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A QUANTITATIVE TECHNIQUE TO ESTIMATE MICROBURST WIND SHEAR HAZARD TO AIRCRAFT

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Low-altitude microburst wind shear encounters can significantly affect aircraft performance during approach or takeoff. Over the past 25 years, hazardous wind shear has been a contributing factor in over two dozen commercial airline accidents in which there were over 500 fatalities. In response to the wind shear problem, a number of agencies including NASA, the FAA and the National Center for Atmospheric Research have been involved in the design and testing of various sensors to detect the hazard. Among the sensors being tested are the ground-based Terminal Doppler Weather Radar (TDWR) and airborne Doppler radar and LIDAR systems. While these sensor systems do measure horizontal wind shear, they do not adequately account for the vertical wind, which is a key component of the microburst hazard to aircraft. This study defines a technique to estimate aircraft hazard from the combined effects of horizontal and vertical winds, given only horizontal wind information.

The wind shear hazard potential to aircraft performance may be quantified in terms of the Bowles F-factor (Bowles and Targ 1988):

$$F = \frac{W_x}{g} - \frac{W_h}{V} \qquad (1)$$

where W_x is the substantial derivative of the horizontal wind along the flight path, W_h is the vertical wind and V is the airspeed of the plane. Term A in Eq. 1 is represents the effect of horizontal wind shear (e.g. headwind loss, tailwind gain) on aircraft performance, while term B constitutes the effect of vertical wind (e.g. downdraft). The effect of the two components is illustrated in a schematic view of an aircraft microburst encounter on approach shown in Fig. 1. The more positive the value for F-factor, the greater the detriment to aircraft performance, with an F-factor in excess of 0.1 considered as hazardous.

F-factors for this study were computed from model simulations using the Terminal Area Simulation System (TASS) convective cloud model developed by Proctor (1987a,b; 1988, 1989). The TASS has been used extensively to produce realistic simulations of numerous microburst environments. Fig. 2 shows that for a composite of nine TASS model simulations, the horizontal shear contribution to the F-factor decreases rapidly with height , to less than 50 percent at altitudes above about 200 meters (650 feet). Therefore, Doppler radar and LIDAR systems will seriously underestimate the total hazard by not taking into account the vertical wind effects.

A method to estimate the total F-factor, given only the horizontal wind information has been developed, based on mass continuity. Assuming an axisymmetric cylindrical microburst, the horizontal divergence is related to the vertical velocity by an altitude-dependent scale factor:

$$\text{scale factor (SF)} = \frac{\text{vertical velocity}}{\text{horizontal divergence}} = \frac{W_h}{\frac{\partial W_x}{\partial X} + \frac{W_h}{R}} \quad (2)$$

The F-factor may then be evaluated according to:

$$\text{FDERIVED} = g^{-1} V \frac{\partial W_x}{\partial X} - \frac{SF^*[\partial W_x/\partial X + W_x/R]}{V} \quad (3)$$

where R is distance from the center of the microburst. Fig. 3 shows the quadratic curve fit for scale factor versus altitude, based on 9 TASS microburst simulations. The scale factor increases due to the increasing importance of the vertical wind and smaller horizontal divergence at higher altitudes Tests on independent cases reveal that the F-factor estimation technique (FDERIVED) shows good agreement with TASS simulated F-factors (FMODEL). Fig. 4 shows the remarkable agreement of FMODEL and FDERIVED at an altitude of 240 meters (790 feet) for the Dallas-Fort Worth microburst of 2 August 1985 for the time of the Delta flight 191 accident. At the same time, the F-factor due to horizontal shear (FHORIZ) significantly underestimated the hazard, failing to reach the critical F-factor of 0.1. Temporal (Fig. 5) and altitude (Fig. 6) analyses also show good agreement between FDERIVED and FMODEL, with serious underestimation of the hazard by FHORIZ at altitudes of greater than 120 meters.

The method presented here shows promise in that it provides a reliable estimate of aircraft performance hazard given only horizontal wind information. It is a simple, straight forward technique which can be easilty integrated with Doppler radar and LIDAR sensing systems. At present, it is limited in that it does not work reliably for very narrow microbursts and has only been tested on axisymmetric microburst cases. Future work will include technique refinement using both two- and three-dimensional versions of TASS. Specifics to be addressed are flight paths which are not through the center of microbursts and axisymmetric microbursts. Also, the technique resolution problem will be looked at in regards to its inadequate treatment of narrow microbursts.

