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PRELIMINARY RESULTS OF THE WEATHER TESTING COMPONENT OF THE TERMINAL DOPPLER WEATHER RADAR OPERATIONAL TEST AND EVALUATION

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1. INTRODUCTION

The Terminal Doppler Weather Radar (TDWR) system (Turnbull et al. 1989), which has been developed by Raytheon Co. for the Federal Aviation Administration (FAA), provides automatic detection of microbursts (Fujita 1985) and low-altitude wind shear. Microburst- and gust front-induced wind shear can result in a sudden, large change in airspeed which can have a disastrous effect on aircraft performance during take off or landing. The second major function of TDWR is to improve air traffic management through forecasts of wind shifts, precipitation and other weather hazards. The TDWR system generates Doppler velocity, reflectivity, and spectrum width data. The base data are automatically dealiased and clutter is removed through filtering and mapping. Precipitation and windshear products, such as microbursts and gust fronts, are displayed as graphic products on the Geographic Situation Display (Fig. 1) which is intended for use by Air Traffic Control supervisors. Alphanumeric messages indicating the various windshear alerts and derived airspeed losses and gains are sent to a flat panel ribbon display which is used by the controllers in the control tower.

The TDWR proof-of-concept and operational feasibility have been demonstrated in a number of FAA-sponsored tests and evaluations conducted by

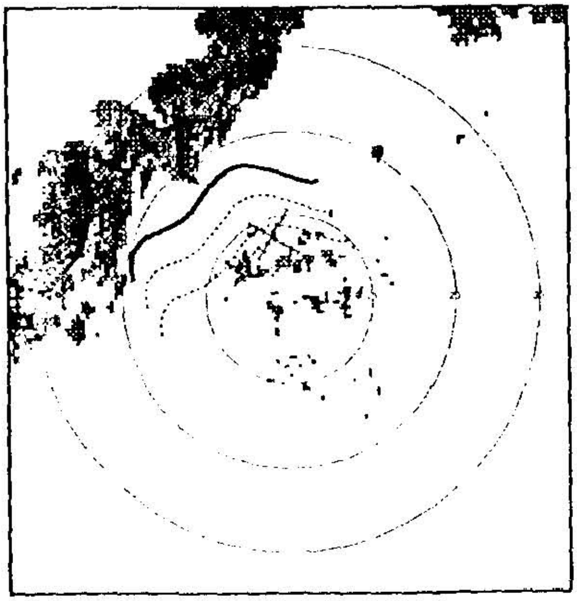

Figure 1. Black and white reproduction of a geographic situation display. The figure is centered near Wiley Post Airport. Precipitation can be seen to the west of the airport and is grey scaled (darkest is heaviest). The heavy solid line is the gust front and the dashed lines are 10 and 20-min forecasts. A control panel to the right is not shown due to space constraints. Range rings are in nautical miles.

Massachusetts Institute of Technology's Lincoln Laboratory (MIT/LL) in Memphis, TN (1985); Huntsville, AL (1986); Denver, CO (1987, 1988); Kansas City, MO (1989), and Orlando Fl. (1990-1992).

In order to verify that the TDWR meets FAA operational suitability and effectiveness requirements, an Operational Test & Evaluation (OT&E) was conducted at the Oklahoma City site during the period from 24 August to 30 October 1992. The testing addressed National Airspace System (NAS)-SS-1000 requirements, weather detection performance, safety, operational system performance, maintenance instruction books, Remote Maintenance Monitoring System (RMMS), system adaptable parameters, bullgear wear, and limited Air Traffic (AT) suitability.

The TDWR OT&E Integration and Operational testing was conducted using a variety of methods dependent on the area being tested. This paper discusses primarily the weather detection performance testing. A rough analysis was performed on the algorithm output and the base data to determine the performance of the TDWR in detecting wind shear phenomena. Final results will be available after additional testing, which is scheduled for Spring of 1993, and post analysis is conducted.

2. SYSTEM DESCRIPTION

The TDWR is a C-Band weather radar consisting of a 25-foot diameter, center-fed parabolic reflector antenna, with the feed mounted on a tripod. The antenna beamwidth is 0.55 degrees. The TDWR transmitter tube is a 250 kW peak-power pulsed klystron, transmitting a 1.1 microsecond pulse (-6 dB width) at pulse repitition frequencies from 250 to 2000 Hz. Large dynamic range is provided for both good clutter suppression and accurate reflectivity measurements. The total dynamic range, over 128 dB, is obtained with 26 dB of Sensitivity Time Control (STC), 42 dB of Automatic Gain Control (AGC), and circuits linear over 61 dB. For more detail on system characteristics the reader is referred to Wieler and Shrader 1991, and Michelson et al. 1990.

