Climate Changes, Impacts and Implications for New Zealand to 2100

Synthesis Report: RA1

Updated Climate Change Projections for New Zealand for Use in Impact Studies

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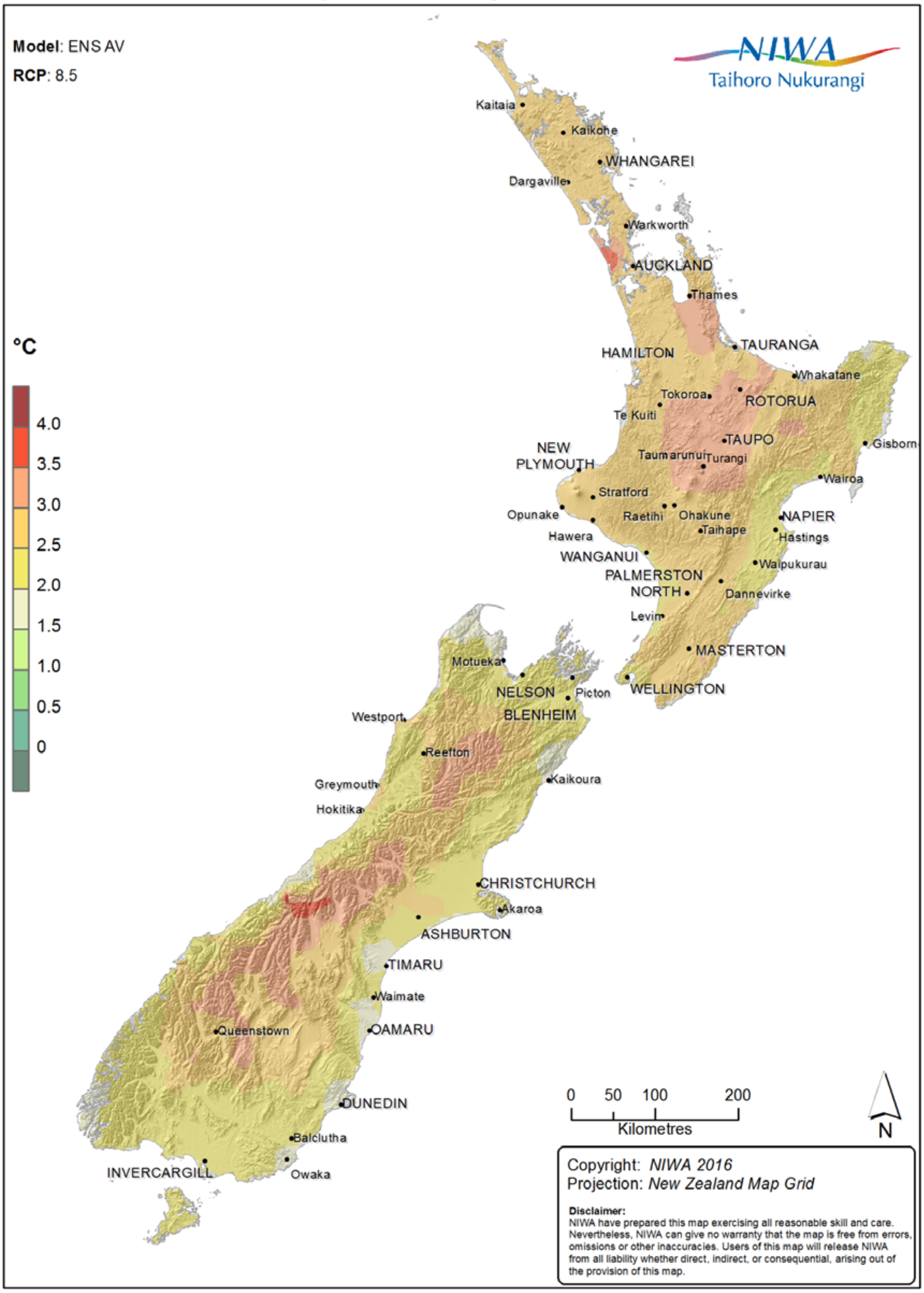
Annual Mean Temperature Change Between 1995 and 2090



HIGHLIGHTS

- Over 35 TB of global climate data were downloaded from the Coupled Model Inter-comparison Project (CMIP-5) data repository from over 40 General Circulation Model (GCM) runs, performed for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).
- The six best-performing GCMs for the New Zealand region were selected, based on comparisons with observations over the historical data period of the models. These models are: HadGEM2-ES (UK), CESM1-CAM5 (USA), NorESM1-M (Norway), GFDL-CM3 (USA), GISS-E2-R (USA) and BCC-CSM1.1 (China). Each of these models performs better than the 12 CMIP-3 models used previously for New Zealand climate change assessments.
- Sea surface temperature (SST) data from these six GCMs were bias-corrected and, together with a global atmospheric GCM, were used as initial and boundary conditions for the higher spatial resolution (~27km) NIWA Regional Climate Model (RCM). Temperature and precipitation data from the RCM were bias corrected using the Linked empirical Modelled and Observed Distribution (LeMOD) correction method and all climate variables and indices were further downscaled to the ~5km grid of the Virtual Climate Station (VCS) data.
- The Ensemble Projections Incorporating Climate (EPIC) model uncertainty method was developed to generate large ensemble projections of maximum and minimum temperatures at daily resolution for all of New Zealand, out to 2100. These data can be used to generate probability density functions (PDFs) of future maximum and minimum temperature.
- The New Zealand-downscaled GCM and RCM data have been analysed and the results presented in a comprehensive report for the Ministry for the Environment (http://www.mfe.govt.nz/node/21990).
- Maps of projected climate changes have been produced for several variables, with the temperature and precipitation maps available for each of the six GCMs and the 6-model-average, via the Our Future Climate New Zealand (http://ofcnz.niwa.co.nz). The OFCNZ tool also allows users to view time series charts of changes in temperature and precipitation for 15 locations around the country.
- The Future Extremes web page (http://futureextremes.ccii.org.nz/) has also been developed. This tool allows the user to select any location in New Zealand and the variable of interest (hot days, frosts, hot spells or cold spells), the emissions scenario, and whether the results should be shown as probabilities, number of events per year, or number of events per decade.
- The CCII RA1 climate dataset is a landmark dataset that will be used by multiple researchers and stakeholders for many years to come, to produce a consistent baseline of knowledge on climate change impacts and implications for New Zealand.

