NASA/CR-2011-216301

30 WS North Base Wind Study

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May 2011

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Executive Summary

The 30 Weather Squadron (30 WS) is concerned about strong winds observed at their northern towers without advance warning. They state that terrain influences along the extreme northern fringes of Vandenberg Air Force Base (VAFB) make it difficult for forecasters to issue timely and accurate high wind warnings for northeasterly wind events. These events tend to occur during the winter or early spring when they are under the influence of the Great Basin high pressure weather regime. The Launch Weather Officers (LWOs) have seen these rapid wind increases in the current northern Towers 60, 70 and 71 in excess of their 35 kt operational warning threshold.

For this task, the 30 WS requested the Applied Meteorology Unit (AMU) analyze data from days when these towers reported winds in excess of 35 kt and determine if there were any precursors in the observations that would allow the LWOs to better forecast and warn their operational customers for these wind events. The 30 WS provided wind tower data for the cool season (October – March) from the period January 2004-March 2010.

The AMU decoded and evaluated the wind tower data for 66 days identified by the 30 WS as having high-wind events. Out of the 66 event days, only 30 had wind speed observations of ≥ 35 kt from at least one of the three northern towers. The AMU analyzed surface and upper air charts to determine the synoptic conditions for each event day along with tower peak wind speed and direction time series and wind rose charts for all 30 event days.

The analysis revealed a trend on all event days in which the tower winds shifted to the northeast for a period of time before the first recorded ≥ 35 kt wind speed. The time periods for the 30 event days ranged from 20 minutes to several hours, with a median value of 110 minutes. This trend, if monitored, could give the 30 WS forecasters a precursor to assist in issuing an operational warning before a high wind event occurs.

The AMU recommends developing a high-wind alert capability for VAFB using a local mesoscale model to forecast these wind events. The model should incorporate all of the VAFB local data sets and have a forecast capability of between 2 to 24 hours. Such a model would allow the meteorologists at VAFB to alert the operational customers of high wind events in a timely manner so protective action could be taken.

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1. Introduction

The 30th Weather Squadron (30 WS) states that terrain influences along the extreme northern fringes of Vandenberg Air Force Base (VAFB) make it difficult for forecasters to issue timely and accurate high wind warnings for that particular part of the base during northeasterly wind events. These events tend to occur during the winter or early spring (October-March) when they are under the influence of the Great Basin high pressure weather regime. The Launch Weather Officers (LWOs) have seen these rapid wind increases in Towers 60, 70 and 71 along the northern edge of VAFB in excess of their 35 kt warning threshold. For this task, the 30 WS requested the Applied Meteorology Unit (AMU) retrieve and analyze data from days when the 30 WS reported that these towers recorded winds in excess of 35 kt and determine if there are any precursors in the observations that would allow the LWOs to better forecast and warn their operational customers for these wind events.

2. Data

The 30 WS provided the tower data for the period of record (POR) January 2004-March 2010 on compact discs (CDs). Figure 1 is a Google Earth map showing the locations of all the wind towers on VAFB. Towers 70, 60 and 71 along the northern part of VAFB are the wind towers identified by the 30 WS to be used in this study. Tower 70 is northernmost and closest to the ocean, Tower 60 is southeast of Tower 70 and in between the other two towers, and Tower 71 is the southernmost and east-southeast of Tower 60. These towers are just west of a mountain ridge line.

The towers are instrumented with wind sensors at 12 and 54 ft. The wind tower data from January 2004 to October 2007 was from mechanical wind sensors and the data from November 2007 to March 2010 was from ultrasonic sensors. The mechanical wind system uses a vane (direction) and cup (speed) mounted separately, but at the same level. The ultrasonic sensor derives wind speed and direction from the effect of wind on the transit time of ultrasonic pulses between three electro-acoustic transducers configured in an equilateral triangle and pointed downward. The AMU extracted the tower data from the CDs and organized them by day/year.

The AMU also retrieved surface weather maps, 850 and 500 mb upper air maps, and VAFB sounding data for each of the event days from Plymouth State University (http://vortex.plymouth.edu/) and the National Centers for Environmental Prediction (NCEP) (http://www.hpc. ncep.noaa.gov/dailywxmap/) in order to categorize and detail the weather on each event day.

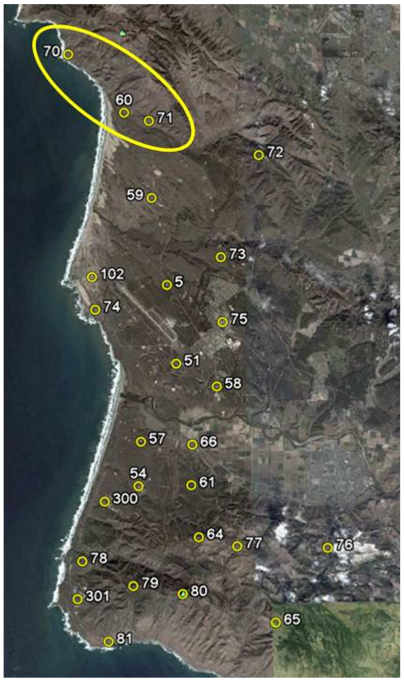


Figure 1. Google Earth map of the VAFB tower locations as yellow circles with white tower numbers. The towers for this task are surrounded by the yellow ellipse.

3. Peak Speed Events

The 30 WS identified 66 days from their cool season (October-March) in the POR that they thought had observations the met the ≥35 kt criterion. The AMU analyzed each of these days in the wind tower database for occurrences of peak wind speeds ≥35 kt and found that some of the days did not have enough data and other days did not have observations that met the event criterion. After the analysis, there were 30 days in which the towers observed peak wind speeds ≥35 kt. The AMU used Microsoft® Excel® (hereafter Excel) to create time-series and wind rose charts of peak wind direction and speed for the three towers to analyze each of these 30 event days.

3.1 Data Analysis

The AMU designed the analysis procedure to compare the mechanical and ultrasonic data at the mechanical temporal resolution of 5 minutes. Excel Visual Basic for Applications (VBA) scripts were written to extract the peak wind speed and direction at 12 and 54 ft from both data sets. Additionally, the S-PLUS® software package was used to reformat the 1-minute ultrasonic data into a 5-minute database. The 5-minute data were then imported into Excel spreadsheets containing the peak wind direction and speed at 12 and 54 ft on each of the towers. Time series charts of wind speed and direction were plotted from these charts and analyzed.

The AMU noted a trend in the time series on most event days in which the prevailing winds at 54 ft switched to the northeast before the peak winds reached or exceeded 35 kt. The timing between the direction switch and the 35 kt speed varied from 10 minutes to several hours. The key was that all peak winds ≥ 35 kt were always from the northeast on each event day. The wind rose charts for each event day of wind direction and peak wind speed clearly showed this northeast wind direction trend. The charts for two of the event days are shown in Section 4.

3.2 Terrain Influences

The northern part of VAFB is influenced by two major features. To the west is the Pacific Ocean, which has very little influence on north to south synoptic wind flow patterns. The terrain raises to the east of the northern wind towers to the peak of Mt. Lopse and associated ridge line extending generally northwest to southeast. Figure 3 shows more detail of the elevated range to the west of the northern towers and associated valleys to the west of the ridge line. These terrain features would focus the wind to a northeasterly direction that would funnel into the valleys, and increase the wind speed.

Figure 2. Google Earth terrain map showing the three northern VAFB tower locations as yellow circles with white tower numbers. The white dashed line highlights top of elevated range to the west and the white arrows highlight valleys that would enhance wind flow out of the northeast.

4. Example Wind Events

Two of the 30 high wind event days, 21 October and 28 November 2007, are highlighted in detail in this section. The first described event, 28 November 2007 details how the tower winds react as high pressure builds into the Pacific Northwest. The second event, 21 October 2007 details how the northern towers react as a cold front moves through the Vandenberg AFB area and then as high pressure builds in behind the cold front. The charts for the other 28 event days are in the Appendix A.

4.1 28 November 2007

On 28 November 2007, a high pressure system had built into the Pacific Northwest with a ridge extending south-southeast into Nevada. The placement of the high and ridge line would result in an east-to-southeast wind flow in the vicinity of VAFB (Figure 3).

