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Science

Climate variability and change

Climate change scenarios for New Zealand

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This material is based on the IPCC 5th Assessment report.

See Climate Change Projections for New Zealand for the detailed 2016 NIWA report to Ministry for the Environment on New Zealand climate change projections based on the IPCC 5th Assessment.

For a summary of likely impacts based on the IPCC 5th Assessment report, see: *IPCC Fifth Assessment - Impacts: New Zealand* [PDF 1090 KB]

For earlier scenarios see previous information based on the IPCC 4th Assessment report.

What is a climate change scenario?

Predicting human-induced ("anthropogenic") changes in climate, over the next 100 years, for a particular part of New Zealand requires:

- A prediction of global greenhouse gas and aerosol emissions for the next century
- A global carbon cycle model to convert these emissions into changes in carbon dioxide concentrations (and similar models for calculating concentrations of other greenhouse gases

and aerosols)
- A coupled atmosphere-ocean global circulation model (AOGCM) which uses the greenhouse gas and aerosol concentration information to predict climate variations forward in time.
- Downscaling of the AOGCM results through a procedure which takes account of the influence of New Zealand's topography on local climate. This can be done either statistically or with a high resolution regional climate model.

Given our current knowledge and modelling technology, there are uncertainties in each of these steps. For example, emission predictions depend on the difficult task of predicting human behaviour, such as changes in population, economic growth, technology, energy availability and national and international policies, including predicting the results of international negotiations on constraining greenhouse gas emissions. Our understanding of the carbon cycle and of sources and sinks of non-carbon dioxide greenhouse gases is still incomplete. As discussed in NIWA's climate modelling web page, there are significant uncertainties in current global climate model predictions—particularly at the regional level.

The climate change scenario approach recognises these uncertainties. A scenario is a scientifically-based projection of one plausible future climate for a region. For guidance on regional impacts of climate change, a range of scenarios is desirable. These can span credible estimates of future greenhouse gas emissions, and the uncertainty range in climate model predictions.

IPCC 5th assessment scenarios

For the IPCC Fifth Assessment, a new set of four forcing scenarios was developed, known as representative concentration pathways (RCPs) (van Vuuren et al, 2011). These pathways are identified by their approximate total (accumulated) radiative forcing at 2100 relative to 1750:

- 2.6 $W\ m^{-2}$ for RCP2.6
- 4.5 $W\ m^{-2}$ for RCP4.5
- 6.0 $W\ m^{-2}$ for RCP6.0
- 8.5 $W\ m^{-2}$ for RCP8.5.

These RCPs include one mitigation pathway (RCP2.6, which requires removal of some of the CO_2 presently in the atmosphere), two stabilisation pathways (RCP4.5 and RCP6.0), and one pathway (essentially 'business as usual') with very high greenhouse gas concentrations by 2100 and beyond.

Figure 1 compares the atmospheric concentrations of carbon dioxide in the 4 RCPs with those from four of the best-known SRES scenarios described in the discussion of earlier scenarios. Note that the new RCP2.6 scenario is very different from all previous scenarios considered by the IPCC.

