FLOW SEPARATION FROM A STEEP ESCARPMENT

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INTRODUCTION

The 480 metres high escarpment, which is the subject of this paper, represents a very large bluff body, the flow over which is of considerable practical interest for design of structures such as communication or broadcasting towers. Some early measurements on this feature were described in a previous paper [1], which concentrated on the determination of 'topographic multipliers' for structural design applications. The present paper describes measurements of the mean flow and turbulence characteristics in the vicinity of the separation region above the escarpment, as measured during two successive winters of medium to strong winds.

THE ESCARPMENT

The measurements were carried out on the feature known as Mount Dandenong, which lies about 35 kilometres west of the centre of the city of Melbourne. The top of the escarpment is about 600 metres above sea level, and about 480 metres above the plain to the west. Figure 1 shows a simplified topographic map of the feature, and shows the wind direction from which data was obtained for the present study. Along the line of maximum steepness (approximately North-West), the escarpment has a slope near the top of 0.48. A television broadcasting tower was available, near the peak of the escarpment, for measurements of wind speed and direction at heights up to 69 metres. The approach terrain from the west and north-west consisted of suburban residential and industrial buildings up to about 1 kilometre from the crest; in the last kilometre, i.e. on the slope of the escarpment, there was forest with trees of 15–20 metres height.

Based on the height of the escarpment and the mean velocities of 12–22 m/s, at 69 metres height the Reynolds Numbers for the results in this paper are 4 to 7 x 10^8.

INSTRUMENTATION

The instrumentation used was designed for long-term measurements in severe weather environments and in high electro-magnetic radiation fields. The system consists of a microprocessor-controlled instrumentation module, mounted on the tower, which converts the signals from cup anemometers and direction vanes into a digital data stream, which is sent to an IBM-compatible PC at the base of the tower. The data stream is decoded, and wind speed and direction are displayed in real time, and monitored for trigger levels. When these levels are exceeded, all data are logged and stored on a hard disk for a preset time. A modem connects the site computer by telephone line to the control base, from which control parameters can be set and to which data files can be transferred.

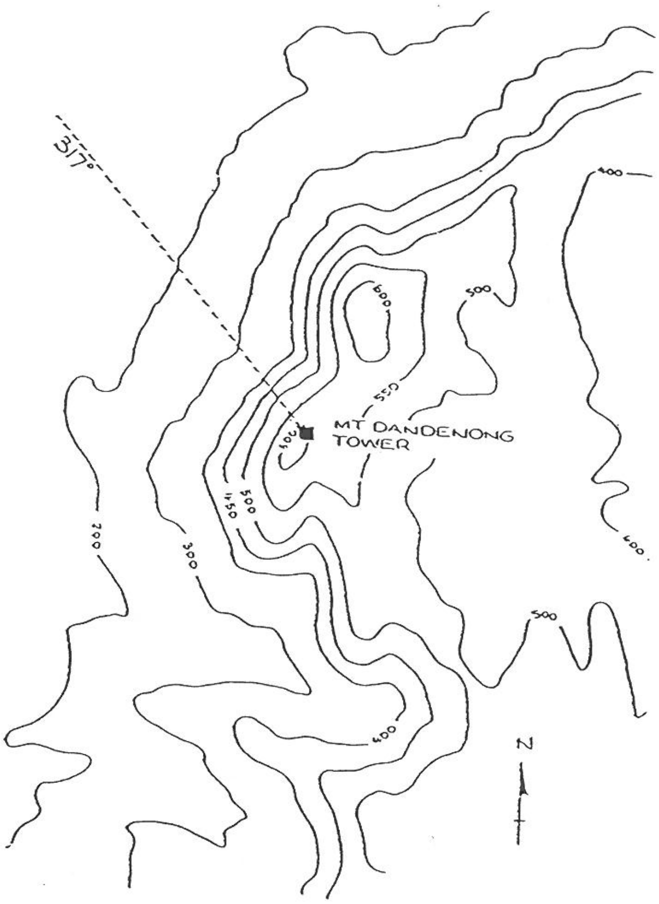

Figure 1. Contour plan of the escarpment.

