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Decadal scale variations in Cook Strait (AS/NZS Region W) station wind speeds and some notes about some recent significant NZ wind storms.

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Abstract

The period from June 2013 to August 2014 has been notable for the high number of intense wind storms with associated insured losses in New Zealand totalling over $250 M. A catalogue of these events is presented here and support this period's claim as one of, if not, the worst 14 months for wind storms in New Zealand records. As part of the effort to put this period in context, the long-term pressure, and mean and gust speed records for Cook Strait region stations were examined and corrections for station moves and orographic effects made. These trends are presented here and compared with climate indices such as the IPO (Inter-decadal Pacific Oscillation) and the SAM (Southern Annular Mode).

Introduction

The period from June 2013 to August 2014 has been notable for the; high number of, recorded intensity of, and wind-related losses ($253 M, Figure 1) caused by storms in New Zealand. A gallery (Figure 2) of these events and brief description of some aspects of them (Table 1) are presented in the first part of this abstract and support this period's claim as one of, if not, the worst 14 months in New Zealand records.

This recent spate of storms has raised many questions about whether this heightened activity is likely to continue because of climate change and how "cyclical" is it? Unfortunately, issues around climate station moves, directional hill-shape effects, changes in instrumentation, and instrument exposure, etc. have made such questions difficult to answer for New Zealand. In the second part of this abstract the effort to start to addressing these difficulties and questions is presented. Here, wind records for the Cook Strait area, (designated as Zone "W" in AS/NZS 1170.2 due to the frequent high winds experienced there) were examined critically and adjustments made to help identify real trends in the gust records. This included examination of mean winds, and the use of the established relationships between the local pressure gradients and station gust speeds (such as described by Reid (1996)) and the use of the Gerris (Popinet, 2003) model to account for directional speed-ups due to orography. Some recent and longer term trends were apparent in the wind records for Welllington Aero and Brother's Island and these are presented here and compared with climate indices such as the IPO (Inter-decadal Pacific Oscillation), SOI (Southern Oscillation Index), and SAM (Southern Annular Mode).

New Zealand Wind storms June 2013 to October 2014

According to the NZ Insurance Council 2013 and 2014 were ranked 3rd and 2nd worst ever respectively in terms of wind-related losses (Figure 1). The worst year was 1968, the year in which ex TC Giselle caused the loss of the Wahine (Revell and Gorman, 2003) in Wellington Harbour. The expansion of housing and agricultural infrastructure (e.g., irrigators associated with the dairy boom of the last decade) undoubtedly accounts for some of the increase in losses. For example, if the famous 1975 Canterbury Nor'wester where recorded wind gust were generally much stronger than in Sep 10, 2013 Nor'wester (Table 1) had occurred in 2013, losses due to damage to irrigators would have been much, much higher. Not just because of replacement cost but loss of productivity caused by delays in repairs and replacements due to overwhelming demand.

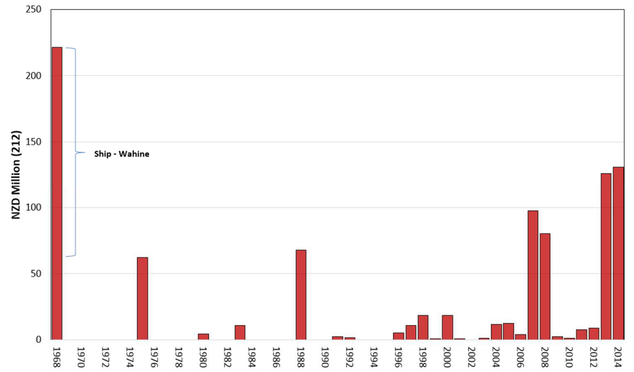

Figure 1. Time series from 1968 to July 2014 of insured losses (inflation adjusted to 2012 NZD) related to storm events where wind damage was a major factor. Numbers are from NZ Insurance council website. http://www.icnz.org.nz/natural-disaster/historic-events.

