"CLUTTER REJECTION IN DOPPLER WEATHER RADARS USED FOR AIRPORT WIND SHEAR DETECTION"[1]

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Abstract

Techniques for the suppression of ground and storm clutter to permit the detection of low altitude windshear by pulse Doppler radars are described. Novel features of the system include the use of clutter residue and range aliased weather echo editing maps which edit out the range-azimuth cells on a "data adaptive" basis.

I. Introduction

Low altitude wind shear has been recognized as a major cause of air carrier fatal accidents in the United States. The Federal Aviation Administration has initiated the Terminal Doppler Weather Radar (TDWR) program to develop a reliable fully automated wind shear detection system using pulse Doppler radars. The TDWR will detect low altitude wind shear phenomena such as microbursts and gust fronts in the terminal area and provide warnings that will help pilots successfully avoid wind shear on approach and departure [1]. Fig. 1 depicts the microburst which is the outflow from a small scale down draft generated by a thunderstorm, rain shower, or perhaps a harmless-looking cumulus cloud[2]. The TDWR will typically be located near an airport at which such microbursts are to be detected and determine the three dimensional structure of the storm by a series of horizontal (PPI) scans near the surface and at various elevation angles aloft.

AIRCRAFT ENCOUNTER WITH A MICROBURST

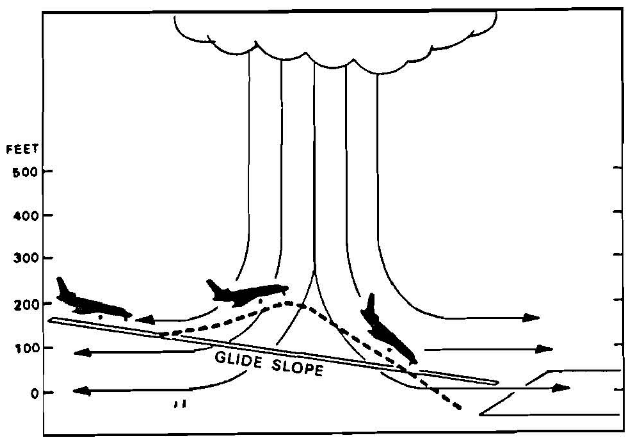

Figure 1

Clutter from fixed and moving objects represents a major challenge to successful operation of the TDWR due to the need to measure the return from low cross section (in some cases, equivalent to a discrete target cross section of -40 dB wrt 1 m^2) tracers in the presence of strong clutter returns. Since the wind shear targets to be detected are spatially extended targets which are detected by pattern recognition techniques [2,3] and, the weather parameter estimates must be obtained from spectral parameter estimation; the approaches taken to clutter suppression have important differences from those used for detection of discrete targets such as aircraft or missiles.

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[2]The role of microbursts as a major cause of accidents was brought to the attention of the aviation community by Prof. Tetsuya Theodore Fujita of the Univ. of Chicago [6]. Prof. Fujita received his doctorate from Tokyo University.

B. Antenna Elevation Angle Adjustments

Adjusting the surface scan antenna elevation angle to place the clutter sources in the antenna nulls and sidelobes while illuminating the wind shear events with the antenna main lobe can provide major reductions in clutter residue level. In the Denver, CO testing, it was found that adjustments as small as 0.1 beamwidths in the elevation angle can yield 10 dB decrease in clutter residue levels.

C. Clutter Residue Editing Map

After MTI filtering, the residual clutter signal (i.e., "clutter residue") can still bias the velocity estimates and/or cause false alarms. A clutter residue editing map is then used to flag clutter residue dominated range gates on a data adaptive basis. The clutter residue is estimated from "clear air" measurements on a day where no weather is present near the airport. The measured data during weather periods is compared to the estimated clutter residue values on a gate by gate basis. If the measured data in a given gate during normal weather detection operations does not exceed the clutter residue level by a site adaptable threshold, the measured data for that gate is rejected. There are a number of important issues in generating the editing map:

1. insuring that the residue map is not contaminated by the radar return from moving clear air scatterers and moving point targets such as birds and planes,

2. handling of clutter residue which is strongly time varying such as vehicles on a highway,

3. setting the threshold for flagging data, and

4. dealing with seasonal variations in the clutter <u>residue</u> environment (which may not be the same as seasonal variations in the clutter environment).

