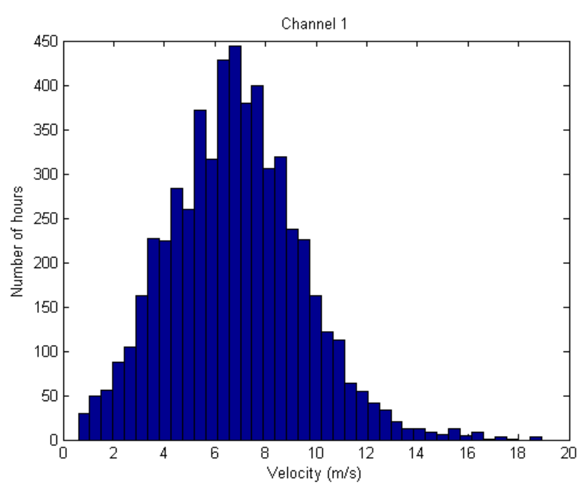


Figure 10.1a: Frequency distribution of wind speeds recorded on channel 1 of the Maryville tower.

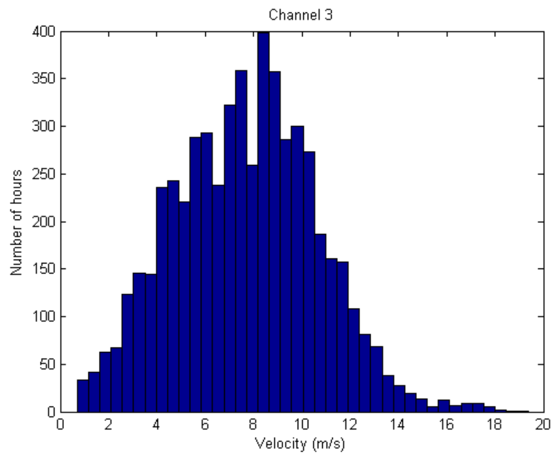


Figure 10.1b: Frequency distribution of wind speeds recorded on channel 3 of the Maryville tower.

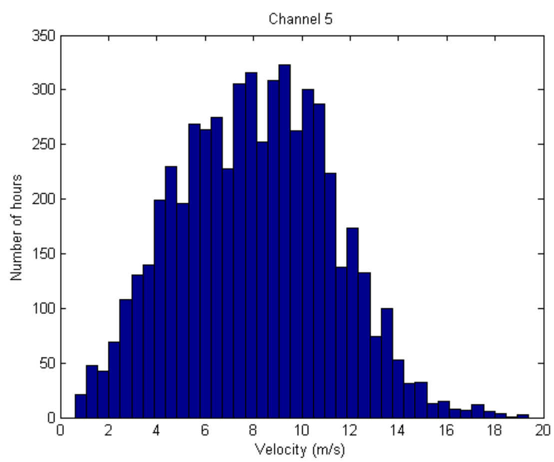


Figure 10.1c: Frequency distribution of wind speeds recorded on channel 1 of the Maryville tower.

10.1.2 Blanchard

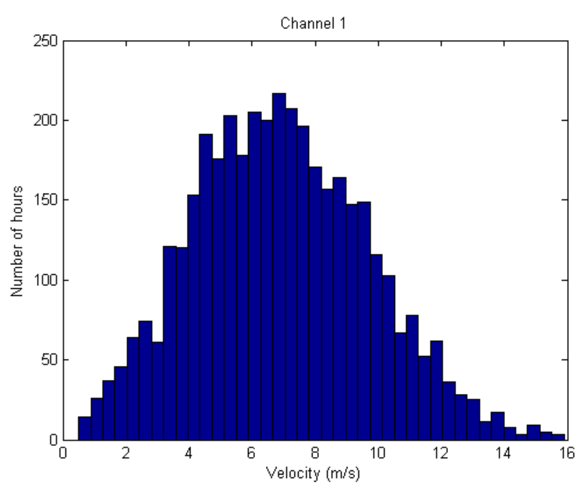


Figure 10.2a: Frequency distribution of wind speeds recorded on channel 1 of the Blanchard tower.

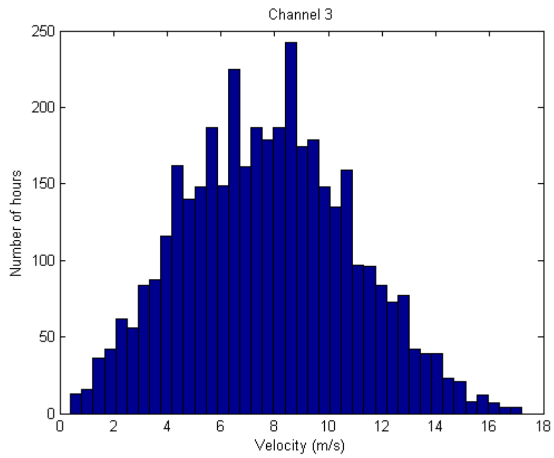


Figure 10.2b: Frequency distribution of wind speeds recorded on channel 3 of the Blanchard tower.

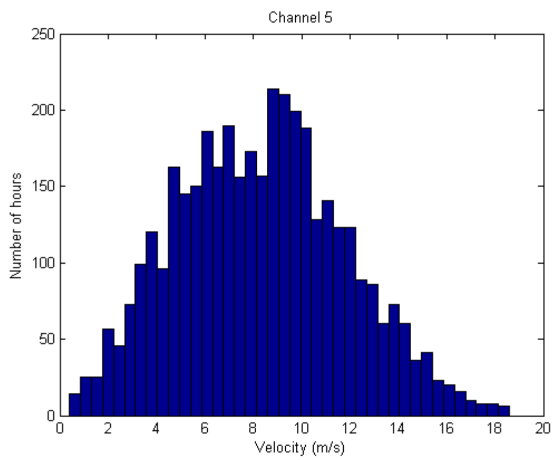


Figure 10.2c: Frequency distribution of wind speeds recorded on channel 5 of the Blanchard tower.

10.1.3 Mound City

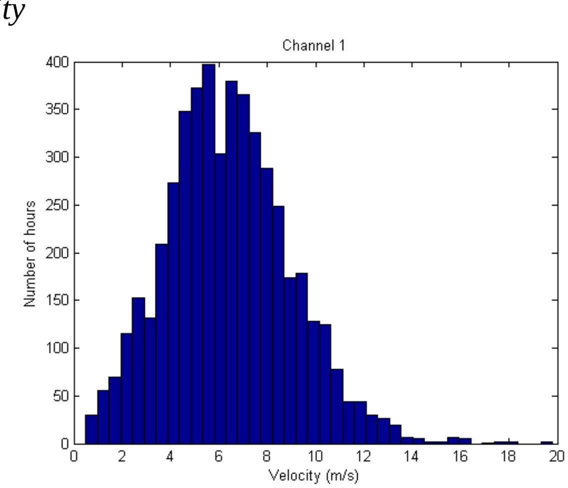


Figure 10.3a: Frequency distribution of wind speeds recorded on channel 1 of the Mound City tower.

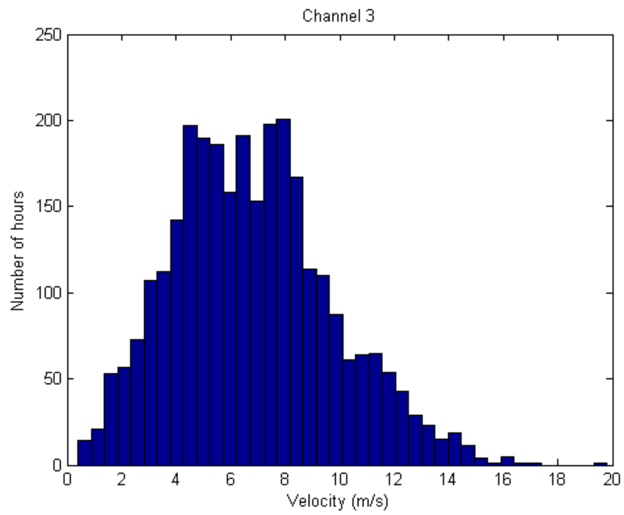


Figure 10.3b: Frequency distribution of wind speeds recorded on channel 3 of the Mound City tower.