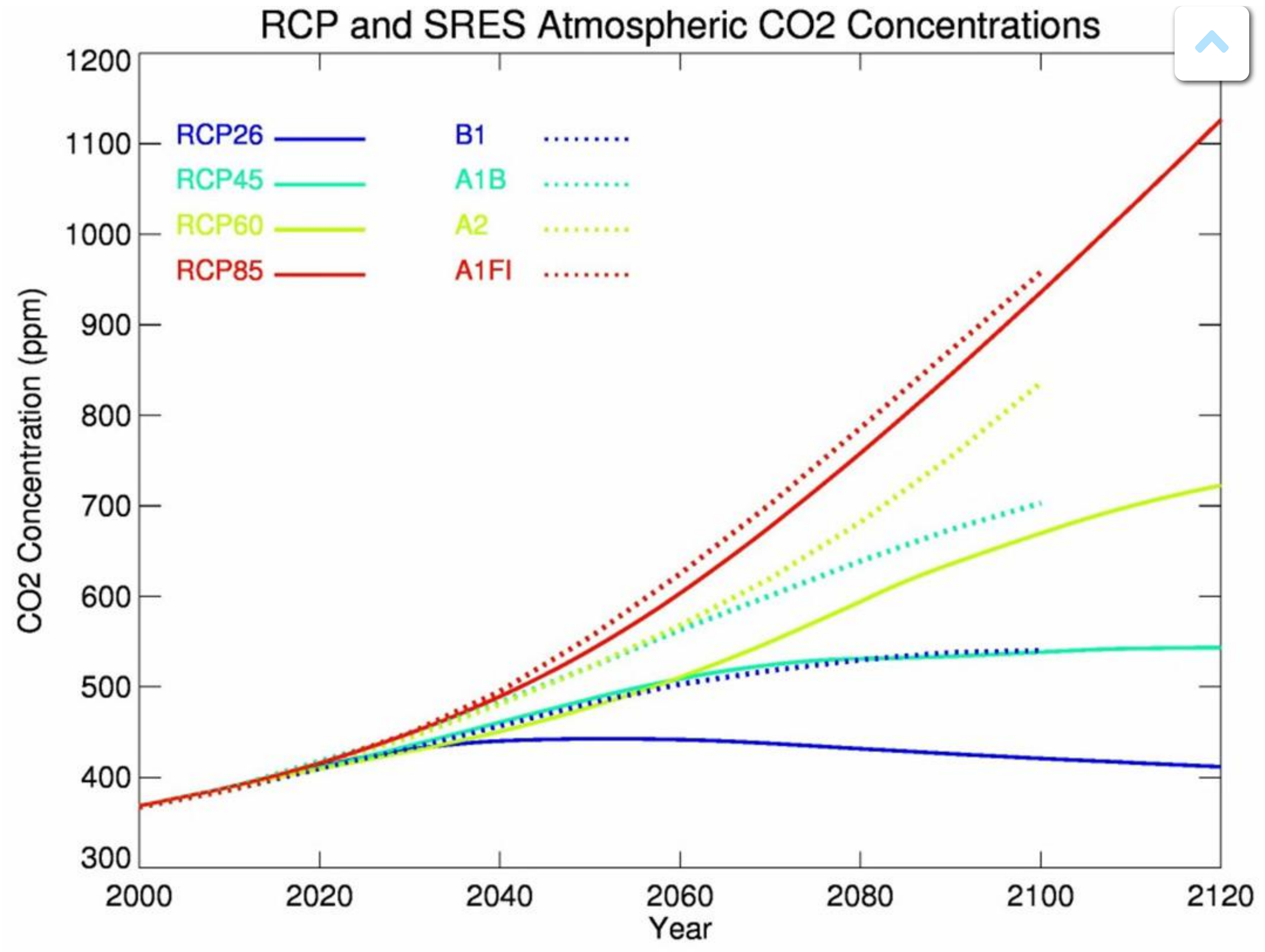


Figure 1: Atmospheric carbon dioxide concentrations for the IPCC Fourth Assessment (dotted lines, SRES concentrations) and for the IPCC Fifth Assessment (solid lines, RCP concentrations) [NIWA]

Many international modelling institutions ran their ocean-atmosphere coupled global climate models, forced by the RCP concentrations. Some institutions ran multiple model versions. NIWA selected 6 of these models for downscaling to the New Zealand region.

Downscaling to New Zealand

'Statistical' downscaling (see Earlier New Zealand regional scenarios) was used to develop temperature and precipitation projections for New Zealand climate change for up to 41 different global climate models (GCMs). See the MfE report referenced above for details.

Six GCMs were selected for 'dynamical' downscaling, and some results are presented below. For this downscaling approach, sea surface temperatures and sea ice concentrations from the six models were used to drive an atmospheric global model, which in turn drove a higher resolution regional climate model (RCM) over New Zealand. The six models were chosen to validate well on present climate. Daily output data were further downscaled to an approximately 5 kilometre grid for the following climate variables: *precipitation, maximum temperature, minimum temperature, potential evapotranspiration, downward solar radiation at the surface, relative humidity, 10-metre wind speed, and mean sea-level pressure.*

Figure 2 shows temperature projections over New Zealand to the year 2120 from the 24 RCM simulations carried out by NIWA (6 models by 4 RCPs).

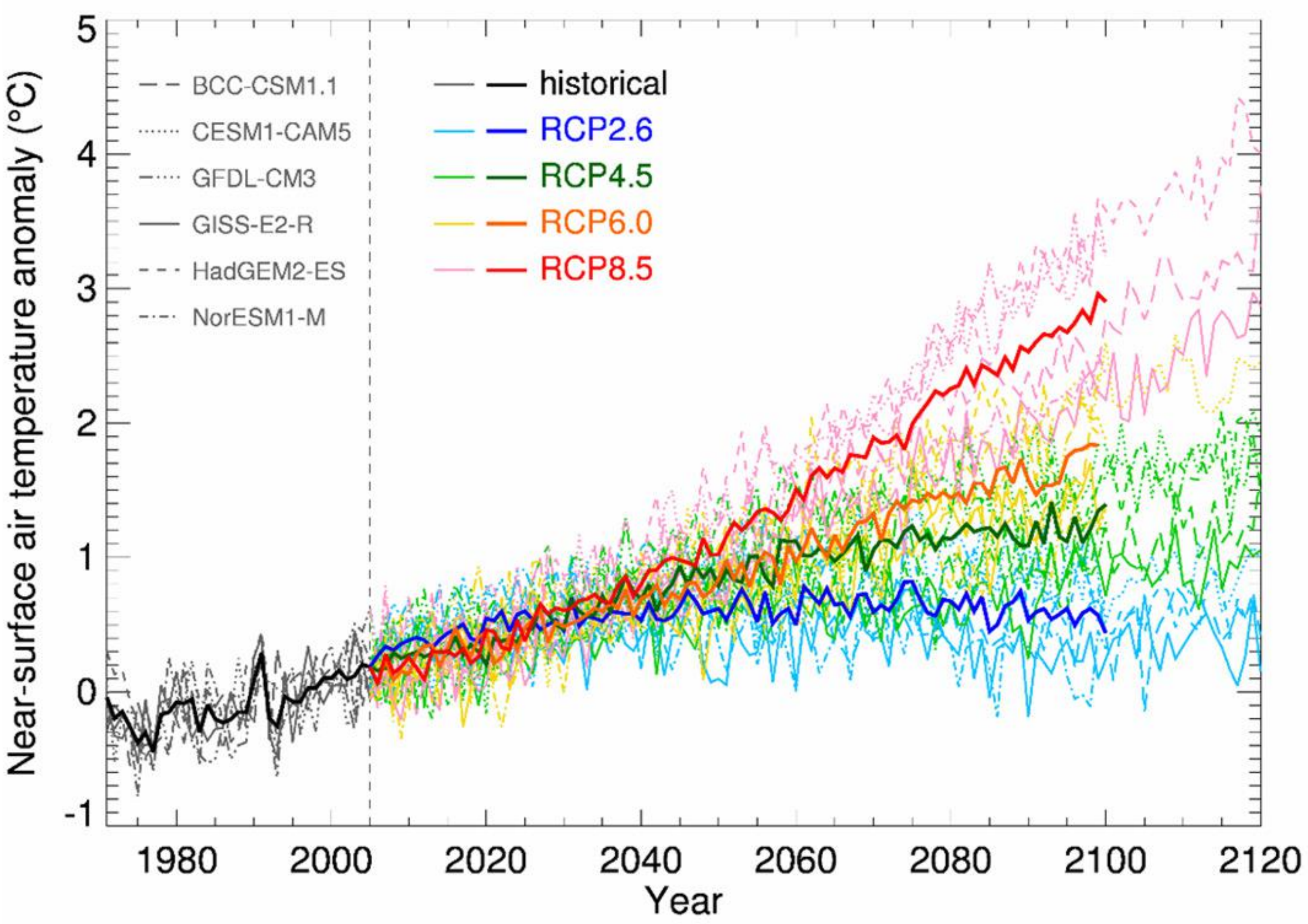


Figure 2: Projected New Zealand-average temperatures relative to 1986-2005, for six IPCC 5th Assessment global climate models, and for the historical simulations (here 1971-2005) and four future simulations (RCPs 2.6, 4.5, 6.0 and 8.5). Individual models are shown by thin dotted or dashed or solid lines (as described in the inset legend), and the 6-model ensemble-average by thicker solid lines, all of which are coloured according to the RCP. [NIWA]

