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Comparison of Windstorm Damage with Computer-Modelled and Measured Wind Speeds

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Abstract

New Zealand's vulnerability to extreme weather is well known, with many population centres and infrastructure assets located in exposed coastal or hilly areas. In many areas wind loading dominates structural design. Historically, extreme weather events have caused significant damage, disruption and financial cost. In 2013 and 2014, two events contributed to insured property losses alone of around $250M per annum. As part of a four-year study aimed at improving New Zealand's long term resilience to windstorms, the New Zealand Wind Engineering Consortium (Opus Research, NIWA (National Institute of Water and Atmospheric Research) and the University of Auckland) have been comparing observed windstorm damage and measured and modelled wind speeds. This comparison has focused on severe windstorms that occurred in Canterbury in 2013, and on the West Coast in 2014. Wind damage records are being used to compare the location, degree and type of damage with (1) full-scale gust wind speed data from meteorological stations, and (2) surface gust wind speed data from numerical model simulations carried out using NIWA's high resolution New Zealand Convective Scale Model (NZCSM). This was to assess the validity of NZCSM as a predictive tool for potential wind damage New Zealand wide.

Introduction

The Wind Engineering Consortium is currently working on a four-year multi-objective project that aims to improve the resilience of New Zealand's infrastructure against the effects of severe windstorms. It is being funded by the Ministry of Business, Innovation and Employment (MBIE) as part of its Natural Hazards platform.

Step one of the project has involved comparing wind damage records with full–scale wind speed data and wind speed predictions from a sophisticated modern computer model for specific extreme wind events. Two recent events were selected: (1) a windstorm in the Canterbury region of New Zealand's South Island in 2013, and (2) a windstorm in the West Coast region of the South Island in 2014. The aim was to assess whether the computer simulation showed a level of agreement with full-scale wind speeds and wind damage that would then, as the second stage of the project, allow it to be applied to the whole of New Zealand, and for the results to then be compared to the design wind speed maps contained the Australia/New Zealand wind loading standard AS/NZS 1170.2.

The three other objectives of the project are; (1) to obtain a better understanding of and document existing and historic wind speed data in New Zealand, (2) engage with the insurance industry and other lifeline organisations to promote the development and uptake of a more comprehensive and detailed recording of wind damage and disruption data, and (3) to identify the potential effects of climate change scenarios on extreme wind speeds in New Zealand using high resolution computer models.

Windstorm Events

In New Zealand, collection of wind damage data has been, and still is, very patchy and incomplete. Some data is collected by insurance companies, civil defence organisations, and local and regional authorities. However, much of the information relates to global statistics, e.g. the total value of insurance claims, the number of homes without power, etc, without significant additional detail being available about specific damage causes and origins.

Canterbury Windstorm - 2013

Through the night of September 10 and the morning of September 11 2013, the Canterbury region on the east coast of New Zealand's South Island was hit by an extreme wind event. This was considered to be the worst windstorm in almost 40 years. It was characterised by extremely strong north-westerly downslope winds. These wind flows caused widespread damage, as well as disruption to services and transport links, including:

- Severe damage to more than 800 agricultural irrigators.
- Power cut to 40,000 homes, with 600 of these still without power more than a week later.
- A significant number of schools closed.
- Water supplies reduced or cut in many areas.
- Some sewerage pumping stations out of action.
- Lightning and downed powerlines caused several fires.
- Several vehicles overturned by strong winds.

The NZ Insurance Council put the insured costs alone in excess of $68M. Uninsured, lifeline and disruption costs are assumed to be much higher than this.

Storm damage location records were obtained from the Orion electricity network, and from the insurers of the damaged irrigators. Wind speed data was also obtained for the 24 meteorological stations in the region, one of which recorded a maximum gust speed of 53m/s. Figure 1 illustrates some of the irrigator damage that occurred during this event.

Figure 1. Agricultural irrigator overturned and damaged.