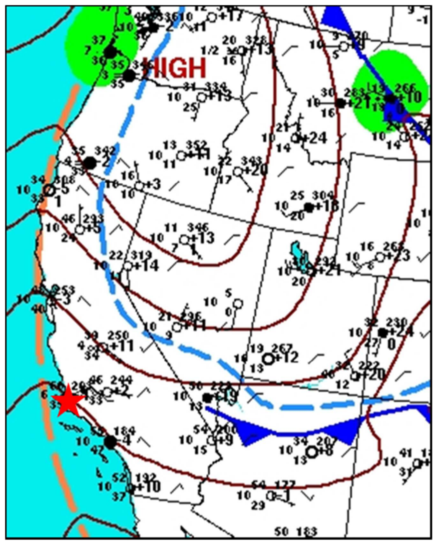


Figure 3. The surface weather map of the west coast for 28 November 2007 at 1200 UTC. A High pressure system is centered in the Pacific Northwest. The isobars (brown lines) indicate the flow at VAFB (red star in lower left) would be east to southeast.

The wind direction and speed time series charts for this event are shown in Figure 4. Before the high wind speed event, the 54 ft winds at the three northern towers were southeast at around 10 kt. By 0400 UTC, the winds began shifting to the northeast and increasing in speed. By 0430 UTC the winds at Tower 71 had switched to the northeast with an increasing wind speed. At 0500 UTC, the winds at Tower 70 shifted to the northeast. Thirty minutes later at 0530 UTC, Tower 70 recorded the first 35 kt peak wind speed. The speeds at all three towers continued to increase for several hours. By 1800 UTC, the winds began to weaken and shift to the northwest.

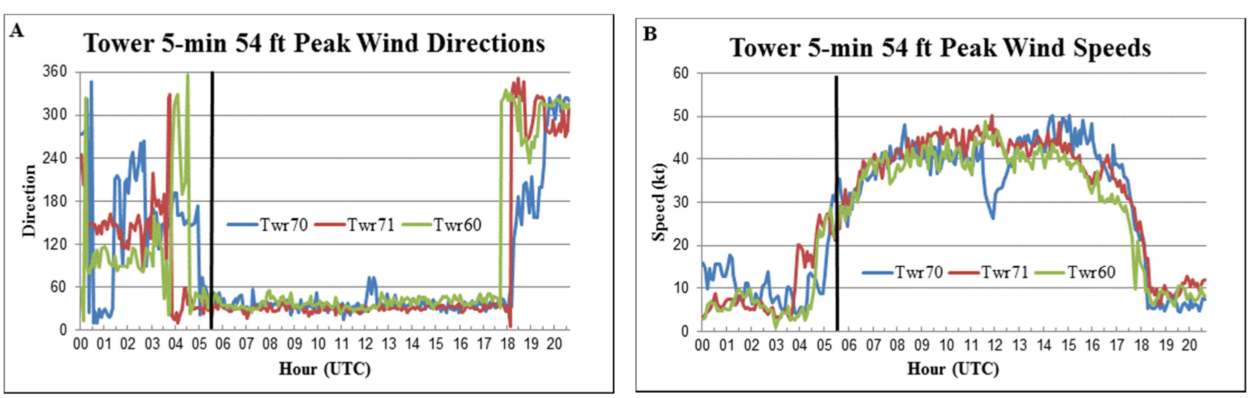


Figure 4. The peak wind direction (A) and speed (B) on 28 November 2007. The thick black vertical line in both charts marks the first 35 kt peak wind speed at Tower 70 (blue curve) at 0530 UTC.

Another way to display the wind direction and magnitude of peak wind speeds is to use wind rose charts. Figure 5 shows the wind rose chart for Tower 70 at 54 ft on 28 November 2007, the first northern tower to report a peak speed ≥35 kt. The red dots are plots of wind speeds ≥35 kt. This chart clearly shows that all of the wind speed observations ≥35 kt were from the northeast. This pattern was also seen in the other two towers (not shown).

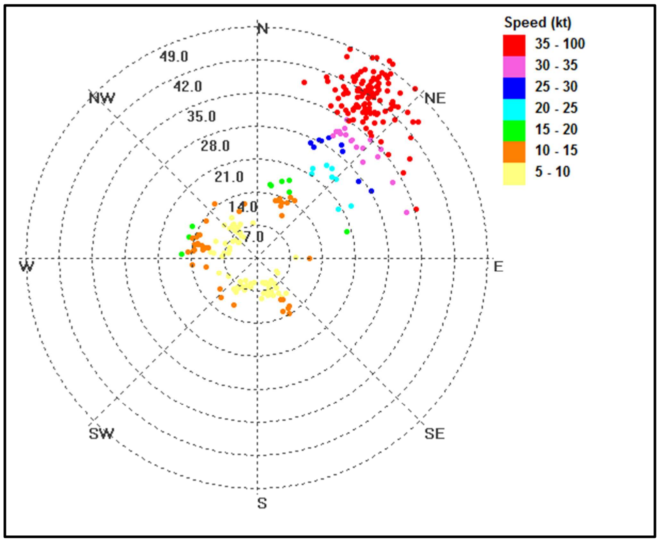


Figure 5. The wind rose plot for Tower 70 at 54 ft on 28 November 2007. Red circles are plots of wind speeds of 35 kt or greater. The legend for other speeds is in the top right.

4.2 21 October 2007

On 20 October, a strong cold front passed through the VAFB area (Figure 6A). As the front moved through all three northern towers reported northwest winds with peaks wind speeds above 35 kt. By 1200 UTC on 21 October, high pressure had built in behind the front centered in the Pacific Northwest with a ridge southward toward Nevada (Figure 6B). The northern VAFB towers recorded a wind shift to the northeast-east as this high pressure system continued to build in.

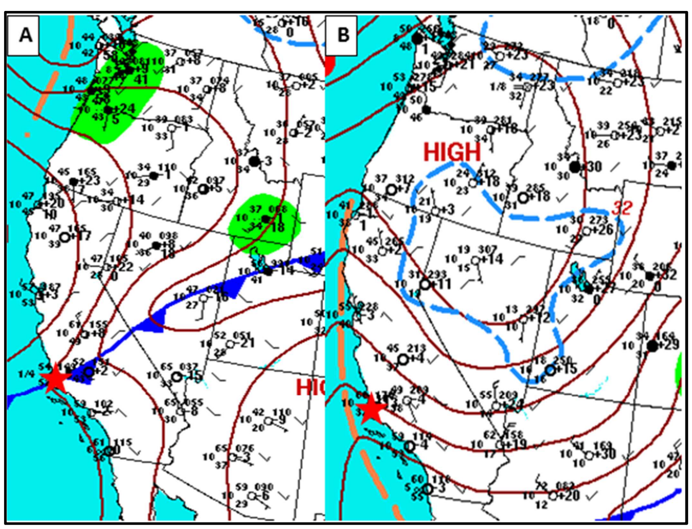


Figure 6. Surface weather maps of the west coast for 20/21 October 2007 at 1200 UTC. Map (A) details a cold front moving through VAFB. By the morning of October 21, 2007 (B) a high pressure system is centered over Oregon with a ridge extending to the southeast. The brown lines depict the pressure pattern, which would produce an east-to-southeast flow near VAFB. The red stars show the location of VAFB.

Figure 7 shows the wind direction and speeds for all three towers during this event. Just behind the cold front between 0000 and 0300 UTC the winds were out of the northwest and gusting ≥ 35 kt. These peak winds were associated with the cold air behind the frontal passage as the high moved into the Pacific Northwest. Several hours later, around 0800 UTC, the winds began shifting to the northeast. At 0945 UTC, the first northeast peak wind speed of ≥35 kt was reported from Tower 71. The other two towers also recorded peak speeds ≥35 kt 15-30 minutes later.

