Impact of climate change on wind risk in Tasmania: A sensitivity study in preparation for the Climate Futures Tasmania CERF project

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Abstract

CSIRO climate change projections based on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) indicate that Tasmania is one of the areas within the Australian region that will experience an increased magnitude of severe winds. Here we undertake a severe wind hazard sensitivity study in preparation for the *Climate Futures Tasmania* CERF project. This study determines the relationship between the wind hazard and risk for the Tasmanian region, assuming the hazard varies uniformly throughout the region. The base hazard was taken from the Australia/New Zealand wind loading standard and varied in the range -5% to +20% (in increments of 5%). Two regions of the island of Tasmania were considered; one in the north (including Launceston, Burnie and Devonport) and one in the south (includes Hobart). The analysis determined that the wind risk was proportional to the wind hazard for the hazard range considered.

Introduction

Climate change will result in global warming that will be expressed by significant regional and local differences in the magnitude of the warming. While the entire globe is expected to warm, the regional differences associated with severe wind hazard are likely to show both regional increases and reductions. CSIRO climate change projections based on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) indicate that Tasmania is one area within the Australian region that will experience an increased magnitude of severe winds (CSIRO, 2007). Figure 1 shows the seasonal changes in the 90th percentile mean 10 metre wind speed for the Tasmanian region. Increases in the extremes (peak gust) are expected to be greater than the mean increase based on detailed modelling undertaken in regional studies (similar to what will be undertaken for Tasmania by CFT). The diagram suggests a greater than 15% increase in the Winter, Spring & Summer seasons which should be of significant concern to emergency services and the community as a whole (impacts with regard to planning, building standards, agriculture, water resources are expected). The physical basis for this increase in wind hazard is that the synoptic "westerly stream weather" (i.e. cold fronts embedded in the mid-latitude westerly winds) will be influenced by an increase in the pressure gradient between the synoptic sub-tropical ridge, which climate models suggest is moving polewards (Hope *et al.*, 2006; Hope, 2006) and the polar front which is expected to remain approximately stationary. Analysis of the model output used for the CSIRO assessment indicates a general agreement regarding this broad climate trend. Significant differences in model performance were evident (Suppiah *et al.*, 2007) suggesting a weighed approach, based on current climate performance (i.e. rejecting poor simulations) may be prudent.

Climate Futures Tasmania Project

Climate Futures for Tasmania is a Commonwealth Environmental Research Facilities (CERF) funded project aimed at informing climate change adaptation options. It will produce fine scale (10-15 km resolution) climate projections for Tasmania under a range of accepted greenhouse emission scenarios. These projections will inform diverse stakeholders about likely impacts of climate change on conditions that are important for their decision making and operations. Outputs will be tailored to produce information stipulated by stakeholders to be most important to their activities. Analyses will be focussed in three main areas of climate futures: a) water status in catchments and reservoirs; b) normal, average climate conditions; and c) extreme events, including severe winds, flooding, and coastal inundation. Geoscience Australia is a partner in the study, providing severe wind hazard and risk evaluation (local level) for both the current climate and a range of future climate scenarios.

