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New Research to Review New Zealand Design Wind Speeds in AS/NZS 1170.2, Incorporating High Resolution Numerical Weather Modelling

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Abstract

Regional design wind speeds in New Zealand have remained essentially unchanged for the past 20 years and the analysis and reasoning for these speeds is being lost. They are also based on information from a relatively sparse array of anemometers. There are substantial uncertainties in the wind direction and lee zone multipliers that are applied to these regional wind speeds for design loading, not only in regard to their magnitude but also the location and extent of their application. This paper considers some of the history of the analysis of design wind speeds in New Zealand, and the specific issues which require review.

In recent years substantial advances in meteorological modelling have been made. This modelling now has the potential to improve regional design wind speed information by identifying and thereby minimizing the effect of local anomalies introduced by ground based weather stations and their surroundings. This paper includes preliminary results from the analysis of a full year (2015) of wind speed forecast outputs from NIWA's New Zealand Convective Scale Model (NZCSM).

1 Introduction

Research is underway which aims to improve the resilience of New Zealand's infrastructure against the effects of wind storms. The strands of this research include improved understanding of the wind speeds that structures are designed to withstand, and also improved understanding of the damage to infrastructure that may result from wind storms.

The wind speeds theme includes incorporating sophisticated modern weather forecasting models, and combining them with the more traditional analysis of anemometer records from windstorms. In addition, the potential changes in design wind speeds caused by a range of climate change scenarios will be described.

The wind damage theme includes a review of wind damage that has occurred during several recent wind storms, or in wind events that may occur during the period of the research, and also the development and promotion of a standardised method for assessing and reporting wind damage.

All buildings and structures in New Zealand are designed to resist the effects of the wind speeds specified in the wind loading standard AS/NZS 1170.2, either directly or via other standards and codes which derive their wind speeds from AS/NZS 1170.2, such as NZS 3604 and AS/NZS 7000. While much of the content of AS/NZS 1170.2 has been prepared in Australia, the design wind speeds for New Zealand are the responsibility of New Zealand researchers and practitioners.

Specific items which need to be addressed in the wind speeds strand of our research include the following:

1. The gust speed definition has been changed from 3 seconds to 0.2 seconds in the most recent edition of the standard, based on analysis of historic Australian wind speed data. The validity of this change for New Zealand, and its consequences for New Zealand design wind speeds is uncertain and will be investigated.

2. Connected with Item 1, the regional wind speeds for New Zealand will be investigated. The research will document the analysis on which the design wind speeds have been based, and will recommend changes to these regional wind speeds where appropriate.

3. Wind speed lee multipliers are a unique feature of design wind speeds for New Zealand. The research will document the analysis on which the wind speed lee multipliers have been based, and will recommend changes to these where appropriate.

2 Gust speed definition

The description of the regional wind speeds listed in AS/NZS 1170.2 has changed from:

> "3-second gust wind data" in AS/NZS 1170.2:2011

to

> "The peak gust has an equivalent moving average time of approximately 0.2 seconds" in AS/NZS 1170.2:2011 Incorporating Amendment Nos 1 and 2 (2012).

There has been no corresponding change in the wind speed values, and consequently little practical change in the resulting wind actions. The change is limited to the definition of the wind speeds listed in the standard, and practicing engineers have had no real reason to notice the change.

The change has come about because the majority of the historical wind speed data that were used to calculate design wind speeds for Australia were measured by Dines pressure tube anemometers. Extensive research in Australia within the last 10 years into the operating characteristics of Dines anemometers has concluded that the anemometers typically measured gust speeds with an averaging time of around 0.2 s. This has consequently lead to the change in the gust speed definition which has been included in AS/NZS 1170.2.

The change to the gust speed definition has been made despite the fact that the World Meteorological Organisation specifies that gust speeds are to be measured using a 3 s moving average, and automatic weather stations now operating in Australia and New Zealand conform with this 3 s moving average specification. Therefore gust speeds being measured now are significantly lower than would be measured using a Dines anemometer.

