PERFORMANCE RESULTS AND POTENTIAL OPERATIONAL USES
FOR THE PROTOTYPE TDWR MICROBURST PREDICTION PRODUCT *

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1. INTRODUCTION

The Terminal Doppler Weather Radar (TDWR) is a ground-based system for providing automated warnings of aviation wind shear hazards. This paper describes a proposed new TDWR product for microburst prediction. The proposed Microburst Prediction (MBP) product provides the ability to predict microbursts prior to the onset of surface outflow. The MBP product uses the ability of the TDWR to scan aloft for precursor signatures which indicate that a microburst is about to occur.

The proposed MBP product provides a complementary capability to the other TDWR wind shear detection and prediction algorithms. As shown in Figure 1, the Microburst and Gust Front algorithms provide safety benefits by detecting wind shears hazards. The Wind Shift Prediction product provides an economic benefit by predicting runway wind shifts up to 20 minutes in advance. The MBP product provides both safety and economic benefits by predicting microburst hazards about 5 minutes in advance.

The development of the MBP product is intended to be evolutionary. The initial implementation of the product relies on TDWR radar data only. Later versions are expected to also employ thermodynamic information, as part

	DETECTION	PREDICTION
MB	MICROBURST DETECTION ALGORITHM	MICROBURST PREDICTION ALGORITHM
GF	GUST FRONT DETECTION ALGORITHM	WIND SHIFT PREDICTION ALGORITHM

Table 1. Relationship of proposed MBP product
to other TDWR wind shear algorithms.

of the Integrated Terminal Weather System (ITWS). However, the radar-only version discussed in this paper will provide a useful interim capability.

The organization of the paper is as follows. Section 2 provides a discussion of the potential operational benefits of the MBP product in improving safety and reducing delay. Section 3 describes the current MBP product algorithm, and section 4 provides performance results for two environments: Kansas City, KS and Orlando, FL. Section 5 provides an example of the product operation in predicting a 50 knot microburst which had substantial impact on airport operations. Section 6 will provide a summary and discuss future work.

2. OPERATIONAL BENEFITS

Safety and economic benefits would result from the installation of the MBP product. The safety benefit would be increased awareness by controllers and pilots of impending hazardous microburst events. The economic benefit would be improved controller planning to avoid loss of runway capacity due to microburst impact.

2.1 IMPROVED SAFETY

Installation of the MBP product would provide air traffic controllers with advance warning that a microburst outflow is anticipated within the next five minutes. This early warning capability would increase controllers' awareness of developing microburst hazards, resulting in improved speed in issuing alerts and decreased risk of failing to issue alerts. It would also improve controllers' ability to correctly assess the microburst hazard potential of developing storms.

Currently, controllers and pilots have only a limited ability to assess whether or not a developing storm will produce a microburst. The vertical development of a storm near the airport is usually obscured by cloud cover and is difficult for controllers to assess from the ground. Pilots on approach are hampered further by nose-down aircraft attitude and the high cockpit workload for this phase of flight.

By contrast, the MBP product makes use of the TDWR's ability to scan aloft in storms to detect reflectivity and velocity features which are precursors to microburst outflow. This ability to scan aloft allows TDWR to detect

impending hazards of which pilots and controllers may not be fully aware.

Figure 2 illustrates such a developing microburst hazard. In the situation depicted, there are two reflectivity
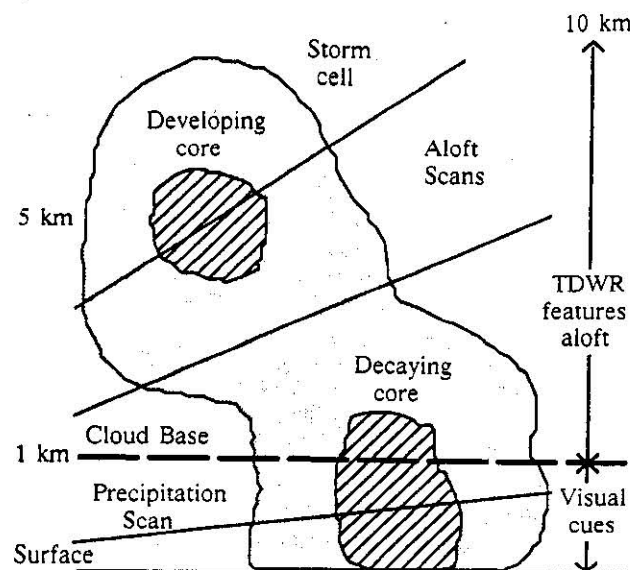

Figure 2. Illustration of TDWR ability to scan aloft for developing reflectivity cores.

cores, a decaying core on the right and a developing core on the left. The developing core is associated with a developing downdraft, which will descend to the surface within the next five to ten minutes and produce a microburst, as well as high intensity rain.