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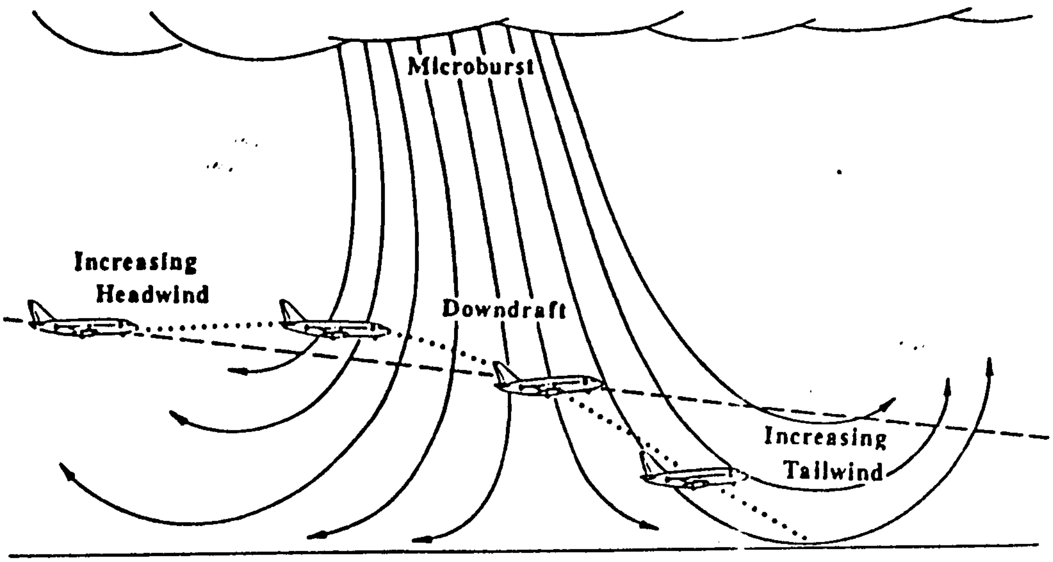

Fig.1: Schematic of an aircraft microburst encounter on approach.

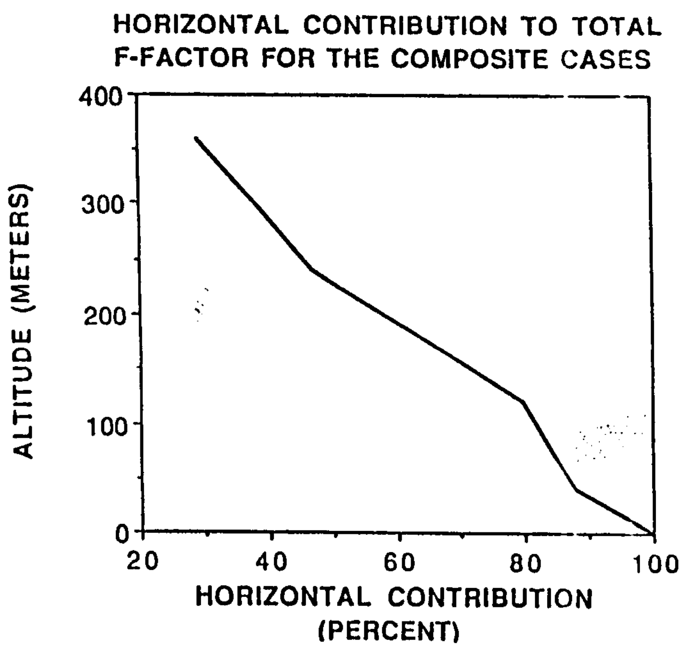

Fig. 2: Horizontal contribution (W_x/g) to the total F-factor for a composite of 9 TASS model simulations.

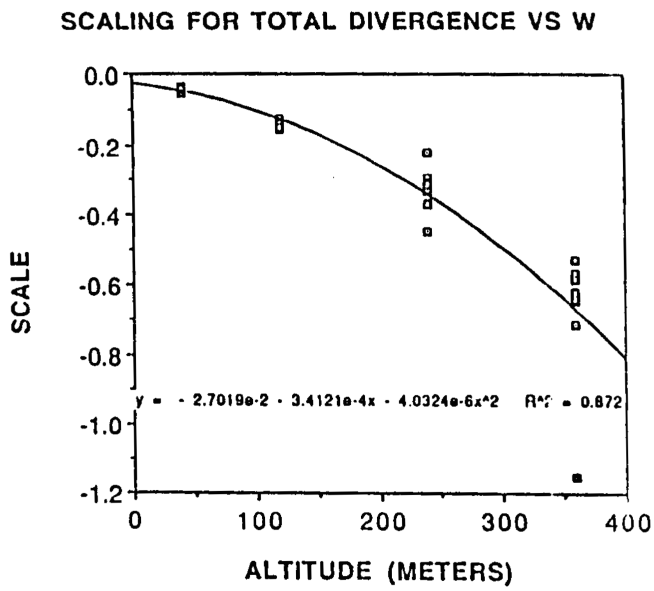

Fig. 3: Quadratic curve fit of scale factor versus altitude.