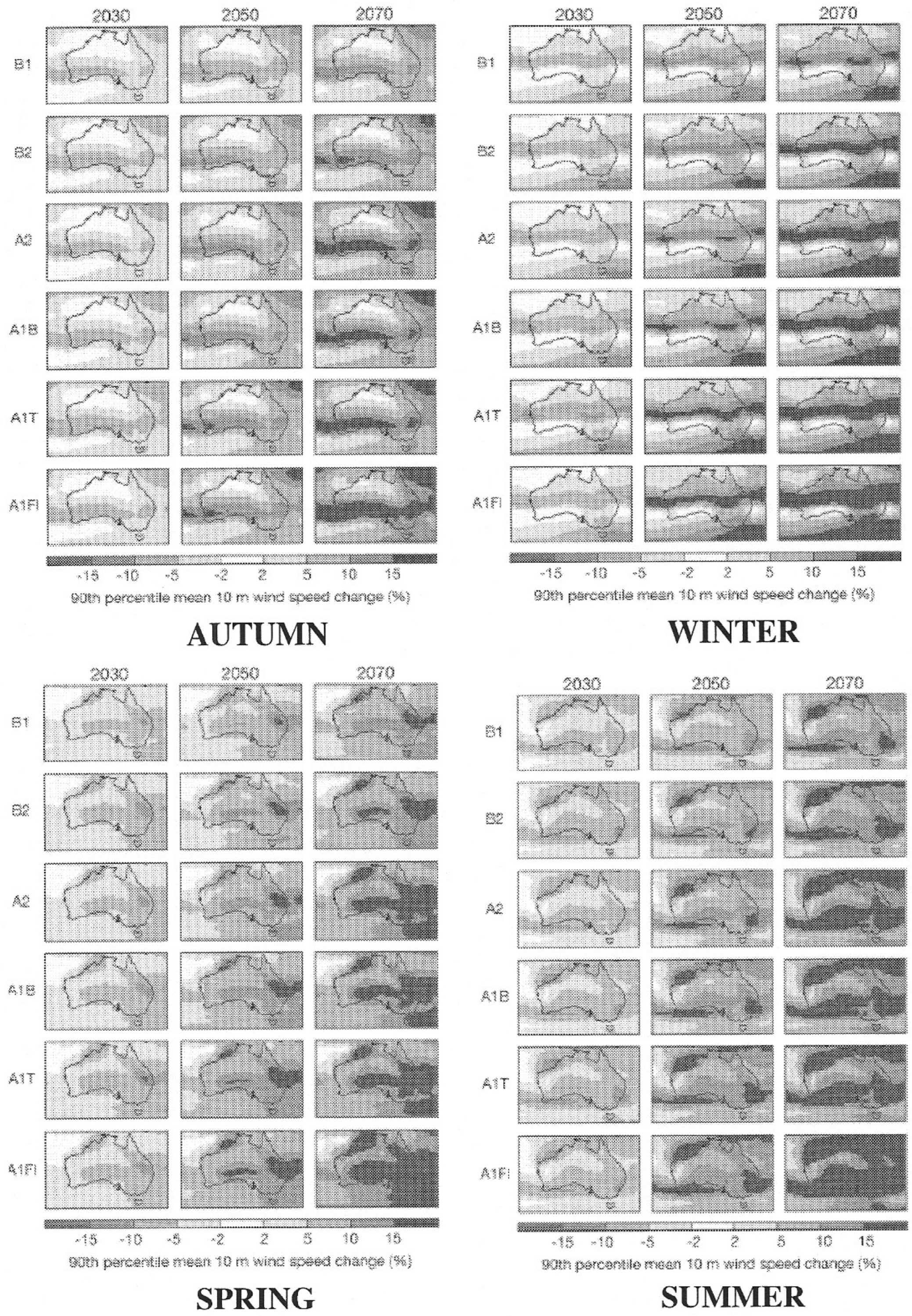


Figure 1. Best estimate 90th percentile mean 10 metre wind speed change (%) for 2030, 2050 and 2070 and six SRES emission scenarios (from CSIRO, 2007).

Risk Methodology

The risk methodology is comprised of hazard, hazard multipliers, infrastructure exposure and vulnerability (Nadimpalli *et al.*, 2007a). The hazard definition is based on the science behind the wind phenomena (cyclone, thunderstorm downburst, tornado, etc) and historical wind data captured at various observation sites. These can be used to simulate events of known rarity or to develop a statistical definition of return period wind speeds at various locations. Probabilistic models predict the likelihood of severe wind speeds being exceeded at a particular location. For this study, probabilistic wind speeds were considered for 50, 100, 200, 500, 1000 and 2000-year return periods. It should be acknowledged that applying the probabilistic wind speed across the whole study area is an approximation; presently utilized in the absence of an event set that characterizes the full range of possible events for the region being considered.

Hazard

The return period regional wind speeds for severe gusts were taken from the Australia/New Zealand wind loadings standard (AS/NZS, 2002). These wind speeds refer to peak 3 second wind gusts at 10m height above ground in level country and were derived from a small number of meteorological recording stations within each of the regions defined in the standard. For the Tasmanian region, meteorological observation from Hobart, Launceston and Wynyard were considered. The 500-year return-period regional design wind speed (V_R) is 45 m/s, and this sensitivity study varies this parameter from 42.75 to 54 m/s.