West Coast Windstorm - 2014

Through the morning of 17 April 2014 Ex Tropical Cyclone Ita struck the West Coast of New Zealand's South Island. This weather system brought strong easterly downslope wind gusts and rain, and caused widespread damage and disruption. Its effects included:

- More than 60 houses in Greymouth lost roofs, and 10 were almost complete or total losses.
- Roads and highways were closed by fallen trees and slips.
- Vehicles, including buses and trucks, were blown over.
- Over 4500 homes lost power, and this was not fully restored for over a day.
- Around 20,000ha of forest was felled, with damage done to another 200,000ha. This included both native and plantation forests.

The New Zealand Insurance Council later put insured costs at over $55M. Non-insured losses and service disruption costs are assumed to be at least similar in magnitude. Legislation was passed to allow for the removal of windblown timber from conservation lands.

Storm damage records were collected by NIWA during post event on-site and postal surveys, and wind speed records were taken from the 18 meteorological stations in the West Coast region, one of which coincidentally also recorded a maximum gust speed of 53m/s. Figures 2 shows some of the damage that occurred.

Figure 2. Light industrial building destroyed.

Modelling Windstorm Events using NZCSM

Followings these two windstorm events NIWA carried out computer simulation modelling of each of them using its sophisticated NZCSM modelling package.

Description of NZCSM

In 2013 NIWA started testing a new ultra-high resolution numerical weather prediction model that had been developed; the New Zealand Convective Scale Model (NZCSM). NZCSM is a local version of the UK Meteorological Office Unified Model, which has been developed at NIWA with international collaborators. It is the largest kilometre-scale weather forecast model used internationally and can reveal atmospheric flow features caused by the interaction of weather systems with complex terrain.

NZCSM forecasts the weather every 6 hours on a 1.5km horizontal grid covering New Zealand and the surrounding ocean, from the surface up to a height of 40km. Wind speeds can be extracted at each level. NIWA has found that the mean wind speeds at 133m above ground level are a reasonable proxy for the gust speeds at 10m above ground level. Table 1 lists the key features of the model.

Item	Notes
Domain size	1200 x 1350 x 70
Computational grid	Rotated latitude / longitude
Model Top	40 km
Levels below 2km	23
Dynamics time step	50 s
Radiation time step	600 s / 10 min
Data Assimilation	Pseudo-analysis (merge NZLAM-12 background)
IAU Period	2 hours (T-1 to T+1)
Observation types used	Surface, Aircraft, Satellite (via NZLAM-12 background)
Forecast period	42 hours
Forecast frequency	4 times per day at 03, 09, 15 and 21 UTC (Analysis Time)
Forecast availability	Analysis Time plus 6 hours 15 minutes
Lateral Boundary Conditions (LBC)	Derived from NZLAM-12 run at 12km horizontal resolution
LBC Update frequency	30 mins
Output frequency	Prognostic fields: 30 mins ; Accumulations: Hourly, 3, 6, 12 hours, 24 hours

Table 1. Features of NZCSM as configured in 2013/2014 for operational forecasting at NIWA (NZLAM – New Zealand Limited Area Model)

Modelling of the Canterbury Windstorm in NZCSM

NZCSM model simulations were carried out for the Canterbury region for the 24 hour period from 12 noon on September 10th to 12 noon on September 11th 2013. The mean speeds at 133m above ground level were extracted for each co-ordinate location. These speeds were compared with the maximum gust speeds measured at meteorological stations during the event, as shown in Figure 3.

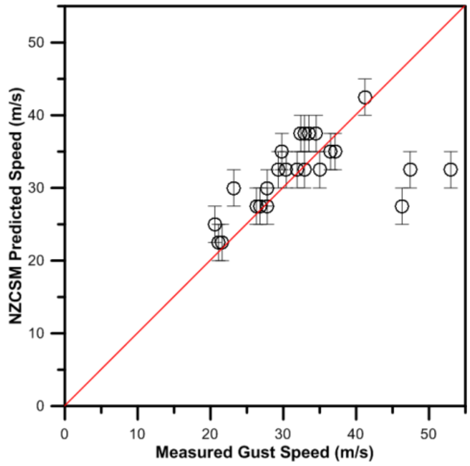

Figure 3. Comparison of measured maximum gust speeds and NZCSM speeds for the Canterbury windstorm, September 2013

The agreement between the measured maximum gust speeds and those from NZCSM is generally good, apart from the three meteorological stations having the highest measured gust speeds, where NZCSM significantly under-predicts the maximum speed.