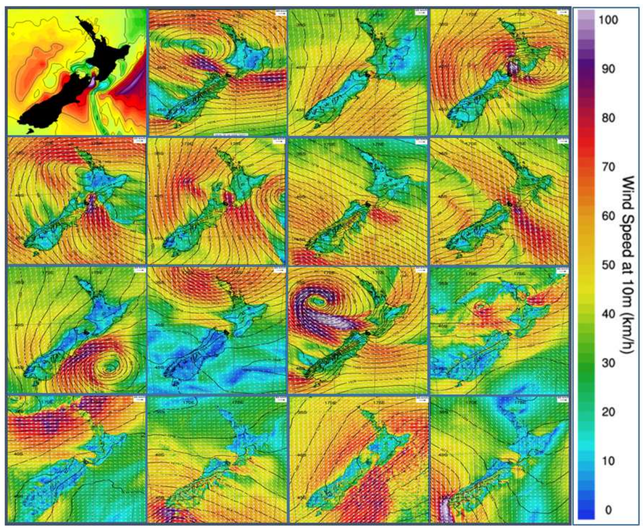

Figure 2. Snapshots from NZLAM (NIWA's weather prediction model) mean wind speed and pressure fields for damaging storms since June 20, 2013. The upper row are 4 significant storms from past years. More information about these events is given in Table 1. The upper left panel is from a RAMS simulation of the Wahine Storm (Revell and Gorman, 2003)

Ex TC Ita (panel 11) Figure 2 stands out and it had a large area of Category 1 (Saffir Simpson scale) Hurricane Force winds associated (Figure 3). Fortunately this storm mainly affected the sparsely populated West Coast, however, it still caused over 55 M in damages.

Ex TC Ita was comparable in intensity and or damage caused to:

- a great storm (also a former Tropical Cyclone) in February 1936 that did much damage in the North Island
- the Wahine storm (ex TC Giselle) of April 1968, and
- ex TC Bola in March 1988. Bola was not as intense as ex TC Ita (central pressures near North Cape were around 980 hPa) but it was very slow moving.

A damage survey of Greymouth where a combination of downslope and channelling effects (Figure 4) similar (but with much stronger gusts) to a damaging 2008 easterly storm described in Turner et al (2011) was carried out following the passage of ex-TC Ita. About 3 times as many properties and more severe damage than 2008 was recorded in the Greymouth suburbs of Blaketown and Cobden.

No	Date	Loss (M)	Comment
1	10-Apr-68	221.4	Ex TC-Giselle (Wahine)
2	30-Jul-08	50.3	Severe Easterly Greymouth
3	12-Mar-10	1.3	Strong Southerly Wellington
4	3-Mar-12	N/A	Patea "Sting Jet" - forestry and power lines
5	20-Jun-13	39.3	Southerly storm Wellington similar intensity to 1974 and worst since Wahine
6	14-Jul-13	<1	Disruptive Storm
7	10-Sep-13	74.5	Canterbury Nor'wester - worst since 1975
8	16-Oct-13	12.4	Strong disruptive Nor'wester
9	4-Mar-14	22.5	Banks Peninsula winds + Heathcote flooding
10	15-Mar-14	3.6	Ex TC-Lusi
11	17-Apr-14	55.3	Ex TC-Ita - Greymouth Record gusts
12	11-Jun-14	37.6	Coromandel and Auckland
13	8-Jul-14	18.8	Northland - Coromandel Record gusts Kaitaia
14	7-Aug-14	N/A	Southland - Power lines
15	21-Sep-14	N/A	Heavy seas, peak annual gust Wellington Aero, major power cuts.
16	7 Oct-14	N/A	Mostly uninhabited areas affected, little damage

Table 1. Summary information about significant storms of 2013 and 2014 that are shown in Figure 2. The numbers in the first column refer to the panels in Figure 2 by stepping left to right and top to bottom, with 1 being top-left and 16 bottom-right. Losses are expressed in 2012 NZD.

A recent advance at NIWA has been the introduction of routine (4 times a day) forecasts done with NZCSM (New Zealand Convective Scale Model, 1.5 km grid spaced configuration of the Unified Model (UM). See Yang et al (2012) for a description of the application of the UM in New Zealand. This has allowed for comparisons between speeds (verified against observations) in support of damage surveys and the development of damage curves for assets such as irrigators. Another example of this is in Figure 5 which shows the location of damaged irrigators (provided by FMG Insurance) following the Sep 10, 2013 storm overlaid on 133 m NZCSM mean winds (a useful proxy for surface gusts), these wind speeds compared well in magnitude and spatial detail to observed peak gusts on this day.

