

Climate Analysis of Growing degree days (base 5°C)

Horizons Region, New Zealand

Climate Change Projections from CCAM-Downscaled CMIP6 Simulations

Prepared by

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For

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1 Executive Summary

Growing degree days (GDD5, base 5°C) is a key agroclimatic variable, widely used for estimating and optimising crop development and maturity, agricultural scheduling, and ecological modelling. Increased GDD5 generally signals a longer and warmer growing season, enabling more rapid plant development but also potentially altering pest dynamics, water use, and crop selection. This synthesis draws on an ensemble of six CMIP6 climate models, dynamically downscaled with the Conformal Cubic Atmospheric Model (CCAM), to characterise past, present, and projected changes to GDD5 in the Horizons region under four plausible emissions scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5) through the 21st century.

All models unanimously project regionally widespread and substantial increases in GDD5, with changes becoming progressively more pronounced over time and as atmospheric greenhouse gas concentrations increase. By late century, under high emissions (SSP5-8.5), projected mean increases in GDD5 are above 1400 GDD, representing a major extension of the thermal growing season. Even under low emissions (SSP1-2.6), increases are robust and significant. Model agreement on baseline GDD5 is exceptionally high ($R^2 > 0.99$), and future projections retain strong spatial coherence, especially at broader regional scales. Magnitude and local spatial details introduce moderate uncertainty, mainly due to inter-model differences, topographic complexity, and climate sensitivity.

While absolute increases are typically largest in lower-elevation and coastal subregions, proportional changes are significant everywhere. The robust upward trend throughout the ensemble and all scenarios—especially the virtual certainty of increased GDD5—carries important implications for agricultural productivity, potential heat-related stress, changing crop suitability, pest and disease pressures, and broader ecosystem processes. Adaptation measures, such as shifts in cultivar choice, altered planting and harvest dates, and enhanced pest management, will be essential to capitalise on positive opportunities and mitigate adverse impacts. Sub-reports underpinning these findings, which include detailed regional breakdowns, seasonality, and percentile-based uncertainty fields, are available on request to Bodeker Scientific.

2 Introduction

Growing degree days (base 5°C, GDD5) provide a cumulative measure of thermal time above a threshold needed for plant growth and are a central metric in agricultural and ecological planning. GDD5 integrates temperature observations over the growing season, offering a meaningful assessment of climate suitability for crop and pasture development, pest life cycles, and phenological events. With climate change, understanding how GDD5 is distributed now and how it might evolve under different emissions pathways is critical for guiding both adaptation and mitigation responses in the Horizons region and beyond.

The objectives of this synthesis report are multifold:

1. To describe the historical spatial distribution of GDD5 across the Horizons region,
2. To assess projected future changes in GDD5 under multiple emissions scenarios,
3. To examine how projected changes evolve through the 21st century,
4. To evaluate the degree of agreement among models,
5. To identify sub-regions most vulnerable to changes, and
6. To characterise the uncertainty inherent in such projections.

Such an approach enables a comprehensive, science-based understanding of the likely trajectory for GDD5 in the region. The baseline characterisation provides a crucial reference for interpreting projected shifts and for contextualising the extent and spatial footprint of change. Scenario-based analysis across four key SSPs



contextualises results for the broadest plausible range of future GHG emissions, from strong mitigation (SSP1-2.6) through to continued high emissions (SSP5-8.5).

Projected increases in GDD5 have wide-ranging implications: crop calendars may shift, potentially favouring new crop species or varieties but also raising risks of heat stress and higher evapotranspiration demands. Pests and diseases may evolve or expand their ranges. The likelihood of double cropping or longer growing seasons will increase but so too will water demand and, in some cases, yield threats from excess heat. Adaptation options should include review of cultivar and crop selection, forward-looking shifts in planting/harvest timing, investment in irrigation and frost protection infrastructure, greater integration of pest and disease modelling, and regular climate change risk assessment embedded in regional agricultural strategies. By integrating strong modelling evidence with scenario planning, this synthesis aims to provide the regional knowledge foundation necessary for proactive and resilient land management approaches.

