Effects of Climate Change on New Zealand Design Wind Speeds

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EGU General Assembly 2020
Vienna | Austria | 3–8 May 2020

CL5.6 - Climate Data Compilations, Homogenisation and Analysis of Variability, Trends and Extremes

POSTER # EGU2020-6247

ABSTRACT

This study aims at (i) analysing the gust wind records of four meteorological stations across New Zealand for 1972-2017; (ii) investigating whether or not the long-term wind gust series have changed significantly; and (iii) assessing the impact of these changes in the estimation of design wind speeds to ensure the safety and reliability of future structures. Historical hourly and daily gust wind speed series recorded at the four selected stations were subjected to a robust quality control and homogenisation protocol. The results demonstrated that the annual and seasonal trends in both magnitudes and frequencies of extreme winds were generally negative over the considered period. Therefore, based on the derived gust trends for these four stations, at this stage, it seems that the long-term gust wind speed trends are not likely to have a significant effect on New Zealand's design wind speeds. Lastly, our findings were compared with gust wind speed trends in several other countries and with IPCC 5th assessment projections for New Zealand.

INTRODUCTION

- The study aims to investigate the question: **"How are New Zealand design wind speeds influenced by different climate change scenarios?"** through analysing long-term trends in near surface wind speeds.
- Extreme winds have serious societal and environmental impacts on countries, and can cause significant damage and costs.
- The estimation of appropriate design wind speeds is an essential first step in the calculation of design wind loads. AS/NZS1170.2 (2011), the reference wind-loading standard in Australia and New Zealand, defines the design wind speed ($V_{\text{sit},\beta}$) as:

$$V_{\text{sit},\beta} = V_R M_d \left(M_{z,cat} M_s M_t\right),$$

where V_R is regional gust wind speed, M_d, $M_{z,cat}$, M_s and M_t are directional, terrain/height, shielding and topography multipliers, respectively.

- For the next version of AS/NZS1170.2, the Australian/New Zealand standard committee is considering adding a new multiplier called **"climate change multiplier (M_c)"**, which allows for possible changes in long-term extreme wind speeds due to different scenarios of climate change.
- In this study, for 4 selected locations in New Zealand we analysed the ***spatiotemporal trends*** in two parameters of maximum gust wind speeds:
  - **(i)** the magnitudes (in m s^{-1}) of annual and seasonal maximum gust speeds; and
  - **(ii)** the frequencies (in days) of occurrence of maximum daily gusts exceeding 90th, 95th and 99th percentiles for 1972 – 2017.

METHOD

Homogenisation

- Wind speed data series can be influenced by several factors, which may cause inhomogeneities, and using wind data observations without quality control and homogenisation can introduce significant errors on the order of 10% - 40% in future analyses.
- Prior to any analysis, it is essential that station records are adjusted/homogenised to account for changes in:
  - Instrument and recording methodology (using wind-tunnel tests)
  - Exposure, mast location and height (using data analysis and computational fluid dynamics (CFD) simulation)
- We aim to eliminate all the breakpoints to ensure that time series are free of any artificial shifts or trends, using the homogenisation algorithm recently proposed by Turner et al. (2019). The flow chart summarises the algorithm, and the figure below shows the result of the homogenisation algorithm applied to the annual maximum gusts recorded at the Wellington.

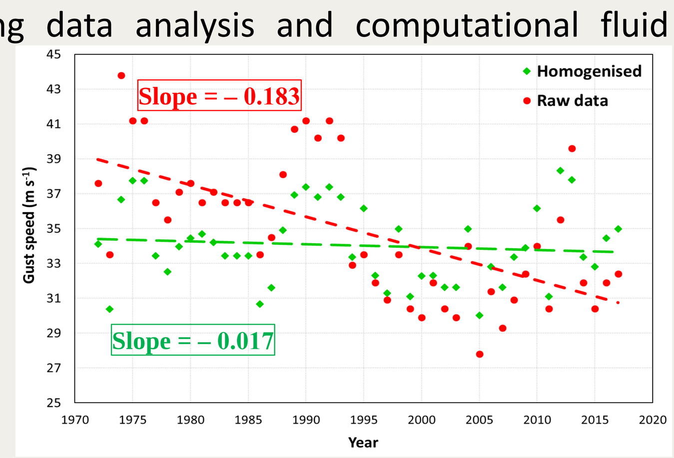


Figure 1: Comparison of raw and homogenised maximum annual gusts recorded at Wellington station during 1972-2017

