P2.7 ASSESSMENT OF THE IMPORTANCE OF CERTAIN WIND TOWERS IN THE CAPE CANAVERAL AFS/KENNEDY SPACE CENTER MESONET FOR PREDICTING CONVECTIVE WINDS

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1. Introduction

The USAF 45th Weather Squadron (45 WS) provides comprehensive weather support to America's space program at Cape Canaveral Air Force Station (CCAFS) and NASA Kennedy Space Center (KSC) (Harms et al. 1999) including weather warnings/watches/advisories for the weather safety of over 25,000 personnel, resource protection of over $20 billion of facilities, and preparation for space launch of multi-billion dollar payloads and vehicles. These facilities are in the east central Florida, in 'Lightning Alley' of the U.S. with many people working outdoors around the clock exposed to the weather. As a result, thunderstorms and their associated hazards are one of the largest operational concerns of the 45 WS, especially lightning and convective winds.

Convective wind warnings are the second most frequent type of weather advisory for this area issued by the 45 WS forecasters (Wheeler and Roeder 1996). The thresholds for the 45 WS convective wind warnings are ≥ 35 kt, ≥ 50 kt, and ≥ 60 kt, from surface to 300 ft, with lead-times of 30 min to 60 min. The 45 WS uses a mesonetwork of 44 weather towers over a 1,200 km^2 area to help predict convective winds among other weather and Range Safety requirements (Figure 1). Budgetary considerations are forcing the 45 WS to justify the cost-effectiveness of this mesonet, along with other weather sensors. This paper will provide a preliminary assessment of the potential impact of removing certain towers on convective wind forecasts by examining how much information they have provided in the past.

Plymouth State University researchers have been studying convective winds at CCAFS/KSC over the past three years (Dinon et al. 2008) and have built an updated warm season climatology on these winds (Cummings et al. 2007), based extensively on 11-years (1995-2005) of weather tower data from the mesonetwork. Other data used in this study included very detailed surface observations from the KTTS (the Shuttle Landing Facility) and other nearby surface METAR observations; KXMR radiosonde soundings; NCDC NEXRAD data; and satellite information.

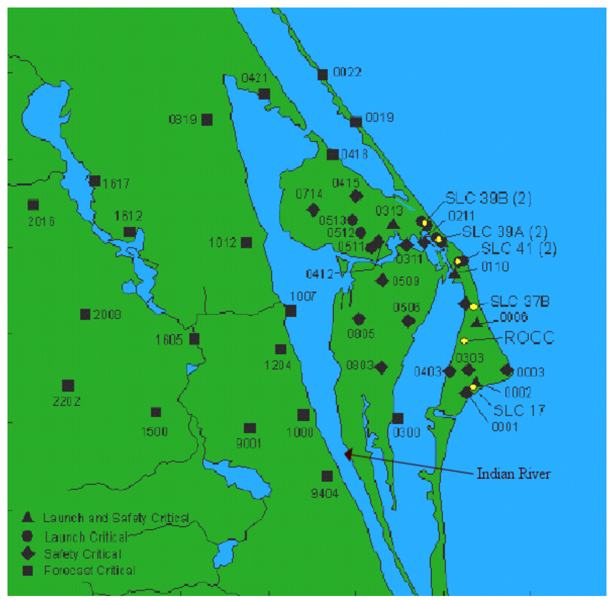

Figure 1. The CCAFS/KSC weather tower meso-network.

During the construction of the convective wind climatology, most of the far western tower sites were not included in the climatology, since they failed to meet the data threshold criterion that observations for a tower had to be available at least 70% of the time during the 11-year study period. Many of those towers provided information much less than 50% of the time, where most of the included towers greatly exceeded the 90% availability threshold. The western towers make up the majority of the towers considered for potential elimination.

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The climatological studies (Cummings et al. 2007) revealed that the majority of the convective events with warning-level criteria winds occurred during westerly flow conditions. Studying individual cell and cell group motions from NEXRAD base reflectivity data, Dinon et al. (2008) have also noted that most of these events have eastward moving cells and cell groups. Therefore, one might conclude that the western towers are important for getting early notice of approaching convective winds. However, Cummings et al. (2007) also showed that the towers just to the west of the Indian River had a significantly lower frequency of reports of warning-level peak winds, when compared to towers further east. The preliminary work of Dinon et al. (2008) may help to explain these seemingly contradictory results since they found that about 75% of the warning-level convective wind episodes are associated with collision events, such as such as cell mergers and outflow boundary (OFB)/sea breeze front (SBF) interactions that generally occurred further east.