Wind Multipliers

The impact of severe wind varies considerably between structures at various locations due to the geographic terrain, the height of the structure concerned, the surrounding structures and topographic factors. Wind multipliers quantify how the local conditions adjust the regional wind speeds at each location. There are four wind multipliers; the terrain (roughness) multiplier (M_z), the shielding multiplier (M_s), the topographic (hill-shape) multiplier (M_t) and directional multiplier (M_d). 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:

$$V_{site} = V_R \times M_d \times M_z \times M_s \times M_t \quad (1)$$

Most damage prediction models take little or no account of the effect of wind direction on regional wind hazard (Holmes, 2004). The directional multipliers in AS/NZS, 2002 have been used in this research as they provide a reasonable measure of the directional characteristics of the regional wind hazard. The surface roughness was used to estimate the terrain/height multiplier and the shielding multiplier. LANDSAT Thematic Mapper (TM) data, which has a 25m spatial resolution was considered to have the best resolution to map and model the spatial variability of the surface roughness. A terrain map for the study region was developed using the terrain classes from the wind loadings standard commentary (AS/NZS Suppl, 2002). The classes were used to classify the urban and peri-urban regions of the areas considered using a range of maximum likelihood algorithms.

The topographic multiplier was estimated using the formulae in the wind standard (AS/NZS, 2002) and also the topographic features of each region captured by a DEM (digital elevation model). Adjustment factors are applied to the derived multipliers to adjust for conservatism in a similar approach to that used for shielding. Windlab Systems was contracted to calculate roughness and topographic accelerations for the regions. The accelerations are calculated at the 10 metre height using the statistical analogue method for the roughness accelerations and the Raptor model (the fine-scale model within *Windscape*) for the topographic accelerations (Ayotte and Taylor, 1995).

Exposure Information

Fundamental to any risk assessment is an understanding of exposure, which includes number and type of buildings, businesses, critical infrastructure and people. The National EXposure Information System (NEXIS) was used to define exposure. NEXIS provides nationally consistent exposure information at buildings level (Nadimpalli et al., 2007b). Specific information regarding the buildings in the region considered was provided by the Tasmanian Valuer Generals office. The NEXIS database contains details necessary for reliable risk assessment including structural system, replacement cost factors, business activity and population demography. It is integrated with a range of hazard models (earthquake, severe wind and tsunami) along with infrastructure failure to assess structural damage and socio-economic impact. This system provides a representative assessment of exposure to various hazards at building location level resolution and demonstrates the geographic distribution of exposure for regional planning in local government areas. For this study, NEXIS provided only the residential exposure for wind risk assessment (direct impact only; indirect impacts such as business disruption not considered). The two areas being considered, North and South Tasmania, are shown in Figure 2, with the cities/towns where building information was utilised highlighted in yellow.