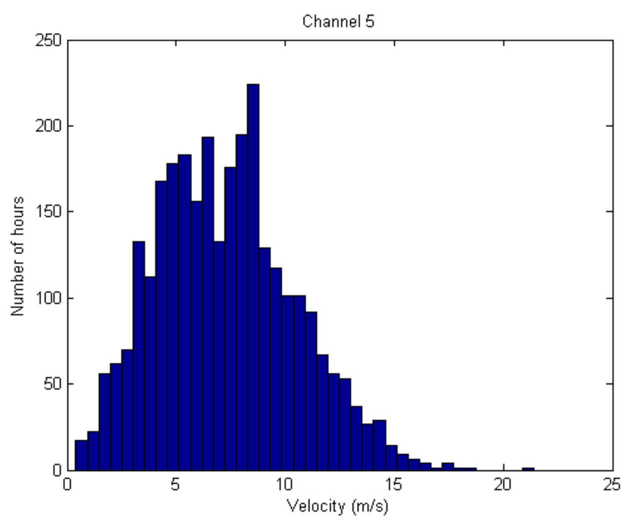


Figure 10.3c: Frequency distribution of wind speeds recorded on channel 5 of the Mound City tower.

10.1.4 Chillicothe

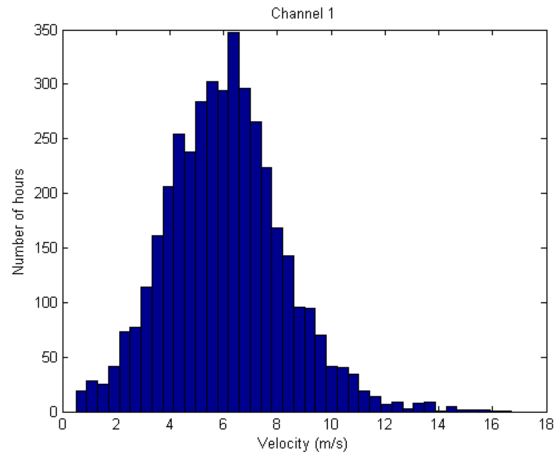


Figure 10.4a: Frequency distribution of wind speeds recorded on channel 1 of the Chillicothe tower.

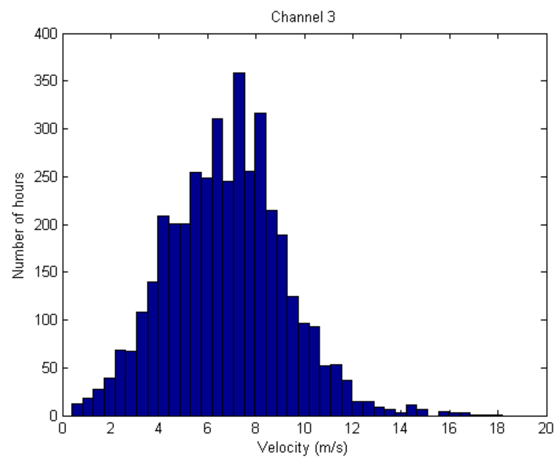


Figure 10.4b: Frequency distribution of wind speeds recorded on channel 3 of the Chillicothe tower.

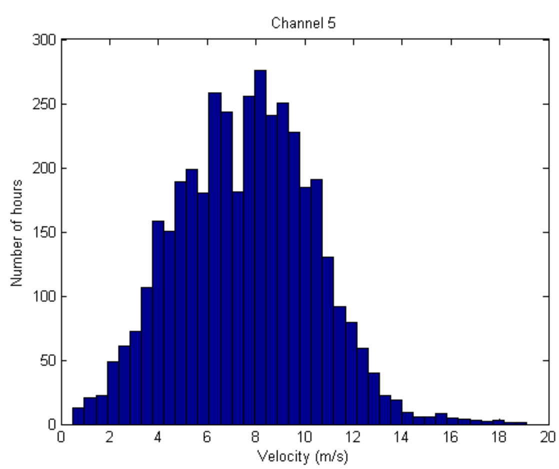


Figure 10.4c: Frequency distribution of wind speeds recorded on channel 5 of the Chillicothe tower.

10.1.5 Miami

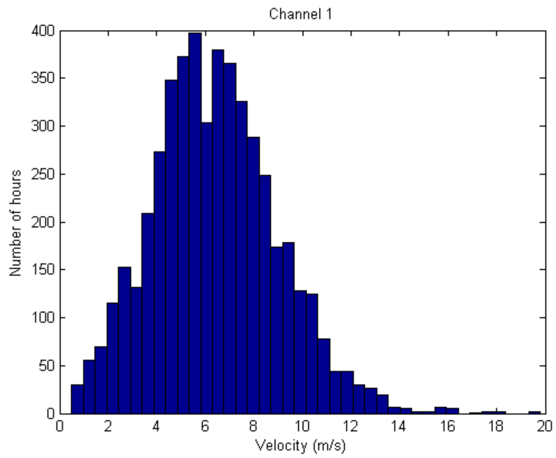


Figure 10.5a: Frequency distribution of wind speeds recorded on channel 1 of the Miami tower.

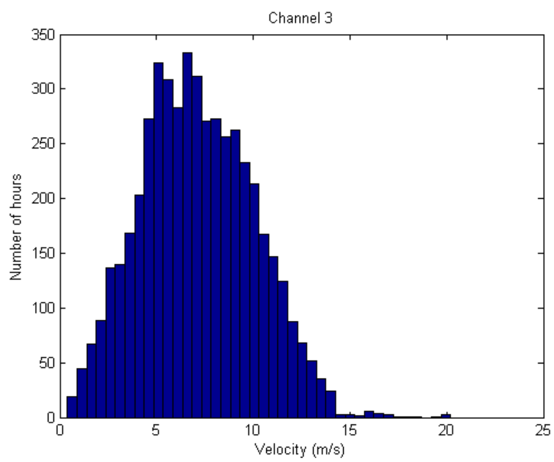


Figure 10.5b: Frequency distribution of wind speeds recorded on channel 3 of the Miami tower.

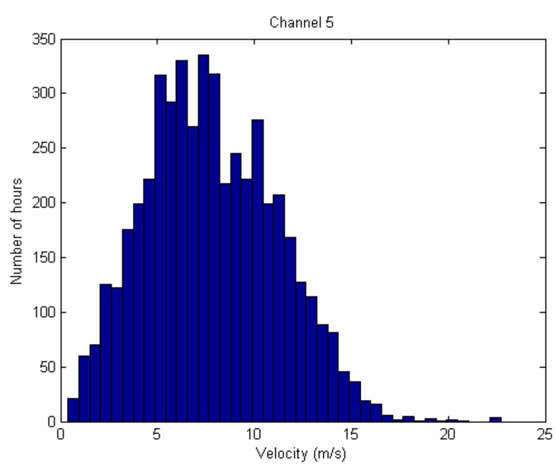


Figure 10.5c: Frequency distribution of wind speeds recorded on channel 3 of the Miami tower.

10.1.6 Raytown

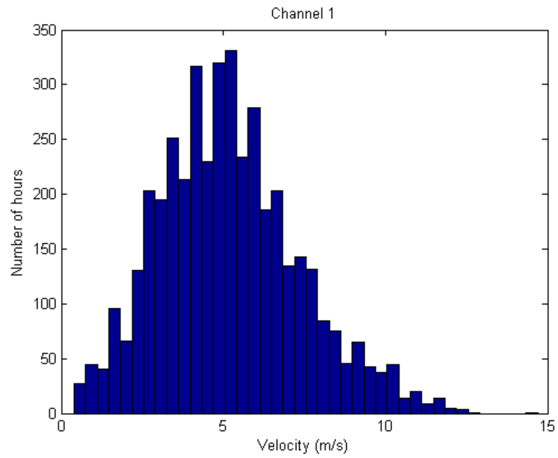


Figure 10.6a: Frequency distribution of wind speeds recorded on channel 1 of the Raytown tower.

