Summary of Climate Change Projections

Horizons Region, New Zealand

Climate Change Projections from CCAM-Downscaled CMIP6 Simulations

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For

Horizons Regional Council

Report:	Climate Impacts Assessment
Baseline:	1986–2005
Scenarios:	SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5
Future periods:	2021-2040, 2041-2060, 2080-2099

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1 Introduction

This overview climate analysis report summarises the most important and high-confidence conclusions derived from 25 climate variable-specific reports that are available here. The projections synthesised in this report were generated using the Conformal Cubic Atmospheric Model (CCAM; see Section 1.1) by Earth Sciences New Zealand; ESNZ. We acknowledge ESNZ and thank them for making these simulations freely and easily available. Simulations were performed for four Shared Socioeconomic Pathway (SSP) emissions scenarios (see Section 1.2) and for three different time horizons (see Section 1.3). Projected changes over these three time horizons are presented with respect to a 1986-2005 baseline.

In this report, to the extent possible, Intergovernmental Panel on Climate Change (IPCC) nomenclature is used to describe the level of confidence in any findings, i.e., if the likelihood of an outcome occurring is >99%, this is referred to as 'virtually certain', for probabilities >95% 'extremely likely', for probabilities >90% 'very likely', for probabilities >66% 'likely', for probabilities >50% 'more likely than not', for probabilities between 33% and 66% 'about as likely as not', for probabilities <33% 'unlikely', for probabilities <5% 'extremely unlikely', and for probabilities <1% 'exceptionally unlikely'. This report focuses on those conclusions for which we have the highest confidence.

1.1 Climate model simulations

CCAM is a regional climate model that dynamically downscales outputs from global climate models to produce higher-resolution climate projections for New Zealand. Papers describing the generation of these climate projections for New Zealand are available here and here. Regional climate modelling is necessary because global climate models typically operate at spatial resolutions that are too coarse to adequately represent New Zealand's complex topography. Mountains, coastlines, and local climatic gradients strongly influence regional climate and require higher spatial resolution to be represented realistically. Output from six global climate models, run as part of the IPCC (Intergovernmental Panel on Climate Change; see the Glossary in Appendix A for expansions of all acronyms) 6^{th} climate model intercomparison project (CMIP6), was used to drive the CCAM simulations (the details of these models can be found in any of the climate variable-specific reports). The models cover a range of equilibrium climate sensitivities (ECSs; see Figure 1) and allow some sense of the uncertainty associated with model structure and climate sensitivity to be quantified.

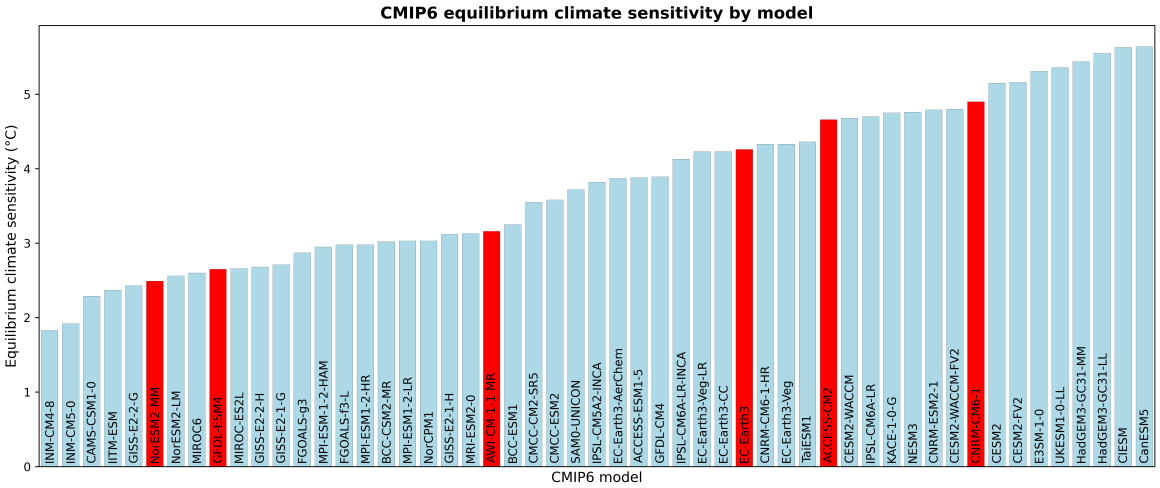


Figure 1: The location of the six guiding CMIP6 models across the full range of equilibrium climate sensitivities (ECSs) of all 53 CMIP6 models. The original of this figure can be downloaded here.

1.2 Selection of scenarios

Projections of changes under four Shared Socioeconomic Pathway (SSP) emissions scenarios have been considered:

1. ***SSP1-2.6:*** A low-emissions pathway consistent with strong global mitigation efforts and relatively limited future climate warming.
2. ***SSP2-4.5:*** An intermediate pathway representing moderate emissions reductions and moderate climate warming.
3. ***SSP3-7.0:*** A medium-to-high emissions pathway associated with substantial future climate warming.
4. ***SSP5-8.5:*** A high-emissions pathway characterised by continued growth in greenhouse gas (GHG) emissions and significant climate warming.

It must be clarified that climate scenarios are not predictions of the future, but tools for exploring uncertainty and assessing risk. While the likelihood of these four scenarios occurring is not equal, governments, regional councils, investors, and insurers must allocate capital effectively. Treating all scenarios as equally likely leads to poor planning, either under-preparing for most likely outcomes and potential risks or over-insuring against highly improbable realisations.

Given the current trajectory of international actions on GHG emissions mitigation, it is highly unlikely the global future climate will follow the SSP1-2.6 scenario. In contrast, the GHG emissions reduction actions that have been achieved to date increasingly rule out the SSP5-8.5 scenario. This is not to say that these two scenarios do not have their uses: SSP1-2.6 shows us what could have been achieved had earlier climate projection pledges been realised, while the SSP5-8.5 scenario shows the world that has been avoided by actions to date. The SSP5-8.5 scenario, representing a severe tail-risk envelope, would also be a valid scenario for stress-testing financial institutions. For planning purposes, however, more weight should be assigned to the SSP2-4.5 and SSP3-7.0 scenarios. As such, it is results from these two scenarios that primarily appear in the summaries below, often quoted in the form of triplets of values P5/P50/P95 where P5 is the 5^{th} percentile, P50 the 50^{th} percentile, and P95 the 95^{th} percentile of the model values across **all** Horizons Region grid cells, across all of the six CCAM models, and across both the SSP2-4.5 and SSP3-7.0 scenarios (typically comprising 11172 data points). While this conflates uncertainty from (i) spatial variability in changes in the target variable, (ii) inter-model spread, and (iii) the spread between the SSP2-4.5 and SSP3-7.0 scenarios, it provides a *very approximate* measure of the uncertainty, while noting that these triplets are conservative.

The availability of a set of six CCAM simulations, rather than relying on a single simulation, is a key strength of the modelling framework used in this assessment. Ensemble approaches allow both the central tendency and uncertainty of projected changes to be assessed. That said, an ensemble of six models does not capture the potential full range of variability. By considering the ECS of each of these models in the context of the much wider range of 53 CMIP6 models (see Figure 1), a method was developed to generate a more complete picture of the potential uncertainty in projected changes. That method is discussed in the companion 'methods' report. See also the variable-specific reports for more detailed descriptions of these more comprehensive uncertainties on the climate projections. For the baseline triplets quoted below (i.e. the 1986-2005 climatological values), there is no scenario spread and very little inter-model spread; the spread results almost entirely from spatial variability.

1.3 Selection of future periods

Projections were considered over three periods, viz.: the near-future (2021-2040), mid-century (2041-2060), and end of the century (2080-2099), all relative to a 1986-2005 baseline climatology. Although the radiative forcing (the rate at which energy is being added to the climate system compared to the pre-industrial baseline) increases to 2.6 W m^{-2} under SSP1 by 2100, to 4.5 W m^{-2} under SSP2 by 2100, to 7.0 W m^{-2} under SSP3 by

2100, and to 8.5 W m^{-2} under SSP5 by 2100, one should not expect that there will always be a consistent (monotonic) increase or decrease in some climate variable from SSP1-2.6 to SSP2-4.5 to SSP3-7.0 to SSP5-8.5 under any of these future periods since the pathways to that 2100 end point can be very different, and over the near-term to mid-century, natural variability can dominate the climate signal; often the climate signal only emerges later in the century. This is demonstrated in Figure 2. It is clear from this figure that both over the

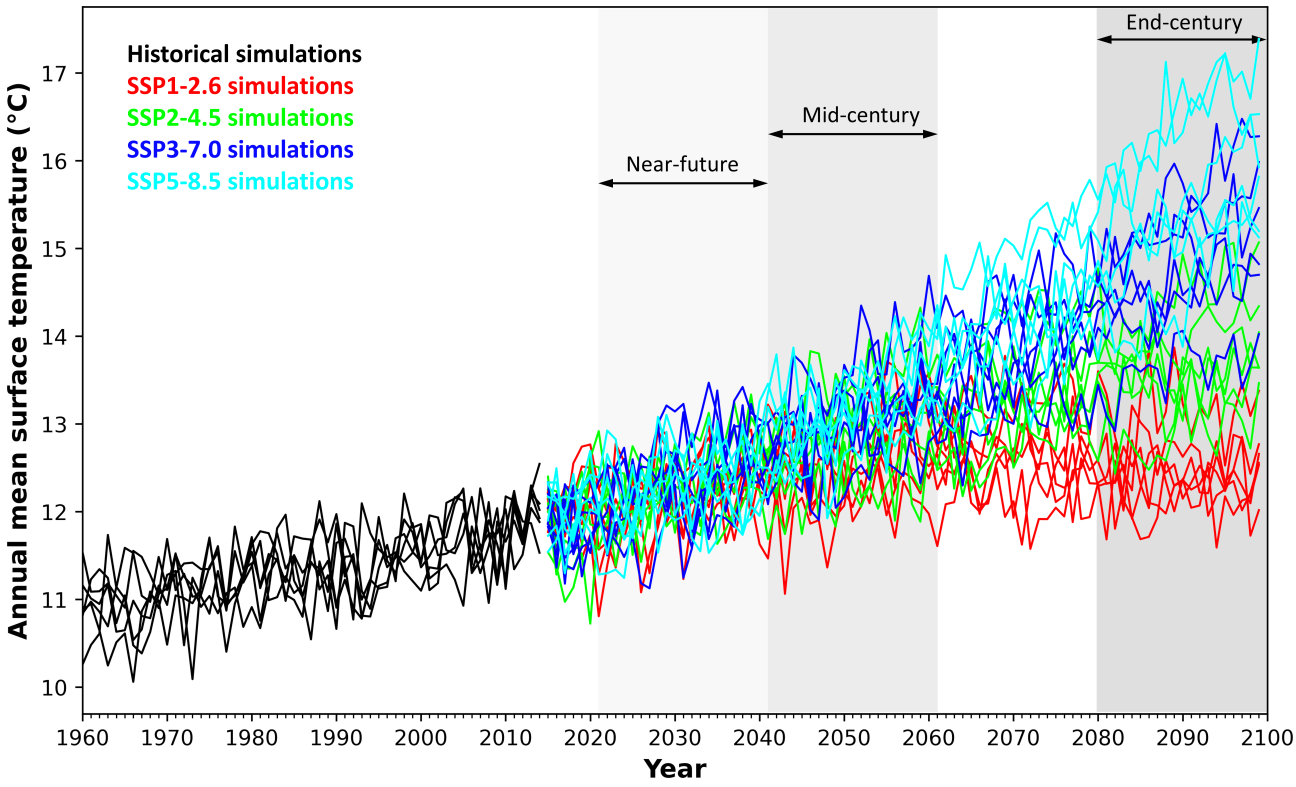


Figure 2: Annual mean surface temperature time series extracted from the six different model simulations, for the Horizons Region, for the historical baseline (black traces) and for the four different SSP scenarios (SSP1-2.6 in red; SSP2-4.5 in green, SSP3-7.0 in blue and SSP5-8.5 in cyan. Also shown are the three different analysis periods considered in this report. The original of this figure can be downloaded here.

near-future and mid-century, the year-to-year variability (unforced climate variability), and inter-model spread, obscures any statistically significant separation of the projections under the four different SSPs.