In New Zealand, wind speeds were measured for many years using Munro cup anemometers, and consequently the regional wind speeds for New Zealand are substantially based on measurements from Munro anemographs. The Munro anemometer has a relatively slow response characteristic, which includes the operation of its chart recording mechanism as well as the movement of the cups. We therefore believe that the 0.2 s definition of gust speeds may well not be appropriate for the historical New Zealand wind speed data.

Some comparison was done by NIWA in the 2000s between wind speed measurements from a Munro anemometer and a Vector anemometer. This will be investigated further.

We know from limited investigations that there is a change in measured gust speeds when anemometer types were changed (e.g. at Wellington Airport in the early 1990s). This may be partly caused by changes to the mast height, the mast location, and changes to upstream sheltering of the anemometer. However, the main cause is likely to be due to the change to the instrument type. Documentation of instrumentation changes is available from the NIWA CliFlo database.

In principle, if the design wind speeds are calculated to correspond to the 0.2 s definition which is specified in the standard, the change from 3-s gust speeds to 0.2-s gust speeds has the potential to increase design wind speeds by about 15%, and the resulting wind loads by about 30%. We are not suggesting that it is likely that design wind speeds should or will be increased to this extent.

3 Regional wind speeds and directional multipliers

The regional wind speeds for New Zealand which are listed in AS/NZS 1170.2 were analysed by Dr Steve Reid, previously of the New Zealand Meteorological Service and NIWA, over the course of many years of research. During his career, Dr Reid provided ongoing updates to the regional wind speeds and the analysis on which they were based. Since his retirement in 2008, the regional wind speeds have been left unchanged. There have also been extreme wind events in the last 10 years that have not been included in the analysis. A selection of Dr Reid's publications which are most relevant to the analysis of design wind speeds are included in the references.

The maximum regional wind speeds for all of New Zealand except Wellington, as listed in AS/NZS 1170.2, are exactly the same as the maximum regional wind speeds for the majority of Australia. This is despite the fact that the weather conditions causing these wind speeds are substantially different.

Apart from the cyclonic regions of Australia, Australia is regions A1 to A5 in AS/NZS 1170.2, and New Zealand is regions A6, A7 and W. For regions A1 to A7, the only difference is in the 8 wind direction multipliers. In each zone there is at least one wind direction where the wind direction multiplier is 1.0.

For the two regions (A6 and A7) which make up all of New Zealand except the Wellington region, the directional multipliers range from 0.8 to 1.0, in intervals of 0.05. There are some steps of 0.1 between adjacent direction sectors. This is clearly a substantial simplification of the true distribution of extreme wind conditions. To what extent our research is likely to result in recommending changes to the design wind speeds is currently uncertain.

4 Lee multipliers

Lee slope winds produce some of New Zealand's most extreme winds. However there remains uncertainty around the science behind the number of lee multiplier zones and their extent.

It is not entirely clear to what extent historical wind speed measurements, where lee slope winds have occurred, may have already been incorporated in the calculation of the regional wind speeds. In New Zealand's hilly terrain, the distinction between lee multiplier wind effects and hill-shape wind effects is also unclear.

There is clearly considerable potential for confusion in the interpretation of the existing map. The existing depiction of zones which are simply shown relative to the coastline of New Zealand is inadequate. We intend that the output of our research will include a GIS map which combines both regional wind speeds and lee multiplier zones, from which the user can obtain the combined design wind speed by entering the GIS coordinates for the site.
We can envisage an ultimate scenario in which all the current design wind speed variables including regional wind speeds, wind direction multiplier, terrain/height multiplier, shielding multiplier, elevation multiplier, hill-shape multiplier will all be incorporated in a single analysis, perhaps done simply by locating a site in Google Maps or similar. However this is well beyond the scope of our current research.

