

Climate Analysis of Growing degree days (base 10°C)

Horizons Region, New Zealand

Climate Change Projections from CCAM-Downscaled CMIP6 Simulations

Prepared by

Bodeker Scientific

www.bodekerscientific.com

For

Horizons Regional Council

Report:	Climate Impacts Assessment
Variable:	Growing degree days (base 10°C) (GDD10)
CCAM variable tag:	GDD10
Baseline:	1986–2005
Scenarios:	SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5

August 4, 2026



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1 Executive Summary

Growing degree days (base 10°C; GDD10) are a critical indicator for understanding heat accumulation relevant to agriculture, horticulture, forestry, and ecosystems. GDD10 quantifies cumulative thermal energy above a baseline temperature (10°C), acting as an integrative measure of season length and intensity for plant growth, phenology, and pest development. Across the Horizons region, this synthesis of 12 detailed sub-reports, each derived from six CMIP6-based CCAM model simulations, reveals a consistent, robust, and spatially extensive signal of increasing GDD10 under all future greenhouse gas (GHG) emissions scenarios. The magnitude, rate, and spatial extent of these increases are closely tied to the emissions pathway followed, but the direction of change—region-wide increases in GDD10—is extremely likely in every scenario considered.

Historical period analysis (1986–2005) reveals extremely high model agreement regarding spatial gradients in GDD10, with warmer, lowland, and coastal areas (particularly Whanganui-Manawātū Lakes, Coastal Whanganui, Puketoi ki Tai) consistently recording the highest values, and cooler, higher-altitude areas (Volcanic Plateau, Upper Rangitīkei) registering the lowest. This spatial pattern persists in all future periods, but is amplified by projected warming.

By the near future (2021–2040), GDD10 is projected to increase by 130–240 GDD regionally, depending on emissions scenario, with virtually all sub-regions and models indicating positive and substantial change. By mid-century (2041–2060), this increase grows to 270–510 GDD, and by century's end (2080–2099), extreme emissions pathways result in projected increases of up to 1,150 GDD or more. 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, reflected in spatial R^2 typically exceeding 0.95. Although some uncertainty remains in the absolute magnitude, especially at decadal time scales and higher altitudes, the qualitative regional signal is robust. Maximum and minimum model projections provide reliable envelopes for upper and lower ends of likely outcomes (comparable to P5 and P95 percentiles), supporting the interpretation that the risk of GDD10 declining anywhere is extremely unlikely.

In summary, 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.

2 Introduction

Growing degree days (base 10°C; GDD10) serve as a fundamental agrometeorological measure that integrates daily temperature to assess cumulative thermal energy available for plant growth, crop development, pest emergence, and ecosystem productivity. For the rural, agricultural, and forested landscapes of the Horizons region, changes in GDD10 have far-reaching implications for sowing and harvest timing, potential yields, crop and variety selection, weed and pest risks, and the distribution of both native and exotic species.

This synthesis draws on 12 detailed sub-reports produced for the Horizons region, each analysing the behaviour of GDD10 over a baseline period (1986–2005) and projecting changes for three future intervals (2021–2040, 2041–2060, 2080–2099) under four global emissions trajectories (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5). Each sub-report incorporates simulations from six state-of-the-art global climate models, dynamically down-scaled by the CCAM regional model, and can be made available on request to Bodeker Scientific.

The synthesis pursues six interconnected objectives:

1. Describe spatial distributions of GDD10 across the Horizons region during the historical baseline period,



2. Examine projected changes in GDD10 under each emissions scenario for different future periods,
3. Analyse temporal evolution and underlying drivers of these changes,
4. Evaluate the degree of consistency and spread among climate models,
5. Identify geographic hotspots and gradients of greatest change or vulnerability, and
6. Characterise the suite of uncertainties associated with GDD10 projections.

The broad increase in GDD10 anticipated for the region is expected to lengthen growing seasons, provide more frequent conditions suitable for temperature-sensitive crops (such as grapes, certain vegetables, or maize), alter competitive balances between crops and weeds, shift pest/disease pressure, and potentially enhance the risk of heat/drought-induced stress on both cultivated and natural landscapes. However, the benefits for productivity are likely to be offset in part by increased evapotranspiration demand, accelerated pest cycles, or mismatches with rainfall, requiring adaptation strategies that may include earlier planting and harvest dates, crop diversification, improved irrigation management, and selection of varieties suited to hotter conditions.

The synthesis also highlights the value of using a climate model ensemble to delineate where confidence is highest—especially regarding the spatial pattern and direction of change—and where uncertainties about magnitude or timing persist. Overall, the report provides a robust foundation for land managers, policy-makers, and communities preparing for climate-driven changes in thermal resources and adapting their practices to make the most of the region's evolving agroclimatic environment.

3 Understanding Growing Degree Days (base 10°C)

Growing degree days (base 10°C; GDD10) aggregate the cumulative exposure of plants or biological systems to temperatures exceeding a growth threshold of 10°C. For each day, the GDD is calculated as the average of the day's maximum and minimum air temperature minus the base value (10°C), provided that this result is positive—otherwise it is zero. Mathematically, for any given day:

$$\text{GDD} = \max\left[\left(\frac{T_{\text{max}} + T_{\text{min}}}{2}\right) - 10^{\circ}\text{C}, 0\right]$$

Where T_{max} and T_{min} are the day's maximum and minimum air temperatures. The daily GDD values are then summed across a defined growing season or calendar year, yielding GDD10, which represents the total thermal time available for plant and pest development. In New Zealand, a base threshold of 10°C is widely used for many agricultural and horticultural applications, though specific base values may be more appropriate for certain species or contexts.

GDD10 is driven primarily by daily mean temperatures and, by extension, by seasonal and annual averages. Changes in GDD10 over time or between regions reflect underlying variations in temperature, which may themselves be modulated by altitude, latitude, proximity to the coast, atmospheric circulation, and local land use. Increased atmospheric GHG concentrations—driving an enhanced greenhouse effect—lead to regional warming, which in turn raises the sum of days where temperatures exceed critical growth thresholds, directly increasing GDD10 values. Shorter- or longer-term fluctuations due to natural climate variability (such as El Niño–Southern Oscillation, or ENSO), decadal oscillations, or volcanic activity can also modulate GDD10 on top of the long-term trend. The metric provides an accessible, intuitive summary for assessing the impact of climate warming on season length, heat accumulation, crop suitability, and biosecurity risks, under both current and projected future climates.

4 Climate Modelling Framework

The projections synthesised in this report were generated using the Conformal Cubic Atmospheric Model (CCAM) by Earth Sciences New Zealand; ESNZ. We acknowledge ESNZ and thank them for making these simu-



lations freely and easily available. CCAM is a regional climate model that dynamically downscales outputs from global climate models to produce higher-resolution climate projections over 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.

Six CMIP6 global climate models were used to drive the CCAM simulations:

1. **ACCESS-CM2** is the second-generation coupled climate model developed by the Australian research community through the Australian Community Climate and Earth System Simulator (ACCESS) project. It combines atmospheric, oceanic, sea-ice, and land-surface components and was developed jointly by the Australian Bureau of Meteorology and CSIRO. The model is widely used for climate projections in the Australia/New Zealand region, including studies of temperature, precipitation, and extreme events.
2. **AWI-CM-1-1-MR** is a coupled Earth system model developed by the Alfred Wegener Institute in Germany. One of its key strengths is in representing ocean and sea-ice processes. Its ocean component uses an unstructured mesh, allowing much finer spatial resolution in regions of interest such as the polar regions while retaining manageable computational costs elsewhere. The model is frequently used in studies of polar climate change and large-scale ocean circulation.
3. **CNRM-CM6-1** is developed by the Centre National de Recherches Météorologiques and CERFACS in France. It includes interactive representations of the atmosphere, ocean, land surface, and sea ice, together with substantial improvements over earlier versions in cloud physics and surface processes. The model is widely used in both European and international climate assessments.
4. **EC-Earth3** is a European climate model developed by a consortium of research institutions from several countries, building on operational weather-forecasting systems from the European Centre for Medium-Range Weather Forecasts (ECMWF). It incorporates sophisticated atmosphere, ocean, land, and sea-ice components and is designed to support a broad range of climate applications, from seasonal forecasting to long-term climate projections. It performs particularly well in reproducing large-scale patterns of historical climate.
5. **GFDL-ESM4** is an Earth system model developed by the Geophysical Fluid Dynamics Laboratory (GFDL), part of the US National Oceanic and Atmospheric Administration (NOAA). In addition to the physical climate system, it includes detailed representations of biogeochemical cycles, allowing interactions between climate, ecosystems, and atmospheric composition to be simulated. The model is widely used for studies of carbon cycling, ocean processes, and future climate change.
6. **NorESM2-MM** is the medium-resolution version of the second-generation Norwegian Earth System Model, developed by a consortium led by the Norwegian Climate Centre. It is based partly on components from the Community Earth System Model but incorporates substantial Norwegian developments, particularly in aerosol processes and ocean dynamics. The model is commonly used in research on high-latitude climate, atmospheric circulation, and climate feedbacks.

These six models cover a range of equilibrium climate sensitivities (ECSs; see Figure 1) and allow some sense of uncertainty associated with model structure and climate sensitivity to be quantified.

Four Shared Socioeconomic Pathway (SSP) emissions scenarios were considered:

1. **SSP1-2.6:** A low-emissions pathway consistent with strong global mitigation efforts and relatively limited future warming.
2. **SSP2-4.5:** An intermediate pathway representing moderate emissions reductions and moderate warming.
3. **SSP3-7.0:** A medium-to-high emissions pathway associated with substantial future warming.

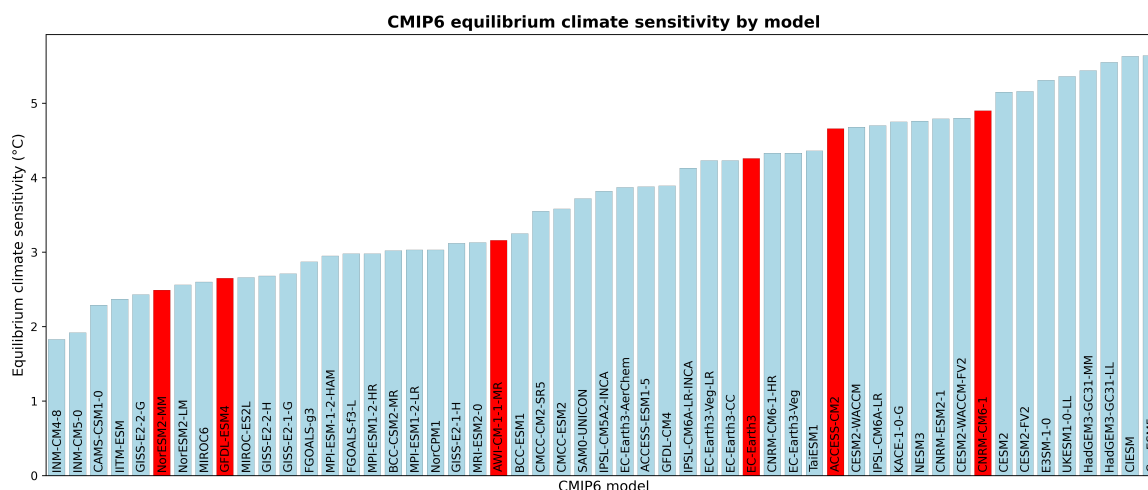


Figure 1: The location of the six guiding CMIP6 models across the full range of equilibrium climate sensitivities (ECSs) of all 53 CMIP6 models. The original of this figure can be downloaded [here](#).

4. **SSP5-8.5:** A high-emissions pathway characterised by continued growth in GHG emissions and large increases in global temperature.

Three future periods were examined:

1. 2021–2040 (near future)
2. 2041–2060 (mid-century)
3. 2080–2099 (late century)

All projections were evaluated relative to a baseline period of 1986–2005.

A key strength of the modelling framework is the use of an ensemble of climate models rather than reliance on a single simulation. 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 “overview” report to this GDD10-specific report. Uncertainty probability density functions (PDFs) generated using this method appear in many of the plots shown herein.

5 Growing Degree Days (base 10°C) Climatology: 1986 to 2005

The CCAM simulated growing degree days (base 10°C) fields, averaged over the period 1986–2005, are shown in Figure 2. This variable is not seasonally disaggregated and so the fields shown in Figure 2 are representative of the whole year. Because the differences between these fields are not readily apparent, differences between each field and the multi-model mean are shown in Figure 3.

For the 1986–2005 baseline, the Horizons region exhibits a pronounced and physically plausible spatial gradient in GDD10, as simulated by the six CCAM-downscaled global climate models. Each model reconstructs a pattern of higher GDD10 in the southwest, lowland, and coastal sub-regions—namely Whanganui-Manawātū Lakes, Coastal Whanganui, and Puketoi ki Tai—with mean values over 1,200–1,350 GDD and local maxima approaching 1,500 GDD. In contrast, the central-eastern highlands (Upper Rangitikei, Volcanic Plateau) exhibit minima as low as 60 GDD, and means under 550 GDD, reflecting the moderating influence of elevation and greater distance from the coast.

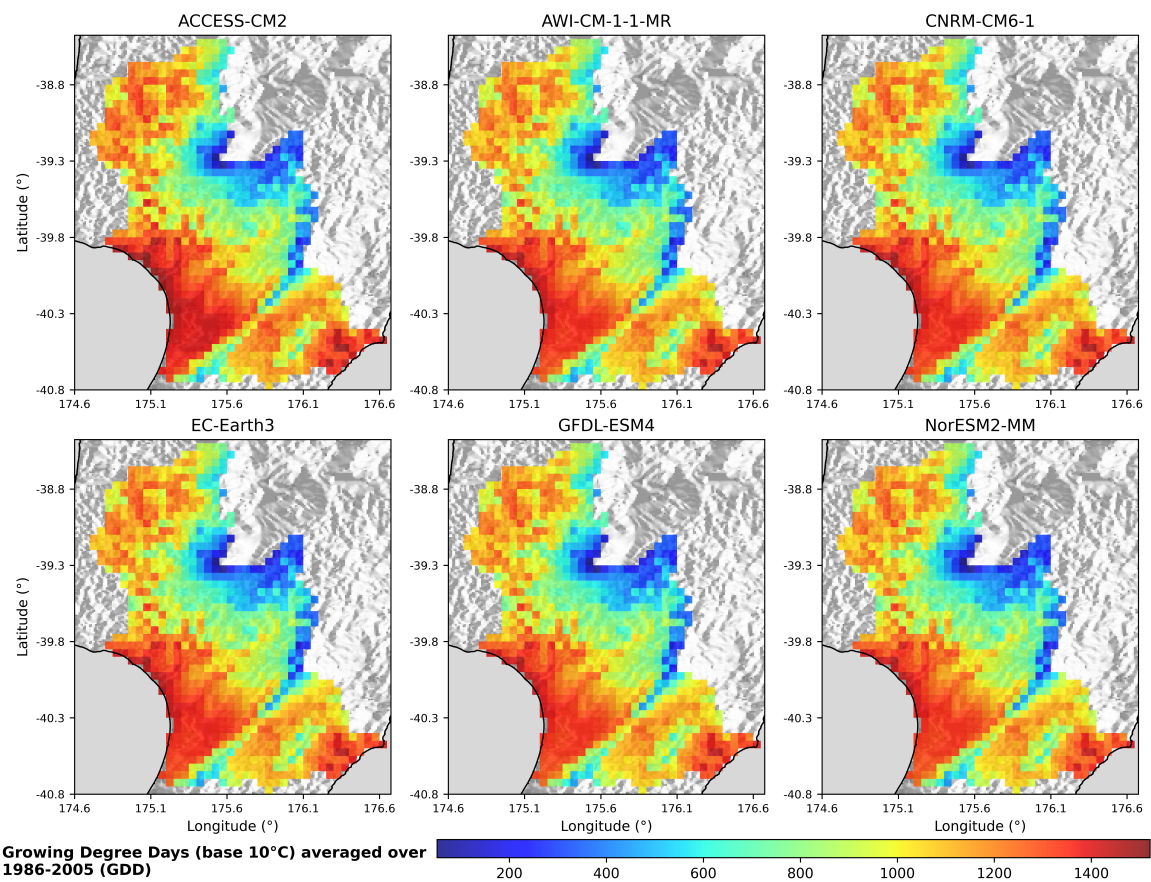


Figure 2: Growing degree days (base 10°C) fields as simulated by the CCAM model and averaged over the period 1986 to 2005. The original of this figure is available [here](#).

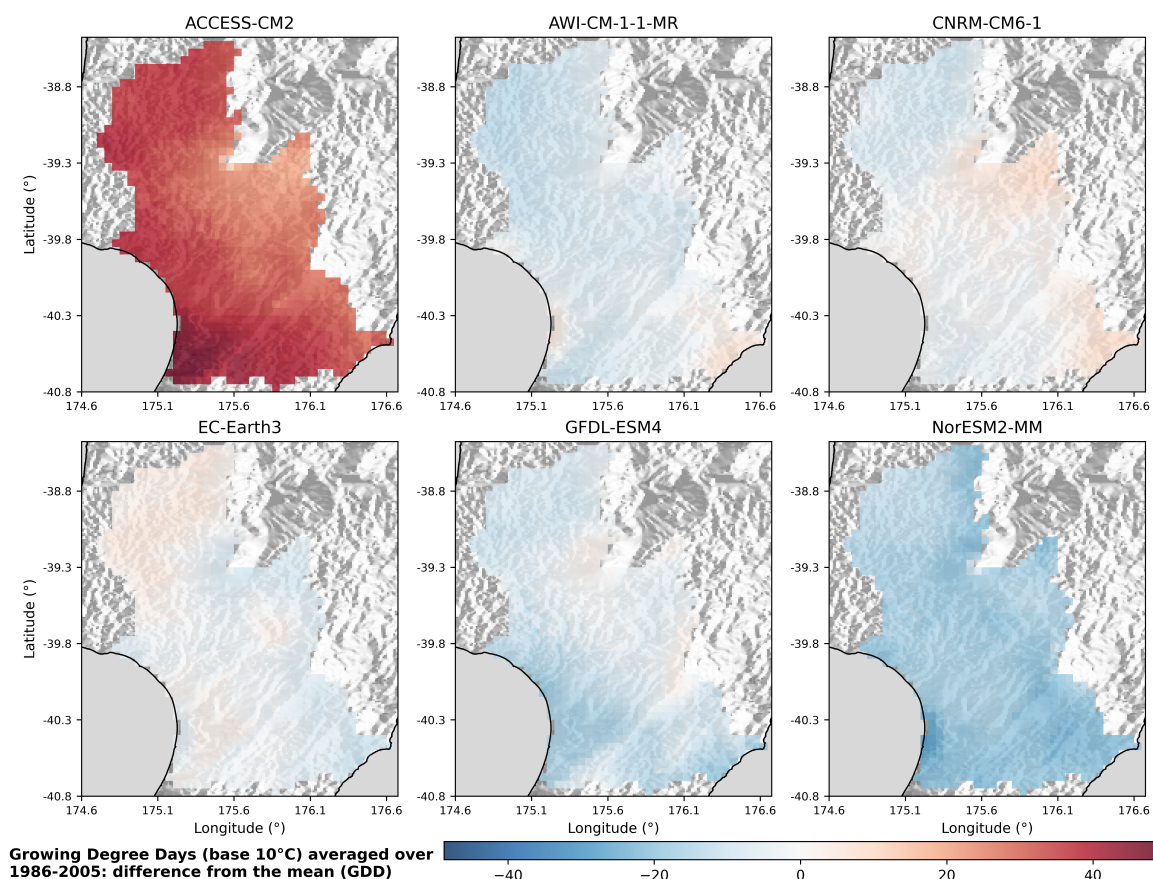


Figure 3: Differences from the multi-model mean. The original of this figure is available [here](#).

The spatial agreement among the six models is extremely high, with spatial correlations (R^2) above 0.999, providing overwhelming confidence in the general pattern and magnitude of GDD10 across the region. The absolute mean across models sits near 970 GDD, while the spread among model means (standard deviation ~ 16 GDD) is modest, and dwarfed by the physical gradient within the region itself (grid point standard deviation ~ 300 GDD). This shows that model structure or configuration exerts little influence on the regional signal for the baseline period: the observed differences with the multi-model mean rarely exceed ± 40 GDD, aside from a systematic positive bias in one model (ACCESS-CM2), which nonetheless retains the broad regional pattern. No evidence exists for systematic bias or localised model artefacts in historical GDD10; deviations between models are minor and highly localised rather than regionally clustered.

This consistency suggests that the principal spatial and temporal controls on GDD10—regional temperature gradients, topography, and proximity to the ocean—are well captured in the model ensemble. Observed minor differences are unlikely to impact broad applications, though fine-scale anomalies should be interpreted cautiously. Collectively, the high level of agreement in GDD10 climatology underpins strong confidence in the suitability of the models to contextualise and project future changes, confirming that GDD10 is a robust and meaningful variable for future climate analysis in the Horizons region.

6 Near-Future Projections (2021–2040)

In the near-future period (2021–2040), all scenarios project a regionally coherent and substantial increase in growing degree days (base 10°C, GDD10) across the Horizons region, compared to the 1986–2005 baseline. The signature of climate warming is evident in all model simulations and scenarios, with projected increases in GDD10 ranging from modest in the lower-emissions scenario to moderate or substantial in higher-emissions



pathways. Spatially, the largest increases are generally found in coastal, lowland, and warmer areas, while upland and high-elevation zones experience smaller but consistently positive changes. Inter-model agreement is extremely high, with spatial R^2 values for projected change patterns typically exceeding 0.8, giving high to extremely high confidence in the spatial distribution and direction of change. While model spread does exist—particularly in the magnitude of the signal rather than its sign—it is much smaller than the projected regional enhancement in GDD10, reinforcing a robust signal of increased thermal accumulation for plant and crop development.

