# PHYSICAL MODELLING OF THUNDERSTORM DOWNDRAFTS BY WIND-TUNNEL JET

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## INTRODUCTION

It has been observed previously [1] that there is a close similarity between the vertical gust profile observed by radar in downbursts occurring in thunderstorms [2], and the mean velocity profile above a wall on to which a continuous jet is impinging normally, i.e., a normal wall jet. In both cases, a maximum in the profile occurs; below the maximum the flow is retarded by surface friction on the wall or ground. In the case of the thunderstorm downburst, the maximum appears to occur at a height of 50-100 metres above ground level.

Pending laboratory simulation of other features of thunderstorm downdrafts, such as the transient characteristics and density gradients, which is likely to be difficult to achieve, the use of a simple continuous wall jet to investigate the essential features of downdraft flow over topographic features and buildings seems appropriate, as a first step. A previous paper [1] used a numerical simulation of a two-dimensional jet to investigate the flow over an embankment.

In the present contribution, preliminary measurements of velocity profile, and topographic multipliers for the same embankment used in the previous study [1], are described.

## EXPERIMENTAL TECHNIQUES

The wind tunnel used was of the blowing type, which, in normal usage, consists of a centrifugal blower of 75 kW capacity, discharging air into a rapid diffuser containing several screens, a settling chamber and a contraction with an area ratio of 1.7:1. The working section is 2.4 m long, and has cross-section dimensions of 1.15 m (horizontal) and 0.85 m vertical. For the present work, tapered fillets were installed in the corners of the test section to give an approximately octagonal exit area. This produced a jet that was roughly axi-symmetric when it impinged on the vertical wall. The latter was made from particle board, was 3.0 m square, and was erected vertically 1.4 m from the wind tunnel exit plane, as shown in Figure 1. The aerodynamic roughness length of the particle board was measured in a separate boundary-layer test and found to be 0.1 mm.

Measurements of mean velocity in the exit plane of the wind-tunnel jet indicated that the flow was uniform within about $\pm$ 2%, over the central 80% of the jet width.

For comparison with the previous computations, or with full-scale downbursts, a nominal geometric scaling ratio of 1/1000 has been assumed. Thus the width of the jet is approximately 1 km in full scale, and the wall roughness length is about 100 mm, representative of open country terrain.

The measurements of the flow near the wall, described in the following section, were made using a constant temperature hot-wire anemometer. A Solartron JM1860 Time-domain Analyser was used to measure voltages from the anemometer.

## RESULTS

The mean velocity profile at a station 1000 mm (1 km in full scale) away from the stagnation point of the jet on the board is shown in Figure 2. The profile has been normalised with respect to the maximum velocity, and to the height, $\delta$, at which the velocity is equal to half the maximum. In the case shown, $\delta$ was 157 mm. Also shown on Figure 2 is the profile at an equivalent position for the two-dimensional jet [1], and from radar observations of a downburst in the NIMROD project [2]. The current tests indicate a broader maximum velocity plateau than the other results but otherwise agree quite well. The extent of the plateau is from 30 to 80 mm from the wall, equivalent to 30 to 80 metres in full scale.

Figure 3 shows the measured topographic multipliers (mean velocity at height Z above hill / mean velocity at height Z above flat ground, in the absence of the hill at the same position in the jet) for the leading edge of a flat-topped embankment of height 40 mm (40 m in full scale). This topographic feature was also used in the previous computational study [1]. The measured multipliers are in good agreement with those computed up to a height equal to the height of the embankment. Both sets of values are considerably less than those obtained for boundary layer flow for the same topographic feature as observed previously.

## CONCLUSIONS

Preliminary experiments in a wind-tunnel jet impinging on a normal wall indicate similar mean velocity profiles to those obtained in radar observations of thunderstorm downbursts and in computations of a two-dimensional jet. Measurements of topographic multipliers for an embankment, also agree well with the computed values, and are considerably lower than those obtained in boundary-layer flow.

This physical modelling technique should be developed in the future to incorporate the transient characteristics and density differences found in real thunderstorm downdrafts, and extended to include flow around, and pressure measurements on buildings.

## REFERENCES


1. Selvam, R.P. and Holmes, J.D. (1991). 'Numerical simulation of thunderstorm downdrafts', *Proceedings, 8th International Conference on Wind Engineering*, London, Ontario, Canada, 8-12 July 1991 (to be published).

2. Fujita, T.T. (1981). 'Tornadoes and downbursts in the context of generalised planetary scales', *J. Atmospheric Science*, Vol.38, pp.1511-1534.