5 NZ Design Wind Speeds – some history

This section discusses the parts of the wind loading standard that are specific to the calculation of design wind speeds in New Zealand.

NZS4203:1992
We'll begin this history with the issuing of NZ Standard NZS4203:1992. It introduced various features which are familiar to current users of AS/NZS 1170.2. Overall there has been relatively little change from the NZ design wind speeds presented in NZS4203:1992 to those in use today.

The new features in NZS4203:1992 included:
1. Regional wind speeds were presented for several numbered regions. The regional wind speeds were constant within each region.
2. The regional wind speeds were presented for an ultimate limit state return period of 1000 years.
3. Lee multiplier zones were introduced.
4. The general calculation of the topographic multiplier.

The new regional wind speeds in 1992 differed greatly from the previous 1984 edition, which presented basic wind speeds as a contour map.There had been substantial differences in the basic wind speeds for different towns in the 1984 edition. For example, the basic wind speeds in Kaitaia (in the far north) were 50% greater than in Tauranga, which was the city with the lowest basic wind speed. This may be compared with the current edition of AS/NZS 1170.2 where the maximum regional wind speeds for Kaitaia and Tauranga are now the same, and have been since the first joint AS/NZS 1170.2 was issued in 2002.

The 1992 edition therefore began the process of reducing the differences between the regional wind speeds. This process was then completed in the 2002 edition. The current regional wind speeds (for a 50 years return period) are about halfway between the 1984 values for Kaitaia and Tauranga.

The main reason for this merging of the regional wind speeds was that there is a large degree of uncertainty in extrapolation of measured wind speeds, from 20 years or so of data, to a return period of 1000 years. Reid (1987) discusses that, in his analysis of the revised regional wind speeds, he was also guided by: "The radical step the Australians have taken in the revision of dispensing with geographically-based wind zones, except for coastal strips around the northern part of the continent." Reid concludes: "A constant basic wind speed for New Zealand is, although a severe simplification of a complex situation, a reasonable way of achieving a simpler design standard."

The introduction of lee multiplier zones in NZS4203:1992 was another radical step. Having simplified regional wind speeds, the standard introduced a new way in which design wind were increased in a few locations. There were six separate lee multiplier zones, where each separate lee multiplier zone includes both a "shadow zone" and an "outer zone". The lee multiplier in the shadow zone is 1.35, reducing by linear interpolation in the outer zone. The lee multiplier therefore has a large effect on the resulting design wind speeds, particularly in the shadow zones.

For the North Island, the lee multiplier zones were carefully drawn avoiding large towns, and no North Island towns were specifically identified as being inside a lee multiplier zone. The exact extent of the zones is unclear. Te Aroha, north east of Morrinsville, is possibly the largest North Island town that is inside a shadow lee zone.

Hanmer Springs was the only town in the 1992 edition that was specifically identified as being in a shadow zone. It is still identified in AS/NZS 1170.2:2011 as the town with the highest design wind speed in New Zealand.

The general calculation of the topographic multiplier was introduced in NZS4203:1992, and is essentially unchanged in the current wind loading standard. AS/NZS 1170.2:2011 states:

4.4 TOPOGRAPHIC MULTIPLIER (M_t)

4.4.1 General

The topographic multiplier (M_t) shall be taken as follows:

(a) For sites in New Zealand and Tasmania over 500 m above sea level:

$$M_t = M_h M_{lee} (1 + 0.00015 E) \quad \text{. . . 4.4(1)}$$

where

M_h = hill shape multiplier

M_{lee} = lee (effect) multiplier (taken as 1.0, except in New Zealand lee zones, see Clause 4.4.3)

E = site elevation above mean sea level, in metres

(b) Elsewhere, the larger value of the following:

(i) $M_t = M_h$

(ii) $M_t = M_{lee}$

Consequently there is a substantial change in the calculation of design wind speeds at an elevation of 500 m.