Figure 4 shows the maximum speeds derived from NZCSM for the Canterbury region for this event, where these predicted speeds were greater than 30m/s. Included on this plot are (1) the centres of the meshblocks where (a) damage to agricultural irrigators was identified and (b) meshblock centres where no irrigator damaged was recorded, or there were no irrigators in place, and (2) damage that occurred on the Orion electricity network.

Meshblocks are the smallest geographical unit for which statistical information is collected by Statistics NZ. They can vary in size from part of a city block to large areas of rural land. Therefore, Figure 4 shows only the approximate location of irrigator damage. It does not identify the number of damaged or undamaged irrigators in any particular meshblock, or whether there are any irrigators in a particular meshblock at all.

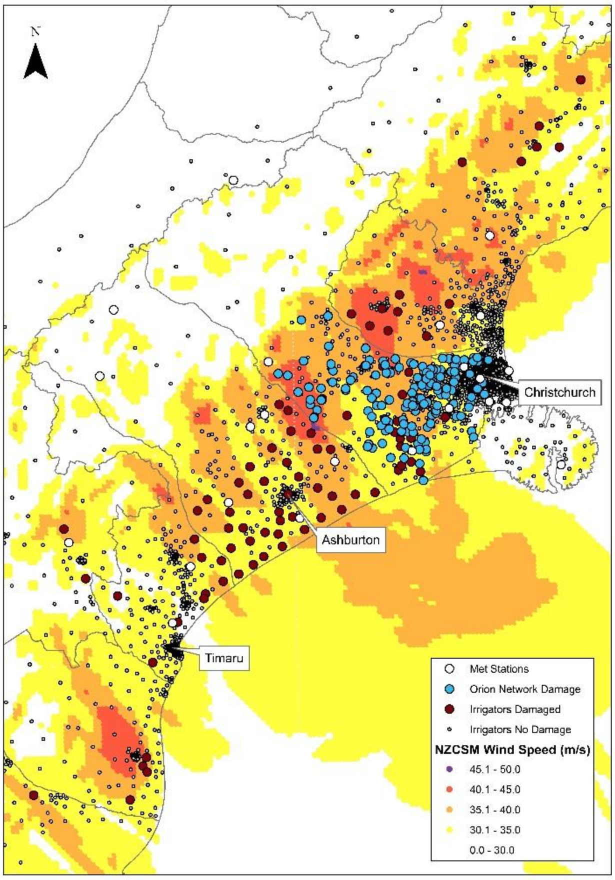

Figure 4. NZCSM predicted maximum speeds for Canterbury extreme event (>30m/s). Includes (a) locations of meshblocks where there was irrigator damage, and where there was no damage or no irrigators, and (b) damage to the Orion electricity network.

This show the patterns of high and very high wind speeds that are typical of north-westerly downslope lee windstorms and channelling out of the river valleys onto the Canterbury plains. It is also evident that much of the irrigator damage occurred in locations where the NZCSM predicted maximum speeds exceeding 30m/s, with some clusters of damage where the predicted gust speeds were over 40m/s. Note that for privacy reasons the specific locations and numbers of damaged irrigator units are buried in the meshblock data. There is also currently no information available about whether measures may have been taken to protect irrigator units by aligning them to the wind or fastening them down.

Nonetheless, the agreement between the NZCSM data, the measured meteorological station data, and the locations of significant wind damage shows promise in being able to identify areas that may be prone to wind damage. It has also highlighted (1) the difficulty in getting detailed wind damage information, despite it being responsible for significant costs and disruption, and (2) that no damage in a particular location where high wind speeds are predicted may just mean (1) that there is nothing to damage, (2) it has been well designed, or (3) the weaker elements have already have been damaged and removed, or strengthened.