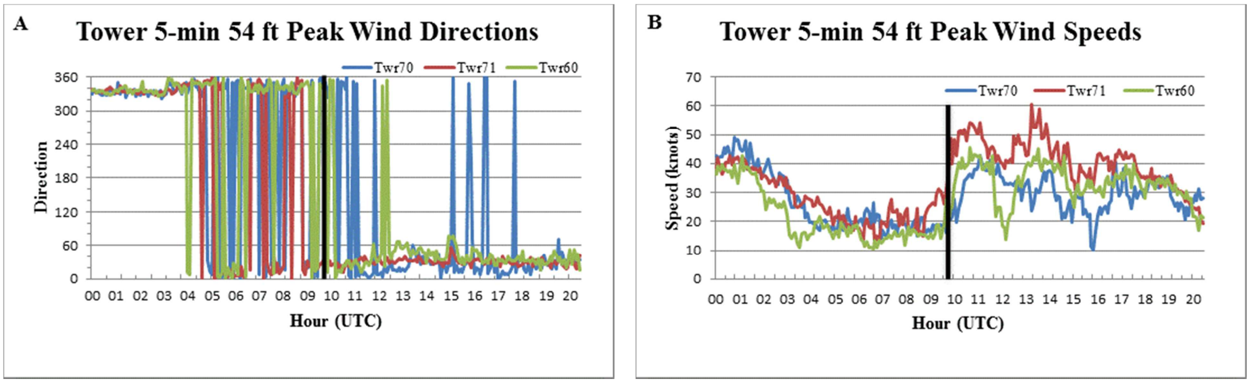


Figure 7. The peak wind direction (A) and speed (B) on 21 October 2007. The black vertical line in both charts highlights the first northeast ≥35 kt peak wind occurrence from Tower 71. The earlier peak wind speeds between 0000-0230 UTC were associated with the cold front that had moved through VAFB.

To show more detail of the wind shift to the northeast at Tower 70, a chronological listing of the observations is given in Table 1. It clearly shows that the wind direction changed from northwest to northeast at 0845 UTC (blue). The wind direction continued from the northeast for an hour before the first peak speed of ≥ 35 kt (red). Monitoring for such northeast wind shifts during the winter months when high pressures systems are north of VAFB could give the forecasters additional lead time in alerting their customers to such events.

Table 1. Tower 71 peak wind speed and direction observations for the event on 21 October 2007.

Time (UTC)	**Speed (kt)**	**Direction (Deg)**
8:35	16.5	358
8:40	14.8	345
8:45	**22.0**	**010**
8:50	23.3	015
8:55	24.7	018
9:00	25.8	033
9:05	26.6	021
9:10	25.6	022
9:15	29.1	013
9:20	31.1	026
9:25	30.3	017
9:30	28.0	025
9:35	26.0	026
9:40	31.3	033
9:45	**37.1**	**022**
9:50	48.6	021

4.3 Summary of Events

The AMU analyzed data from 30 event days that had useable tower data. Table 2 shows the variables associated with the direction switch to the northeast and the occurrence of the peak wind speed of ≥ 35 kt for each event. The first column has the date of each event followed in the second column by the initial time the 54 ft wind sensor at one of the three northern towers recorded a wind shift from a sector other than northeast to the northeast. The third column shows the time when a tower reported the first peak wind speed ≥ 35 kt. The fourth column shows the wind direction at the time of the first peak speed. The fifth and most important column gives the time difference between the initial wind shift on one of the three northern wind towers and the first reported peak wind speed of ≥ 35 kt. This time difference could be the lead-time a forecaster would have in issuing an operational warning of a possible high wind event. For all events, the lead-time ranged from 20 minutes to several hours (835 minutes, or 13 hours 55 minutes). The median time difference value is 110 minutes.

Table 2. Details of the 30 wind events including date, time of wind direction change to the northeast, time of first peak wind ≥ 35 kt, direction of the first peak wind, and the time between the wind shift to the northeast and the ≥ 35 kt observation.

Date (mm/dd/yyyy)	Time of Initial Wind Change	Time 1st Wind ≥ 35 kt	Wind Direction	Time Diff (Minutes)
11/01/2004	14:15	16:05	19	110
12/14/2004	1:50	2:45	67	55
11/21/2004	13:15	15:35	45	140
12/21/2004	15:20	16:10	70	55
03/10/2005	12:30	14:20	45	110
01/12/2005	20:05	21:50	46	105
11/15/2005	5:10	6:00	55	50
01/17/2005	11:25	12:40	58	75
01/31/2005	3:30	4:20	67	50
10/31/2005	3:00	4:50	63	110
12/02/2006	5:00	7:00	41	120
02/05/2006	3:30	4:35	79	65
12/09/2007	5:30	10:25	27	295
12/11/2007	8:55	12:40	32	225
10/21/2007	8:45	9:45	22	60
11/24/2007	1:45	3:50	23	125
11/28/2007	4:55	5:30	43	35
12/31/2007	2:30	3:15	27	45
11/06/2008	4:30	6:50	32	140
12/09/2008	3:30	5:30	25	120
01/13/2008	2:50	5:00	30	130
01/16/2008	7:10	9:00	28	110
11/13/2008	15:30	15:50	20	20
12/17/2008	3:40	17:35	39	835
11/21/2008	2:10	3:55	32	205
12/21/2008	2:40	4:20	30	160
10/22/2008	0:20	1:15	35	55
01/09/2009	1:55	2:35	34	40
10/25/2009	7:55	11:10	29	195
03/27/2010	6:30	9:15	23	205

5. Summary and Recommendations

This report presented an analysis of the cool season peak wind events at three northern towers on VAFB. The AMU processed seven years of tower data and discovered 30 event days when the peak speed met the operational wind warning threshold of ≥ 35 kt. Peak wind speed and direction time series and wind rose charts were developed and analyzed for each of the event days.

The analysis revealed a trend on all event days in which the tower winds shifted to the northeast for a period of time before the first recorded ≥ 35 kt wind speed. The time periods for the 30 event days ranged from 20 minutes to several hours, with a median value of 110 minutes. This trend, if monitored, could give the 30 WS forecasters a precursor to assist in issuing an operational warning before a high wind event occurs. Two of the peak wind events were detailed in the report and the time series wind charts for the other 28 events are presented in Appendix A.

The AMU recommends conducting a two stage feasibility study to determine if a local mesoscale model that incorporates all the local data sets could be used to forecast these high wind events. The first phase would look at similar cool season synoptic days when the northern towers do not report peak speeds of 35 kt to see if the northeast wind shift is a valid precursor. If it is, then the second phase would look at setting up a mesoscale model for VAFB. The model should then be tested to see if it can forecast these types of events with a lead time of up to 24 hours. This type of modeling effort could give the 30 WS forecaster additional lead-time to warn their operational customers to these type of wind events. If the feasibility study shows favorable modeling results, the next step in developing a high-wind speed alert capability for VAFB would be to design, test and install a local mesoscale model that could incorporate all of the local data sets. Such a model would allow the meteorologist at VAFB to alert the operational customers of high wind events in a timely manner so protective action could be taken.

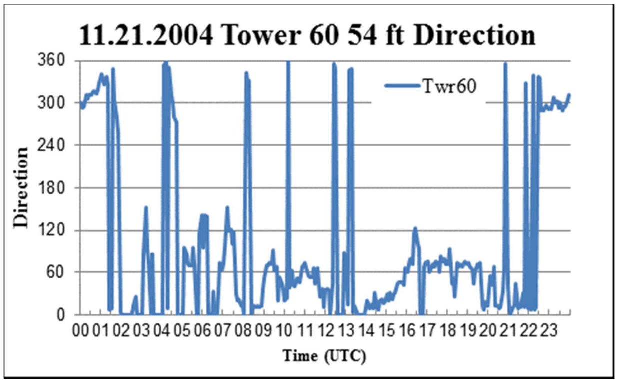
List of Acronyms

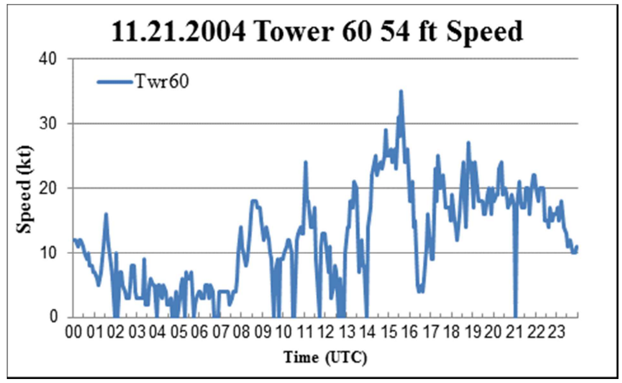
30 WS	30th Weather Squadron
AMU	Applied Meteorology Unit
LWO	Launch Weather Officer
NCEP	National Centers for Environmental Prediction
UTC	Coordinated Universal Time
VAFB	Vandenberg Air Force Base

6. Appendix A: Tower Peak Wind Speed and Direction Plots for all other Events

The following Excel charts are tower peak wind direction (left) and speed (right) plots for each of the 28 remaining event days. The plots from 2004 to October 2007 are from the mechanical sensor on Tower 60 at 54 ft. The plots from November 2007 through March 2010 are from all three ultrasonic instrumented Towers 70, 60 and 71 at 54 ft.

