10.13 OPERATIONAL EXPERIENCE WITH TDWR/LLWAS-NE INTEGRATION AT THE DALLAS,TX INTERNATIONAL AIRPORT (DFW)

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1. INTRODUCTION†

At nine major airports, both the Terminal Doppler Weather Radar (TDWR) and Network Extension of the Low-Level Wind shear Advisory System (LLWAS-NE) data will be used to detect and warn Air Traffic Control (ATC) of dangerous wind shear conditions. The integration of wind shear alerts from the two systems is currently being carried out by the TDWR software and will be accomplished by Integrated Terminal Weather System (ITWS) software when the ITWS is installed at these airports.

Previous studies of the performance of the TDWR/LLWAS-NE integrated system were carried out at Denver, CO, Dallas, and Orlando, FL (see, e.g., [Isaminger, et. al 2000]). Additionally, there have been recent concerns about false alarms with the LLWAS-NE [Fahey, 2000].

In this study, we examine the performance of the integrated system at Dallas-Ft. Worth International Airport (DFW) over a 6-month period in 2000 with particular emphasis on integrated wind shear alerts produced during a number of cases where the TDWR had difficulty making detections due to:

1. radially aligned gust fronts over DFW,
2. radially aligned divergent features, divergence behind gust fronts and divergence embedded within gravity waves, and/or
3. TDWR radome attenuation or excessively aggressive clutter residue editing.

DFW is a particularly good airport for such a study because there is an additional TDWR [for Dallas Love airport (DAL)] located in close proximity to DFW and situated in such a way that it provides a very good viewing angle for wind shear events that may not be well characterized by the DFW TDWR radial velocity data. DFW is also an ITWS demonstration system test site with trained meteorologists who review the wind shear detection performance after all convective weather events at DFW.

2. DFW WIND SHEAR SENSOR OVERVIEW

2.1 LLWAS-NE

The LLWAS-NE at the DFW airport consists of 19 anemometers on 100 feet towers, strategically positioned near the airport's runways in order to provide wind shear alert coverage for the DFW Areas Noted for Attention (ARENAS). Depending on the location of wind shear events, relative to the LLWAS-NE sensors, wind shear alerts are determined by a triangulation estimate of three sensors or an edge using two sensors. In either case, the validity of wind shear alerts produced by the LLWAS-NE is dependent are several factors. These include sheltering, sensor failure, overly conservative parameter settings and noise produced from gusty winds [Isaminger, et. al, 2000]. At DFW, sheltering is an issue for only one sensor.

2.2 TDWR Sensors

The DFW ITWS has two TDWRs: the DFW TDWR sited 17 km north-northeast of the DFW airport, and the Dallas Love (DAL) TDWR located 7.8 km east of the DFW airport. Although the Love TDWR is not currently used to provide wind shear warnings at DFW, the data from the DAL radar (which has a different viewing angle of the DFW runways) can be used to validate the DFW integrated wind shear warnings.

3. DEGRADATION OF GUST FRONT DETECTIONS

We have found that the TDWR radial velocity convergence signature can disappear as gust fronts propagate over the DFW radar site. Unfortunately, a significant percentage of cold fronts that track through the DFW area are orientated from southwest-to-northeast, leading to radial alignment problems as the front approaches the airport. A study of 60 gust front events that impacted DFW airport between January 1st, 2000 and July 31st, 2000 showed that 35% were so aligned. Figure 1 illustrates a typical missed TDWR-only detection.

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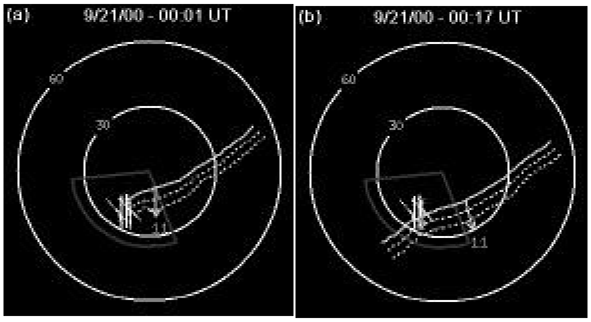

Figure 1. Detection of a strong cold front (solid gray line) crossing the DFW airport. The detection became degraded (a) when the westernmost portion of the front became radially aligned with the DFW TDWR. Later, the detection was reestablished (b) because the front was no longer radially aligned with the radar.