AS/NZS 1170.2:2002

The introduction of the first joint Australian/New Zealand wind loading standard in 2002 saw some further changes to New Zealand design speeds which essentially continued the process which had been begun in NZS4203:1992.

The changes included:

1. The number of New Zealand wind regions was reduced from seven to three by combining several of the 1992 regions. Essentially:
   - Regions I and II of 1992 were combined to create Region A6, with the main effect that Northland wind speeds were reduced.
   - Regions III, IV, VI and VII were combined to create Region A7, with the main effect that Southland design wind speeds were reduced.
2. The resulting maximum design wind speeds were reduced by 8 % for much of the country, although were unchanged in the main population region of Auckland.
3. There was an anomaly in NZS4203:1992 that the non-directional basic wind speeds were less than the directional basic wind speeds. This anomaly was eliminated in the AS/NZS 1170.2:2002.
4. The 1000-years maximum regional wind speeds for the Wellington region were increased from 50 m/s to 53 m/s. This was done partly to avoid the need to apply a channelling multiplier which had previously been specified for the whole of the Welington region. The use of the channelling multiplier was eliminated in the standard.

AS/NZS 1170.2:2011

New Zealand design wind speeds have been unchanged since 2002, except for the changes to the lee multiplier zones in the 2012 amendments to AS/NZS 1170.2:2011.

There are now 11 lee multiplier zones (treating the Tongariro region as two zones). The changes in the 2012 amendments edition include:

1. The North Island zones south of Palmerston North are all new, plus a new zone north of Kaikoura.
2. All the zones have been redrawn with essentially straight line boundaries instead of curved lines.

Reid and Turner (2008) discussed the analysis that led to these changes. To some extent the new zones are a response to specific wind events which are known to have occurred. This leads to the possibility that other zones might be added, as new specific wind wind events occur. For example, there are currently no lee multiplier zones for southeasterly winds in the south island, although there are several such zones in the north island. The map of New Zealand wind regions and lee multiplier zones recommended by Reid and Turner (2008) which have been incorporated in AS/NZS 1170.2:2011 is shown in Figure 1.

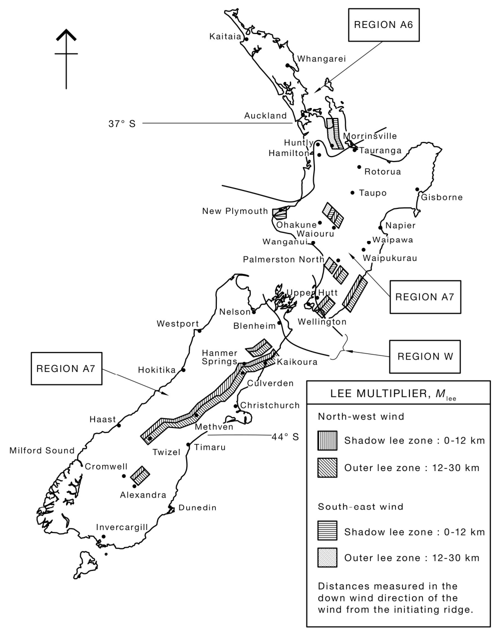

Figure 1. Map of New Zealand wind regions and lee multiplier zones

Reid and Turner (2008) also analysed and reviewed wind speed data from many sites for the period 1972 to 2007. One of their findings was that in Region A7 (the majority of New Zealand) the data indicates that: "In Region A7 there seem to be more discrepancies than are recognised in the code, with some sites showing high southerlies and northerlies as well as westerlies and northwesterlies." However this observation has not resulted in any subsequent changes to AS/NZS 1170.2., where the wind direction multiplier M_d is still listed as 0.90 for both northerly and southerly wind directions in Region A7.

6 High Resolution Numerical Weather Modelling

Numerical weather models operated by NIWA include the New Zealand Limited Area Model (NZLAM) which uses a 10 km grid, and the New Zealand Convective Scale Model (NZCSM) which uses a 1.5 km grid. NZCSM has been operational since 2014, producing daily weather forcasts.