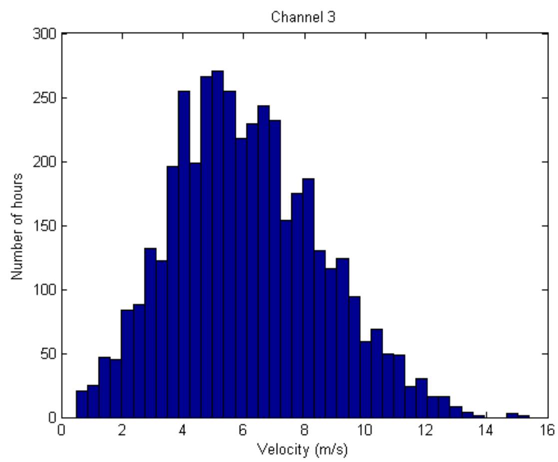


Figure 10.6b: Frequency distribution of wind speeds recorded on channel 3 of the Raytown tower.

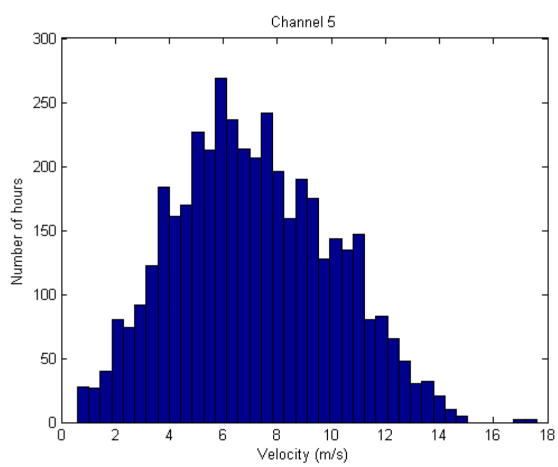


Figure 10.6c: Frequency distribution of wind speeds recorded on channel 5 of the Raytown tower.

10.2 Wind power density

In this section we present frequency distributions of power density calculated from the wind speeds observed at each tower. The calculation of these values is detailed in section 9.4. There is much that can be done with this data, which will be attempted in the future.

a. Tabulating the number of hours or percentage of time above a threshold power density value for assessing viable wind energy development.
b. Correlating high power availability with wind direction.
c. Correlating high power availability with low-level jet incidence.
d. Correlating power level with wind shear values.

The mean power densities presented here are calculated from the maximum wind speed at each height found as described in section 9.3.

10.2.1 Maryville tower

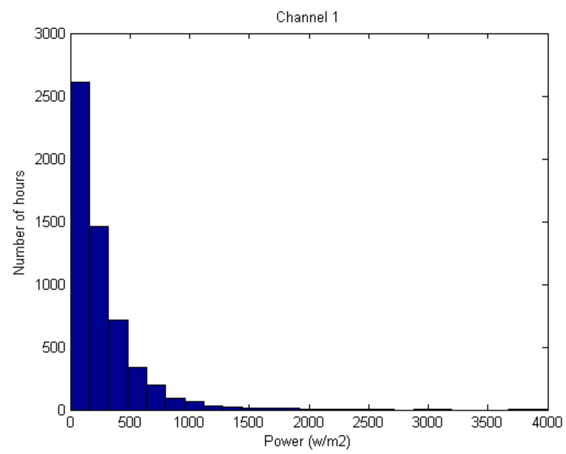


Figure 10.7a: Frequency distribution of power density for the low level on the Maryville tower.

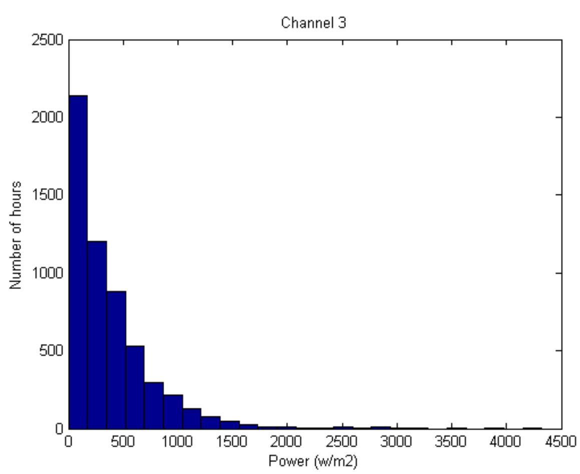


Figure 10.7b: Frequency distribution of power density for the middle level on the Maryville tower.

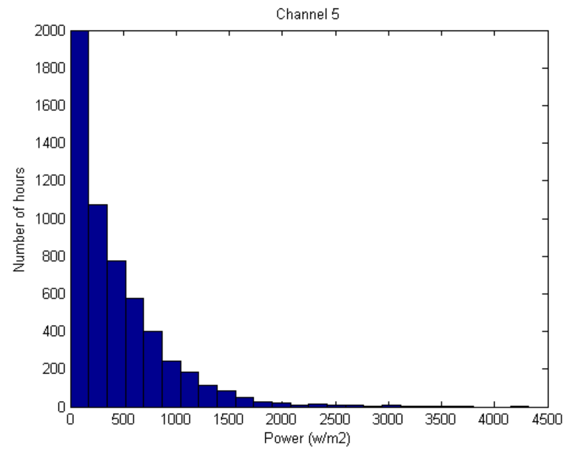


Figure 10.7c: Frequency distribution of power density for the upper level on the Maryville tower.

10.2.2 Blanchard

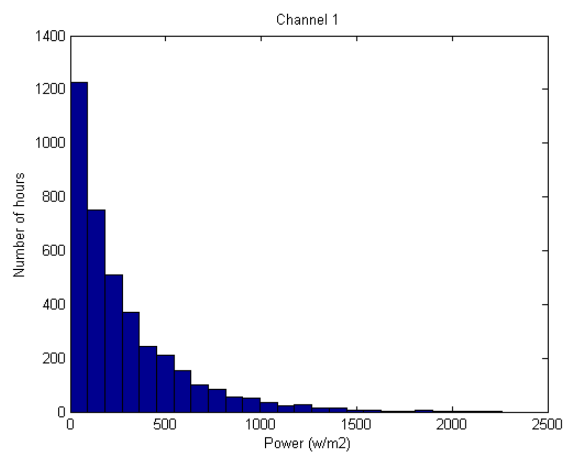


Figure 10.8a: Frequency distribution of power density for the low level on the Blanchard tower.

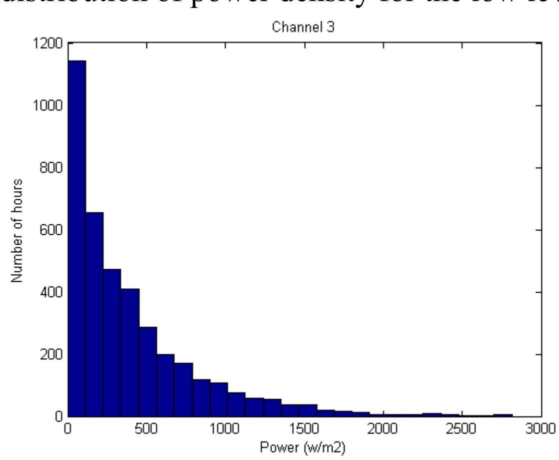


Figure 10.8b: Frequency distribution of power density for the middle level on the Blanchard tower.

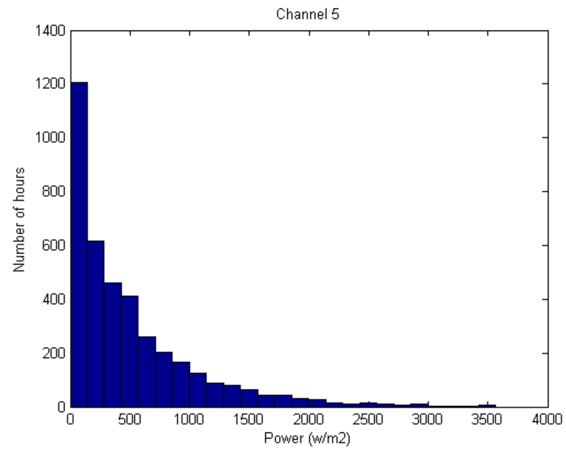


Figure 10.8c: Frequency distribution of power density for the upper level on the Blanchard tower.

