8.21 ITWS AND ITWS/LLWAS-NE RUNWAY ALERT PERFORMANCE AT DALLAS-FT. WORTH AND ORLANDO *

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1. INTRODUCTION

The Integrated Terminal Weather System (ITWS) provides runway-orientated wind shear and microburst alerts to enhance the safety of flight operations at major U.S. airports. The alerts are reported as either losses or gains of airspeed, representing performance decreasing or performance increasing wind shears. The performance of ITWS as a stand-alone system has been thoroughly documented in previous research. During the 1994 ITWS Demonstration and Validation testing, the probability of detection (POD) and probability of false alarm (PFA) at Memphis (MEM) and Orlando (MCO) for all loss events were > 90 and < 5 percent, respectively, based on single-Doppler truth (Klingle-Wilson, 1995).

The Low-Level Windshear Alert System–Network Expansion (LLWAS-NE) also generates runway alerts in the same format as ITWS (Cole and Todd, 1993). LLWAS-NE is not subject to viewing angle problems such as those experienced by single-Doppler radar. However, false alarms caused by LLWAS-NE sensor failures at some Terminal Doppler Weather Radar (TDWR) sites have reduced user confidence in the system. At those ITWS sites with an LLWAS-NE, the ITWS alerts derived from TDWR data will be integrated with LLWAS-NE alerts, hopefully to improve the performance. The ITWS integration algorithm is identical to the TDWR version, with the exception of a few adaptable parameter changes. The ITWS/LLWAS-NE parameters were modified slightly to account for ITWS and TDWR algorithm performance differences.

In this paper, the performance of a stand-alone ITWS and the ITWS/LLWAS-NE integration algorithm at the MCO and Dallas-Ft. Worth (DFW) demonstration sites will be discussed. This assessment is considered unique since the radar and anemometer data were combined to create the runway truth. The focus of this research is to identify the shortcomings of both systems in order to recommend modifications that will improve the integration algorithm performance.

2. TRUTHING METHODOLOGY

The truth for this evaluation was generated by human analysts using both radar and anemometer data. Truth consisted of the runway-oriented convergence or divergence based on the radar velocity field and surface wind data for every active Area Noted for Attention (ARENA). A minimum truth-value of 10 knots was used to provide a 5-knot buffer below the minimum alert value. This methodology was consistent with previous scoring exercises for ground-based wind shear detection systems (Dasey, et al., 1996). In the case of DFW, the radar data produced every five minutes from the Dallas Love (DAL) TDWR were used to supplement the truth in case of viewing angle or radar data quality problems. While this did not mimic dual-Doppler truth used in previous scoring exercises, it afforded the opportunity to expand on the single-Doppler truth used in the 1994 ITWS evaluation. The anemometer data had to be scrutinized carefully in both a spatial and temporal context to filter out wind differences caused by faulty sensors or sheltering. The combination of multiple radars and anemometers should allow for a more accurate truth database devoid of viewing angle and data quality problems.

3. PERFORMANCE RESULTS

The scoring metrics reported herein are POD, PFA, probability of underwarning (PU), and probability of overwarning (POW). The POD is calculated by the number of valid detections divided by the valid detections plus the misses. The PFA is calculated by dividing the number of false detections from the total number of detections (valid + false). An underwarning is defined as a wind shear strength alert (15-25 knots) for a microburst event (30+ knots), while a microburst alert for a wind shear strength event constitutes overwarning. These two statistics were used to document the accuracy of the alert intensities reported by each system. An alert was

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considered valid if it was associated with a minimum loss value of 10 knots. The DFW performance values are shown in Table 1, while the MCO results are listed in Table 2. Overall, there were ~ 1800 and 1400 truth events on a minute-by-minute basis in the DFW and MCO database, respectively. For this study, a loss event was defined as 10-15 knots, while a wind shear (WS) event was categorized as 20-25.