2 Variable specific findings

2.1 Temperature related variables

Projections for all considered future periods and emissions scenarios indicate extremely likely increases in daily mean air temperatures (T_{mean}; see Figure 3). Over the near-future (2021–2040), daily mean temperatures are projected to increase by 0.4/0.9/1.2°C over the regional mean baseline of 8.1/11.9/13.3°C. By mid-century these increases are projected to be 0.8/1.5/2.1°C. Warming intensifies with higher emissions and over time, reaching increases of 1.5/2.7/4.0°C by the end of the century. The spatial distribution of warming is remarkably uniform, with only minor local amplifications in elevated inland areas, notably the Volcanic Plateau. While all seasons warm, the largest increases occur in summer and autumn, while winter and spring exhibit weaker (but still substantial) warming. The seasonality of change is most pronounced in upland zones, which are both cooler at present and projected to warm slightly more (especially in summer). The agreement among models is extremely high for the signal and direction of change across the region, even though fine-scale spatial patterns and exact magnitudes exhibit moderate spread. These robust, region-wide projections of increases in T_{mean}

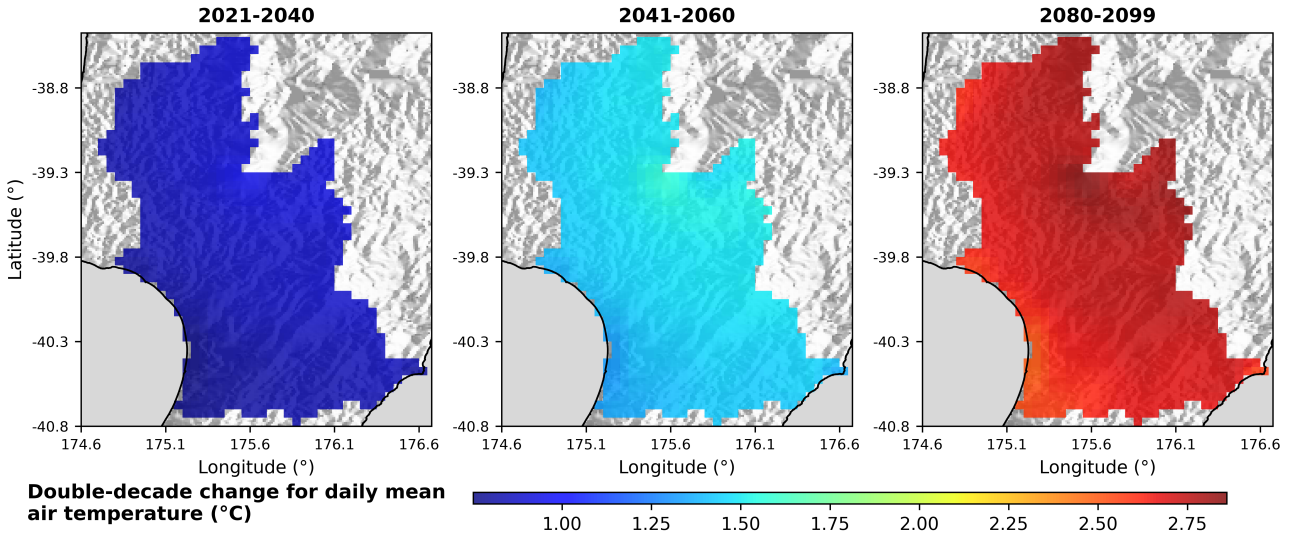


Figure 3: Projected changes in daily mean temperature. In each panel the mean of 12 fields is shown (6 models across the SSP2-4.5 and SSP3-7.0 scenarios). In these cases all 12 model fields agree on the *sign* of the change, i.e., positive.

have clear implications: increased heat stress on people, livestock, and crops; lengthening of growing seasons (more on this below); shifts in phenology and potential invasive species expansion; heightened risk of drought and bushfire; and altered demands on energy and water sectors.

The CCAM model simulations show that daily minimum temperatures (TN) across the Horizons Region are also very likely (greater than 90% probability) to increase in all future scenarios and timeframes. The signal is regionally coherent: baseline spatial gradients (cooler in the northeast and warmer in the south and west), are extremely well reproduced among models, providing very high confidence in the foundational climatology (regional averages of 3.8/7.2/9.1°C). Projected changes reveal robust and spatially uniform increases in daily minimum temperatures, with the amplitude of change very likely to increase with atmospheric GHG concentrations and through time. Near-future TN increases are modest (0.4/0.8/1.1°C), while mid-century changes are 0.9/1.4/2.0°C, and by late-century 1.5/2.6/3.8°C. Seasonal variations are present, with the largest increases generally in summer and autumn, and lesser but still significant increases in winter and spring. Model agreement is extremely high on the direction and broad spatial pattern of change, while fine-scale spatial uncertainty is greater, particularly for detailed sub-regional or local projections.

Daily maximum temperatures (TX) show similar increases. Projections unanimously indicate substantial increases in TX across all scenarios. Starting from a baseline of 12.5/16.5/17.8°C, increases in the near-future are around 0.5/0.9/1.3°C, with the warming signal virtually certain everywhere and strongest in summer. Mid-century projections show an intensifying signal, with mean warming of 0.8/1.5/2.1°C; spatial variability remains subdued, though central and inland sub-regions see slightly greater increases. By late century, mean TX increases are 1.5/2.8/4.2°C, with the summer seasonal maximums exceeding 5°C in northern/eastern sectors. Regionally, no sub-region escapes warming. Volcanic Plateau and Upper Rangitīkei consistently register the largest increases, while Horowhenua and Whanganui-Manawatū Lakes show the smallest but still substantial rises. Model agreement remains very high throughout, both for the sign and broad pattern of change, though uncertainty in magnitude increases with GHG emissions level and projection time horizon (greater uncertainty at later future periods).

Across the Horizons Region, the historical daily temperature range (the difference between the daily maximum and minimum temperature; DTR) pattern is dominated by a pronounced north-south gradient, with consistently higher values inland and to the north, above 10°C in some locations during summer and generally lower values (about 7°C) in coastal and southern areas. This gradient is extremely likely to be a persistent and robust feature, confirmed by extremely high inter-model agreement in baseline simulations. Seasonally, DTR is highest in summer and lowest in winter, mirroring larger-scale climatic controls. Projections suggest small to

moderate increases in DTR across most of the Horizons Region. These increases are generally spatially coherent and are most pronounced in warmer seasons (spring and summer) and in inland sub-regions, notably the Upper Rangitīkei, Volcanic Plateau, and Puketoi ki Tai. Over the near-future to mid-century periods, increases in DTR are likely under all emission pathways, with high confidence in the direction of change and moderate confidence for its local magnitude (-0.2/0.1/0.3°C in the near-future increasing slightly to -0.1/0.1/0.4°C by mid-century). By century's end, DTR increases become more pronounced on the order of 0.0/0.2/0.5°C. The regional consensus is that lowland coastal areas such as Horowhenua and Whanganui-Manawatū Lakes will see smaller, sometimes negligible or even slightly negative, DTR changes. Inter-model uncertainty is greatest for these locations and for winter.

CCAM simulations of temperatures on the hottest day of each year (TXx) indicate region-wide increases whose magnitude and confidence increase under higher GHG emissions scenarios and later time periods. Over the near-future (2021–2040), regional mean increases over the 1986-2005 baseline climatology are 0.5/1.2/1.9°C with extremely high model agreement and minimal spatial divergence. By mid-century, these changes increase to 1.2/1.8/2.8°C, and by 2080–2099 to 1.7/3.2/5.2°C with some locations seeing increases of more than 6°C. While, model agreement is virtually certain for the sign of change, there is some uncertainty around exact magnitudes, particularly in complex topography.

Across the Horizons Region, projections show, with very high confidence, a widespread and persistent reduction in the severity of coldest day of the year temperatures (TNn) from their 1986–2005 baseline values of (-7.0/-4.0/-1.5°C). This consistent warming signal appears across all plausible future emissions scenarios. Historically, TNn has exhibited a clear spatial gradient of lower annual minimum temperatures at higher elevations and inland, and milder near the coast, a feature captured virtually identically by all six CCAM simulations. Over the 21^{st} century, all models agree: TNn is projected to increase everywhere in the region, with the direction of change (warmer coldest days of the year) extremely likely even under the most ambitious mitigation scenarios. The magnitude of future change, however, depends on future atmospheric GHG concentrations. In the near-future increases of 0.1/0.6/1.2°C are projected. By mid-century this increases to 0.5/1.1/1.7°C and by century's end to 1.2/2.0/3.3°C. While fine-scale patterns of change remain less certain, the consensus is very high regarding widespread regional warming of annual coldest temperatures. Somewhat greater changes are projected for historically colder sub-regions and at higher elevations, but all areas will experience milder minimums. Ensemble spread is relatively low compared to the climate signal, lending high confidence to the conclusions. While uncertainty increases for exact quantification, amplification, and localisation of changes, no scenario or model suggests any return to the historical climatology. The implications are profound for frost risk, plant phenology, disease vectors, and energy demand. Reductions in cold extremes will ease winter stress on agriculture and infrastructure but may introduce challenges for species and systems adapted to severe frost.

