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Correlation of Observed Wind Damage with Modelled and Measured Wind Storm Speeds

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Abstract

New Zealand is vulnerable to extreme weather events, with a large proportion of the population and infrastructure assets being located in exposed coastal areas or on hilly terrain. In many areas, extreme winds dominate the design loading of buildings and structures, often outweighing earthquake loads. Extreme weather events in 2013 and 2014 caused insured property losses alone in excess of $250M per annum. As part of a wider four-year multi-objective study aimed at improving New Zealand's long term resilience to wind storms, Opus Research, NIWA (National Institute of Water and Atmospheric Research) and the University of Auckland, are beginning investigations into the degree of correlation between observed wind storm damage patterns and measured and modelled wind speeds. This study will initially focus on severe wind storms that occurred in Canterbury in 2013, and on the West Coast in 2014, where two sets of extensive wind damage records were collected by NIWA immediately after the events. These will be used as case studies to compare the location, degree and type of damage with (1) the available full-scale gust wind speed data from the sparsely spaced meteorological stations in each of these two areas, and (2) surface gust wind speed data from retrospective numerical model simulations carried out using NIWA's high resolution New Zealand Convective Scale Model (NZCSM). This will test the validity of using NZCSM as a predictive tool for potential wind damage on a New Zealand wide basis.

Introduction

Research has begun on a four-year project that aims to improve the resilience of New Zealand's infrastructure against the effects of severe wind storms. This project is being funded by the Ministry of Business, Innovation and Employment (MBIE) as part of its Natural Hazards platform. It is being undertaken by researchers from the New Zealand Wind Engineering Consortium, comprising Opus Research, NIWA, GNS Science and the University of Auckland.

The first element of this research involves assessing the degree of correlation between wind damage, full–scale wind speed data and wind speed predictions from a sophisticated modern computer model for specific extreme wind events. The two events that were selected were a wind storm in the Canterbury region of New Zealand's South Island in 2013, and a wind storm in the West Coast region of the South Island in 2014.

The second element of the project next step is to apply the computer model simulation to the entire country if there is a reasonable correlation between the wind damage and the computer model predictions of wind speed. These wind speed predictions will then be compared with the design wind speed maps contained the Australia/New Zealand wind loading standard AS/NZS 1170.2. This comparison will include consideration of: (a) the level of agreement between maximum wind speed levels, (b) areas where significant discrepancies exist, and (c) areas identified in the Standard as having increased loading factors (i.e. lee slope multipliers and channelling multipliers).

The third strand of the research is to obtain a better understanding of and document existing and historic wind data in New Zealand. From this the intention is to make recommendations for changes to the design wind speed maps as required, on the basis of reanalysis of the available data and the computer model outputs.

We know that the collection of wind and related damage data is difficult and time-consuming, and has been patchy and incomplete in the past in New Zealand. Much of the information comes from insurance data on losses to insured buildings, structures and other infrastructure, without significant additional detail being available about specific damage causes and origins. Accordingly, another objective of this project is to engage with the insurance industry and other lifeline organisations (power, phone, transport) to promote the development and uptake of a more comprehensive and detailed recording of wind damage and disruption data. This will potentially enable future events, including those during the four-year project span, to be better captured, the causes and costs to be better identified, and possible damage mitigation options and strategies to be assessed.

The final objective of the project is to identify the potential effects of climate change scenarios on extreme wind speeds in New Zealand using high resolution computer models. This will generate more up-to-date range estimates on the frequency and intensity of extreme wind events. It will also allow estimates to be made of the likely impacts of climate change on the levels of wind damage that could be expected.

Wind Storm Events

The Canterbury Wind Storm of 2013

On the night of September 10 and the morning of September 11 2013, the Canterbury region was hit by an extreme wind event, which was considered to be the worst wind storm since August 1975. Wind speeds at Mt Hutt, in the Southern Alps, were measured to be in excess of 200km/h. The extremely strong north-westerly downslope winds caused widespread damage and severe disruption to services and transport links. This included:

- More than 800 irrigators were severely damaged, affecting farm irrigation and effluent dispersal, with repairs taking several months.
- Power was cut to 40,000 homes in the Selwyn, Christchurch, Waimakariri and Hurunui districts. Around 600 homes remained without power more than a week later.
- Power outages and fallen trees closed several schools.
- Water supplies were reduced in many areas.