Table 1. DFW Runway Alert Performance

	ITWS			ITWS/LLWAS-NE		
	Loss	WS	MB	Loss	WS	MB
POD	.70	.81	.96	.78	.84	.97
PFA		.07	.02		.14	.12
PU	.45			.41		
POW	.18			.19		

Table 2. MCO Runway Alert Performance

	ITWS			ITWS/LLWAS-NE		
	Loss	WS	MB	Loss	WS	MB
POD	.88	.96	.99	.89	.95	1.0
PFA		.02	0		.05	.04
PU	.12			.12		
POW	.15			.18		

A comparison of the results shows that both ITWS and the integration algorithm performed well for microburst (MB) strength events at both sites, i.e., POD of > 95 percent. In terms of the MB PFA, the addition of LLWAS-NE alerts raised the value significantly at DFW, but not MCO. By comparison, the POD for WS and loss events was considerably different between the two sites. At MCO, the lowest POD was for the ITWS loss category, i.e., 88 percent. This was in stark contrast to the DFW performance, which peaked at 84 percent for integrated WS events. The POD for ITWS and integrated loss events was only 70 and 78 percent, respectively. While there were definitely lower VIL features such as gravity waves and divergence behind the gust front in the DFW database, LLWAS-NE essentially did little in regards to detecting these events. At both sites, the PFA for WS events doubled when integration was performed. The PU at DFW for both the ITWS and integration algorithms was three to four times higher than that at MCO. In contrast, the POW was similar at each site, i.e., < 20 percent.

4. DISCUSSION OF FAILURE MECHANISMS

In this section, we will delve into the failure mechanisms that have been identified for the ITWS and LLWAS-NE systems. It is crucial to classify the type/frequency of failure modes in order to recommend potential improvements to these algorithms.

4.1 LLWAS-NE Failure Mechanisms

The three distinct types of LLWAS-NE failure modes based on the DFW and MCO results are sheltering, sensor failures, and overly-conservative parameter settings. An analysis of the DFW data for false alarms and overwarning events showed the frequency caused by conservative parameter settings and sensor failures was almost identical, i.e., 54 versus 46 percent. We do not have any detailed statistics on the frequency of sheltering, but it is not considered to be a major issue at this time. An example of each problem will be shown from data collected at the ITWS demonstration sites.

Figure 1 illustrates sensor sheltering during a DFW event. The image has been magnified to encompass the runways (rectangles) and LLWAS-NE stations in the vicinity of the problem. The wind arrows point in the direction the wind is blowing, while the speed (knots) is shown at the base of the arrow. In this case, there is a fairly persistent northwesterly wind evident across the network due to an earlier cold front passage. Evidence of

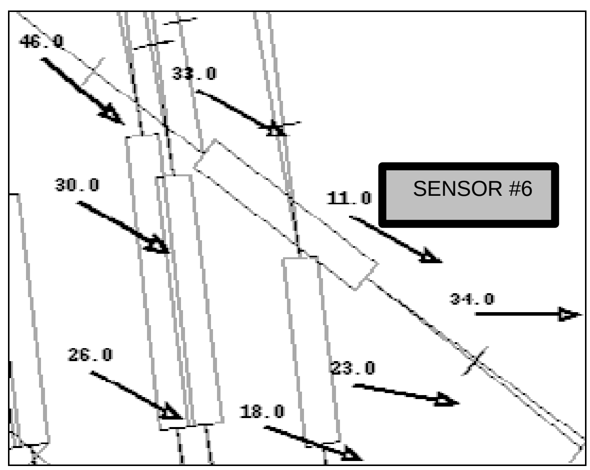

Figure 1. An example of sheltering from DFW.

sheltering is indicated by sensor #6, which reports the wind as being 10-20 knots lower than the surrounding sensors. The wind speed difference between this sensor and surrounding stations was sufficient to produce false LLWAS gain and loss alerts on the runway. The sensor southeast of #6 is also showing a directional bias in comparison to the network.

The second data quality issue with LLWAS-NE is a sensor/hardware component failure (Meyer, et al., 1999). An example of this problem from MCO is shown in Figure 2. In this case, there is a microburst outflow impacting the network. At this time, sensor #5 is reporting a 74-knot wind, while the maximum from any other station is 29 knots.