Space permits only consideration of issues (1) and (4). Fig. 3 compares the clutter map estimated from an average of approximately 20 PPI scans with the corresponding median. The average value is seen to have a number of large values along the runway approach and departure corridors which correspond to returns from aircraft. Since these returns are relatively infrequent (e.g., occur less than 5 % of the time) in practice, the corresponding cells should not be flagged. Hence a median estimator has been used for the operational testing to date.

Fig. 4 shows the clutter residue map made from Denver measurements in April 1988 and the differences between this map and the maps made from measurements in May, July and October 1988. We see that there is a trend for clutter residue to decrease over the period, but that differences are not large (i.e., typically between ± 4 dB) over a period of 3 months. This suggests that clutter residue map updates can be carried out on an operationally convenient time schedule.

D. Performance Evaluation

We have focussed on experimental verification experiments whereby the performance at detecting known events is determined as a function of clutter suppression parameters such as the clutter residue map data measurement period and the data flagging threshold. Preliminary results show a marginal improvement in the already good microburst detection near Denver (in part due to the lack of extended clutter near the airport runways), but a major improvement in gust front detection performance by flagging of clutter from ridges to the west of the airport. In particular, the use of a clutter residue map reduced the gust front algorithm false alarm rate from approximately 45 % (in 1987) to only 2 % (in 1988) without degrading the detection probability [9].

VI. <u>Minimizing Clutter Due to Range Aliasing of Distant Storms</u>

Doppler weather radars operating at constant pulse repetition frequencies (PRF) also must cope with the clutter caused by range aliased echoes from distant storms. The TDWR makes measurements on a 360° scan at a low PRF to unambiguously locate distant storms. The high PRF's used for Doppler measurements are then selected to minimize the area near the airport in which first trip data is corrupted by range-aliased returns. When the adaptive PRF selection is not totally effective [7], the data from the low PRF measurements is used to create an "out-of-trip weather clutter" editing map which is used in a method analogous to the ground clutter residue editing map [8]. Preliminary tests on 3 days of data from Kansas City, MO in which range aliased echoes produced many false alarms showed that the use of such an editing map would reduce the number of false alarms by 80 % [Isaminger, personal communication, 1989].

VII. Summary

Clutter suppression is a challenging problem for the TDWR due to the need to observe returns from weak scatterers (in some cases clear air returns) in the presence of strong urban clutter and/or range aliased weather echoes. We have shown that a combination of "classical" radar design features together with the use of clutter editing maps (to take advantage of the spatially extended nature of the weather phenomena) has provided reliable wind shear detection performance in the challenging environment. Issues which arise from the generation and use of such maps were discussed in some detail.

ACKNOWLEDGEMENT

The work described here represents the concentrated efforts of a large group of people at Lincoln Laboratory who developed, operated and analyzed the results of the TDWR testbed radar. Special mention should go to E. Ducot, and S. Troxel for their contributions to development of the clutter residue map editing algorithm and software. B. Stevens developed the software for editing of clutter due to out-of-trip weather and performed the threshold optimization studies leading to the results reported in section VI. The observations by M. Isaminger, N. Fischer and P. Biron at the TDWR testbed have been invaluable in identifying and resolving various issues as well as in assessing the performance.