New Zealand regional climate change scenarios

Table 1 summarises the main features of these New Zealand climate projections. The future periods focussed on are labelled as "2040" (the 2031-2050 average), and "2090" (2081-2100 average). In the full report, a further period "2110" (2101-2120) was also considered. All the changes are relative to the 1986-2005 period (or "1995"), referred to as the baseline historical climate.

Table 1: New Zealand climate change projections for 2040 and 2090 (Ministry for the Environment, 2016).

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation

Climate variable	Direction of change	Magnitude of change	Spatial and season variation
Mean temperature	Progressive increase with greenhouse gas concentration. Only for RCP2.6 does warming trend peak and then decline.	By 2040, from +0.7°C [RCP2.6] to +1.0°C [RCP8.5]. By 2090, +0.7°C to +3.0°C.	Warming greatest at higher elevations. Warming greatest summer/autumn and least winter/spring.
Minimum and maximum temperatures	As mean temperature.	Maximum increases faster than minimum. Diurnal range increases by up to 2°C by 2090 (RCP8.5).	Higher elevation warming particularly marked for maximum temperature.
Daily temperature extremes: frosts	Decrease in cold nights (minimum temperature of 0°C or lower).	By 2040, a 30% [2.6] to 50% [8.5] decrease. By 2090, 30% [2.6] to 90% [8.5] decrease.	Percentage changes similar in different locations, but number of days of frost decrease (hot day increase) greatest in the coldest (hottest) regions.
Daily temperature extremes: hot days	Increase in hot days (maximum temperature of 25°C or higher).	By 2040, a 40% [2.6] to 100% [8.5] increase. By 2090, a 40% [2.6] to 300% [8.5] increase.	
Mean precipitation	Varies around the country and with season. Annual pattern of increases in west and south of New Zealand, and decreases in north and east.	Substantial variation around the country, increasing in magnitude with increasing emissions.	Winter decreases: Gisborne, Hawke's Bay and Canterbury. Winter increases: Nelson, West Coast, Otago and Southland. Spring decreases: Auckland, Northland and Bay of Plenty.

Climate variable	Direction of change	Magnitude of change	Spatial and season variation
Daily precipitation extremes: dry days	More dry days throughout North Island, and in inland South Island.	By 2090 [8.5], up to 10 or more dry days per year (~5% increase).	Increased dry days most marked in north and east of North Island, in winter and spring.
Daily precipitation extremes: very wet days	Increased extreme daily rainfalls, especially where mean rainfall increases.	More than 20% increase in 99th percentile of daily rainfall by 2090 [8.5] in South West of South Island. A few percentage decrease in north and east of North Island.	Increase in western regions, and in south of South Island. No increase in 99th percentile in parts of north and east of North Island.
Snow	Decrease.	Snow days per year reduce by 30 days or more by 2090 under RCP8.5.	Large decreases confined to high altitude or southern regions of the South Island.
Drought	Increase in severity and frequency.	By 2090 [8.5], up to 50mm or more increase per year, on average, in July–June PED.	Increases most marked in already dry areas.
Circulation	Varies with season.	Generally, the changes are only a few hectopascals, but the spatial pattern matters.	More northeast airflow in summer. Strengthened westerlies in winter.
Extreme wind speeds	Increase.	Up to 10% or more in parts of the country.	Most robust increases occur in southern half of North Island, and throughout the South Island.

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Storms	Likely poleward shift of mid-latitude cyclones and possibly also a small reduction in frequency.	More analysis needed.	See full report.
Solar radiation	Varies around the country and with season.	Seasonal changes generally lie between -5% and +5%.	By 2090 [8.5], West Coast shows the largest changes: summer increase (~5%) and winter decrease (5%).
Relative humidity	Decrease.	Up to 5% or more by 2090 [8.5], especially in the South Island.	Largest decreases in South Island in spring and summer.

Comments in Table 1 above summarise projections from both the dynamical downscaling of 6 models, and statistical downscaling of up to 41 climate models (number of models varies with RCP). All the figures in the remainder of this section summarise projections from the dynamical downscaling only. In all cases, the figures are produced by calculating the changes from each of the models separately, and then averaging them—to produce what is called the "ensemble-mean".

Figures are shown only for 2090 and for the highest of the four RCPs (RCP8.5), because these most clearly demonstrate the direction of the change. Other RCPs, or changes to 2040, will have smaller projected changes (see full MfE report).

Mean temperature

Figure 3 shows the regional model projections of New Zealand mean temperature at the end of the century (2081-2090 average, relative to 1986-2005) under RCP8.5. Temperature increases everywhere, and the increases tend to be larger in summer, and in the North Island, and at higher altitude.