Forty one significant gust front events were selected for analysis based on the following criteria: the TDWR-based gust front detection algorithm made a valid detection over the DFW ARENAS, gain alerts were generated by the LLWAS-NE, or a wind shift caused a runway reconfiguration. Of the 41 events examined, the TDWR-based detection was partially or completely degraded over the DFW runways for 24 events. The majority of the TDWR-only detection performance degradation was caused by gust front radial alignment. Of these 24 events, the LLWAS-NE generated alerts at DFW for 13 of them. The remaining 11 were characterized by wind shifts, which although of interest to traffic managers were not strong enough to generate wind shear alerts on the ARENAS.

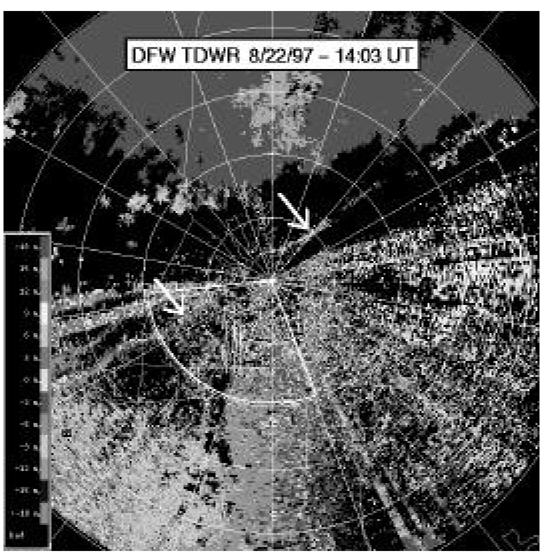

Figure 2. DFW TDWR velocity data showing the location of a gust front (white arrows) in a data void region.

A secondary and less frequent detection problem, illustrated in figure 2, occurs when velocity data is flagged due to corruption of first-trip returns by out-of-trip weather. Missed TDWR detections due to out-of-trip weather, which were picked up by the LLWAS-NE, were observed on three occasions during the period of the study.

4. LINE DIVERGENCE AND DIVERGENCE BEHIND GUST FRONTS

Occasionally, the DFW airport is impacted by line divergence wind shear events[1]. These line divergences arise from three different weather phenomena: 1) a line of storms producing multiple microbursts along the line, 2) divergence behind a gust front, and 3) divergence within a set of buoyancy (gravity) waves [Miller, 1999].

In the four line divergent cases observed between January and July 2000 in which the TDWR missed a detection over the airport, the divergence was generally oriented in a southwest-to-northeast fashion (Figure 3). In such cases, the velocity feature becomes radially aligned to the DFW TDWR as it crosses the DFW airport, essentially becoming invisible to the DFW TDWR-based wind shear detection algorithms.

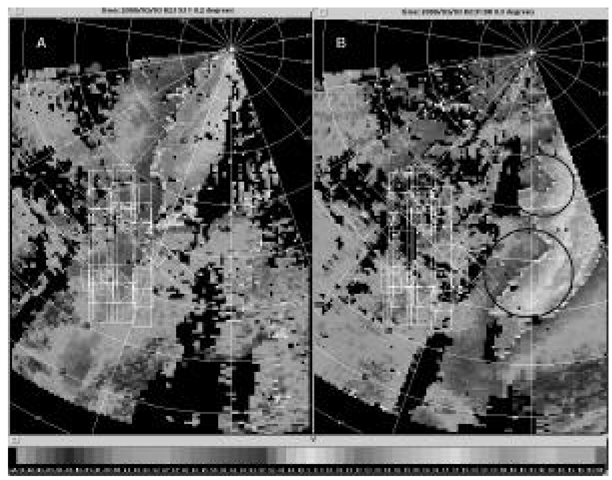

Figure 3. Velocity data from the DFW TDWR as a line of storms cross DFW. The group of white boxes in the center of each image is the DFW ARENAS. (A) Velocity data as the storms impact the airport. (B) Velocity data 12 minutes later. The circled areas depict detectable areas of divergence that can be discerned after the divergence was no longer radially aligned.