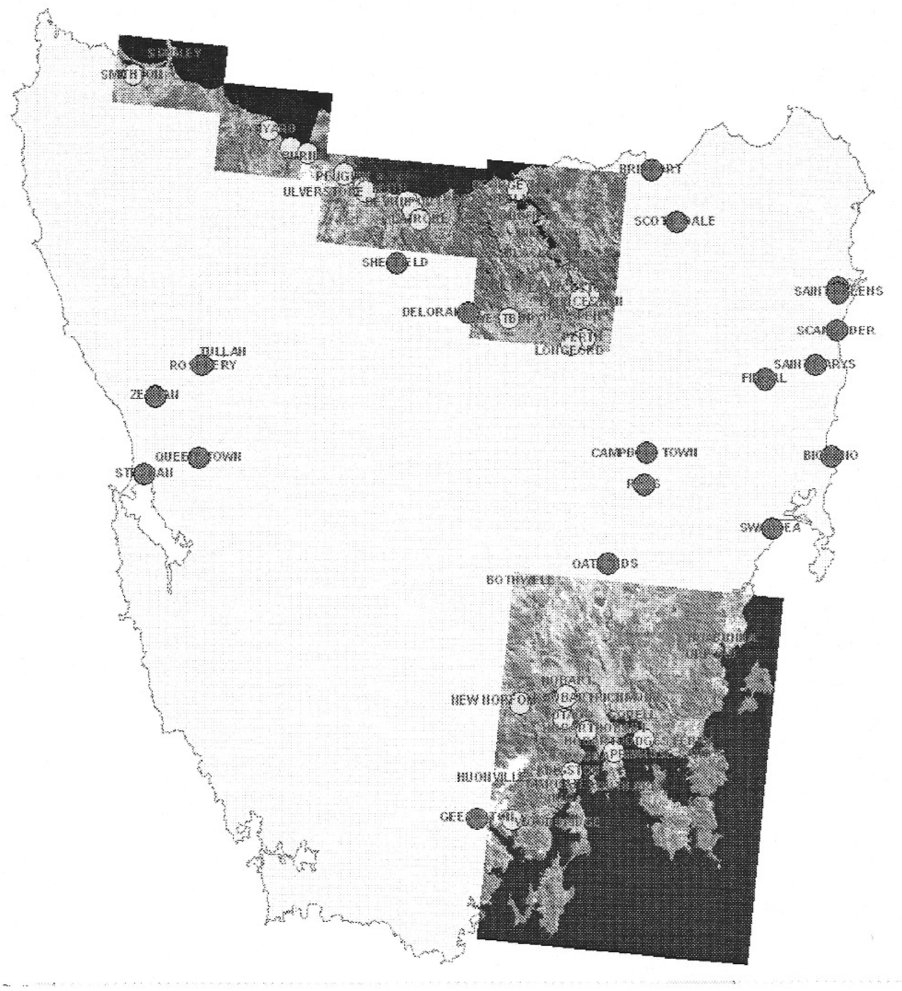


Figure 2. Towns (major business and residential centres) identified and considered as part of South & North Tasmania infrastructure (shown in yellow).

Vulnerability

There is a paucity of published wind vulnerability models applicable to Australian structures. The insurance and reinsurance industry have proprietary models but these are not readily available. Vulnerability is a key component of any wind risk assessment, and Geoscience Australia is conducting research directed at improving the knowledge of wind vulnerability. Through a series of expert workshops and the systematic collection of post event wind damage data a limited suite of residential wind vulnerability curves have been developed. These largely heuristic relationships were used for this study.

Risk Estimation

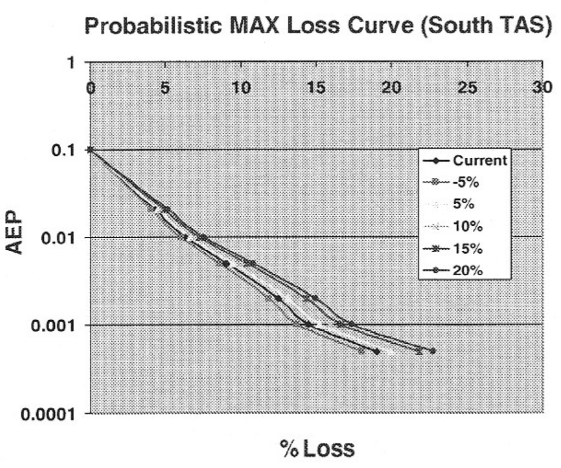
The return period of exceedence loss levels (50, 100, 200, 500, 1000 & 2000 years) were evaluated at building level across each region. In turn these losses were aggregated to obtain study region losses. As a first step in assessing wind risk these were regressed to obtain a Probable Maximum Loss (PML) curve for each study region. These were subsequently used to evaluate annualised losses, which represent the average annual cost to the region of 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 the total reconstruction value gives a measure of the intensity of the risk to the studied community that is not as evident from simple dollar values.

Results and Discussion

This study seeks to determine the approximate relationship between the wind hazard and risk for the Tasmanian region, assuming the hazard varies uniformly throughout the region (as it does in AS/NZS, 2002)). The base hazard was taken from the Australian/New Zealand wind loading standard and varied in the range -5% to +20% in increments of 5%. The analysis determined that the wind risk was proportional to the wind hazard for the hazard range considered (i.e. approx. 10% increase in hazard results in a similar percentage increase in risk). The exposure and vulnerability relationships were consistent (not varied) for each hazard utilised in the risk assessment.

Figure 3 shows a regression of the hazard return period (expressed as the annual exceedence probability; AEP) to the percentage building population, known as the Probable Maximum Loss (PML). The South Tasmania and North Tasmania regions are shown separately, however results are very similar indicating a strong similarly in the building population (construction types and building ages). The area under each PML curve was integrated to evaluate an annualised loss for each PML curve, and the annualised loss estimates for each hazard level (and each region) are plotted in Figure 4.