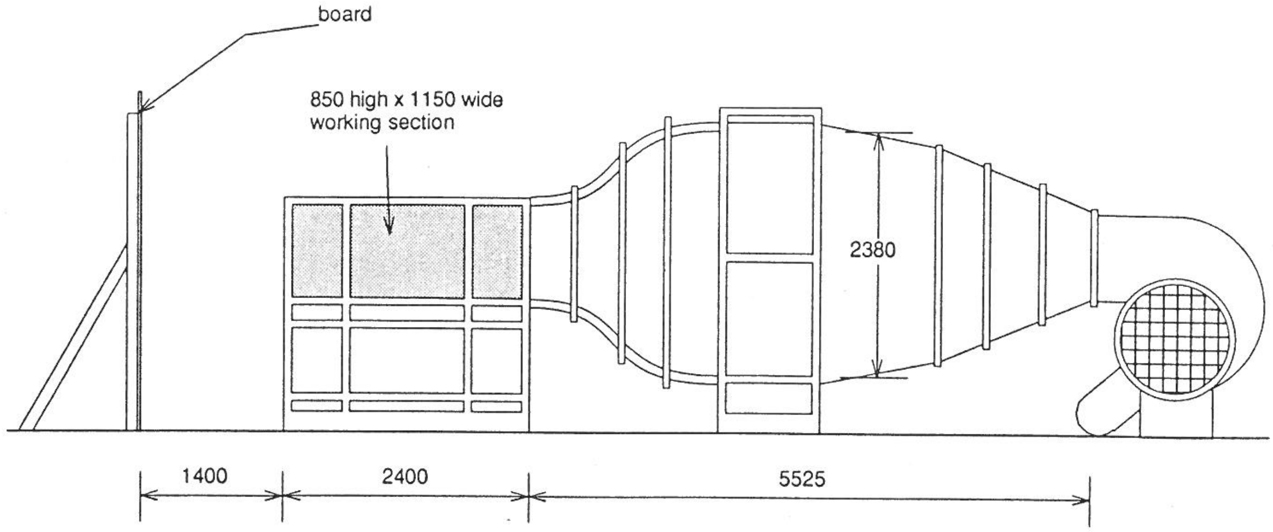


Figure 1. Experimental arrangement

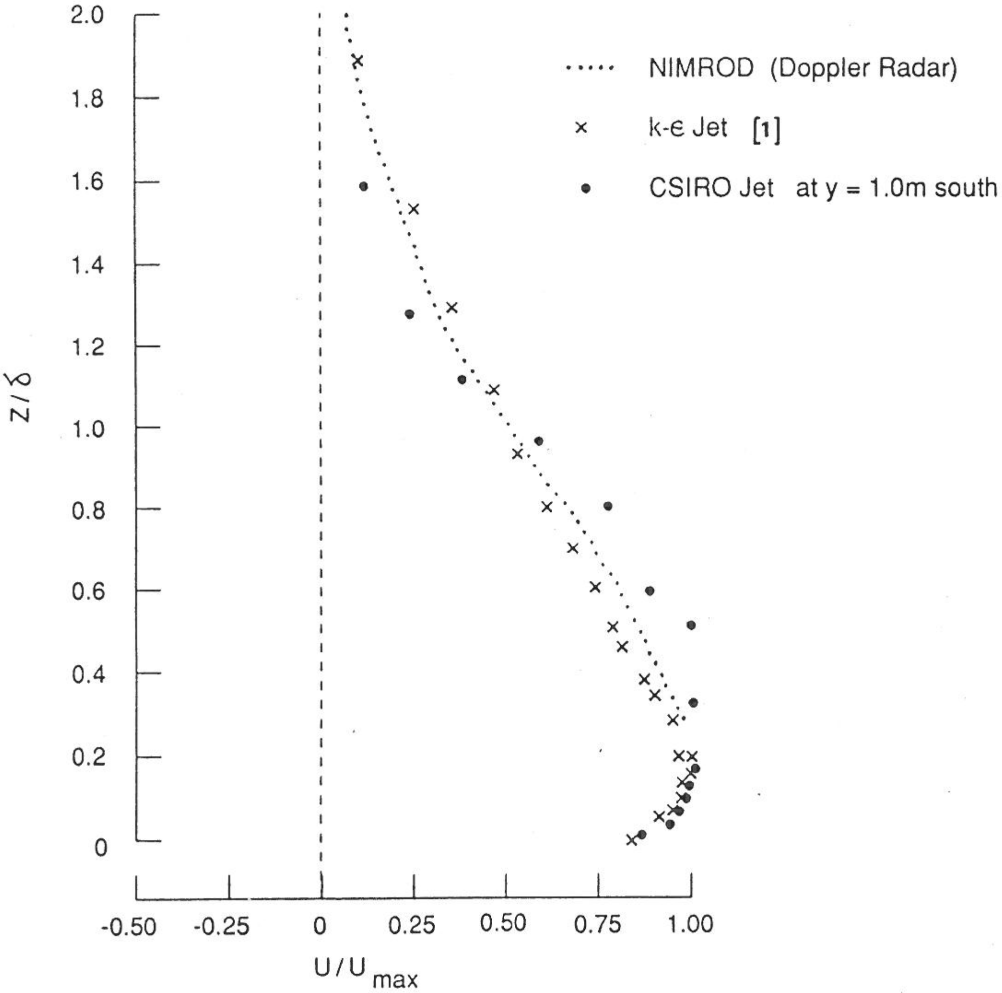


Figure 2. Normalised mean velocity profiles