INTRODUCTION

The CCII project

The "Climate Changes, Impacts and Implications" (CCII) project is a four-year project (October 2012 – September 2016) designed to address the following question:

> *What are the predicted climatic conditions and assessed/ potential impacts and implications of climate variability and trends on New Zealand and its regional biophysical environment, the economy and society, at projected critical temporal steps up to 2100?*

The CCII project brings together a strong research team with knowledge and modelling capabilities in climate, ecosystems, land and water use, economics, and sociocultural research to address the environment sector investment plan priority of "stronger prediction and modelling systems".

The project is based around five inter-related Research Aims (RAs) that will ultimately provide new climate change projections and advancements in understanding their impacts and implications for New Zealand's environment, economy and society. The five RAs are:

Research Aim 1: *Improved Climate Projections*

Research Aim 2: *Understanding Pressure Points, Critical Steps and Potential Responses*

Research Aim 3: *Identifying Feedbacks, Understanding Cumulative Impacts and Recognising Limits*

Research Aim 4: *Enhancing Capacity and Increasing Coordination to Support Decision-making*

Research Aim 5: *Exploring Options for New Zealand in Different Changing Global Climates*

The overall purpose of RA1 is to: Update and improve regional-scale projections of climate trends and variability across New Zealand out to 2100 based on the latest global projections. This synthesis report describes the process of updating and improving regional-scale climate projections for New Zealand and describes how users can access the new data. Work done on generating a large ensemble of temperature projections for New Zealand is also presented, as are web-based tools for exploring visualisations of the data.

The need for updated climate data

Anthropogenic climate change poses critical challenges for New Zealand. Therefore, it is critical that robust, up-to-date climate projection data are produced and made readily available and 'user friendly', to improve our understanding of the potential impacts and implications of climate change on New Zealand's environment, economy and society.

For the CCII project (and for multiple related ongoing and future projects), the RA1 team worked closely with NIWA's Regional Climate Modelling Programme[1] to produce updated, state-of-the-art downscaled New Zealand climate projections and a large ensemble of temperature projections for New Zealand based on a pattern scaling approach. These datasets were made available to the researchers in RAs 2 and 3 (see the Synthesis Reports associated with these two RAs for details on the modelling work that incorporated the climate data), and have also been shared with other researchers outside the CCII project.

[1]https://www.niwa.co.nz/climate/research-projects/regional-modelling-of-new-zealand-climate

BACKGROUND

Previous climate change projections for New Zealand

In 2008, NIWA completed a set of future projections of mean temperature and rainfall for New Zealand based on statistically downscaling output from 12 General Circulation Models (GCMs). These GCMs had been recently (at the time) updated for the purposes of the Climate Model Intercomparison Project, phase 3 (CMIP-3). Output from CMIP-3 was used extensively by climate change researchers around the world with maps and summaries of the projections being reported in the Intergovernmental Panel on Climate Change 4th Assessment (AR4) Working Group 1 Report (Solomon et al., 2007).

The New Zealand downscaling work was based on a statistical model that generated relationships between observed mean monthly temperature and rainfall for New Zealand (using Virtual Climate Station data; Tait et al., 2006; Tait, 2008) and indices derived from gridded large-scale pressure, temperature and humidity fields over and around New Zealand (Mullan et al., 2001). The statistical relationships were then applied to the CMIP-3 model data from 12 of the available GCMs.

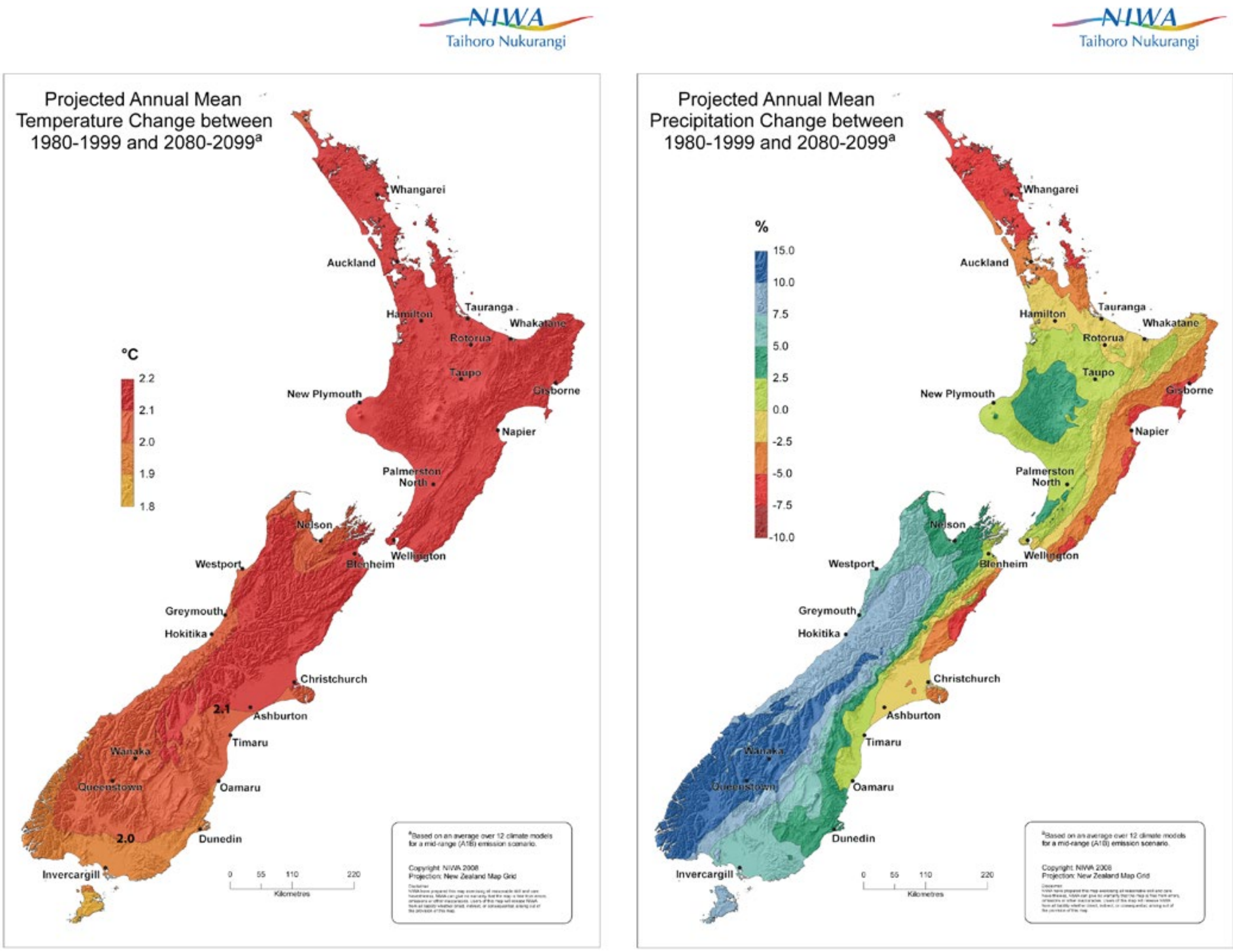


Figure 1: Maps made in 2008 of the projected change in mean annual temperature (left) and precipitation (right) between 1980-1999 and 2080-2099, based on a middle-of-the-road greenhouse gas emissions scenario (A1B) and the average of 12 GCMs (statistically downscaled onto a 5km grid for New Zealand).