Temperature metrics involving threshold exceedances, e.g. >25°C (TX25) or >30° (TX30) show very non-linear behaviour. As shown in Figure 4, a small shift in the mean of a distribution of temperatures (commensurate with climate warming) can drive unprecedented temperatures, particularly above higher thresholds. The historical climatologies for TX25 and TX30 show that these are predominately a summer phenomena; TX30 is historically rare in the Horizons Region, averaging less than one day per year even in the hottest locations and

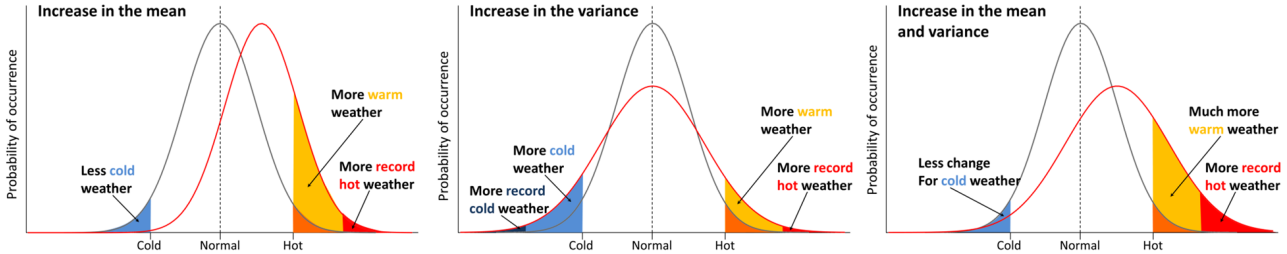


Figure 4: A schematic showing how small shifts in the distribution of temperatures can drive significant changes in the likelihood of extreme events occurring.

almost exclusively confined to summer. The more common TX25 events are concentrated in lowland, northern, and inland sub-regions, with virtually no occurrence in winter and rare events in autumn or spring. Model agreement on this pattern is extremely strong, lending high confidence to both the current spatial distribution and the reliability of the projections. Region-wide increases in TX25 are simulated for under all future scenarios and over all projection time horizons, most prominently in summer but increasingly extending into autumn and, to a lesser extent, spring by mid- to late-century and under higher emissions scenarios. Projected changes in TX30 are entirely driven by summer, with minor increases in autumn and negligible changes in winter and spring. The spatial and temporal evolution of hotspots reveals significant new exposure for the region, with the greatest amplification in already warmer areas. Inter-model agreement is high on the direction and seasonality of change.

Given the warming previously noted, it should not be surprising that from a climatology of 0.5/8.7/20.3 days per year (i.e., less than one exceedance in two years to 20 such days in any one year), the number of TX25 days increases by 0.8/8.8/19.9 days per year in the near-future, by 2.1/18.0/37.2 days per year by mid-century and by 6.0/39.2/80.5 days per year by century's end, i.e., generally an increase by about a factor of $\sim$5 or more (depending on which statistic is considered). Even more extreme changes are projected for TX30. The baseline (at most one event every 5 years) suggests a very low likelihood of occurrence of these temperature extremes across the region historically. By the near-future, this is projected to increase to once every year (changes of -0.1/0.1/0.9 days per year) for some locations, to twice per year by mid-century (changes of 0.0/0.2/2.1 days per year), to two weeks or more of such days each year (changes of 0.0/1.2/12.8 days per year) by century's end. The absolute and relative increases are greatest in already warm, low-elevation areas, while higher altitudes see smaller absolute changes. Model agreement is extremely high on both the sign and pattern of future change, though there is moderate uncertainty on the exact magnitude and local details, especially for shoulder seasons. The largest increases are consistently found in sub-regions such as NorthernZone-Taumarunui and Puketoi ki Tai.

Confidence is extremely high that the Horizons Region will experience significant increases in very hot days, with the scale and regional distribution dictated substantially by future emissions. As these rare extremes become more routine, the need to adapt infrastructure, urban planning, emergency services, and land management is critical.

2.2 Plant production variables

Growing degree days (GDDs), is a measure of heat accumulation, used extensively in agronomy, horticulture, and ecology to estimate growth, development rates, or maturity of plants and invertebrates. GDD is calculated as the sum over a defined period (commonly the growing season) of the daily mean temperature in excess of a set threshold; in this case either 5°C or 10°C. GDD5 represents the growth for cool season crops and pastures such as wheat or ryegrass whereas GDD10 represents warm season crops and pastures such as clover and maize. To calculate GDD5 mathematically, for each day:

GDD5 = max[T_{mean} – 5°C, 0]

where T_{mean} is the daily mean temperature measured in °C. Daily GDD values are summed over the period of interest, providing an annual total that reflects the cumulative thermal opportunity for growth or development.

All models unanimously project regionally consistent and substantial increases in the number of growing degree days above a 5°C threshold (GDD5), with changes becoming progressively more pronounced over time and as atmospheric GHG concentrations increase. Over the near-future, mean increases across the Horizons Region, over the 1986-2005 baseline of 1370/2532/3026 growing degree days, are increases of 145/298/437 growing degree days per year in the near-future, 292/523/723 additional growing degree days per year by mid-century, and 538/915/1428 additional growing degree days per year by century's end, representing a major extension of the thermal growing season. Model agreement on these projected increases is exceptionally

high, supporting virtually certain confidence in qualitative regional messages, and extremely high confidence in the quantitative outlook for long-term planning. Future projections retain strong spatial coherence, especially at broader regional scales. The magnitude and local spatial details introduce some uncertainty, mainly due to inter-model differences and topographic complexity. While absolute increases are typically largest in lower-elevation and coastal sub-regions, all areas, including typically cooler and higher-elevation regions, are projected to experience substantial gains in the number of growing degree days. Scenario uncertainty becomes the dominant driver of projection spread by mid-century and beyond, but for all plausible scenarios, a large and spatially pervasive increase in GDD5 is expected.

Not too surprisingly, a similar result occurs for the number of growing degree days above a 10°C threshold (GDD10). Over the near-future, mean increases across the Horizons Region, over the 1986-2005 baseline of 382/1026/1367 growing degree days, are increases of 118/219/334 growing degree days per year in the near-future, 217/376/575 additional growing degree days per year by mid-century, and 383/689/1184 additional growing degree days per year by century's end. Although the absolute magnitude varies with elevation, proximity to the coast, and scenario, no sub-region shows a decline in GDD10 in any model. Agreement across models is extremely high for the direction and spatial pattern of change.

The most pronounced absolute increases are expected in already warm, lowland, and coastal regions, i.e. the same areas underpinning much of the region's productive capacity. As such, the Horizons Region will, with extremely high confidence, experience substantial and spatially coherent increases in growing degree days through this century, implying longer, warmer, and potentially more productive growing seasons, though impacts are also likely for water demand, pest dynamics, and crop or species suitability.

The CCAM projections reveal robust, regionally consistent, extremely likely deceases in the annual and seasonal incidence of frost days across all three future time horizons. This signal emerges with high agreement across all models, spatial domains, and emissions scenarios, and is most marked in the coldest, most frost-prone sub-regions, such as the Volcanic Plateau and Upper Rangitīkei. Starting from a baseline of 4.7/22.3/75.8 frost days per year, decreases of 1.8/6.4/14.4 days per year are projected for the near-future, 3.5/10.1/23.7 fewer frost days per year by mid-century, and 4.3/16.4/39.2 fewer frost days per year by century's end. Warmer, coastal regions, already characterised by few frost days, are projected to experience near total elimination of annual frost events. Seasonal analysis highlights that the majority of frost day losses will occur in winter (JJA), with autumn and spring also showing substantial declines. Summer frosts, already rare, become virtually extinct everywhere. This reduction is tightly linked to projected regional warming but is also shaped by topography, with the largest declines in high elevations and inland valleys. There is extremely high model confidence in the sign, spatial coherence, and broad magnitude of the projected changes, with minor inter-model differences primarily affecting the fine-scale quantification of loss, rather than its presence or general spatial structure.

Potential evapotranspiration deficit (PED) is a crucial climate variable for the Horizons Region, reflecting the difference between atmospheric moisture demand and available water supply at the land surface. It is a direct indicator of soil moisture stress, drought risk, and potential impacts on agriculture, natural ecosystems, and water resource management. The historical climate in the Horizons Region exhibits a clear north–south gradient in PED, with southern and southeastern coastal sub-regions experiencing the highest annual moisture deficits. Model agreement on this spatial pattern is extremely high. Projections unanimously point to increasing PED across most of the region (see Figure 5), signifying a likely escalation in soil moisture deficits and drought risk, particularly under higher GHG emission scenarios. PED changes from a climatological baseline of 14.2/100.4/287.6 mm by -34.7/23.2/74.2 mm over the near-future (indicating wetting in some regions), by -19.0/30.6/108.9 mm by mid-century, and by 1.8/65.5/167.0 mm by century's end. The highest absolute projected increases cluster in the eastern and interior sub-regions, especially Puketoi ki Tai, which already faces high PED in the historical period. Model agreement is strongest for the direction of change (increased PED), though uncertainty persists over the precise spatial patterns and local magnitudes.

The humidity climatology (84.2/88.1/92.9%) reveals a robust, spatially consistent pattern of average relative humidity, with values increasing from the drier southeast to the moister northwest, supported by very high

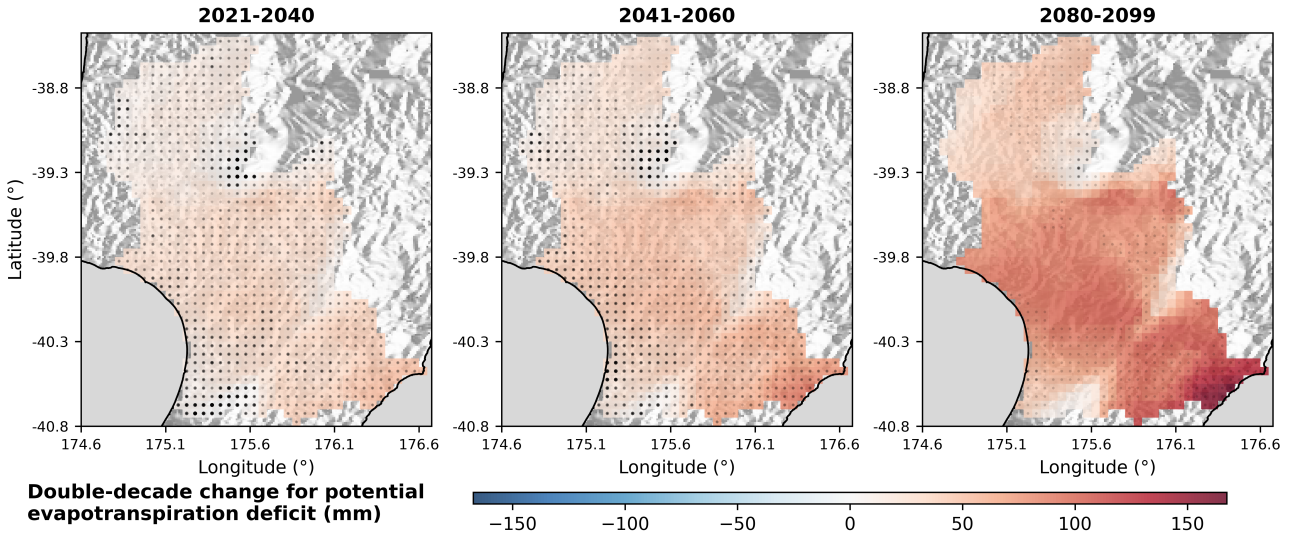


Figure 5: Projected changes in potential evapotranspiration deficit. In each panel, the mean of 12 fields is shown (6 models across the SSP2-4.5 and SSP3-7.0 scenarios). Cells without any dots show where the 12 fields are in unanimous agreement as to the *sign* of the change. Increasing disagreement amongst the fields is shown by increasingly large and opaque dots; where 6 fields project positive changes and 6 negative changes, the dots are very large and completely opaque.

inter-model agreement and virtually certain confidence in both spatial and seasonal gradients. Summer (DJF) is the driest season and winter (JJA) the moistest, with intra-regional contrasts of about five percentage points and remarkably low inter-model spread. Projections (-0.6/-0.2/0.5 percentage point changes over the near-future, -0.8/-0.3/0.5 percentage point changes by mid-century, and -1.1/-0.4/0.4 percentage point changes by century's end) suggest modest yet regionally consistent decreases in average relative humidity. Declines are most pronounced in spring and summer and are geographically strongest in central and eastern/inland sub-regions such as Upper Rangitīkei and Puketoi ki Tai. These projected decreases are typically less than one percentage point through the mid-century, and only rarely approach 2-3% by century's end. Coastal and lowland areas (e.g., Horowhenua, Whanganui–Manawatū Lakes) are notably stable, and in some cases may even see minimal increases or no significant change. Inter-model agreement is high on sign and magnitude for these future changes.