- **Examples of wind-tunnel tests and CFD simulations:**

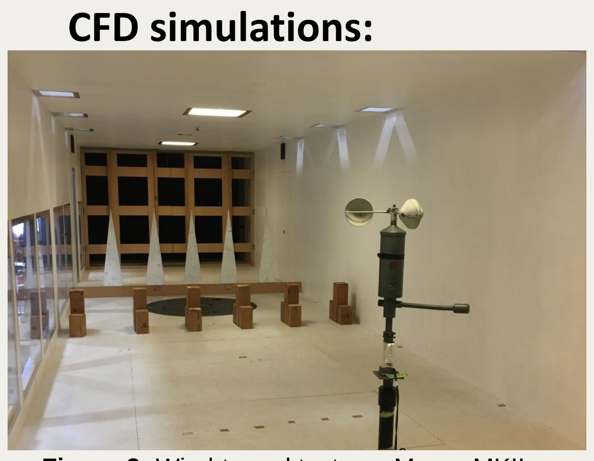


Figure 2: Wind-tunnel tests on Munro MKII anemometer in the boundary-layer wind tunnel at the University of Auckland

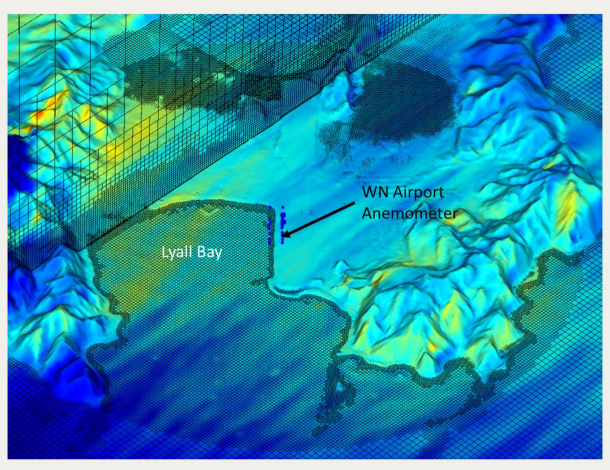


Figure 3: CFD simulation of the Wellington region at the location of the wind mast at Wellington Airport. Colours correspond to the standard deviation of the wind speed. Blue colours correspond to > 2 m/s, and red colours to > 4 m/s.