November 21, 2004





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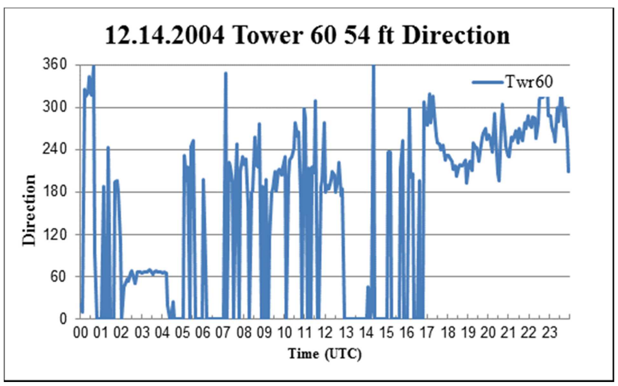

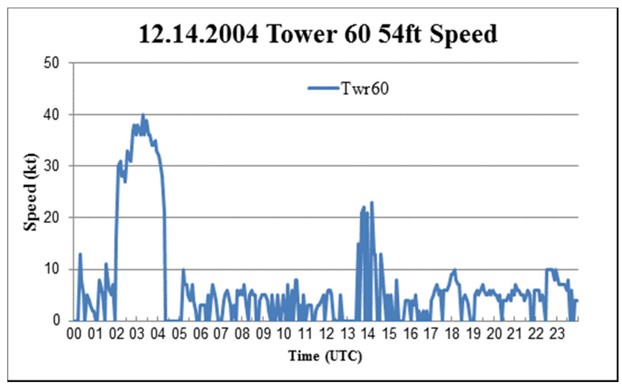

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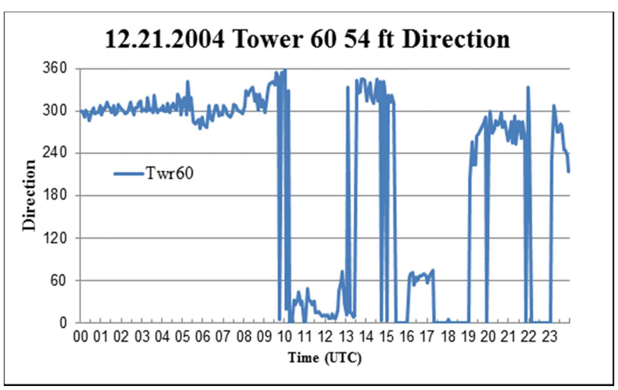

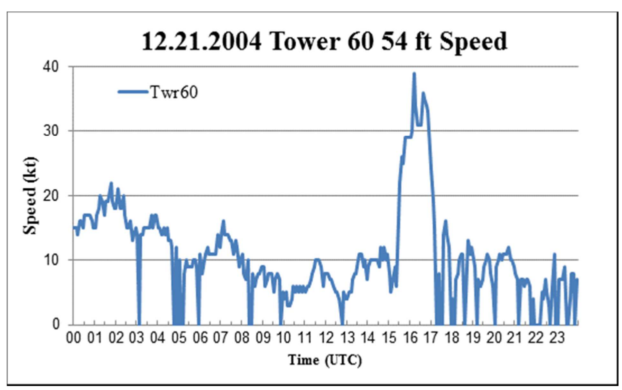

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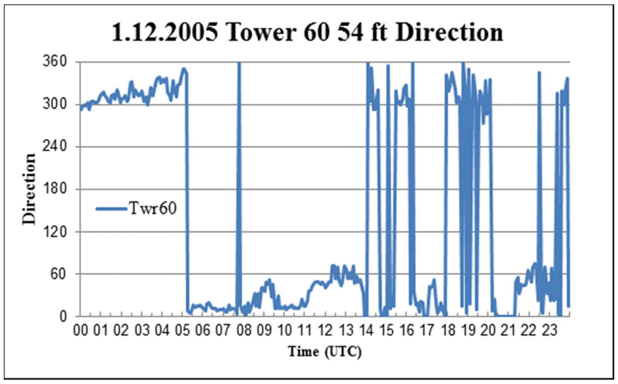

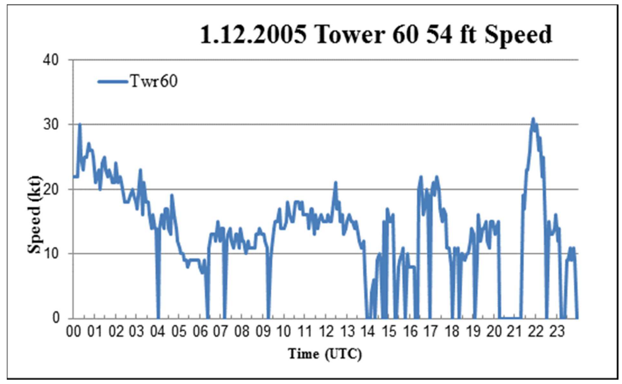

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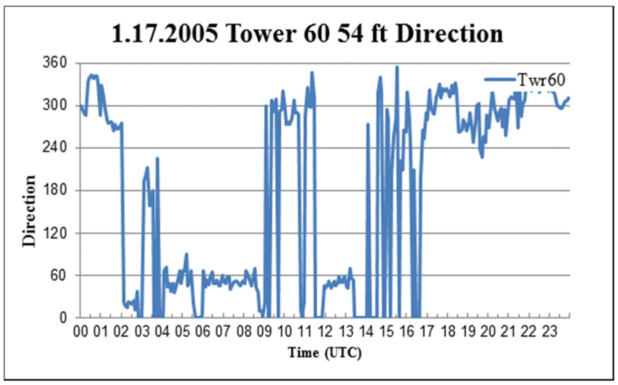
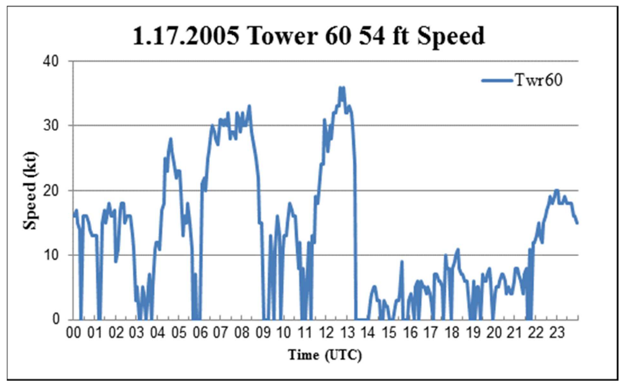
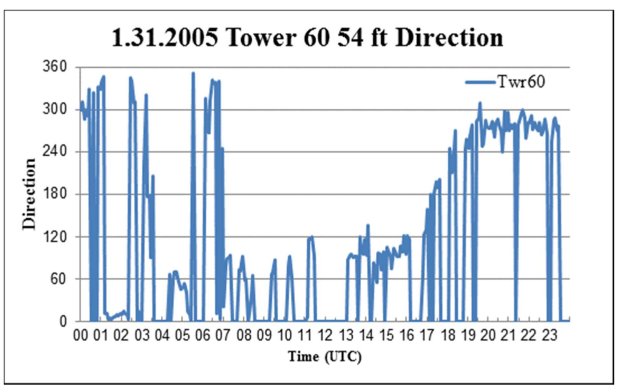
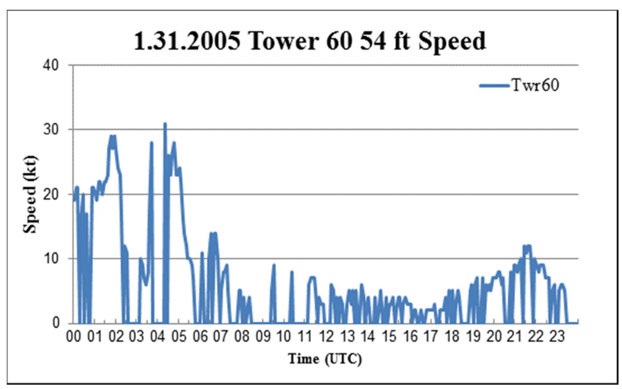