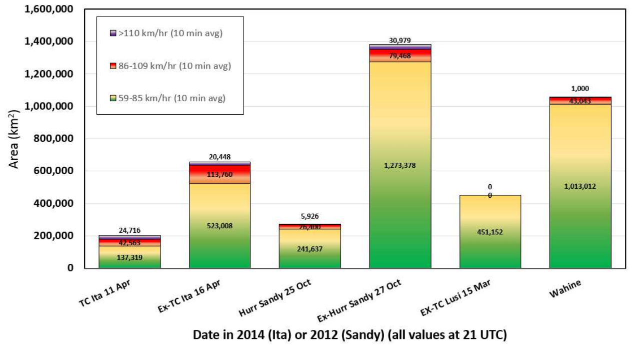

Figure 3. Estimated area of storm force winds (open water) for Tropical and post-tropical phase for Cyclone Ita (2014 South Pacific), Hurricane Sandy (North Atlantic), ex TC Lusi (2014 South Pacific) and ex TC Giselle (Wahine, 1968 South Pacific)

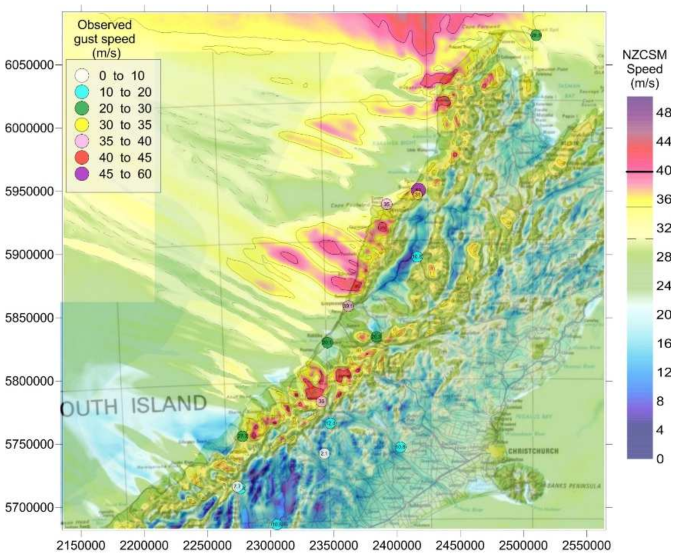

Figure 4. NIWA NZCSM short-range forecast of peak surface gust speeds over the upper South Island during the passage of ex TC Ita on April 17, 2014. Gust observations where available are plotted.

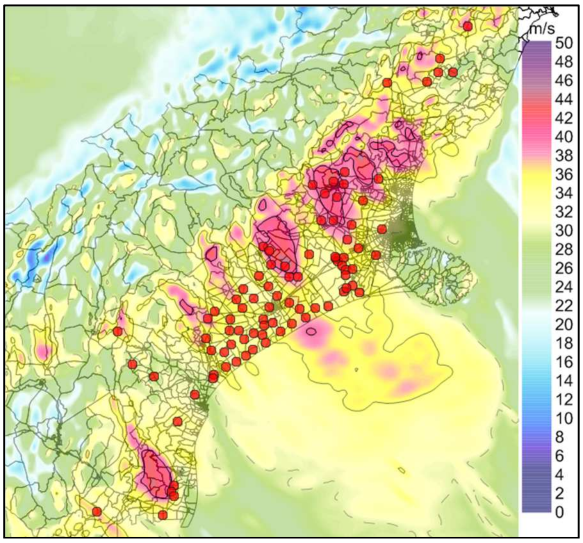

Figure 5. Peak 133 m mean wind speeds from NZCSM short range forecast for Sep 10, 2013 over Canterbury. These are overlaid on mesh-blocks for the Canterbury region. The red dots are centroids of the mesh-blocks within which damage to irrigators was reported.

Long term trends in Cook Strait Wind records

As the spate of wind events continued many questions from power companies, media, and the general public were asked about whether this was the worst ever period for wind in Wellington (as well as other parts of New Zealand). An initial inspection of long term wind records at Wellington Aero (Figure 6), showed that while the June 2013 southerly was the worst in 20 years, it did not seem as strong as some storms of the 1970's and was dwarfed by the Wahine storm of 1968. Also apparent in this figure is a station shift at Wellington airport around 1993-1994 (a period of redevelopment) and this seems to have resulted in a drop of 1.8 m/s in mean gust speeds during northerlies (Figure 7). However, Reid (1996) established that due to the strong channelling effect of Cook Strait there is a strong relationship between Northerly gusts at Wellington airport and positive pressure gradients between Paraparaumu airport (to the North of Cook Strait) and Wellington Aero, and this relationship is shown by the good agreement (Figure 7) in the time-series of this gradient (for days with northerly gusts at Wellington Aero) were plotted (and smoothed) when compared against the northerly gusts. This suggests the station move may not solely account for the drop in gust and mean speeds. In fact, the change in average pressure gradient for these cases accounts for 1.4 m/s of the 1.8 m/s drop in average gust speed between the averaging periods of 1972-1992 and 1994-2014.