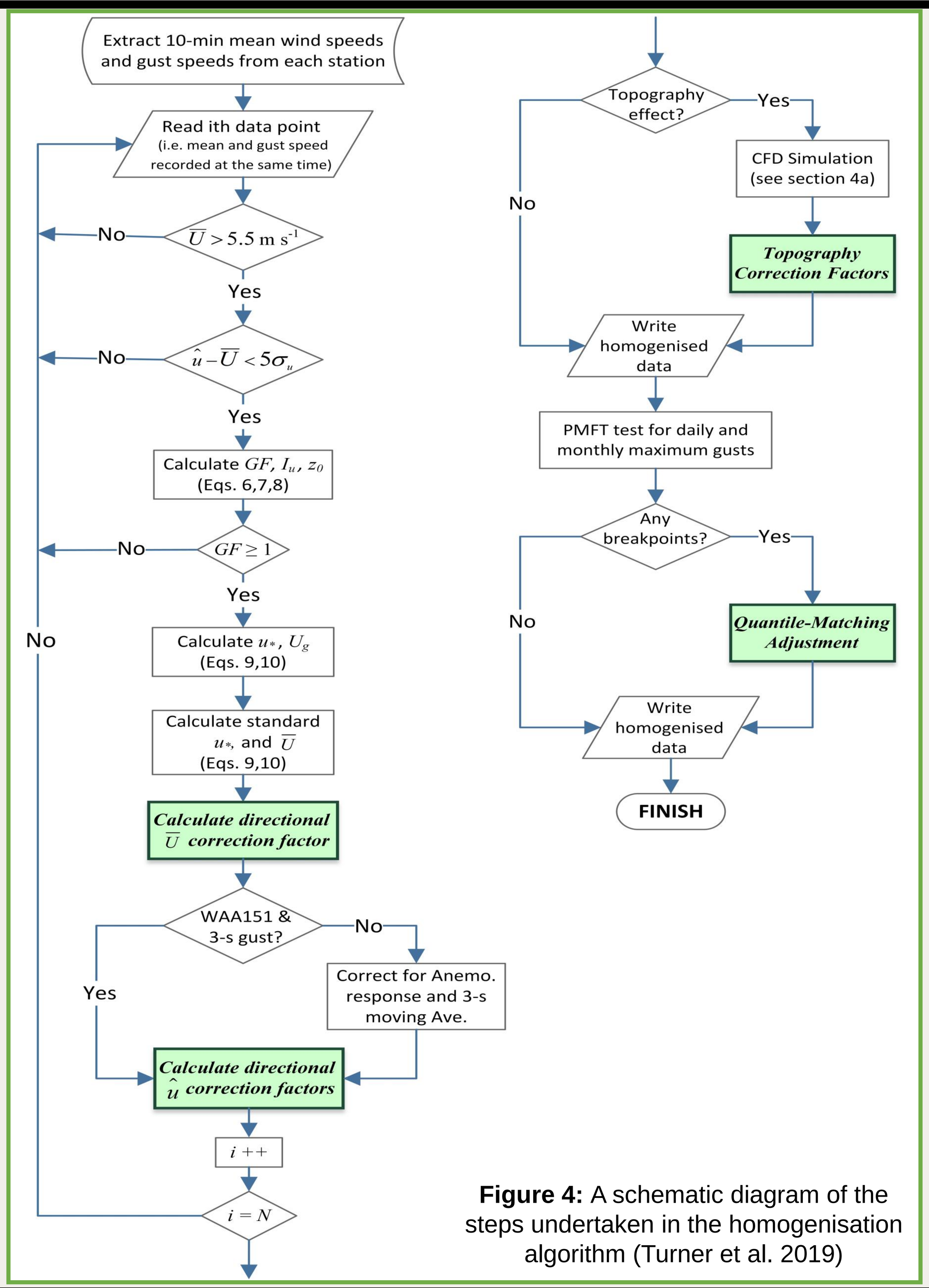


Figure 4: A schematic diagram of the steps undertaken in the homogenisation algorithm (Turner et al. 2019)

Trend Analysis and Selected Stations in NZ

- For this preliminary study, four stations, namely Wellington, Auckland, Christchurch and Invercargill were selected.
- Daily and hourly maximum gust speeds, 10-minute mean speeds and directions were extracted from NIWA's climate database.
- The nonparametric correlation coefficient of **Mann-Kendall's tau-b** was applied to assess the statistical significance of the linear trends at annual and seasonal time scales by determining significant trends at two p-value thresholds, namely at 0.05 and 0.10.
- The trend analysis is based on the application of the **Sen's slope method**.
- Trends in the magnitudes and frequencies are reported in m s^{-1} decade^{-1} and day decade^{-1}, respectively.