10.2.3 Mound City

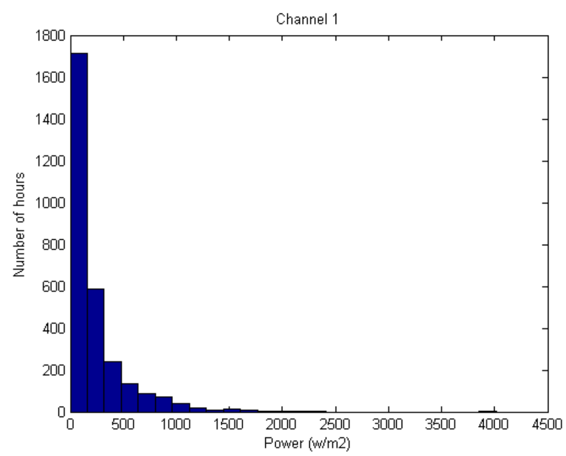


Figure 10.9a: Frequency distribution of power density for the lower level on the Mound City tower.

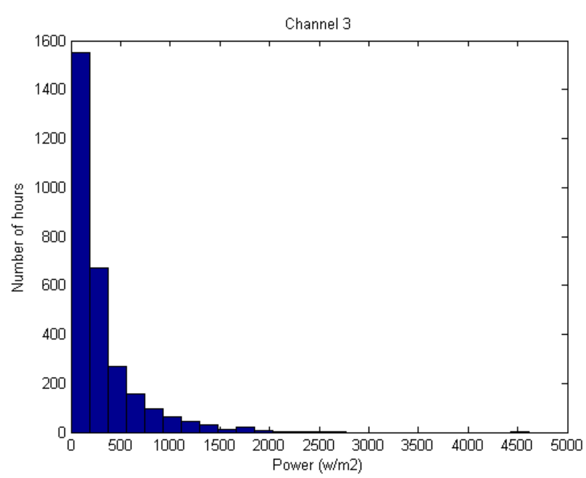


Figure 10.9b: Frequency distribution of power density for the middle level on the Mound City tower.

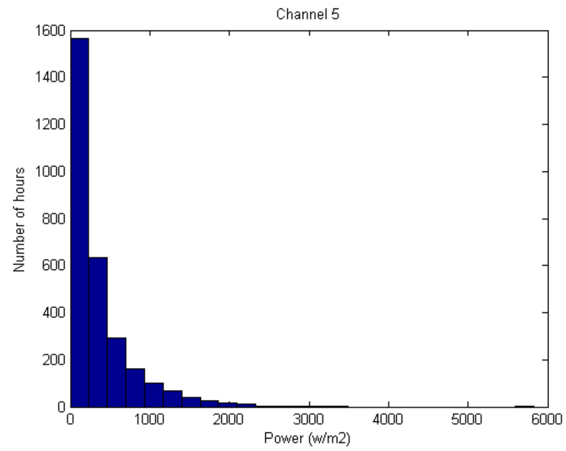


Figure 10.9c: Frequency distribution of power density for the upper level on the Mound City tower.

10.2.4 Chillicothe

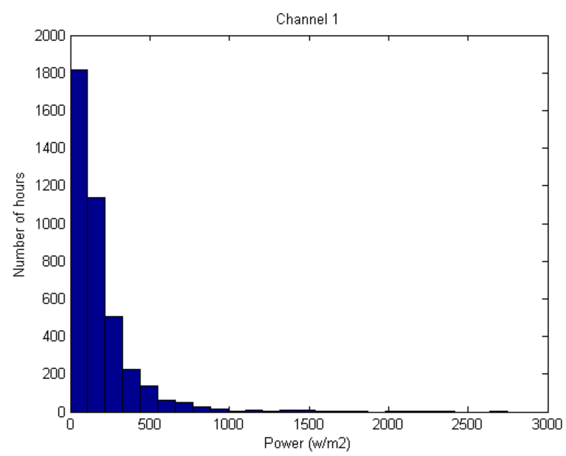


Figure 10.10a: Frequency distribution of power density for the lower level on the Chillicothe tower.

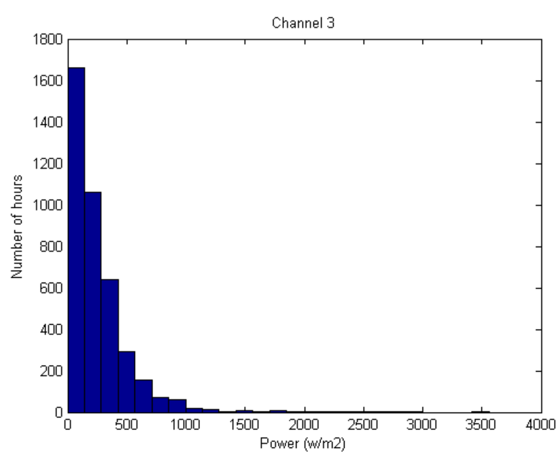


Figure 10.10b: Frequency distribution of power density for the middle level on the Chillicothe tower.

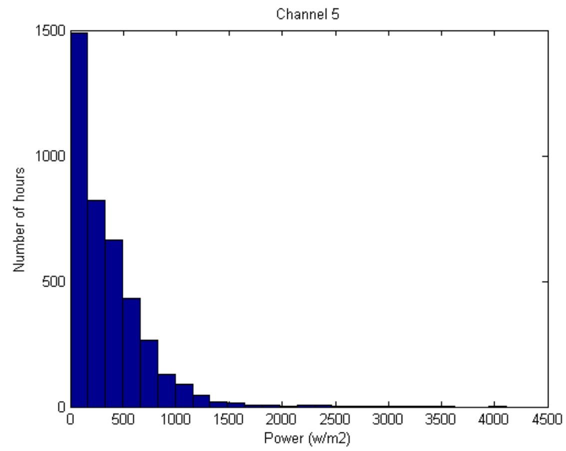


Figure 10.10c: Frequency distribution of power density for the upper level on the Chillicothe tower.

10.2.5 Miami

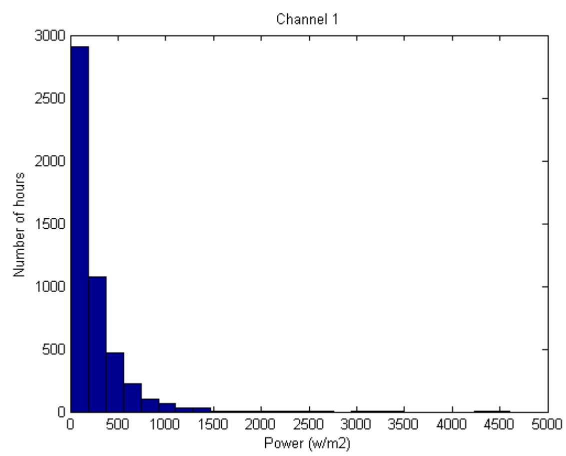


Figure 10.11a: Frequency distribution of power density for the lower level on the Miami tower.

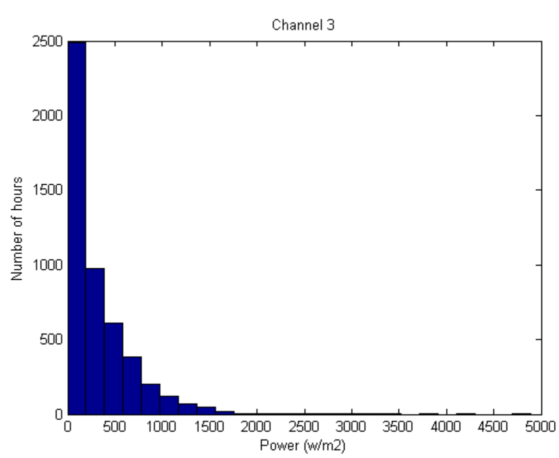


Figure 10.11b: Frequency distribution of power density for the middle level on the Miami tower.

