Regional Wind Multiplier development for Australia: A Broad Brush approach

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1 INTRODUCTION

The current study has developed a national methodology for assessing the hazard that peak wind gusts pose to Australian communities. The key components of the hazard assessment model include the regional wind hazard and the hazard modification multipliers. The local effects on return period regional wind speeds were determined utilising remote sensing techniques, digital elevation data, and formulae presented in the wind loadings standard AS/NZS 1170.2 [1]. The estimation of the local wind speeds was evaluated by combining the local wind multipliers (terrain/height, shielding and topographic) for eight cardinal directions with the return period regional wind speeds (from [1]) on a 25 metre grid across the areas examined for each region. Here we seek to use the 500 year return period wind gust hazard from the Australian/New Zealand wind loadings standard (AS/NZS 1170.2) [1], which is a building design document that seeks to "envelope" possible wind effects, as a proxy for the regional hazard. Arthur *et al*. [2] provide a new hazard assessment for the Australian continent, which we plan to utilise in future updates. Tanh and Letchford [3] compared current US, Australian/New Zealand, European and Japanese wind standards and reported that the treatment of topographic effects in these design standards is on the whole conservative. Holmes [4] proposed adjustments to remove the conservatism from the methods in the Australian wind loading standard to assess risk. These proposals and several other initiatives were adopted to improve various components of the model from its initial steps [5] towards a reliable nationally consistent wind hazard assessment for Australia.

2 METHODOLOGY

There are three wind multipliers named terrain/height multiplier (M_z), shielding multiplier (M_s) and topographic (hill-shape) multiplier (M_h). The return period windspeed for each of eight cardinal directions can be determined using a fourth factor, M_d. The relationship between the regional wind speed (V_R) in open terrain at 10 metre height, the maximum local (site) wind speed (V_{site}) and the local wind multipliers (referred to here as the M4 multipliers) is:

$$V_{site} = V_R \times M_z \times M_s \times M_h \times M_d \qquad \text{(Equation 1.)}$$

For this study, the spatial algorithms developed from the wind multiplier formulae detailed in [1] and [6] were used to estimate the influence of terrain and topography. These algorithms are used to quantify local wind conditions at each location. Over city and major town urban regions the wind multipliers were evaluated at high spatial resolution (25 metre grid) by applying remote sensing techniques, GIS software and elevation datasets in conjunction with the formula. The principles of surface roughness and hill shape are defined in AS/NZS 1170.2 [1]. The principles are conservative and are prone to estimate excess wind speeds. Spatial algorithms were developed to estimate the influence of terrain and topography. A significant attempt was made to remove the conservatism associated with the wind loading standard in the spatial approach of wind multipliers. The Chair of the Australian wind standards committee, Prof. John Holmes, has reviewed the wind multipliers approach [4], which is detailed in [7] as applied to the Perth region.

Probabilistic M4 calculations for SLA

The influence of all multipliers was aggregated to 1388 areas (statistical local areas; SLA's) over the Australian region using a cumulative probability approach developed utilising the results from all major cities and some towns. Only wind multipliers relevant to current urban and peri-urban regions were evaluated (i.e. only regions containing residential housing were assessed). This work has been used in a study that assesses wind risk on residential housing [8], and therefore the remainder of the SLA areas was not considered (which cover commercial, industrial and environmental regions). The cumulative probability approach was used to estimate and aggregate the influence of the wind multipliers for ABS mesh-block regions within SLA areas containing residential structures, for a sample of over 100 SLA's, (capital cities and major towns). This approach was generalised to the entire Australian region by matching non-sampled SLA's with sampled SLA's considering the percent slope, aspect (direction of slope), building density, vegetation cover and the wind loading region.

Hazard extraction - Probability calculation

Maximum values from eight cardinal wind directions of all the four multipliers (topographic, terrain, shielding, and directional) were extracted as one raster dataset. This maximum value spatial dataset was clipped to SLA boundaries containing points with M4 value. The frequency and cumulative frequency of each M4 value in the SLA was calculated using a frequency analyzer. Table 1 shows the frequency and cumulative frequency of M4 values for the Hobart-inner SLA. The cumulative frequency of M4 is then "density-sliced" to select a small range of discrete values to represent the full range depicted. This was determined using a graphical/mathematical approach shown in Figure 1. An XY scatter plot was drawn between M4 values (on x axis) and the cumulative frequency of M4 (on y axis) and the small range of values (usually 5 to 7 M4 values) extracted manually to represent the full range. The range distribution of M4 probability is recorded from the scatter plot, and the fit of this reduced number of M4 values for the Hobart-inner SLA is shown in Table 2. The probability values of the M4 cumulative probability distribution were then used with the maximum wind speeds (from AS/NZS 1170.2, [1]) to calculate the hazard for each SLA region.