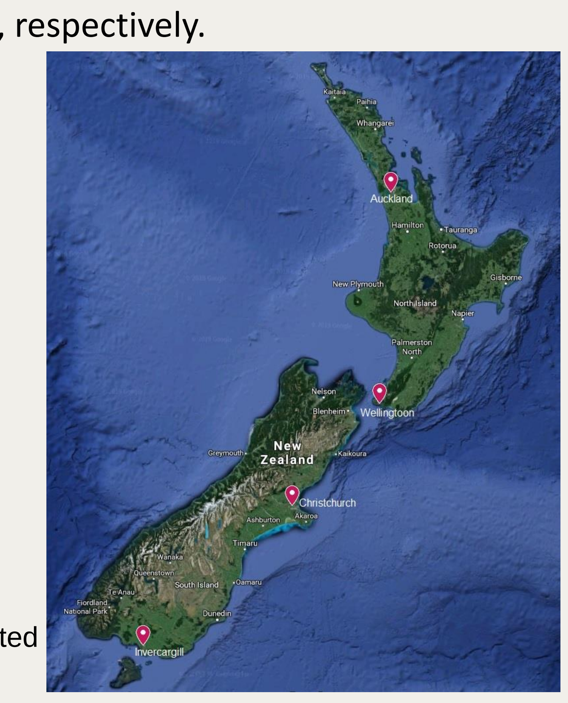


Figure 5: Locations of the four selected stations across New Zealand

RESULTS

Trends in Magnitudes

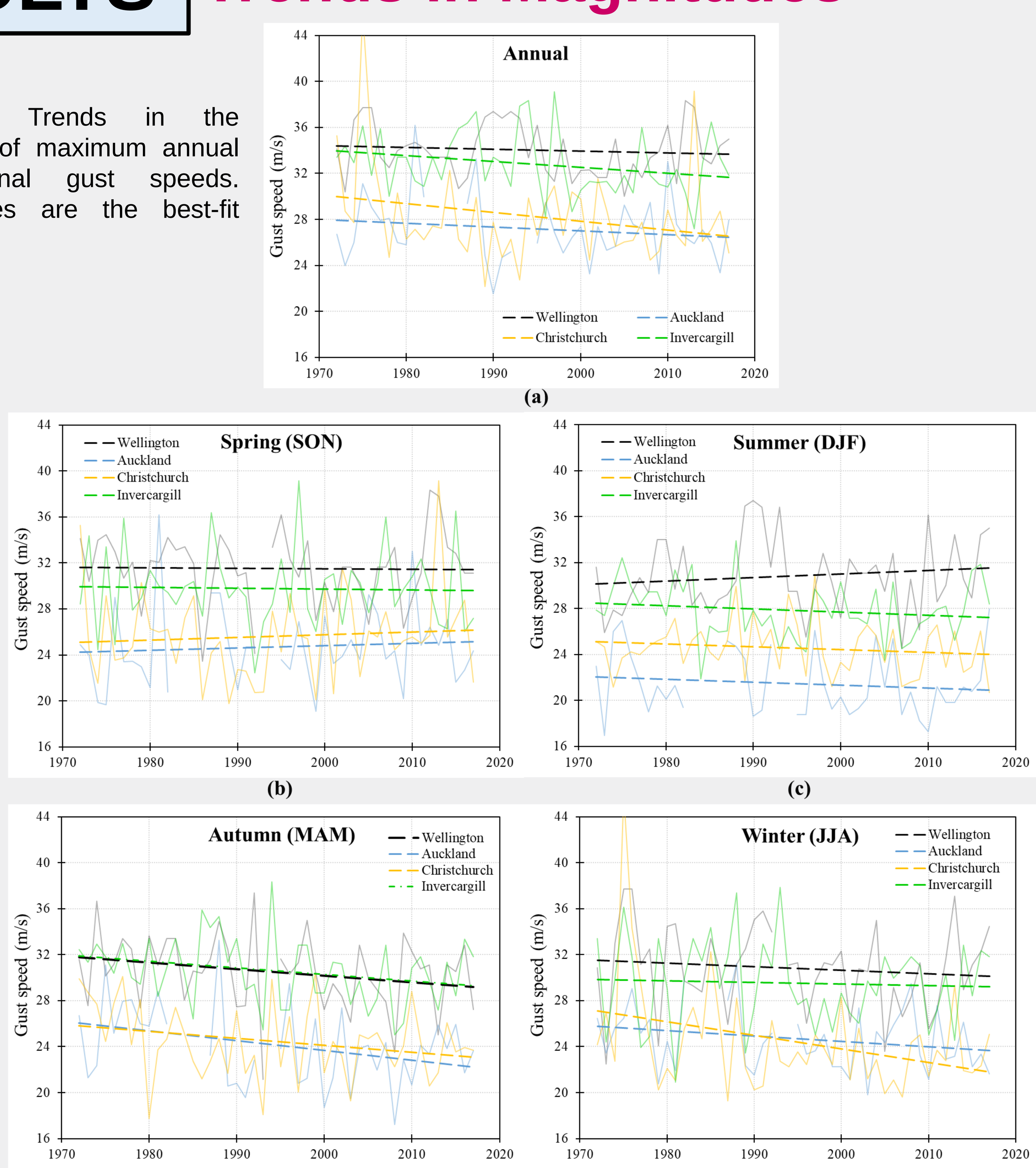


Figure 6: Trends in the magnitudes of maximum annual and seasonal gust speeds. Dashed lines are the best-fit linear trends.

- Magnitudes of maximum gust speeds shown in the figure above generally have decreasing trends at all the stations in all seasons.
- Except at Auckland and Christchurch stations the trends are positive in spring, also at Wellington station in summer the maximum gust speeds showed a positive trend.
- Autumn and winter had the strongest downward trends.
- Annually, all the stations experienced a decreasing trend, and the strongest trends happened at Invercargill (p < 0.05) and Christchurch (p < 0.10).

	Wellington	Auckland	Christchurch	Invercargill
Annual	−0.186	−0.147	**−0.503**	(**−0.435**)
Spring (SON)	−0.251	0.252	0.255	−0.171
Summer (DJF)	0.412	−0.211	−0.236	−0.267
Autumn (MAM)	**−0.531**	−0.670	**−0.689**	**−0.589**
Winter (JJA)	−0.362	−0.455	−0.615	**−0.099**

Table 1: Annual and seasonal trends in maximum gust wind speeds (m s^{-1} decade^{-1}). Statistically significant trends are defined as those $p < 0.10$ (in bold) and $p < 0.05$ (in bold and in parenthesis)