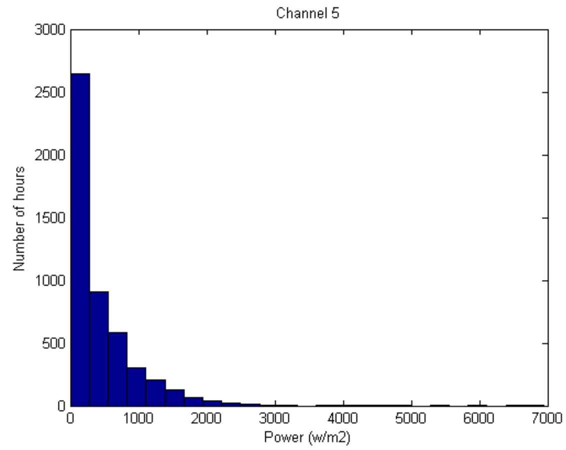


Figure 10.11c: Frequency distribution of power density for the upper level on the Miami tower.

10.2.6 Raytown

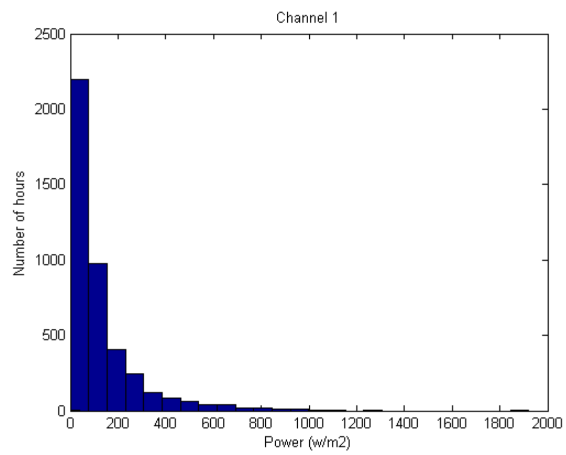


Figure 10.12a: Frequency distribution of power density for the lower level on the Raytown tower.

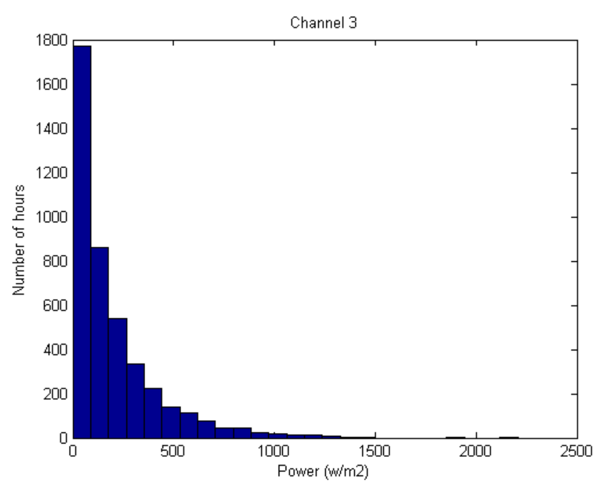


Figure 10.12b: Frequency distribution of power density for the middle level on the Raytown tower.

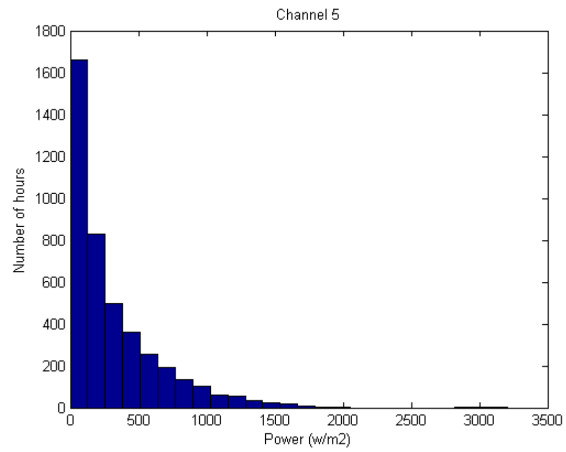


Figure 10.12c: Frequency distribution of power density for the upper level on the Raytown tower.

11. Wind shear

Wind shear at turbine heights is an indicator of the stresses that turbine blades may experience. To find the shear the top and bottom anemometers were used to calculate the shear parameter, α, as shown in equation 11.1:

$$\alpha = \frac{\ln(u_2 / u_1)}{\ln(z_2 / z_1)} \tag{11.1}$$

Here u_2 and u_1 are the wind speeds observed at the higher (z_2) and lower elevations (z_1) respectively.

Again shear frequency distributions are displayed as histograms for each tower for the entire period of record This means that the towers, once again, have different periods represented by the data. The data used were the hourly average winds. In each case periods of calm winds, defined as wind speed less than 3 m s^{-1}, were excluded from the analysis. This follows the methodology of Schwarz and Elliot (2006) and helps remove erroneous values of shear where an anemometer at one level is recording near zero. It is also justified on the basis that at low wind speeds the shear across a turbine is not important as there will be little stress placed on the blade at that time.

The patterns observed at each tower are similar, and also appear similar to those reported by Kelley at al. (2004) from the Lamar Low-Level Jet Project. However, the values reported herein appear to be somewhat greater than those previously reported for Midwest locations. This may reflect different local conditions, in particular greater surface roughness, than at other sites. Indeed, one can see that the locations with the greatest shear parameters reported are those that appear to have the roughest terrain. Notably, the Raytown data, which comes from an urban setting shows a broad spectrum of values, as does the data from Maryville, where the tower is reasonably close to the city.

The greatest shear parameter values (and widest range) are observed at the Miami location. While this is a rural area it is also probably the most undulating, with the largest changes in land elevation in the surrounding area. This is also the lowest elevation tower and sits in close proximity to the Missouri River.

In contrast to this, the lowest shear parameter values and narrowest distributions are observed at the Blanchard and Chillicothe sites. The first of these is clearly the most exposed location, and although this is a reasonable hilly area, there are very few trees and the gradients are not as steep as in the vicinity of Miami. The Chillicothe tower, despite being within a few kilometers of the city, resides in the flattest locale of any of the towers in this study.

The information on shear patterns at the various sites has not been extensively researched to date and much remains to be done. This work will include:

a. Statistical examinations of the values and distributions of the shear parameters, following the ideas set out in Kelley *et al*. (2004).

b. Breaking down the values of the shear parameters by month and season to determine dependence on time of year. (This may be an issue as vegetation changes such as crop growth and foliage may impact the surface roughness).

c. Stratifying the shear parameter by wind direction to determine if the characteristics of the surface in differing upwind directions affects the shear profile.

d. Calculation of surface roughness from shear and wind profile information. This is necessary for comparison with the wind map which has a roughness parameterization that does not account for seasonal variation, directional dependence or fine scale features (Brower, 2005). It is hypothesized that the use of single value roughness parameters in conjunction with gross land type descriptors limits the ability of the model used to generate the wind map to identify true local scale variability in the wind field.

e. Correlation of shear parameter values with low-level jet incidence. This is required to test the idea that the occurrence of the low-level jet is responsible for increased shear and, hence, stress on turbine blades that may be located in the areas under investigation.

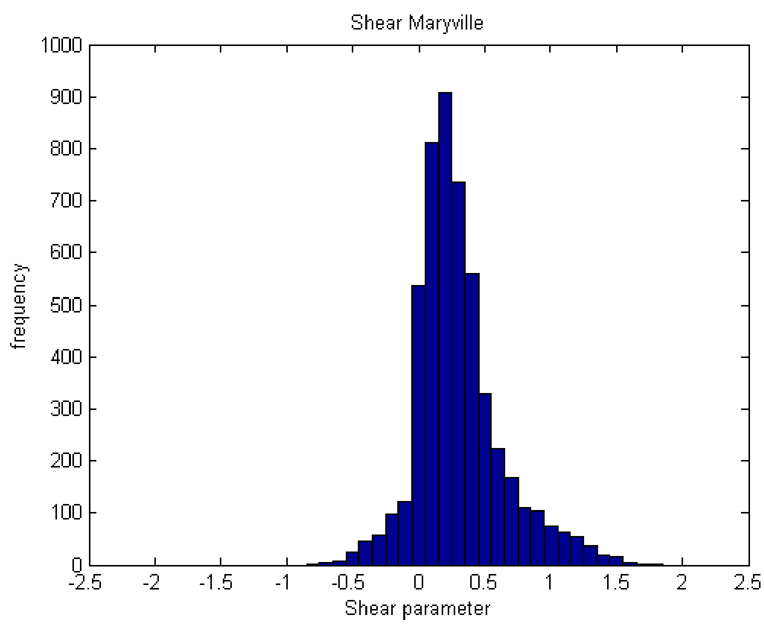


Figure 11.1: Shear parameter frequency distribution for Maryville.