January 31, 2005





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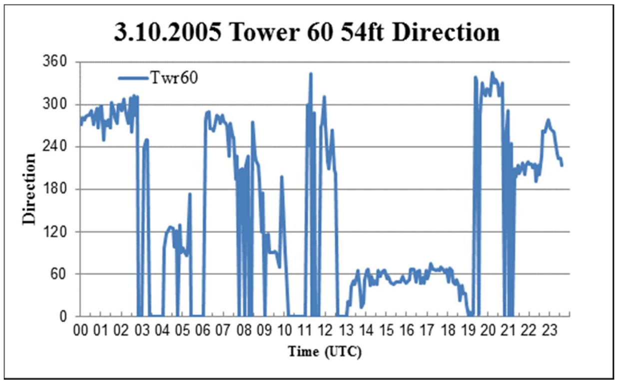

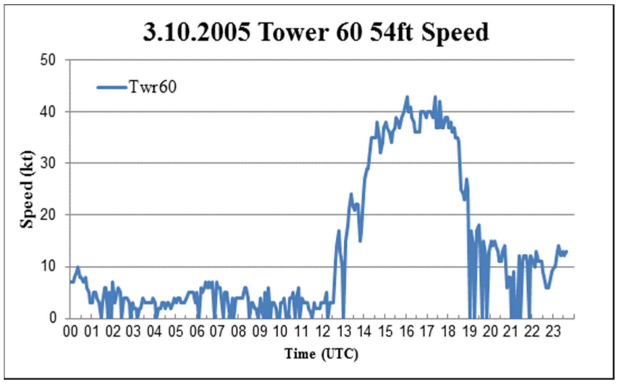

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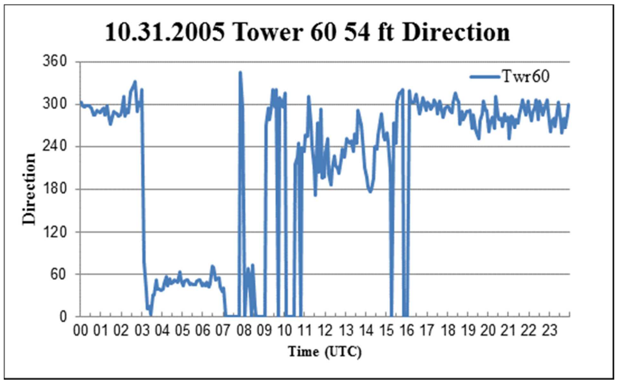

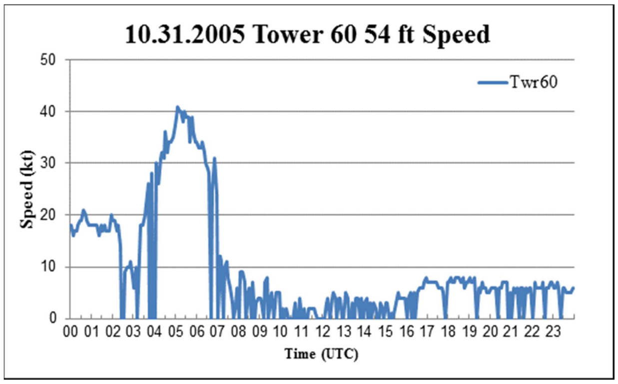

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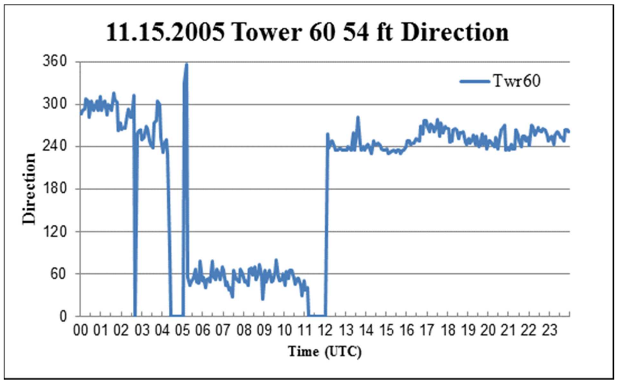

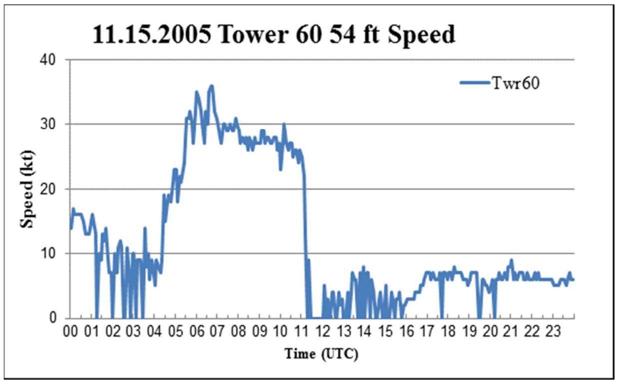

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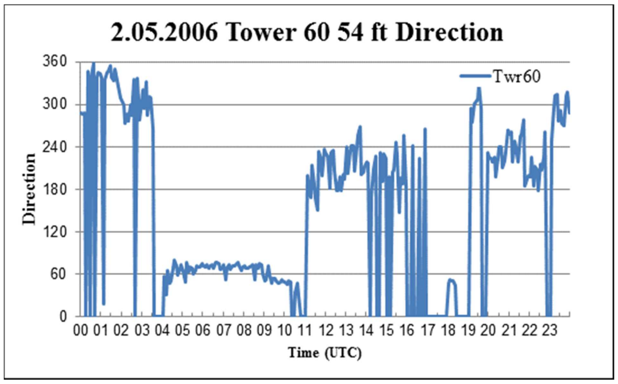
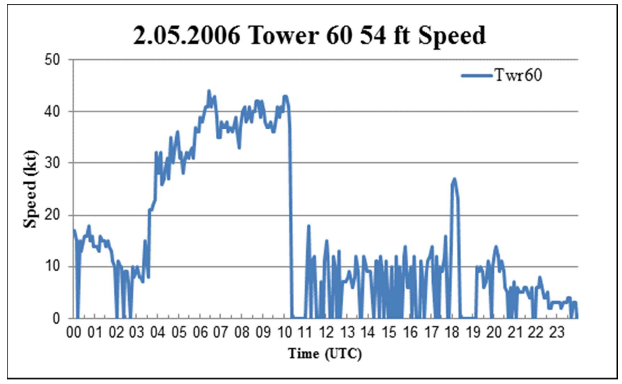
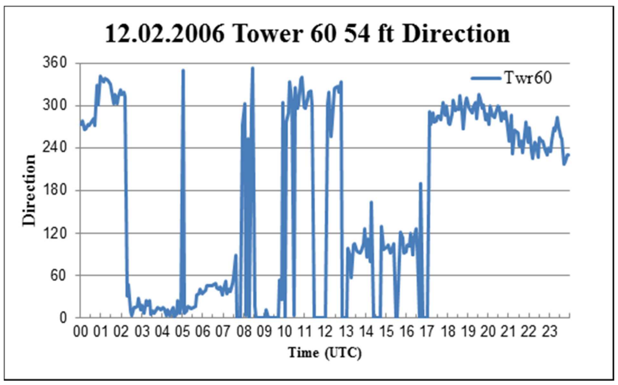
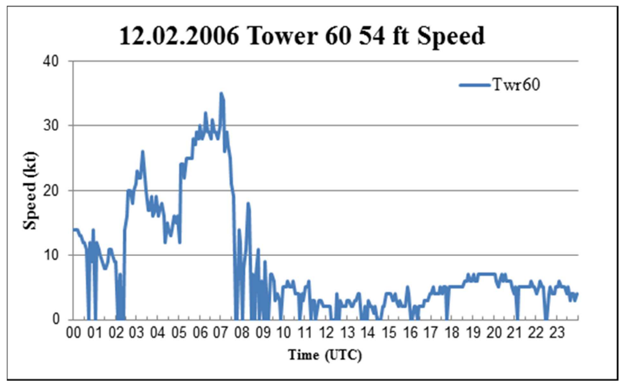