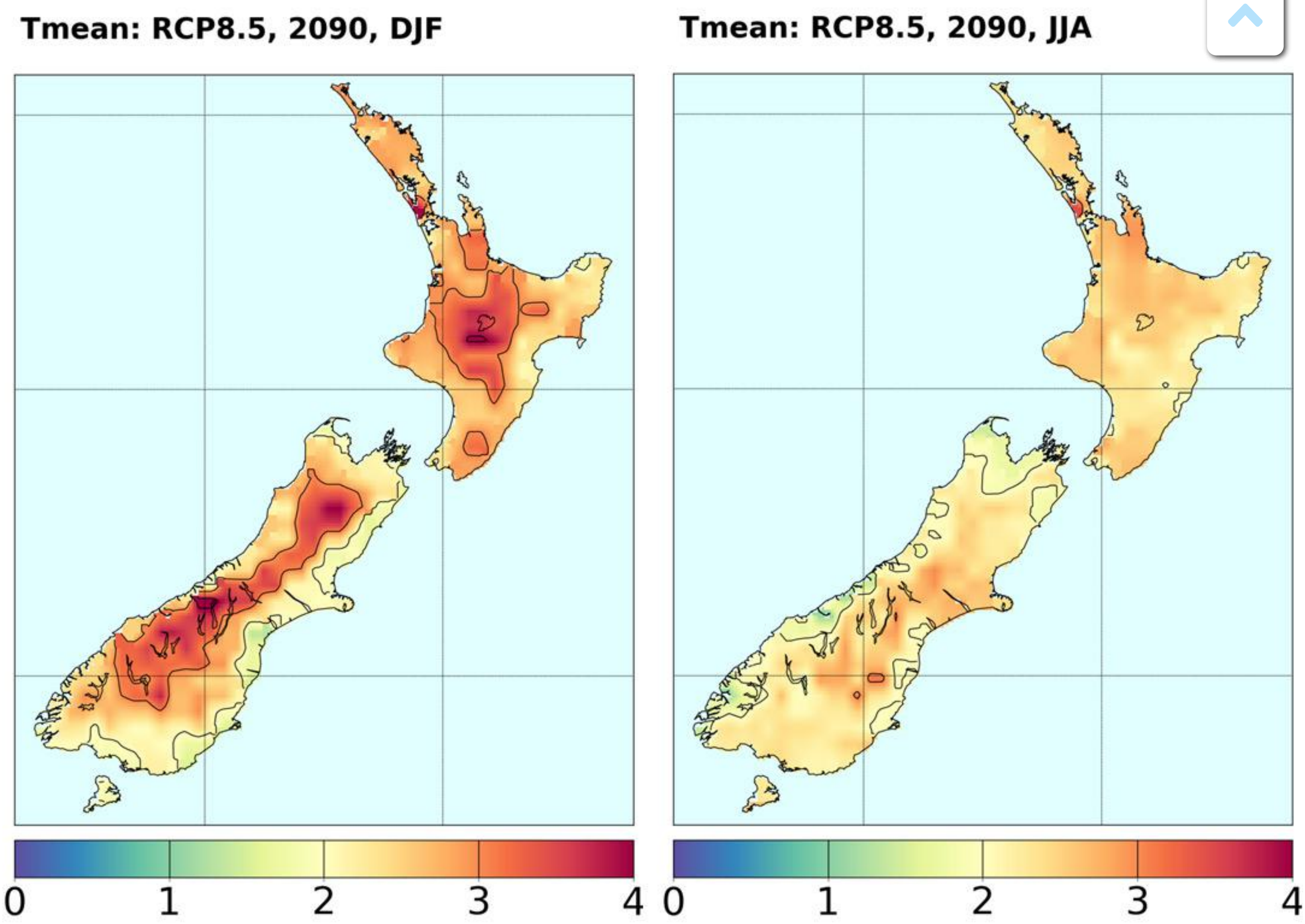


Figure 3: Projected changes in mean temperature (in °C) for summer (Dec-Jan-Feb) and winter (Jun-Jul-Aug) by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO_2 concentration scenario RCP8.5 from the IPCC 5th Assessment. [NIWA]

Precipitation

Figure 4 shows the regional model projections of New Zealand mean precipitation at the end of the century (2081-2090 average, relative to 1986-2005), under RCP8.5. In summer, precipitation generally either decreases or shows little change for most of the country, except for the West Coast of the South Island, and parts of Canterbury. In winter, precipitation changes show a pattern of increases in the west and south, and decreases in the east and north of the country, reflecting an increase in prevailing westerly quarter winds. Small changes in precipitation are usually a consequence of lack of consensus between the different climate models in the seasonal changes in circulation.