Trends in Frequencies

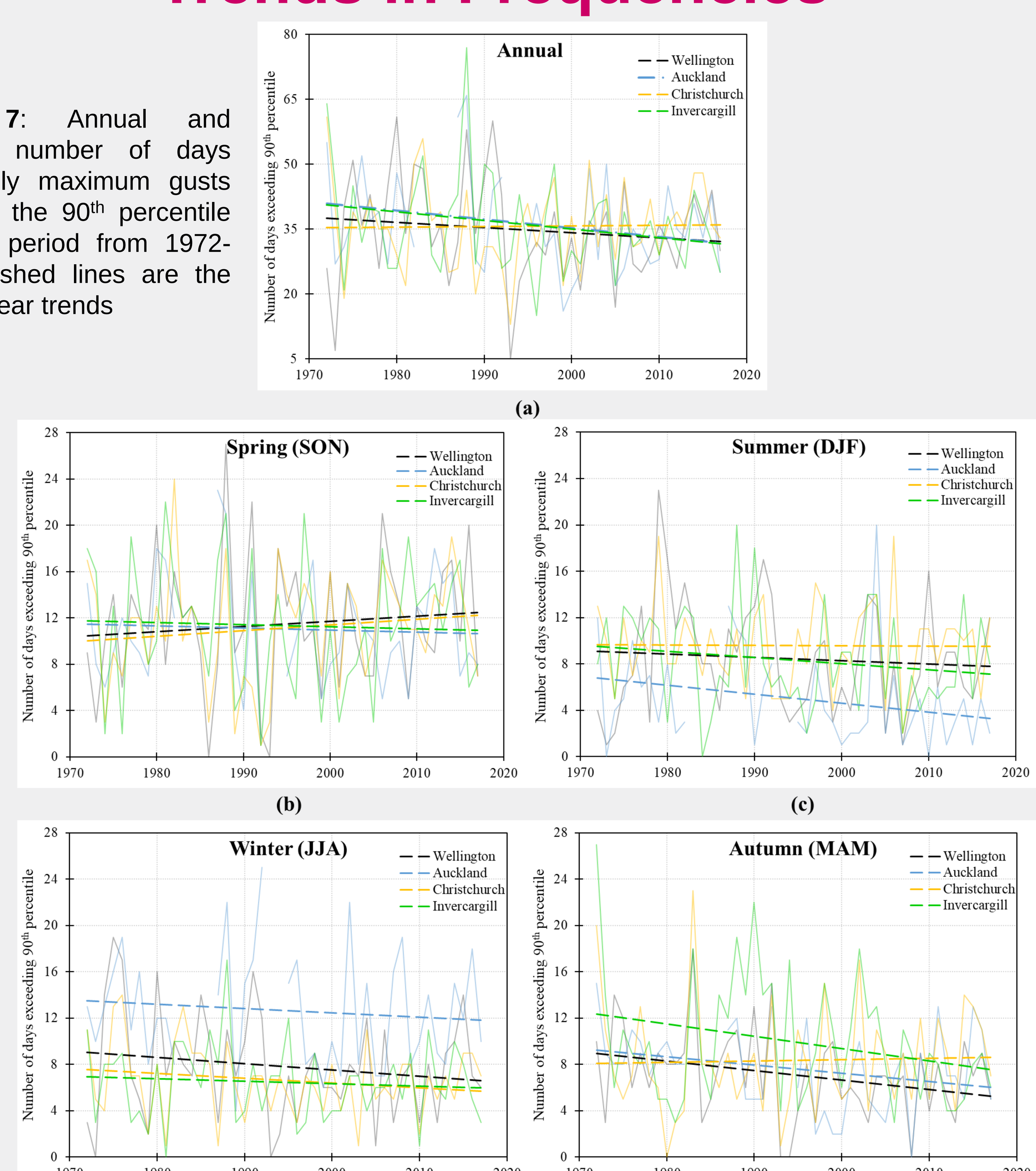


Figure 7: Annual and seasonal number of days when daily maximum gusts exceeded the 90th percentile of whole period from 1972-2017. Dashed lines are the best-fit linear trends

- Annually and seasonally, the trends in the occurrence of extreme winds are generally negative.
- Autumn and winter experienced the strongest decreasing trends in all stations.
- At higher percentiles (i.e. 95th, 99th) the trends become small or even negligible.
- Overall, the negative trends in the frequencies agree with the magnitude trends.

Percentile		Wellington	Auckland	Christchurch	Invercargill
90th	Annual	−1.25	−1.43	0.50	−1.43
	Spring (SON)	0.37	0.00	0.45	0.00
	Summer (DJF)	0.00	(**−0.77**)	0.00	−0.45
	Autumn (MAM)	**−0.71**	−0.67	0.31	−0.81
	Winter (JJA)	0.00	−0.25	0.00	0.00
95th	Annual	−1.00	−0.50	−1.11	−1.00
	Spring (SON)	0.31	0.32	0.00	0.00
	Summer (DJF)	0.00	0.00	0.00	0.00
	Autumn (MAM)	(**−0.43**)	**−0.50**	0.00	**−0.56**
	Winter (JJA)	0.00	−0.57	(**−0.56**)	0.00
99th	Annual	0.00	−0.36	−0.37	(**−0.30**)
	Spring (SON)	0.00	0.00	0.00	0.00
	Summer (DJF)	0.00	0.00	0.00	0.00
	Autumn (MAM)	0.00	**−0.26**	(**−0.25**)	0.00
	Winter (JJA)	0.00	**−0.19**	**−0.20**	0.00

