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USE OF FEATURES ALOFT IN THE TDWR MICROBURST RECOGNITION ALGORITHM

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1. INTRODUCTION

This paper describes the use of features aloft in the Terminal Doppler Weather Radar (TDWR) microburst recognition algorithm. The paper is divided into three sections: algorithm description, scan strategy and recent results. The prototype algorithm recognizes features aloft associated with microbursts, such as descending reflectivity cores and convergence aloft. The algorithm uses these signatures to improve the detection performance and timeliness of microburst hazard warnings. For example, the algorithm can use features aloft to make a microburst declaration while the surface outflow is still weak, thereby increasing the hazard warning time.

An important factor in microburst recognition algorithm performance is the scan strategy employed. The TDWR scan strategy is designed for timely detection of microburst surface outflows and features aloft. The rationale for the prototype TDWR scan strategy is presented using Denver's Stapleton airport as an example.

Recent results are presented demonstrating the ability of the system to recognize features aloft for microburst events observed during the summer of 1988 at Denver, CO. It is shown that the ability to recognize features aloft improved the probability of detection and hazard warning time for these events.

2. MICROBURST RECOGNITION ALGORITHM

The initial version of the microburst recognition algorithm used surface velocity data only to identify the characteristic surface outflow signature associated with microbursts [Merritt, 1987]. The algorithm was subsequently augmented with the use of features aloft to improve the timeliness and reliability of microburst recognition [Campbell, 1988]. The current version of the TDWR microburst recognition algorithm is described in Campbell and Merritt, 1988. The prototype TDWR microburst recognition algorithm was implemented in the FAA/Lincoln Laboratory FL-2 radar testbed, and successful real-time operation was demonstrated in a two-month operational test during the summer of 1988 at Stapleton airport in Denver, CO.

The organization of the microburst recognition algorithm is shown in Fig. 1. The algorithm is divided into three types of modules: feature extraction, vertical integration and microburst recognition. The feature extraction modules identify two-dimensional regions of precipitation and shear from base reflectivity and velocity data. The shear regions identified include divergence, convergence, and rotation; the precipitation regions include three levels of reflectivity processing (e.g., 15, 30 and 45 dBZ). These modules are invoked for each elevation scan.

The vertical integration modules combine the regions identified from scans aloft into three-dimensional reflectivity and velocity structures. Velocity structures include convergence aloft, rotation aloft, divergence aloft (i.e., storm top divergence) and lower divergence (i.e., above the surface but below 1 km AGL). Reflectivity structures include reflectivity cores, storm cells and low reflectivity cells.

The microburst recognition modules use these structures aloft to aid the recognition of microbursts from surface outflows. The surface outflow algorithm identifies microburst outflows using only the temporal and spatial correlation of surface divergence features. The microburst precursor algorithm recognizes structures aloft which indicate that a microburst is imminent, such as a descending reflectivity core coupled with a convergence aloft. The surface microburst algorithm uses structures aloft and precursors to aid the recognition of microbursts from surface outflows. For example, an early microburst declaration can be made from a weak surface outflow combined with a microburst precursor signature.