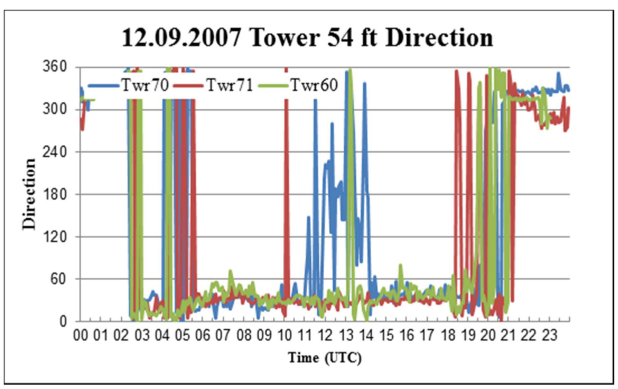


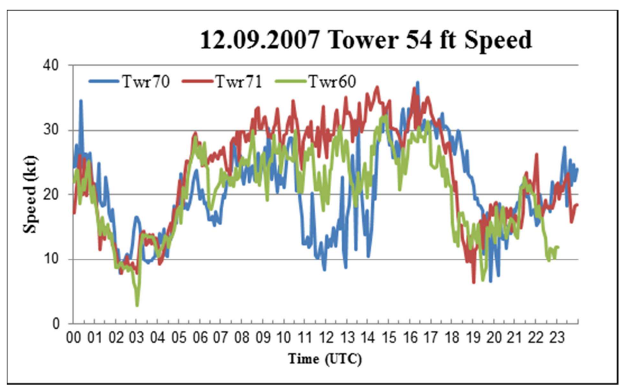
December 2, 2006



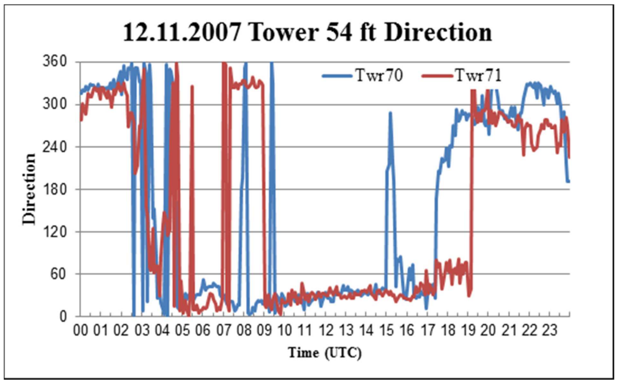


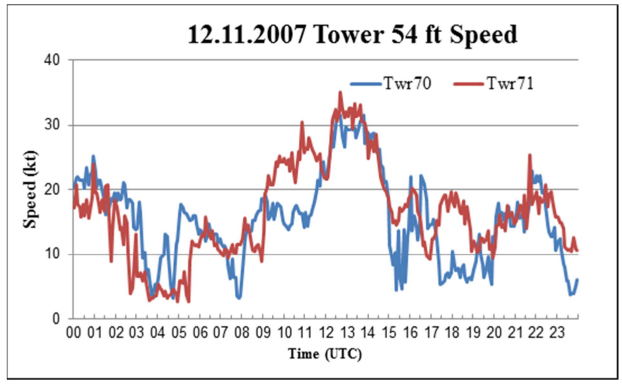
December 9, 2007



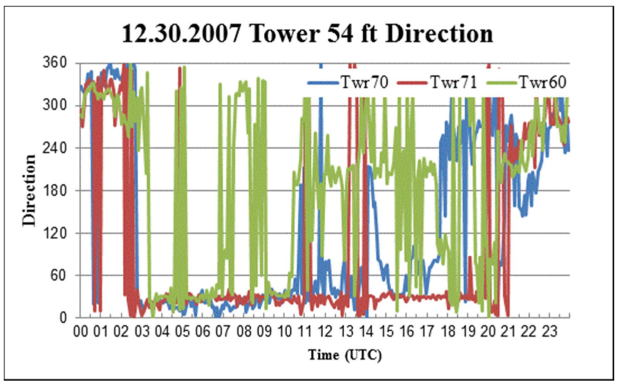


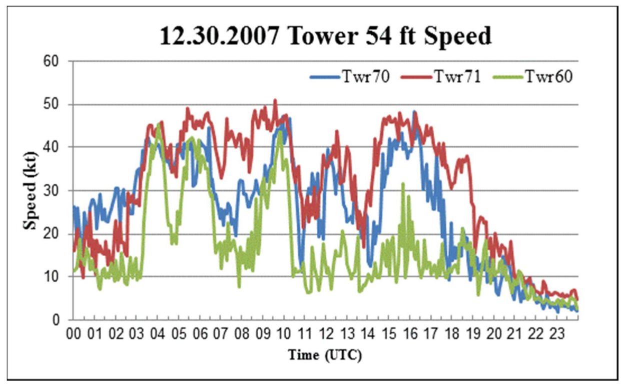
December 11, 2007



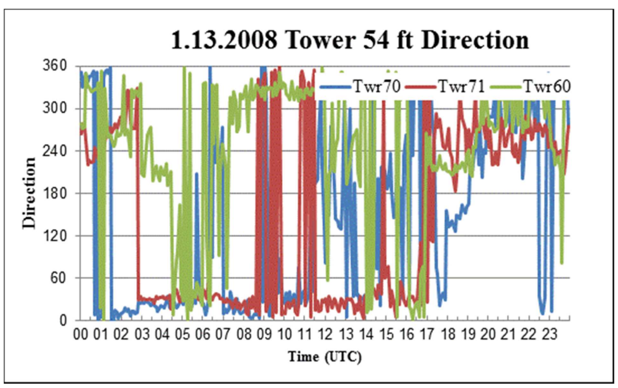


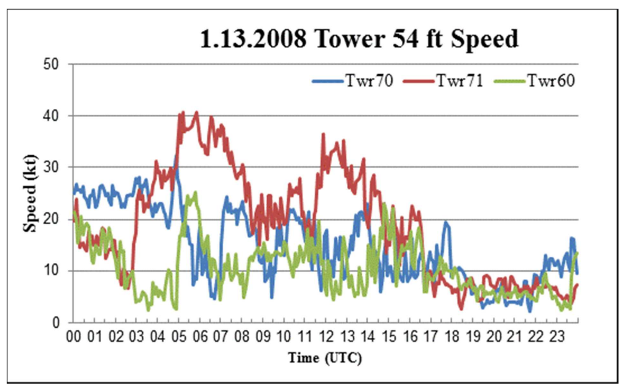
December 31, 2007



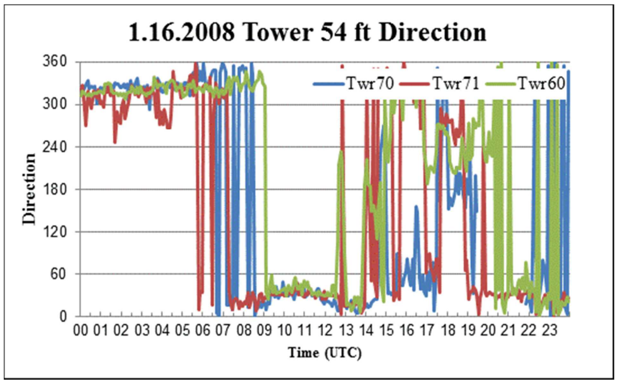


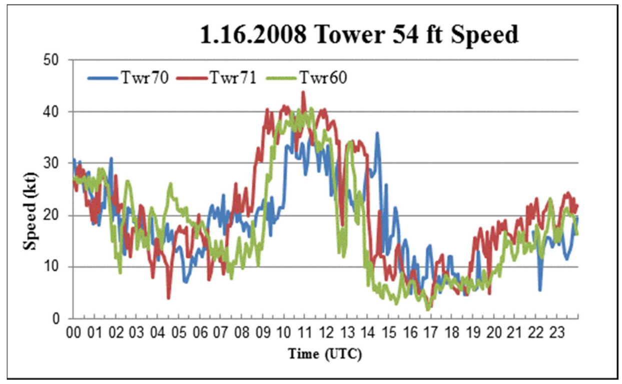
January 13, 2008



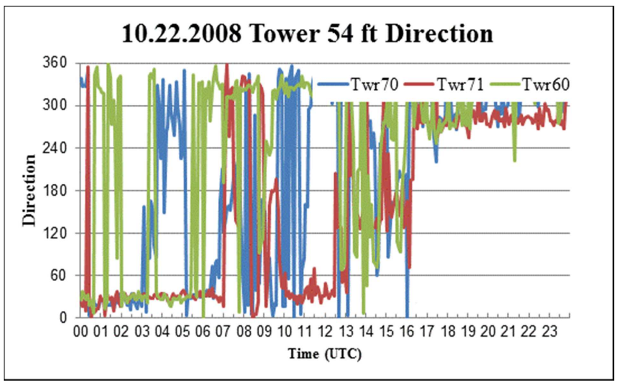