The goal of this research is to estimate the value of the most costly to maintain weather towers in convective wind warnings in order to aid potential decision-making on which towers to keep or remove for future budget considerations. This study will evaluate the utility of those towers in convective wind warnings and only as independent information sources. The possible synergistic value of these towers with other data sources is not evaluated here.

2. Tower Removal Scenarios

We initially considered five scenarios for possible tower configurations:

1) keep all towers,
2) remove towers most costly to maintain (see Figure 2),
3) remove all towers west of the Indian River,
4) remove all towers west of the Indian River except those next to the Indian River,
5) remove only towers 0022 and 0019, or just 0022, or just 0019.

For the purposes of this study, we have only considered options 2 and 4. However, the results from evaluating those two scenarios directly relate to providing information on the other scenarios.

Note that the fourth scenario is very similar to the second scenario except that it keeps the very costly towers, 0022 and 0019, which reside on KSC property. It should also be noted that all of the towers under consideration for removal only report peak winds at the 54 feet elevation.

3. Tower data availability

We examined the availability of peak wind observations for the towers under consideration for removal during the entire 11-year (1995-2005) warm season (May-Sep) periods. Results are shown in Table 1. Recall that nearly all of the western towers identified for possible elimination had not previously been included in the Cummings et al. (2007) climatology for not meeting their 70% availability threshold. Tower 1612 was included in their study, but only for the months of May and August, when the data appeared to be more consistently available.

4. Contribution to convective wind forecasts

Next, we reviewed the contributions of the towers for all convective periods, recently refined by Dinon et al. (2008), which met or exceeded the minimum warning criteria (≥ 35 kt). As indicated in Table 2, there were 273 of these convective periods during the warm seasons of 1995-2005. These averaged to about 25 warning-level convective periods per season. Of the 273 warning-level events, 52 (about 5 per year) met or exceeded the higher criteria (≥ 50 kt) and 9 (about 1 per year) of those events met or exceeded the highest warning-level criteria (≥ 60 kt). For our analysis on potential tower contributions of wind forecasts, we did not consider the latter cases separately because of the low number of occurrences and since they were included in the lower category's statistics.

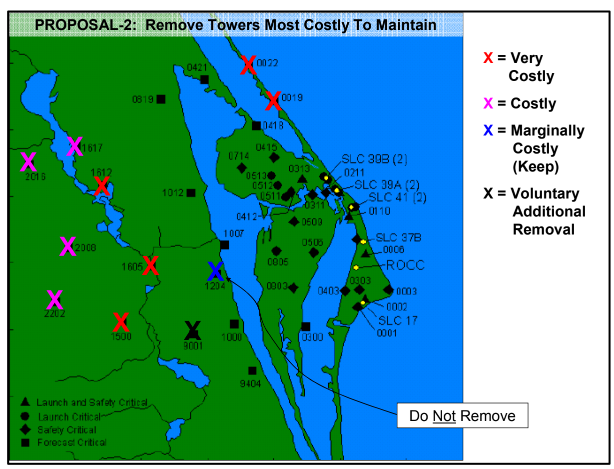

Figure 2. Towers classified by maintenance cost, which is primarily a function driving time from CCAFS, which is affected both by distance and accessibility in a swampy overgrown environment.

Table 1. Percentage of the time that the towers under consideration for removal provided data during all of the warm seasons of 1995-2005.

Tower ID	% Availability
0019	84.3
0022	81.9
1500	60.7
1605	49.8
1612	75.5
1617	42.7
2008	56.7
2016	31.1
2202	47.6
9001	64.2

Table 2. Frequency of categories of convective periods for May-September from 1995 through 2005 (Dinon et al. 2008).

QUANTITY	NUMBER	%
Total convective periods	773	100
Periods with winds ≥ 35 knots	273	35
Periods with winds ≥ 50 knots	52	7
Periods with winds ≥ 60 knots	9	1.2

We first examined 272 of the 273 warning-level events, omitting one, since it spanned two months, which was not handled well by our analysis software. For the ten identified towers, we looked at the period from 1-hour before to the start of the first observation in the mesonetwork meeting or exceeding warning-threshold criteria.

Table 3. Percent (%) frequency of the highest observation (if any) in a given wind speed category by tower for the 1-hour period prior to ≥ 35 Kt warning-level events.