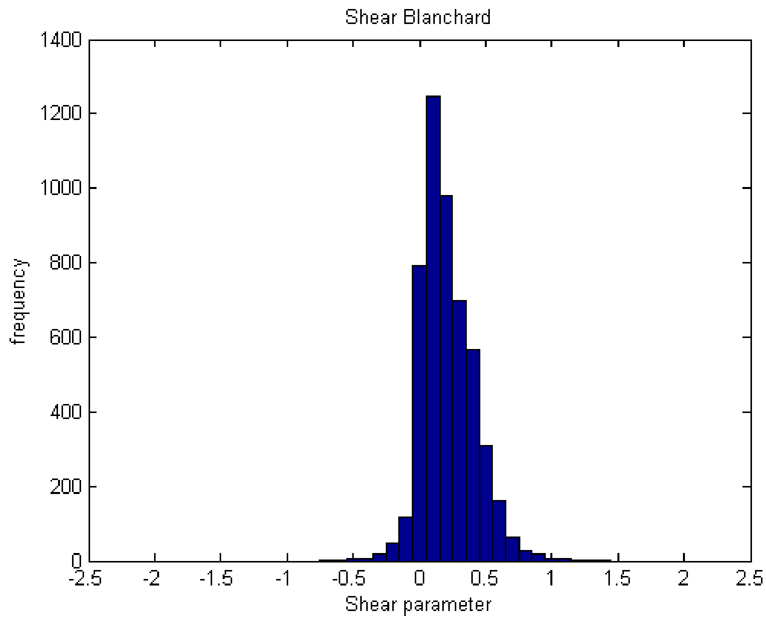


Figure 11.2: Shear parameter frequency distribution for Blanchard.

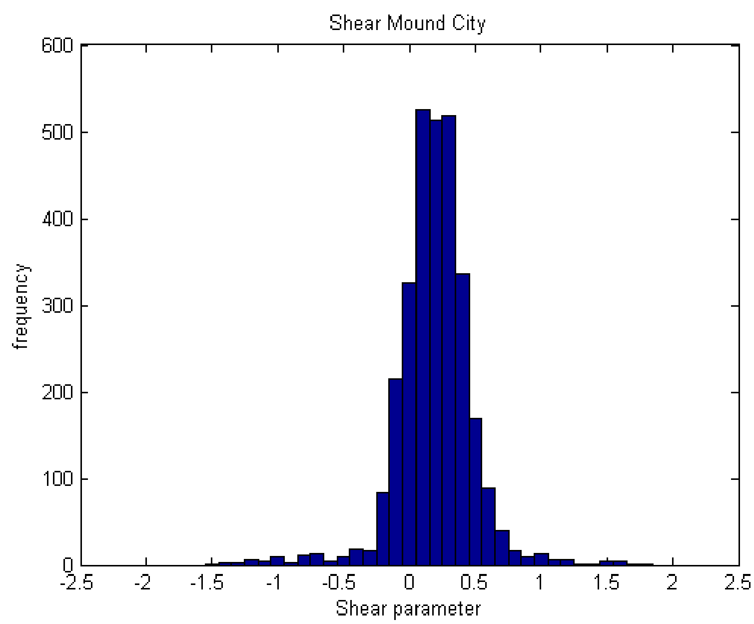


Figure 11.3: Shear parameter frequency distribution for Mound City.

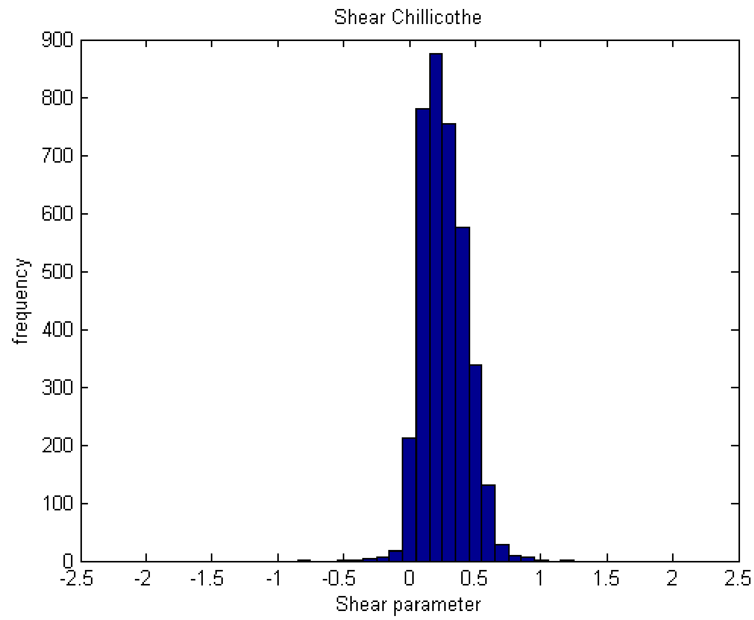


Figure 11.4: Shear parameter frequency distribution for Chillicothe.

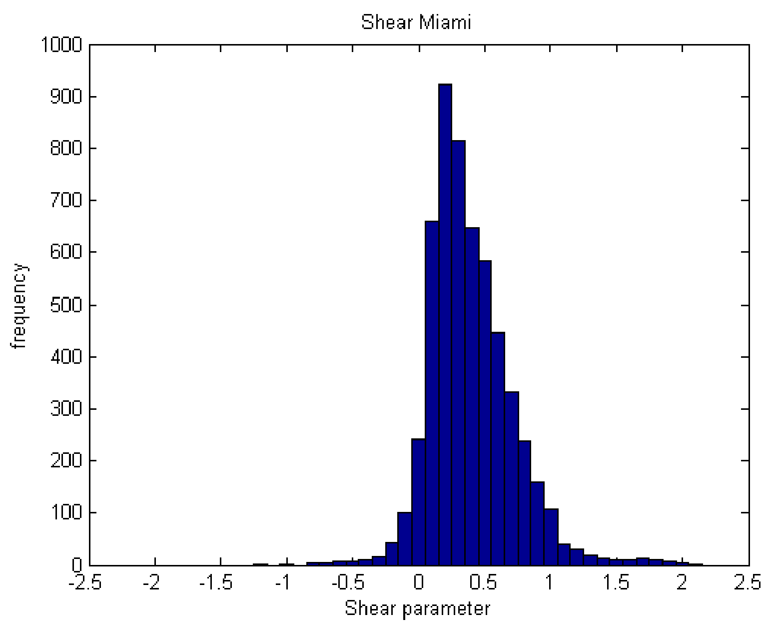


Figure 11.5: Shear parameter frequency distribution for Miami.

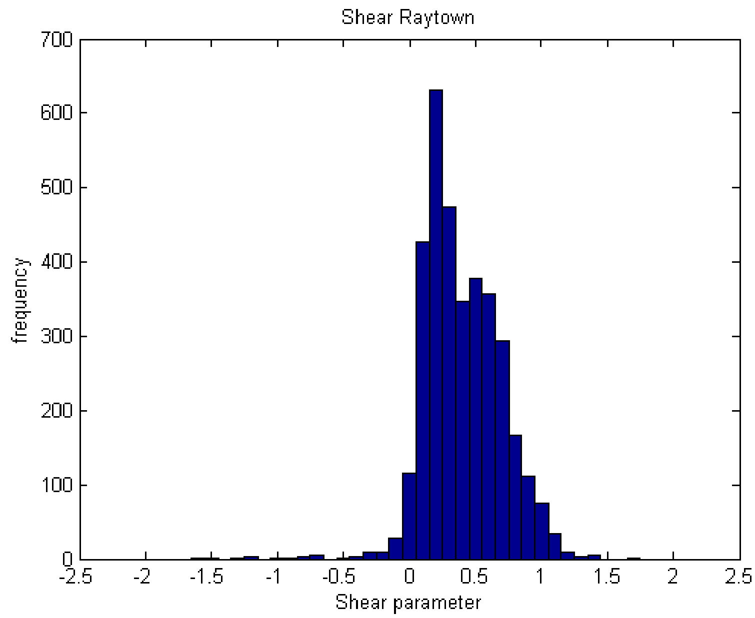


Figure 11.6: Shear parameter frequency distribution for Raytown.