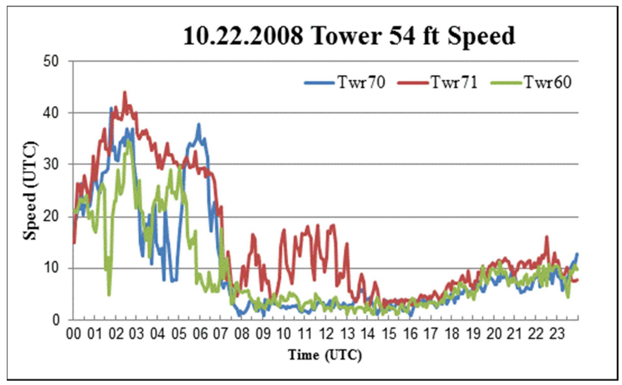
January 16, 2008



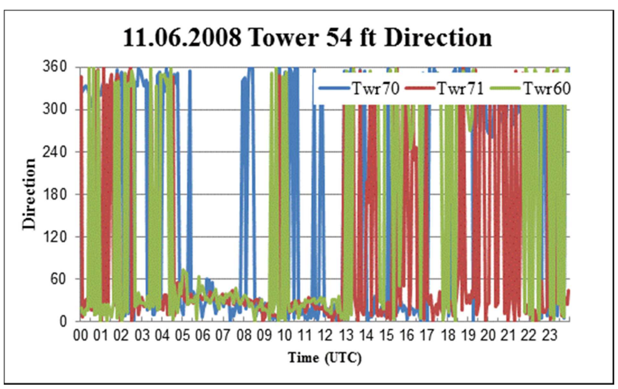


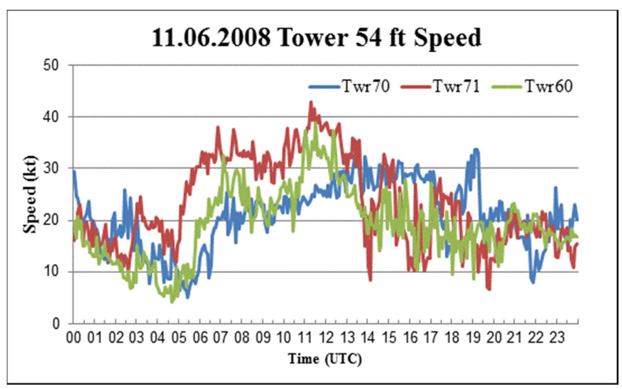
October 22, 2008



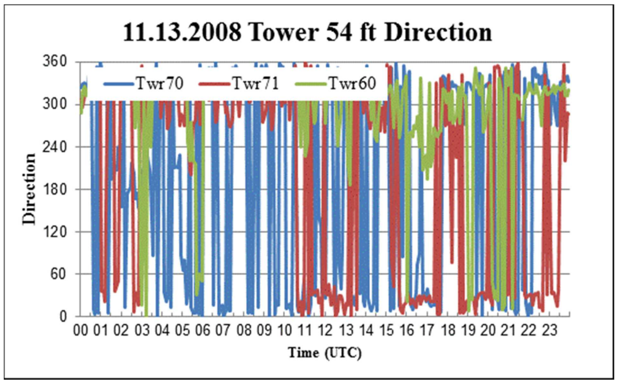


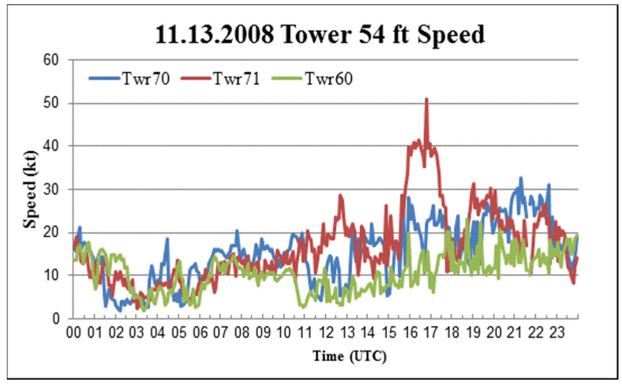
November 6, 2008



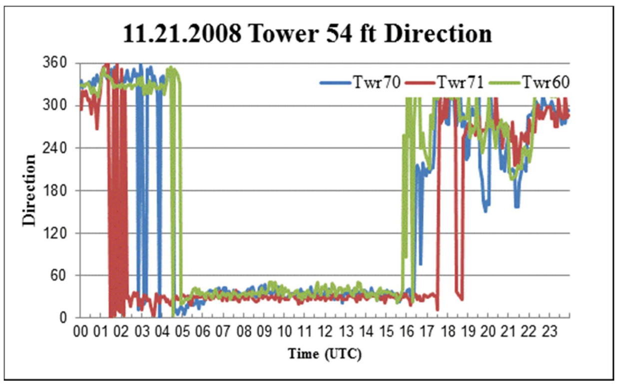


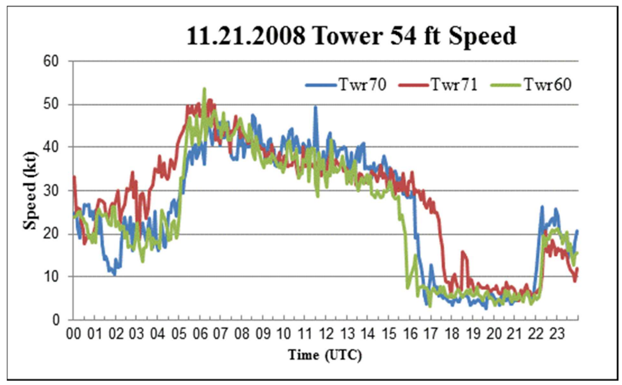
November 13, 2008



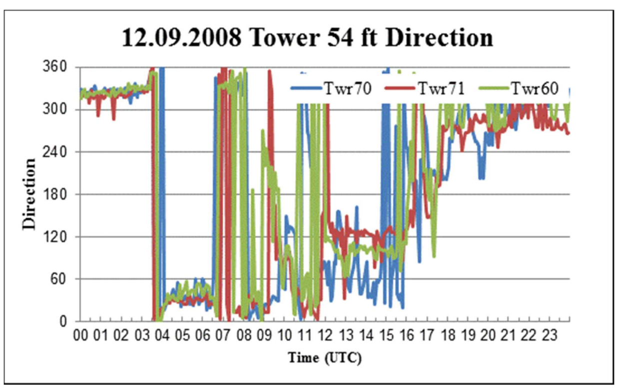


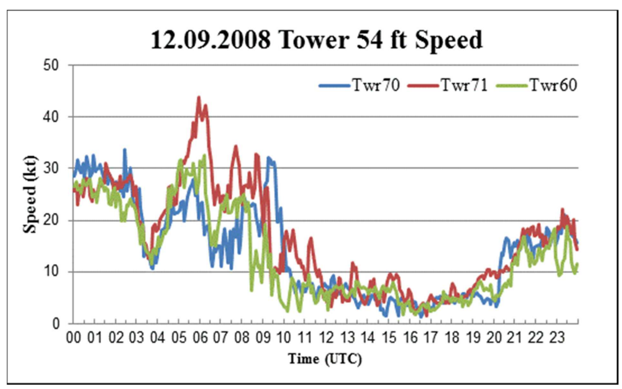
November 21, 2008



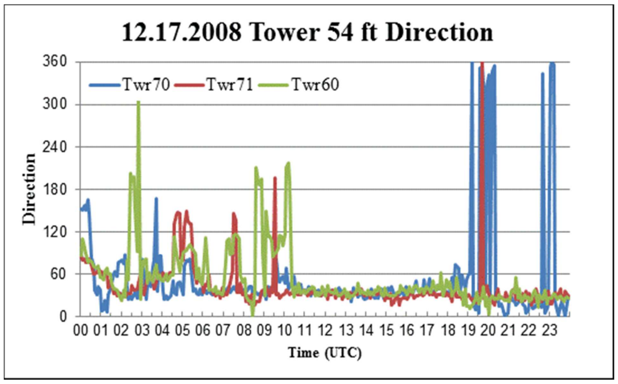


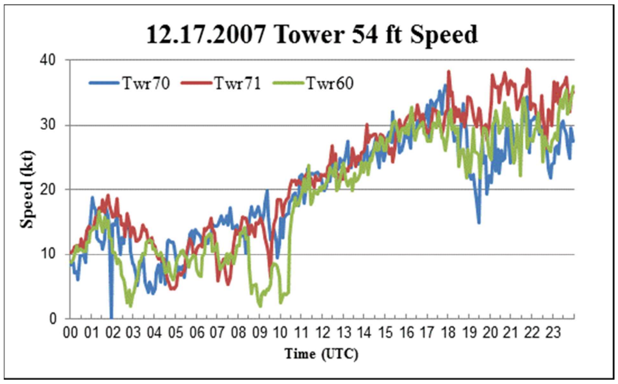