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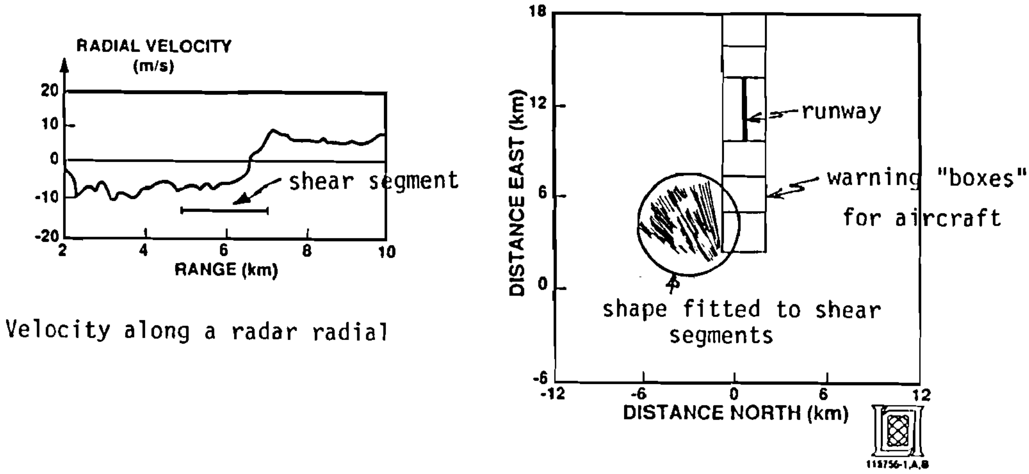

Fig. 2 Microburst Outflow Detection Algorithm

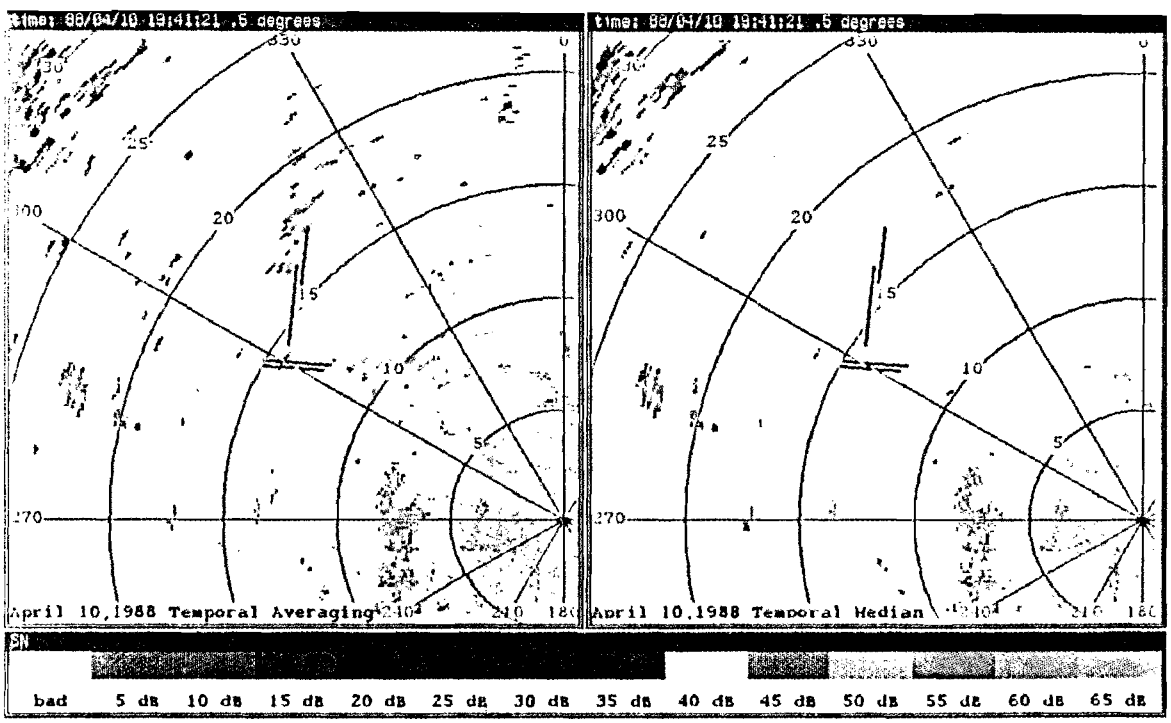

Fig. 3 Comparision of Clutter Residue Maps Using the Temporal Average and Temporal Median of the Measured Data