RESULTS – MEAN FLOW

Results are presented for runs of 5 or 10 minutes duration, for which the mean flow direction at a height of 69 metres on the Mount Dandenong tower, was 317 degrees, plus or minus 10 degrees (see Figure 1). For twenty runs in 1994, measurements were available from heights of 32 metres and 69 metres. For 76 runs in 1995, measurements were made at heights of 45 metres and 69 metres.

From the first set of data, values of the ratio of mean velocities at 32 metres and 69 metres could be obtained, and from the second set, the ratio of mean velocities at 45 metres, and 69 metres, could be derived. These ratios are plotted in Figure 2. Clearly, the mean velocity at 32 metres is very low, compared with those at 45 metres and 69 metres height. Also shown in Figure 2 is the logarithmic law normalised by the mean velocity at 69 metres (dashed). The dotted line is the same law but renormalised by the expected topographic multiplier, M_t, of 1.51 at 69 metres [1], and represents the expected mean velocity profile on the flat level terrain upwind of the escarpment. The fact that the mean velocity ratio at 32 metres lies close to the dotted line is coincidental, but indicates that there is negligible 'speed-up' of the mean flow over the escarpment at this height.

A low measured value of mean velocity at 32 metres would be obtained if this height lay beneath the average position of the separated shear layer from the front of the escarpment, and this is believed to be the reason for the measurements obtained. The separation 'bubble' region is also a region of high turbulence, and this aspect is discussed in the following section.

RESULTS – TURBULENCE

Figure 3 shows the ratio of r.m.s. longitudinal turbulent velocity at 32 and 45 metres compared with that at 69 metres. Figure 4 shows the corresponding ratios for the lateral velocities, derived from the fluctuations in wind direction indicated by the direction vanes. Clearly the r.m.s. velocities at 32 metres and 45 metres are significantly higher than those at 69 metres. This result is again compatible with the location of a separated flow region, or 'bubble', enveloping the 32 metres height, and intermittently affecting the 45 metres height.

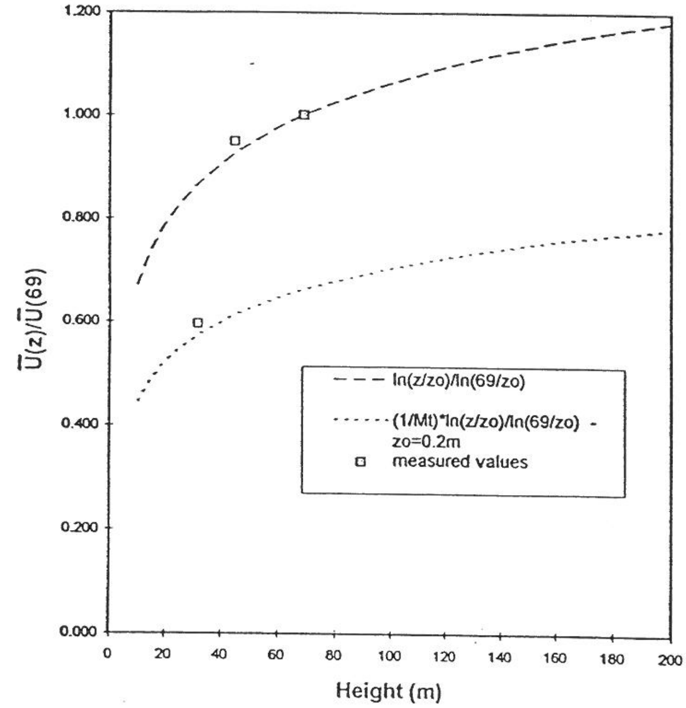

Figure 2. Mean velocity profile.

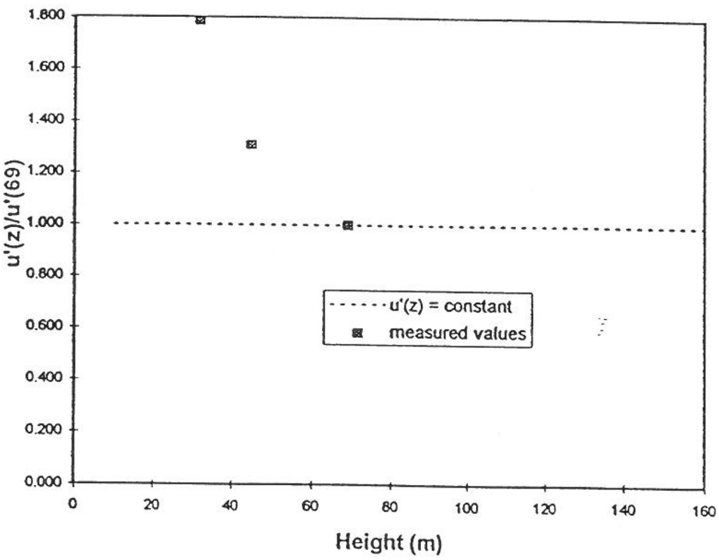

Figure 3. R.m.s. longitudinal velocity.