December 9, 2008



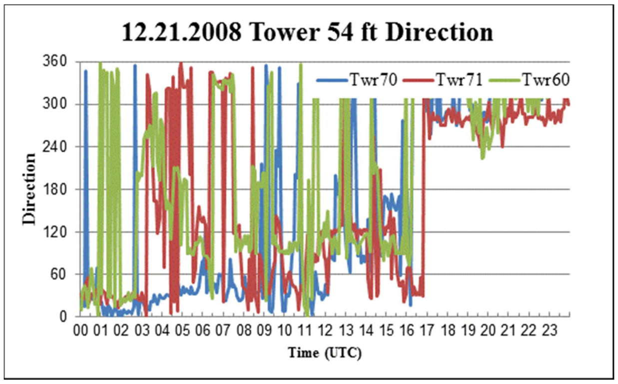


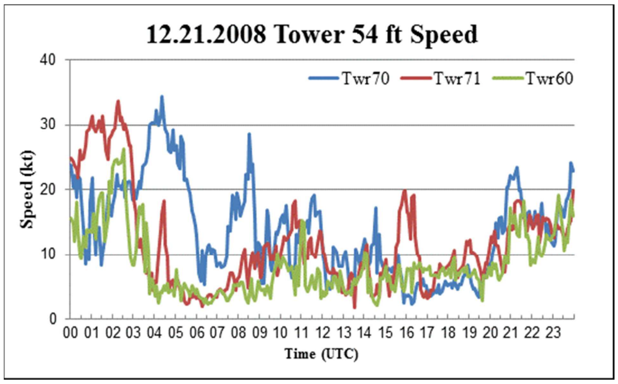
December 17, 2008



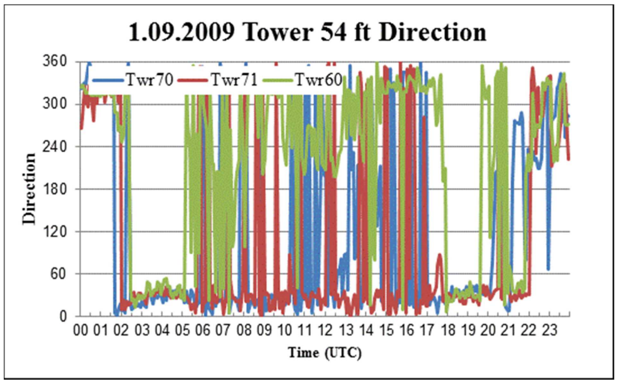


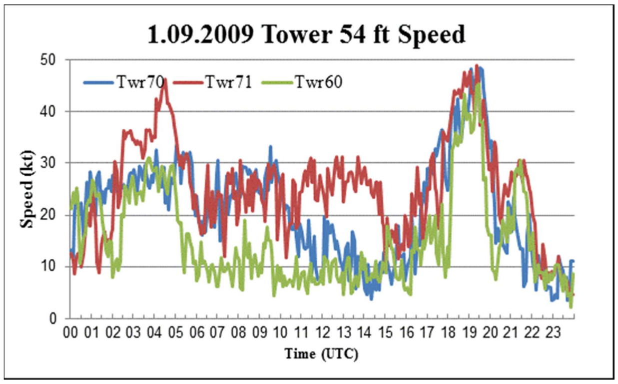
December 21, 2008



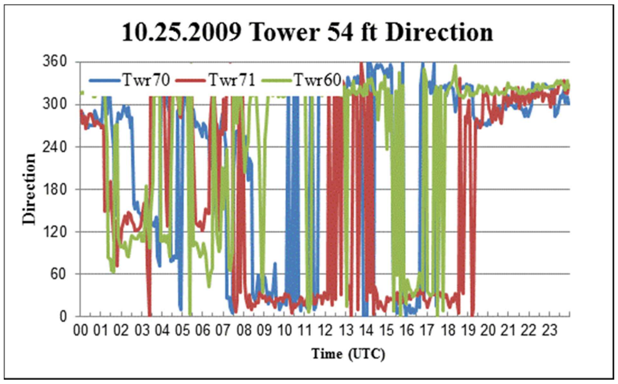


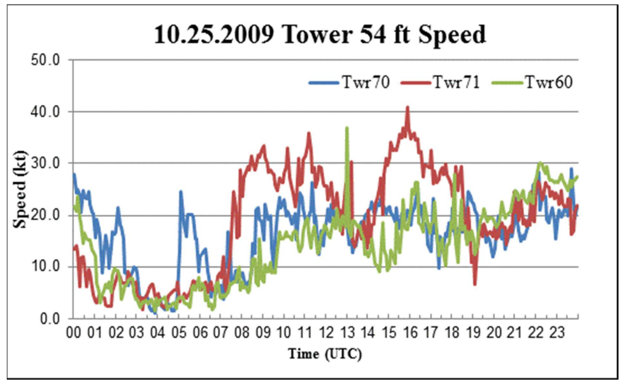
January 9, 2009



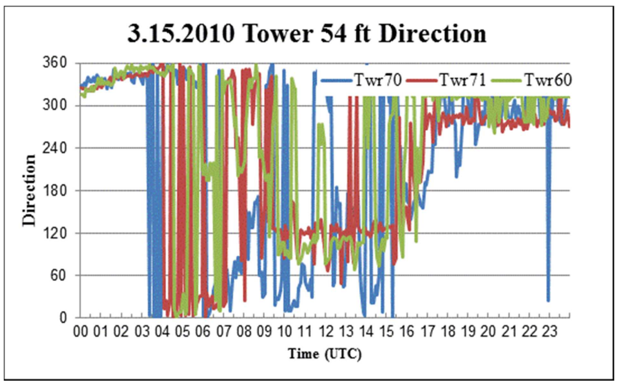


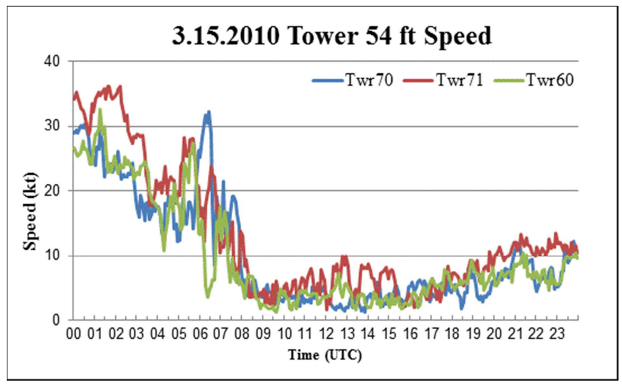
October 25, 2009



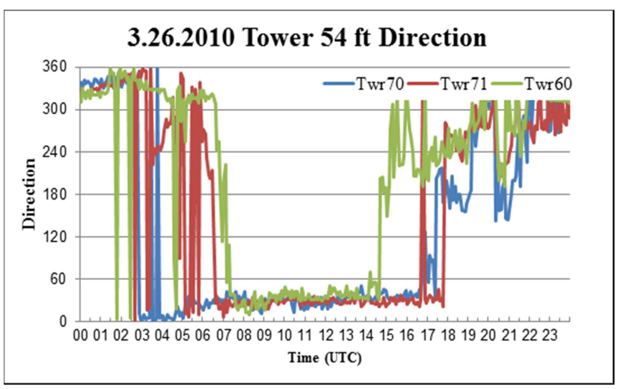


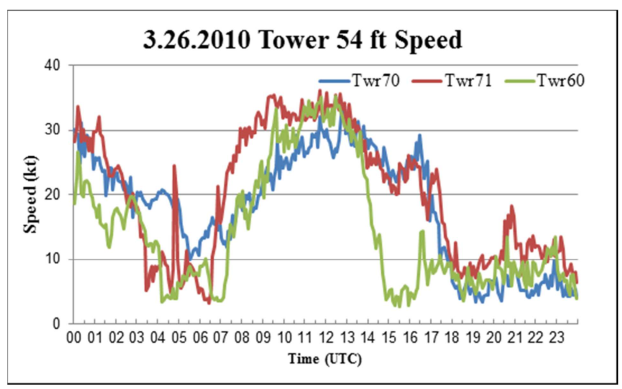
March 15, 2010





March 26, 2010





NOTICE