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2.3 Heating and cooling related variables

In terms of building energy use and other infrastructure that requires heating below some threshold, or cooling above some threshold, the number of cooling degree days provides a measure of the energy required to cool buildings in summer while the number of heating degree days provides a measure of the energy required to heat buildings in winter. For both of these a threshold of 18°C has been set with cooling considered to be required above this threshold (CD18) and heating (HD18) required below this threshold. So, for example, a day with a daily mean temperature of 21°C would add 3 cooling degree days to the annual total of CD18 and nothing to the annual total of HD18. A day with a mean temperature of 16°C would add 2 heating degree days to the annual total of HD18 and nothing to the annual total of CD18. Not too surprisingly, given the warming trends detailed above, the CD18 increases from a baseline of 30/133/196 cooling degree days (CDDs) in each year by 19/54/99 CDDs in the near-future, by 37/102/183 CDDs above the baseline by mid-century, and by 71/203/427 additional CDDs by century's end, indicating that the population across the Horizons Region should anticipate greater heat exposure and increased energy demand for cooling, with the largest absolute increases in existing warm sub-regions. Multi-model agreement on both the direction and spatial pattern of these changes is extremely high, with widespread increases virtually certain under both the SSP2-4.5 and SSP3-7.0 scenarios. The historical distribution of CD18 is closely tied to topography, with lowland and coastal regions

displaying the highest values and upland/plateau areas the lowest. Projections show that these differences persist while the magnitude of CD18 increases throughout the region. Isolated locations of change i.e. coastal, lowland, and already warm sub-regions, are projected to experience the largest increases both in absolute and relative terms. Inter-model spread in the absolute magnitudes of projected changes does not undermine the robust consensus on the direction and pattern of change.

In contrast, the number of heating degree days (HD18) decreases from a baseline of 1899/2364/3640 heating degree days (HDDs) in the climatology by 118/259/359 HDDs in the near-future, by 251/435/587 HDDs by mid-century, and by 463/748/1101 HDDs by century's end, indicating significant reductions in the need for heating for environments requiring heating. These findings are supported by exceptionally high inter-model agreement, indicating that both the pattern and magnitude of projected change is reliable and well constrained by the ensemble. Spatially, the most pronounced reductions are projected for the colder, uplifted Volcanic Plateau and Upper Rangitīkei sub-regions, i.e., areas with the highest historical HD18. While absolute reductions are largest in the coldest areas, all sub-regions exhibit a very high likelihood of reduced winter heating demand. Confidence in the sign and broad magnitude of change is extremely high throughout the region and across scenarios. Collectively, these findings highlight that, regardless of emissions pathway, the Horizons Region is virtually certain to see substantial declines in heating degree days this century.

2.4 Precipitation related variables

Historically, the Horizons Region exhibits a highly structured spatial rainfall climatology dominated by orographic influences, with annual means near 819.9/1221.6/2198.2 mm and gradients exceeding 4000 mm across the highest uplands. The spatial agreement of the climatological pattern is virtually across the six models (dry summers, wet winters, persistent regional gradients). Projections for 2021–2040, 2041–2060, and 2080–

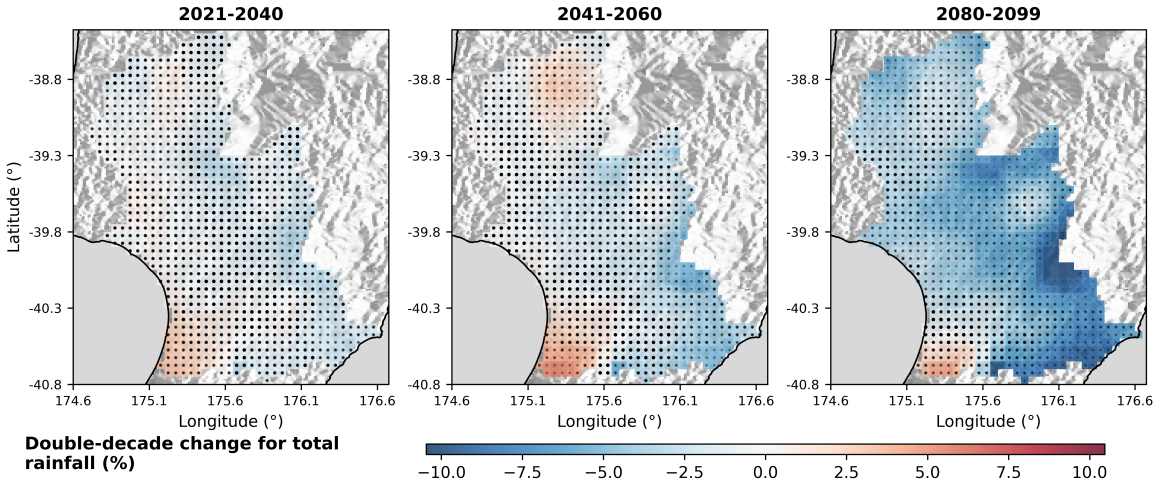


Figure 6: Projected changes in annual total rainfall. In each panel, the mean of 12 fields is shown (6 models across the SSP2-4.5 and SSP3-7.0 scenarios). Cells without any dots show where the 12 fields are in unanimous agreement as to the *sign* of the change. Increasing disagreement amongst the fields is shown by increasingly large and opaque dots; where 6 fields project positive changes and 6 negative changes, the dots are very large and completely opaque.

2099 indicate remarkable stability in annual rainfall, i.e., -10.2/0.6/7.4% changes over the near-future, -11.8/-0.2/9.0% changes by mid-century, and -18.1/-3.5/6.3% changes by century's end. Strong agreement amongst the models of decreases in precipitation of up to 10% is seen only over the mountainous eastern regions of Western Ruahine and north-eastern Tararua and only by the end of the century; coherent region-wide shifts are highly unlikely. Spatial and seasonal nuance emerges in pronounced autumn and spring drying (up to $\sim$10–20%), counterbalanced by robust signals for increased winter rainfall, especially in western/coastal sub-regions (e.g., Horowhenua). Summer changes are minor (about as likely as not using IPCC nomenclature). Local hotspots of greater change appear in the eastern uplands (notably Puketoi ki Tai) for drying, and in

Horowhenua for increased winter-and-spring rainfall, revealing differentiated regional vulnerability. Uncertainty in projected change is higher for spatial detail and sub-seasonal projections, with model spread, scenario divergence, and natural variability all contributing. Ensemble mean signals are much stronger for the direction (e.g., drying in autumn, wetting in winter) than for the precise magnitude or spatial pattern. Overall, the key finding is that total annual rainfall is highly unlikely to shift dramatically, but rainfall seasonality will intensify, exposing certain sub-regions to increased hydrological variability.

Near-term projections of the number of dry days (DD1mm, defined as days receiving less than 1 mm of precipitation) in each year indicate only minor changes, i.e. changes of -7.8/-0.8/4.8 days per year from a baseline of 187.9/224.3/254.8 days per year, with weak spatial coherence, and notable inter-model variability. Winter is projected to become slightly wetter (fewer dry days), while autumn may see a modest increase in dryness. By mid-century, limited but more structured changes of -5.7/-0.2/6.3 days per year emerge with increases in dry occurrence in summer, spring, and especially autumn, with a concurrent reduction in winter, signalling likely seasonal redistribution rather than strong annual trends. By late-century, increases in the number of dry days becomes more marked, i.e., changes of -1.4/6.2/15.3 days per year, most robustly in spring and summer, with spatial hotspots in eastern and upland sub-regions. There is high confidence in the overall trajectory toward more dry days under higher emissions, supporting the need for adaptive management of water resources

Historically, the number of rainy days per year (RR1mm; days per year with precipitation $\geq$1 mm) displays an extremely robust spatial pattern with more frequent rainy days in western and high-elevation areas, with annual frequency almost double that of lower-lying and coastal zones. Model agreement is exceptionally high for the baseline (110.2/140.7/177.1 days per year), and seasonality is clearly expressed: rainy days peak in winter, dip in summer and autumn, and are intermediate in spring. Projected changes through to 2040 are generally small (-4.8/0.8/7.8 days per year) and spatially heterogeneous regardless of emissions scenario, with ensemble means fluctuating near zero and wide inter-model spread. Single model extremes do not represent robust local trends, and by IPCC standards, any near-term change is about as likely as not. By mid-century changes of -6.3/0.2/5.7 days per year are projected with strongest reductions in spring and summer; winter wet day frequency is projected to slightly increase or remain stable. By late-century, region-wide reductions (changes of -15.3/-6.2/1.4 days per year) are very likely, with spring and autumn showing the largest and most certain declines. The spatial coherence of these reductions is strong, except for low-lying Horowhenua, which persistently diverges from the broader trend.

The climatology of the number of very rainy days (RR25mm, defined as days with precipitation >25 mm) shows strong spatial structure, with higher frequencies in southwestern and orographically exposed sub-regions, and models demonstrate extremely high agreement on the spatial pattern and magnitude. Projections for the near-future indicate only modest changes in RR25mm of -2.1/0.5/2.3 days/year from a baseline of 2.9/7.8/23.4 days/year. The magnitude of change is typically well within interannual variability and model spread. By mid-century changes of -1.9/0.5/3.0 days per year are projected and by late-century changes of -2.5/0.6/3.1 days per year. A pattern emerges of slightly increasing RR25mm, especially in the western and southern Horizons Region, with the Horowhenua sub-region standing out as most likely to experience significant increases, particularly under higher emissions scenarios and in winter. Coastal and lowland areas generally show a more robust signal than upland or eastern sub-regions, where changes may be negative or negligible. Uncertainty remains high in the precise magnitude and spatial distribution of projected changes, especially in the early-to-mid 21st century and under lower emission scenarios

CCAM simulations of heavy rainfall extremes, measured here as the 99th percentile of daily precipitation (R99pVAL), demonstrate extraordinarily high model agreement in the region's heavy rainfall climatology, with maxima in southeastern and coastal areas and 1986-2005 climatological values of 23.2/33.3/52.4 mm. Projections show a regionally consistent but quantitatively modest increase in the intensity of heavy rainfall events, with confidence and magnitude generally scaling with emissions and time horizon. Over the near-future, extreme rainfall increases are likely, though spatial heterogeneity and inter-model spread remain high (changes of -6.1/4.1/13.6%); local trends are subtle and often not statistically distinct from internal variability. By

mid-century, projected changes are -6.1/4.5/19.9% and, by late-century, -5.5/7.9/24.0%. Seasonal signals are strongest in winter and spring, but increases are apparent in other seasons as well. Model agreement regarding the sign of regional change becomes steadily stronger with warming, and confidence in regional increases in heavy rainfall extremes is high, especially under high emissions scenarios. However, robust spatial coherence (i.e., at local catchment scales) is not apparent in the model simulations. Uncertainty remains intrinsic to such projections, underscoring the need for scenario-informed flexible planning.