Virtual Climate Station (VCS) data are interpolated from daily observations of rainfall, temperature, wind speed, etc. to a regular 0.05° lat/long (approx. 5km) grid covering all of New Zealand. More information can be found here: https://www.niwa.co.nz/climate/our-services/virtual-climate-stations.

Maps of the projected change in the mean annual temperature and precipitation between 1980-1999 and 2030-2049 (50 year change) and 2080-2099 (100 year change), based on the A1B middle-of-the-road greenhouse gas emissions scenario and the 12-model average, were produced (e.g. Figure 1). Projections were also made for each GCM and other emission scenarios, with these data summarised in tables, figures and text and published as a report for the New Zealand Ministry for the Environment (MfE, 2008a).

The NIWA report formed the basis for the MfE publication "Preparing for Climate Change: A guide for local government in New Zealand" (MfE, 2008b), which has subsequently been used extensively by local government and others (e.g. engineers, researchers, businesses) for the last eight years.

Also included in the NIWA and MfE publications was some very early output from the NIWA Regional Climate Model (RCM; see Section 3 of this report for details). Over the last eight years NIWA has invested an extensive effort to improve and validate the RCM, and the CCII project has capitalised on this work. Also in this period since 2008, the IPCC published the 5th Assessment Report (AR5; IPCC, 2013) which reported on results from the most-recent CMIP phase (CMIP-5).

Thus it was a perfect opportunity to update the climate change projections for New Zealand based on CMIP-5 GCM output (incorporating all the advances and improvements at a global climate modelling level) and using the latest version of NIWA's RCM. This update was the core function of CCII RA1.

The CMIP-5 dataset

The IPCC AR5 Working Group Reports, Summary for Policy Makers and Synthesis Report were published in 2013 and 2014. The majority of the Working Group 1 assessment was based on output from CMIP-5 GCMs (IPCC, 2013). The number of GCM runs submitted to CMIP-5 (around 40, with varying run lengths) was much larger than for CMIP-3 (the models used for the previous IPCC AR4). All the CMIP-5 output was downloaded by NIWA and Bodeker Scientific, for use in the CCII RA1 analyses.

All told, the CMIP-5 dataset takes up over 35 TB of disk storage space. The large temperature ensemble analysis (see Section 3.3) using a pattern-scaling approach utilised all of these data, while the RCM (due to the significant amount of time needed to run the simulations on NIWA's supercomputer) was coupled to the output from six GCMs (Table 1). The selection of the six GCMs was based on an assessment of the best-performing models for simulating the past climate of New Zealand (Mullan et al., 2013a,b). This selection approximately spans the climate sensitivity of the complete set of CMIP-5 models.

Representative Concentration Pathways (RCPs)

The most significant change between CMIP-3 and CMIP-5 was that the GCMs for CMIP-5 were "forced" with updated data on future atmospheric greenhouse gas concentrations. Previously, these concentrations were calculated based on a prescribed set of greenhouse gas emission scenarios; the so-called SRES scenarios (i.e. B1 = low emissions, A1B = mid-range emissions, A2 = mid-high emissions) (Nakicenovic and Swart, 2000). For the IPCC AR5, the SRES emission scenarios were replaced with a set of Representative Concentration Pathways (RCPs) (Van Vuuren et al., 2011).

Table 1: Listing of the six CMIP-5 models dynamically downscaled via NIWA's regional climate model (RCM), and the scenarios and periods of the simulations.

CMIP5-Models	Historic	RCP2.6	RCP4.5	RCP6.0	RCP8.5
HadGEM2-ES MOHC (UK)	1971-2005	2006-2120	2006-2120	2006-2099	2006-2120
CESM1-CAM5 NSF-DOE-NCAR (USA)	1971-2005	2006-2120	2006-2120	2006-2120	2006-2100
NorESM1-M NCC (Norway)	1971-2005	2006-2100	2006-2100	2006-2100	2006-2100
GFDL-CM3 NOAA-GFDL (USA)	1971-2005	2006-2100	2006-2120	2006-2100	2006-2100
GISS-E2-R NASA-GISS (USA)	1971-2005	2006-2120	2006-2120	2006-2100	2006-2120
CC-CSM1.1 BCC (China)	1971-2005	2006-2120	2006-2120	2006-2099	2006-2120

The RCPs are identified by their approximate total 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, and 8.5 W m-2 for RCP8.5. These RCPs include one mitigation scenario (RCP2.6. which requires removal of some of the CO2 presently in the atmosphere), two stabilization scenarios (RCP4.5 and RCP6.0), and one scenario with very high greenhouse gas concentrations.

Figure 2 compares the SRES and RCP atmospheric carbon dioxide concentrations. Although the AR4 and AR5 scenarios do not correspond directly to each other, CO2 concentrations under RCP4.5 and RCP8.5 are very similar to those of the SRES scenarios B1 and A1FI, respectively.