3. WEATHER TESTING RESULTS

This section describes results of the weather-detection component of the TDWR OT&E. The National Severe Storms Laboratory developed procedures to address three main components of the TDWR weather detecting capability: 1) Assess that the base data are of high quality; 2) Determine if the algorithms are functioning properly; 3) Verify that appropriate alarms are disseminated according to the system design.

3.1 Base data

In a qualitative assessment, the judgement of the Investigative Panel, a group of expert radar meteorologists from the National Center for Atmospheric Research (NCAR), MIT/Lincoln Laboratory and NSSL, is that the raw base data were of high quality. All of the NAS requirements related to measurements of base velocity, reflectivity, and spectrum width were fulfilled.

Suppression of ground clutter is important for "clean" base data and for prevention of false alarms. The TDWR uses two techniques to reduce contamination from ground clutter sources. The first involves the use of IIR (infinite impulse response) filters to suppress high reflectivity returns that have near-zero velocities. The second step is to generate a clutter residue editing map (CREM) on a clear day with no weather echoes. Experience has shown the best condition for taking clutter measurements is low clear-air reflectivities and a minimal amount of moving sources such as birds and insects.

Clutter map generation begins with an automated determination of a clear-air reflectivity (CAR) value. The CAR estimate and a maximum velocity threshold are then used to distinguish clutter residue from clear-air returns caused by birds and/or insects. It was determined that the process for building the CREMs may not be straightforward at each site. A large amount of bird activity (and possibly insects) as well as evolving boundary layer characteristics resulted in having to make the CAR estimate before sunrise. It is anticipated that each site will have its own peculiarities.

3.2 Algorithm performance

3.2.1 Microburst detection algorithm

The Microburst Detection Algorithm (MDA) detects low-altitude divergent shears associated with storms (Merritt et al. 1989). Since most of the data were collected in high-wind environments, classic microburst signatures were rarely seen.

Because a limited amount of data are available for evaluation, only rough assessments of the MDA performance are available. Detection performance was excellent although a number of false alarms were observed. Large flocks of birds departing from roosting sites in the early morning hours caused divergent signatures similar to microbursts. There were numerous false alarms from this phenomena prior to the implementation of the storm cell test which validates alarms based on reflectivity aloft (Evans 1990). Many of the other false alarms were the result of clutter breakthrough or noise in the velocity data. Note the clutter breakthrough around the airport in Fig. 1.

3.2.2 Gust front detection algorithm

The Gust Front Detection Algorithm (GFDA) detects lines of convergence in Doppler radial velocity fields and forecasts the movement of these wind shifts and the winds behind them up to 20 minutes in advance (Hermes et al. 1992). An example of a gust front detection is shown in Fig. 1. Test results indicate that the forecasting function of the algorithm performed well, as did the estimation of winds behind the wind shift. As a gust front passed over Wiley Post Airport on 10 September, data from the local automatic surface observing site agreed well with the windshift value behind the gust front detection.

The GFDA performed well during the OT&E. However, as with the MDA, false alarms were observed. The majority of the false alarms were detected outside 20 km and thus would not impact the airport. Many of the GFDA false alarms were the result of vertical wind shear where the winds veered (turned) with height and were not the typical low-level jet situations which have been noted as a potential cause of false alarms. However, some false alarms were caused by more classical low-level jets. We are classifying these vertical wind shears and low-level jets as false alarms since they were not generated by a thunderstorm outflow. It could be argued, however, that these features are operationally significant. There were also a number of false alarms due to dealiasing errors and range folding. Minor software changes are being made to reduce the number of false alarms.

4. CONCLUSIONS

The initial Operational Test & Evaluation of the Terminal Doppler Radar showed that weather detection performance was generally acceptable. A set of NAS-SS-1000 requirements was satisfied. Base data quality appears to be excellent and the two primary algorithms, microburst detection and gust front detection, are in general working well. Minor software changes are being made to improve system performance.

Issues surrounding building accurate ground clutter suppression maps became apparent and will need to be addressed at future sites. Additional testing is scheduled for Spring 1993 after which final results will be published in the 5th International Aviation Weather Conference to be held in August, 1993.

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