First Steps Towards a National Assessment of Australian Wind Risk

Krishna Nadimpalli, Mark Edwards and Bob Cechet - Geoscience Australia

Introduction

Severe wind is one of the major natural hazards in Australia. These severe winds are chiefly produced by cyclones in the coastal north of the continent and cold fronts or thunderstorms in the south. In this study, the wind risk in terms of probable maximum losses and annualised losses was determined for four Australian cities that are subject to this range of extreme wind types; Perth, Cairns, Brisbane, and the Gold Coast. In this process the regional return period wind gusts were defined using the regional wind speeds presented in the wind loadings standard (AS/NZS 1170.2, 2002). Adjustment factors as defined in the same standard were adapted and further applied to evaluate the local wind effects for residential structures. The work has provided some very preliminary indicators of wind risk and has highlighted areas for future research.

Localised Wind Modelling/Multipliers

The impact of severe wind varies considerably between equivalent structures located at different sites due to the local roughness of the upwind terrain, the shielding provided by upwind structures and topographic factors. Wind multipliers quantify how local effects adjust the regional wind speeds (defined as open terrain at 10 m height) at each location. There are three wind multipliers; the terrain/height multiplier (M_z), the shielding multiplier (M_s) and the topographic (also called hill-shape) multiplier (M_t). The relationship between the regional wind speed (V_R) in open terrain at 10 m height, the maximum local (site) wind speed (V_{site}) and the local wind multipliers is:

$$V_{site} = V_R \times M_z \times M_s \times M_t \qquad \text{- EQ. 1}$$

The three wind multipliers were evaluated at high spatial resolution (25 m grid) over the four city regions through the application of satellite remote sensing techniques, GIS software and a digital elevation dataset in conjunction with the topographical formulae in the wind standard. An overview of the methodology that determines terrain/height, shielding and hill-shape multipliers for eight cardinal wind directions is shown in Figure 1. Details of the approach taken are presented under separate headings below.

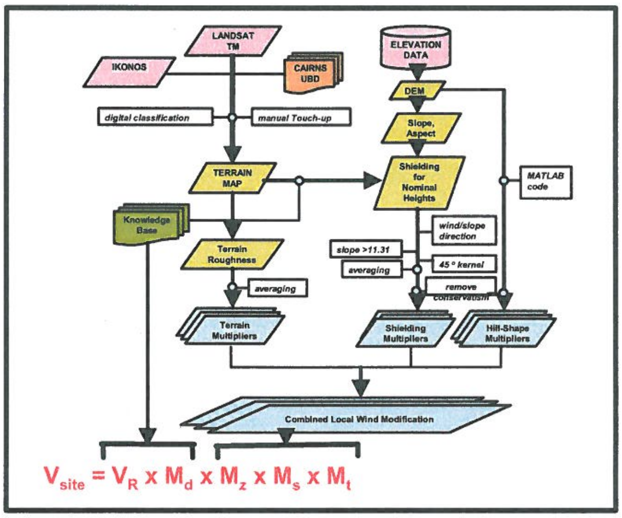

Figure 1. Diagram of methodology used to estimate local wind modification multipliers

Terrain Multiplier (M_z)

Landsat Thematic Mapper data were the primary input used to map the terrain of each study area. They have a 25 m spatial resolution and six frequency bands. Terrain classes from AS/NZS 1170.2 Supp 1 (2002) were used to classify the metropolitan areas for the four cities. These were subsequently converted into M_z values for a 5 m height applicable to the wind hazard for residential structures. Table 1 lists the various terrain classifications, the interpolated terrain categories and the corresponding terrain/height multipliers for a 5 m height derived from Table 4.1(A) of AS/NZS 1170.2.

Table 1. Terrain multipliers derived from AS/NZS 1170.2 for each terrain class in different regions.

Terrain Class	Terrain Category	M_z *(Cairns)*	M_z *(Others)*
City Buildings	4.00	0.8	0.75
Forest	3.77	0.8	0.77
High density (Industrial)	3.65		0.78
Town Centres	3.30	0.8	0.805
Suburban/ Wooded	3.00	0.8	0.83
Long grass with few trees	2.50	0.85	0.87
Crops	2.25	0.875	0.89
Open rough areas/airfield	2.00	0.9	0.91
Cut grass	1.60	0.9	0.966

Shielding Multiplier (M_s)

The shielding multiplier (M_s) of a structure depends on the number of upwind buildings that are located in a predefined shielding zone and have at least the same height as the structure of interest. A formula is provided in the standard which requires a detailed knowledge of the height, width and number of the buildings affording shielding in the upwind sector area. With the assistance of John Holmes (Holmes, 2004) a more generalised method was developed and adopted that furnished a representative overall shielding value and hazard for populations of structures, while lacking accuracy for individual structures.

Topographic Multiplier (M_t)

The topographic (or hill-shape) multiplier, M_t, was estimated using the formulae from AS/NZS 1170.2. The multiplier was evaluated on a 25 m grid using code that interrogated DEM (digital elevation model) derived long sections that extended several kilometres either side of the point of interest to capture the basic two-dimensional topographic features and assign M_t values.

Spatial Distribution of Regional Wind Speed

In the application of this "first steps" methodology to the four city regions, return period regional wind speeds for severe gusts were taken from AS/NZS 1170.2. The wind speeds were derived from an analysis of weather station observations made at several locations around Australia which were assigned to broader zones due to the uncertainties in the data. Degrees of conservatism are present in some of the values (e.g. Region C), due largely to the design focus of the source document.