- Sewer pumping stations were out of action in many areas.
- Lightning strikes and downed powerlines caused several fires, burning vegetation and farm buildings.

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.

Wind speed data and some available damage records collected or obtained from insurance providers by NIWA were made available for this project. Figure 1 shows the maximum gust wind speeds that were recorded at meteorological stations around the Canterbury region during the event, and Figures 2 and 3 illustrate some of the damage that occurred. Figure 4 shows the storm damage that occurred on the Orion electricity distribution network.

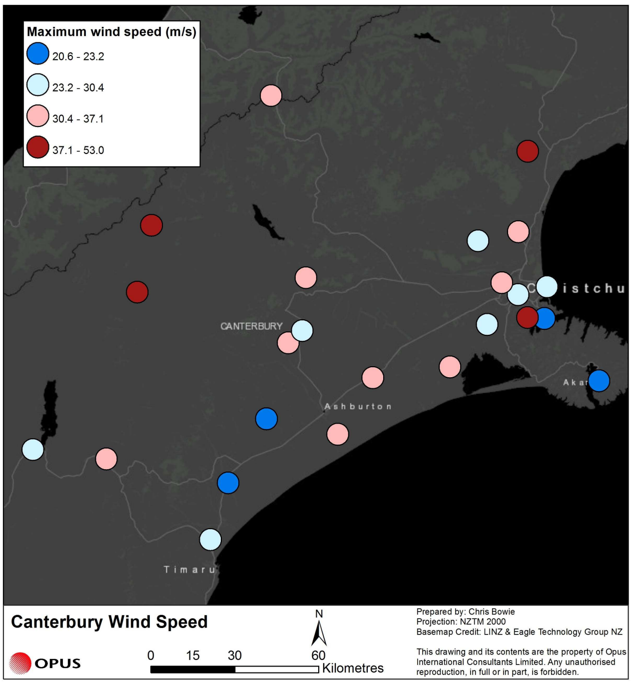

Figure 1. Maximum full-scale wind speeds during the storm.

Figure 2. Farm irrigator blown over and damaged.

Figure 3. Agricultural building destroyed.

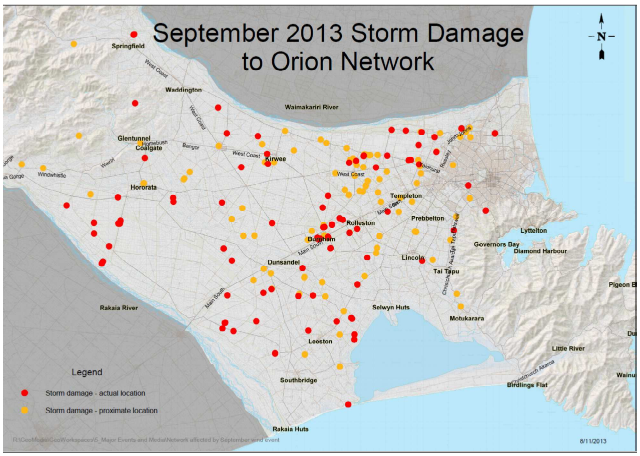

Figure 4. Storm damage to the Orion electricity network.

The West Coast Storm of 2014

During the morning of 17th April 2014 Ex Tropical Cyclone Ita struck New Zealand, with the West Coast region of the South Island bearing the brunt of the storm. This severe weather event, which brought strong easterly downslope wind gusts and rain, caused widespread damage and disruption. The effects included:

- At least 60 houses in Greymouth lost roofs, and around 10 were almost complete or total losses.
- Roads and highways were closed.
- Vehicles, including buses and trucks, were blown over.
- Power was cut to more than 4500 homes, and this was not fully restored for more than 24 hours.
- An estimated 20,000ha of forest was felled, with damage done to a further 200,000ha. This included damage to both native and plantation forests.