Tower ID	Missing	< 20 knots	20-24 knots	25-29 knots	30-34 knots	35-39 knots	40-44 knots	45-49 knots	≥ 50 knots
0019	9.6	48.5	16.5	13.6	5.1	5.9	0.7	5.9	0.0
0022	8.8	44.5	18.4	14.3	5.9	5.1	1.5	5.1	0.4
1500	26.8	53.3	15.1	3.7	1.1	0.0	0.0	0.0	0.0
1605	46.3	30.9	14.3	5.9	0.7	1.1	0.7	1.1	0.0
1612	14.3	47.8	21.0	8.8	5.1	2.2	0.7	2.2	0.4
1617	44.1	32.4	12.1	6.6	1.1	2.6	0.4	2.6	0.0
2008	28.7	46.7	13.2	7.4	2.2	1.1	0.7	1.1	0.0
2016	58.5	25.7	8.1	4.8	1.5	0.4	0.4	0.4	0.0
2202	54.8	24.3	10.3	4.0	1.5	1.8	2.2	1.8	0.0
9001	24.3	65.4	6.6	3.3	0.0	0.4	0.0	0.4	0.0

Table 4. Average lead-time (minutes) for the events in Table 3 prior to ≥ 35 Kt warning events.

Tower ID	Missing	< 20 knots	20-24 knots	25-29 knots	30-34 knots	35-39 knots	40-44 knots	45-49 knots	≥ 50 knots
0019	N/A	33	20	19	20	0	0	0	0
0022	N/A	32	23	24	22	0	0	0	0
1500	N/A	32	23	24	22	0	0	0	0
1605	N/A	33	25	27	22	0	0	0	0
1612	N/A	33	24	22	31	0	0	0	0
1617	N/A	32	33	30	10	0	0	0	0
2008	N/A	33	32	24	30	0	0	0	0
2016	N/A	38	32	29	37	0	0	0	0
2202	N/A	39	30	32	27	0	0	0	0
9001	N/A	33	18	24	0	0	0	0	0

For these periods, we considered whether the data were missing or flagged as bad through previous quality control efforts (Lambert 2002; Loconto et al. 2006; Cummings et al. 2007; Dinon et al. 2008). We also stratified the reports based upon the highest wind category achieved and the corresponding time prior to the first reported warning level event. Categories used for this were less than 20 knots, 20-24 knots, 25-29 knots, 30-34 knots, 35-39 knots, 40-44 knots, 45-49 knots, and greater than or equal to 50 knots. These results are summarized in Tables 3 and 4.

From Table 3, there were few missing or bad observations for towers 0019 and 0022, as expected. However, the western towers (except for tower 1612) showed data shortcomings ranging from around 25% to nearly 60% of the time. When you add those percentages to the less than 20 knot reported values, the western tower results range from 54% at tower 1612 to 79% at tower 2202, indicating that for a majority of time these towers were not playing a significant role in anticipation of warning-level events.

Looking at the higher speed categories, one can also see that a very low percentage of occurrence at these ranges, indicating that the western towers only infrequently “telegraph” incoming warning-level events. The western towers also report very few warning-level events. On the other hand, towers 0019 and 0022 seem to play a more significant role and their results are very similar to one another. This supports the alternative idea of keeping only one of those two towers.

Tables 5 and 6 provide similar results for the stronger peak wind events (≥ 50 kt). If we consider the 35-49 knot range of winds in Table 5 as precursor conditions for anticipating stronger convective winds, which may move towards the launch complex, the eastern two towers again seem to provide the greatest amount of useful information. However, the eastern towers provide less lead time (Table 6). However, the western towers had winds in this range only about 2% to nearly 10% (tower 1612) of the time, but did have average lead times of generally more than 30 minutes prior to initiation (see Table 6). This indicates that these western towers may provide a forecaster some information that could be used for anticipating these events. To put these results in perspective, this only equates to at most five events over a 10-year period for the western towers and the other towers just to the west of the Indian River may provide sufficient information to cover most of these situations.

Table 5. Percent (%) frequency of the highest observation (if any) in a given wind speed category by tower for the 1-hour period prior to ≥ 50 Kt warning-level events.

Tower ID	Missing	< 20 knots	20-24 knots	25-29 knots	30-34 knots	35-39 knots	40-44 knots	45-49 knots	≥ 50 knots
0019	9.6	36.5	9.6	21.2	3.8	5.8	3.8	5.8	5.8
0022	5.8	32.7	13.5	13.5	7.7	5.8	3.8	5.8	13.5
1500	26.9	46.2	17.3	7.7	0.0	0.0	1.9	0.0	0.0
1605	36.5	27.8	13.5	15.4	0.0	3.8	0.0	3.8	1.9
1612	15.4	38.5	21.2	7.7	11.5	3.8	1.9	3.8	0.0
1617	38.5	26.9	13.5	11.5	3.8	3.8	0.0	3.8	1.9
2008	32.7	36.5	17.3	9.6	1.9	0.0	1.9	0.0	0.0
2016	61.5	17.13	7.7	7.7	1.9	3.8	0.0	3.8	0.0
2202	57.7	21.2	7.7	5.8	0	1.9	3.8	1.9	0.0
9001	23.1	53.8	7.7	11.5	1.9	1.9	0.0	1.9	0.0