Uncertainty assessment, using both the range across models and estimated percentiles (P5, P95), supports the validity of minimum and maximum projections as practical bounds for likely change, with statistical fields and regression analyses confirming this closely. All sub-regions within the Horizons region are projected to record positive increases in GDD10, confirming the universal nature of the trend. The near-future rise in GDD10 is highly relevant for primary industries, agricultural planning, and ecosystem functioning, as it directly supports a longer and warmer growing season. These findings represent a convergence of multiple independent models, emissions trajectories, and regions within Horizons, and indicate that increased thermal accumulation is a near-certain outcome for the next two decades, whatever the emissions pathway followed.

6.1 SSP1-2.6: Extremely likely modest, regionally widespread increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP1-2.6 scenario, as simulated by the six different models, are shown in Figure 4.

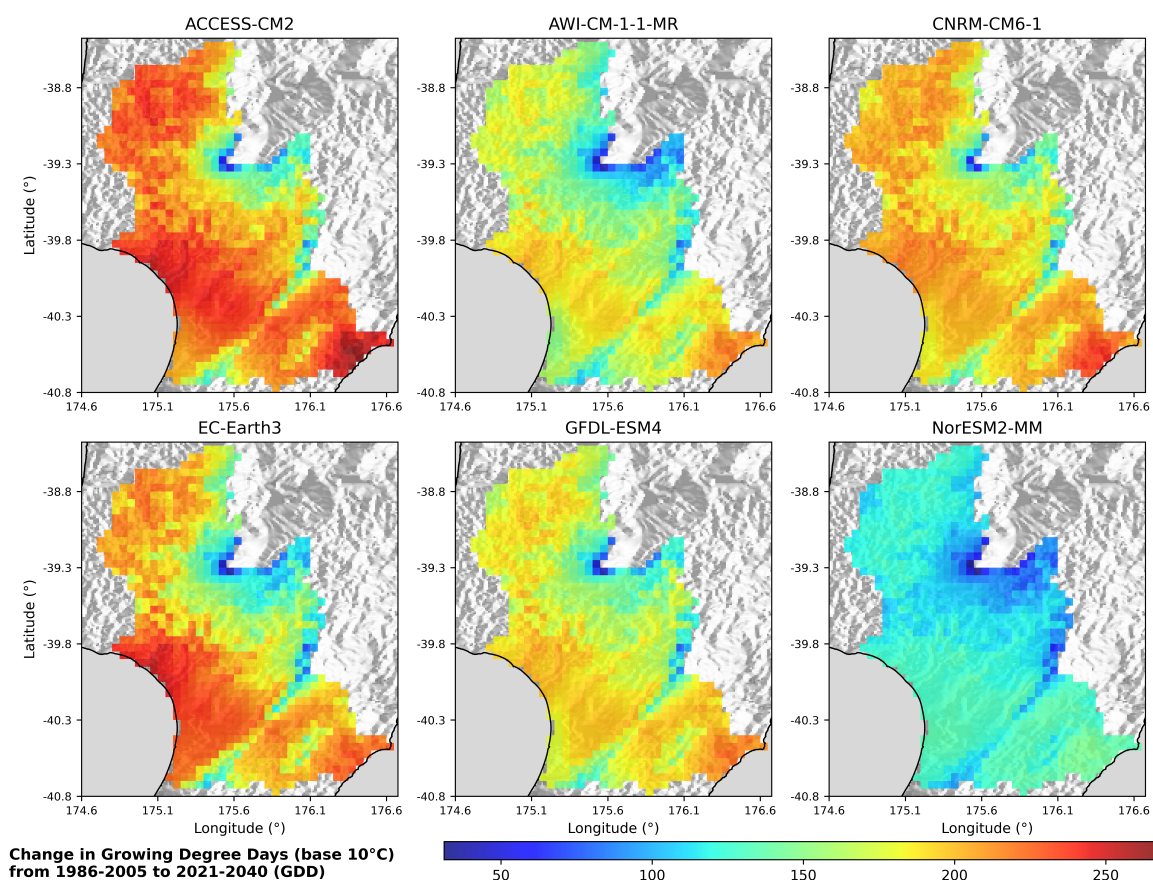


Figure 4: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP1-2.6 scenario. The original of this figure is available [here](#).

Projections under SSP1-2.6 show that growing degree days (base 10°C, GDD10) are very likely to increase across the entire Horizons region in the near future (2021–2040) relative to the late twentieth-century baseline. In-



dividual climate models display strong spatial agreement in both the direction and magnitude of projected GDD10 changes, with mean increases around 170 GDD for the region as a whole. The magnitude of increases is modulated slightly by topography and proximity to the coast, with the largest relative rises in warmer, low-lying and inland areas, while elevated and cooler sub-regions experience more muted, but still positive, changes. The minimum projected increase (mean minimum ~ 43 GDD) underscores the robustness of this warming signal; even the least responsive areas will almost certainly see a notable rise in GDD10.

Inter-model agreement on the spatial distribution of changes is very high, supported by a mean spatial R^2 of approximately 0.88. The spread in model projections (approximately 120 to just over 200 GDD) reflects moderate but non-dominant uncertainty. Statistical fields indicate that the minimum and maximum ensemble projections provide conservative, extremely likely bounds for the likely envelope of change, supported by exceptionally high R^2 values (>0.97) in comparisons with P5 and P95 uncertainty fields. Sub-region analysis shows all areas experience positive changes; the greatest absolute increases are projected for the coastal and inland lowland regions, with elevated zones at the lower end of the increase spectrum.

Overall, these findings justify extremely high confidence that moderate, regionally widespread increases in GDD10 will be a defining feature of the Horizons region's near-future climate under SSP1-2.6.

6.2 SSP2-4.5: Extremely likely moderate, widespread positive increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP2-4.5 scenario, as simulated by the six different models, are shown in Figure 5.

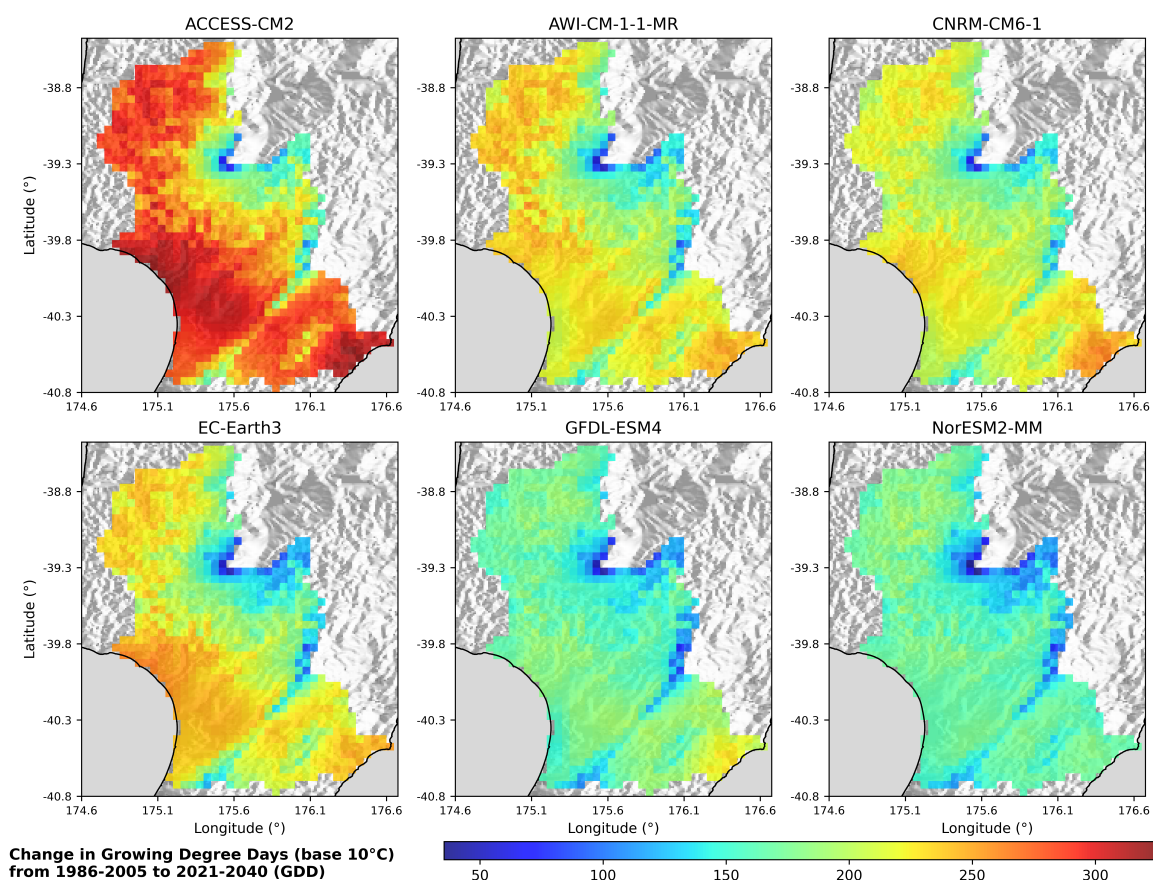


Figure 5: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

The intermediate-emissions scenario SSP2-4.5 projects a very likely region-wide enhancement in growing de-



gree days (GDD10) during 2021–2040 compared to the baseline. The mean projected increase is over 200 GDD for most of the region, with higher elevations showing somewhat smaller—but still positive—rises. All model simulations display spatially consistent increases, with maximum local increases typically in coastal and low-land areas (often exceeding 230 GDD), while the Volcanic Plateau and other uplands see the smallest mean changes (about 158–161 GDD). Inter-model agreement on the spatial character of GDD10 change is extremely high, as indicated by spatial R^2 statistics averaging 0.86. The moderate spread between the ensemble minimum and maximum (mean minima $\sim$ 50 GDD, maxima up to $\sim$ 258 GDD) shows near-universal agreement on the sign of change and strong consensus on the spatial pattern.

Statistical uncertainty assessments confirm the minimum and maximum fields are practical proxies for the 5th and 95th percentiles, with regression R^2 values well above 0.96. Inter-model standard deviations are modest (mean of 32 for the means), indicating that the range of plausible outcomes is significant but tightly clustered around positive, meaningful increases. Sub-region analysis highlights the maintenance of an east-west and elevation-driven gradient, but with all areas experiencing robust increases; those with the highest baseline GDD10—such as Puketoi ki Tai, Coastal Whanganui, and Whanganui-Manawātū Lakes—are also projected to see the greatest absolute rises in thermal accumulation. There are no sub-regions with projected decreases in GDD10.

Taken together, the patterns under SSP2-4.5 establish extremely likely, moderate, spatially extensive increases in GDD10 across all areas in the region for the near term.

6.3 SSP3-7.0: Extremely likely moderate, widespread regional increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP3-7.0 scenario, as simulated by the six different models, are shown in Figure 6.

The high-end socio-economic pathway SSP3-7.0 leads to a very robust projection of increasing growing degree days (GDD10) across the Horizons region by 2021–2040, with all six models indicating a positive and spatially consistent trend. Mean increases of around 230 GDD for the region are evident, with the actual range in model means spanning approximately 115 to 330 GDD. Spatial agreement among models is very strong (spatial R^2 values for projected change generally exceeding 0.85), confirming the likelihood of widespread regional increases. The most pronounced rises occur in the lower-elevation and coastal warming areas, while higher elevations exhibit modest but clearly positive changes. Sub-regions such as Puketoi ki Tai and Coastal Whanganui see the largest absolute changes (exceeding 260 GDD).

Uncertainty metrics and statistical diagnostics show that the maximum ensemble projection closely matches the 95th percentile ($R^2 = 0.99$, slope near 1), providing a virtually certain upper bound. The minimum is a less strict, but still likely, proxy for the 5th percentile ($R^2 \sim 0.95$). Analysis of sub-region uncertainty and spread demonstrates that even the lowest projected GDD increases (at least 100 GDD per annum) represent a substantial extension of the growing season, and there is no region where models disagree about the sign of change. The spatial standard deviation is noticeably low in coastal and lowland sub-regions, indicating very high confidence in those areas.

In sum, projected changes under SSP3-7.0 indicate extremely likely, moderate–substantial, spatially widespread increases, with especially pronounced increases in already warmer, lower-elevation locations.

6.4 SSP5-8.5: Extremely likely moderate, widespread positive changes

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP5-8.5 scenario, as simulated by the six different models, are shown in Figure 7.

Near-future (2021–2040) projections under SSP5-8.5 indicate an extremely likely increase in GDD10 through-

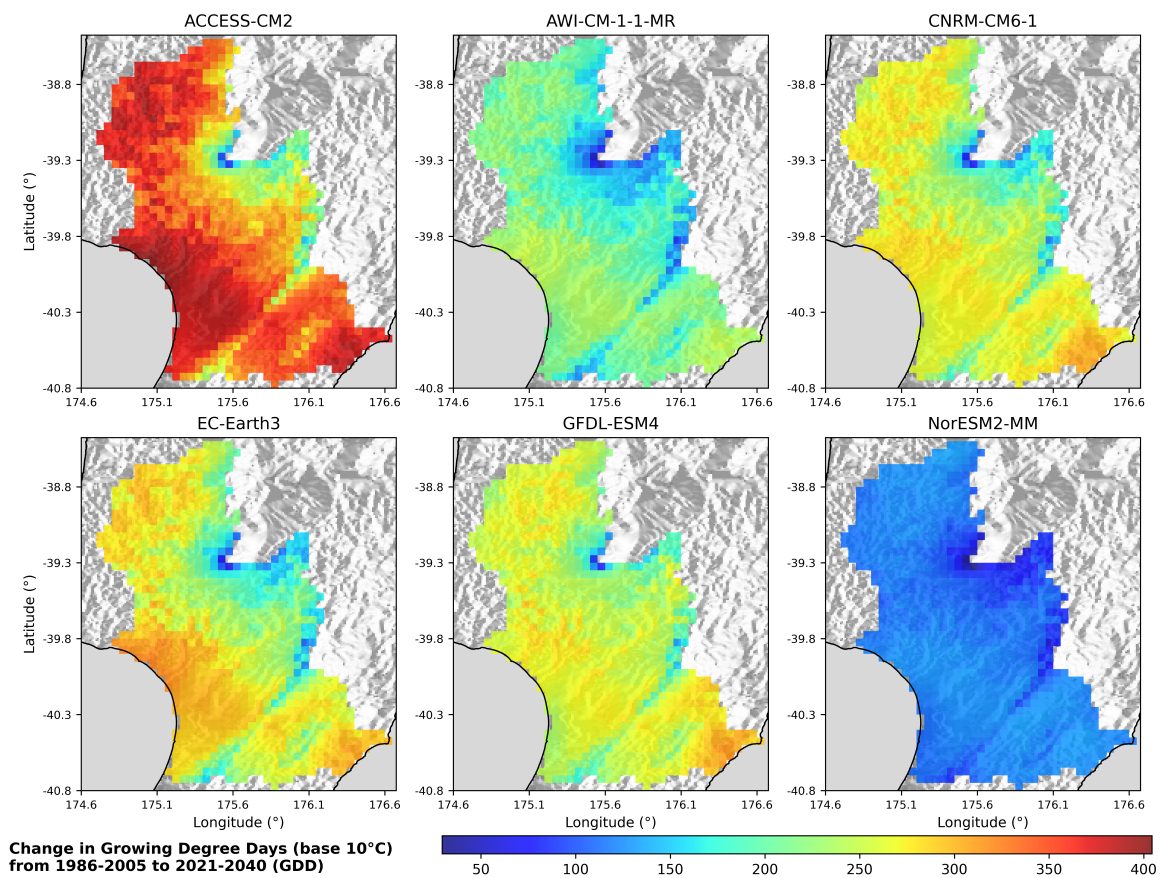


Figure 6: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

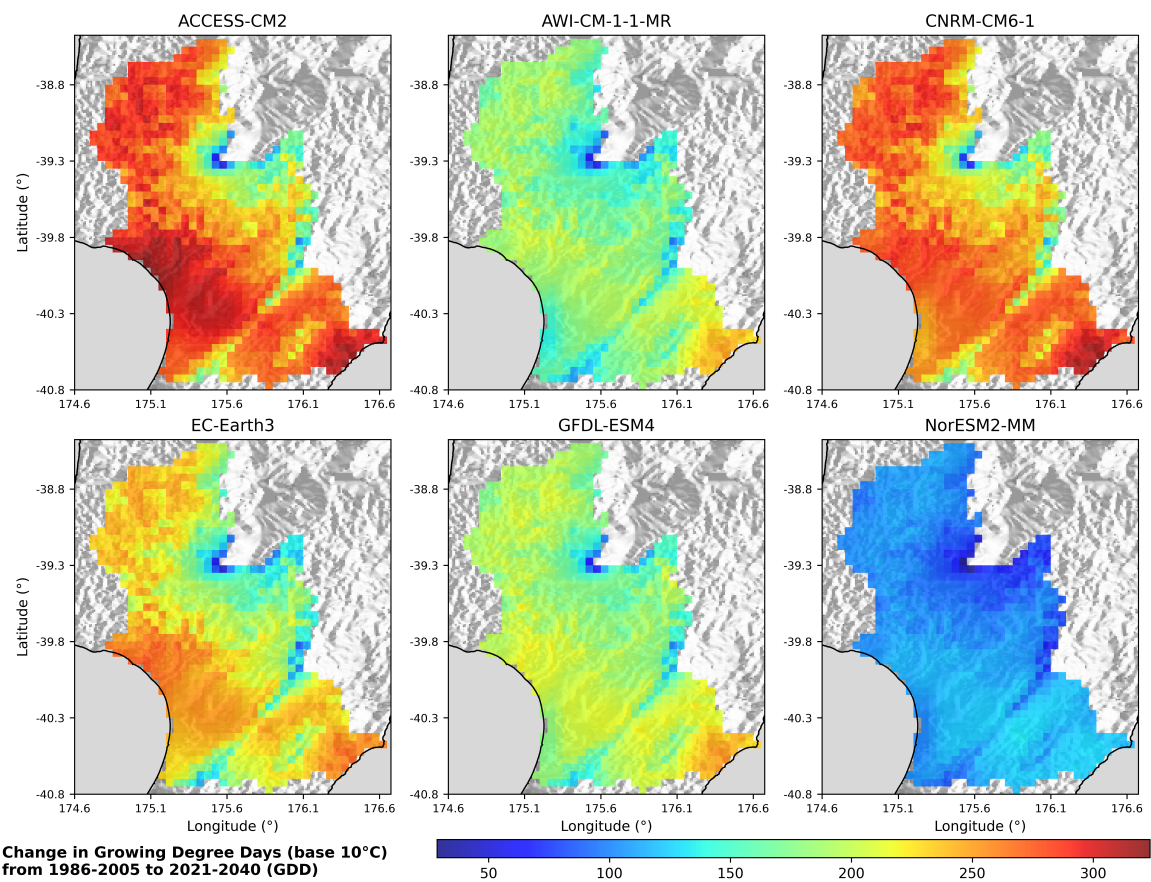


Figure 7: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2021-2040 under the SSP5-8.5 scenario. The original of this figure is available [here](#).



out the Horizons region, exceeding 200 GDD across most of the area. The largest increases are regionally coherent and most pronounced in lowland, coastal, and eastern sub-regions (often in excess of 225 GDD), while the smallest changes are projected for the Volcanic Plateau (around 158 GDD) and similar upland zones. Strong inter-model agreement (spatial R^2 mean approximately 0.79, range 0.64–0.98) supports very high confidence in these increases across models and space.

The ensemble mean, minimum, and maximum statistics show a robust range of plausible futures, but all models and sub-regions depict an increase with the absolute magnitude of change varying from about 100 to 260 GDD for regional means. The magnitude of inter-model disagreement is much smaller than the projected increase, and the spatial pattern of change is persistent across the ensemble. Regression analyses show the minimum and maximum serve as reasonable proxies for the 5th and 95th percentiles, respectively (R^2 values of 0.90 and 0.99), although the lower and upper bounds are slightly conservative.

The regional pattern holds, with coastal and lowland areas consistently exhibiting the highest absolute and relative changes. Sub-regions with high baseline GDD10, such as Puketoi ki Tai and Coastal Whanganui, are projected to experience the strongest increases. Confidence is extremely high that all areas in the Horizons region will see substantial positive GDD10 changes during the coming two decades, regardless of emissions trajectory.

6.5 Comparison Across Scenarios

Across all four emissions scenarios, projections for 2021–2040 display a clear, extremely likely, and spatially extensive increase in growing degree days (GDD10) for the Horizons region relative to the late-20th-century baseline. The signal is robust across models, with the magnitude of increase scaling with scenario stringency, but with all regions and sub-regions projected to experience positive changes. The spatial distribution of change is highly consistent: low-elevation, coastal, and warmer areas regularly show the largest increases, while upland and cooler areas see smaller, but still significant, gains. Statistical analysis confirms that the sign and broad pattern of change are robust to model selection and scenario differences, although the range of plausible outcomes is wider under higher emissions pathways. Overall, greater warming under higher-emissions scenarios results in larger GDD10 increases, though the core regional pattern remains unchanged. The universality of the projected direction of change inspires extremely high confidence and provides a solid foundation for near-term adaptation efforts across the horizon of plausible future climate conditions.