Table 2: Annual and seasonal trends in the number days when daily gusts exceeded 90th, 95th and 99th percentiles for 1972 - 2017 (in day decade-1). Statistically significant trends are defined as those $p < 0.10$ (in bold), $p < 0.05$ (in bold and parenthesis)

IPCC 5th Assessment

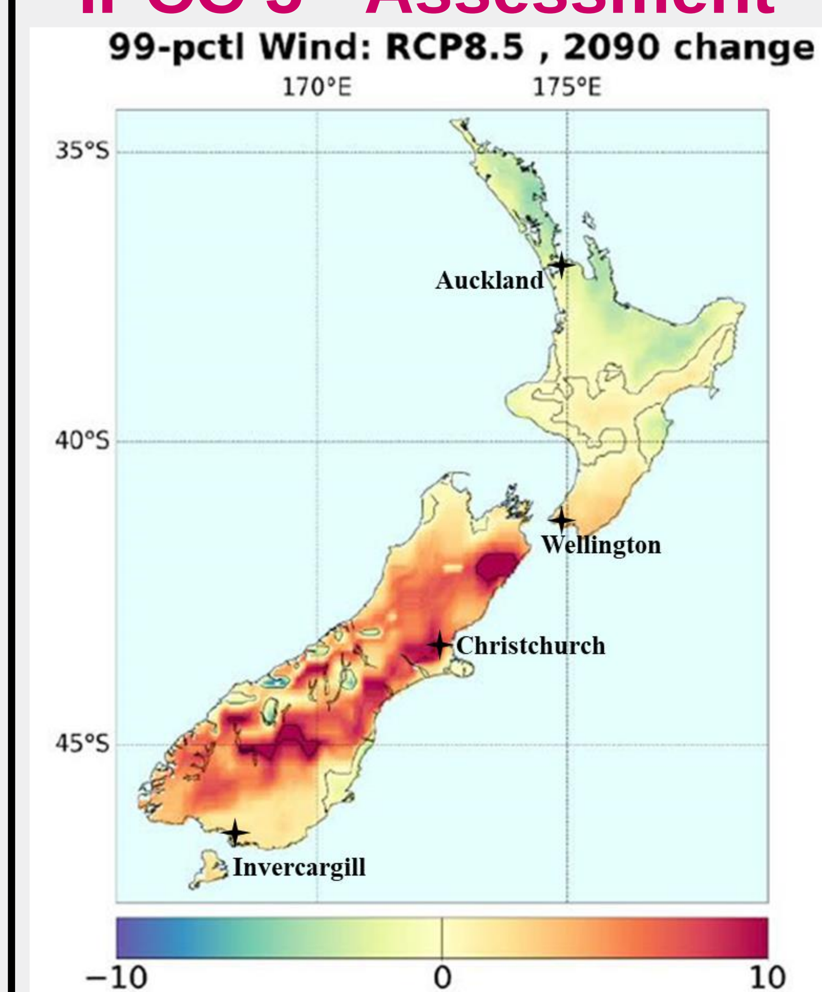
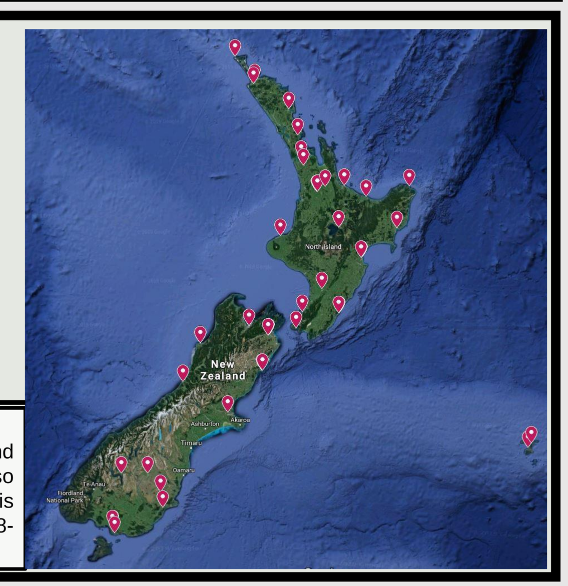