5. Discussion

Cummings et al. (2007) showed the importance of the various thunderstorm flow regimes as described by Lericos et al. (2002) in the strength of convective periods. Their results indicated that westerly flow regimes are most often associated with stronger convective wind episodes. Our summaries for the warning criteria events, which are shown in Tables 7 and 8, support this conclusion with 200 of the 273 (or 73%) warning level-events occurring during westerly flow regimes (SW-2, SW-1, and NW) with the other events associated with alternative flow regimes. For the stronger (≥ 50 kt) events, nearly 87% were associated with one of the three westerly flow regimes with a similar distribution between the three categories. Only seven of the 52 strong events were associated with the alternative regimes.

Dinon et al. (2008) have also reviewed radar echo and echo group movements for a significant number of these periods and their preliminary results show that most warning-level convective periods are associated with eastward moving echoes and echo groups. However, our results in the previous section seem to show that there is little correlation with near warning-level or warning-level winds at the westernmost towers, transitioning eastward with the cells or cell groups.

Table 6. Average lead-time (minutes) for the events in Table 5 prior to ≥ 50 Kt warning events.

Tower ID	Missing	< 20 knots	20-24 knots	25-29 knots	30-34 knots	35-39 knots	40-44 knots	45-49 knots	≥ 50 knots
0019	N/A	37	11	25	17	23	20	23	0
0022	N/A	25	28	28	33	16	15	16	0
1500	N/A	32	32	30	0	0	45	0	0
1605	N/A	43	22	25	0	47	0	47	0
1612	N/A	33	21	42	37	27	35	27	0
1617	N/A	36	29	33	35	30	0	30	0
2008	N/A	34	30	37	40	0	40	0	0
2016	N/A	29	27	48	55	32	0	32	0
2202	N/A	40	13	48	0	45	45	45	0
9001	N/A	32	8	27	35	20	0	20	0

Table 7. Number of ≥ 35 knots convective periods versus thunderstorm flow regimes. Total = 273 warning level convective periods.

Flow Regime	Number
SW-1	60
SW-2	114
NW	26
SE	33
NE	8
Other	25
Missing	7

Table 8. Number of ≥ 50 knots convective periods versus thunderstorm flow regimes. Total = 52 strong convective periods.

Flow Regime	Number
SW-1	14
SW-2	22
NW	9
SE	2
NE	0
Other	3
Missing	2

These seemingly contradictory results can be explained by the other conclusions of Dinon et al. (2008) that indicate that most of the warning level events were triggered by interactions of eastward moving cells/cell groups with other cells/cell groups and/or their associated OFBs and/or SBFs, which tended to occur further to the east and closer to the coast. This also calls into question the importance of the westernmost towers in providing meaningful information to assist with issuing convective wind warnings.

6. Summary

In this research, we examined the climatology of towers in the CCAFS/KSC mesonetwork that are under consideration for elimination. Based on the results of reviewing the observations for warning-level convective periods over an 11-year period (1995-2005), we conclude that the eight westernmost towers provide little useful information for anticipating convective winds, even though stronger wind events are associated with westerly flow regimes and eastward moving cells/cell groups. This conclusion was based on data availability and the low frequency of events indicating the presence of precursor winds that transition eastward. It was also supported by the work of Dinon et al. (2008) that showed the importance of OBF/SBF interactions that generally occur further east than the westernmost towers. Radar would appear to be the best tool for anticipating these interactions.

The northern towers of 0019 and 0022, on the beach at the south end of Mosquito Lagoon, do show significantly more contributions for providing significant information to help with the convective wind problem. They certainly fall within the region most frequently affected by OFB and SBF interactions. However, they may often be on the tail end of the event and may not in the best place for anticipating warning-level events. In any case, the data for these towers indicate that they both catch events at nearly identical times. Therefore, we conclude that only one of those towers is needed to adequately cover that region.

It is important to note that this analysis only considered the weather towers under consideration for removal as independent data sources. The utility of these towers in synergy with other data sources can be important, but exceeded the scope of this project.

More detailed data, analyses, and many of the references for these studies are available online at the following URL:

http://vortex.plymouth.edu/conv_winds/

7. Acknowledgements

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7. References

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