According to the New Zealand Insurance Council the insured costs alone of the West Coast storm were in excess of $55M. Non-insured losses and service disruption costs are assumed to be of similar magnitude. The New Zealand Parliament even passed legislation to allow for the removal of windblown timber from conservation lands.

Wind speed data and damage records collected or obtained by NIWA during post event on-site and postal surveys were made available for this project. This included the location and type of damage to specific building elements, e.g. roof or walls. Table 1 lists the maximum wind speeds that were recorded at some of the meteorological stations located on the West Coast during the event, and Figures 5 and 6 show some of the damage that occurred.

Station	Maximum Gust Speed (m/s)
Millerton	53
Greymouth Aero	39
Ivory Glacier	36
Westport Aero	35
Stockton	31
Farewell Spit	29
Franz Josef	27
Pidgeon Creek	28

Table 1. Maximum gust speeds at some meteorological stations during the West Coast storm of April 2014.

Figure 5. Greymouth Band Hall in Blaketown destroyed.

Figure 6. Aircraft hangar at Greymouth Airport destroyed.

Modelling Storm Events in NZCSM

Subsequent to these two extreme events NIWA carried simulation modelling of each of them using its sophisticated NZCSM modelling package.

Description of NZCSM

During 2013 NIWA scientists developed and began testing a new ultra-high resolution numerical weather prediction model, the New Zealand Convective Scale Model (NZCSM). This is a local configuration of the UK Met Office Unified Model, and was 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 New Zealand's complex terrain, features not previously seen. Table 2 lists the key features of the NZCSM 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 2. Key features of NZCSM as configured in 2013/2014 for operational forecasting at NIWA (NZLAM – New Zealand Limited Area Model)

Every 6 hours, this model forecasts the weather on a 1.5 km horizontal grid covering the entire NZ land mass and adjacent ocean areas, from the surface to 40 km altitude, out to 36 hours ahead. Wind speeds at each level can be provided as output. It has been found that the mean wind speeds at 133m above ground level are a reasonable predictor of the gust speeds at 10m above ground level.

NZCSM Modelling of Canterbury Wind Storm of 2013

NZCSM model simulations were carried out by NIWA for the period spanning the 24 hour period from 12 midday on September 10th through to midday on September 11th 2013. From these simulations the mean speeds at 133m above ground level were extracted for each co-ordinate location, where these speeds are considered to be a good predictor of the gust speeds at 10m above ground level.

Figure 7 shows a graphical colour-coded representation of the maximum gust speeds derived from NZCSM for the Canterbury event. Included on this plot are the centres of the meshblocks where the damage to agricultural irrigators has been identified from insurance records.

Meshblocks are the smallest geographical unit for which statistical information is collected by Statistic NZ. They can vary in size from part of a city block to large areas of rural land. Accordingly, the information in Figure 7 shows only the approximate location of irrigator damage, and does not identify the number of damaged irrigators in any particular meshblock.

recorded at the full-scale meteorological stations within the simulation area.

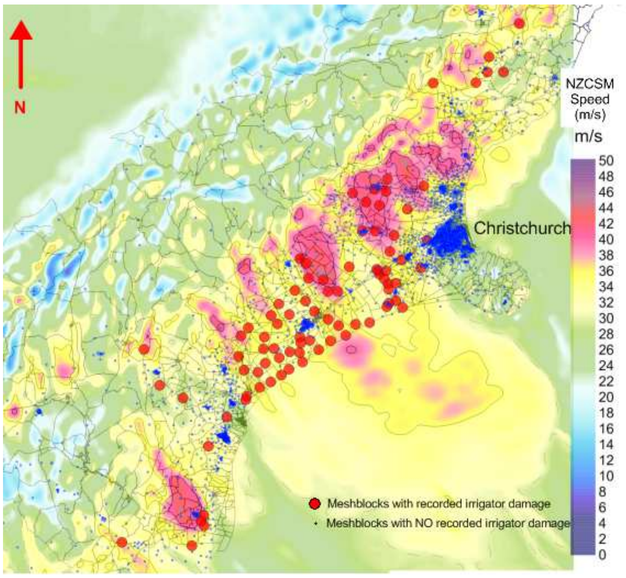

Figure 7. NZCSM Gust Speeds for Canterbury extreme event. Also includes the locations of meshblocks where there was irrigator damage, and where there was no damage.