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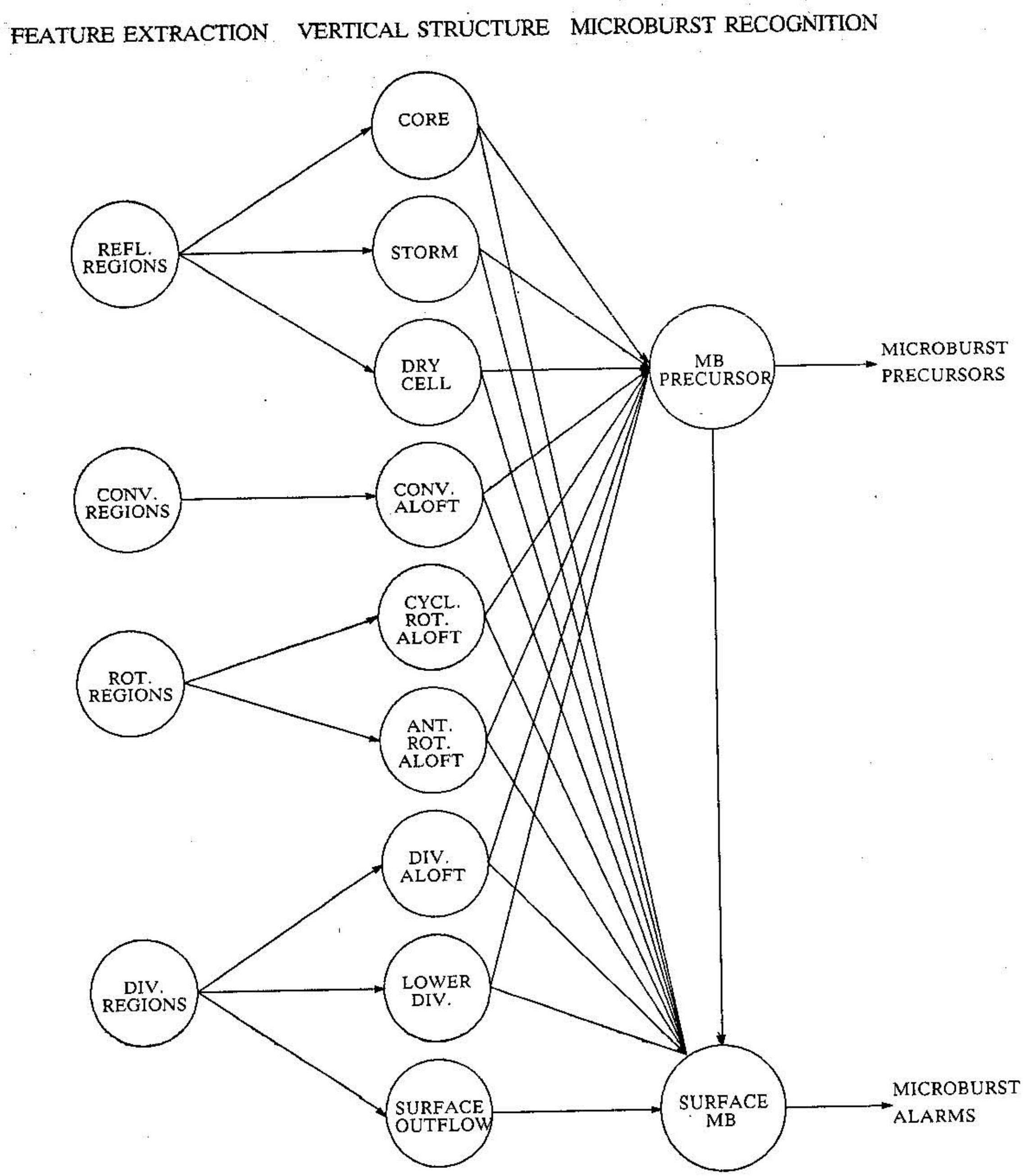

Figure 1. Prototype TDWR microburst recognition algorithm structure.

If no features aloft are present, the microburst recognition algorithm requires two successive surface outflows to be detected, with the second outflow having a velocity of at least 10 m/s. If the microburst algorithm finds a surface divergence feature which is at least 10 m/s but is not preceded by any surface outflow feature, then features aloft are used to attempt to make the alarm declaration. If such a surface divergence feature overlaps one or more of the following:

- a reflectivity core, *or*
- a rotation or convergence aloft extending below 3.5 km AGL, *or*
- a lower divergence (divergence above surface but below 1 km AGL), *or*
- a divergence aloft (divergence above 7 km AGL),

then the microburst alarm is declared. Thus, the timeliness of alarms can be maintained even if no previous surface divergence was detected.

Furthermore, the algorithm can also make an early declaration of the microburst event based on a weak surface outflow (< 10 m/s) accompanied by a microburst precursor. Three types of microburst precursor signatures are currently recognized:

- a descending reflectivity core and any convergence aloft, rotation aloft, lower divergence or divergence aloft, *or*

- a reflectivity core and a convergence or rotation aloft extending below 3.5 km AGL, *or*

- a descending convergence or rotation aloft.

A descending reflectivity core is declared when the lower altitude limit of a reflectivity core descends below 2 km AGL; a descending convergence or rotation is declared when its lower altitude limit and centroid descend below 3 km AGL. In either case, the structure is declared as descending until it falls below 0.5 km AGL. Thus, if a surface divergence feature is weak (i.e., between 7.5 and 10 m/s) and it overlaps a detected precursor, then the microburst event is declared without waiting for the outflow to reach the alarm threshold.

3. SCAN STRATEGY

Figure 2 shows the sector scan used for the Denver operational test. The required coverage region was the area within 3 nm from the end of each runway, as indicated by the egg-shaped region surrounding the airport. The FL-2 radar was located about 15 km to the Southeast of the airport at the Buckley Air National Guard base. Thus, the coverage region was from 7 to 23 km from the radar.

Figure 3 shows the scans aloft used in the TDWR scan strategy. This scan strategy is designed to provide a worst case vertical spacing between scans of 1 km over the coverage region up to an altitude of 6 km AGL. As discussed in Roberts and Wilson (1985) and Isaminger (1987), the 5-6 km AGL altitude is the region where microburst precursors aloft initially develop for wet microbursts. It has been observed from field experience that a reflectivity core signature typically requires about five minutes to descend from this altitude to the surface, so the scans aloft sequence is designed to repeat on the average every 2.5 minutes; this scan sequence permits the observation of a descending core at least twice during its descent.