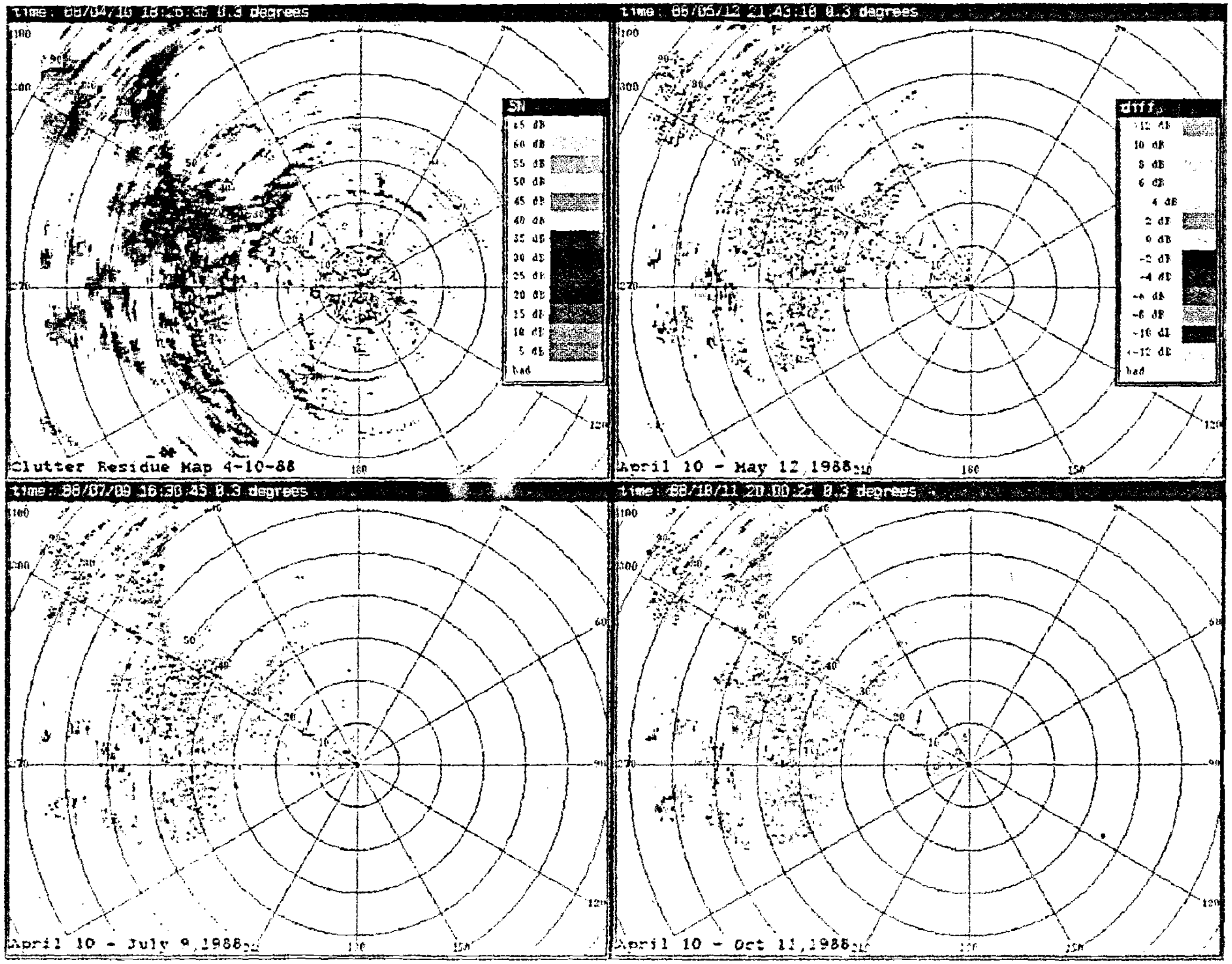

Fig. 4 Variation in Clutter Residue Map at TDWR Denver Test Site Over the 1988 Experimental Season.