7 Mid-Century Projections (2041–2060)

By the mid-century period (2041–2060), all emissions scenarios continue to project widespread and significant increases in growing degree days (GDD10) throughout the Horizons region relative to the 1986–2005 baseline. The absolute magnitude of change intensifies compared to the near future, with region-wide mean increases in GDD10 often exceeding 270 GDD under lower-emissions scenarios and reaching or surpassing 400 GDD in higher-emissions scenarios. The spatial gradient deepens, with low-elevation, coastal, and eastern sub-regions experiencing the largest absolute increases, closely followed by adjacent lowland areas, while upland and central zones maintain the smallest, but still substantial, increases.

Inter-model agreement remains very strong, evidenced by mean spatial R^2 values typically above 0.90 for the pattern of projected change, and the direction of change (positive increases) is virtually certain for all sub-regions. Ensemble spread in the regional mean and local magnitudes does increase with emissions intensity, but remains much smaller than the projected central estimate, especially for sign and spatial pattern. Statistical fields (minimum, maximum, percentile estimates) confirm that the range of model outputs provides robust uncertainty bounds, with minimum and maximum changes strongly correlating with the P5 and P95 estimated percentiles.



By mid-century, the degree of projected change for GDD10—in some areas approaching over one-third to one-half of historical baseline values—implies potentially transformative shifts in regional agroclimate. The high consistency among models and scenarios strongly supports an expectation that plant growth, crop timing, and pest and disease lifecycles will be increasingly influenced by markedly warmer seasonal conditions through the mid-21st century.

7.1 SSP1-2.6: Extremely likely moderate, regionally widespread increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2041-2060 under the SSP1-2.6 scenario, as simulated by the six different models, are shown in Figure 8.

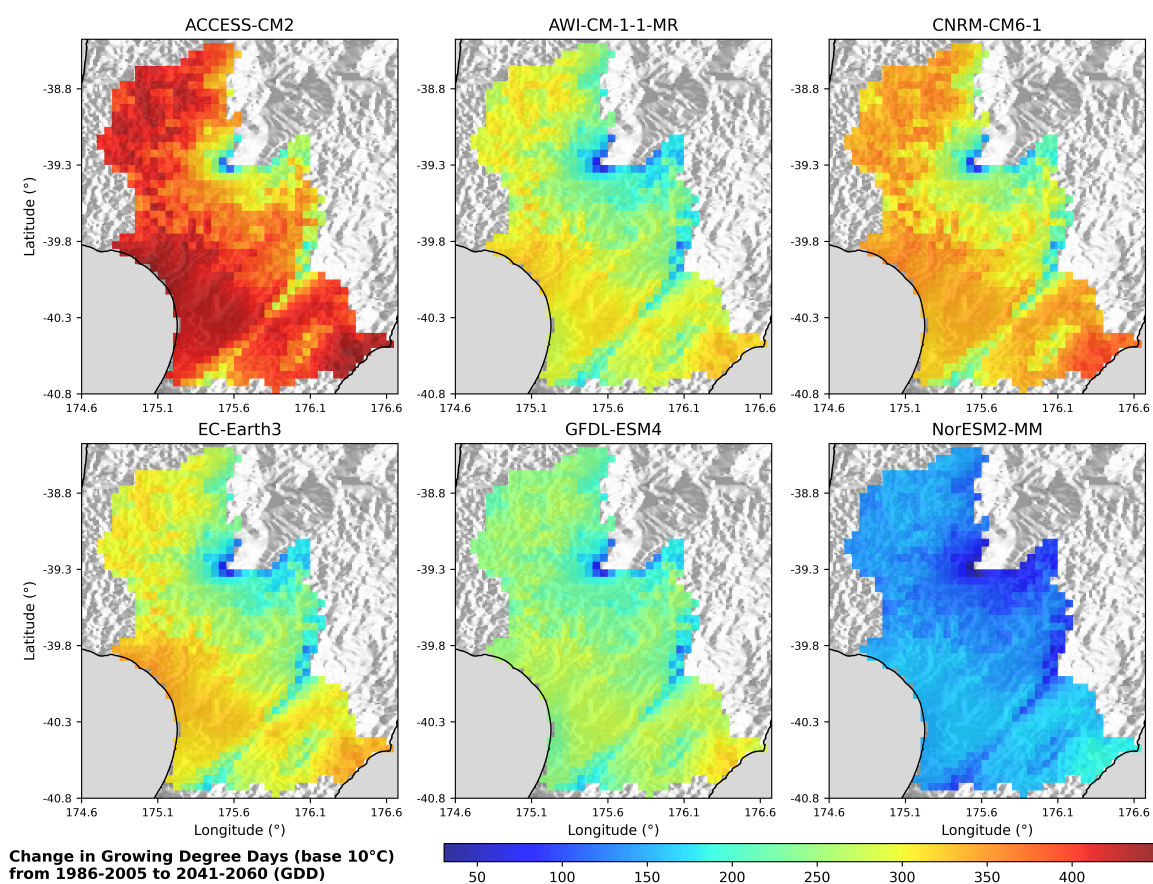


Figure 8: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2041-2060 under the SSP1-2.6 scenario. The original of this figure is available [here](#).

Under SSP1-2.6, typically viewed as a strong mitigation pathway, mid-century projections (2041–2060) indicate a very likely and spatially robust increase in annual GDD10 across the Horizons region. All six climate models assessed simulate a marked rise in growing degree days, with regional mean increases generally around 270 GDD, and ranges from approximately 140 to 380 GDD depending on location and model. While the spatial structure of change is consistent—largest increases in lower-elevation, coastal, and eastern areas—some localised gradients linked to topography are visible. The relative change is considerable compared to the baseline, and agricultural or ecological thresholds may be crossed in some areas.

Inter-model agreement is exceptionally high for both sign and spatial pattern (mean spatial R^2 near 0.90, minimum about 0.83), conferring extremely high confidence in projected change direction. The standard deviation between model means is modest (typically under 30 GDD per sub-region), reflecting confidence in the central tendency of the projections. Statistical analysis confirms the minimum and maximum fields are reliable proxies for the P5 and P95 percentiles, corroborated by regression slopes near unity and R^2 values above 0.98,



although slightly conservative for lower extremes.

Sub-regional analyses underscore consistent increases everywhere, with larger gains in warmer sub-regions (over 300 GDD in Whanganui-Manawātū Lakes and Coastal Whanganui, more than 315 GDD in Puketoi ki Tai), and more modest but meaningful increases in cooler upland or plateau areas. There are no sub-regions with a projected decrease in GDD10; the warming signal is universal. These results point to extremely likely, moderate-to-significant, spatially extensive GDD10 increases, with exceptionally high model agreement.

7.2 SSP2-4.5: Virtually certain moderate, widespread positive increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2041-2060 under the SSP2-4.5 scenario, as simulated by the six different models, are shown in Figure 9.

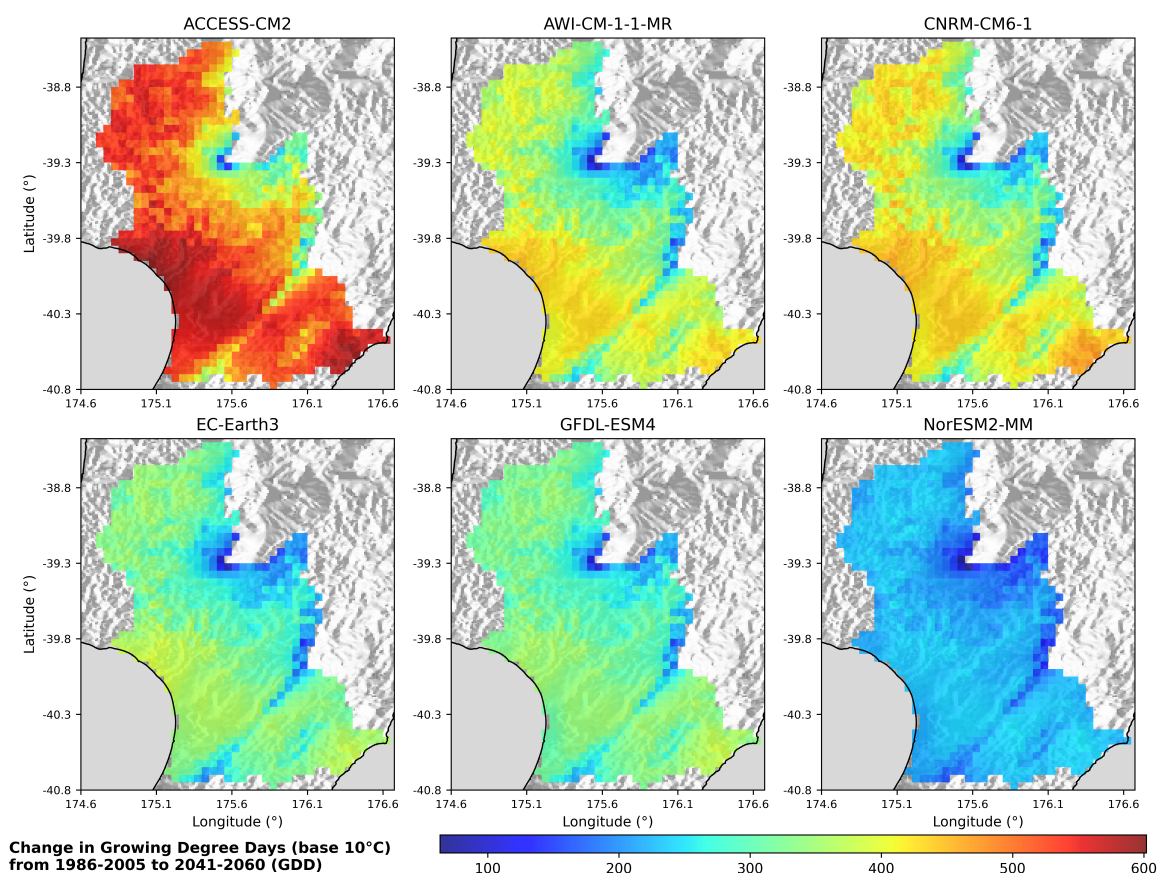


Figure 9: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2041-2060 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

SSP2-4.5, representing an intermediate emissions pathway, is associated with a substantial and spatially uniform increase in GDD10 for the Horizons region by 2041–2060. Projected mean increases are close to 345 GDD across the region, with model ranges spanning approximately 220 to 495 GDD in the ensemble means. No region shows a projected decrease; all sub-regions and grid cells indicate positive rises in thermal accumulation. Inter-model agreement is extremely high—mean spatial R^2 values exceed 0.93—and even the lowest model-specific R^2 remains above 0.82. The largest projected increases are concentrated in coastal and lowland zones that already exhibit the highest baseline GDD10 values, further widening potential suitability for heat-loving crops and extended growing seasons.

Uncertainty analyses affirm that the minimum and maximum ensemble projections are reliable proxies for the lower and upper uncertainty bounds (P5 and P95 percentiles), with R^2 values very close to unity, and systematic deviations between methods are minor for practical use. Mid-century changes reach up to 600 GDD in some



areas, with minimum model increases always above 60 GDD, confirming a region-wide, positive signal. Inter-model variability is present for magnitude, especially within upland zones like the Volcanic Plateau and Upper Rangitikei, but the qualitative consensus on direction is unwavering.

Overall, GDD10 is projected to increase very likely everywhere, especially in lowland and coastal areas (approaching or exceeding 390 GDD in places), with slightly smaller but significant increases in upland and plateau sub-regions. The finding rests on extremely high agreement (virtually certain sign) and substantial projected magnitudes.

7.3 SSP3-7.0: Extremely likely substantial, widespread positive increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2041-2060 under the SSP3-7.0 scenario, as simulated by the six different models, are shown in Figure 10.

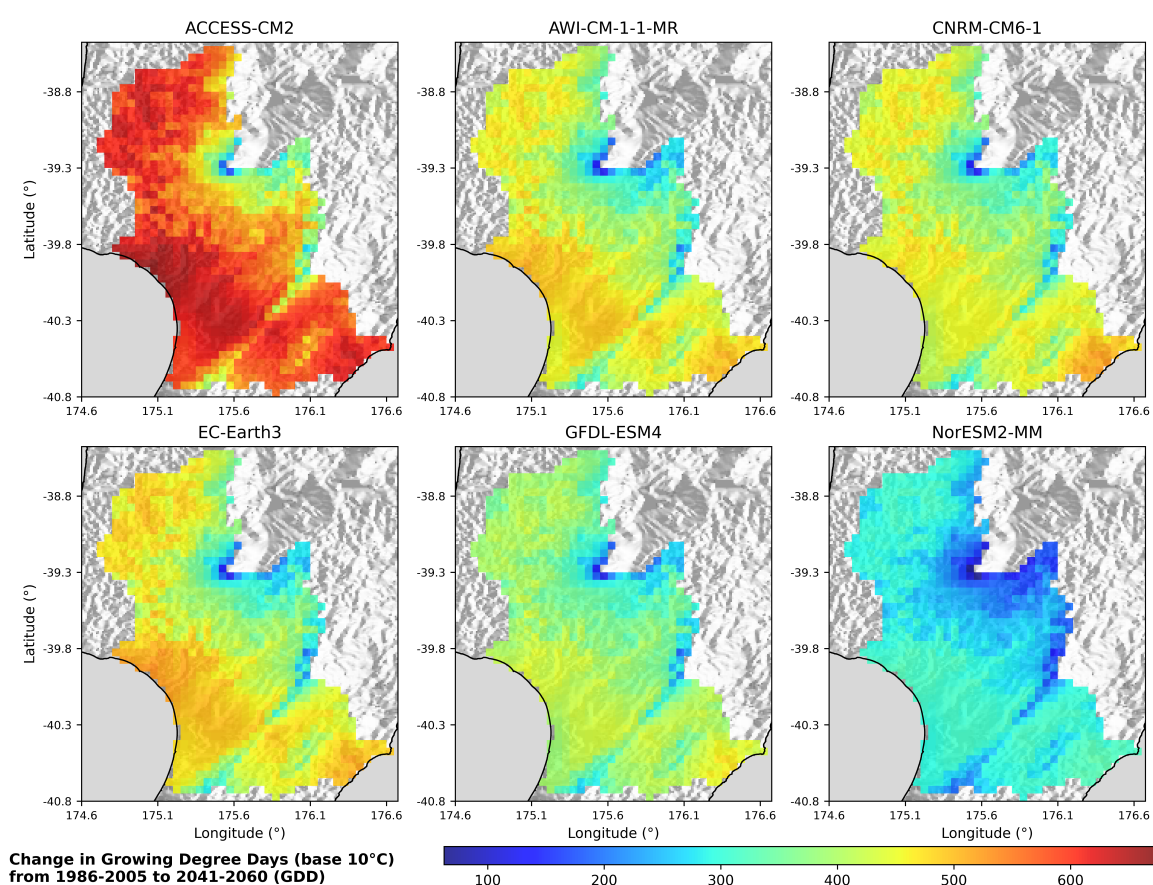


Figure 10: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2041-2060 under the SSP3-7.0 scenario. The original of this figure is available here.

Mid-century projections under SSP3-7.0 indicate extremely likely and spatially extensive increases in GDD10 across Horizons. All models simulate significant gains, with regional mean increases typically exceeding 400 GDD, and individual model ensemble members projecting increases from about 275 to 670 GDD depending on location. The largest absolute changes are projected for coastal, lowland, and eastern sub-regions (often exceeding 460 GDD), while high-elevation zones (Volcanic Plateau, Upper Rangitikei) maintain the lowest—but still strongly positive—increases (just over 320 GDD). Model agreement on the spatial pattern of change is extremely high, with mean spatial R^2 values above 0.95.

Statistical analysis confirms that the minimum and maximum ensemble values coincide closely with the P5 and P95 uncertainty bounds, both showing regression slopes near unity and R^2 values above 0.99. The standard



deviation of the change in means is moderate (~ 60 – 82 GDD), reflecting some spread in magnitude, but not in the spatial pattern or sign of projected change. Sub-regionally, the greatest increases persist in already warm regions (Coastal Whanganui, Puketoi ki Tai, and Whanganui-Manawatū Lakes), further amplifying spatial gradients in thermal accumulation. Areas of higher baseline GDD10 not only maintain the largest totals but amplify their lead, while upland, cooler areas see narrower, slightly smaller increases, but with robust model consensus.

Together, these results strongly support the conclusion that it is extremely likely that all parts of the Horizons region will see significant and spatially extensive increases in GDD10 by mid-century under high-emissions conditions.

7.4 SSP5-8.5: Extremely likely substantial, widespread positive increases

The projected changes in growing degree days (base 10°C) from 1986–2005 to 2041–2060 under the SSP5-8.5 scenario, as simulated by the six different models, are shown in Figure 11.

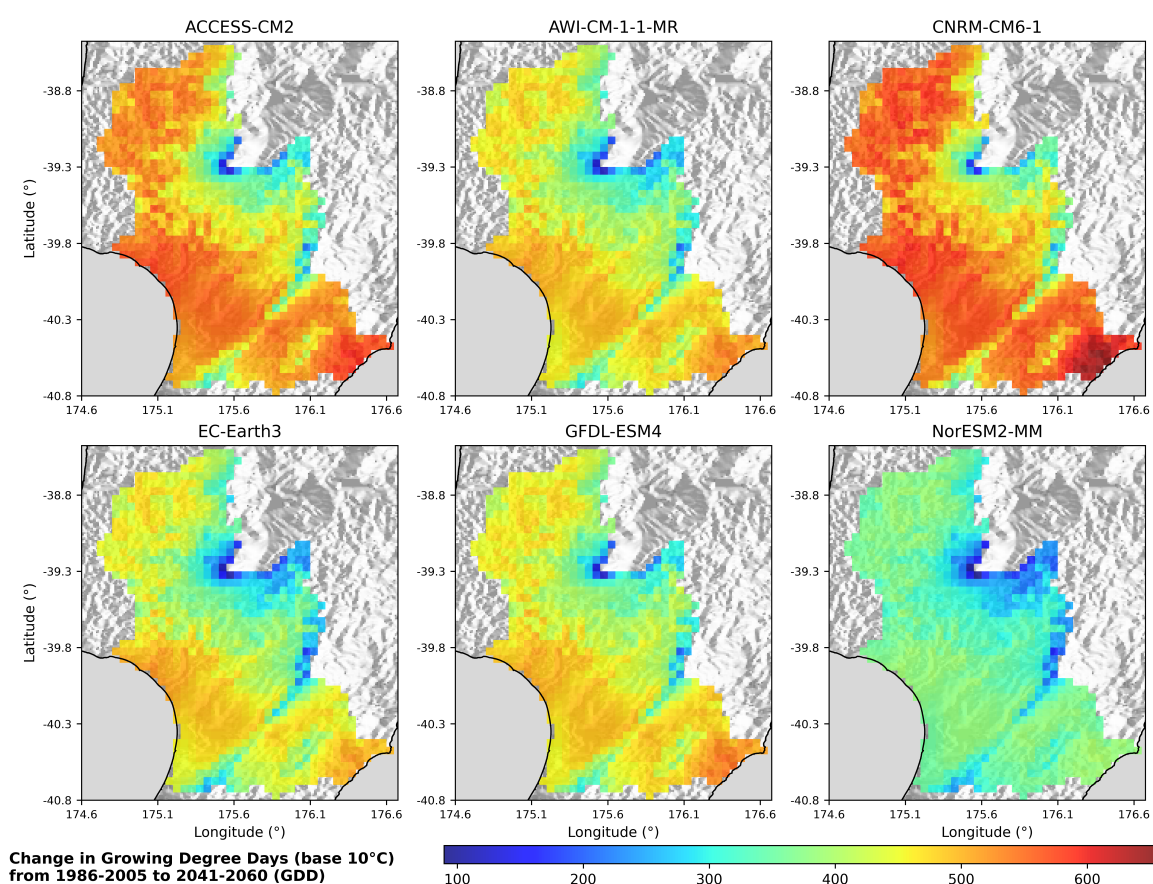


Figure 11: Projected changes in growing degree days (base 10°C) from 1986–2005 to 2041–2060 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

The SSP5-8.5 high-emissions scenario results in a robust, rapid, and spatially uniform increase in GDD10 for the Horizons region by 2041–2060. Projected mean increases in GDD10 are around 435 GDD across the region, with model means per sub-region varying from roughly 340 to 510 GDD. The maximum projected mean increases are usually in Puketoi ki Tai and other lowland or coastal areas (above 500 GDD), while the Volcanic Plateau consistently shows the smallest absolute but still substantial rise (minimum above 270 GDD). The rise in GDD10 is universal across all model ensemble members; there are no projected decreases. Inter-model agreement is extremely high, with spatial R^2 values mostly above 0.94, ensuring robust consensus on both direction and spatial form of the warming.



Uncertainty metrics (minima, maxima, P5, P95) for the projected changes also indicate strong correspondence, with regression R^2 values above 0.98 and slopes near unity. The minimum and maximum can reliably serve as practical proxies for the tails of the model spread. The standard deviation among model means is low to moderate (around 54 GDD), reinforcing that model disagreement plays only a minor role in shaping confidence in the direction and magnitude of change. Sub-region assessments indicate the largest increases in coastal/lowland areas and lower, though robust, gains in upland and inland sub-regions.

In sum, it is extremely likely that GDD10 will increase markedly and consistently throughout the Horizons region under SSP5-8.5 by mid-century, with moderate spatial variation primarily controlled by baseline climate and elevation.