Modelling of the West Coast Windstorm in NZCSM

Model simulations in NZCSM were performed for the 24 hour period from 12 midday on April 16th through to midday on April 17th 2014. The mean speeds at 133m above ground level were extracted for each co-ordinate location, where these speeds are considered to be a good proxy of the gust speeds at 10m above ground level. Figure 5 compares the maximum gust speeds measured at the meteorological stations with the NZCSM predicted speeds.

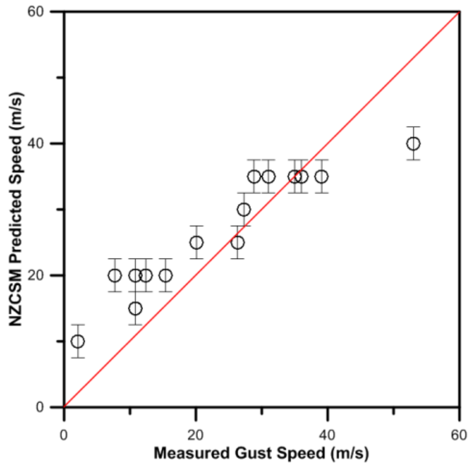

Figure 5. Comparison of measured maximum gust speeds and NZCSM predicted speeds for the West Coast Windstorm, April 2014.

As for the Canterbury storm, the agreement between the measured maximum gust speeds and those from NZCSM is generally good, although for the meteorological station having the highest measured gust speed, NZCSM significantly underestimates the maximum speed.

Figure 6 shows the maximum gust speeds derived from NZCSM for the West Coast event, where the predicted maximum speeds were greater than 25m/s.

The wind speed distributions for this event show patterns of high and very high wind speeds that are typical of an easterly downslope lee windstorm, and channelling out of the West Coast mountain passes and valleys. Given the sparseness of larger urban areas on the West Coast many of the very highest speeds occurred outside these urban areas, which is where much of the forestry damage was observed. It also shows that high wind speeds were predicted around Greymouth and Westport, but not so high at Hokitika. It is interesting that most of the damage in urban areas occurred in Greymouth where there was a maximum measured gust speed of 53m/s, but the predicted speeds were around 25-35m/s. However, while speeds of 30-35m/s were also predicted for Wesport, there was considerably less damage there. This suggests that either (1) the spatial resolution in NZCSM may not be sufficient to model local topographic features, or it is not sufficiently accurate in modelling the extreme wind speeds.

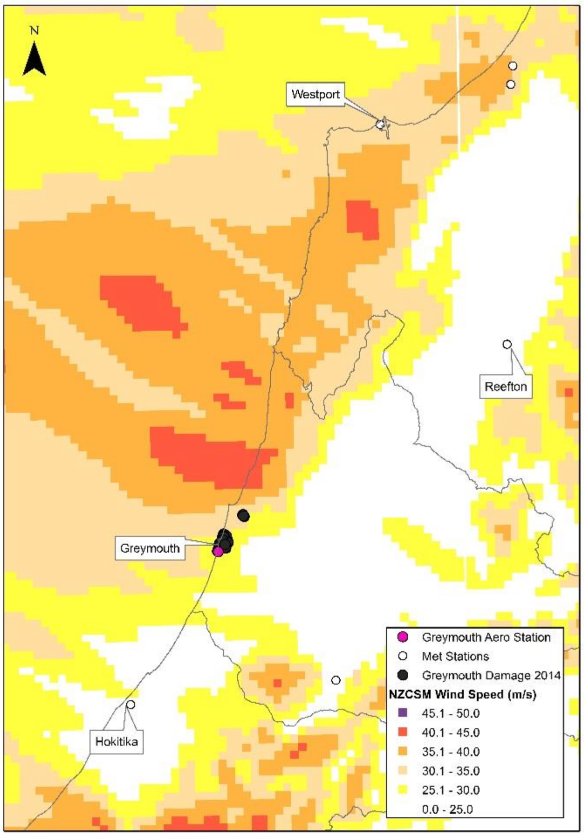

Figure 6. NZCSM predicted gust speeds for West Coast extreme event (>25m/s).

Windstorm Damage in Greymouth

Figure 7 shows the locations of the wind damage that occurred in the Greymouth area, overlaid on an aerial photo.