Similarly, heavy rainfall extremes only on wet days, represented by the 99^{th} percentile of daily rainfall on days with precipitation >1 mm (R99pVALWet) are projected to experience modest, spatially variable, increases over the near-future of -5.3/5.5/19.1%, with high confidence in a weakly positive regional signal but substantial uncertainty in local detail. By mid-century, projected increases intensify (-5.5/7.0/25.1%) and become more robust across the region, especially under higher emissions scenarios. By late century, the models simulate region-wide intensification (-3.4/13.0/34.7%). Seasonally, the increases are generally largest in summer and spring, although both the magnitude and seasonality of changes vary between sub-regions and scenarios. Projection uncertainties are substantial at local scales and result from model differences, emissions scenario uncertainty, and natural climate variability. Nonetheless, there is very high confidence in the regional signal of increasing heavy rainfall extremes, especially by the end of the century under higher emissions scenarios.

2.5 Renewables: wind and solar radiation

The CCAM simulated climatology of average wind speed (sfcWind) shows a pronounced southeast-to-northwest gradient in wind speed, with highest values in the southeast (notably Puketoi ki Tai and Tararua) and lowest in the northwest (e.g., NorthernZone-Taumarunui). This spatial structure is extremely likely to be robust, with very high inter-model agreement and excellent consistency across all four seasons, particularly revealing pronounced seasonal cycles with spring being the windiest season and autumn the calmest. Projections of changes in average wind speeds show modest to moderate declines for most of the region, most notably in the northern and central sub-regions, especially in summer and autumn. From a climatology of 2.9/4.3/6.5 m/s, changes over the near-future, of -4.9/-1.1/1.3% are simulated. Reductions in mean wind speed become very likely by mid- to late-century, with mid-century changes of -5.2/-1.0/2.4% and late-century changes of -7.4/-2.8/1.5%, and even more pronounced localised declines reaching over 10% in some projections under higher-emissions pathways. A regional contrast unfolds in the southeast and elevated sub-regions (Tararua, Puketoi ki Tai), which, especially in winter and spring, are likely to experience stable or increasing wind speeds—sometimes with robust positive changes exceeding 2–4 m/s. However, overall, it is extremely likely that the great majority of the region will witness reduced wind speeds over summer and autumn.

CCAM simulations of the number of windy days, i.e. days with wind speeds exceeding 10 m/s (Wd10), exhibit a strong southeast-to-northwest gradient, with the southeast and coastal zones experiencing the highest frequency of windy days, well above 100 to 200 days per year in exposed locations (the baseline climatology indicates 3.8/50.8/168.8 days per year). This robust spatial pattern is virtually certain, with extremely high agreement among models. Over the near-future and mid-century, changes in the number of windy days per year are modest, i.e., -10.2/-1.0/3.6 days/year. Through mid-century, the likely change in annual windy days is again modest, i.e. -11.3/-0.9/5.1 days per year. By the end of the century there is some indication of a decrease in the number of windy days each year: -15.3/-3.2/1.1 days per year. Seasonal trends are more pronounced than annual means, with winter and spring generally projected to become slightly windier, especially in already exposed sub-regions, while summer and autumn show declines. Projected changes are accentuated in the region's wind hotspots (notably Puketoi ki Tai and Tararua), but the signal is still moderate relative to the climatology and natural variability. In conclusion, the Horizons Region is extremely likely to remain wind-prone, with the baseline gradient persisting and only modest, seasonally nuanced changes in Wd10 expected by century's end.

The climatology of extreme wind events, quantified by the 99^{th} percentile of daily maximum wind speed (here-

after 'strong wind'), across the Horizons Region is dominated by a persistent southeast-to-northwest gradient, with the highest extremes in the Puketoi ki Tai and Tararua sub-regions. This spatial signal is highly robust across all seasons and models. Projected changes in strong wind extremes are modest across all emission scenarios. Starting from a 1986-2005 climatology of 9.7/14.0/17.9 m/s, changes of -2.7/-0.5/2.4% are simulated for the near-future, -2.8/-0.5/2.8% by mid-century, and -3.2/-0.5/2.3% by century's end. There is, however, a marked seasonality with reductions in strong wind projected to be very likely in summer and autumn in most sub-regions, whereas winter winds show robust, regionally coherent increases, particularly in the eastern high country. Substantial sub-regional diversity remains, underscoring the need for locally specific adaptation. Model agreement is high on broad regional and seasonal signals but considerably lower for fine spatial structures, reflecting the role of natural variability and inter-model differences.

The CCAM simulations generate a consistent, spatially robust climatology of average solar radiation (incoming shortwave solar radiation), with higher values in the southeast and lower values in the northwest. This pattern is exceptionally well captured across all models, presenting very high confidence in the baseline climatology and seasonal variation with summer peaks being stronger and winter values notably lower, as expected for a mid-latitude landscape. Projections reveal a modest but consistent increase in average solar radiation across the region, with only minor local differences between models. Starting from a climatology of 160.6/177.2/190.8 W/m^2, over the near-future, changes of -4.7/1.5/4.6 W/m^2 are simulated, by mid-century, changes of -3.9/2.1/6.5 W/m^2, and by century's end, changes of -3.0/3.1/7.5 W/m^2. The strongest and most consistent increases are projected for spring and, to a lesser extent, summer, while changes in autumn and winter tend to be smaller or even neutral. Uncertainty across model ensembles is moderate in magnitude but does not obscure the robust regional signal of increases in spring and summer becoming very likely (probability >90%) by mid-to-late century under higher emissions scenarios.

3 Region specific findings

This section reports on projected changes in the target climate variables for the regions shown in Figure 7.

The statistics detailed below consider only (i) changes under the SSP2-4.5 and SSP3-7.0 scenarios (providing the range of values quoted), (ii) changes from a 1986-2005 baseline, (iii) the multi-model mean (unless otherwise stated), (iv) do not quote values indicating the spatial variability in the variable across the region, and (v) consider only changes across the year (no seasonal changes); for more nuanced results, please consult the region-specific tables in the appendices of the variable-specific reports.

3.1 NorthernZone-Taumarunui

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.3°C to 1.6°C by mid-century, and then by 2.2°C to 3.2°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.2°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.0°C to 1.2°C are projected for the near term (over a climatological value of 27.5°C). By mid-century these hottest day temperature increases are 1.8°C to 2.1°C, and by century's end 2.5°C to 4.1°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -4.7°C by 0.5°C to 0.8°C in the near term, by 1.0°C to 1.2°C by mid-century, and by 1.6°C to 2.5°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from around 1 day per decade in the 1986-2005 climatology to around 8 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase

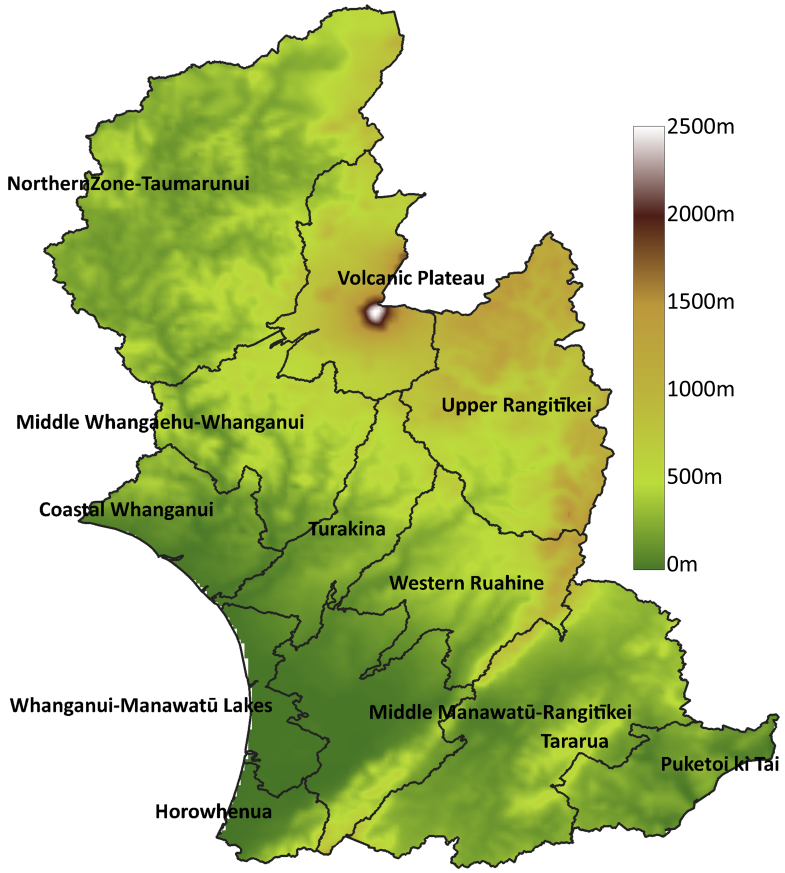


Figure 7: The 12 regions reported on in this section together with a map of the elevation (in metres) across the whole Horizons Region.

from a climatological value of 2528 growing degree days by about 286 to 320 growing degree days in the near term, then further by 472 to 560 additional growing degree days by mid-century, and 780 to 1162 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 1035 growing degree days by about 213 to 246 growing degree days in the near term, then further by 358 to 431 additional growing degree days by mid-century, and 602 to 934 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 30 days per year by 7 to 8 days per year in the near-term, and by a further 12 to 13 days per year by mid-century, and 18 to 23 days per year by century's end reducing frost days from around 1 month in each year to around 1 to 2 weeks each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 37.8 mm by 12.2 to 14.5 mm in the near term, by 22.0 to 22.5 mm by mid-century, and by 29.5 to 54.0 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 150 CDDs by 57 to 72 CDDs in the near term, by 104 to 133 additional CDDs by mid-century, and then further by 182 to 321 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 2393 HDDs by 240 to 260 HDDs in the near term, by 384 to 445 HDDs by mid-century, and by 619 to 865 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -0.7 to 0.1 % changes in the near term from a climatological value of 1598.2 mm, by 0.1 to 0.6 % by mid-century, and by -4.9 to -1.8 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 2.4 to 7.1 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -7.1 to -2.4 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain

(likely), increasing from a climatological value of 40.5 mm by 4.0 to 4.5 % in the near term, by 6.8 to 7.8 % by mid-century, and by 7.3 to 11.0 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.4 times that of R99pVAL from a climatological value of 52.0 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 35.1 days per year, decreasing by 1.8 to 2.2 days per year in the near term, by 2.2 to 2.7 days per year by mid-century, and by 4.3 to 6.6 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 3.6 m/s, decreasing by 1.9 to 2.1 % in the near term, by 1.9 to 2.6 % by mid-century, and by 3.8 to 6.2 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 12.9 m/s, decreasing by 0.2 to 0.8 % in the near term, by 0.4 to 0.8 % by mid-century, and by 1.1 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 172.4 W/m^2, with increases of 0.5 to 2.2 W/m^2 in the near term, of 1.6 to 2.6 W/m^2 by mid-century, and of 2.1 to 4.5 W/m^2 by century's end.