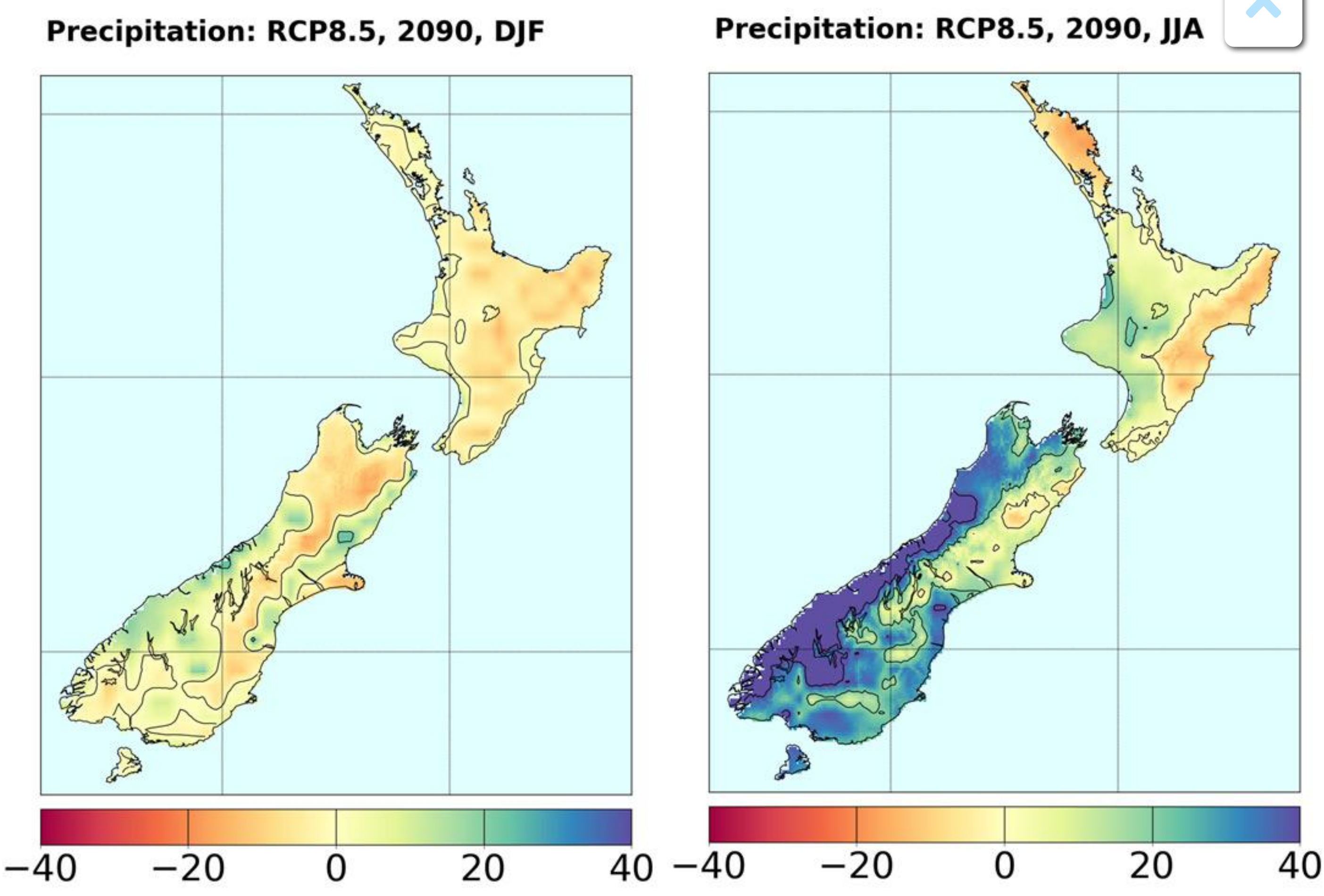


Figure 4: Projected changes in precipitation (in %) for summer (Dec-Jan-Feb) and winter (Jun-Jul-Aug) by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO_2 concentration scenario RCP8.5 from the IPCC 5th Assessment. [NIWA]

Online Tool for exploring temperature and rainfall projections

The Our Future Climate New Zealand tool is an online menu-based system for exploring projected temperature and rainfall maps for New Zealand and charts for a selection of locations. The maps and charts are based on the same six dynamically downscaled models and four RCPs, described above. Every combination of model and RCP can be explored.

Note that while the base period (1986-2005) and the end-century period (1981-2100) are the same as were used for the MfE (2016) report, the mid-century period (2046-2065) is slightly different and there is also a near-term period (2016-2035). These are the same periods used by the IPCC Fifth Assessment Report Climate Change Atlas available as an annex pdf from the IPCC 5th Assessment report webpage.

Changes in extremes

The greatest impact of climate change is likely to be experienced first by changes in extremes rather than by changes in mean conditions. In earlier New Zealand scenarios prepared from IPCC 4th Assessment models, changes in extremes were estimated by applying projected monthly changes to daily observational data. In these latest scenarios based on IPCC 5th Assessment models, daily extreme extremes are simulated directly by NIWA's regional climate model.

High and low temperature extremes

Increasing temperatures result in more "hot days" and fewer frosts. Figure 5 quantifies these changes by the end of the century under RCP8.5. New Zealand, with its maritime climate, does not experience the extreme high temperatures that occur in many other parts of the world. A daily maximum temperature threshold of 25°C has therefore been chosen to mark a "hot day" in Figure 5. This threshold has a practical application for New Zealand agriculture—beef and dairy cattle tend to start experiencing heat stress at temperatures above this threshold.

Hot days increase much more in already warmer regions of the country (like the north of the North Island), whereas cold (frosty) nights will show much larger decreases in occurrence in colder regions. For example, very little change in frost frequency occurs in warmer coastal parts of the North Island.