12. Low-level jet identification

Two independent means have been explored to identify episodes of low-level jet (LLJ) activity and assess their impact on wind patterns observed at the tall towers. The first compares data collected by a wind profiler in the vicinity of the towers to the in situ observations in a number of ways. The second uses archival rapid update cycle (RUC) model data to establish a baseline climatology of LLJ characteristics in Missouri. The third will combine these approaches to compare coincident model analyses with profiler and tower data. Once a rigorous and objective methodology of identifying LLJ occurrence and properties has been established comparisons can be made between wind speeds and profiles observed at the towers during LLJ and non-LLJ times.

12.1 Using profiler data

Wind Profiler data was collected from http://mtarchive.geol.iastate.edu for Lathrop, MO to be compared with the observational tower data. The Lathrop, MO profiler was chosen because it is the only profiler in the northwest portion of Missouri. The profiler also happens to be conveniently situated among the center of the tower locations. The Lathrop, MO wind profiler is a part of the NOAA profiler network. The 6-minute profiler data was averaged to an hourly value to match the hourly average tower data.

The profiler data was then fed into Matlab where it was used to create the graphs of tower winds versus profiler winds at 500 m above sea level. The profiler winds were correlated to the surface winds to determine if the upper-level profiler winds could be extrapolated to the surface and used as an estimate for the surface winds. The profiler winds also assisted in determining a threshold for the location of the low-level jet. In this case the tower winds were extrapolated upwards to 500 m and correlated to the profiler winds.

Winds from the tower sites were extrapolated to 500 m using a logarithmic profile and plotted against the 500 m profiler winds to determine if a correlation was present. Lines of one standard deviation were added to these plots to determine where the majority of the outliers were located. The location of the low-level jet is thought to be related to the location of the outlying points. Lines were added to the chart denoting plus/minus one standard deviation.

Examples of the plots produced are shown in figures 13.1 – 13.4. These show scatterplots of winds observed by the profiler at 500m against the winds observed at the towers projected to that height using a logarithmic profile. As can be seen the projected winds at 500m tend to be higher than those observed suggesting that the simple extrapolation is not a good representation of the true wind profile. The theory is that extremely high estimates of extrapolated winds (shown by points lying above the upper broken line) suggest a LLJ below the 500m level that directly affects the winds at tower height. Low estimates, represented by points lying below the lower broken line suggest a LLJ above 500m which influences winds at 500m, but not at tower level.

The numbers of each of these instances are currently being found and once this is done the timings of these occurrences can be compared to LLJ incidence documented in meteorological model analyses. Considerations of tower location and wind direction relative to the profiler at

Lathrop also need to be examined. It can be seen that there is a varying degree of scatter evident at the different towers. For example, Maryville (figure 12.2) shows a better correlation than the other sites, and this may be due to the relative locations of the towers and the profiler.

This is an ongoing area of research which we will continue to follow.

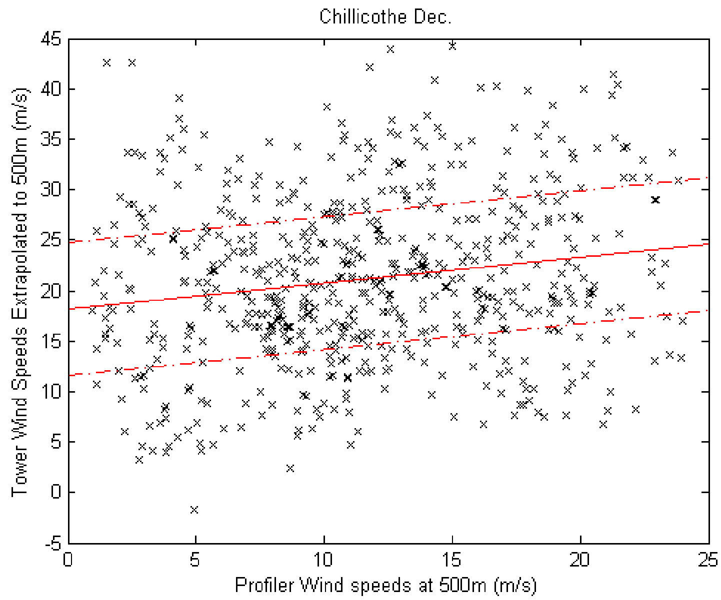


Figure 12.1: Comparison of Lathrop profiler winds at 500m to winds extrapolated to 500m from tall tower observations at Chillicothe during December 2006.

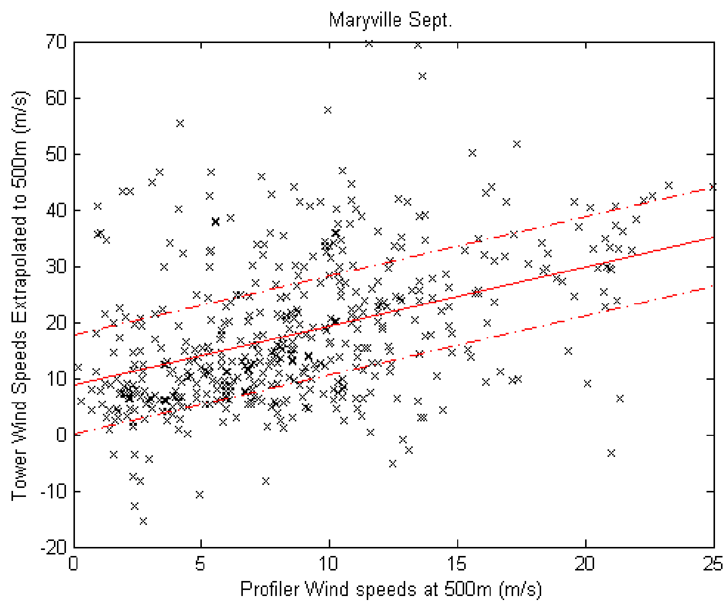


Figure 12.2: Comparison of Lathrop profiler winds at 500m to winds extrapolated to 500m from tall tower observations at Maryville during December 2006.

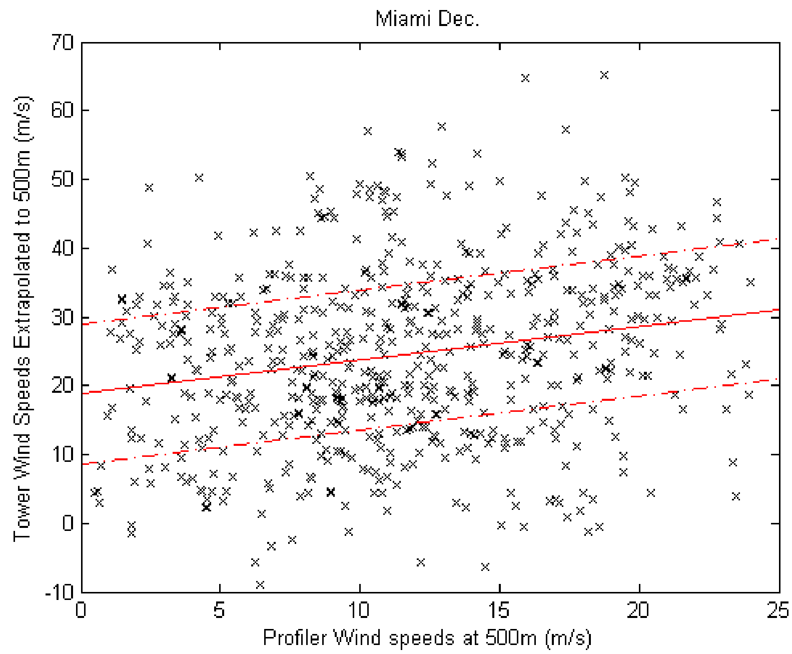


Figure 12.3: Comparison of Lathrop profiler winds at 500m to winds extrapolated to 500m from tall tower observations at Miami during December 2006.