3.2 Volcanic Plateau

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.9°C in the near-term, by 1.4°C to 1.6°C by mid-century, and then by 2.3°C to 3.3°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.2°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.1°C to 1.2°C are projected for the near term (over a climatological value of 25.2°C). By mid-century these hottest day temperature increases are 1.8°C to 1.9°C, and by century's end 2.4°C to 4.0°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -6.2°C by 0.7°C to 0.8°C in the near term, by 1.1°C to 1.3°C by mid-century, and by 1.7°C to 2.5°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from less than 1 day per decade in the 1986-2005 climatology to around 2 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 1664 growing degree days by about 266 to 297 growing degree days in the near term, then further by 439 to 519 additional growing degree days by mid-century, and 722 to 1086 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 542 growing degree days by about 158 to 186 growing degree days in the near term, then further by 269 to 324 additional growing degree days by mid-century, and 446 to 710 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 64 days per year by 12 to 13 days per year in the near-term, and by a further 19 to 22 days per year by mid-century, and 31 to 40 days per year by century's end reducing frost days from around 2 months in each year to around 1 month each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 31.2 mm by 10.4 to 12.3 mm in the near term, by 19.2 to 19.5 mm by mid-century, and by 21.5 to 47.0 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 63 CDDs by 29 to 37 CDDs in the near term, by 56 to 71 additional CDDs by mid-century, and then further by 97 to 182 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 3303 HDDs by 285 to 306 HDDs in the near term, by 451 to 525 HDDs by mid-century, and by 726 to 1027 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -2.2 to -1.3 % changes in the near term from a climatological value of 1873.4 mm, by -1.3 to -0.5 % by mid-century, and by -6.7 to -2.7 % by century's end. The

multi-model mean projects a change in the number of dry days by century's end of 2.6 to 8.3 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -8.3 to -2.6 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 43.0 mm by 2.7 to 3.0 % in the near term, by 5.7 to 5.8 % by mid-century, and by 6.1 to 8.2 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.5 times that of R99pVAL from a climatological value of 51.9 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 37.3 days per year, decreasing by 1.6 to 2.4 days per year in the near term, by 1.9 to 2.6 days per year by mid-century, and by 3.6 to 6.1 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.0 m/s, decreasing by 1.9 to 2.3 % in the near term, by 2.2 to 2.8 % by mid-century, and by 3.7 to 6.4 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 12.8 m/s, decreasing by 0.5 to 1.1 % in the near term, by 0.9 to 1.2 % by mid-century, and by 1.3 to 1.6 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 162.8 W/m^2, with increases of 1.2 to 2.9 W/m^2 in the near term, of 2.3 to 3.5 W/m^2 by mid-century, and of 2.8 to 6.1 W/m^2 by century's end.

3.3 Upper Rangitīkei

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.9°C in the near-term, by 1.4°C to 1.6°C by mid-century, and then by 2.3°C to 3.3°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.3°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.2°C to 1.3°C are projected for the near term (over a climatological value of 25.3°C). By mid-century these hottest day temperature increases are 1.8°C to 2.0°C, and by century's end 2.6°C to 4.0°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -6.3°C by 0.6°C in the near term, by 1.0°C to 1.1°C by mid-century, and by 1.6°C to 2.2°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from less than 1 day per decade in the 1986-2005 climatology to around 2 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 1670 growing degree days by about 267 to 297 growing degree days in the near term, then further by 440 to 518 additional growing degree days by mid-century, and 723 to 1081 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 550 growing degree days by about 161 to 189 growing degree days in the near term, then further by 274 to 329 additional growing degree days by mid-century, and 455 to 716 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 62 days per year by 11 days per year in the near-term, and by a further 17 to 20 days per year by mid-century, and 28 to 36 days per year by century's end reducing frost days from around 2 months in each year to around 1 month each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 92.8 mm by 24.5 to 26.2 mm in the near term, by 33.6 to 40.8 mm by mid-century, and by 52.8 to 82.8 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 64 CDDs by 31 to 39 CDDs in the near term, by 57 to 73 additional CDDs by mid-century, and then further by 101 to 183 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 3310 HDDs by 282 to 302 HDDs in the near term, by 449 to 521 HDDs by mid-

century, and by 722 to 1022 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -1.8 to -1.3 % changes in the near term from a climatological value of 1316.0 mm, by -3.0 to -1.2 % by mid-century, and by -7.6 to -3.9 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 5.3 to 12.3 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -12.3 to -5.3 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 33.3 mm by 4.8 % in the near term, by 5.7 to 7.4 % by mid-century, and by 9.0 to 12.3 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.3 times that of R99pVAL from a climatological value of 44.1 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 35.0 days per year, decreasing by 1.0 to 1.9 days per year in the near term, by 0.9 to 1.6 days per year by mid-century, and by 2.2 to 4.3 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.0 m/s, decreasing by 1.6 to 2.1 % in the near term, by 1.7 to 2.2 % by mid-century, and by 3.1 to 5.6 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 11.9 m/s, decreasing by 0.2 to 0.8 % in the near term, by 0.3 % by mid-century, and by 0.3 to 0.4 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 178.6 W/m^2, with increases of 1.3 to 2.5 W/m^2 in the near term, of 2.3 to 3.2 W/m^2 by mid-century, and of 3.3 to 5.7 W/m^2 by century's end.

3.4 Western Ruahine

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.4°C to 1.6°C by mid-century, and then by 2.2°C to 3.3°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.2°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.1°C to 1.3°C are projected for the near term (over a climatological value of 26.6°C). By mid-century these hottest day temperature increases are 1.7°C to 1.9°C, and by century's end 2.4°C to 4.0°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -3.9°C by 0.6°C in the near term, by 0.9°C to 1.2°C by mid-century, and by 1.7°C to 2.6°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from less than 1 day per decade in the 1986-2005 climatology to around 4 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2316 growing degree days by about 280 to 314 growing degree days in the near term, then further by 472 to 556 additional growing degree days by mid-century, and 776 to 1152 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 900 growing degree days by about 197 to 230 growing degree days in the near term, then further by 341 to 406 additional growing degree days by mid-century, and 569 to 883 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 25 days per year by 7 to 8 days per year in the near-term, and by a further 11 to 12 days per year by mid-century, and 16 to 20 days per year by century's end reducing frost days from between 2 and 3 weeks in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 123.6 mm by 29.4 to 29.7 mm in the near term, by 41.7 to 47.5 mm by mid-century, and by 65.2 to 100.2 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 111 CDDs by 46 to 58 CDDs in the near term, by 86 to 109

additional CDDs by mid-century, and then further by 151 to 269 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 2585 HDDs by 252 to 274 HDDs in the near term, by 410 to 475 HDDs by mid-century, and by 658 to 922 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -1.9 to -0.8 % changes in the near term from a climatological value of 1237.5 mm, by -2.6 to -2.1 % by mid-century, and by -7.9 to -4.4 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 3.8 to 10.1 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -10.1 to -3.8 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 31.2 mm by 3.0 to 4.8 % in the near term, by 2.8 to 3.8 % by mid-century, and by 6.4 to 9.8 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.6 times that of R99pVAL from a climatological value of 41.2 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 44.3 days per year, decreasing by 0.6 to 1.8 days per year in the near term, by 0.5 to 1.5 days per year by mid-century, and by 1.9 to 4.2 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.2 m/s, decreasing by 0.7 to 1.3 % in the near term, by 0.7 to 1.0 % by mid-century, and by 1.5 to 3.0 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 13.1 m/s, decreasing by 0.2 to 1.2 % in the near term, by 0.5 to 0.8 % by mid-century, and by 0.7 to 0.9 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 171.4 W/m^2, with increases of 1.1 to 2.3 W/m^2 in the near term, of 1.9 to 3.2 W/m^2 by mid-century, and of 2.6 to 5.4 W/m^2 by century's end.

3.5 Tararua

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.3°C to 1.6°C by mid-century, and then by 2.2°C to 3.2°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.2°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.2°C to 1.4°C are projected for the near term (over a climatological value of 27.2°C). By mid-century these hottest day temperature increases are 1.8°C to 2.0°C, and by century's end 2.6°C to 4.0°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -3.6°C by 0.7°C in the near term, by 1.1°C to 1.3°C by mid-century, and by 1.7°C to 2.6°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from around 1 day per decade in the 1986-2005 climatology to around 5 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2536 growing degree days by about 281 to 314 growing degree days in the near term, then further by 470 to 557 additional growing degree days by mid-century, and 779 to 1154 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 1029 growing degree days by about 209 to 241 growing degree days in the near term, then further by 358 to 427 additional growing degree days by mid-century, and 604 to 928 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 18 days per year by 5 to 6 days per year in the near-term, and by a further 9 days per year by mid-century, and 13 to 15 days per year by century's end reducing frost days from between 2 and 3 weeks in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological

value of 160.9 mm by 29.9 to 34.9 mm in the near term, by 45.6 to 55.1 mm by mid-century, and by 74.8 to 106.7 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 126 CDDs by 51 to 64 CDDs in the near term, by 94 to 119 additional CDDs by mid-century, and then further by 168 to 292 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 2357 HDDs by 240 to 260 HDDs in the near term, by 390 to 454 HDDs by mid-century, and by 630 to 882 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -1.4 to -0.8 % changes in the near term from a climatological value of 1306.0 mm, by -3.0 to -2.9 % by mid-century, and by -8.4 to -4.7 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 4.0 to 10.4 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -10.4 to -4.0 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 36.1 mm by 3.6 to 5.7 % in the near term, by 2.8 to 4.4 % by mid-century, and by 5.5 to 7.2 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.9 times that of R99pVAL from a climatological value of 48.8 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 116.7 days per year, decreasing by 0.4 to 3.0 days per year in the near term, by 0.2 to 1.3 days per year by mid-century, and by 2.1 to 5.0 days per year by century's end. Average wind speeds are projected to remain about the same from a climatological value of 5.6 m/s, changing by -0.5 to 0.2 % in the near term, by 0.2 to 0.5 % by mid-century, and by -0.9 to 0.0 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to remain about the same from a climatological value of 16.1 m/s, changing by -0.2 to -0.0 % in the near term, by 0.3 to 0.5 % by mid-century, and by 0.4 to 0.7 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 182.4 W/m^2, with increases of 0.4 to 1.0 W/m^2 in the near term, of 0.5 to 1.4 W/m^2 by mid-century, and of 1.0 to 2.4 W/m^2 by century's end.