There appears to be approximately a linear relationship between the wind hazard and the wind risk for the two Tasmanian regions considered. This assessment assumes that the hazard varies uniformly throughout the region. The *Climate Futures Tasmania* Project will in time inform the level and spatial variability of the current climate hazard (including directional characteristics) as well as the hazard that can be expected under a range of future climate scenarios. These outputs will be crucial to informing climate change adaptation options with regard to wind loading for the Tasmanian region.



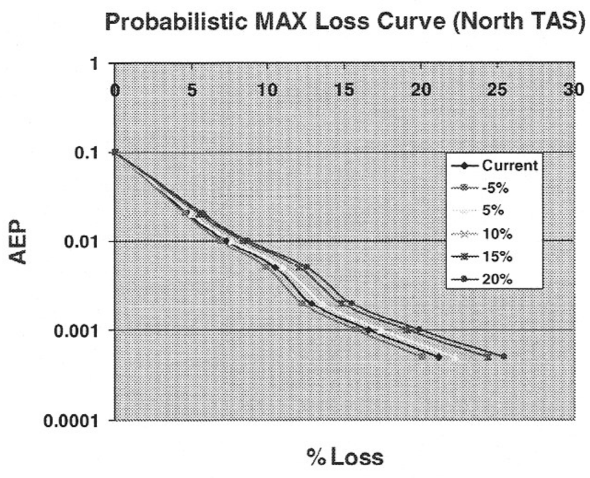


Figure 3. Probable Maximum Loss (PML) curves for the South Tasmania and North Tasmania regions showing the relationship between the annual exceedence probability (AEP) for the hazard and the percentage population loss.

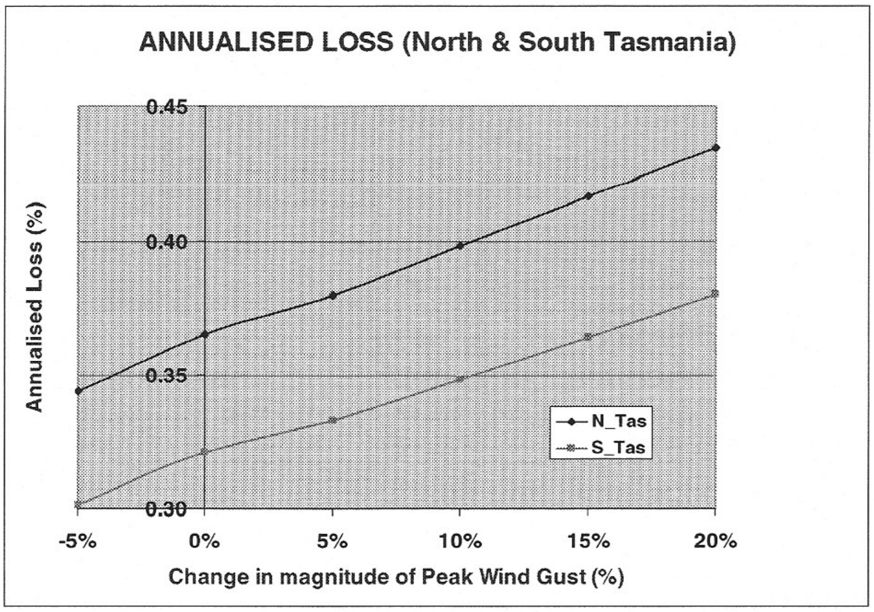


Figure 4. The annualised loss estimates (% of building reconstruction value) for each hazard level and each region, expressed as a percentage change in hazard (peak wind gust).

Conclusion

Analysis of the modelling results from IPCC Fourth Assessment Report (AR4) indicates that Tasmania is one of the areas within the Australian region that will experience an increased magnitude of severe winds. This study was undertaken to assess the sensitivity of the wind risk to changes in the wind hazard (in preparation for the *Climate Futures Tasmania* CERF project). It was determined that an approximately linear relationship exists between the wind hazard and the wind risk for the two Tasmanian regions considered (assuming the hazard varies uniformly throughout the region). *Climate Futures Tasmania* will provide a high resolution assessment of the current wind hazard for the Tasmanian region as well as an indication of how this hazard will change, including spatial extent, under a range of climate change scenarios. These outputs will be crucial to informing climate change adaptation options with regard to wind loading for the Tasmanian region.

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