3 Understanding Growing Degree Days (base 5°C)

Growing degree days (GDD), particularly GDD5 (base 5°C), is a measure of heat accumulation, used extensively in agronomy, horticulture, and ecology to estimate growth, development rates, or maturity of plants and invertebrates. GDD is calculated as the sum over a defined period (commonly the growing season) of the daily mean temperature in excess of a set threshold—here, 5°C. Mathematically, for each day:

$$\text{GDD5} = \max[(T_{\text{max}} + T_{\text{min}})/2 - 5^{\circ}\text{C}, 0]$$

where T_{max} and T_{min} are the daily maximum and minimum temperatures, respectively. Daily values are summed over the period of interest, providing an annual (or seasonal) total that reflects the cumulative thermal opportunity for growth or development.

Drivers of changes in GDD5 are fundamentally linked to surface air temperature, but also affected by shifts in diurnal temperature range, length of growing season, and frequency of temperature extremes. Increases in mean temperature, reduced frost frequency, and earlier spring warming all tend to raise GDD5. Conversely, cool or wet summers, increases in cloudiness, or increased frequency of cold extremes could moderate GDD5.

In climate modelling, future GDD5 values are simulated using projected daily temperatures from global and regional climate models, which incorporate changes in radiative forcing, regional circulation, and land surface feedbacks. In this assessment, GDD5 draws from dynamically downscaled output (via CCAM) driven by six CMIP6 models, providing both spatially detailed and ensemble-based metrics. This framework enables quantification of GDD5 sensitivity to emissions, climate model formulation, and natural climate variability, and supports robust, regionally specific projections of thermal time.

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 simulations 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.

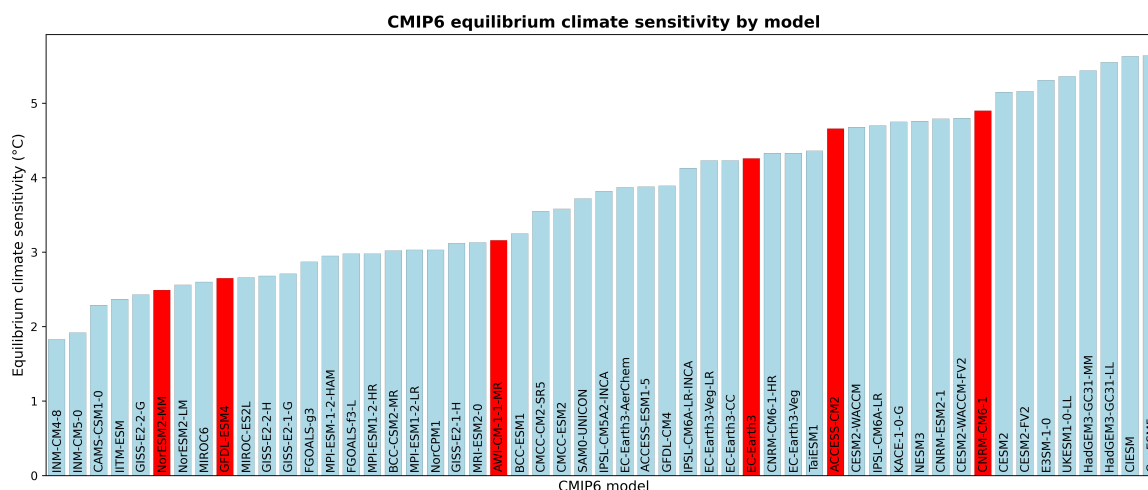


Figure 1: The location of the six guiding CMIP6 models across the full range of equilibrium climate sensitivities (ECSs) of all 53 CMIP6 models. The original of this figure can be downloaded [here](#).