7.5 Comparison Across Scenarios

All four emissions scenarios project a regionally uniform and substantial increase in GDD10 for 2041–2060 compared to the historical baseline, with mean increases scaling directly with emissions intensity. The spatial form of the projected change is preserved across scenarios, and the sign of warming (increased GDD10) is robust everywhere, with virtually no projected decreases in any scenario or model. Differences between scenarios at mid-century are mainly in the magnitude of change, not in its direction or broad spatial pattern, underscoring very high agreement among models. The regional pattern of the greatest increases in coastal and lowland areas, and more restrained gains in upland or cooler zones, is evident throughout. Inter-model spread grows with increasing scenario severity, but not to a degree that undermines confidence in the qualitative conclusions. Overall, GDD10 increases of substantial, widespread, and climatically meaningful magnitude are virtually certain by mid-century for all plausible futures and emissions pathways.

8 Late-Century Projections (2080–2090)

By the late-century period (2080–2099), model projections under all emissions scenarios indicate extremely likely and spatially extensive increases in growing degree days (GDD10) across the Horizons region, relative to the 1986–2005 baseline. The magnitude of projected change becomes more scenario-dependent: while the low-emissions pathway (SSP1-2.6) shows increases of around 260–300 GDD over much of the region, higher-emissions pathways result in dramatic uplifts—often exceeding 600, 900, or even 1,100 GDD in the strongest warming scenario. The spatial pattern remains consistent, with the largest increases in lowland, coastal, and eastern sub-regions, and more modest but still notable gains in higher-elevation and interior areas. These increases represent a profound shift, potentially doubling or more the accumulated thermal resources for plant and crop growth in some locations.

Inter-model agreement remains extremely high concerning both the direction and detailed spatial distribution of change, as reinforced by mean spatial R^2 values routinely above 0.95. The minimum and maximum ensemble projections retain strong correlation with the P5 and P95 uncertainty fields, allowing their continued use as robust proxies for quantifying likely bounds of change. Although inter-model spread increases most under higher-emissions scenarios (standard deviations also rise), all models and statistical percentiles point in the same qualitative direction.

With the increases in GDD10 by late century, significant implications emerge for land-use planning, crop selection, and ecosystem dynamics. These projections indicate an extremely likely, substantive, and geographically broad enhancement in heat accumulation and growing season length throughout Horizons, confirming that climate change will fundamentally alter regional agroclimate by the end of the 21st century.



8.1 SSP1-2.6: Extremely likely moderate, widespread positive increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP1-2.6 scenario, as simulated by the six different models, are shown in Figure 12.

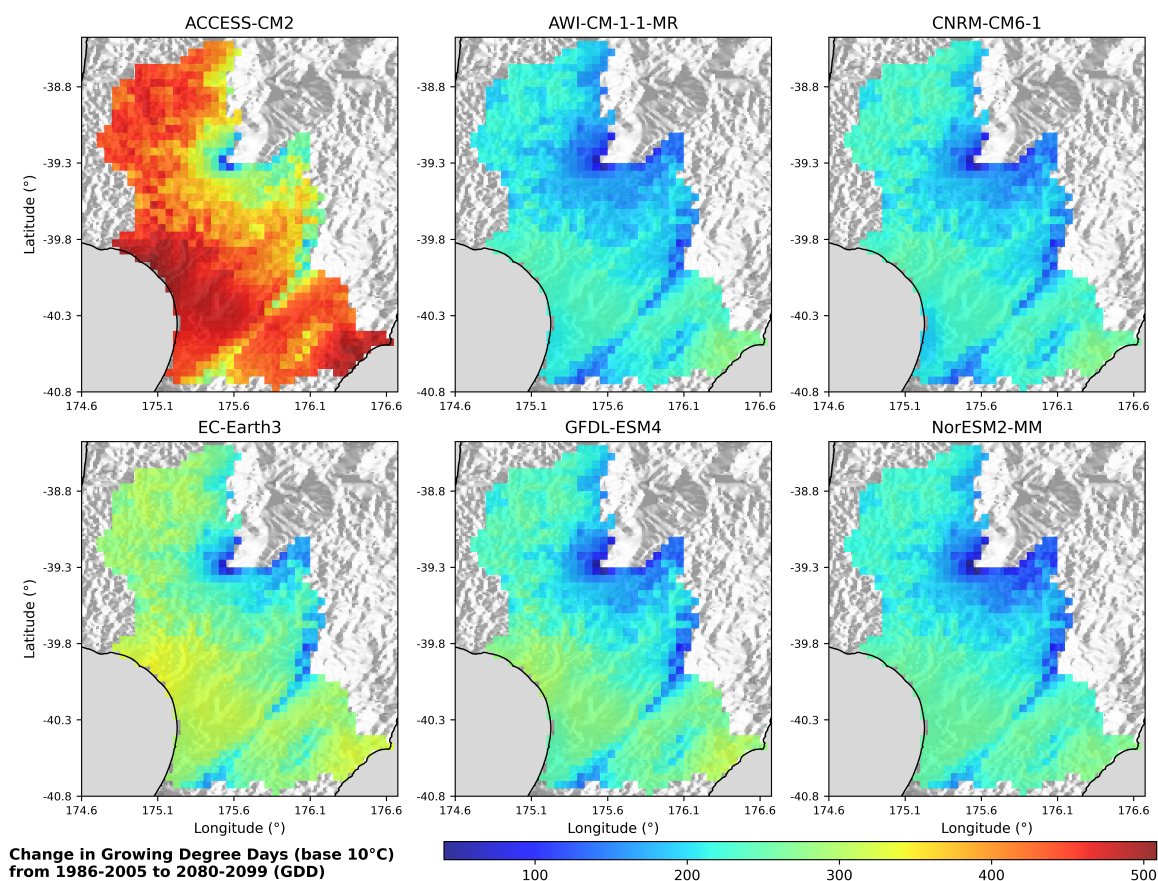


Figure 12: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP1-2.6 scenario. The original of this figure is available [here](#).

Late-century (2080–2099) projections under SSP1-2.6 indicate an extremely likely and spatially persistent increase in GDD10, with mean increases of around 260 GDD across the region, and maxima in sub-regions exceeding 300–400 GDD. All models agree strongly on the direction and general magnitude of warming, though some intensification toward the coast, lower elevations, or inherently warmer areas is present in the spatial pattern. Inter-model spread is moderate (differences of ~200 GDD in mean changes), but signs of change remain consistent everywhere. Spatial R^2 for model agreement persists at high levels (mean ~0.91), ensuring extremely high confidence in the regional and sub-regional response.

Statistical analysis (minimum, maximum, P5, P95 fields) confirms that the lower and upper bounds of projected change are robust, though the lower bound (minimum relative to P5) becomes slightly more conservative. Sub-region analyses highlight no areas where the sign of change is in question and showcase the largest increases in the lowland, coastal, and eastern sub-regions, with uplands and the Volcanic Plateau consistently showing the smallest, but still substantial, rises in GDD10.

The scale of this regional warming is highly significant for primary production and land management: although less dramatic than higher-emissions outcomes, the increase in GDD10 under SSP1-2.6 still marks a substantial extension of the warm-season envelope and growing opportunities. The overall assessment is thus extremely likely, moderate, regionally widespread increases in GDD10 for Horizons by 2100 under strong mitigation.



8.2 SSP2-4.5: Extremely likely substantial, widespread positive increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP2-4.5 scenario, as simulated by the six different models, are shown in Figure 13.

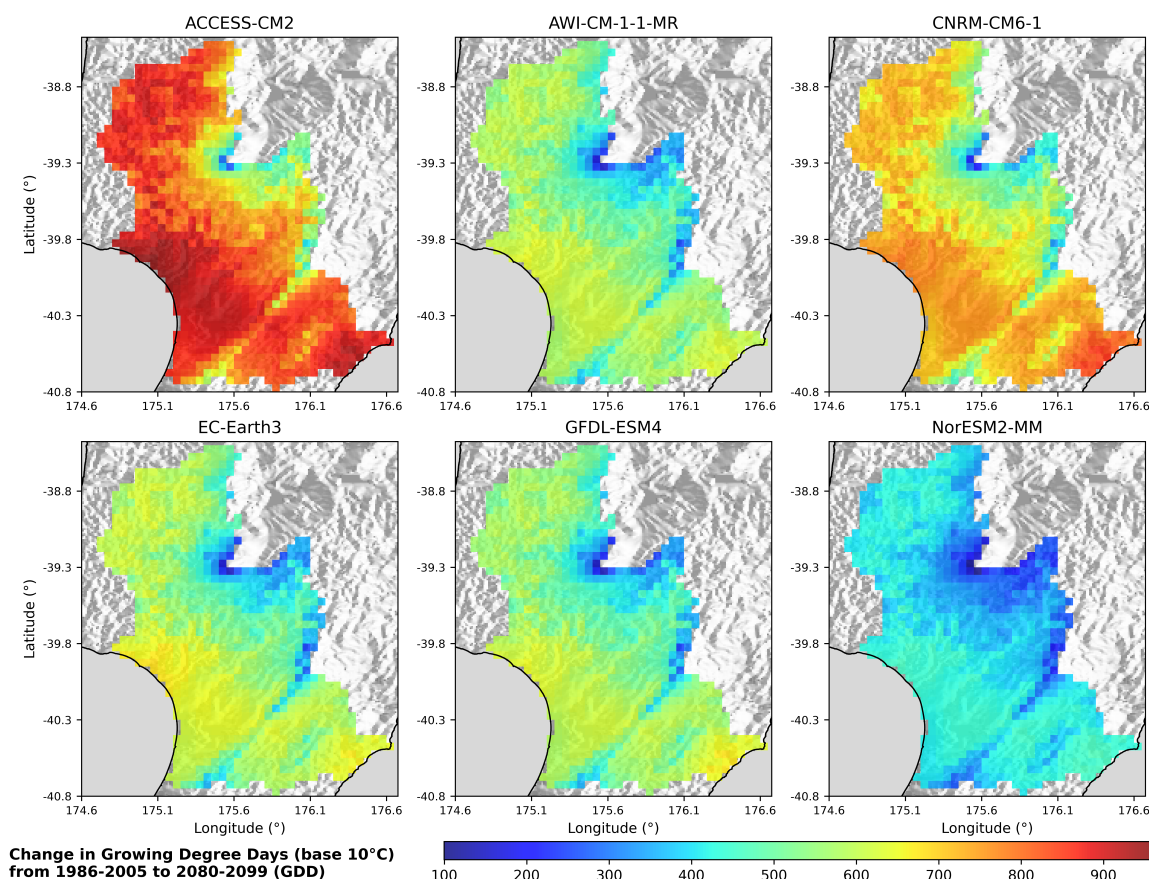


Figure 13: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

Under the mid-range emissions scenario SSP2-4.5, projections for 2080–2099 indicate extremely likely and spatially extensive increases in GDD10 across all sub-regions. Mean projected increases often exceed 500 GDD region-wide, with a typical range of about 400–800 GDD, and the highest changes found in the already warm, lowland and coastal areas (above 660–670 GDD). No model, region, or percentile interval projects a decrease. Model spread increases (standard deviations ~ 90 for mean changes), but agreement remains extremely high, with spatial R^2 values above 0.95. The minimum and maximum ensemble fields track closely with statistical percentiles (P5, P95), supporting their use as reliable uncertainty bounds.

Spatial gradients from west to east and lowland to upland persist, amplifying the differences between already warm and cooler areas. Upland and interior sub-regions (Volcanic Plateau, Upper Rangitikei) receive the lowest, but still substantial, increases (ca. 450 GDD), translating to upward shifts exceeding 80% above baseline level; coastal and lowland areas reach high absolute GDD10 values, signalling a long and very warm growing season ahead.

These results confirm extremely likely, substantial, and regionally widespread increases in GDD10 by late century, with large absolute changes even under intermediate emissions. This has strong implications for land use, crop adaptation, and ecological dynamics, as all sub-regions will see a marked increase in growing season heat.



8.3 SSP3-7.0: Extremely likely very large, regionally extensive increases

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP3-7.0 scenario, as simulated by the six different models, are shown in Figure 14.

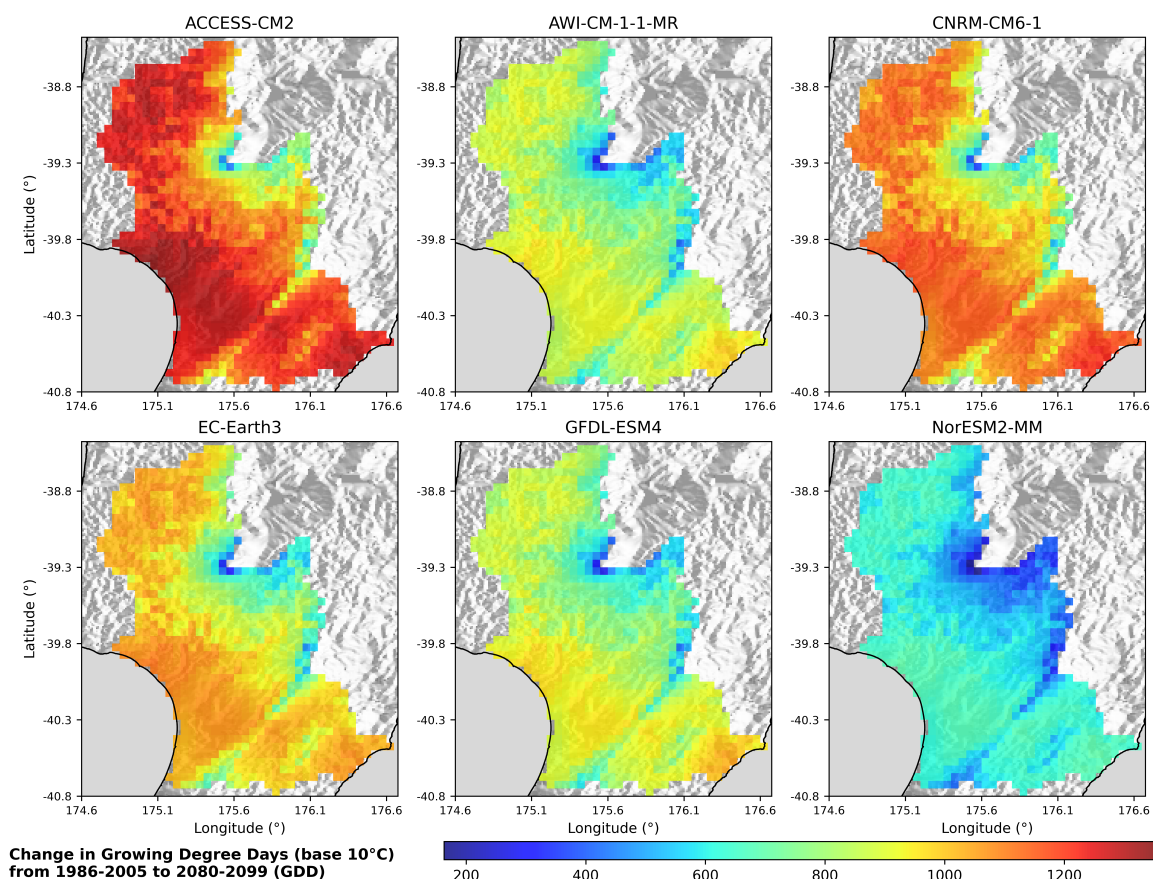


Figure 14: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

Projections for 2080–2099 under SSP3-7.0 show an extremely likely, dramatic increase in GDD10 throughout the Horizons region, with typical mean increases of approximately 900 GDD, and some model projections exceeding 1,000 GDD in the warmest sub-regions. This change is spatially coherent and sustained across all models, with spatial R^2 values near 0.98, and minimal location-to-location disagreement in the direction of change. Standard deviations in model means rise to around 125–180 GDD, indicating growing spread as emissions and associated warming escalate, but the direction and coherence of the response remain robust.

Sub-region assessments show increases of 700–1,000 GDD, with the largest increases concentrated in coastal and lowland areas (over 1,000 GDD), while uplands and interior areas experience significant, albeit slightly lower, uplifts (all well above 700 GDD). The minimum and maximum model projections continue to serve as reliable surrogates for P5 and P95, with regression analysis yielding $R^2 \sim 0.99$. All areas, even those with wider model spreads (cool, topographically complex zones), display the same qualitative outcome: a major increase in heat accumulation and growing season length.

This substantial warming, under a strong forcing scenario, signifies a profound shift in agroclimatic regime by the end of the century, with transformative implications for plant growth, agricultural viability, and biotic responses throughout the Horizons region. The outcome is an extremely likely, very large, and consistently region-wide positive change in GDD10.



8.4 SSP5-8.5: Extremely likely very large, widespread positive changes

The projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP5-8.5 scenario, as simulated by the six different models, are shown in Figure 15.

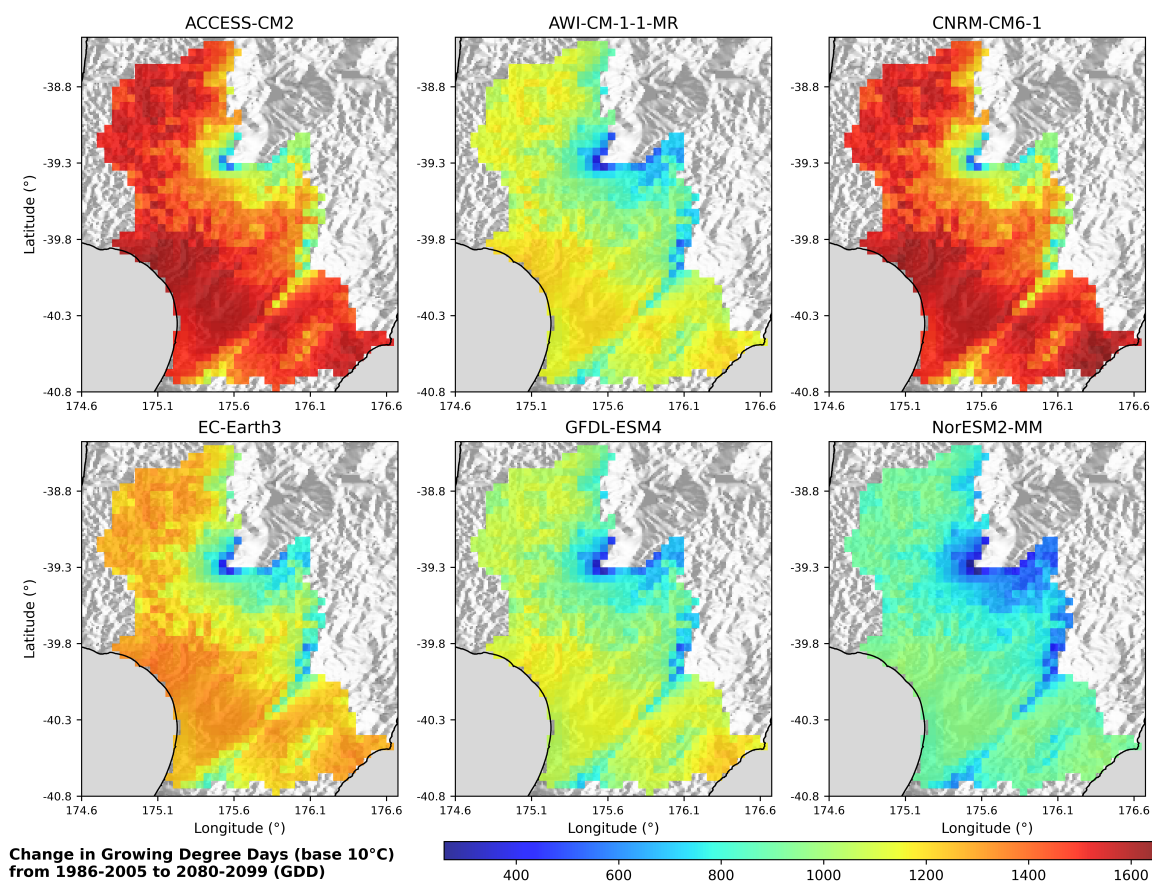


Figure 15: Projected changes in growing degree days (base 10°C) from 1986-2005 to 2080-2099 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

Late-century (2080–2099) projections under SSP5-8.5—the strongest forcing scenario—demonstrate an extremely likely, regionally pervasive increase in GDD10, with average increases of around 1,150 GDD and local maxima surpassing 1,400 GDD. All models and all parts of the region indicate substantial rises, with spatial R^2 values consistently above 0.95, highlighting extremely high confidence in both the sign and spatial organisation of change. The spatial pattern persists: the Volcanic Plateau and other higher altitudes see smaller, though still robust, increases; lowland, coastal, and eastern areas record the largest gains (over 1,280 GDD mean, and some models showing maxima greater than 1,580 GDD).

Standard deviations increase with scenario severity (now ~ 150 – 210 GDD), but the qualitative message is unchanged: the direction of change is universally positive. Minimum and maximum ensemble projections closely track the percentile-based uncertainty bounds (P5 and P95) with regression slopes near 1.0 and extremely high R^2 values (>0.98), indicating their continued robustness as uncertainty guides.

Sub-regional and percentile analyses confirm an extremely likely, very large, and spatially extensive warming signal, with even the coolest, highest, or most topographically complex areas experiencing projected changes of several hundred GDD. These results highlight a substantially transformed agro-climate for the Horizons region by 2100, almost doubling (or more) the thermal resources for plant and crop growth in areas already warm and extending a much longer growing season everywhere. The evidence leaves little doubt—by the end of the century, GDD10 increases will be substantial, spatially coherent, and highly robust to model or scenario assumptions.