It can be seen that the cloud base prevents the developing core from being observed visually. Note also that the surface precipitation scan also does not observe the developing core. By contrast, the TDWR scans aloft detect the core and other features aloft associated with the developing microburst.

2.2. IMPROVED PLANNING

The MBP product would also improve the ability of controllers to plan for microburst impact along the approach and departure paths. Advance microburst warning would allow controllers to vector aircraft to alternative runways, instead of aircraft executing missed approaches or entering holding patterns. This gain in otherwise lost runway capacity would reduce delay and result in an economic benefit.

Figure 3 illustrates how microburst prediction could be used to avoid airport delay. Suppose that a microburst is predicted on the approach path to the currently active runway, as shown in (a). Without the advance knowledge provided by the prediction product, the aircraft will encounter the microburst and be forced to carry out a missed approach. With the prediction product, the aircraft can be vectored to an alternate runway and land successfully.
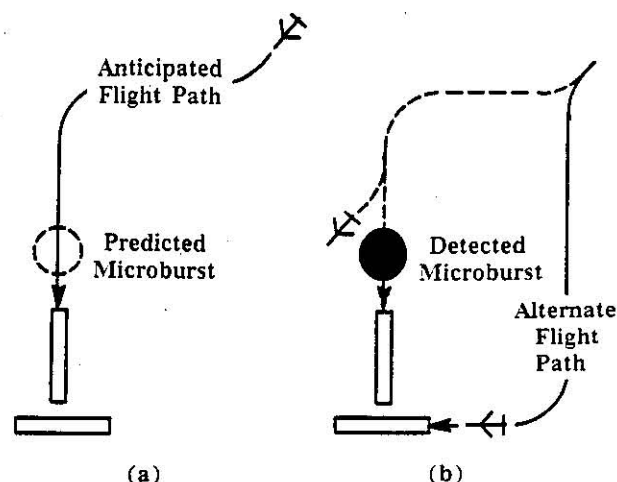

Figure 3. Reducing arrival delay.

3.   ALGORITHM DESCRIPTION

The basic operation of the microburst prediction product was reported previously in Campbell (1990). The MBP product is an extension of the existing TDWR microburst recognition algorithm. The microburst recognition algorithm relies on the ability of the TDWR to scan both at the surface for microburst outflows and aloft in the parent cloud for features associated with microbursts. Features aloft associated with microbursts include high reflectivity cores, mid-level convergence and rotation, and upper-level divergence. These features aloft are used to both confirm the existence of a microburst outflow and to detect microburst precursors.

The criteria for declaring a microburst precursor are that a reflectivity core must be detected along with a mid-level convergence, mid-level rotation (cyclonic or anticyclonic) or upper-level divergence. The reflectivity core must meet certain site adaptable criteria, such as a minimum height of 4.5 km and a maximum reflectivity of at least 54 dBZ. In addition, one of two additional criteria must be satisfied: either the reflectivity core must be descending, or a convergence (or rotation) must extend below 3.5 km altitude. These criteria are intended to detect the presence of a strong downdraft which will lead to a microburst outflow at the surface.

The microburst prediction product is a simple extension of the existing microburst precursor recognition capability. The first time that a precursor is detected for a particular event, a microburst prediction is issued for five minutes in the future at the precursor location. This prediction is counted down for each subsequent surface scan (once per minute) until either the microburst occurs or a total of seven minutes elapse. The prototype prediction product does not predict the strength of the outflow, although the site adaptable parameters are intended to predict those microbursts reaching at least 15 m/s (30 knots) intensity.

4. PERFORMANCE

The performance of the prototype MBP product has been evaluated for two environments, Kansas City, KS and Orlando, FL, as shown in Table 1. This evaluation was

Table 1. Microburst Prediction product performance results for Kansas City and Orlando.