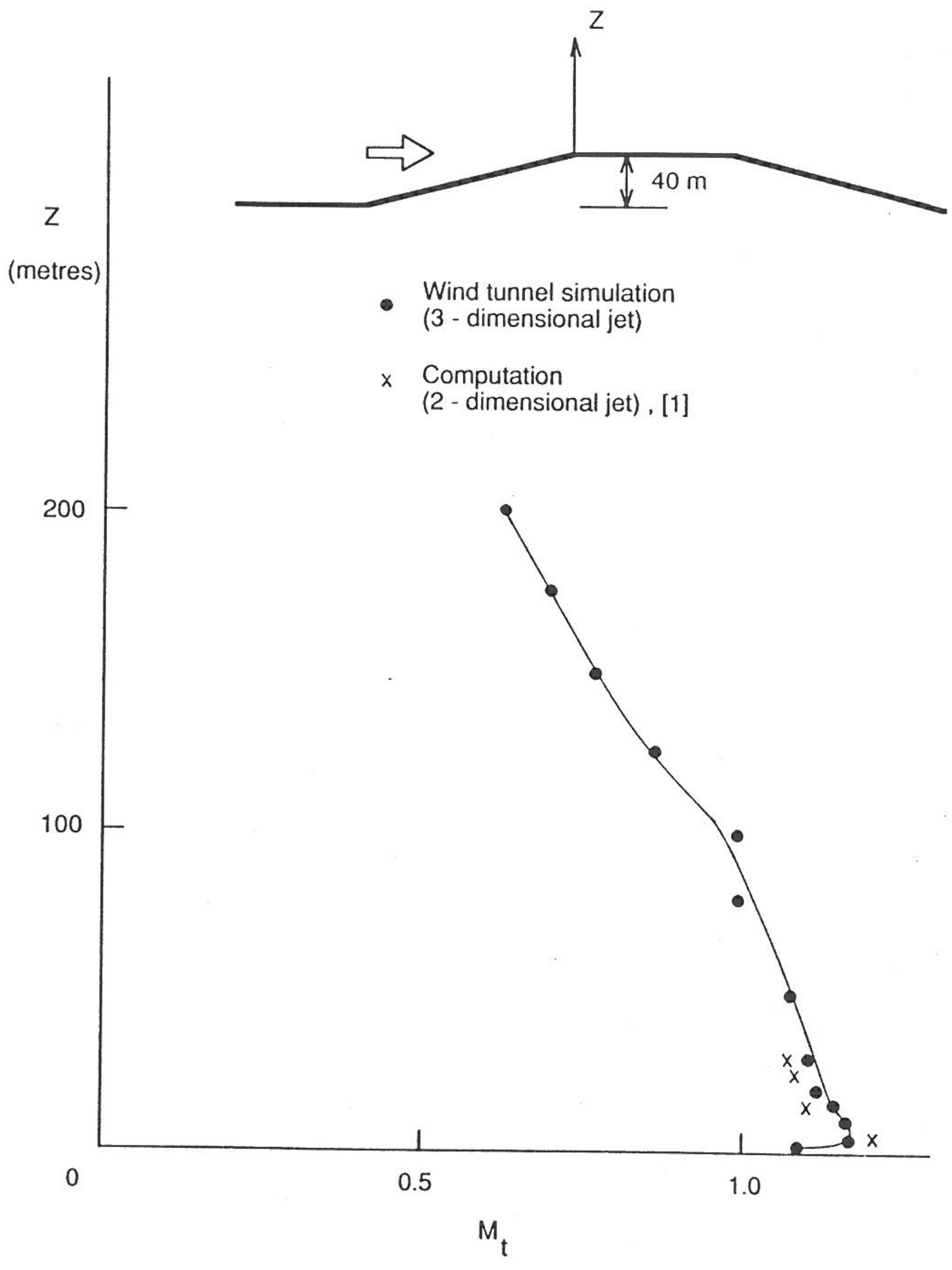


Figure 3. Measured and computed [1] mean topographic multipliers for an embankment.