All previous analysis of design wind speeds for New Zealand has been mainly based on data from cup anemometer recordings. Our intention in this research is to examine the statistical outputs from the numerical weather models, and investigate how they can be used to make the analysis of design wind speeds more accurate.

To provide some initial indication of how this may be achieved, Figure 2 shows a forecast from NZLAM for 16 March 2015 with the passage of Cyclone Pam close to the North Island of New Zealand. The plot shows predicted 10-minute mean wind speeds at 10 m height above ground level.

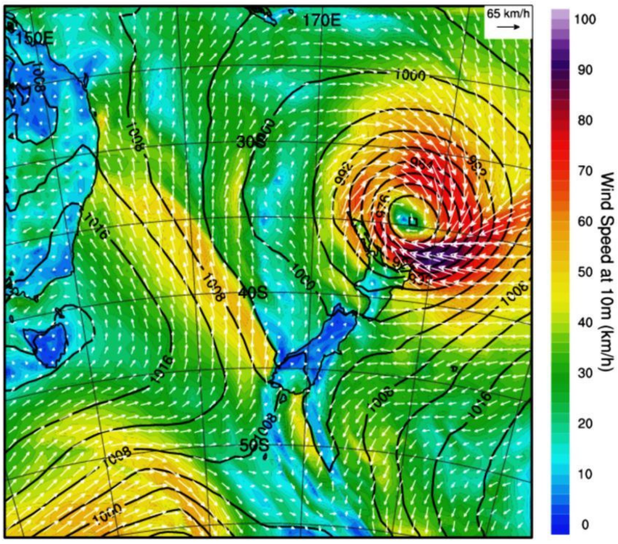

Figure 2. Example of a single a forecast from NZLAM for 16 March 2015 showing the passage of Cyclone Pam.

In Figure 3, the more detailed information from NZCSM has been combined for all 365 days of forecasts for 2015, including the passage of Cyclone Pam. The plot shows the combined maximum 3 s gust speeds at 10 m above ground (or sea) level for the whole year. In this example, the plot has been shaded to emphasize the tracks of individual weather events over the sea. The passage of Cyclone Pam can be seen as the largest track, to the north of New Zealand. Also included in Figure 3 are the locations of the 180 anemometer stations (shown as small circles), from which the measured wind speeds can be compared to the NZCSM forecasts.

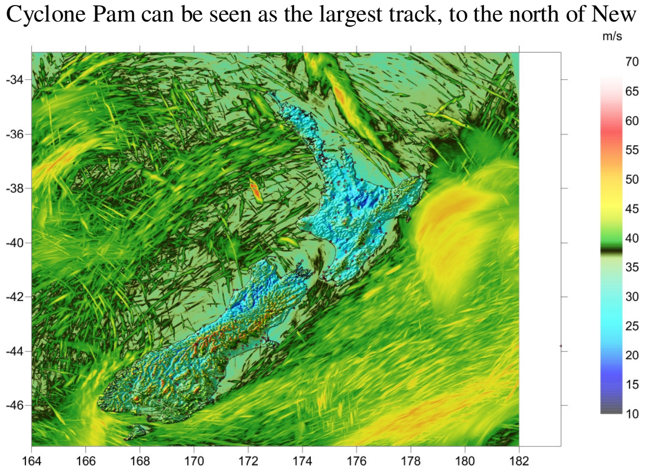

Figure 3. Example of analysis from NZCSM, which combines 365 days of forecasts for 2015.

7 Climate Change

Another strand of our research is to assess the potential effects on design wind speeds from a range of potential climate change scenarios. Reid (1990) reviewed the potential effects of climate change and concluded:

1. Tropical cyclones potentially become the dominant cause of high winds over much of the North Island.
2. Elsewhere, shifts in dominant wind directions are expected, but with no significant effect on basic wind speeds.

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