	PMP (≥ 15 m/s)	PFP (< 10 m/s)	Warning (min)	
			Mean	Std Dev
KC '89 (36 events)	61%	11%	5.0	2.8
Orlando '90 (96 events)	51%	13%	5.5	2.4
Mean	56%	12%	5.2	2.6

carried out using the TDWR testbed radar operated by Lincoln Laboratory in 1989 at Kansas City and in 1990 at Orlando. The Kansas City results were reported previously in Campbell (1990). For both evaluations, all microbursts developing in the airport sector were considered for June, July and August.

The Probability of Microburst Prediction (PMP) is the probability that a microburst event reaching 15 m/s intensity was predicted, and the Probability of False Prediction (PFP) is the probability that a given prediction did not result in a microburst event of at least 10 m/s intensity. The warning time is the time from the first prediction to the onset of surface outflow.

As seen from the table, the product performed better at Kansas City than at Orlando. In Kansas City, the product predicted about 60% of the microbursts reaching 15 m/s (30 kts) intensity, but only about 50% of the Orlando events reaching this intensity. Conversely, the warning time was slightly greater for Orlando than for Kansas City. The probability of false prediction was about the same for both environments.

It appears that the prototype algorithm works better in a highly sheared environment such as Kansas City. The current algorithm requires the presence of velocity structures in order to declare a precursor (and therefore make a prediction). These velocity structures are usually present when the parent storm cell is vertically sheared, but often do not occur when the storm is unsheared. Since vertical shear is more likely when storms are moving, it is significant that storm motion was greater in Kansas City than in Orlando.

The reasons for failing to predict microbursts in Orlando were: core not tall enough (33%), no velocity feature found (23%), precursor overlapped existing micro-

burst (21%), no core found (14%), and velocity feature not low enough (9%). Thus, reliance on detection of velocity features accounts for 1/3 of the missed predictions. Another 1/3 relate to difficulty in determining whether a given reflectivity core will produce a microburst on the basis of height alone. The remaining misses could potentially be eliminated with some algorithm changes.

Recent work at Lincoln Laboratory indicates that microburst prediction performance could be significantly improved with the addition of thermodynamic information about the ambient atmosphere. For example, the current algorithm does not attempt to predict the strength of the outflow. The use of thermodynamic information may permit strength estimation as well as improving the overall prediction performance. One possible approach employing this information is described in Wolfson (1990), which employs a simple microphysical storm model to produce quantitative estimates. This promising line of inquiry will be pursued in the context of the ITWS program (Evans, 1991).
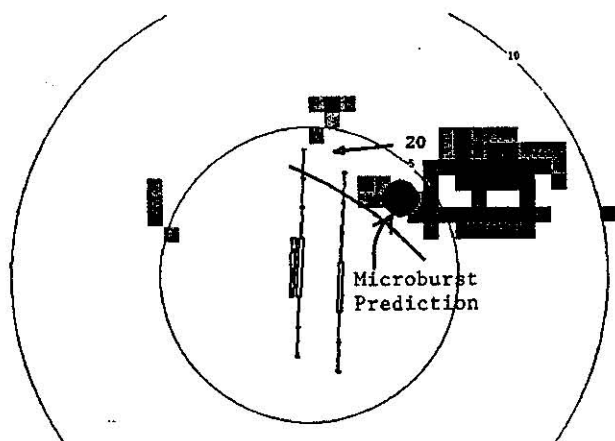
5. EXAMPLE

The potential usefulness of the microburst prediction product will now be illustrated with an example that occurred during operational testing during the summer of 1990. On July 7th, a storm cell approached the Orlando International airport from the east. The airport was operating in a South configuration, with approaches from the North and departures to the South. Figure 4 shows the Geographic Situation Display (GSD) that would be provided to Tower and TRACON supervisors if the microburst prediction product were implemented. It should be stressed that the microburst prediction product was not displayed on the GSD during the actual event.

Figure 3a shows the state of the GSD at 18:43:30 (Universal Time). A microburst prediction is displayed to the west of the storm cell and indicates that a microburst outflow is expected at this location in approximately five minutes. As shown in Figure 3b, a microburst outflow of 20 kts is detected at the predicted location at 18:50:30 or seven minutes after the initial microburst prediction. Five minutes later, the microburst outflow reached 50 kt intensity at 18:55:30, as shown in Figure 3c.