3.6 Middle Manawatū-Rangitīkei

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.3°C to 1.5°C by mid-century, and then by 2.1°C to 3.2°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.1°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 0.9°C to 1.4°C are projected for the near term (over a climatological value of 27.6°C). By mid-century these hottest day temperature increases are 1.8°C, and by century's end 2.3°C to 4.0°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -3.0°C by 0.7°C in the near term, by 1.0°C to 1.4°C by mid-century, and by 1.9°C to 2.7°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from around 1 day per decade in the 1986-2005 climatology to around 6 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2763 growing degree days by about 274 to 309 growing degree days in the near term, then further by 467 to 552 additional growing degree days by mid-century, and 773 to 1146 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 1185 growing degree days by about 214 to 250 growing degree days in the near term, then further by 375 to 444 additional growing degree days by mid-century, and 629 to 964 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number

of frost days is projected to decrease (virtually certain) from around 16 days per year by 5 to 6 days per year in the near-term, and by a further 8 to 9 days per year by mid-century, and 12 to 14 days per year by century's end reducing frost days from between 2 and 3 weeks in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 185.3 mm by 24.5 to 26.3 mm in the near term, by 36.7 to 41.3 mm by mid-century, and by 61.3 to 89.1 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 149 CDDs by 55 to 72 CDDs in the near term, by 105 to 131 additional CDDs by mid-century, and then further by 185 to 322 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 2145 HDDs by 225 to 244 HDDs in the near term, by 370 to 431 HDDs by mid-century, and by 599 to 837 HDDs by century's end.

Projected changes in rainfall are small and uncertain: 0.2 to 0.6 % changes in the near term from a climatological value of 1219.7 mm, by 0.3 to 0.8 % by mid-century, and by -3.8 to -0.4 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 2.0 to 7.0 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -7.0 to -2.0 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 32.0 mm by 3.6 to 4.2 % in the near term, by 4.7 to 6.7 % by mid-century, and by 7.6 to 9.5 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.7 times that of R99pVAL from a climatological value of 43.0 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 81.6 days per year, decreasing by 1.5 to 3.7 days per year in the near term, by 1.1 to 2.7 days per year by mid-century, and by 4.1 to 6.9 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.8 m/s, decreasing by 0.2 to 0.8 % in the near term, by -0.0 to 0.1 % by mid-century, and by 0.4 to 1.2 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 15.3 m/s, decreasing by -0.1 to 0.7 % in the near term, by 0.4 % by mid-century, and by 0.5 to 0.8 % by century's end. Projected changes in humidity are statistically insignificant. The models project more likely than not increases in solar radiation from a climatological value of 179.3 W/m^2, with increases of -0.2 to 0.9 W/m^2 in the near term, of 0.1 to 1.2 W/m^2 by mid-century, and of 0.2 to 1.9 W/m^2 by century's end.

3.7 Horowhenua

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.7°C to 0.8°C in the near-term, by 1.2°C to 1.5°C by mid-century, and then by 2.1°C to 3.1°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.1°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 0.7°C to 1.3°C are projected for the near term (over a climatological value of 27.4°C). By mid-century these hottest day temperature increases are 1.6°C to 1.8°C, and by century's end 2.2°C to 3.8°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -3.3°C by 0.6°C to 0.7°C in the near term, by 1.0°C to 1.3°C by mid-century, and by 1.7°C to 2.6°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from around 1 day per decade in the 1986-2005 climatology to around 4 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2640 growing degree days by about 255 to 293 growing degree days in the near term, then further by 441 to 521 additional growing degree days by mid-century, and 736 to 1096 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually

certain to increase from a climatological value of 1102 growing degree days by about 193 to 230 growing degree days in the near term, then further by 344 to 408 additional growing degree days by mid-century, and 581 to 897 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 19 days per year by 6 days per year in the near-term, and by a further 9 to 10 days per year by mid-century, and 13 to 16 days per year by century's end reducing frost days from between 2 and 3 weeks in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 81.1 mm by 5.9 to 6.0 mm in the near term, by 16.1 to 17.4 mm by mid-century, and by 20.0 to 43.7 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 122 CDDs by 45 to 60 CDDs in the near term, by 90 to 111 additional CDDs by mid-century, and then further by 158 to 280 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 2248 HDDs by 218 to 242 HDDs in the near term, by 363 to 424 HDDs by mid-century, and by 595 to 835 HDDs by century's end.

Projected changes in rainfall are small and uncertain: 1.9 to 3.6 % changes in the near term from a climatological value of 1703.7 mm, by 4.4 to 4.8 % by mid-century, and by 1.5 to 4.6 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of -0.2 to 2.9 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -2.9 to 0.2 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 42.3 mm by 3.0 to 4.4 % in the near term, by 4.5 to 6.3 % by mid-century, and by 7.2 to 7.7 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.2 times that of R99pVAL from a climatological value of 55.7 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 54.1 days per year, decreasing by 2.2 to 2.8 days per year in the near term, by 1.7 to 3.0 days per year by mid-century, and by 4.2 to 6.4 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.4 m/s, decreasing by 1.0 to 1.3 % in the near term, by 0.9 to 1.3 % by mid-century, and by 1.9 to 3.1 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 14.0 m/s, decreasing by 0.2 to 0.6 % in the near term, by 0.3 to 0.6 % by mid-century, and by 0.5 to 1.0 % by century's end. Projected changes in humidity are statistically insignificant. The models project about as likely as not increases in solar radiation from a climatological value of 170.0 W/m^2, with increases of -0.8 to 0.3 W/m^2 in the near term, of -1.4 to 0.1 W/m^2 by mid-century, and of -1.7 to 0.2 W/m^2 by century's end.

3.8 Whanganui-Manawatū Lakes

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.7°C to 0.8°C in the near-term, by 1.3°C to 1.5°C by mid-century, and then by 2.1°C to 3.1°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.1°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 0.8°C to 1.2°C are projected for the near term (over a climatological value of 28.0°C). By mid-century these hottest day temperature increases are 1.6°C to 1.7°C, and by century's end 2.2°C to 3.6°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -2.1°C by 0.6°C to 0.7°C in the near term, by 1.0°C to 1.4°C by mid-century, and by 1.9°C to 2.7°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from around 1 day per decade in the 1986-2005 climatology to around 5 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase

from a climatological value of 3023 growing degree days by about 263 to 300 growing degree days in the near term, then further by 455 to 534 additional growing degree days by mid-century, and 753 to 1111 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 1365 growing degree days by about 216 to 254 growing degree days in the near term, then further by 384 to 451 additional growing degree days by mid-century, and 644 to 976 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 9 days per year by 4 days per year in the near-term, and by a further 6 to 7 days per year by mid-century, and 8 to 9 days per year by century's end reducing frost days from around 1 to 2 weeks in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 220.5 mm by 16.5 to 18.5 mm in the near term, by 32.1 to 33.8 mm by mid-century, and by 53.6 to 83.6 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 169 CDDs by 58 to 77 CDDs in the near term, by 114 to 138 additional CDDs by mid-century, and then further by 199 to 341 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 1894 HDDs by 207 to 225 HDDs in the near term, by 344 to 399 HDDs by mid-century, and by 557 to 772 HDDs by century's end.

Projected changes in rainfall are small and uncertain: 1.3 to 1.6 % changes in the near term from a climatological value of 953.9 mm, by 0.8 to 2.4 % by mid-century, and by -3.3 to 0.8 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 2.4 to 7.0 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -7.0 to -2.4 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 27.6 mm by 3.3 to 5.1 % in the near term, by 4.1 to 8.5 % by mid-century, and by 9.4 to 9.8 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.4 times that of R99pVAL from a climatological value of 39.1 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 90.1 days per year, decreasing by 2.5 to 4.6 days per year in the near term, by 2.3 to 3.9 days per year by mid-century, and by 5.7 to 9.7 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 5.2 m/s, decreasing by 0.6 to 1.1 % in the near term, by 0.4 to 0.7 % by mid-century, and by 1.0 to 2.3 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 15.9 m/s, decreasing by -0.1 to 0.4 % in the near term, by 0.3 to 0.4 % by mid-century, and by 0.4 to 0.9 % by century's end. Projected changes in humidity are statistically insignificant. The models project about as likely as not increases in solar radiation from a climatological value of 185.1 W/m^2, with increases of -0.6 to 0.5 W/m^2 in the near term, of -0.3 to 0.6 W/m^2 by mid-century, and of -0.2 to 1.1 W/m^2 by century's end.

3.9 Coastal Whanganui

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.3°C to 1.5°C by mid-century, and then by 2.1°C to 3.2°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.1°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.1°C to 1.2°C are projected for the near term (over a climatological value of 26.8°C). By mid-century these hottest day temperature increases are 1.6°C to 1.8°C, and by century's end 2.3°C to 3.9°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -1.6°C by 0.6°C to 0.7°C in the near term, by 1.0°C to 1.4°C by mid-century, and by 1.8°C to 2.6°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end,

e.g., TX30 increases from less than 1 day per decade in the 1986-2005 climatology to around 4 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2921 growing degree days by about 279 to 317 growing degree days in the near term, then further by 472 to 559 additional growing degree days by mid-century, and 781 to 1148 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 1274 growing degree days by about 226 to 265 growing degree days in the near term, then further by 394 to 468 additional growing degree days by mid-century, and 663 to 1004 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 6 days per year by 3 days per year in the near-term, and by a further 4 to 5 days per year by mid-century, and 5 to 6 days per year by century's end reducing frost days from less than 1 week in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 191.6 mm by 24.3 to 31.1 mm in the near term, by 41.0 to 43.9 mm by mid-century, and by 71.9 to 104.0 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 153 CDDs by 61 to 78 CDDs in the near term, by 113 to 141 additional CDDs by mid-century, and then further by 200 to 345 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 1980 HDDs by 220 to 241 HDDs in the near term, by 362 to 420 HDDs by mid-century, and by 583 to 806 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -0.4 to 0.8 % changes in the near term from a climatological value of 987.8 mm, by -0.8 to 0.1 % by mid-century, and by -5.7 to -1.6 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 4.1 to 10.9 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -10.9 to -4.1 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 27.8 mm by 2.3 to 5.5 % in the near term, by 5.6 to 9.2 % by mid-century, and by 9.6 to 10.6 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.1 times that of R99pVAL from a climatological value of 40.3 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 48.5 days per year, decreasing by 1.0 to 2.3 days per year in the near term, by 1.0 to 2.2 days per year by mid-century, and by 3.1 to 5.9 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.3 m/s, decreasing by 0.9 to 1.3 % in the near term, by 0.6 to 0.9 % by mid-century, and by 1.3 to 2.9 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 13.9 m/s, decreasing by -0.1 to 0.8 % in the near term, by 0.7 to 0.9 % by mid-century, and by 0.3 to 0.9 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 184.7 W/m^2, with increases of 0.1 to 1.3 W/m^2 in the near term, of 1.0 to 1.8 W/m^2 by mid-century, and of 1.3 to 3.3 W/m^2 by century's end.

3.10 Turakina

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.3°C to 1.6°C by mid-century, and then by 2.2°C to 3.2°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.2°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.0°C to 1.3°C are projected for the near term (over a climatological value of 27.0°C). By mid-century these hottest day temperature increases are 1.7°C to 1.9°C, and by century's end 2.3°C to 4.0°C.