8.5 Comparison Across Scenarios

Across all scenarios for 2080–2099, GDD10 increases are extremely likely, regionally extensive, and of a magnitude that scales with emissions pathway. While the spatial structure—largest increases in lowland, coastal, and eastern areas—remains intact, the intensity of change ranges from moderate under strong mitigation to transformative under continued high emissions. The minimum and maximum projections strongly coincide with percentile-based bounds, supporting robust uncertainty assessment, and all models agree on the sign and primary pattern of change. Importantly, the late-century period sees even the lowest increases surpassing those predicted for the near and mid-century under the same scenarios. The long-term outcome is thus a region-wide, robust, and substantial extension of thermal resources for crops and ecosystems, set to fundamentally reshape the Horizons region’s climate and land-use environment.

9 Evolution of Regional Hot-spots

A full breakdown on projected changes in growing degree days (base 10°C) by region is given in the Appendices. What follows below is a brief overview of those results.

Projected changes in GDD10 across the Horizons region reveal the emergence and amplification of regional hotspots of thermal accumulation, linked consistently to topographical and latitudinal gradients. In every future time period and scenario, areas that are already the warmest under historical climatology—such as Whanganui-Manawātū Lakes, Puketoi ki Tai, and Coastal Whanganui—stand out as the locations with the largest absolute increases in GDD10. For example, these regions record mean baseline GDD10 values in excess of 1,200–1,350, and by the late 21st century, projected increases commonly range from 900 to 1,400 GDD even under intermediate scenarios; under high-emissions scenarios (SSP5-8.5 or SSP3-7.0), gains can locally reach 1,200–1,800 GDD or more. This amplification effect is consistently observed across the model ensemble and is robust to the specific emissions pathway considered.

The spatial structure of change persists through time: lower elevation and coastal areas consistently show both high baseline values and the largest future gains. These locations are thus doubly exposed—not only already warm, but projected to experience the most intense increases in GDD10. This holds across all model realisations and is particularly pronounced in long-term, high-emissions scenarios where the signal-to-noise ratio is greatest.

Conversely, higher-altitude sub-regions—Volcanic Plateau and Upper Rangitīkei—are consistently hotspots for less pronounced, but still significant, change. While these sub-regions display the smallest absolute increases (as low as 130–200 GDD by 2040, and around 270–450 GDD by mid-century depending on scenario), the proportional change relative to their baseline is substantial—often a 50% or greater increase. However, these upland areas exhibit slightly wider model spread (standard deviation for projected change up to 90 GDD at century’s end) due to the complex interplay of orography, cold-air drainage, and potential biases in topographic representation. The magnitude of inter-model uncertainty in these zones cautions against over-interpretation of projected changes at fine scales, but does not undermine the robust regional trend.

No sub-region displays contradictory or outlier behaviour in any model or scenario. Rather, evolutionary ‘hotspots’ are a function of the amplification of the baseline thermal gradient that already characterises the Horizons region. Even in the coolest sub-regions, projected increases are robust and well above zero in all model percentiles, with minimum model increases of GDD10 rarely dipping below 100 GDD.

Importantly, this consistent pattern signals that climate adaptation may be urgently needed in the currently warmest and most agriculturally productive areas, as these are likely to experience the most pronounced lengthening and intensification of growing seasons, and thus, perhaps, a heightened risk of pests, diseases, water demand, and extreme heat events. Proactive adjustments in crop selection, irrigation, and pest/disease management will be required, with attention to the spatial gradients in the magnitude and certainty of pro-



jected GDD10 increases.

10 Understanding Projection Uncertainty

10.1 Why uncertainty matters

Uncertainty is inherent to climate projections, reflecting natural climate variability, incomplete knowledge of future GHG emissions, and structural differences among models. For GDD10, uncertainty is crucial because it defines the envelope within which planners and decision-makers must operate—whether evaluating crop risks, infrastructural investments, or biosecurity strategy. Uncertainty evolves across timescales: in the near future (2021–2040), it remains dominated by natural variability and inter-model differences, meaning that the precise magnitude of change remains only ‘likely’ to ‘very likely’ but the direction (increase) is seldom in doubt. By the later 21st century, scenario (emissions) uncertainty becomes dominant: the divergence between scenarios such as SSP1-2.6 and SSP5-8.5 is substantial, leading to extremely high confidence in the direction of change, but a broader envelope of possible magnitudes. For adaptation, this means strategies must be robust to a range of plausible outcomes—while the probability of GDD10 decrease is extremely unlikely, the scale and rate of increase may still surprise, depending on emissions and natural climate drivers.

10.2 Interpreting Ensemble Spread

The six-member model ensemble used in these projections enables systematic assessment of inter-model agreement and disagreement. Where all models project similar changes in GDD10—both in spatial pattern and magnitude—confidence is highest, and adaptation planning can proceed with relatively low residual risk. This is observed in the Horizons region for most future periods and scenarios, as indicated by spatial R^2 values exceeding 0.95 in nearly all ensemble averages. Where model spread is wider (as seen in particular upland or highly heterogeneous sub-regions), caution is warranted; this may reflect either true physical uncertainty or limitations of model resolution. Notably, long-term climate trends (especially under high-emissions scenarios) rapidly outpace the ensemble’s model spread, so that by 2080–2099, the ensemble mean and individual model fields display strong spatial correlation, and confidence in the broad directional signal becomes extremely high. Inter-model differences thus provide a conservative basis for bracketing plausible outcomes, but do not undermine sectoral preparedness for a future with more GDD10.

10.3 Minimum, Maximum and Percentile Fields

Minimum and maximum values across the six-model ensemble form practical, conservative bounds on likely projections for GDD10 changes—generally mirroring the 5th (5th percentile) and 95th (95th percentile) percentile fields derived using established uncertainty frameworks. Regression analyses confirm exceptionally high spatial R^2 between model minima and P5, and between maxima and P95, typically above 0.97–0.99, with slopes close to one. This confirms that, for the Horizons region and variable considered, the ensemble maxima provide strong, interpretable surrogates for upper-end outcomes, and are essentially equivalent to ‘extremely likely’ bounds per IPCC calibration. The minimum values, while also strong proxies, sometimes slightly underestimate the true P5, especially in regions of higher inter-model variability; however, in practical adaptation planning this subtlety is unlikely to materially affect strategic conclusions. Decision makers should thus interpret the maximum GDD10 increases as reliable ‘worst-case’ outcomes, with minimum changes reflecting ‘best-case’ (least increase) within the plausible model space.



11 Equilibrium Climate Sensitivity and Growing degree days (base 10°C) Change

11.1 Understanding ECS

Equilibrium climate sensitivity (ECS)—the equilibrium global temperature response to a doubling of atmospheric CO₂—is a key property differentiating climate models. In these analyses, models with higher ECS generally project greater overall regional warming and, thus, proportionally larger increases in GDD10. However, while ECS helps to explain some of the differences among projected GDD10 increases across models, it does not solely determine them. Local factors—such as topographic gradients, oceanic influences, and regional circulation changes—modulate local temperatures independently of global mean response. Additionally, GDD10 incorporates not only summer warmth but also shifts in shoulder seasons, and is sensitive to extreme cold and short-term temperature dips, all of which may respond differently to rising GHGs and model-specific physics. As such, while there is a pattern of higher GDD10 increases in high-ECS models, especially under high-emissions scenarios and for lowland areas, regional detail is additionally shaped by model differences in representing seasonal cycles and topography. ECS nonetheless remains a useful summary indicator of warming-driven changes, and regions exhibiting the strongest ECS–GDD10 correspondence highlight where future warming is most predictable.

12 Sources of Uncertainty

12.1 Emissions Uncertainty

By late century, the dominant source of projection spread is emissions uncertainty: the difference in future atmospheric GHG concentrations as described by various Shared Socioeconomic Pathway (SSP) scenarios. Early in the century, GDD10 increases are similar across scenarios; by 2080–2099, the spread becomes substantial—ranging from moderate increases under SSP1-2.6 to extremely large increases under SSP5-8.5. This has direct implications for policy: strong mitigation reduces upward pressure on GDD10; unrestrained emissions sharply enhance the pace and magnitude of change. The full envelope of plausible GDD10 futures thus depends strongly on future choices regarding fossil fuel use, land use, and global climate action.

12.2 Climate Model Uncertainty

Structural uncertainty among global models—differences in ECS, representation of regional ocean and atmosphere dynamics, and seasonal cycles—remains an important source of spread in projected GDD10, especially for mid-century and upland regions. Nevertheless, in the Horizons region, the spatial agreement in the direction and general pattern of change is extremely high. Detailed variation in local magnitude, especially for complex terrain and transitional zones, still depends on model configuration, highlighting the value of ensemble-based projections for cautious planning.

12.3 Natural Climate Variability

Natural climate variability—driven by interannual (e.g., ENSO) and decadal oscillations—modulates regionally averaged temperatures and thus GDD10, especially in the near term. In these projections, variability is captured implicitly by the model simulations, but cannot entirely be separated from forced climate trends. The primary effect is to add noise to decadal averages, such that some near-term periods may see smaller or larger increases than otherwise expected. By the end of the century, however, warming signals reach such magnitude that natural variability no longer dominates risk assessment for GDD10.



12.4 Downscaling Uncertainty

The projections are derived using the CCAM regional climate model. Regional downscaling provides substantial benefits because it improves representation of New Zealand's complex topography and climatic gradients. However, downscaling introduces its own uncertainties associated with model parameterisations, boundary conditions, and spatial resolution. Although these uncertainties are difficult to quantify directly, they should be recognised when interpreting local-scale projections. Importantly, the broad consistency of projected regional patterns across multiple climate models suggests that the major conclusions of this report are unlikely to be substantially altered by downscaling uncertainties.

13 Confidence Assessment

Using IPCC confidence language, the Horizons region is extremely likely (>95% probability) to experience substantial, widespread increases in GDD10 throughout this century, regardless of the emissions scenario. The evidence supporting this assessment is overwhelming: six-model ensemble agreement in both spatial pattern and sign exceeds 0.95 in spatial R^2 correlations, and the calculated minimum and maximum projections tightly bracket the plausible range of change.

Model structural uncertainty and natural variability do leave some ambiguity regarding the precise magnitude of increases and the detailed spatial pattern at sub-regional scales (particularly in areas of complex topography, such as the Volcanic Plateau), but at regional scale and decadal-to-century timeframes the direction of change is virtually certain (>99% probability). The upper and lower model projections reliably bound likely outcomes in each time period and scenario, lending 'very likely' or 'extremely likely' confidence for most planning applications.

The linkage between ECS and regional GDD10 change further supports qualitative confidence in warming-driven outcomes, though quantitative magnitude will remain somewhat scenario-dependent. Overall, the scientific basis for projecting longer, warmer, and more productive growing seasons across the region—accompanied by ancillary risks such as increased evapotranspiration demand, potential pest or weed expansion, and shifts in agroecological suitability—is robust, highly credible, and suitable as the basis for adaptation planning.

14 Conclusions

Projections for growing degree days (base 10°C; GDD10) across the Horizons region reveal a compelling and unanimous signal: cumulative thermal energy available for plant growth will increase substantially and pervasively through this century, with both magnitude and spatial extent closely following future GHG emissions. Every global model and scenario examined supports this conclusion, with high agreement concerning the regional spatial gradients and the direction of change. The most pronounced absolute increases are expected in already warm, lowland, and coastal regions—the same areas underpinning much of the region's productive capacity.

Although the scale of increase is modulated by emissions scenario, model configuration, orographic effects, and natural variability, no plausible scenario or model realisation shows any area at risk for decreased GDD10. The higher the emissions and further into the future, the greater and more spatially extensive the increase. Patterns of elevated uncertainty are generally confined to the margins—higher elevations or complex terrain—where caution is warranted for local-scale impact assessment, but not for overarching regional trends.

From a practical perspective, these outcomes portend longer growing seasons, scope for new or altered crops, greater frequency of threshold exceedances for pests and weeds, and potentially higher water and nutrient demand. Adaptation in agricultural practice, crop and variety selection, irrigation investment, and biosecurity



readiness should proceed on the assumption of markedly warmer growing seasons. Confidence in these broad conclusions is extremely high, with only the rate and exact magnitude of change remaining contingent on global emission outcomes and model details.

15 Appendices

A map of the sub-regions reported on below is provided in Figure 16. Some of these sub-regions exhibit a



Figure 16: A map of the regions reported on in these appendices.

wide range of elevations which can increase the spatial heterogeneity of the data, especially for temperature related climate variables. This is visible in the larger 1σ standard deviations for those regions listed in the tables below which represent the *spatial spread* of the values within each region (not the intrinsic uncertainty on the values). Histograms of elevations for each region, at the native resolution of the CCAM model, are shown in Figure 17. The Volcanic Plateau, Upper Rangitikei, and, to a lesser extent, the Western Ruahine regions contain a significant number of model cells at elevations above 700 m. For locations at elevation extremes within any region, the regional average values listed in the tables below may not be indicative of the value at that specific location and the user would do better to consult the data shown as maps for the whole Horizons region and consider the CCAM model value closest to their location.

15.1 Region: NorthernZone-Taumarunui

Area: 5084.04 km²

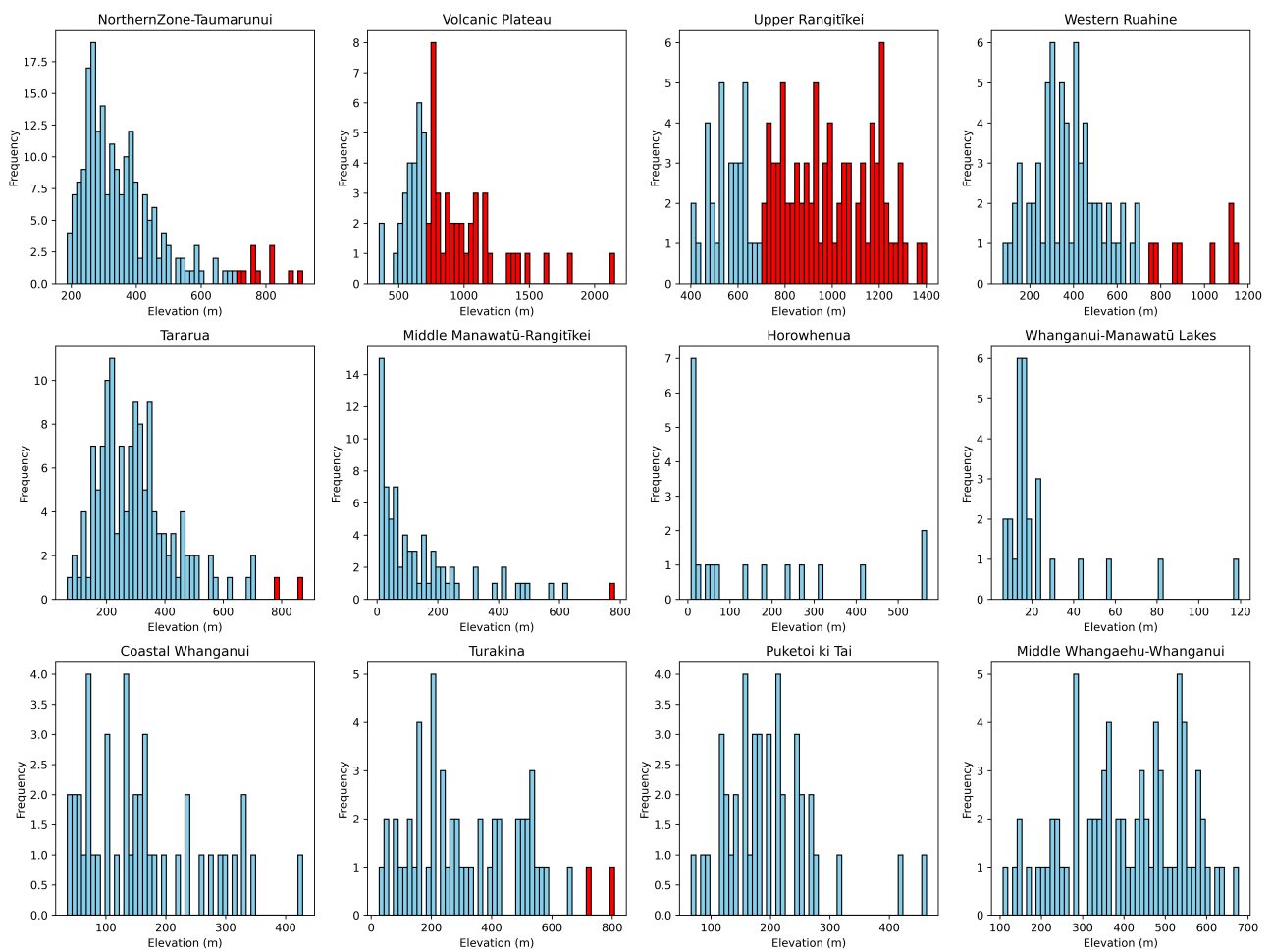


Figure 17: Histograms showing the number of CCAM model cells at each elevation. Histogram bars at elevations exceeding 700 m are shown in red. The original of this figure is available [here](#).



A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 18. The statistical summary of projected changes in growing degree days (base 10°C) over this

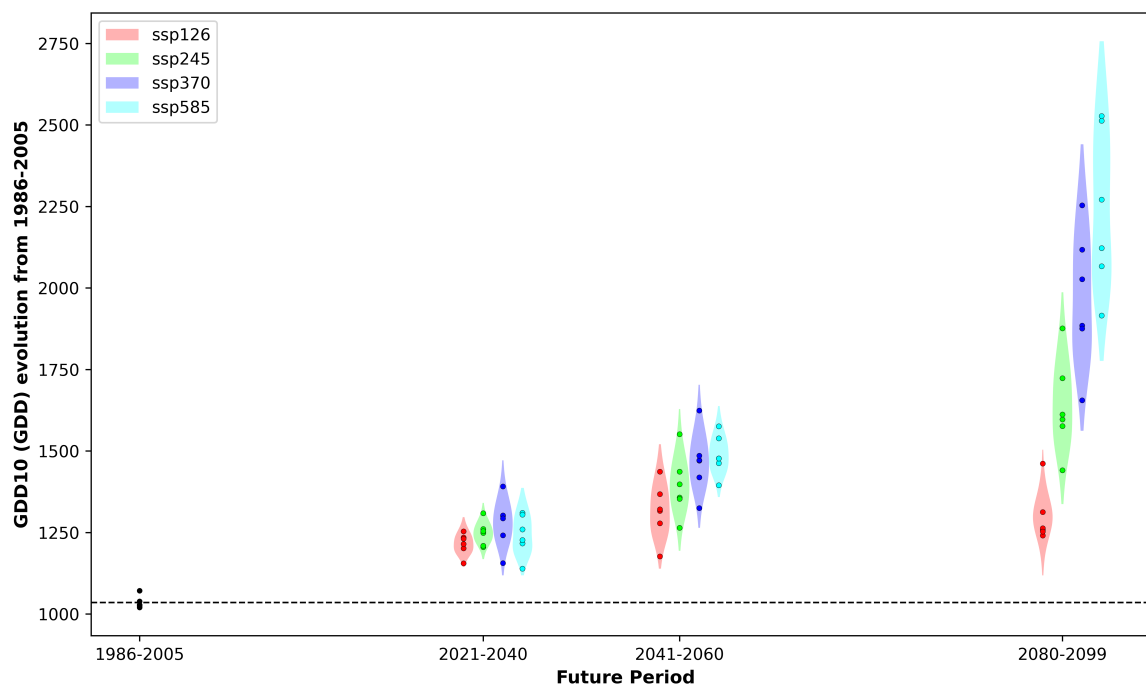


Figure 18: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the NorthernZone-Taumarunui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

region is shown in Table 1. Annual growing degree days (GDD, base 10°C) in the NorthernZone-Taumarunui region are projected to increase relative to the 1986–2005 baseline under all future scenarios. In the near term (2021–2040), GDD increases are projected to be modest (about 180–250 GDD increase, depending on scenario), and model spread is low. This suggests it is very likely that growing degree days will rise in the short term, with high confidence due to scenario consistency.

By mid-century (2041–2060), the rise becomes more pronounced, with mean increases from approximately 280 (SSP1-2.6) up to around 450 (SSP5-8.5), indicating likely larger thermal accumulation. The model ensembles' projections are generally consistent, but scenario divergence increases, lowering scenario agreement to about 10%.

By late century (2080–2099), projected increases are highly scenario-dependent, with changes ranging from about 260 (SSP1-2.6) up to 1200 (SSP5-8.5) above baseline, and spread across models also grows. Scenario agreement drops to zero, so confidence in the magnitude of late-century change is lower, but it is extremely likely this region will experience substantially more GDD than historically. This will very likely enhance crop suitability and lengthen growing seasons, especially under higher emission pathways.

Spatial variability within the region remains moderate. Overall, consistent warming-driven increases in GDD are extremely likely, but future changes depend strongly on the emissions pathway followed.