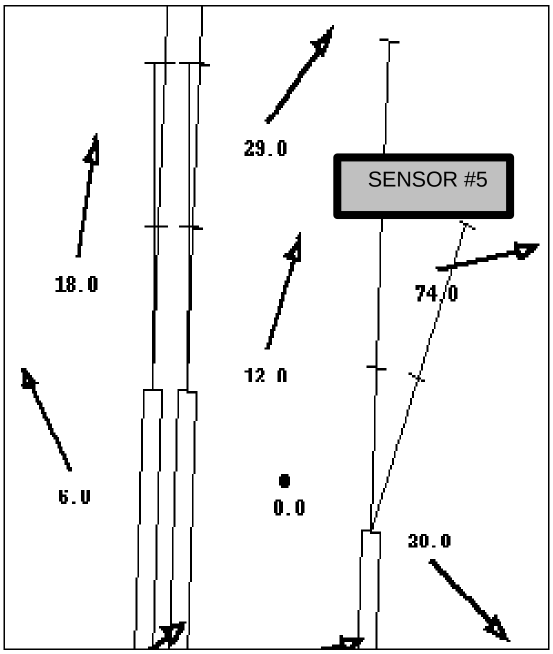

Figure 2. An example of overspeeding from MCO.

The radar data in this case only showed a maximum differential velocity of 35 knots in this locale. Since the TDWR at MCO is located south of the runways, the wind at sensor #5 would be perpendicular to the radar beam. Thus, it could be that asymmetry played a role in this discrepancy. This theory was rebuked based on anan analysis of the time-series plot from this station (Figure 3), which showed an abnormal spike in the wind speed. Also, this sensor consistently over-reported the wind speed during the time period in question. This type of detailed temporal and spatial analysis is required to determine the accuracy of the data portrayed by the anemometers.

The final factor that contributes to LLWAS-NE overwarning is the overly-conservative parameter set used in generating alerts. LLWAS-NE uses a series of station pairs associated with each ARENA to construct the triangles/edges required to detect convergence and divergence. The edge length between pairs is allowed to be as large as 4.5 km to account for sensor outages. An edge length of this magnitude allows LLWAS-NE to compute losses and gains on ARENAs with little or no actual wind shear. An example from DFW is shown in Figure 4. In this case, there is a wind shear event impacting the network. The strongest shear is confined to the runways in close proximity to #3, which is reporting a 23-knot southwest wind. Based on the conservative edge setting, sensor #16 is associated with #3 for alerting purposes. The wind differential between these two stations (32 knots) contributes to a microburst alert on the westernmost runway. In actuality, the loss across this corridor was about 15 knots according to anemometer and radar data. The most critical problem we have discovered with the overly-conservative triangles/edges is that microburst alerts can be generated on one end of a runway when the event is located on the opposite end. This would essentially close the runway corridor for any arrival or departure operations.

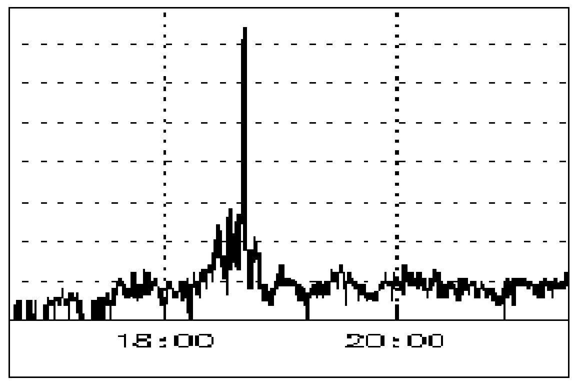

Figure 3. Time-series plot of wind speed versus time for LLWAS-NE station #5 on 990514. The horizontal dashed lines each represent 10 knots.

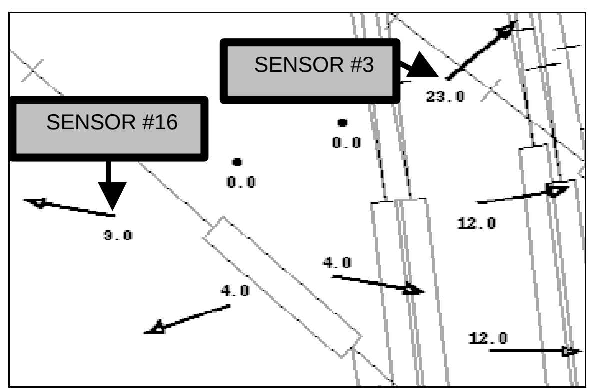

Figure 4. An example of overly conservative triangles and edges from DFW.