There is evidence from the ATC voice communication tapes that the TRACON and tower controllers could have benefitted from the advance warning provided by the MBP product. Although the controllers were aware of the approaching storm and monitored its development closely, they were not able to anticipate the sudden descent of the precipitation core and rapid development of the surface outflow.
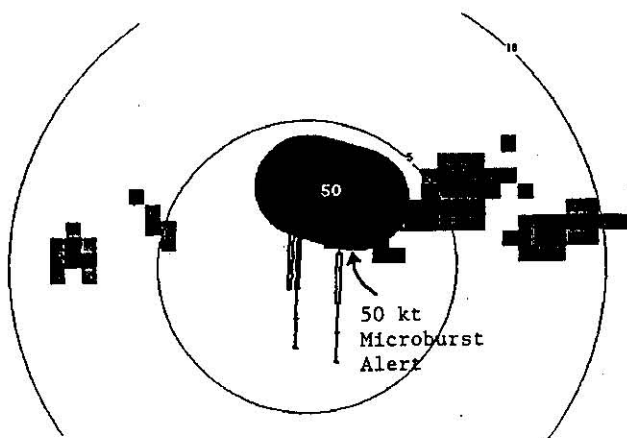
The storm was viewed as relatively nonthreatening as late as 18:47:30 (i.e., five minutes after the initial microburst prediction). Ninety seconds later, lightning was observed in the storm, and, by 18:49:30, the storm looked

(a) 1843 UT
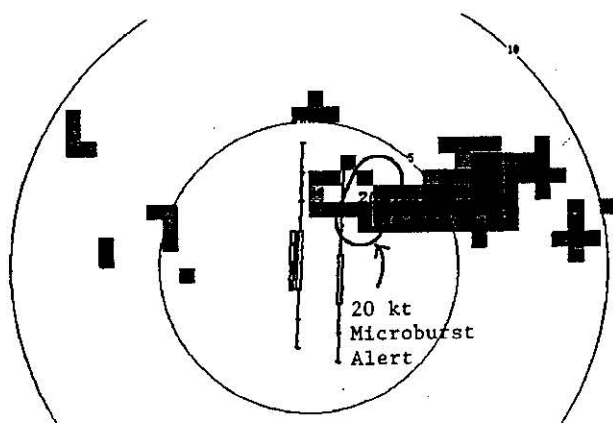
(b) 1850 UT

(c) 1855 UT

Figure 4. Microburst prediction example
for July 7, 1990 at Orlando, FL.

highly threatening. The initial microburst outflow was de-
tected by the TDWR testbed radar one minute later.

This microburst had a substantial impact on air
traffic operations at Orlando International airport for about
30 minutes. One aircraft made a missed approach and sev-

eral others were put into holding patterns. Several aircraft
also held on the ground during the microburst alert period.

This example suggests that the MBP product
could have been useful in providing a heightened awareness
of the impending microburst hazard to the air traffic con-
trollers. It also points up the difficulty that they experienced
in assessing the hazard potential of the approaching storm
based visual cues alone.

Advance warning of the impending microburst
hazard might have allowed controllers to divert the all ap-
proaching aircraft to the South (this was only done for one
aircraft and after a holding delay). It would have avoided
the necessity of holding aircraft along the approach routes,
which would appear to be undesirable given the lack of ma-
neuvering room close to the airport. The missed approach
which occurred might also have been avoided.

6.   SUMMARY

Based on this investigation, it appears that the
MBP product could be useful in alerting both controllers
and pilots to developing wind shear hazard situations. Us-
ing the ability of the TDWR to detect features aloft (such
as descending reflectivity cores) which are not typically ob-
servable by controllers or pilots, the MBP product could
provide heightened awareness of impending hazards and
improved operational planning.

The present radar-only version of the algorithm
predicts approximately half of the microburst events in
high-reflectivity environments with a low probability of
false alarm. Since this algorithm does not have thermody-
namic information, it does not estimate microburst
strength. Research is currently in progress on an advanced
microburst prediction product employing thermodynamic
information. It is also planned to investigate methods to im-
prove the prediction of microburst onset time, location and
spatial extent.

7.   ACKNOWLEDGEMENTS

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