Similarly, temperatures on the coldest days of the year increase from a climatological value of -3.1°C by 0.6°C in the near term, by 0.9°C to 1.2°C by mid-century, and by 1.7°C to 2.5°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from less than 1 day per decade in the 1986-2005 climatology to around 5 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2555 growing degree days by about 283 to 319 growing degree days in the near term, then further by 478 to 564 additional growing degree days by mid-century, and 786 to 1163 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 1050 growing degree days by about 210 to 245 growing degree days in the near term, then further by 363 to 432 additional growing degree days by mid-century, and 607 to 935 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 19 days per year by 6 to 7 days per year in the near-term, and by a further 9 to 10 days per year by mid-century, and 13 to 16 days per year by century's end reducing frost days from between 2 and 3 weeks in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 165.2 mm by 31.0 to 33.4 mm in the near term, by 48.5 to 49.4 mm by mid-century, and by 72.3 to 108.9 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 137 CDDs by 54 to 69 CDDs in the near term, by 101 to 127 additional CDDs by mid-century, and then further by 177 to 309 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 2350 HDDs by 240 to 260 HDDs in the near term, by 391 to 453 HDDs by mid-century, and by 627 to 875 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -1.2 to -0.2 % changes in the near term from a climatological value of 952.4 mm, by -1.5 to -1.4 % by mid-century, and by -6.5 to -3.0 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 4.8 to 11.4 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -11.4 to -4.8 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 25.9 mm by 3.6 to 5.1 % in the near term, by 4.5 to 6.7 % by mid-century, and by 8.6 to 11.4 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.6 times that of R99pVAL from a climatological value of 35.8 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 47.9 days per year, decreasing by 0.7 to 2.1 days per year in the near term, by 0.7 to 1.8 days per year by mid-century, and by 2.3 to 5.1 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.2 m/s, decreasing by 0.8 to 1.4 % in the near term, by 0.7 to 1.0 % by mid-century, and by 1.5 to 3.2 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 13.8 m/s, decreasing by -0.3 to 0.7 % in the near term, by 0.3 % by mid-century, and by 0.3 to 0.7 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 178.2 W/m^2, with increases of 0.9 to 2.0 W/m^2 in the near term, of 1.8 to 2.8 W/m^2 by mid-century, and of 2.4 to 4.9 W/m^2 by century's end.

3.11 Puketoi ki Tai

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.3°C to 1.6°C by mid-century, and then by 2.2°C to 3.2°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being

up to 0.2°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.2°C to 1.3°C are projected for the near term (over a climatological value of 27.8°C). By mid-century these hottest day temperature increases are 1.8°C to 2.0°C, and by century's end 2.6°C to 3.7°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -1.7°C by 0.6°C in the near term, by 1.1°C to 1.3°C by mid-century, and by 1.8°C to 2.6°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from around 1 day per decade in the 1986-2005 climatology to around 6 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2908 growing degree days by about 287 to 320 growing degree days in the near term, then further by 475 to 564 additional growing degree days by mid-century, and 791 to 1159 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 1274 growing degree days by about 234 to 268 growing degree days in the near term, then further by 395 to 470 additional growing degree days by mid-century, and 669 to 1009 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 5 days per year by 2 days per year in the near-term, and by a further 3 days per year by mid-century, and 4 to 5 days per year by century's end reducing frost days from less than 1 week in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 338.0 mm by 46.9 to 49.0 mm in the near term, by 66.5 to 85.7 mm by mid-century, and by 111.1 to 157.0 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 157 CDDs by 64 to 78 CDDs in the near term, by 114 to 143 additional CDDs by mid-century, and then further by 207 to 345 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 1999 HDDs by 226 to 245 HDDs in the near term, by 365 to 425 HDDs by mid-century, and by 589 to 820 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -2.5 to -1.5 % changes in the near term from a climatological value of 1071.4 mm, by -4.3 to -4.1 % by mid-century, and by -10.2 to -6.2 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 5.5 to 11.5 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -11.5 to -5.5 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (more likely than not), increasing from a climatological value of 37.0 mm by 0.2 to 1.0 % in the near term, by 0.0 to 0.4 % by mid-century, and by 1.7 to 3.3 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 4.2 times that of R99pVAL from a climatological value of 56.1 mm.

The number of windy days (>10 m/s) is projected to remain about the same from a climatological value of 160.3 days per year, changing by -2.3 to 0.6 days per year in the near term, by -0.1 to 0.2 days per year by mid-century, and by -4.4 to -0.7 days per year by century's end. Average wind speeds are projected to remain about the same from a climatological value of 6.4 m/s, changing by -0.2 to 0.3 % in the near term, by 0.4 to 0.7 % by mid-century, and by -0.7 to 0.3 % by century's end. Extreme winds (above the 99^{th} percentile) are projected to increase from a climatological value of 18.2 m/s, increasing by -0.0 to 0.2 % in the near term, by 1.0 to 1.2 % by mid-century, and by 0.8 to 1.2 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely increases in solar radiation from a climatological value of 188.9 W/m^2, with increases of 0.4 to 0.6 W/m^2 in the near term, of 0.5 to 1.1 W/m^2 by mid-century, and of 1.0 to 2.0 W/m^2 by century's end.

3.12 Middle Whangaehu-Whanganui

The CCAM projections show virtually certain increases (warming) across all temperature related variables for this region. Daily mean air temperatures are projected to increase by about 0.8°C to 0.9°C in the near-term, by 1.3°C to 1.6°C by mid-century, and then by 2.2°C to 3.2°C by century's end. Similar increases are projected for the daily minimum and maximum air temperature, though with maximum temperature increases being up to 0.2°C higher than the daily mean changes. Virtually certain increases in the temperature on the hottest day of the year of 1.0°C to 1.2°C are projected for the near term (over a climatological value of 26.7°C). By mid-century these hottest day temperature increases are 1.7°C to 1.9°C, and by century's end 2.3°C to 4.0°C. Similarly, temperatures on the coldest days of the year increase from a climatological value of -3.6°C by 0.5°C to 0.6°C in the near term, by 0.9°C to 1.0°C by mid-century, and by 1.5°C to 2.3°C by century's end. Days exceeding temperature thresholds, >25°C (TX25) and >30°C (TX30), increase dramatically by century's end, e.g., TX30 increases from less than 1 day per decade in the 1986-2005 climatology to around 4 days per year by century's end.

For agriculture, the number of growing degree days above a 5°C base (GDD5) is virtually certain to increase from a climatological value of 2424 growing degree days by about 283 to 318 growing degree days in the near term, then further by 476 to 561 additional growing degree days by mid-century, and 783 to 1160 additional growing degree days by century's end. For a 10°C base (GDD10), the number of growing degree days is virtually certain to increase from a climatological value of 956 growing degree days by about 204 to 239 growing degree days in the near term, then further by 350 to 418 additional growing degree days by mid-century, and 588 to 909 additional growing degree days by century's end. Not surprisingly, given the regional warming, the number of frost days is projected to decrease (virtually certain) from around 23 days per year by 7 days per year in the near-term, and by a further 11 to 12 days per year by mid-century, and 16 to 19 days per year by century's end reducing frost days from between 2 and 3 weeks in each year to less than 1 week each year. Drought risk, quantified by potential evapotranspiration deficit (PED), is projected to increase (likely) from a climatological value of 96.2 mm by 26.7 to 29.0 mm in the near term, by 44.4 to 44.7 mm by mid-century, and by 60.5 to 96.1 mm additional PED by century's end.

Regarding building energy requirements, the number of cooling degree days (CDDs) is projected to increase (virtually certain) from a climatological value of 124 CDDs by 51 to 64 CDDs in the near term, by 94 to 119 additional CDDs by mid-century, and then further by 164 to 291 additional CDDs by century's end. With the warming noted above, the number of heating degree days (HDDs) is projected to decrease (virtually certain) from a climatological value of 2469 HDDs by 245 to 265 HDDs in the near term, by 397 to 460 HDDs by mid-century, and by 639 to 891 HDDs by century's end.

Projected changes in rainfall are small and uncertain: -0.6 to -0.2 % changes in the near term from a climatological value of 1146.8 mm, by -1.3 % by mid-century, and by -6.6 to -2.4 % by century's end. The multi-model mean projects a change in the number of dry days by century's end of 3.7 to 10.3 days per year. Similarly, the number of wet days in each year shows a multi-model mean projected change of -10.3 to -3.7 days per year by century's end. Projections of increases in heavy rainfall (above the 99^{th} percentile; R99pVAL) are more certain (likely), increasing from a climatological value of 28.8 mm by 3.0 to 4.7 % in the near term, by 4.7 to 6.7 % by mid-century, and by 8.0 to 10.2 % by century's end. Similarly, the 99^{th} percentile precipitation only on wet days (>1 mm) shows increases about 1.5 times that of R99pVAL from a climatological value of 38.2 mm.

The number of windy days (>10 m/s) is projected to decrease from a climatological value of 44.8 days per year, decreasing by 0.7 to 1.9 days per year in the near term, by 1.3 to 1.8 days per year by mid-century, and by 2.7 to 5.4 days per year by century's end. Average wind speeds are projected to decrease from a climatological value of 4.1 m/s, decreasing by 1.1 to 1.6 % in the near term, by 1.1 to 1.4 % by mid-century, and by 1.9 to 3.9 % by century's end. Extreme winds (above the 99^{th} percentile) are also projected to decrease from a climatological value of 13.7 m/s, decreasing by -0.5 to 0.8 % in the near term, by 0.0 to 0.7 % by mid-century, and by 0.4 to 0.7 % by century's end. Projected changes in humidity are statistically insignificant. The models project likely

increases in solar radiation from a climatological value of 175.0 W/m^2, with increases of 0.9 to 2.4 W/m^2 in the near term, of 2.0 to 3.1 W/m^2 by mid-century, and of 2.9 to 5.7 W/m^2 by century's end.

A Glossary

Word / acronym / abbreviation / te reo Māori	Full description/translation
CCAM	Conformal Cubic Atmospheric Model
CD18	Cooling degree days (base 18°C)
CDDs	Cooling degree days
CMIP6	The 6^{th} Coupled Model Intercomparison Project of the IPCC
DJF	December, January and February
DTR	Daily temperature range
ECS	Equilibrium climate sensitivity; the temperature reached in a climate model after doubling the CO_2 concentration and allowing the model to reach its equilibrium state
ESNZ	Earth Sciences New Zealand
GDD5	Growing degree days above a 5°C threshold
GDD10	Growing degree days above a 10°C threshold
GHG	Greenhouse gas
HD18	Heating degree days (base 18°C)
HDDs	Heating degree days
IPCC	Intergovernmental Panel on Climate Change
JJA	June, July and August
MAM	March, April and May
PED	Potential evapotranspiration deficit
SON	September, October and November
SSP	Shared Socioeconomic Pathway
T_{mean}	The daily mean temperature
TN	Daily minimum temperature
TNn	The temperature on the coldest day of each year
TX	The daily maximum temperature
TXx	The temperature on the hottest day of each year
TX25	The number of days in each year when the daily maximum surface temperature exceeds 25°C
TX30	The number of days in each year when the daily maximum surface temperature exceeds 30°C

Table 1: Acronyms and their expansions used in this report.