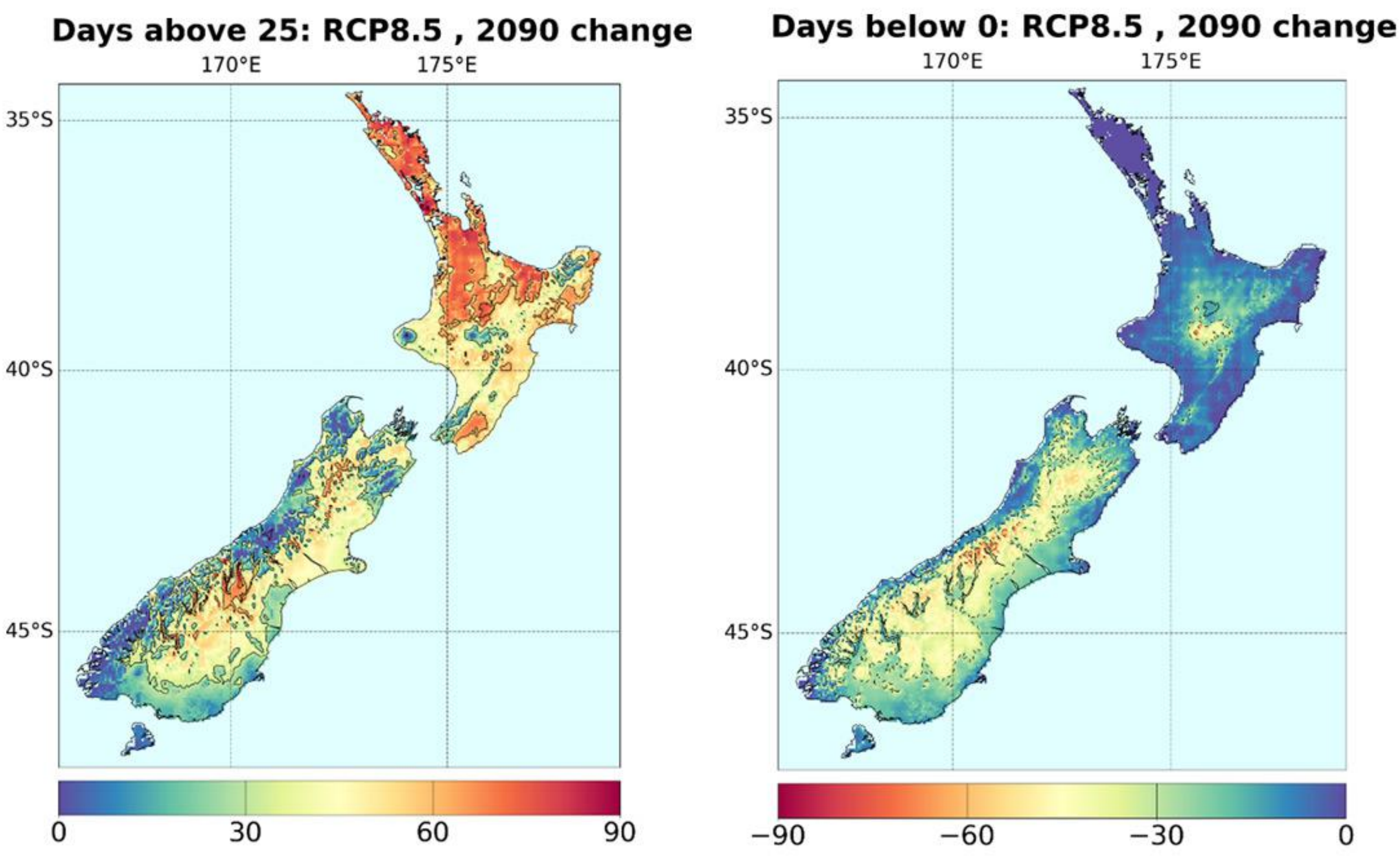


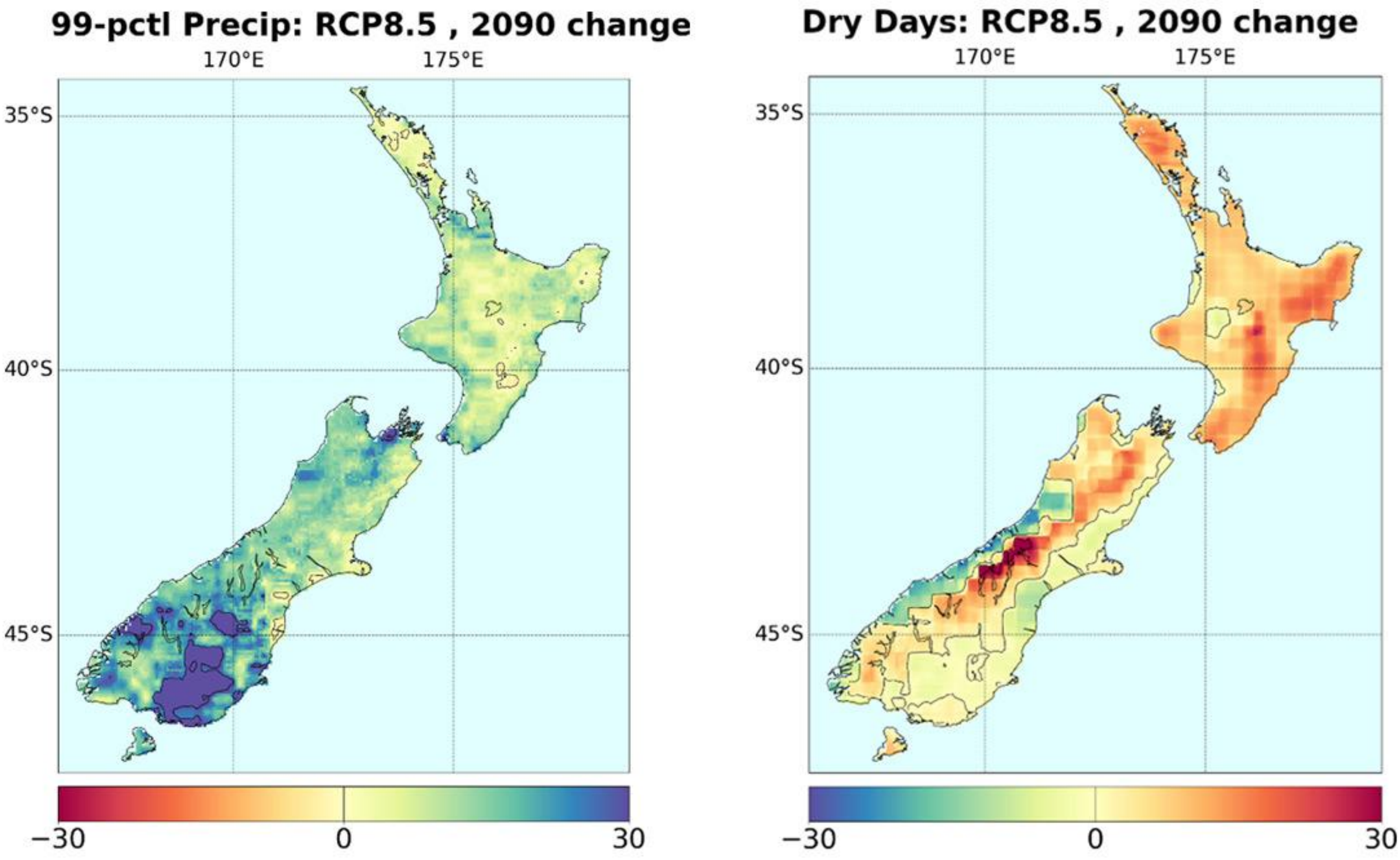
Figure 5: Projected changes in the annual number of hot days (maximum temperature 25°C or above) and cold nights (minimum temperature 0°C or below) by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO_2 concentration scenario RCP8.5 from the IPCC 5th Assessment.