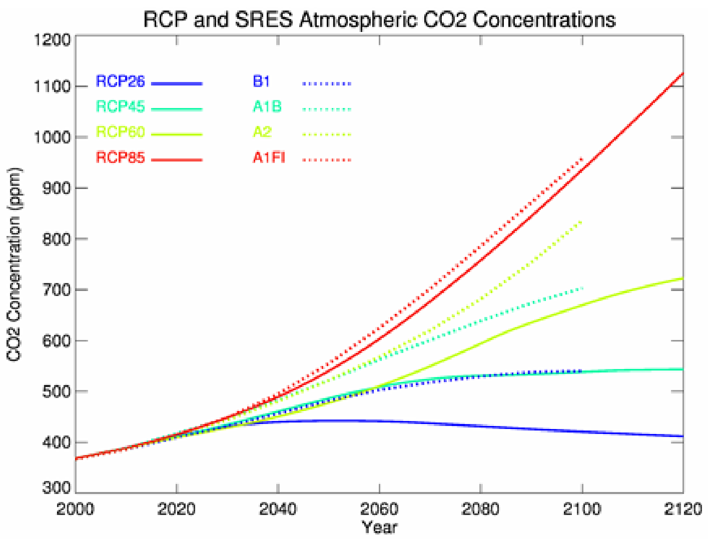


Figure 2: Atmospheric carbon dioxide concentrations for the IPCC 4th Assessment (dotted lines, SRES scenarios) and for the IPCC 5th Assessment (solid lines, RCP scenarios).

DERIVATION OF CLIMATE DATA

Dynamical downscaling using NIWA's Regional Climate Model

Dynamical downscaling, compared with statistical downscaling, yields realistic simulations of a physically consistent set of temporally and spatially highly resolved fields. The interactions of the large-scale circulation with higher resolution orography and other surface features (e.g. land-sea interface, vegetation cover, large lakes etc.) are well captured in Regional Climate Model (RCM) simulations resolving a diverse range of climatic features and thus suited for environmental and climate impact studies. Nevertheless, errors inherent in representing local surface conditions, atmospheric processes and external forcing in RCMs lead to considerable systematic biases in simulating regional variables. Reducing biases in RCM data is necessary to increase confidence in regional climate impact studies. The iterative dynamical downscaling procedure developed at NIWA is designed to reduce systematic biases over a wide range of spatiotemporal scales.

The "NIWA" dynamical procedure involves forcing a "free running" global atmospheric general circulation model (AGCM) by sea surface temperatures (SST) and sea ice fields extracted from CMIP5 data archive. The SST data exhibit considerable biases in the historic period both at global and regional scales. The monthly SST climatologies are bias corrected over the baseline (1961-2005) period with respect to high resolution gridded SST observational dataset, HadISSTv1.1 (Rayner et al., 2003) to reduce the general circulation biases. The biases in variables strongly influenced by SST, such as precipitation and wind patterns, are expected to be reduced (Nguyen, K.C. et al., 2012).

In the next step, the improved lateral boundary conditions are extracted from AGCM simulations described above to drive the regional climate model, HadRM3, a limited area version of HadAM3, to dynamically downscale projections over the New Zealand domain. The regional SST for the RCM domain are again bias corrected on the finer spatial scale for improving regional projections.

Further bias corrections and downscaling

Further bias correction procedures are performed separately on RCM data for the primary climate variables only; minimum and maximum temperature and precipitation. A newly devised "Linked empirical Modelled and Observed Distribution (LeMOD)" correction method is applied to correct biases in the distributions of the daily data and thus to consistently remove the highest order systematic local model errors (Sood, 2016). This method is designed to remain valid even under nonstationary climatic conditions. Subsequently all climate data are downscaled to higher spatial resolution (e.g. VCS resolution) by bilinear interpolation and additionally using local wind direction and elevation data where appropriate.

The large-scale circulation biases inherent in the driving fields of the climate models remain unaffected. This results in considerable spread in model results for the past control period (1971-2000). The climatological mean of the primary climate variables for the control period are adjusted to match the observed values based of VCS data for all individual models. By applying the same adjustment to the future projection enables direct comparison and evaluation of impact model output with observations for the control period and as well determine the climate impacts in future projections.

The bias corrected data exhibits lower root-mean-square-error and higher temporal correlations relative to uncorrected or the most commonly-used quantile matching bias correction procedure. Since reducing model biases is expected to reduce the spread in model results in the past climate, except where the spread is related to internal variability, this feature is expected to persist in transient climate future projections and contribute towards reducing uncertainties in model projections.

Large ensemble temperature projections using pattern scaling

One of the principal challenges of adapting to changes in climate is dealing with uncertainties in projections of climate change in a comprehensive way. Even for a given greenhouse gas emissions scenario, the provision of a small number of RCM projections from a limited set of regional climate models (see Table 1) does not adequately describe the full spectrum of possible futures describing the impacts and implications of climate change on New Zealand's regional biophysical environment, economy and society. It is essential for decision-making that the full spectrum of uncertainty is captured in climate change projections. These uncertainties arise from

(1) our incomplete understanding of the processes affecting the sensitivity of the climate system to increases in greenhouse gas concentrations; and (2) the representation of these processes in the global and regional models used to generate the projections. To this end, the EPIC (Ensemble Projections Incorporating Climate model uncertainty) method was developed in RA1 to generate large ensemble projections of maximum and minimum temperatures (hereafter X), at daily resolution, out to 2100.

Each EPIC ensemble member is constructed by adding contributions from (1) a climatology derived from VCS data (see Section 2.1) that represents the time invariant part of the signal; (2) a contribution from forced changes in X where those changes can be statistically related to changes in global mean surface temperature (T_{global}); and (3) a contribution from unforced variability that is generated by a stochastic weather generator. Because GCMs and RCMs are less likely to correctly represent unforced variability compared to observations, the stochastic weather generator takes as input measures of variability derived from observations but also allows that variability to respond to changes in T_{global}.

The statistical relationships between changes in X (and its patterns of variability) with T_{global} are obtained in a 'training' phase. Then, in an 'implementation' phase, 190 simulations of T_{global} are generated using a simple climate model tuned to emulate 19 different CMIP-5 GCMs and 10 different carbon cycle models. Using the 190 T_{global} time series and the correlation between the forced changes in X and T_{global}, the forced change in the X field can be generated 190 times. Any change in the variability of X that can be attributed to changes in Tglobal can be calculated in a similar way.

This 190 member ensemble is further expanded by applying the results of a Monte Carlo analyses on the uncertainty in the correlations between X and Tglobal, and by using the stochastic weather generator model to generate a realistic representation of weather (including spatial coherence) that also responds to forced changes in climate in a way that is consistent with the RCM projections. Such a large ensemble of projections permits a description of a probability density function (PDF) of future climate states rather than individual story lines within that PDF which may not be representative of the PDF as a whole; the EPIC method corrects for such potential sampling bias. The method is useful for providing projections of changes in climate to users wishing to investigate the impacts and implications of climate change in a probabilistic way. A tailored web-based system to deliver the summary statistics describing the probability of different futures to a wide range of potential users was also developed (see Section 5.2).