15.2 Region: Volcanic Plateau

Area: 1664.65 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1035 ± 183	1035 ± 183	1035 ± 183	1035 ± 183
	2021-2040	180 ± 14	213 ± 16	246 ± 17	208 ± 15
	2041-2060	281 ± 21	358 ± 27	431 ± 32	453 ± 34
	2080-2099	263 ± 21	602 ± 47	934 ± 65	1201 ± 79
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	181 ± 14	214 ± 17	248 ± 17	211 ± 15
	2041-2060	284 ± 21	361 ± 28	434 ± 32	455 ± 35
	2080-2099	265 ± 22	608 ± 47	945 ± 66	1219 ± 80
Multi-model minimum	Baseline	1020 ± 185	1020 ± 185	1020 ± 185	1020 ± 185
	2021-2040	120 ± 6	169 ± 12	121 ± 6	104 ± 6
	2041-2060	141 ± 10	229 ± 12	289 ± 22	360 ± 23
	2080-2099	206 ± 18	405 ± 31	621 ± 43	880 ± 60
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	131 ± 9	160 ± 11	138 ± 8	118 ± 7
	2041-2060	158 ± 12	224 ± 15	295 ± 22	364 ± 26
	2080-2099	148 ± 12	395 ± 34	639 ± 48	858 ± 64
Multi-model maximum	Baseline	1071 ± 184	1071 ± 184	1071 ± 184	1071 ± 184
	2021-2040	219 ± 17	274 ± 24	356 ± 28	276 ± 21
	2041-2060	402 ± 27	516 ± 39	589 ± 44	541 ± 40
	2080-2099	426 ± 36	841 ± 60	1218 ± 80	1492 ± 87
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	238 ± 20	275 ± 25	374 ± 29	317 ± 25
	2041-2060	428 ± 31	517 ± 43	591 ± 45	558 ± 45
	2080-2099	393 ± 33	850 ± 63	1292 ± 87	1626 ± 98

Table 1: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the NorthernZone-Taumarunui region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).



shown in Figure 19. The statistical summary of projected changes in growing degree days (base 10°C) over

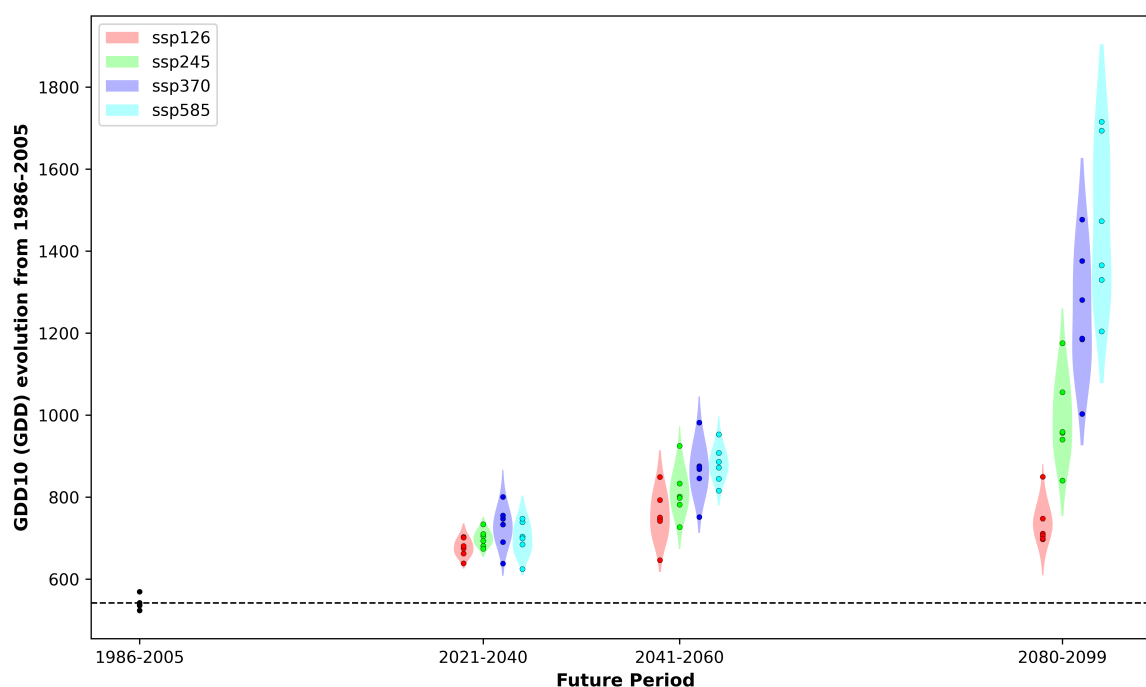


Figure 19: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Volcanic Plateau region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

this region is shown in Table 2. Projections for the Volcanic Plateau reveal a robust increase in annual growing degree days (base 10°C) relative to the 1986-2005 baseline, with the magnitude of change strongly dependent on emissions scenario and time period. By 2021-2040, all scenarios indicate a likely increase of 130–185 GDD (multi-model means), suggesting an extremely likely warming trend in the near-term, with high model agreement and limited spread. By mid-century (2041-2060), scenario dependence becomes more pronounced: mean increases range from ~210 (SSP1-2.6) up to ~340 GDD (SSP5-8.5). This divergence grows by late-century (2080-2099), where the lowest-emissions pathway (SSP1-2.6) projects a mean increase of ~190 GDD, but the highest (SSP5-8.5) projects an increase near 920 GDD. Spatial variability also rises notably over time, especially by 2080-2099 (stdv reaching ~170 GDD under SSP5-8.5), indicating increasing intra-regional disparity in warming.

Model agreement is high for the near-term but decreases over time and with scenario, with no agreement across scenarios by late century, reflecting very high scenario dependency. Overall, it is very likely that the Volcanic Plateau will experience continued, substantial increases in thermal growing potential, particularly under higher emissions. Confidence in the warming trend is very high, while confidence in the precise magnitude at century's end is medium due to model and scenario divergence.

15.3 Region: Upper Rangitikei

Area: 2694.06 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 20. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 3. Projected changes in annual growing degree days (GDD10; base 10°C) for the Upper Rangitikei sub-region show a clear upward trend throughout the 21st century, with the magnitude of



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	542 ± 207	542 ± 207	542 ± 207	542 ± 207
	2021-2040	135 ± 28	158 ± 34	186 ± 38	158 ± 32
	2041-2060	213 ± 42	269 ± 54	324 ± 63	338 ± 69
	2080-2099	193 ± 41	446 ± 90	710 ± 132	922 ± 169
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	136 ± 28	158 ± 34	187 ± 38	160 ± 32
	2041-2060	215 ± 43	271 ± 54	326 ± 64	339 ± 69
	2080-2099	195 ± 41	450 ± 91	718 ± 133	935 ± 171
Multi-model minimum	Baseline	524 ± 207	524 ± 207	524 ± 207	524 ± 207
	2021-2040	96 ± 19	132 ± 30	96 ± 20	83 ± 15
	2041-2060	104 ± 23	185 ± 35	210 ± 48	274 ± 57
	2080-2099	151 ± 34	298 ± 64	461 ± 97	663 ± 131
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	100 ± 20	127 ± 27	108 ± 23	96 ± 17
	2041-2060	119 ± 25	179 ± 34	222 ± 46	272 ± 59
	2080-2099	112 ± 24	286 ± 64	477 ± 97	636 ± 130
Multi-model maximum	Baseline	569 ± 212	569 ± 212	569 ± 212	569 ± 212
	2021-2040	164 ± 34	192 ± 43	259 ± 55	206 ± 42
	2041-2060	307 ± 59	383 ± 77	440 ± 85	411 ± 77
	2080-2099	308 ± 66	634 ± 120	935 ± 164	1174 ± 197
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	176 ± 37	194 ± 41	276 ± 57	233 ± 51
	2041-2060	325 ± 63	376 ± 78	445 ± 84	415 ± 81
	2080-2099	286 ± 59	638 ± 122	992 ± 174	1274 ± 218

Table 2: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Volcanic Plateau region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	550 ± 214	550 ± 214	550 ± 214	550 ± 214
	2021-2040	139 ± 24	161 ± 27	189 ± 30	165 ± 25
	2041-2060	221 ± 34	274 ± 46	329 ± 52	348 ± 57
	2080-2099	204 ± 34	455 ± 76	716 ± 111	935 ± 143
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	140 ± 24	162 ± 28	190 ± 30	167 ± 26
	2041-2060	223 ± 34	276 ± 46	331 ± 53	350 ± 57
	2080-2099	205 ± 34	459 ± 76	723 ± 112	946 ± 145
Multi-model minimum	Baseline	534 ± 213	534 ± 213	534 ± 213	534 ± 213
	2021-2040	99 ± 15	135 ± 23	97 ± 15	90 ± 14
	2041-2060	112 ± 20	194 ± 28	217 ± 40	277 ± 46
	2080-2099	163 ± 32	312 ± 54	467 ± 81	670 ± 110
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	105 ± 18	131 ± 22	113 ± 19	106 ± 14
	2041-2060	129 ± 22	187 ± 29	232 ± 39	282 ± 49
	2080-2099	125 ± 21	303 ± 53	493 ± 82	657 ± 109
Multi-model maximum	Baseline	574 ± 215	574 ± 215	574 ± 215	574 ± 215
	2021-2040	166 ± 29	195 ± 36	253 ± 42	209 ± 33
	2041-2060	311 ± 47	386 ± 66	438 ± 72	411 ± 63
	2080-2099	315 ± 54	628 ± 102	924 ± 138	1175 ± 168
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	179 ± 32	197 ± 35	275 ± 44	235 ± 39
	2041-2060	329 ± 49	376 ± 67	443 ± 69	424 ± 67
	2080-2099	293 ± 49	637 ± 103	986 ± 146	1275 ± 186

Table 3: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Upper Rangitikei region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

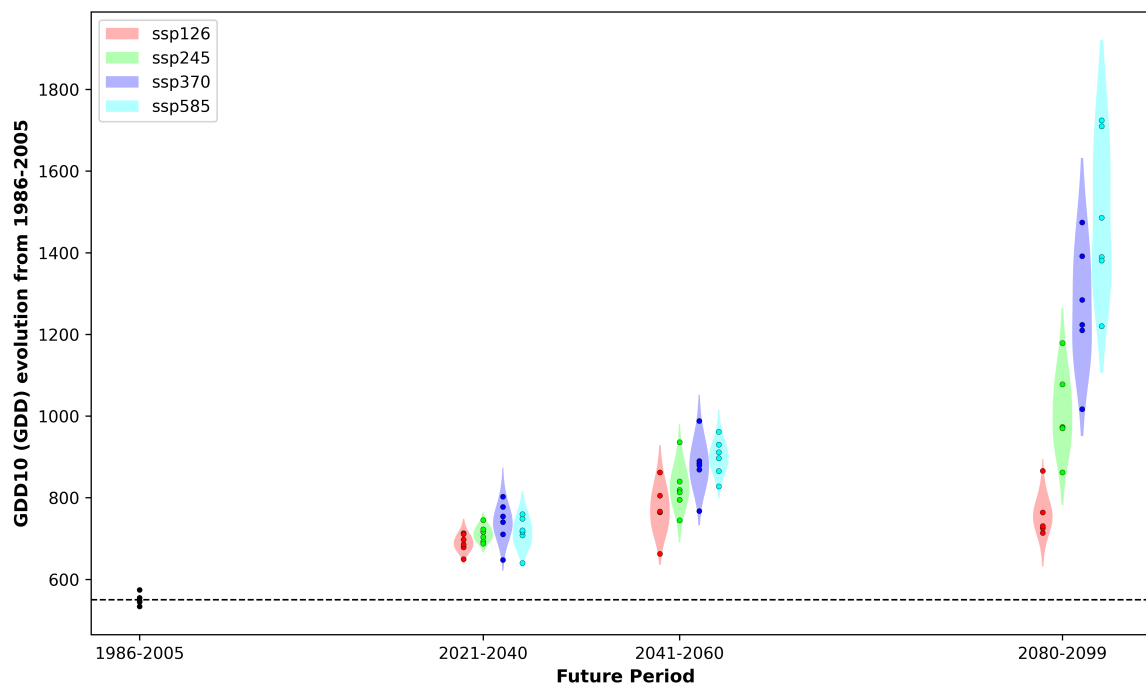


Figure 20: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Upper Rangitikei region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

change strongly dependent on emissions scenario. For 2021–2040, all scenarios indicate an increase in annual GDD10 compared to the 1986–2005 baseline, with very likely (IPCC: >90%) increases around 140–190 GDD. By mid-century (2041–2060), further increases of roughly 220–350 GDD are projected, and by late century (2080–2099), disparities between scenarios become pronounced: a moderate increase of about 200 GDD remains under low emissions (SSP1-2.6), but high emissions scenarios (SSP3-7.0 and SSP5-8.5) indicate very likely increases exceeding 700 and 900 GDD, respectively.

Model agreement is very high regarding the direction of change (virtually certain increase), but inter-scenario agreement diminishes through the century (agreement among scenarios declines from ~30% in the near-term to 0% by century's end). Spatial variability within the sub-region remains lower than the projected change, but increases with the magnitude of warming—particularly under high emissions. The consistent and robust increase in GDD10 suggests, with high confidence, that the agricultural growing season will lengthen substantially, especially in high-emission futures, with important implications for land use and productivity in Upper Rangitikei.

15.4 Region: Western Ruahine

Area: 1758.32 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 21. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 4. Projected annual growing degree days (base 10°C; GDD10) in Western Ruahine show a robust tendency towards increases through the 21st century. All emissions scenarios (SSP126–SSP585) indicate very likely rises in GDD10 relative to the 1986–2005 baseline, with the magnitude strongly dependent on emissions pathway and time horizon.



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	900 ± 233	900 ± 233	900 ± 233	900 ± 233
	2021-2040	172 ± 22	197 ± 26	230 ± 29	197 ± 25
	2041-2060	265 ± 34	341 ± 44	406 ± 51	429 ± 55
	2080-2099	252 ± 35	569 ± 74	883 ± 104	1145 ± 130
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	173 ± 23	198 ± 26	232 ± 29	200 ± 25
	2041-2060	267 ± 34	343 ± 45	408 ± 51	430 ± 55
	2080-2099	254 ± 35	574 ± 75	892 ± 105	1160 ± 132
Multi-model minimum	Baseline	882 ± 234	882 ± 234	882 ± 234	882 ± 234
	2021-2040	120 ± 12	157 ± 19	117 ± 11	111 ± 11
	2041-2060	141 ± 18	221 ± 21	277 ± 34	339 ± 38
	2080-2099	205 ± 26	386 ± 48	588 ± 71	839 ± 98
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	131 ± 15	147 ± 16	135 ± 15	123 ± 12
	2041-2060	158 ± 21	217 ± 24	285 ± 34	350 ± 44
	2080-2099	149 ± 19	377 ± 52	613 ± 76	823 ± 103
Multi-model maximum	Baseline	931 ± 235	931 ± 235	931 ± 235	931 ± 235
	2021-2040	206 ± 29	255 ± 40	323 ± 45	255 ± 34
	2041-2060	372 ± 45	490 ± 64	548 ± 70	500 ± 60
	2080-2099	400 ± 58	788 ± 97	1140 ± 129	1421 ± 146
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	220 ± 32	256 ± 38	341 ± 46	287 ± 41
	2041-2060	392 ± 49	486 ± 69	548 ± 70	521 ± 68
	2080-2099	368 ± 53	798 ± 101	1209 ± 140	1542 ± 164

Table 4: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Western Ruahine region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

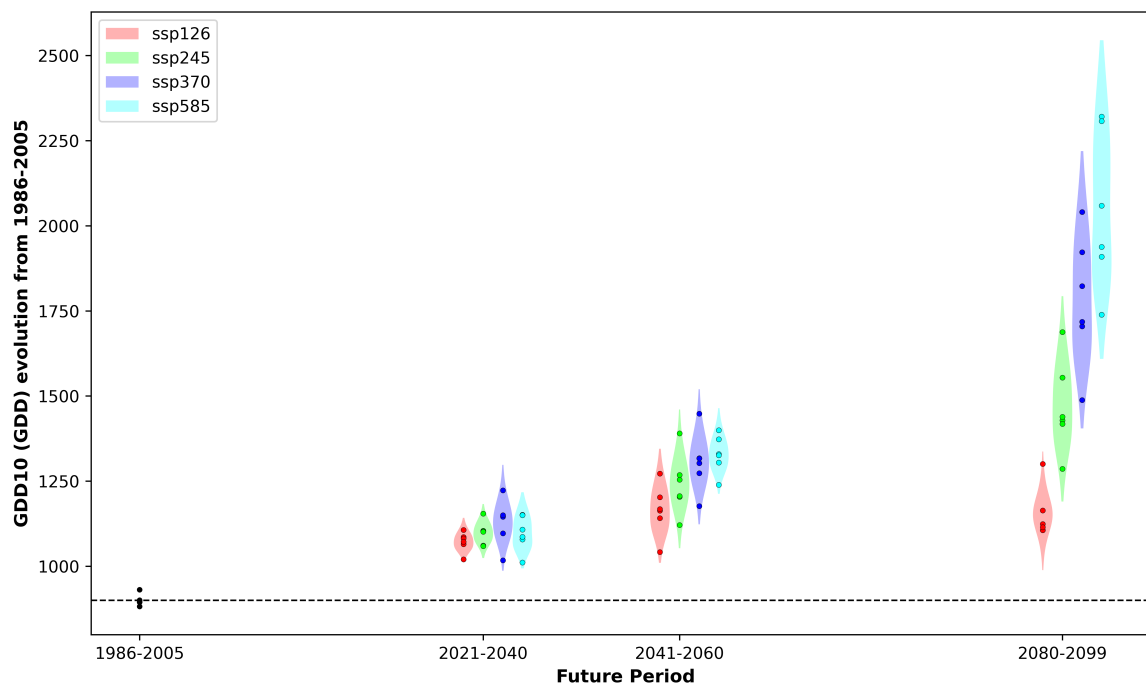


Figure 21: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Western Ruahine region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

By mid-century (2041–2060), multi-model mean increases range from roughly 265 GDD under SSP126 (strong mitigation) to over 425 GDD under SSP585 (very high emissions), indicating a likely substantial shift in thermal growing conditions. By 2080–2099, this divergence widens markedly, with multi-model means spanning from just above 250 GDD (SSP126) to over 1140 GDD (SSP585), suggesting that high-emissions futures would virtually certainly bring strong warming impacts on regional agriculture. This signal is consistent across models for direction, but model spread for magnitude is substantial under higher emissions; spatial variability in change also increases with emissions strength and time.

Inter-model agreement is strong for the near-term but declines for later periods as scenario pathways diverge—by century's end, scenario agreement is essentially nil, reflecting high scenario uncertainty. Overall, it is virtually certain that Western Ruahine will experience increased GDD10 with the increase being extremely likely to be greater under higher emissions scenarios; considerable planning adaptation may be required given the very likely magnitude of these changes.

15.5 Region: Tararua

Area: 3155.23 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 22. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 5. Growing degree days (base 10°C, GDD10) in Tararua are projected to increase substantially across all emission scenarios (SSPs) and time periods relative to the 1986–2005 baseline. In the near-term (2021–2040), a likely increase in GDD10 of roughly 180–240 units is projected, with minimal scenario spread and high inter-model agreement, indicating very high confidence in a moderate signal of warming-driven lengthening of the growing season. By mid-century (2041–2060), increases are more pronounced (approximately 280–455 units depending on scenario), but inter-scenario differences begin to emerge, reflecting



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1029 ± 161	1029 ± 161	1029 ± 161	1029 ± 161
	2021-2040	182 ± 15	209 ± 17	241 ± 18	208 ± 18
	2041-2060	282 ± 23	358 ± 28	427 ± 32	455 ± 36
	2080-2099	270 ± 23	604 ± 46	928 ± 62	1195 ± 76
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	183 ± 15	210 ± 17	243 ± 18	210 ± 18
	2041-2060	285 ± 23	361 ± 28	430 ± 32	457 ± 36
	2080-2099	271 ± 23	609 ± 46	937 ± 63	1209 ± 77
Multi-model minimum	Baseline	1008 ± 161	1008 ± 161	1008 ± 161	1008 ± 161
	2021-2040	130 ± 7	163 ± 11	123 ± 7	120 ± 7
	2041-2060	159 ± 13	229 ± 14	294 ± 21	355 ± 24
	2080-2099	217 ± 21	412 ± 32	622 ± 43	887 ± 60
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	142 ± 10	158 ± 12	143 ± 11	134 ± 11
	2041-2060	176 ± 16	229 ± 17	305 ± 23	370 ± 29
	2080-2099	166 ± 16	406 ± 35	655 ± 48	872 ± 64
Multi-model maximum	Baseline	1065 ± 162	1065 ± 162	1065 ± 162	1065 ± 162
	2021-2040	213 ± 19	268 ± 23	337 ± 25	263 ± 21
	2041-2060	388 ± 27	510 ± 37	569 ± 41	533 ± 41
	2080-2099	420 ± 33	819 ± 54	1181 ± 71	1472 ± 86
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	229 ± 22	270 ± 24	357 ± 27	298 ± 26
	2041-2060	410 ± 31	510 ± 40	571 ± 43	557 ± 45
	2080-2099	386 ± 31	841 ± 59	1259 ± 79	1591 ± 92

Table 5: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Tararua region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

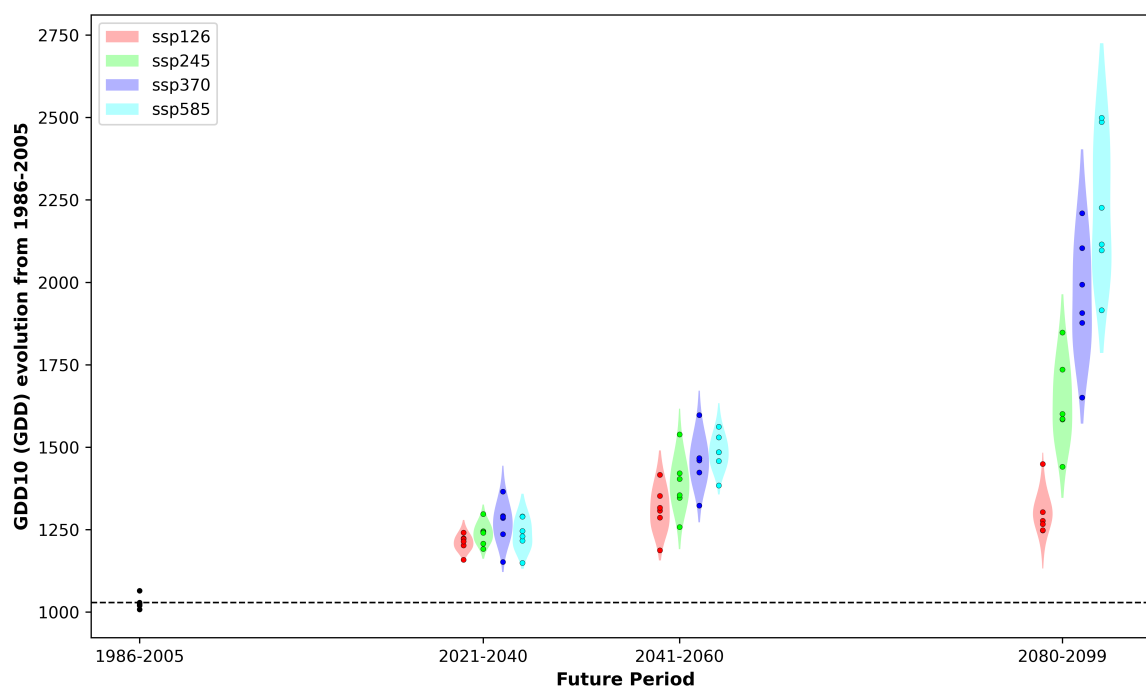


Figure 22: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Tararua region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

a likely signal of further warming that is increasingly scenario dependent. By late-century (2080–2099), the spread between low (SSP1-2.6) and high (SSP5-8.5) emissions becomes pronounced, from about 270 up to nearly 1200 units. This represents a very likely, but scenario-dependent, acceleration of GDD10 accumulation, with differences across models also growing, reflected in higher spatial standard deviation. Percentage agreement across SSPs drops to zero by late century, indicating that results are virtually certain to be strongly scenario dependent and highlighting declining confidence in a scenario-agnostic signal. Overall, it is virtually certain that Tararua will experience higher GDD10 values, indicating longer productive growing seasons, but the ultimate magnitude is very likely to depend on future emissions pathways.