Heavy rainfall and dry days

A warmer atmosphere can hold more moisture, and so the potential for more intense rainfall events is increased. Cycling of water through the atmosphere (i.e., evaporating from the surface, transportation by winds, and ultimately precipitating out) accelerates under global warming by about 3% per d of warming, which is not as fast as the rate of increase in moisture holding capacity (about 7-8 degree of warming). Thus, recharge of atmospheric moisture takes a bit longer and results in more dry days in many locations. Thus for rainfall, as opposed to temperatures, extremes increase at **both** ends of the spectrum: more heavy rainfall and more dry days.

Figure 6 illustrates this pattern of extremes. Almost the entire country shows some increase in heavy rainfall, with increase above 30% in much of Otago and Southland. “Heavy” or “extreme” rainfall is defined here as the 99th percentile of the daily rainfall distribution over 1986-2005 (at every 5 km pixel on the map). For places where it rains, on average, every 3 or 4 days, this corresponds approximately to the average annual maximum. More extreme rainfall, such as 1 in 100 year events, are expected to show even larger increases.

The number of dry days (daily precipitation of less than 1mm) increases over most of New Zealand. The banded pattern over the Southern Alps is thought to be due, at least in part, to more precipitation falling as rain which falls out more quickly in the west, compared to snow which falls more slowly and gets carried further across the mountains.



Projected changes in extreme precipitation (in %) and in the number of dry days per year by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO_2 concentration scenario RCP8.5 from the IPCC 5th Assessment. [NIWA]

Strong winds

Figure 7 shows projected changes in strong winds. As with rainfall, the 99th percentile threshol determined (for both present and future climate) by ranking daily values over a 20-year period (2005 and 2081-2100). The figure maps the percentage change in the 99th percentile threshold.

The largest increases in extreme daily wind speed occur in coastal Canterbury and central Otago, with increases in excess of 10%, by the end of the century under RCP8.5. It is likely that these increases are associated with stronger foehn winds in the lee of the Southern Alps, occurring in winter and spring with stronger prevailing westerlies.

Figure 7 suggests little change or even a decrease in extreme daily winds in Northland and Bay of Plenty. This may be an underestimate: it is suspected that the geographic domain of NIWA's regional climate model is too small to properly intensify ex-tropical cyclones entering the New Zealand region. In the global models, tropical cyclones are too weak because of the low model resolution and the small scale of these intense circulations.

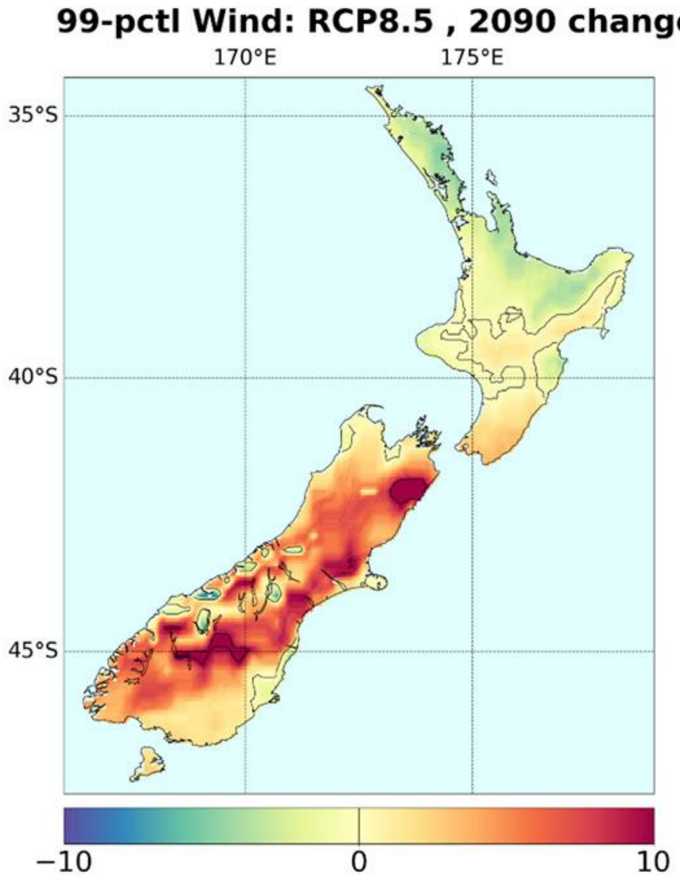


Figure 7: Projected changes in extreme daily wind speed (in %) by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO_2 concentration scenario RCP8.5 from the IPCC 5th Assessment. [NIWA]