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.
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 GDD5-specific report. Uncertainty probability density functions (PDFs) generated using this method appear in many of the plots shown herein.

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

The CCAM simulated growing degree days (base 5°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.

Within the baseline period (1986–2005), GDD5 shows a strongly spatially coherent pattern across the Horizons region, with values dictated primarily by latitude, elevation, proximity to the sea, and prevailing temperature regimes. Across all six CCAM simulations, there is exceptional agreement in both the absolute magnitude and the spatial distribution of GDD5, with R^2 values virtually certain to exceed 0.99 for spatial means—indicative of high model skill and limited structural uncertainty for the present climate.

GDD5 values are lowest in high-elevation areas such as the Volcanic Plateau and Upper Rangitikei, where annual totals cluster around 1,660–1,670 GDD. By contrast, lowland and coastal locations (e.g., Whanganui–Manawatū Lakes, Coastal Whanganui) average baseline GDD5 above 2,900–3,000, reflecting both lower elevations and milder maritime climate. This east–west and elevation-dependent gradient is apparent in all individual models. Subtle localised differences, often mapped to fine-scale topographic or coastal proximity, emerge in the difference-from-mean fields, but these deviations are minor (typically ± 40 GDD) and spatially diffuse. The narrow inter-model standard deviation and limited divergence in spatial structure further reinforce the reliability and reproducibility of the ensemble baseline climatology.

The spatial climatology also sets the stage for interpreting change, as heat accumulation and thus crop maturity windows, growing season length, and pest/disease development are currently tightly linked to geography across the region. Model spread at the baseline is largely inconsequential for regional means and only slightly