This plot shows patterns of high and very high wind speeds typical of north-westerly downslope lee windstorms and channelling out of the river valleys that impact the Canterbury plains. The high winds can continue over considerable distances out from the ranges.

Figure 7 also shows that nearly all of the irrigator damage identified occurred in areas where the NZCSM gust speeds were predicted to have exceeded 30m/s, and that there were clusters of damage that occurred where gust speeds were predicted to exceed 40m/s. However, there are currently some known limitation in the irrigator damage data. In particular, (1) the specific locations and numbers of damaged irrigator units are buried in the meshblock data, mostly for privacy reasons, and (2) there is currently no information on where measures may have been taken to protect units, either by aligning them to the wind, or fastening them down.

Nevertheless, the NZCSM model simulation does show promise in being able to identify areas that may be prone to irrigator damage. We are currently looking at better defining the irrigator and other damage with the insurance companies, and network (electricity and phone) providers.

NZCSM Modelling of West Coast Wind Storm of 2014

NZCSM model simulations were carried out for the period spanning the 24 hour period from 12 midday on April 16th through to midday on April 17th 2014. From these simulations the mean speeds at 133m above ground level were extracted for each co-ordinate location, where these speeds are considered to be a good predictor of the gust speeds at 10m above ground level.

Figure 8 shows a graphical colour-coded representation of the maximum gust speeds derived from NZCSM for the West Coast event. Included on this plot are the maximum gust speeds recorded at the full-scale meteorological stations within the simulation area.

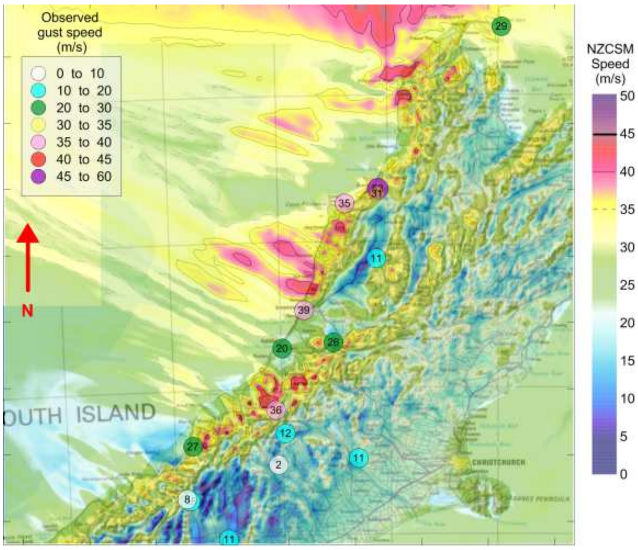

Figure 8. NZCSM Gust Speeds for West Coast event. Also includes the locations of the full-scale meteorological stations and the maximum gust speeds measured during the event.

As for the Canterbury event of 2013, the wind speed distributions for the West Coast event show patterns of high and very high wind speeds typical of an easterly downslope lee windstorm and channelling from the West Coast mountain passes and valleys. The NZCSM model does appear to be in good agreement with the full-scale gust speeds that were measured at meteorological stations during the event. It is also encouraging that the NZCSM model predicted very high wind speeds (around 40m/s or higher) in the vicinity of Greymouth, which is approximately in the centre of the plot in Figure 8.

Ongoing Work

At this time work is ongoing to refine the damage data for the Canterbury event, and to compare the date from the NZCSM model with the West Coast damage survey data.

Conclusions

Comparison of the available wind damage data from two extreme wind events with maximum wind speeds predicted by NIWA's NZCSM computer model shows that:

- NZCSM shows promise in being able to predict areas of likely wind damage to vulnerable structures in extreme events.
- Considerable refinement and clarification of the wind damage data is required before the actual degree of correlation with the NZCSM predicted maximum wind speeds can be established.

Acknowledgments

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References

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