Figure 8: Percentage change in the magnitude of the 99th percentile of "daily-mean" wind speed for RCP8.5 scenario by the end of the 21st century relative to the daily 99th percentile in the baseline 1986–2005 period (Ministry for the Environment, 2018)

- New Zealand Ministry for the Environment (2018) reported projected overall changes in various climate variables under different climate change scenarios.
- Figure above shows the percentage changes in the magnitude of 99th percentile of daily-mean wind speed under one the most severe of the climate change scenarios, RCP8.5, by year 2090.
- Most part of the North Island experiences a reduction in wind speeds, which agrees with our findings for Auckland.
- However, the increasing trends in Wellington, Christchurch and Invercargill areas reported in IPCC 5th assessment are in contrast with our results.
- There was no attempt by Ministry for the Environment (2018) to homogenise the observational datasets. Therefore, more analyses are required to evaluate the accuracy of the IPCC 5th assessment.

CONCLUSION AND FUTURE WORK

- Generally, trends in both magnitudes and frequencies of maximum gust wind speeds were negative.
- Annually, the strongest downward trends in the magnitudes of extreme winds were observed at Christchurch and Invercargill. In addition, autumn and winter experienced strongest negative magnitude and frequency trends.
- The results demonstrated that the trends in the frequency of the upper tail of extreme wind speed distributions (i.e. 95th and 99th), which are important in the estimation of design wind speeds, have not changed significantly.
- It was shown that the trends are mostly negative or negligible suggesting that at this stage no extra multiplier is required to be applied to the design wind speeds.
- The results of this study are limited due to the low number of stations. Currently, more work is underway to analyse the long-term wind gust trends at more stations across New Zealand, as shown in the figure.
- For future work, the potential impact of changes in ex-tropical cyclones should also be investigated.



Select Reference

- Turner, R., Safaei Pirooz, A. A., Flay, R. G. J., Moore, S. and Revell, M. (2019) 'Use of High-Resolution Numerical Models and Statistical Approaches to Understand New Zealand Historical Wind Speed and Gust Climatologies' *Journal of Applied Meteorology and Climatology*, Vol. 58: 1195-1218 DOI: https://doi.org/10.1175/JAMC-D-18-0347.1.
- Safaei Pirooz, A. A., and Flay, R. G. J. (2018) 'Response characteristics of anemometers used in New Zealand' in: *The 19th Australasian Wind Engineering Society Workshop*, 4-6 April, 2018, Torquay, Victoria.
- Safaei Pirooz, A. A., Turner, R. and Flay, R. G. J. (2018) 'New Zealand gust climatology - Part II: revising New Zealand regional wind speeds' *NZ Hydrological Society & Meteorological Society of NZ Joint Conference*, 4-7 December, 2018, Christchurch, New Zealand.
- Ministry for the Environment 2018. *Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition*. Wellington: Ministry for the Environment.

Acknowledgements

The research was funded by New Zealand's Ministry of Business, Innovation and Employment through New Zealand Natural Hazard Research Platform. This work was also supported by the project #2017-03780 funded by Vetenskapsrådet. This presentation is supported by the Ramon y Cajal fellowship (RYC-2017-22830) and the grant # RTI2018-095749-A-I00 (MCIU/AEI/FEDER, UE)