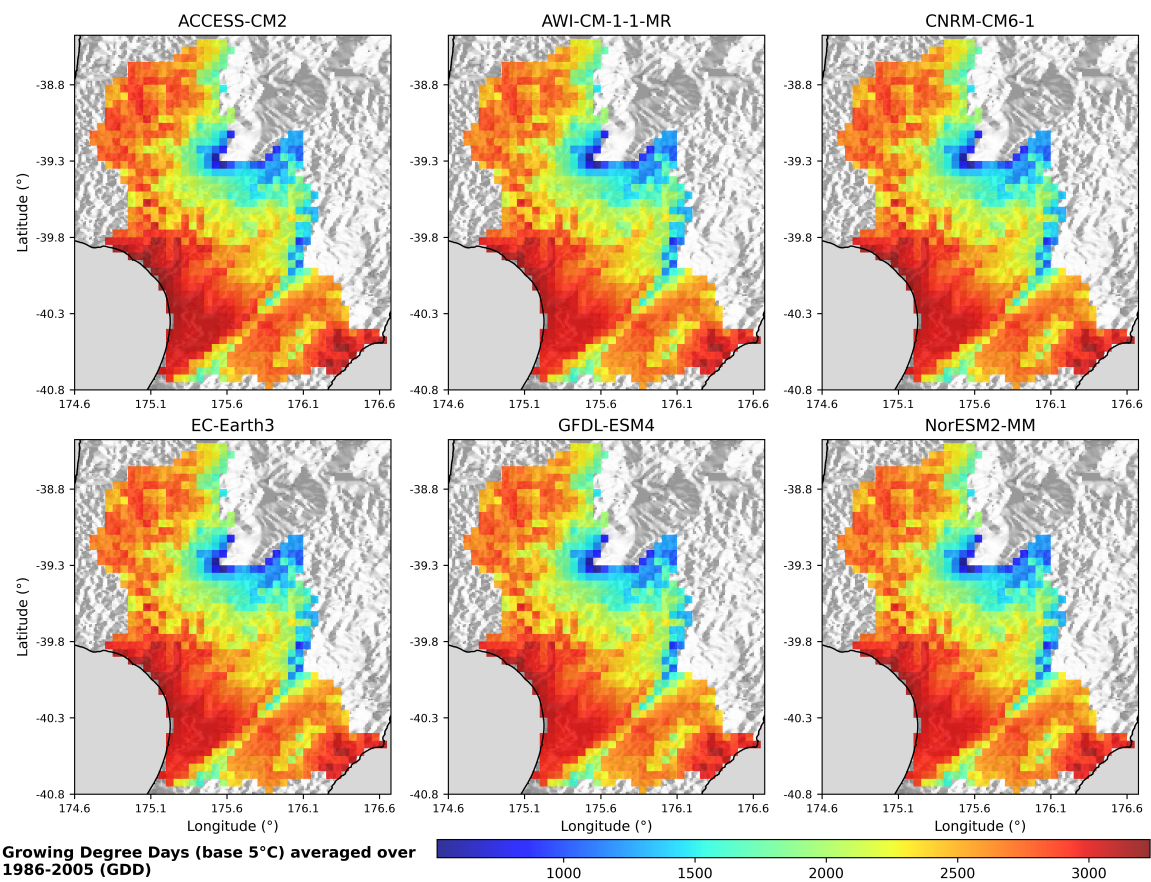


Figure 2: Growing degree days (base 5°C) fields as simulated by the CCAM model and averaged over the period 1986 to 2005. The original of this figure is available [here](#).