IMPROVED CLIMATE PROJECTIONS FOR NEW ZEALAND

RCM-derived data

The core set of downscaled (to the 5km grid) surface-level climate variables outputted from the RCM and made available to other CCII researchers is as follows (an asterisk denotes whether the variable has been bias-corrected using the LeMOD technique):

- Maximum daily temperature (K)*
- Minimum daily temperature (K)*
- Daily precipitation total (mm)*
- Daily average solar radiation (MJ/m^2)
- Daily average wind speed at 10 m (m/s)
- Daily average mean sea level pressure (hPa)
- Daily average relative humidity (%)

The following additional variables were also derived and made available for specific modelling work:

- Daily average vapour pressure (hPa)
- Daily potential evapotranspiration total (mm)
- Daily dew point temperature (K)

Lastly, the following summary data were also produced when requested:

- Growing degree days (base 5°C and 10°C)
- Days with Tmax > 25°C
- Days with Tmin < 0°C
- Days with precipitation ≥ 1 mm

For the first two sets of variables above, daily, monthly and annual values were produced. For the final set, only annual data were produced. For every climate variable, datasets were generated for the historic period 1971-2005 and for the future period corresponding to the particular GCM and RCP shown in Table 1. All data were saved in NetCDF format. All told, the CCII RA1 RCM-based dataset comes to over 2 TB of disk space. This is much too large to put on a website, so users should contact NIWA to enquire about accessing some or all of this dataset.

Section 5 describes a new web-based tool called "Our Future Climate New Zealand", which can be used to view multiple maps and time series plots of the RCM-based temperature and precipitation data. Figure 3 shows a small sample of these maps, for the projected annual mean temperature and precipitation changes for New Zealand for a mid-range greenhouse gas concentration pathway (RCP6.0), between 1986-2005 and 2081-2100.

The maps in Figure 3 can be broadly compared with those shown in Figure 1 above, taking into account the differences in the number of GCMs used in the average (6 versus 12); the different GCM origins (i.e. the international modelling groups) and their version (CMIP-5 versus CMIP-3); the different base climate period (1986-2005 versus 1980-1999); and the method of downscaling (statistical versus dynamic). What can be seen is that while there is definitely a broad similarity, the increase in spatial detail in the new maps, especially in the mountainous regions, is apparent. Also, projected annual precipitation change in the area of the Canterbury foothills and plains is distinctly different between the old and new maps, likely related to changes in the strength of the westerly winds and the changing fraction of precipitation falling as rain versus snow.

A complete analysis of the downscaled (using both statistical and dynamical methods) CMIP-5 data for New Zealand has recently been performed by NIWA for the Ministry for the Environment (MfE, 2016). This report is an update to the MfE (2008) local government guidance manual[5].

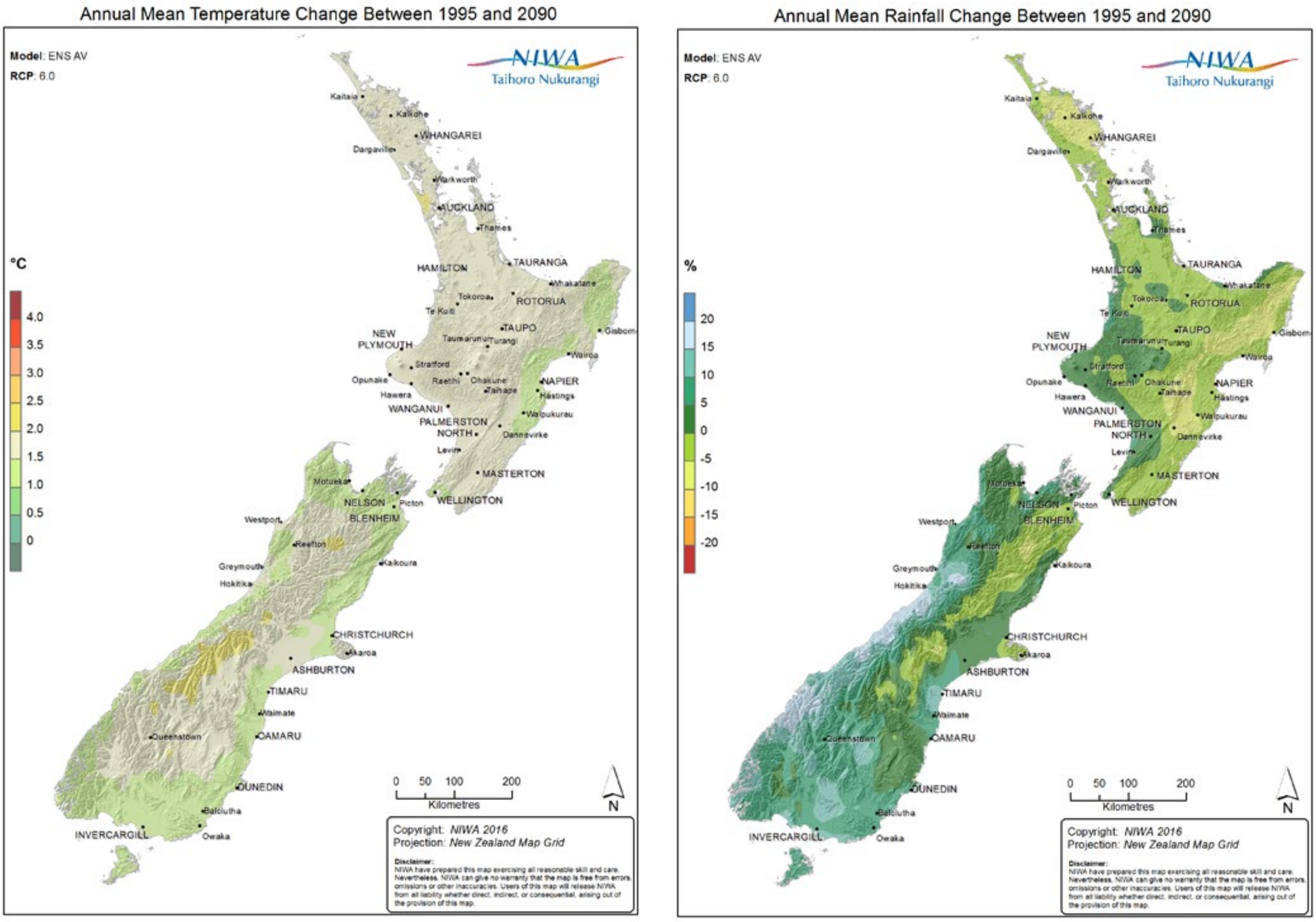


Figure 3: New maps of the projected change in mean annual temperature (left) and precipitation (right) between 1986-2005 and 2081-2100, based on a middle-of-the-road representative concentration pathway (RCP6.0) and the average of six GCMs (dynamically downscaled onto a 5km grid for New Zealand).