Damage Estimation and Risk Calculation

There is presently a paucity of Australian wind vulnerability models for buildings. Adopting models published in the international literature could lead to errors as building construction varies around the world and insurance loss derived relationships incorporate distortions. For these studies the insurance data derived relationships developed by Dr. George Walker of Aon Re (Walker, 2005) for North Queensland structures were used. Walker's pre-1980 curve represents the vulnerability of North Queensland residential structures before the lessons of cyclones Althea (1971) and Tracey (1974) influenced construction practice. His post-1980 curve shows a significantly reduced vulnerability as achieved through changes to the Queensland Building Act. Both curves were used for the Cairns study and assigned on the basis of building age. Walker's pre-1980 vulnerability curve was utilised for the residential building populations of Perth, Brisbane and the Gold Coast. A lower vulnerability for Brisbane and Gold Coast contemporary homes could be anticipated due the application of higher building standards but was not captured in this present work.

The return period of exceedence loss levels (50, 100, 200, 500, 1000 and 2000 years) were evaluated at Census District (CD) level across each region. In turn the CD losses were aggregated to full study region losses. The values obtained are presented in Table 2 and are plotted on a semi-log plot in Figure 2. As a first step is assessing wind risk these were regressed to obtain a Probable Maximum Loss (PML) curve for each study region. The losses represented by the curve range from frequent minor losses through to catastrophic wind events that have disastrous effects on the region.

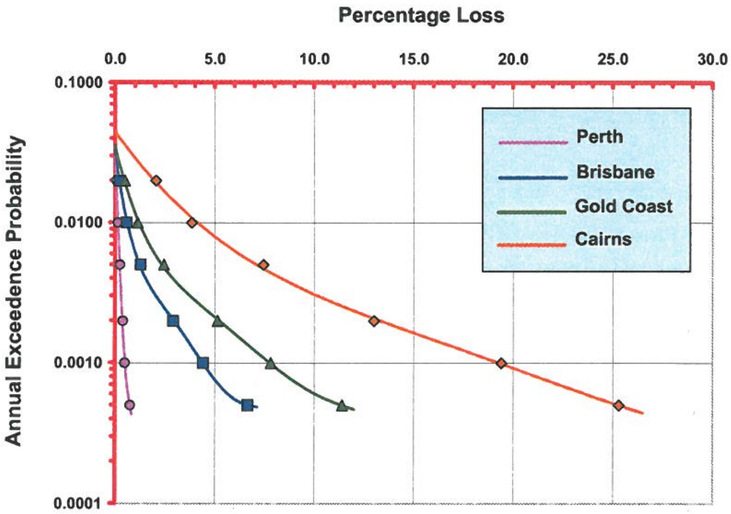

Figure 2. Probable Maximum Loss curves for the four metropolitan regions at each of six return periods

Annualised losses were also evaluated for each study region using the PML curves. These losses represent the average annual cost to the region due to exposure to the hazard in question if viewed through a very wide window in time. For the risk studies reported, a time window of 2000 years was adopted. Expressing the annualised loss as a percentage of total reconstruction cost gives a measure of the intensity of the risk to the studied community that is not so evident in simple dollar values. Annualised losses are also presented in Table 2.

The regional wind speeds in AS 1170.2 yielded the highest wind risk for cyclonic Cairns. If regional wind speeds derived by Harper (1999) are used, which were derived using the relatively short (45 years) observed Cairns region cyclone history, this risk would be much smaller. The Gold Coast and Brisbane were also assessed to have significant risk, though lower than Cairns. The Gold Coast losses were calculated to be double those of Brisbane which may be partly due to the more exposed and coastal nature of Gold Coast residential development. The wind risk of the Perth metropolitan area was found to be relatively small.

Table 2. Percentage losses for the four metropolitan regions at each of six return periods using AS/NZS 1170.2 regional wind speeds.

Return Period	Perth	Cairns	Brisbane	Gold Coast
50-years	0.07	2.0	0.2	0.5
100-years	0.13	3.8	0.6	1.1
200-years	0.24	7.4	1.3	2.4
500-years	0.38	13.0	2.9	5.1
1000-years	0.48	19.4	4.4	7.8
2000-years	0.74	25.3	6.6	11.4
Annualised	**0.0039**	**0.131**	**0.021**	**0.040**

Summary and Directions for Future Research

This work represents the first step in the development of a national methodology for severe wind risk. At this stage it contains considerable uncertainty in the assessed risks due to both incomplete data and the modelling assumptions made. However, the methodology will be progressively refined and improved until the goal of reliably estimating the risk posed by peak wind gusts is achieved. The research reported has pointed to the following research areas that need to be pursued:-

- The hazard definition has a direct bearing on the assessed risk. Clearly improved assessments of regional wind speed are required. To this end GA will be working with the Bureau of Meteorology and CSIRO to assess the spatial variation of regional wind speed in the Australian region.
- Local factors greatly influence local wind speeds, the most significant of which is the topographic multiplier. Over the following year GA will be evaluating the topographic multiplier, M_t , using 3D analysis that will capture complex terrain and topographic shielding not addressed by current wind loading standards methodologies.
- Building vulnerabilities directly influence damage assessment. Work is continuing with the Cyclone Testing Station of James Cook University to develop residential vulnerability models for a wide range of structure types. A workshop of wind engineers is proposed this calendar year to heuristically derive an initial suite of wind curves for Australian structures which will be progressively refined.
- The statistical hazard assessment approach has limitations and tends to over-estimate risk. The methodology will move from the current hazard map approach to one which is event based. This will involve the use of both a tropical cyclone wind model and a general synoptic scale wind model for the Australian region. Stochastic "event-based" modelling of the assumed climatology will then follow using a Monte Carlo sampling technique to allow the full range of environmental parameters to be explored.

References

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