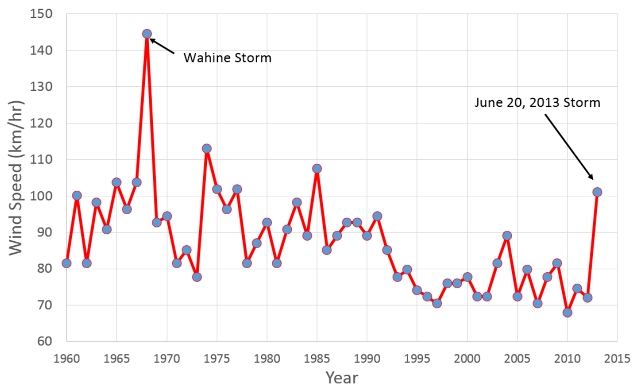

Figure 6. Maximum sustained (10 minute average) wind speeds for each year since 1960 as recorded at Wellington Airport.

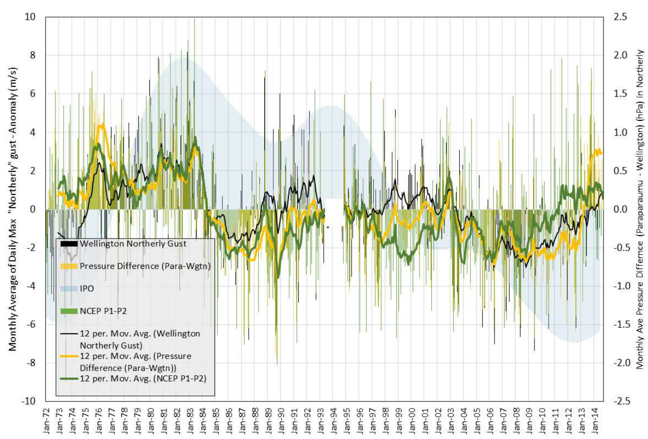

Figure 7. Time series from 1972 to 2014 of monthly averages of maximum daily northerly gusts at Wellington Aero (12pt moving average black line), the Paraparaumu-Wellington Pressure gradient (12 pt moving average Yellow line) and the NCEP reanalysis pressure gradient (12 pt moving average Green line). The shaded blue curve is the IPO index.

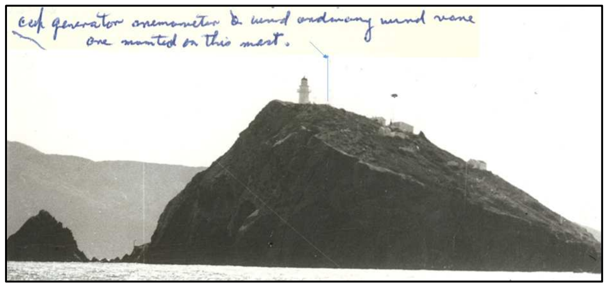

Figure 8. A photo from the mid 1970's (?) showing the Brothers Island from a view looking west, the light blue arrow points to the mast on which the cup anemometer was mounted.

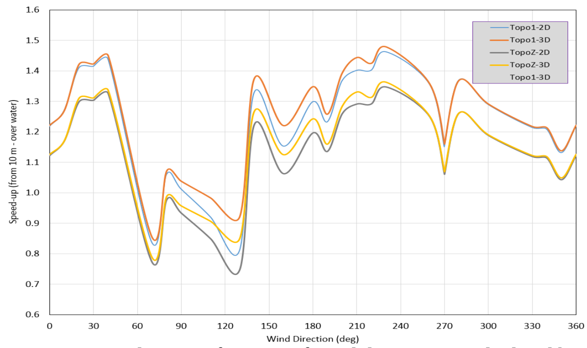

Figure 9. Speed-up as a function of wind direction as calculated by Gerris for the Brothers Island anemometer for various configurations of the Topographic data.