Large ensemble temperature projections

Large ensembles of projections of daily maximum and minimum temperatures using the EPIC method are available by contacting BodekerScientific[6]. Projections are available for each node of the VCS grid (approximately 5km spatial resolution) for all of New Zealand for all four RCP emissions scenarios. As an example of the analyses that can be performed with these large ensembles, probability density functions of daily maximum temperatures for four population centres around New Zealand are shown in Figure 4.

The ensemble temperature dataset has also been used to produce maps showing the current and future number of hot days (Tmax > 25°C) for New Zealand, based on RCP8.5 (RSNZ, 2016).

http://www.unidata.ucar.edu/software/netcdf/
E-mail: climate-enquiries@niwa.co.nz
http://www.mfe.govt.nz/publications/climate-change/climate-change-projections-new-zealand

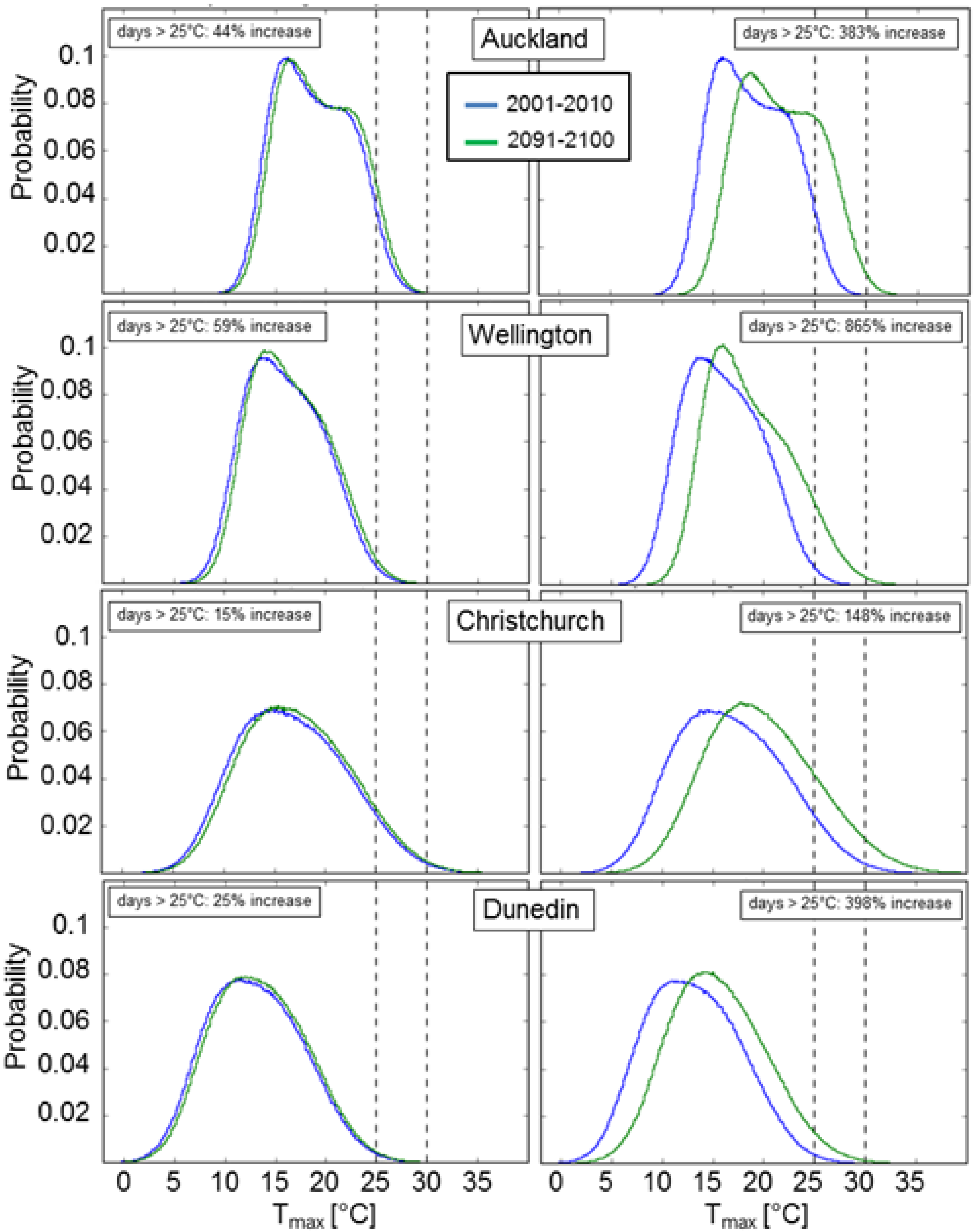


Figure 4: Histograms of daily maximum temperature for RCP 2.6 (left column) and RCP 8.5 (right column) scenarios for four population centres in New Zealand. Thresholds of 25°C and 30°C are shown with vertical dashed lines.

WEB-BASED VISUALISATION TOOLS

The goal of the CCII RA1 team was to produce updated and improved regional-scale projections of climate trends and variability across New Zealand out to 2100 based on the latest global projections. These data were primarily for the purpose of the other CCII modelling teams in RAs 2 and 3, as well as other researchers. Over the course of the project, it was agreed that resources should also be devoted to web-based visualisation tools, so that users can explore the new climate data.

Our Future Climate New Zealand

The CCII project, in collaboration with the NIWA Climate Vulnerability, Impacts and Adaptation Programme, have developed the "Our Future Climate New Zealand" (OFCNZ) web tool[8]. Figure 5 shows the homepage with the two main components of the tool: the exploration of maps and charts; and Figure 6 shows the menu and display features of these two components.

Ease-of-use and multi-functionality were the two primary objectives when designing the OFCNZ tool. Users can select from all the available GCMs (6 plus the 6-model-average), all the RCPs (4), temperature or precipitation, and annual or seasonal data. For the maps, users can also select from three future 20-year periods (2016-2035, 2046-2065, and 2081-2100) to compare with the historic period 1986-2005. The maps can be enlarged and saved for use in presentations, reports or publications. For the charts, users can select from 15 main centre locations around New Zealand.