15.6 Region: Middle Manawatū-Rangitīkei

Area: 1838.51 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 23. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 6. For the Middle Manawatū-Rangitīkei sub-region, annual growing degree days (base 10°C) are projected to increase throughout the 21st century, with the magnitude and acceleration of change strongly dependent on emissions scenario. Under all SSPs, model means indicate an initial increase of about 200 GDD by 2021–2040 (virtually certain, high confidence). By mid-century (2041–2060), this grows to approximately 290–470 GDD depending on the scenario. Toward the end of the century (2080–2099), projections diverge, ranging from an increase of roughly 280 GDD under the lowest scenario (SSP1-2.6) to over 1200 GDD in SSP5-8.5 (extremely likely, high confidence for an increasing trend; low confidence in precise magnitude for late-century).

Between models, there is generally close agreement in early periods (high inter-model consistency), but spreads increase with both time and scenario stringency. Inter-scenario agreement drops markedly from about 39%



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1185 ± 224	1185 ± 224	1185 ± 224	1185 ± 224
	2021-2040	186 ± 20	214 ± 21	250 ± 23	211 ± 22
	2041-2060	289 ± 28	375 ± 36	444 ± 41	468 ± 45
	2080-2099	280 ± 30	629 ± 59	964 ± 79	1238 ± 98
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	187 ± 20	215 ± 21	252 ± 24	214 ± 22
	2041-2060	292 ± 28	378 ± 36	447 ± 41	470 ± 45
	2080-2099	281 ± 30	635 ± 59	973 ± 79	1255 ± 99
Multi-model minimum	Baseline	1167 ± 224	1167 ± 224	1167 ± 224	1167 ± 224
	2021-2040	127 ± 8	164 ± 13	121 ± 8	117 ± 8
	2041-2060	154 ± 13	231 ± 16	298 ± 26	362 ± 30
	2080-2099	218 ± 25	421 ± 38	642 ± 55	914 ± 76
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	139 ± 11	153 ± 12	140 ± 13	126 ± 12
	2041-2060	173 ± 17	231 ± 20	307 ± 29	381 ± 37
	2080-2099	162 ± 19	419 ± 43	673 ± 61	903 ± 81
Multi-model maximum	Baseline	1224 ± 223	1224 ± 223	1224 ± 223	1224 ± 223
	2021-2040	222 ± 26	286 ± 32	365 ± 35	283 ± 32
	2041-2060	407 ± 36	541 ± 50	604 ± 53	540 ± 47
	2080-2099	448 ± 46	866 ± 73	1240 ± 92	1519 ± 109
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	242 ± 30	285 ± 33	380 ± 37	313 ± 36
	2041-2060	427 ± 41	545 ± 55	605 ± 56	571 ± 55
	2080-2099	411 ± 43	881 ± 77	1315 ± 100	1652 ± 119

Table 6: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Middle Manawatū-Rangitikei region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

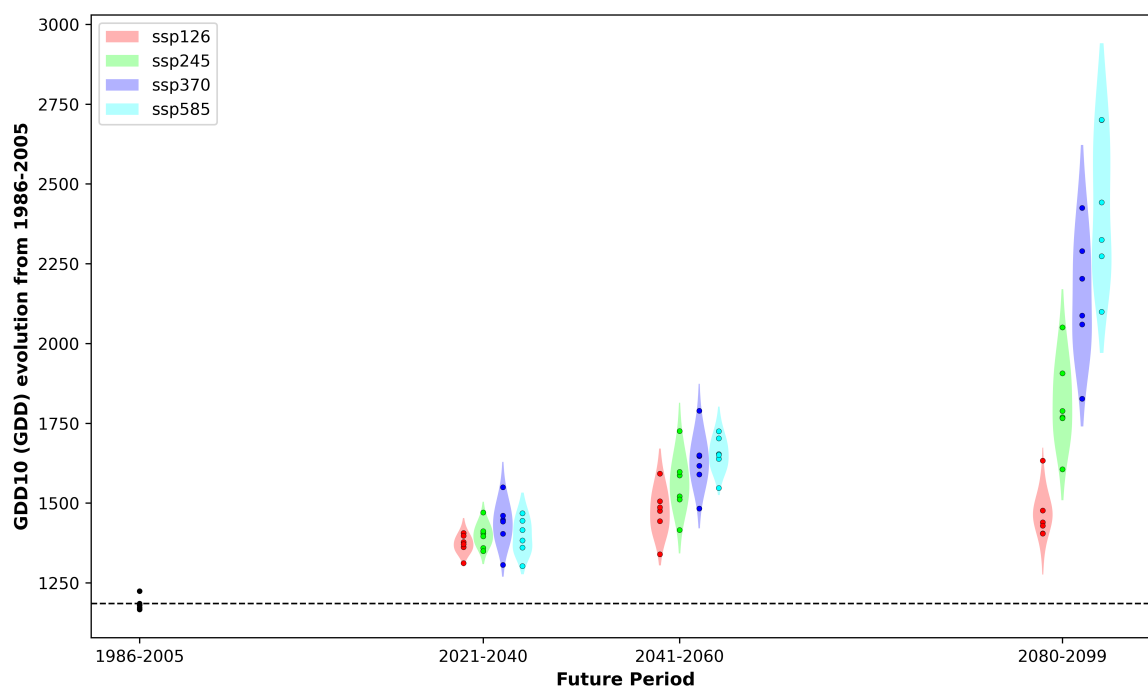


Figure 23: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Middle Manawatū-Rangitikei region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

in 2021–2040 to zero by 2080–2099, reflecting that long-term changes are dominated by emissions pathway. Spatial variability within the region is small relative to the total projected changes, particularly under the highest scenarios late in the century.

In summary, it is extremely likely that Middle Manawatū-Rangitikei will experience substantial increases in GDD10, especially later this century under higher emissions, with scenario choice becoming the dominant influence after mid-century.

15.7 Region: Horowhenua

Area: 448.71 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 24. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 7. The projections for annual growing degree days (GDD, base 10°C) in Horowhenua show a consistent increase across all climate models and emission scenarios relative to the 1986–2005 baseline. By 2021–2040, mean increases range from approximately 170 to 230 GDD, increasing further in subsequent periods. By the end of the century (2080–2099), GDD increases are strongly scenario-dependent, with low-emission (SSP1-2.6) changes of about 250 GDD, while high-emission (SSP5-8.5) scenarios project increases exceeding 1150 GDD. These changes are extremely likely under all pathways (high model agreement within scenarios), with the magnitude and divergence between scenarios growing with time—agreement between scenarios effectively vanishes by century’s end.

Across all periods, increases in GDD are spatially robust, as evidenced by modest spatial standard deviations relative to the magnitude of change. The spread among models within each scenario and time period remains moderate, giving high confidence in the warming signal itself, but growing uncertainty about the exact rate of



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1102 ± 261	1102 ± 261	1102 ± 261	1102 ± 261
	2021-2040	167 ± 19	193 ± 21	230 ± 24	186 ± 20
	2041-2060	265 ± 29	344 ± 37	408 ± 42	427 ± 45
	2080-2099	253 ± 30	581 ± 62	897 ± 83	1152 ± 102
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	168 ± 19	195 ± 21	232 ± 24	189 ± 21
	2041-2060	268 ± 29	347 ± 37	411 ± 42	428 ± 46
	2080-2099	254 ± 30	586 ± 63	907 ± 83	1168 ± 103
Multi-model minimum	Baseline	1081 ± 261	1081 ± 261	1081 ± 261	1081 ± 261
	2021-2040	121 ± 10	147 ± 13	109 ± 7	103 ± 7
	2041-2060	140 ± 14	208 ± 14	277 ± 28	334 ± 31
	2080-2099	193 ± 24	383 ± 40	587 ± 56	843 ± 79
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	127 ± 11	137 ± 12	124 ± 11	106 ± 9
	2041-2060	155 ± 17	208 ± 19	282 ± 31	347 ± 37
	2080-2099	144 ± 19	382 ± 46	617 ± 63	830 ± 85
Multi-model maximum	Baseline	1149 ± 263	1149 ± 263	1149 ± 263	1149 ± 263
	2021-2040	199 ± 29	257 ± 31	340 ± 36	253 ± 29
	2041-2060	378 ± 39	499 ± 51	556 ± 53	500 ± 48
	2080-2099	410 ± 46	806 ± 76	1165 ± 98	1425 ± 114
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	213 ± 28	260 ± 32	356 ± 39	283 ± 34
	2041-2060	397 ± 43	505 ± 59	556 ± 56	521 ± 55
	2080-2099	375 ± 43	819 ± 81	1237 ± 107	1549 ± 123

Table 7: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Horowhenua region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

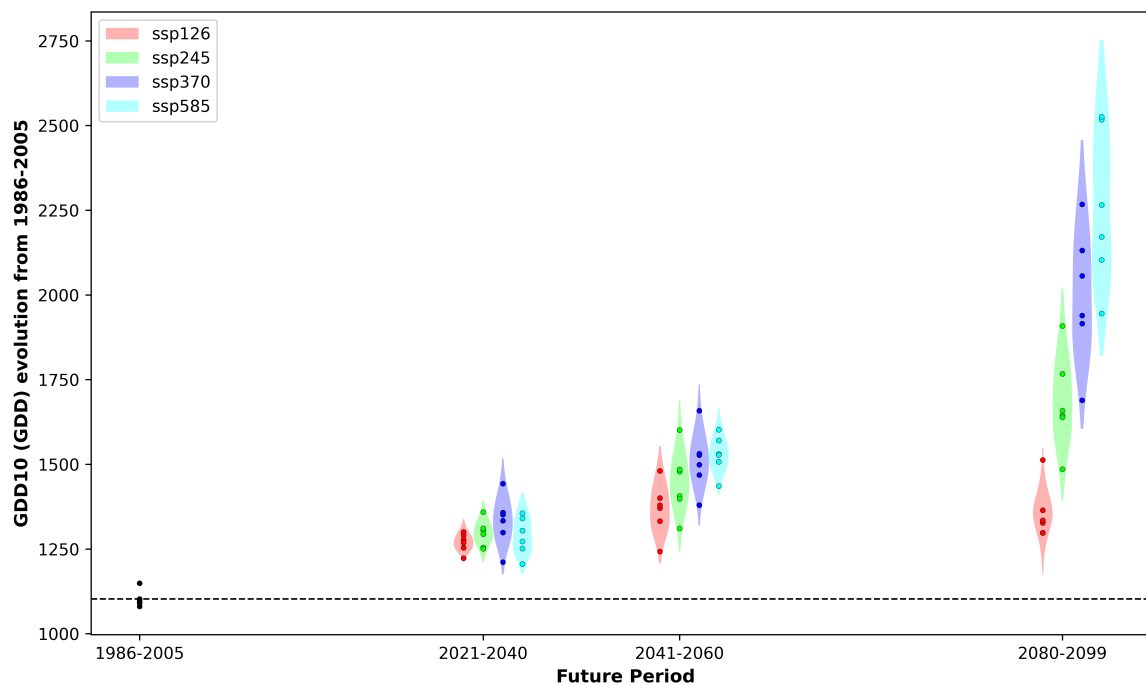


Figure 24: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Horowhenua region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

increase under divergent emissions.

Scientifically, the findings indicate a likely lengthening of the warm season and increased potential for plant growth, aligned with wider patterns of New Zealand warming. By late century, scenario divergence becomes the dominant source of uncertainty, underscoring the sensitivity of Horowhenua's climate to global emissions trajectories.

15.8 Region: Whanganui-Manawatū Lakes

Area: 623.11 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 25. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 8. The Whanganui-Manawatū Lakes sub-region is projected to experience a substantial increase in annual growing degree days (GDD, base 10°C) relative to the 1986-2005 baseline. All scenarios show a very likely increase in GDD throughout the 21st century, with the magnitude of change strongly scenario-dependent by late century. Near-term (2021-2040) increases are similar across SSPs (likely 190–250 GDD above baseline for SSP126–SSP370), with moderate spatial variability (stdv ~6–9 GDD) and moderate inter-model agreement.

By mid-century (2041-2060), increases remain robust across all pathways. For the highest emissions scenarios (SSP370 and SSP585), projected gains reach 450–475 GDD (very likely), substantially greater than for SSP126 (~295 GDD). Inter-model agreement begins to diverge, and spatial variability also increases but remains moderate (stdv ~7–13 GDD).

By 2080-2099, scenario spread dominates: under SSP585, GDD increases by over 1,250 GDD (virtually certain), nearly twice that of SSP370 and quadruple SSP126. Inter-model agreement across scenarios disappears, re-



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1365 ± 39	1365 ± 39	1365 ± 39	1365 ± 39
	2021-2040	189 ± 7	216 ± 6	254 ± 7	209 ± 9
	2041-2060	295 ± 7	384 ± 9	451 ± 12	474 ± 13
	2080-2099	287 ± 9	644 ± 15	976 ± 21	1251 ± 27
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	190 ± 7	218 ± 6	257 ± 7	212 ± 9
	2041-2060	299 ± 7	387 ± 9	454 ± 12	477 ± 13
	2080-2099	289 ± 9	650 ± 15	986 ± 21	1268 ± 27
Multi-model minimum	Baseline	1343 ± 39	1343 ± 39	1343 ± 39	1343 ± 39
	2021-2040	132 ± 3	161 ± 6	116 ± 4	108 ± 5
	2041-2060	155 ± 3	224 ± 6	302 ± 7	364 ± 8
	2080-2099	213 ± 12	424 ± 9	645 ± 16	920 ± 22
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	138 ± 4	147 ± 6	133 ± 6	112 ± 8
	2041-2060	169 ± 6	226 ± 8	308 ± 9	386 ± 9
	2080-2099	159 ± 8	424 ± 11	674 ± 19	910 ± 24
Multi-model maximum	Baseline	1408 ± 38	1408 ± 38	1408 ± 38	1408 ± 38
	2021-2040	232 ± 7	296 ± 10	381 ± 7	295 ± 11
	2041-2060	424 ± 7	563 ± 13	616 ± 16	541 ± 15
	2080-2099	469 ± 14	895 ± 20	1269 ± 24	1537 ± 29
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	250 ± 12	299 ± 10	398 ± 8	326 ± 12
	2041-2060	445 ± 10	570 ± 13	618 ± 17	580 ± 18
	2080-2099	430 ± 13	908 ± 21	1342 ± 25	1672 ± 32

Table 8: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Whanganui-Manawatū Lakes region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

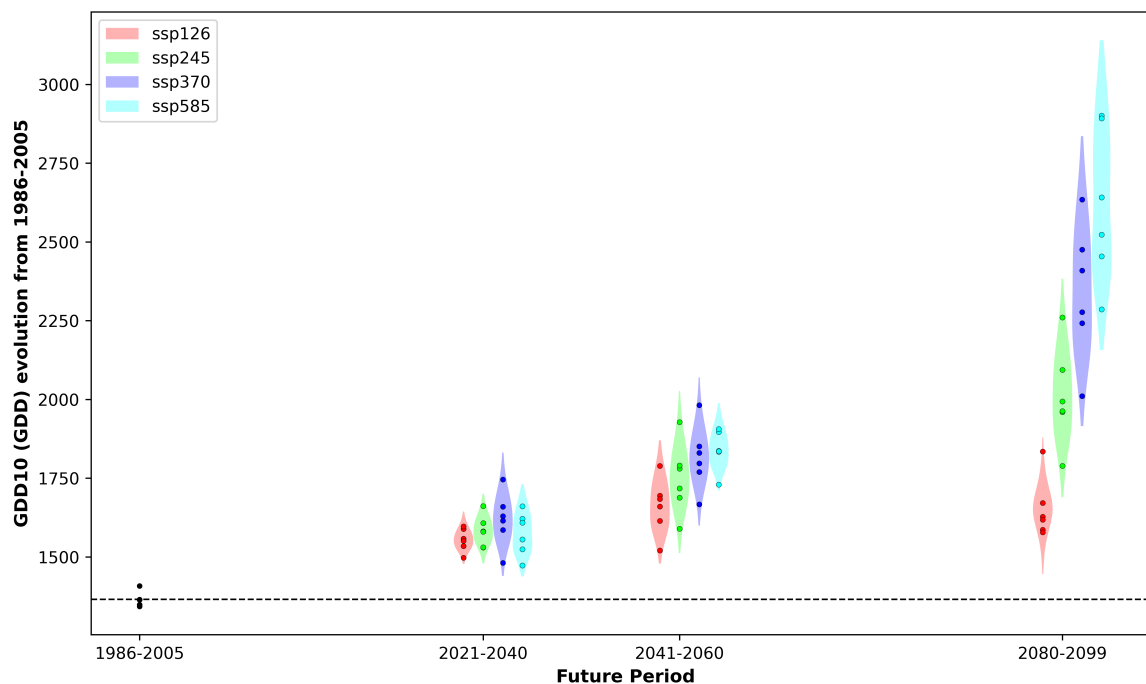


Figure 25: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Whanganui-Manawātū Lakes region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

flecting increased climate response uncertainty. The spatial variability grows (stdv up to ~27 GDD for SSP585), indicating locally differentiated impacts. The progression from high agreement to divergence across scenarios and models with time suggests results for late century are more dependent on global emissions trajectories. Overall, it is virtually certain that GDD will increase, with the magnitude very likely dependent on future emissions.

15.9 Region: Coastal Whanganui

Area: 1048.57 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 26. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 9. The projections for growing degree days (GDD, base 10°C) in Coastal Whanganui indicate a robust and persistent warming signal, characterised by increases across all emission scenarios and time periods relative to the 1986–2005 baseline. By mid-century (2041–2060), mean GDD increases range from about 300 under SSP1-2.6 to nearly 500 under SSP5-8.5, suggesting it is very likely that the region will experience a substantially longer growing season, with the magnitude of change scaling with scenario. By the late 21st century (2080–2099), projected increases diverge sharply, from approximately 300 under low emissions (SSP1-2.6) up to nearly 1,300 under high emissions (SSP5-8.5). This divergence reflects a very high sensitivity of GDD to greenhouse gas pathway, and virtually certain ongoing increases in all scenarios.