References

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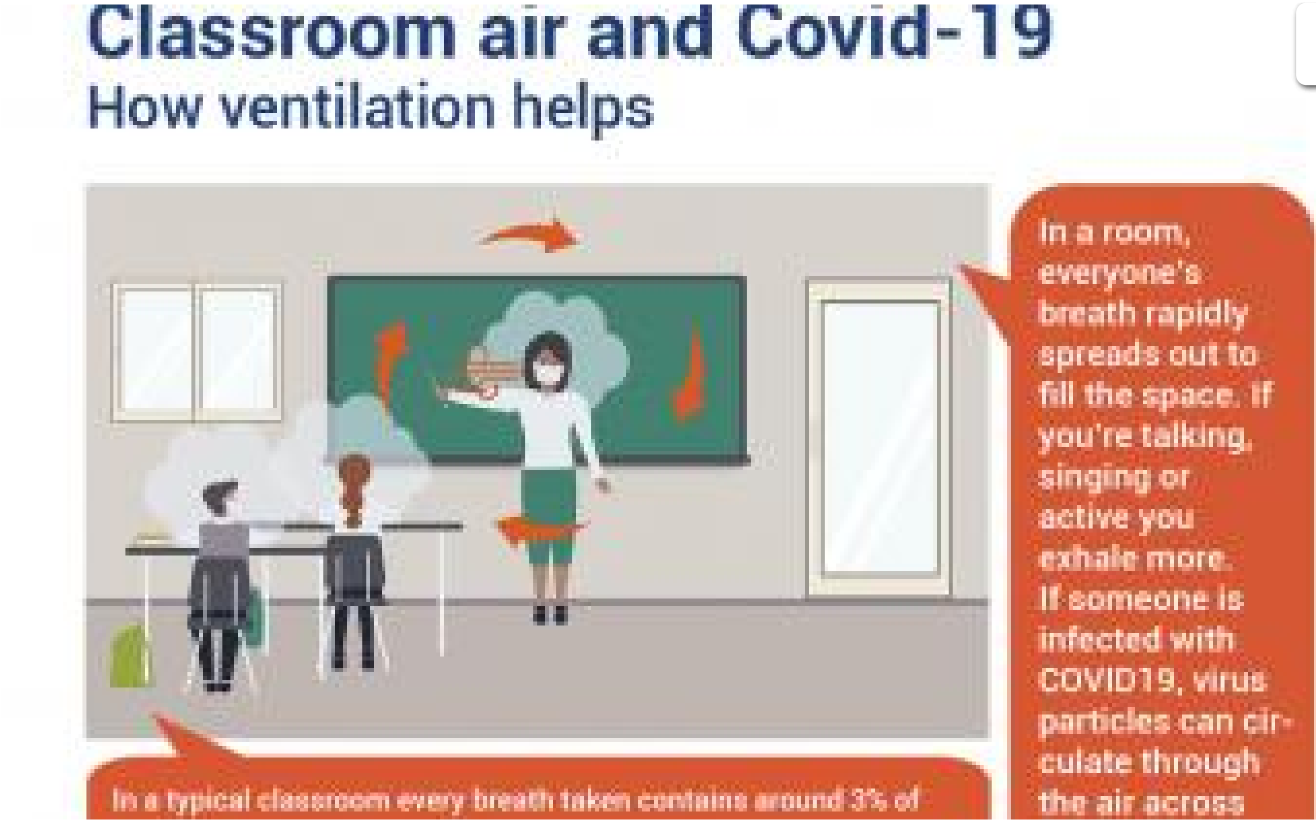

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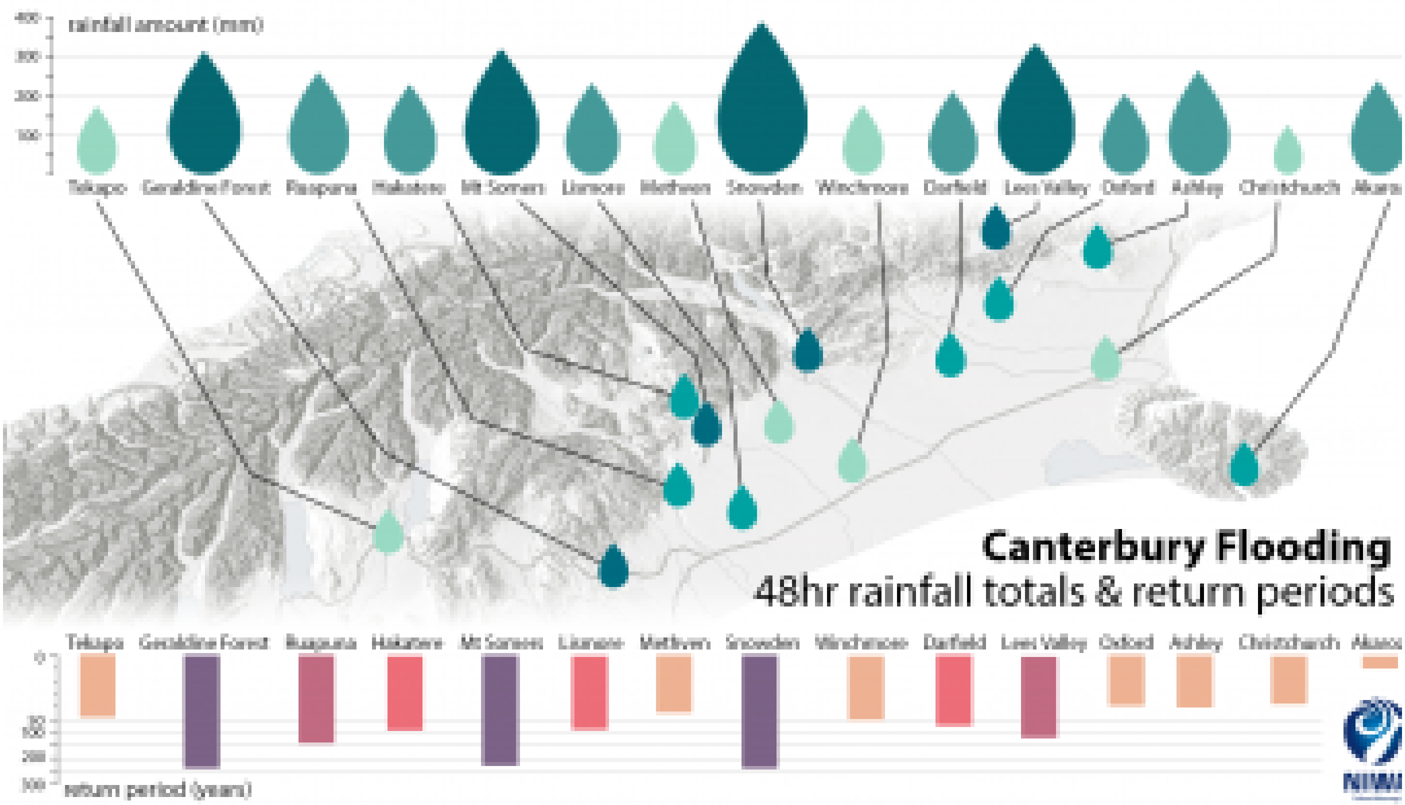

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