4.2 ITWS Failure Mechanisms

The radar-based failure modes can be grouped into the following categories: data quality errors, radar viewing angle/altitude coverage issues, and algorithm deficiencies. The primary data quality problems that impacted ITWS microburst detection performance were weather removal by the clutter polygons, noisy velocities, and low Vertically Integrated Liquid Water (VIL) values due to radome attenuation. Algorithm deficiencies were caused by an underestimation of the velocity differential or a deficiency in the flight-path shear integration technique (Klingle-Wilson, 1995). While the shear integration algorithm typically produces favorable results in terms of reducing overwarning, it can also occasionally cause the underestimation or removal of valid events.

Due to time constraints, we were not able to determine the frequency of radar-based failures. However, each of the issues will be discussed briefly to provide a synopsis of the ITWS failure mechanisms. The TDWR system employs clutter maps and polygons to help mitigate false alarms caused by stationary ground targets. If these maps are too aggressive, they can significantly degrade the performance of the wind shear detection algorithms (Isaminger, et al., 1996). During the early 1998 DFW evaluation period, the clutter polygons over the airport were much too aggressive and accounted for significant algorithm performance degradation. While the current maps have served to reduce the degradation, they can still cause problems depending on the reflectivity intensity and location. A more detailed study is required to determine the overall impact of clutter polygons on algorithm performance.

Another issue that was recently discovered at DFW concerns the removal of valid divergent detections due to attenuation-induced low VIL values. Radome attenuation can occur when a line of strong thunderstorms impacts the TDWR site. Signal loss due to water coating on the dome results in lower reflectivity and VIL values across the entire coverage region. While this problem is typically short-lived, it can cause microburst-strength events to go undetected. We are investigating lowering the VIL threshold at all ITWS sites to help mitigate this problem. A lower VIL value would also increase the detection rate for non-convective induced wind shear phenomena like gravity waves. This parameter adjustment will ultimately require a detailed study to determine the trade-off between POD and PFA.

The other two issues that can cause missed events or underwarning are deficiencies in the velocity loss calculation and shear integration failures. The ITWS MB algorithm uses a shear-based approach to estimate the velocity loss (Dasey, et al., 1996) and this typically results in a 3-6 knot underestimation. Events near the wind shear or microburst threshold are especially susceptible to this problem. The main area of concern with shear integration is the removal of events located near the edge/side of the ARENA. This scenario generally ensues when the detection shape does an inadequate job of covering the shear region.

5. DFW CASE STUDY

A case study from DFW on 990528 will be shown to illustrate the advantage and disadvantage of integrating (Figure 5). The data on the left are from DFW, while the data on the right are from DAL. The event is outlined by the white rectangle on the DAL image and the white detection shape in the DFW panel. Since DAL is located closer to the event, it is able to detect the stronger velocities (40-45 knots) down near the surface. DFW, on the other hand, is underestimating the strongest velocities due to beam overshooting and only reports a wind shear strength (25 knot) event. An examination of the alerts in Table 3 shows the benefit of integration. ITWS is only reporting a wind shear strength event on 18RA and 13LA, while the integrated alert values for these runways are 35 and 30 knots, respectively, because LLWAS-NE detected the outflow better. There is also a weaker event located over Runway 13RA/RD that is not detected at all by ITWS (enclosed by white rectangle in the DFW image). While LLWAS-NE is overwarning in terms of the actual intensity, at least there is an alert for this event. Integration has correctly reduced the intensity to wind shear strength since only one system detected it. Finally, one of the negative aspects to integration is also shown in this example. LLWAS-NE produced a 45 knot MB alert on Runway 18RD, even though the velocity data do not support this. This is a case where the conservative alerting strategy employed by LLWAS-NE can produce false alerts or overwarning on the opposite end of an ARENA.