In two of the four cases cited, the cause was a microburst-producing line storm. In the remaining two cases, which represented divergence behind a gust front or within gravity waves, the situation is more complicated. The divergence may be detected, but often is far enough away from the precipitation field that there is no obvious "storm" associated with the divergent feature [Miller, 1999]. Both the TDWR and the ITWS attempt to reduce microburst false alarms by using reflectivity aloft to validate the detections. For example,

[1] Diverging surface winds give rise to microburst alerts or wind shear alerts with loss; most microburst outflows are approximately circular.

the current ITWS wind shear detection algorithm uses vertical integrated liquid (VIL) to determine whether there is a storm present near an area of divergence. If a predetermined VIL threshold and proximity tests are not met, the ITWS algorithm will disregard a radial velocity divergent feature as a false detection[2].

In each of the four cases, the integration of the LLWAS-NE alerts enabled the ITWS to issue wind shear alerts when the TDWR-based wind shear algorithm alone was unable to do so.

5. TDWR DATA QUALITY ISSUES

During the six months between January and July of 2000, there were five specific events where TDWR data quality issues lead to the loss of wind shear alerts. The two data quality issues examined in this section are radome attenuation and clutter residue editing.

5.1. RADOME ATTENUATION

Dome attenuation occurs when heavy precipitation coats a radome with a layer of water, causing lowered radar returns or attenuation. Because radome attenuation reduces the power returned to the radar, the computed storm reflectivities (and VIL) in a microburst-producing storm are reduced (Figure 4). In such cases, a wind shear or microburst event may be detected in the velocity field but rejected by the TDWR or ITWS wind shear algorithm because the reflectivity field will not pass the "storm present" test. Figure 4 illustrates the dramatic drop in VIL values due to radome attenuation[3].

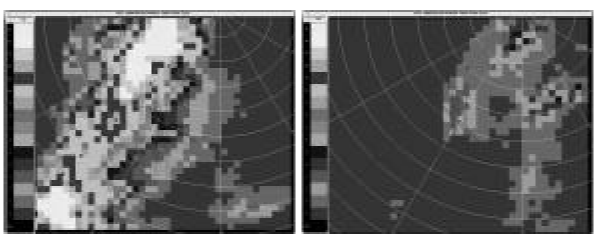

Figure 4. VIL data from the DFW TDWR. The image on the left shows VIL values within a line of storms before they impacted the DFW TDWR. The image on the right shows the same storms twenty minutes later, as the radar was being impacted. Notice the significant drop in the VIL values. This storm spawned a microburst at this time, with a loss of up to 26 m/s. However, it would have been missed by TDWR-only based processing.

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[2] The current TDWR software has a similar test based on finding "storm cells" aloft based on a region of reflectivity aloft exceeding a threshold[Merritt, et. al, 1989].

[3] It has been recommended as an ITWS enhancement to recognize cases of radome attenuation and lower the VIL threshold in real time. Since there typically is a high enough signal to noise ratio in these cases even with radiome attenuation, the TDWR radial doppler field accurately depicts the divergence region., Hence, dynamically lowering the VIL threshold would suffice to product an accurate microburst warning.

There were three events during the January to July 2000 period where radome attenuation caused a loss of wind shear alerts over DFW ARENAS. In each case the LLWAS NE generated credible wind shear alerts.

5.2. CLUTTER RESIDUE EDITING

The removal, or editing, of the base data to remove residual stationary and moving ground targets, or clutter, is a very important feature of the TDWR system. Since the return from moving vehicles and certain high-reflectivity stationary targets is often not eliminated by the TDWR clutter filters, the TDWR has Clutter Residue Editing Maps (CREM) that are used to flag returns from gates whose reflectivity does not exceed the map threshold for that gate [Mann, 1988; Hynek, 1990]. The CREMs are created using a combination of automatic processing and manually added regions. There is a potential problem when the manually added polygons are too aggressive in their spatial extent and/or threshold such that the resulting CREM inadvertently flags as clutter base data that is not, in fact, contaminated by clutter residue. For example, before the latest set of CREMS for the DFW TDWR was installed, a large number of wind shear and microburst events were missed due to very large CREM polygons near the runways. Reducing these polygons helped decrease the number of missed detections within the DFW ARENAS. However, some regions still exist near the DFW airport where the CREM levels are strong enough to flag valid base data as clutter residue. This aggressive clutter editing can be seen in Figure 5. Note the data void between the DFW runways.