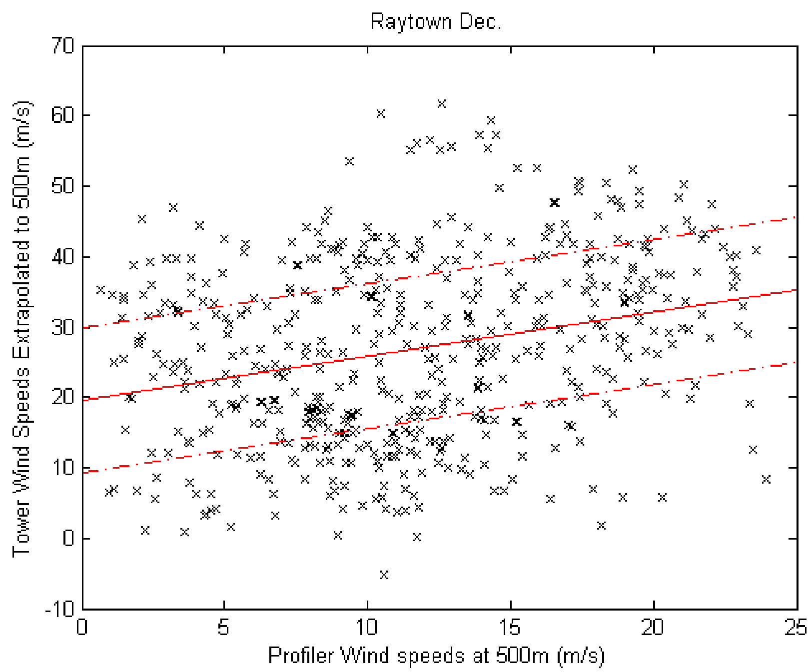


Figure 12.4: Comparison of Lathrop profiler winds at 500m to winds extrapolated to 500m from tall tower observations at Raytown during December 2006.

12.2 Using historical model reanalysis studies

Archival Rapid Update Cycle (RUC) meteorological model output was acquired from the National Climate Data Center (NCDC) for the 12-month period June 2003-May 2004. This data provides the best analysis of the state of the atmosphere on an hourly basis at high resolution. The RUC has enough vertical levels in the lower atmosphere that it enables an assessment of enhanced wind speed at tower heights. The goal is to identify occasions where low-level jets were present over Missouri to generate a climatology of jet incidence and type.

The RUC data will be compared, for each time period and each sigma level (up to level approx. equal to 800 millibars), to the actual wind speed, frequency, height, and duration observations. The data collected will span, at least, 365 consecutive days. Statistical methods will be used to find relationships/similarities between the RUC analysis and the actual observations.

First, a formulation of what will be defined as characteristics of the low-level jet (LLJ), in terms of velocity and height, will establish a criterion of the LLJ for this study.

The wind speed (in m/s) and direction (in Cartesian coordinates) for this experiment will be gathered from the 40-km Rapid Update Cycle (RUC) Model. This data will be collected on various Sigma levels (terrain following levels) for every grid point in Missouri. Compiled from one complete year (365 days), this data will be used to gain an improved understanding of the character of LLJ and to establish a LLJ climatology in Missouri by conducting wind speed, frequency, height, and duration analysis of the low-level wind patterns. In addition to the RUC data, actual observations of wind speed and direction in the state of Missouri will also be obtained via outside sources. Synoptic conditions associated with LLJ types are also determined in this study.

The RUC data will be compared to the actual wind speed, frequency, height, and duration observations. The data collected will span 365 consecutive days. Statistical analysis will be used to find relationships/similarities between the RUC analysis and the actual observations.

LLJ criteria will include those low-level wind maxima that exhibited a decrease of at least 2 m s^{-1} at vertical levels both above and below the level of the peak value [Andreas et al. (2000) and Banta (2001)]. Banta (2001) found that the average height of the LLJ in his Kansas study was around 100m, which is lower than most other studies in the Great Plains.

13. Problems encountered

13.1 Tower set-up

The primary problem encountered during the project has been the establishment of the towers. There are numerous suitable towers in good locations, but some owners are reluctant to allow the placement of our equipment or wish to charge commercial rates which are beyond the financial compass of the project. In general, local owners of towers have seen the potential benefit to their communities of these investigations and been more accommodating than national corporations. Indeed, it should be noted that a number of owners have allowed the use of their towers at no charge.

Arranging installation of instruments has been an ongoing issue. Trying to find and book a crew to work on the towers can be a problem, and scheduling their time along with those of the tower owners and University personnel has delayed some installations significantly.

13.2 Equipment

In general the equipment has operated well. The sensors (anemometers, wind vanes, temperature probes) have not appeared to malfunction and have even withstood some harsh conditions (see section 14.3). However there remain some unresolved questions on some individual instruments. To answer these questions it will be necessary to commission a tower crew to examine whether there is a problem with the instrument or the wiring. As there are no towers on which there is a lack of wind speed observation at any of the three heights, maintenance of this type has been delayed until after all the towers have been instrumented.

There have been a number of problems with logger reliability. This has resulted in periods where particular channels on individual towers have not recorded useful data. This has been the case on the Mound City tower (for which channels 1,2 and 3 were lost for some time – *insert period*); Blanchard (for which channels 1,3 and 5 were lost – *insert period)*; and …

It is not known what initiates these problems, but the loggers concerned have been replaced under warranty.

13.3 Data Retrieval

Data retrieval has been an issue throughout the project. By the nature of the tower site selection the majority of the towers are in remote locations where direct access is difficult. The initial plan was to install cellphone units on the loggers to transmit the data automatically each day and this was attempted. Due to the remoteness of most of the towers this approach has only proved successful in three locations: Raytown, Chillicothe and Santa Rosa (this latter has been very intermittent).

It is hoped that in future local volunteers can be identified and trained to download and send the data on a regular basis.

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Appendix A: Presentations and outreach

Attempts have been made to use the project and publicity around it to promote the work underway, the development of wind power in the State of Missouri and environmental approaches to energy production in general. Four lines of outreach have been taken. The first involved a number of media interviews that have taken place. This has led to a large number of contacts from interested parties, ranging from individuals interested in wind power, land owners looking to investigate the potential for wind energy development and major wind energy producing companies. Dr. Fox has appeared at town meetings. While few scientific results have been, early results from the work have been presented at scientific meetings and in seminars. Much more is planned in this area.

A1. Media Interviews

Numerous interviews have been undertaken both for radio stations within Missouri and for newspapers. Much of the interest has centered on the northwest part of the State, but calls have come in from other areas, such as St. Louis.

A2. Meetings

Neil Fox has used the following opportunities where he has been invited to speak to advertise and promote the project and the cause of wind power development in Missouri in general.

- Northwest Missouri Town Meeting on wind energy development, Maryville, 26th April 2006.
- North Missouri Town Meeting on Wind energy development, Kirksville, 12th September 2006.
- 1st Symposium on Advancing Renewables in the Midwest, Columbia, MO. Neil Fox participated as a plenary session panel member. 29th March 2006.

A3. Seminars and presentations

Department of Soil, Environmental and Atmospheric Sciences Seminar: Energy options for the world and Missouri – Neil Fox. University of Missouri – Columbia, 7th February 2007.

Department of Soil, Environmental and Atmospheric Sciences Seminar: A tall tower wind investigation of NW Missouri. Rachel Redburn. University of Missouri – Columbia, 11th April 2007.

Missouri Academy of Sciences Annual Meeting: A network of tall towers for wind investigations. Neil Fox. St. Joseph, MO, 21st April 2007,

Missouri Academy of Sciences Annual Meeting: A tall tower wind investigation of NW Missouri. Rachel Redburn. St. Joseph, MO, 21st April 2007.