The seasonal and annual VCS and climate model data associated with all the charts are accessible by clicking on the "Download Data" link above the charts display area. Data for other locations and data at higher temporal resolution (e.g. monthly or daily) are available from NIWA upon request. GIS datasets associated with the maps are also available upon request.

NIWA are considering adding more climate variables to this tool, and will continue to work on this, with the webpage being maintained by NIWA even though the CCII programme has ended. Potential variables include wind, solar radiation, and relative humidity. Also under consideration are derived variables like potential evapotranspiration, growing degree days, and the number of hot (Tmax > 25°C) and frost (Tmin < 0°C) days.

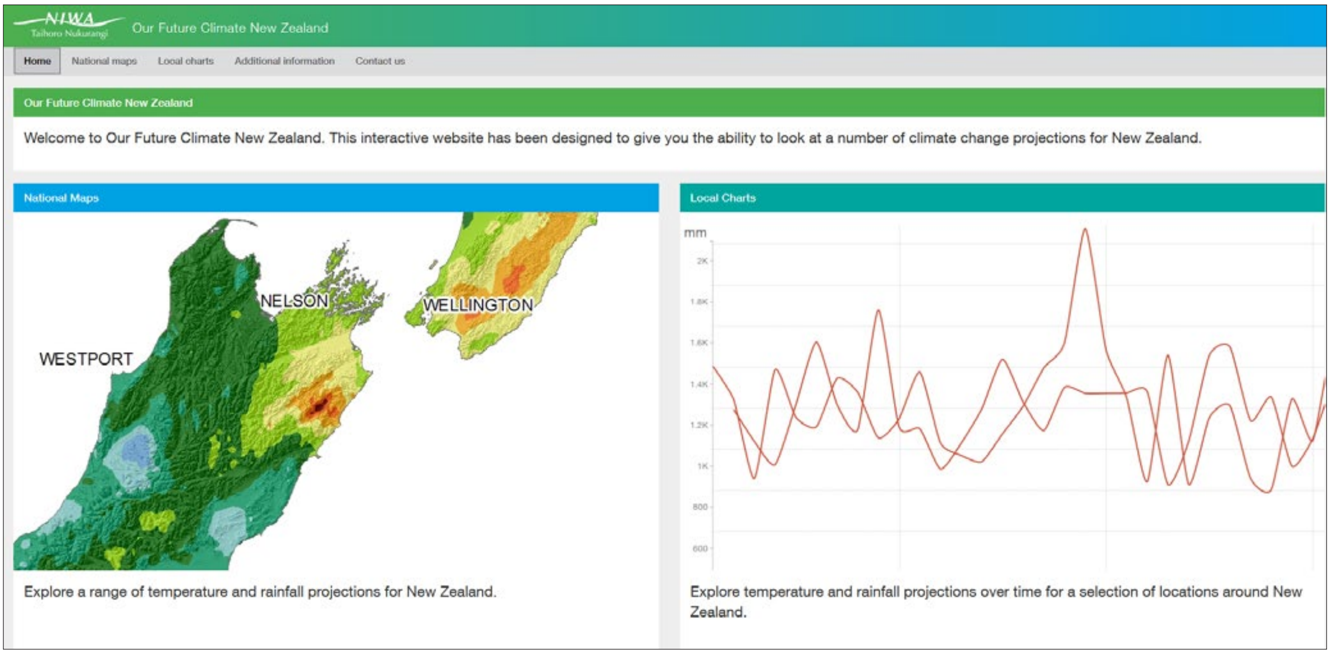


Figure 5: The Our Future Climate New Zealand "homepage", showing options for exploring maps (right) and charts (left).