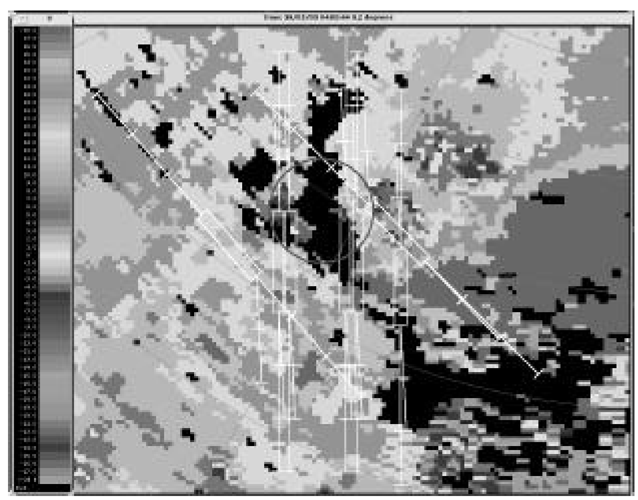

Figure 5. Doppler velocities from the DFW TDWR during a microburst event. The dark region in the center of the DFW runways indicates a region where aggressive clutter editing is occurring. The circle indicates the presence of a microburst event that was undetected by the TDWR-based wind shear algorithm.

On two occasions during the January to July 2000 study, wind shear events were missed or dropped due to clutter residue editing. During both events, the DFW LLWAS NE produced valid alerts.

6. CONCLUSIONS

There has been recent controversy over the operationally utility of the LLWAS-NE at a number of the TDWR/LLWAS major airports [Fahey, 2000]. In this study, we have examined the performance of the DFW LLWAS-NE in complementing the TDWR wind shear alerts in cases where the TDWR-only detection alerts were inadequate.

The loss or degradation of a front crossing over the DFW ARENAS was by far the most common event, with the bulk of degraded detections caused by radial alignment of the gust front due to poor viewing geometries. The other types of TDWR-only wind shear algorithm degradations that were studied occurred far less frequently.

In all of the cases examined in this study, the LLWAS-NE alert integration with TDWR based alerts effectively complimented the shortcomings of a TDWR-only wind shear detection suite, whether implemented in the TDWR itself or in the ITWS demonstration system at DFW.

As noted in the introduction, the study reported in this paper focused on cases where it was noted that a TDWR-only wind shear detection algorithm experienced problems. We need to look closely at the DFW cases where the LLWAS-NE with the new sonic anemometers experienced false alarms of the type discussed by [Fahey, 2000]. This work is in progress and will be reported subsequently.

At the ITWS sites that have multiple TDWR's in the vicinity of an airport (e.g., Dallas, Chicago, New York, Houston, Miami and Washington DC), it is also possible to provide TDWR-based gust fronts based on integration of information from multiple TDWRs [Shaw, 2000]. This additional integration option could be effective in improving gust front detection performance in poor viewing geometries.

It should also be noted that the radially aligned gust fronts, which were hard to detect with the DFW TDWR, principally provide a cross-runway shear, as opposed to an along-runway wind shear. Hence, although the radially aligned gust fronts technically met the criteria for an operationally significant gust front, they may not have been operationally significant in terms of head wind change for an aircraft. This same issue arises also for "line microbursts" because they are associated with squall lines or dry lines that have a preferred orientation that causes TDWR radial velocity viewing angle problems. Here again, the DFW along runway shear may be enough weaker than the cross-runway shear so that the microburst is not an operationally significant threat. This issue of cross-runway shear versus along-runway shear is important because the TDWRs have been specifically sited to do a good job of measuring along runway shear on the major runways at an airport.

7. REFERENCES:

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