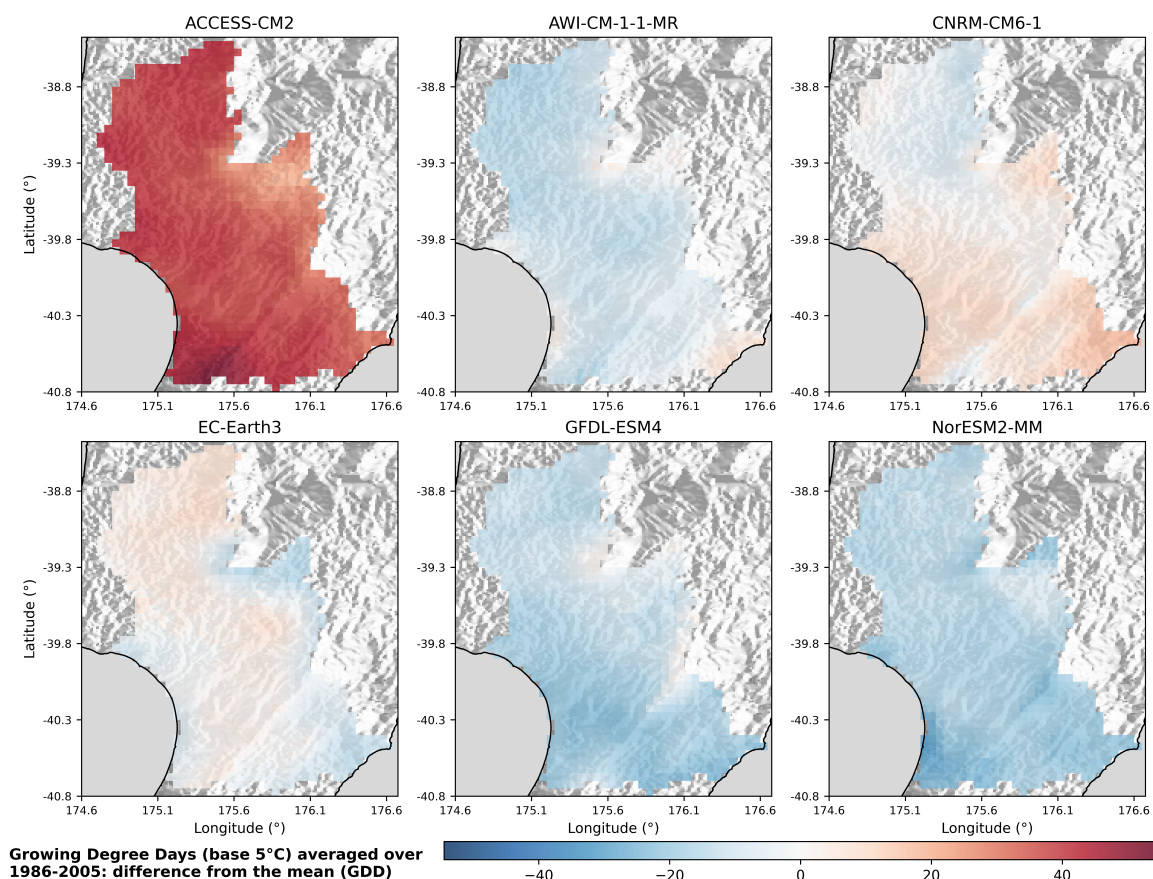


Figure 3: Differences from the multi-model mean. The original of this figure is available [here](#).

more notable in localised anomaly diagnostics, confirming that the dominant controls on current GDD5 are physical geography and not model-dependent details. The high reliability at baseline strengthens subsequent future projections and increases confidence in their spatial application across both landscapes and sectoral planning.

6 Near-Future Projections (2021–2040)

In the near-term period (2021–2040), ensemble projections for growing degree days (base 5°C; GDD5) in the Horizons region are robust and consistent in signalling increases across all emission scenarios and model realisations. This universal increase in GDD5 reflects an underlying warming climate, which is projected to result in longer and more thermally favourable growing seasons region-wide. The spatial pattern of change is generally coherent: increases are larger at lower elevations and in warmer, lowland parts of the region, while higher elevations experience smaller increases—a direct reflection of topographic influences on temperature-derived heat accumulation.

All models, across all scenario analyses, show a positive signal, with the magnitude of increases varying by scenario and model but remaining substantial compared to inter-model spread and year-to-year climate variability. Model means indicate regional average increases in GDD5 typically between about 220 and 310 GDD, depending on the scenario, with an ensemble mean standard deviation of approximately 40–90 GDD. This provides very high confidence (IPCC: extremely likely) in the direction of change, though some ongoing uncertainty in magnitude persists at finer spatial scales and in complex terrain.

Spatial coherence among models is moderate to high, as reflected in spatial R^2 values in the range of 0.45–0.51 for most scenarios; some lower spatial agreement is noted in scenarios and models where terrain or local



microclimate effects are less well resolved. Inter-model consistency is highest at regional scale and for the sign of change, while more caution is warranted in interpreting the magnitude and local spatial detail. All plausible emission trajectories maintain the robust overall regional signal of increasing GDD5, though the precise local outcomes should be interpreted as indicative, not deterministic. These findings, documented in detail in the 12 supporting sub-reports (available on request to Bodeker Scientific), provide a basis for adaptation planning in climate-exposed sectors.

6.1 SSP1-2.6: Extremely likely widespread, moderate regional increases

The projected changes in growing degree days (base 5°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.