M4	FREQUENCY	CUM_FREQENCY	M4	FREQUENCY	CUM_FREQENCY
0.76	1	1.000	0.59	53	0.635
0.75	6	0.999	0.58	84	0.581
0.74	5	0.993	0.57	69	0.496
0.73	4	0.988	0.56	77	0.426
0.71	1	0.984	0.55	116	0.348
0.68	3	0.983	0.54	66	0.230
0.67	7	0.980	0.53	41	0.163
0.66	13	0.973	0.52	34	0.122
0.65	34	0.959	0.51	37	0.087
0.64	65	0.925	0.50	20	0.050
0.63	61	0.859	0.49	18	0.029
0.62	70	0.797	0.48	9	0.011
0.61	48	0.726	0.47	2	0.002
0.60	42	0.677			

Table 1. Cumulative frequency of M4 values in Hobart – inner SLA

Range_Low	Range_high	Midvalue	M4	Range Difference	M4* Difference		%Probability
0	16	8	0.5	16	8		0.16
16	34	25	0.54	18	9.72		0.18
34	49	41.5	0.56	15	8.4		0.15
49	72	60.5	0.58	23	13.34		0.23
72	79	75.5	0.61	7	4.27		0.07
79	92	85.5	0.63	13	8.19		0.13
92	97	94.5	0.65	5	3.25		0.05
97	100	98.5	0.73	3	2.19		0.03
				Sum ofM4* Difference	57.36	0.5736	
Probabilistic M4_SLA = 0.57							

Table 2. Probabilistic M4 values for Hobart – inner SLA

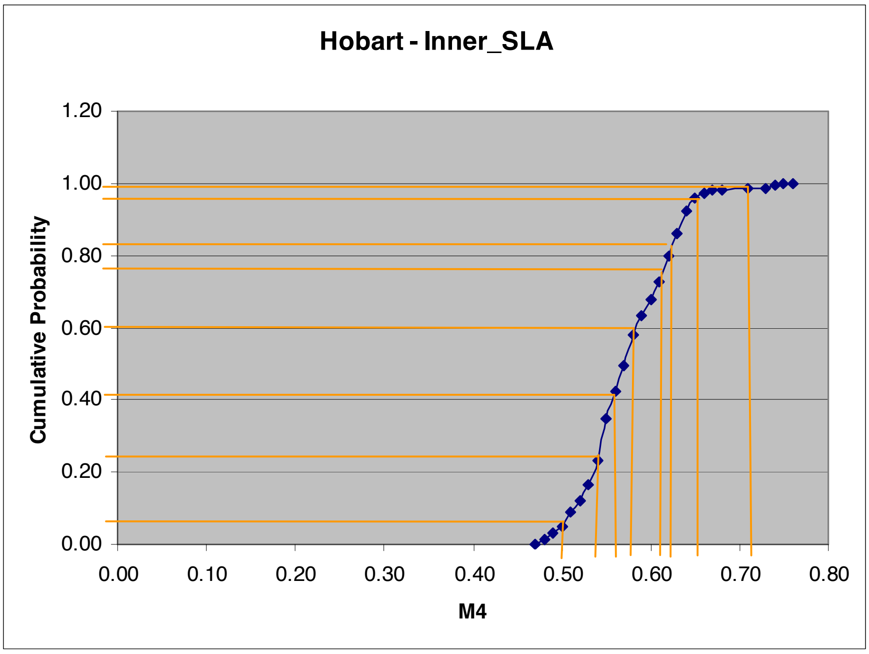

Figure1: Cumulative probability extraction based on M4 distribution trend at SLA level.

Procedure for Generalization / Broad-brush of probabilistic M4 values for un- sampled SLAs
Terrain roughness and shielding effects are compared between sampled and un-sampled SLAs visually from satellite imagery, with density and estimated height of built-up areas (residential areas only) used as the basis for comparison. Topography is compared, taking slope into consideration from visual interpretation of DEM and satellite imagery. Un-sampled SLAs with maximum visual similarities in roughness, shielding and topographic factors to that of sampled SLAs are assigned the same probabilistic wind speed (M4) values.