Figure 5 shows the vertical correlation of the longitudinal velocity components at 32 and 45 metres, with respect to that at 69 metres. The measured values are compared with the exponential expression:

$$\rho(z,69) = \exp - | z - 69 | / {}^{z}L_u \qquad (1)$$

where the length scale ${}^{z}L_u$ has been taken to be 50 metres.

The measured correlations are less than predicted by the empirical expression. Again this is to be expected if the turbulence at 32 and 45 metres is associated with the flow separation from the front of the escarpment rather than the approaching turbulence.

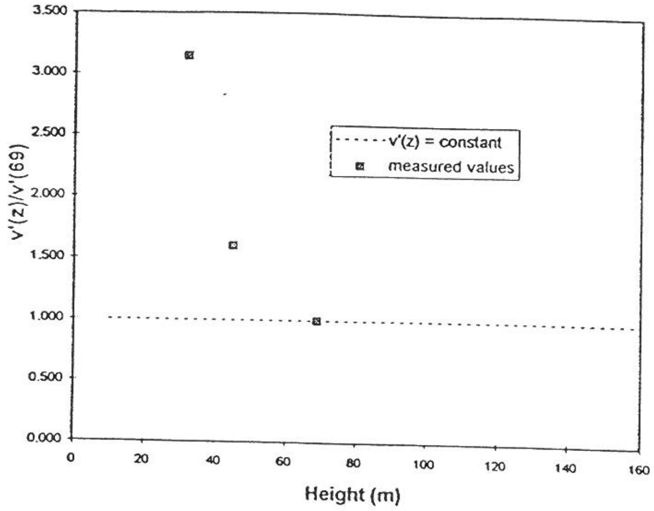

Figure 4. R.m.s. lateral velocity

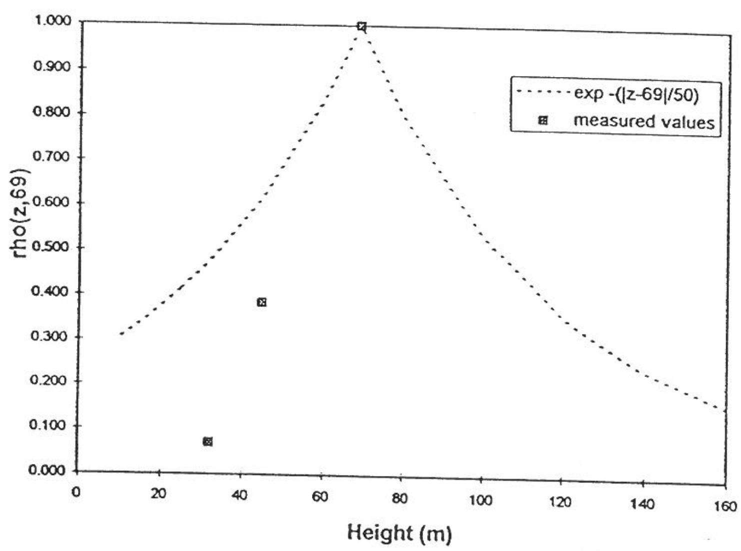

Figure 5. Vertical correlation of longitudinal component.

CONCLUSIONS

Measurements of mean flow and some turbulence parameters at three different heights near the crest of an escarpment, 480 metres high, have been presented. The results indicate the presence of a separated flow region which strongly affects the readings at the lowest anemometer (32 metres), and has a lesser effect on the measurements at the intermediate height (45 metres).

REFERENCES

1. Banks, R.W., Holmes, J.D. and Paevere, P. Full-scale measurements of topographic multipliers for a steep escarpment. Proceedings, Ninth International Conference on Wind Engineering, 9–13 January, 1995, New Delhi. pp 27–35. Wiley Eastern Limited, New Delhi.