Inter-model agreement on the sign of change is extremely likely, as all models project increases. However, the spread between scenarios grows markedly with time: agreement across scenarios drops from 42% in the near term to 0% by century's end, highlighting scenario-dependence as the dominant source of uncertainty post-2060. Spatial variability in GDD within the region is modest compared to the projected trend. Overall, there is high confidence that GDD will increase substantially in Coastal Whanganui, with the largest changes



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1274 ± 140	1274 ± 140	1274 ± 140	1274 ± 140
	2021-2040	199 ± 9	226 ± 9	265 ± 10	225 ± 9
	2041-2060	304 ± 12	394 ± 16	468 ± 18	492 ± 20
	2080-2099	297 ± 14	663 ± 26	1004 ± 33	1287 ± 40
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	200 ± 9	228 ± 9	268 ± 10	228 ± 9
	2041-2060	308 ± 12	397 ± 17	471 ± 18	495 ± 20
	2080-2099	298 ± 14	669 ± 26	1015 ± 34	1305 ± 41
Multi-model minimum	Baseline	1256 ± 140	1256 ± 140	1256 ± 140	1256 ± 140
	2021-2040	124 ± 5	169 ± 6	122 ± 5	110 ± 5
	2041-2060	154 ± 8	229 ± 9	308 ± 13	371 ± 14
	2080-2099	232 ± 10	434 ± 18	662 ± 25	947 ± 35
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	140 ± 6	157 ± 7	146 ± 6	126 ± 6
	2041-2060	177 ± 8	237 ± 10	318 ± 13	395 ± 16
	2080-2099	168 ± 9	437 ± 19	696 ± 27	939 ± 36
Multi-model maximum	Baseline	1312 ± 141	1312 ± 141	1312 ± 141	1312 ± 141
	2021-2040	239 ± 11	303 ± 14	382 ± 16	302 ± 15
	2041-2060	424 ± 16	569 ± 24	639 ± 24	568 ± 20
	2080-2099	477 ± 23	919 ± 33	1299 ± 40	1576 ± 43
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	268 ± 13	309 ± 15	406 ± 16	344 ± 15
	2041-2060	457 ± 17	579 ± 27	644 ± 24	608 ± 24
	2080-2099	441 ± 21	934 ± 35	1378 ± 42	1719 ± 47

Table 9: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Coastal Whanganui region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

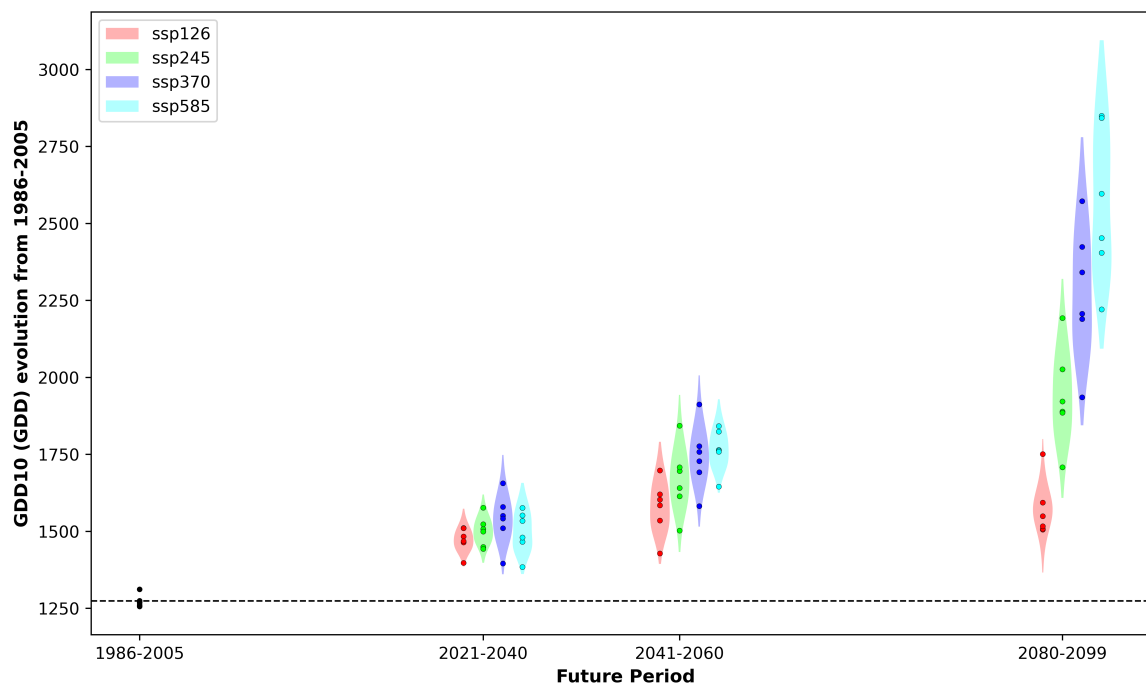


Figure 26: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Coastal Whanganui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

under high-emissions scenarios.

15.10 Region: Turakina

Area: 1237.15 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 27. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 10. The figure and statistics jointly indicate that Turakina is very likely to experience significant increases in annual growing degree days (base 10°C) throughout the 21st century. Relative to the 1986–2005 baseline, multi-model mean increases in GDD10 are projected for all future periods and emission scenarios. By 2021–2040, mean increases range from about 180 to 245 GDD, and by 2080–2099 the range expands markedly: from approximately 270 GDD (SSP1-2.6, low emissions) to over 1,200 GDD (SSP5-8.5, high emissions). This upward trend is extremely likely, with higher emissions scenarios yielding greater increases.

The inter-model agreement within scenarios is high, as suggested by the relatively narrow spread of values within each scenario, but agreement across scenarios declines with time: by 2080–2099, projected increases span a wide range, and the probability of consensus across emission pathways is virtually nil. Spatial variability within Turakina remains low compared to the projected changes, with standard deviations typically below 100 GDD even under extreme warming.

These findings suggest it is very likely that Turakina will see substantial lengthening and intensification of the growing season, with implications for agriculture and ecosystems. However, the ultimate magnitude of change later in the century is strongly scenario dependent, and projections diverge between lower and higher emissions pathways, resulting in reduced confidence in the exact amount of increase under higher uncertainties.



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1050 ± 228	1050 ± 228	1050 ± 228	1050 ± 228
	2021-2040	183 ± 17	210 ± 18	245 ± 22	208 ± 18
	2041-2060	282 ± 25	363 ± 34	432 ± 39	455 ± 42
	2080-2099	270 ± 29	607 ± 59	935 ± 79	1208 ± 96
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	184 ± 17	211 ± 19	247 ± 22	211 ± 19
	2041-2060	285 ± 25	366 ± 35	435 ± 39	457 ± 42
	2080-2099	271 ± 29	613 ± 59	945 ± 80	1225 ± 97
Multi-model minimum	Baseline	1033 ± 228	1033 ± 228	1033 ± 228	1033 ± 228
	2021-2040	122 ± 8	165 ± 10	121 ± 8	109 ± 9
	2041-2060	146 ± 14	227 ± 12	290 ± 26	355 ± 26
	2080-2099	213 ± 21	405 ± 37	620 ± 54	884 ± 76
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	134 ± 11	154 ± 8	140 ± 10	123 ± 8
	2041-2060	165 ± 16	227 ± 16	300 ± 26	370 ± 32
	2080-2099	155 ± 16	400 ± 41	647 ± 58	871 ± 80
Multi-model maximum	Baseline	1082 ± 232	1082 ± 232	1082 ± 232	1082 ± 232
	2021-2040	221 ± 20	275 ± 32	349 ± 37	275 ± 30
	2041-2060	397 ± 31	524 ± 52	587 ± 54	529 ± 44
	2080-2099	431 ± 48	842 ± 77	1213 ± 97	1491 ± 103
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	241 ± 25	276 ± 32	369 ± 36	312 ± 32
	2041-2060	420 ± 35	524 ± 57	588 ± 55	556 ± 53
	2080-2099	398 ± 43	855 ± 80	1285 ± 104	1625 ± 115

Table 10: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Turakina region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

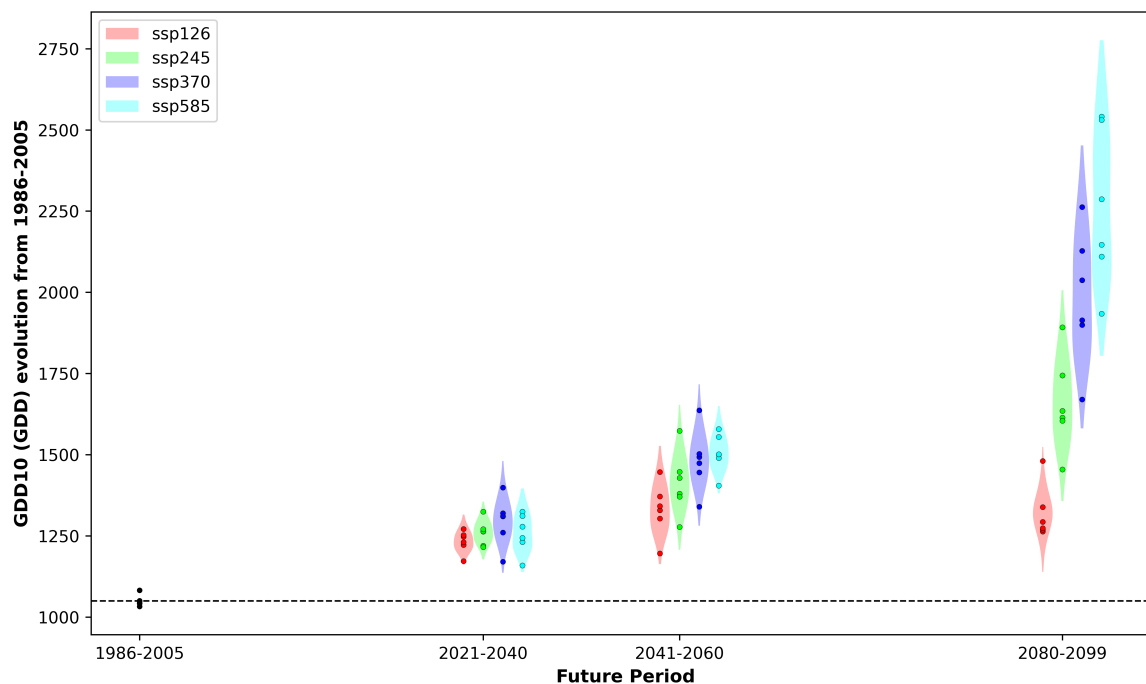


Figure 27: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Turakina region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

15.11 Region: Puketoi ki Tai

Area: 966.64 km²

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 28. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 11. Projections for annual growing degree days (base 10°C, GDD10) in Puketoi ki Tai show a robust increase over the 21st century relative to the 1986–2005 baseline. Multi-model means indicate that GDD10 increases by roughly 200–270 GDD in 2021–2040, rising to 320–510 GDD by 2041–2060, with scenario divergence becoming pronounced by 2080–2099: SSP1-2.6 projects an increase of about 310 GDD, while high-emission scenarios (SSP3-7.0 and SSP5-8.5) suggest increases exceeding 1000 and 1280 GDD, respectively. This signal is visible in the figure, with violin plots and model points indicating consistent warming-related GDD gains, particularly under stronger emission scenarios.

There is high consistency across models within each scenario, evidenced by the relatively narrow inter-model spread in the near term, but by the end of the century inter-scenario agreement is lost (0% overlap), highlighting increasing scenario dependency. Spatial variability of GDD10 within Puketoi ki Tai remains moderate compared to the overall magnitude of projected mean change. IPCC likelihood language supports that it is extremely likely GDD10 will increase in all scenarios, with very high confidence in continued, emission-dependent rises through the century. The large increases under higher-emissions scenarios underscore strong scenario dependence, with implications for land-based productivity and ecology in Puketoi ki Tai.

15.12 Region: Middle Whangaehu-Whanganui

Area: 1816.56 km²



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1274 ± 139	1274 ± 139	1274 ± 139	1274 ± 139
	2021-2040	207 ± 13	234 ± 13	268 ± 14	238 ± 15
	2041-2060	319 ± 18	395 ± 20	470 ± 24	510 ± 28
	2080-2099	309 ± 19	669 ± 34	1009 ± 44	1281 ± 50
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	208 ± 13	236 ± 13	270 ± 14	240 ± 15
	2041-2060	322 ± 19	398 ± 21	473 ± 24	512 ± 28
	2080-2099	310 ± 19	675 ± 34	1017 ± 43	1295 ± 50
Multi-model minimum	Baseline	1253 ± 140	1253 ± 140	1253 ± 140	1253 ± 140
	2021-2040	140 ± 5	171 ± 7	127 ± 4	124 ± 4
	2041-2060	181 ± 11	238 ± 10	320 ± 14	381 ± 16
	2080-2099	256 ± 18	446 ± 20	666 ± 28	946 ± 38
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	157 ± 7	173 ± 9	155 ± 7	149 ± 8
	2041-2060	203 ± 13	246 ± 12	340 ± 18	403 ± 19
	2080-2099	196 ± 14	448 ± 23	719 ± 35	944 ± 43
Multi-model maximum	Baseline	1308 ± 138	1308 ± 138	1308 ± 138	1308 ± 138
	2021-2040	245 ± 17	304 ± 18	370 ± 18	298 ± 18
	2041-2060	426 ± 21	561 ± 28	608 ± 26	609 ± 37
	2080-2099	472 ± 27	890 ± 38	1256 ± 44	1581 ± 60
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	266 ± 19	307 ± 19	400 ± 22	344 ± 24
	2041-2060	458 ± 25	571 ± 32	624 ± 31	637 ± 39
	2080-2099	434 ± 25	933 ± 46	1357 ± 53	1694 ± 58

Table 11: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Puketoi ki Tai region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

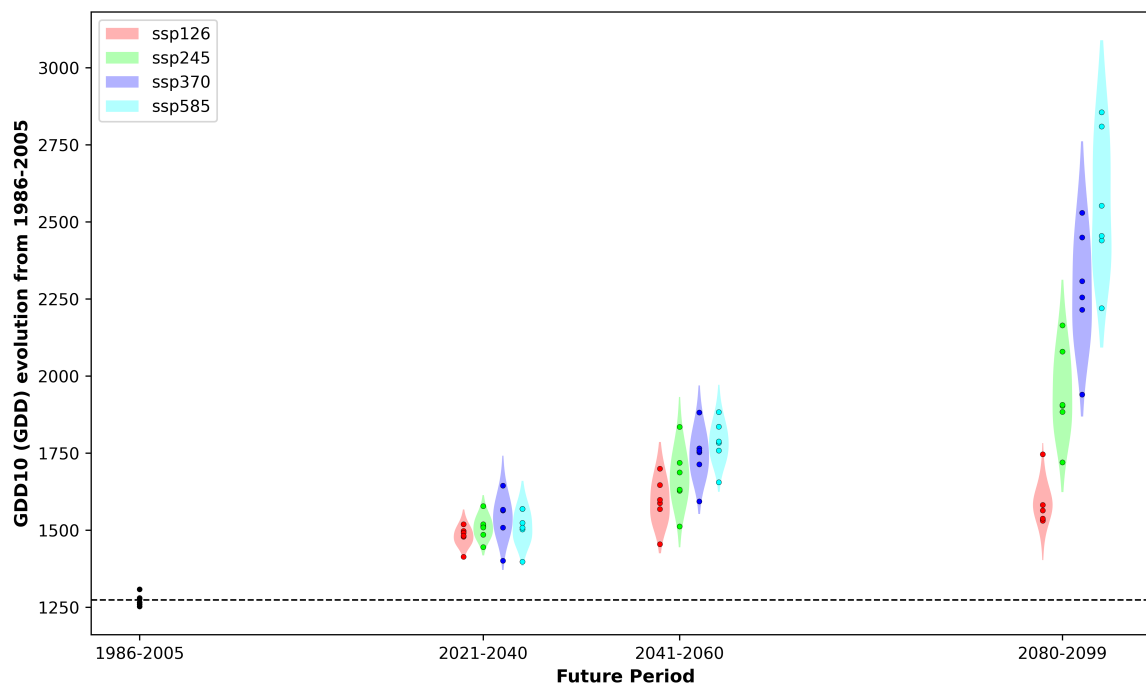


Figure 28: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Puketoi ki Tai region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).

A plot of the evolution in growing degree days (base 10°C) from the 1986-2005 baseline over this region is shown in Figure 29. The statistical summary of projected changes in growing degree days (base 10°C) over this region is shown in Table 12. Projections for annual growing degree days above 10°C (GDD10) in Middle Whangaehu-Whanganui indicate substantial increases across all scenarios, relative to the 1986–2005 baseline. By 2021–2040, increases in GDD10 are likely (medium confidence), with multi-model means spanning 176 to 239 GDD depending on scenario. Increases continue through the century, with moderate scenario divergence emerging after mid-century. By 2041–2060, mean increases range from roughly 273 (SSP1-2.6) to 439 GDD (SSP5-8.5), and by 2080–2099, from 258 (SSP1-2.6) to 1173 GDD (SSP5-8.5), showing a clear dependence on emissions pathway.

Inter-model agreement is very high on the direction of change (virtually certain increase), but the magnitude is scenario-dependent and diverges strongly by late century. Scenario agreement drops from 37% (2021–2040) to 0% (2080–2099), reflecting reduced cross-scenario certainty in the magnitude under different emissions.

Spatial variability across the region is moderate, with increasing standard deviation later in the century and under higher-emissions scenarios, indicating elevated local variability. The magnitude of increases projected for GDD10 would significantly extend the region’s effective growing season, with greatest change expected under SSP5-8.5. In summary, it is extremely likely that Middle Whangaehu-Whanganui will experience substantial increases in GDD10, with the most pronounced changes under higher emissions scenarios and in the latter half of the century.



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	956 ± 198	956 ± 198	956 ± 198	956 ± 198
	2021-2040	176 ± 16	204 ± 18	239 ± 19	203 ± 18
	2041-2060	273 ± 23	350 ± 31	418 ± 35	439 ± 38
	2080-2099	258 ± 25	588 ± 51	909 ± 68	1173 ± 83
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	177 ± 16	205 ± 18	241 ± 19	205 ± 18
	2041-2060	276 ± 23	353 ± 31	421 ± 35	441 ± 38
	2080-2099	259 ± 25	593 ± 51	919 ± 69	1190 ± 83
Multi-model minimum	Baseline	939 ± 199	939 ± 199	939 ± 199	939 ± 199
	2021-2040	115 ± 7	165 ± 11	116 ± 6	103 ± 7
	2041-2060	137 ± 13	224 ± 13	276 ± 24	344 ± 23
	2080-2099	203 ± 21	391 ± 35	600 ± 46	855 ± 66
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	129 ± 10	155 ± 10	136 ± 10	119 ± 9
	2041-2060	157 ± 16	222 ± 17	288 ± 25	356 ± 29
	2080-2099	147 ± 16	385 ± 38	625 ± 52	840 ± 71
Multi-model maximum	Baseline	988 ± 201	988 ± 201	988 ± 201	988 ± 201
	2021-2040	213 ± 17	262 ± 27	338 ± 27	265 ± 24
	2041-2060	386 ± 27	503 ± 42	569 ± 45	515 ± 42
	2080-2099	413 ± 38	820 ± 63	1183 ± 79	1456 ± 86
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	233 ± 22	263 ± 27	359 ± 30	303 ± 28
	2041-2060	411 ± 32	502 ± 47	572 ± 46	538 ± 49
	2080-2099	382 ± 35	830 ± 66	1254 ± 88	1585 ± 98

Table 12: The statistics of the projected changes in growing degree days (base 10°C) in units of GDD over the Middle Whangaehu-Whanganui region. Baseline values are shown in absolute units while values for each of the three future periods are shown as changes from the baseline. This variable is not seasonal and so the results shown here are for the whole year. The uncertainties on each value are indicative of the *spatial spread* of the values across the region, not the inter-model spread. The inter-model spread should be diagnosed from the multi-model minimum (and its associated 5th percentile row) and the multi-model maximum (and its associated 95th percentiles).

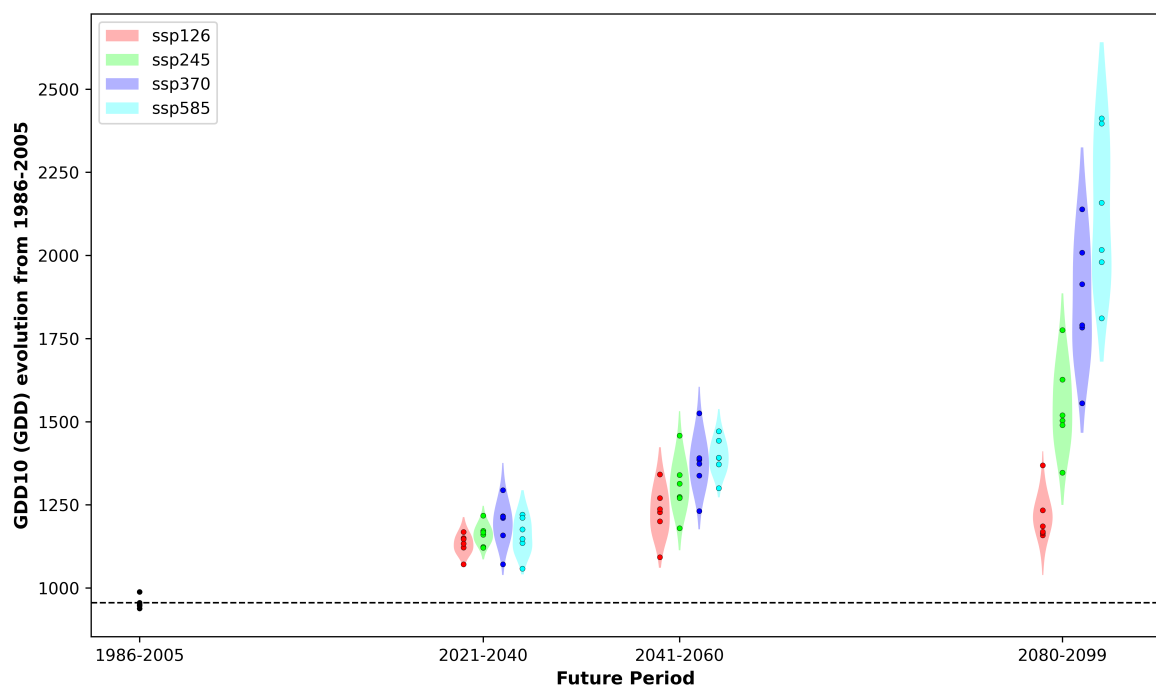


Figure 29: The time evolution of growing degree days (base 10°C) from the 1986-2005 baseline in units of GDD over the Middle Whangaeu-Whanganui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in different colours. The change values for future periods, extracted from the data files, are offset by the *mean* of the baseline model data. The original of this figure can be downloaded [here](#).