3 CONCLUSIONS

We have developed a national methodology for assessing the severe gust wind hazard for 1388 Statistical Local Area (SLA) regions of the Australian continent (Fig. 2). The key components of the hazard assessment model include the regional wind hazard from AS/NZS 1170.2, 2002 [1] and the hazard modification multipliers, determined spatially at high-resolution utilising remote sensing techniques, digital elevation data, and the formulae presented in the wind loadings standard [1]. This approach was generalised to the entire Australian region by matching non-sampled SLAs with sampled SLAs considering the percent slope, aspect (direction of slope), building density, vegetation cover and the wind loading regions. This analysis is being utilized as part of the National Wind Risk Assessment (NWRA), a collaborative project between Geoscience Australia and the Department of Climate Change and Energy Efficiency.
Next step forward considers specific case study regions (current and scenarios for future climate) where the hazard, vulnerability and risk are assessed at the building level. The specific case study regions are of the following communities:-
Cairns/Innisfail was selected as one of the study regions because it is in AS/NZS 1170.2 (2002) Region C (cyclonic) and also due to the excellent understanding of the structures due to Geoscience Australia "house-to-house" surveys associated with the *Cairns Cities* project.
Hobart was selected because of the high quality residential buildings exposure database available from the Tasmanian Valuer Generals office, and also due to the fact that wind hazard is likely to increase due to a strengthening of the westerly pressure gradient in a changing climate [9] [10]. Hobart is in AS/NZS 1170.2 (2002) Region A.
Perth and **Southeast Queensland**, which are in AS/NZS 1170.2 (2002) Region A and Region B respectively, were selected due to the concern regarding the southward movement of cyclone tracks influence by climate change.

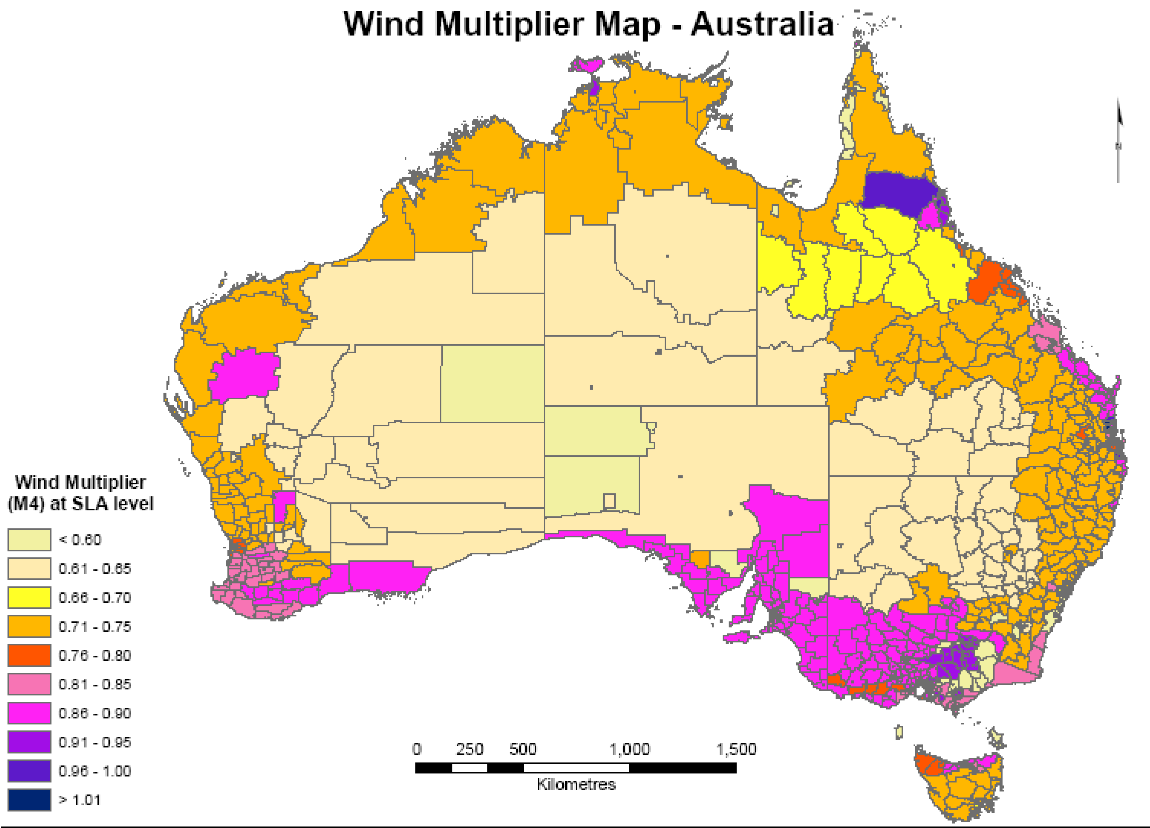

Figure2: Maximum gust wind speed (Multiplier) values of Australia at SLA level

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