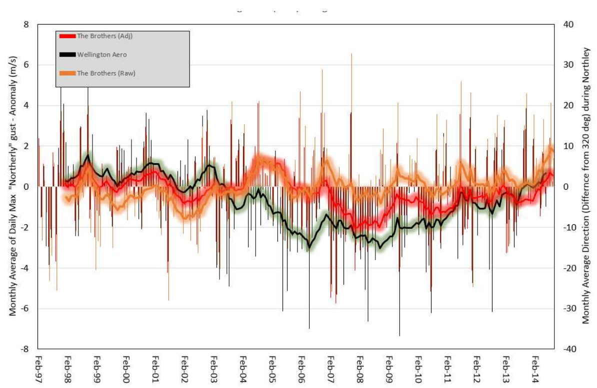

Figure 10. Time series since 1997 of gust speeds (12 pt moving averages) for unadjusted Brothers Island (Orange line), Wellington Aero (Black line) and the adjusted Brothers Island for directional topographic speed-ups (red line).

As another check on later trends (post 1997) in the record, comparisons against the gust record for Brothers Island (Figure 8) station located at the NW entrance to Cook Strait were made. Significant hill-shape speed ups occur at Brothers Island and these need to be accounted for when comparing with other sites. For the Brothers Island modelling was done using the CFD code Gerris in a similar way as for the Belmont Hills project (King et al, 2012). Gerris uses a time varying, adaptive grid to solve the Navier Stokes equations, and is described in Popinet, 2003. The topography (both 3D and 2D sets were tested) was based on coarse resolution terrain contours every 20 m in the vertical and the Gerris model resolution is 10 m in the vertical and 10 m in the horizontal at the highest resolution. The model was run for 20 minutes of simulated time to allow the flow to settle down and then statistics were generated over the next 20 minutes. Thirty six simulations for each terrain data set was done with the inflow condition being a wind from every 10 degrees of direction with a constant vertical profile based on a roughness length of 1 cm and a speed of 10 m/s. A free slip lower boundary condition was used and it was assumed that the dominant turbulence production in the lower layers would be created by flow separation off the fairly rough upstream terrain. No parameterisation of sub-grid scale turbulence was added to the model. The speed-up factors are shown in Figure 9. Note, the mast is at a height of 68 m above sea-level and 10 m agl.

The raw Brothers Island gust speeds (Figure 10 – upper panel) show no consistent longer term trend with Wellington Aero gust speeds. However, when the speed-up factors are applied, the adjusted series (Figure 10 lower panel) becomes much more consistent with Wellington Aero and the Paraparaumu-Wellington pressure gradient.

Conclusions and discussion

A consistent trend in both the Paraparaumu-Wellington mean sea-level pressure gradient and gust speeds at Wellington Airport was obtained, and this was also consistent with trends in the NCEP Reanalysis and gust speeds at Brothers Island, after adjusting for hill-shape directional speed-ups.

There was a 1.8 m/s decline in mean gust speed after the station shift at Wellington Aero in 1993-1994, we estimate approximately 0.4 m/s of this decline attributable to the shift, and 1.4 m/s to a climate signal.

There seems to have been a recent increase (from mid-2013) in gust speeds) from a “benign” period in the early 2000’s. This benign period may have been related to an increase in the SAM index (where higher pressures occur at mid-latitudes) due to a pole-ward contraction of the westerly wind belt which was attributed to the increase in size of the Ozone hole.

Correlations between monthly means of daily maximum northerly gust speeds at Wellington aero with monthly SAM, IPO, and SOI indices were calculated (not presented here). There was found to be weak and negative correlation (around -0.1) with the SAM and none with either the IPO or SOI. No lagged correlation calculations have been done yet.

The pressure differences anomalies in the period from mid-2013 are similar to what was seen in in the mid 1970’s, a period which was also characterised by some of the stronger storms on record in the Cook Strait region.

Avenues for future work are to complete the analysis for southerlies at Wellington airport. Gerris (or similar CFD) runs will be required, however, a complication is that a hill to the south of the old anemometer position was removed during the airport redevelopment and no lidar exist for the older orography. Additionally, Baring Head gust records need to be analysed as well and this will require Gerris analysis for directional speed-ups. It is also interesting to note that the drought of 2013 has been attributed to anomalous high pressures patterns that dominated the New Zealand weather in the first half of 2013 and these have been associated with climate change (Harrington et al (2014). The period of intense wind-storms followed this and possible linkages also need to be explored.

Acknowledgments

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