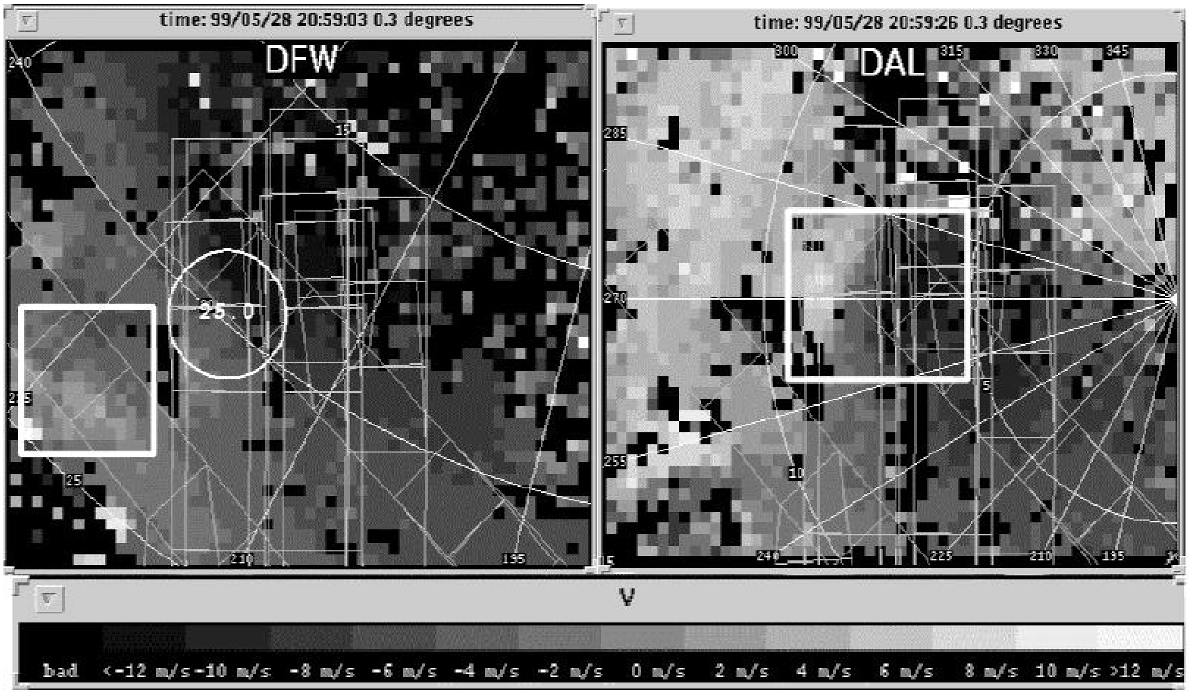

Figure 5. This image is a comparison of the DAL and DFW velocity fields for several outflows over the DFW ARENAs (white rectangles) on 990528.

Table 3. 990528 DFW ARENA Alerts

RUNWAY	ITWS	LLWAS-NE	INTEGRATED
13LA	25-	35-	30-
17RA	20-	0	20-
13RA	0	30-	25-
13RD	0	20-	20-
18RA	25-	45-	35-
18RD	0	45-	45-
18LA	25-	0	25-

6. SUMMARY/RECOMMENDATIONS

The performance of the ITWS and ITWS/LLWAS-NE integration algorithms at MCO and DFW were reported herein. This analysis showed that both algorithms performed better at MCO. While the POD for microburst events at each site was excellent, the wind shear detection performance at DFW was lacking, even with integration. Also, the inclusion of LLWAS alerts doubled both the wind shear and microburst PFA at each site. Finally, the DFW results exhibited a significant amount of underwarning primarily due to ITWS MB algorithm failures such as underestimating the velocity loss and shear integration. This research has clearly shown that both ITWS and LLWAS-NE were responsible for the performance degradation.

The following recommendations, if implemented, should provide more accurate runway alerts from these two systems.

- Investigate modifications to the LLWAS-NE edge length parameter, especially when integrating. The conservative parameters could still be used if the TDWR was not operational.
- Install a minimal product-level VIL threshold to downgrade clear air LLWAS-NE microburst alarms to wind shear alerts.
- Modify the ITWS microburst parameter set to allow a lower VIL threshold to account for dome attenuation. This would also involve additional parameter changes to mitigate false alarms.
- Ensure that LLWAS-NE sensor failures are adequately monitored.
- Investigate changing parameters used for the ITWS loss calculation.

7. REFERENCES

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