[8]http://ofcnz.niwa.co.nz

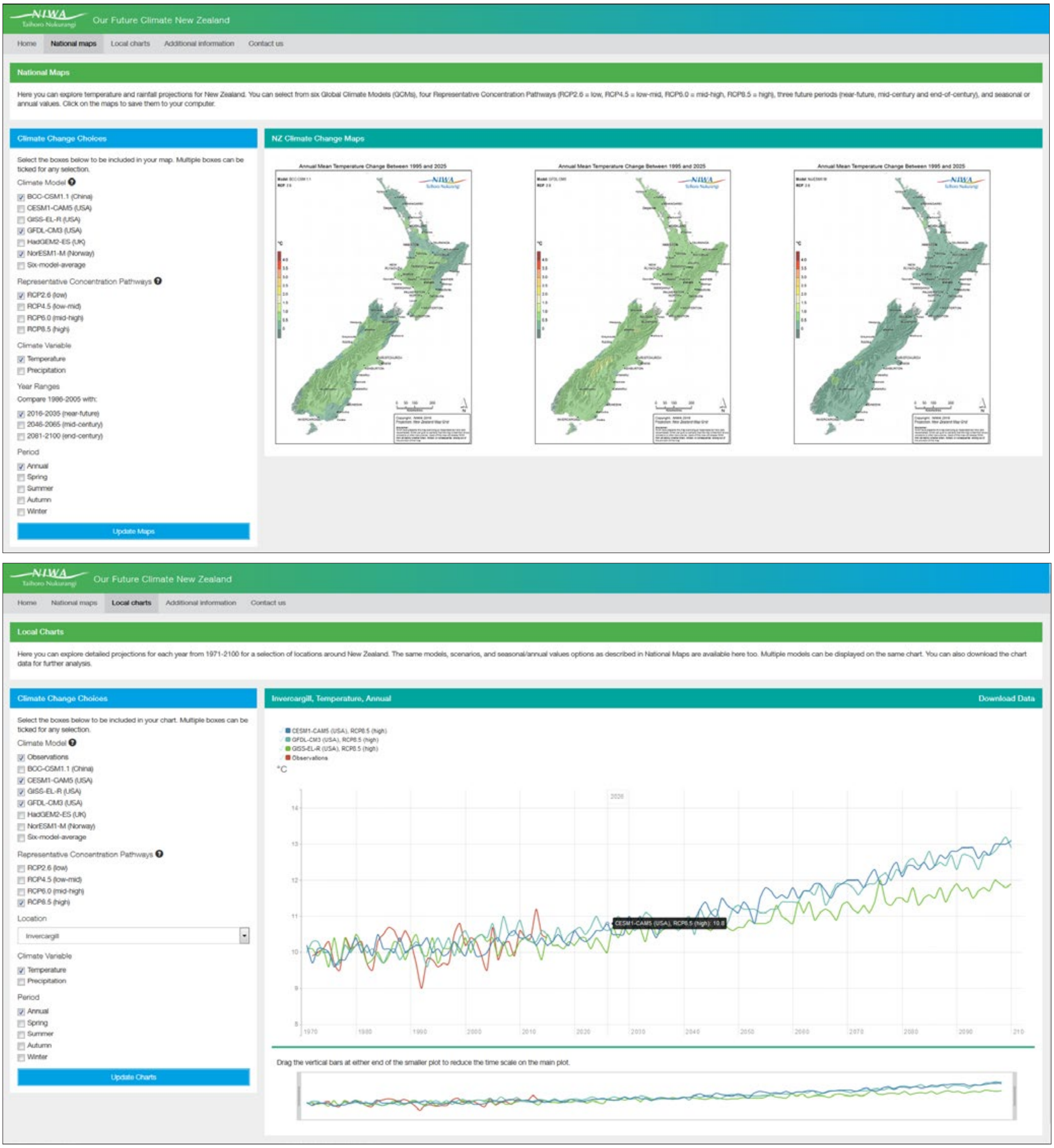


Figure 6: The Our Future Climate New Zealand map interface (top) and the chart interface (bottom).

The Future Extremes interactive web page

The CCII project also developed the Future Extremes web page . The web page allows the user to select any location in New Zealand, either through an interactive map (see Figure 7) or by entering the latitude and longitude of the location, as well as the variable of interest (hot days, frosts, hot spells or cold spells), the emissions scenario, and whether the results should be shown as probabilities, number of events per year, or number of events per decade.

[9]http://futureextremes.ccii.org.nz/

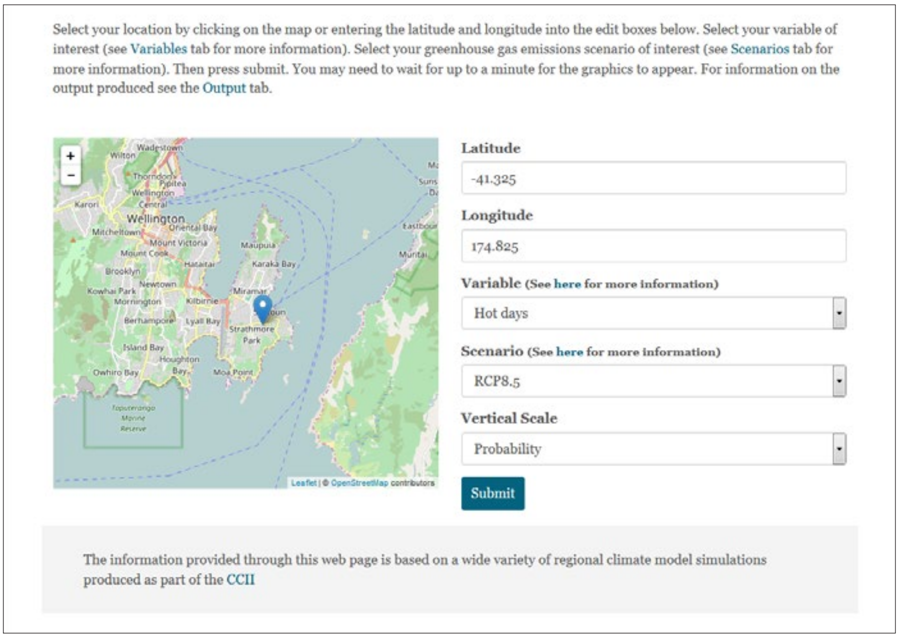


Figure 7: An example of the front page of the future extremes web page.

The EPIC method is then used to generate a large ensemble of projections for the selected location, variable, and scenario from which probability density functions are calculated for the first and last decades of the 21st century. An example of the results generated by the future extremes web page is provided in Figure 8.

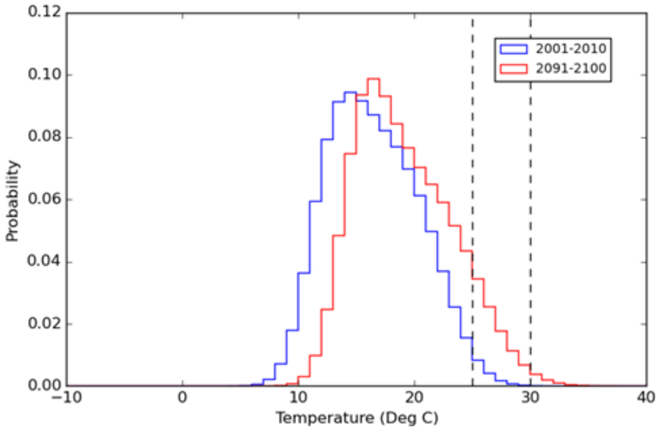


Figure 8: The change in the frequency of hot days through the 21st century for 41.325°S and 174.825°E (Wellington City) under the RCP8.5 greenhouse gas emissions scenario. The likelihood of occurrence of different daily maximum temperatures is shown for the first decade (blue) and the last decade (red) of this century. Over 2091-2100, on about 40 days of each year, the daily maximum temperature is projected to exceed 25°C in contrast to about 5 days in each year over 2001-2010.

CONCLUSIONS

The CCII RA1 climate dataset is a major resource for climate change impact assessment in New Zealand. The terabytes of climate data that have been produced have been the primary input for the RA2 and RA3 modelling work, and will be the basis for virtually all climate change assessments in New Zealand for several years to come. In particular, the potential for using the large ensemble temperature dataset in probabilistic impact assessments is yet to be fully realised.

Of course, research will continue well beyond the life of the CCII project to refine and improve these datasets, e.g. using a higher resolution version of the RCM, performing bias corrections on additional variables, producing a large ensemble precipitation dataset, and analysing the output of the New Zealand Earth Systems Model (currently being developed under the auspices of the Deep South National Science Challenge[10]). It is the nature of climate modelling that ongoing improvements such as these will be made and revised climate projections will be produced.

However, it is also vital to produce *landmark* datasets that can be used by multiple researchers and stakeholders to produce a consistent baseline of knowledge on climate change impacts and implications. The CCII RA1 climate dataset is such a landmark dataset. It is very likely that impact modelling-based papers using these climate data (including many coming from the CCII RA2 and RA3 modelling work) will significantly contribute to the New Zealand chapter of the IPCC Sixth Assessment, slated for release around 2021/22, as well as to many other important national and international reports and documents.

[10]http://www.deepsouthchallenge.co.nz/

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