The scan strategy is also designed to provide for surface elevation scans every minute and 360° gust front detection scans every five minutes. In addition, a low PRF (Pulse Repetition Frequency) scan is provided to allow real-time computation of an optimum PRF for minimization of range aliased returns, as described in Crocker, 1989.

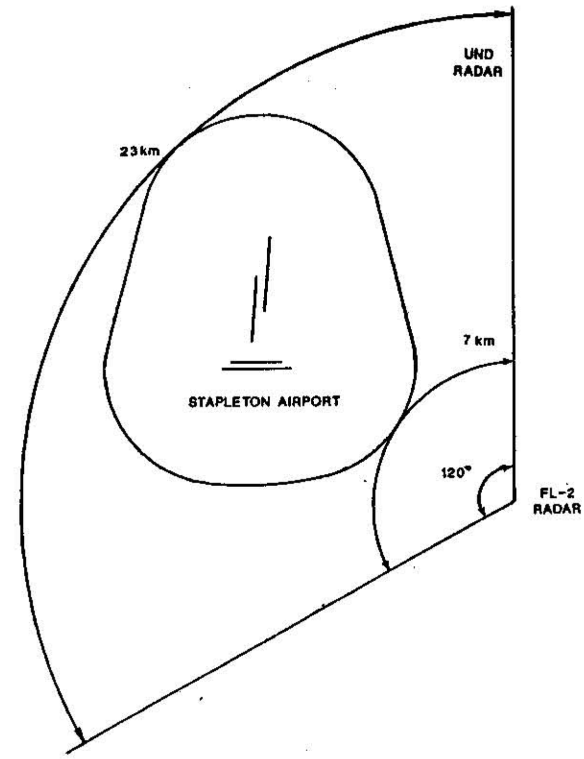

Figure 2. FL-2 sector scan for Stapleton airport.

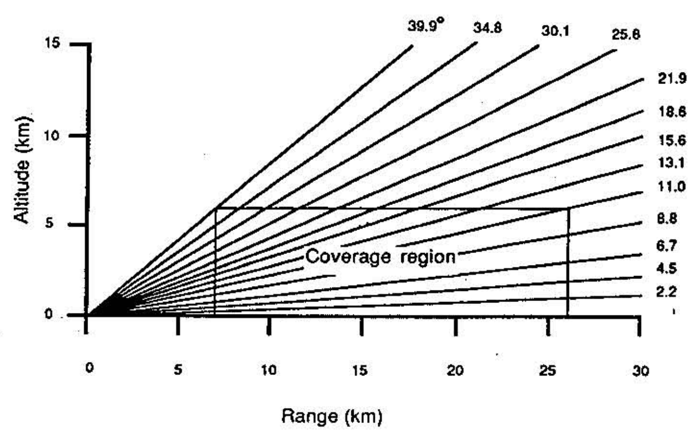

Figure 3. Scans aloft for TDWR scan strategy.

4 RESULTS

Table 1 shows preliminary microburst recognition algorithm scoring results for five days of Denver '88 data. The algorithm performance was determined using an automated scoring procedure described in Campbell, Merritt & DiStefano (1989). This automated procedure compares algorithm outputs against a truth database generated by expert radar meteorologists to determine the Probability of Detection (POD) and Probability of False Alarm (PFA). The POD is the probability that a microburst outflow is detected on a given surface scan, and PFA is the probability that a given microburst alarm is false. It can be seen from the table that the use of features aloft increased the probability of detection by 4.5% without significantly impacting the probability of false alarm.

Table 1. Probability of detection (POD) and probability of false alarm (PFA) with and without features aloft for five days of FL-2 radar data during summer '88 at Denver, CO (June 10, 21 & 25, July 7 & 17).

Features Aloft Enabled	Probability of Detection (POD)			Probability of False Alarm (PFA)
	<15 m/s	>15 m/s	All	
No	72.6%	93.3%	85.5%	5.3%
Yes	82.7%	94.6%	90.0%	5.5%

The event recognition rate and alarm timeliness were also assessed for the algorithm. For the 26 microbursts considered, event recognition rate was 100% with and without the use of features aloft (i.e., the microburst was detected at least once during its lifetime). However, the timeliness of microburst alarms with respect to the initial 10 m/s surface outflow was improved by an average of 0.51 minutes with the use of features aloft. Moreover, it was found that 46% (12 of 26) of these initial microburst alarms were made using features aloft. These results are consistent with earlier reports by Campbell & Isaminger (1989) and Campbell, Merritt & DiStefano (1989).

5. SUMMARY

This paper has discussed the use of features aloft in the prototype TDWR microburst recognition algorithm. The structure of the prototype algorithm and the scan strategy were described. Results were presented showing that the use of features aloft improves the reliability and timeliness of microburst alarms for radar data collected during the summer of 1988 at Denver, CO.

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