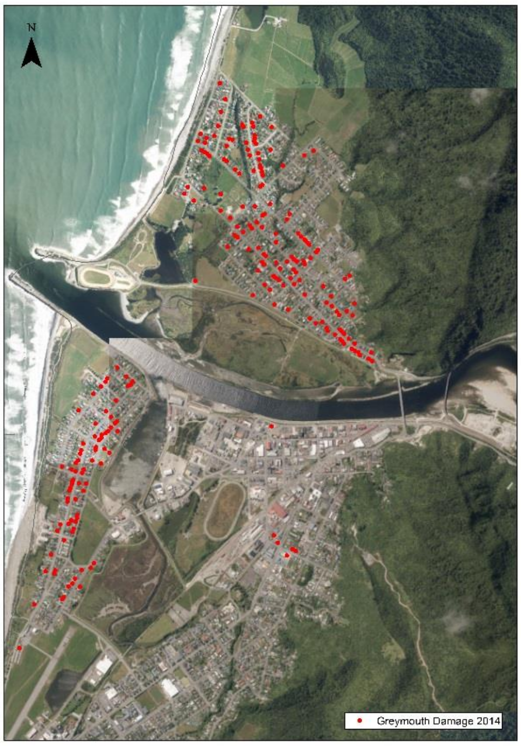

Figure 7. Wind damage locations in the Greymouth area during the West Coast event (image - LINZ Data Service and Eagle Technology, 2017).

This shows that the damage occurred mainly in two largely residential areas, downwind of the gap in the hills created by the Grey River, while there was apparently little reported damage in the commercial/industrial area lying between one of these areas and the hills. Figure 8 shows that a significant proportion of the reported damage occurred to older houses, built prior to 1970.

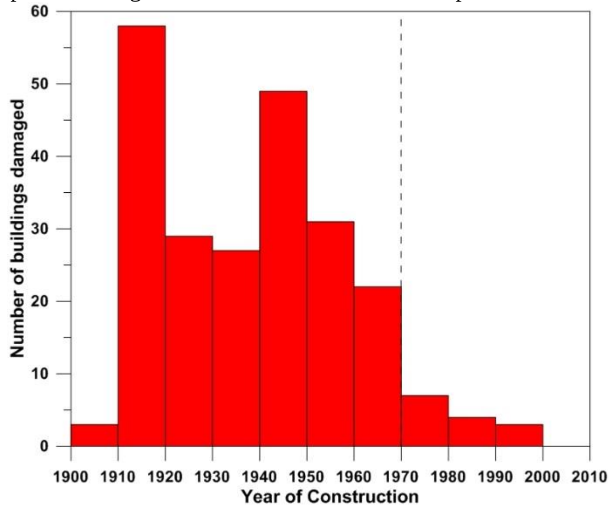

Figure 8. Distribution of windstorm damage with age of construction

Ongoing Work

At this time NIWA is continuing the development and refinement of NZCSM that has been ongoing since 2013. Work is also carrying on to analyse the existing wind damage data for both the Canterbury and West Coast events, and to collect additional damage data if possible, particularly in terms of forestry damage during the West Coast event, and infrastructure damage during the Canterbury event.

Conclusions

The comparison of wind damage data from two windstorm events (Canterbury 2013, West Coast 2014) with maximum wind speeds predicted by NIWA's NZCSM computer model and measured maximum gust speeds shows that:

- There is reasonable agreement between the maximum speeds predicted by NZCSM and maximum full-scale gust speeds, apart from some locations, where NZCSM significantly underestimates the peak speeds.
- NZCSM shows promise in the prediction of areas where significant wind damage is likely, with areas where predicted maximum speeds are around 30m/s or higher having a greater likelihood of wind damage.
- Consistent and detailed collection of wind damage data is required to better assess causes and vulnerabilities, and allow for targeting of damage mitigation options.

Acknowledgments

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References

[1] Gillespie, A. (2014) West Coast Regional Weather Event Ex Tropical Cyclone Ita 17 April 2014, West Coast Regional Council.