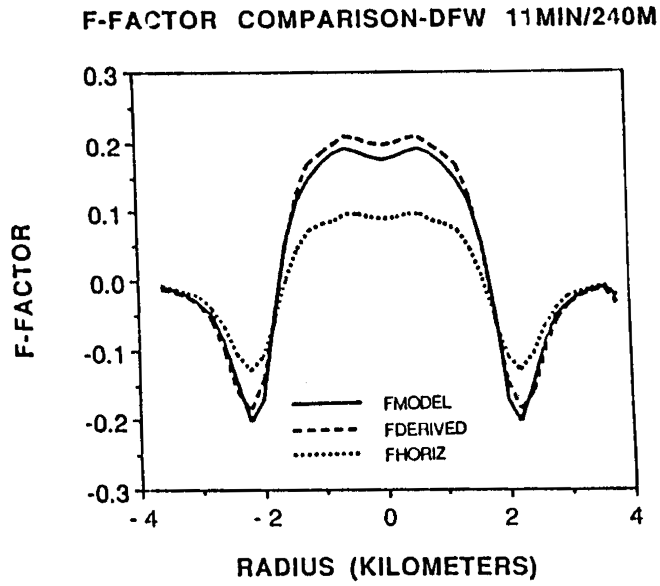

Fig. 4: F-factor comparison for DFW case of 2 August 1985 at an altitude of 240 meters near Delta accident time.

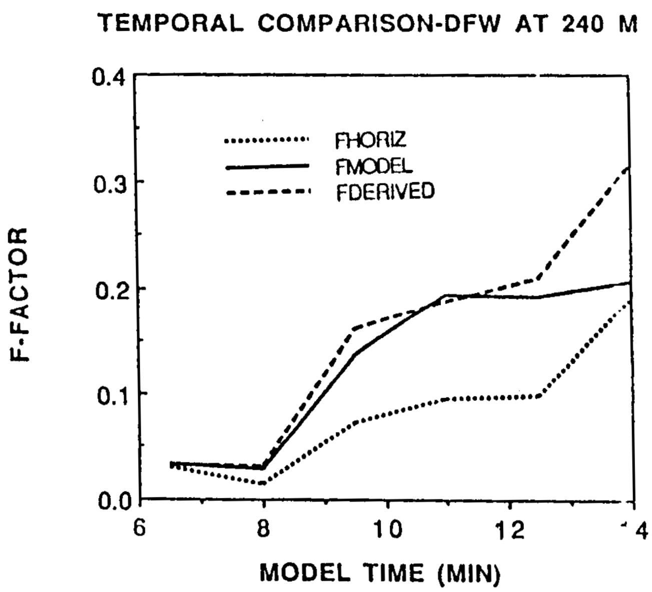

Fig. 5: Temporal plot of maximum F-factor for DFW case at an altitude of 240m.

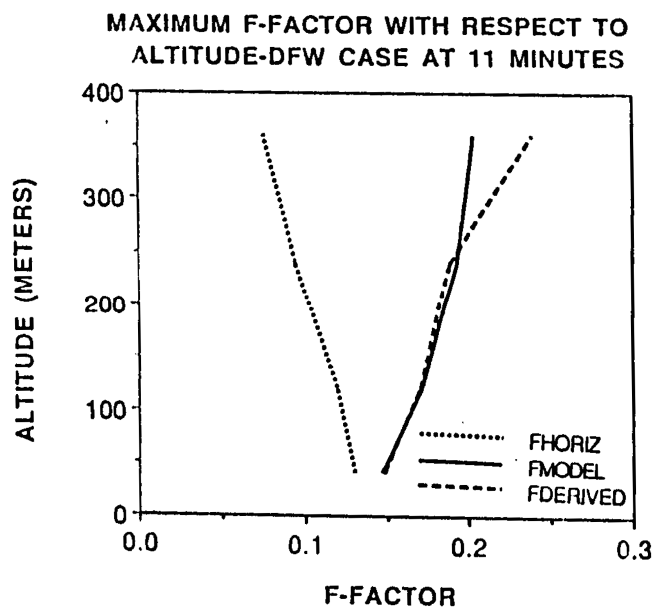

Fig 6: Plot of maximum F-factor versus altitude