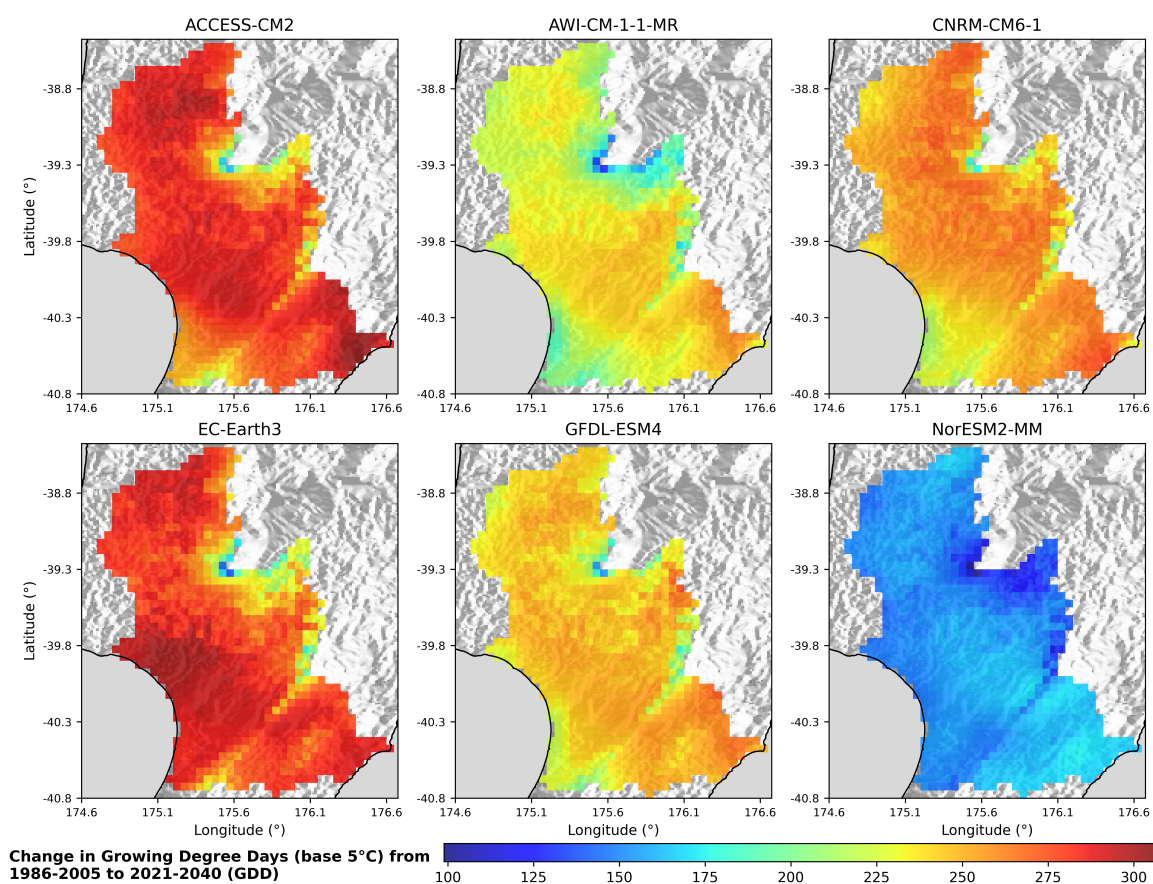


Figure 4: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2021-2040 under the SSP1-2.6 scenario. The original of this figure is available [here](#).

Under the low-emissions SSP1-2.6 scenario, the near-term period (2021–2040) projects a clear and regionally consistent increase in GDD5 across the Horizons region. The ensemble mean increase is close to 240 GDD, with individual model means ranging from roughly 150 to 280 GDD. All six models agree on the direction of change, and none project decreases in any part of the region, supporting extremely likely confidence (IPCC). Larger increases are observed in lower-elevation and coastal areas, with more muted gains in upland and complex terrain.

Spatial agreement is robust at the regional scale, with moderate agreement seen for spatial distribution (mean spatial $R^2 \approx 0.51$), but less so in the local detail, where topography can introduce variability. Despite this, inter-model spread is moderate; one model (NorESM2-MM) projects a stronger increase than the others, but this does not fundamentally alter the regional message. The calculated inter-model standard deviation in regional mean change is around 40 GDD. The range between ensemble minimum and maximum is typically from 140



up to 460 GDD for local extremes, reaffirming the strength of the warming signal when compared to historical variability.

Minimum and maximum ensemble values serve as practical, though slightly conservative, proxies for the 5th and 95th percentiles, respectively, when estimating local uncertainty (with $R^2 \approx 0.89$ for both min–P5 and max–P95 regressions). In summary, the near-term period under SSP1-2.6 signals a widespread, robust increase in GDD5, with local uncertainties present mainly where topography complicates the climate response.

6.2 SSP2-4.5: Very likely widespread, moderate regional increases

The projected changes in growing degree days (base 5°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.

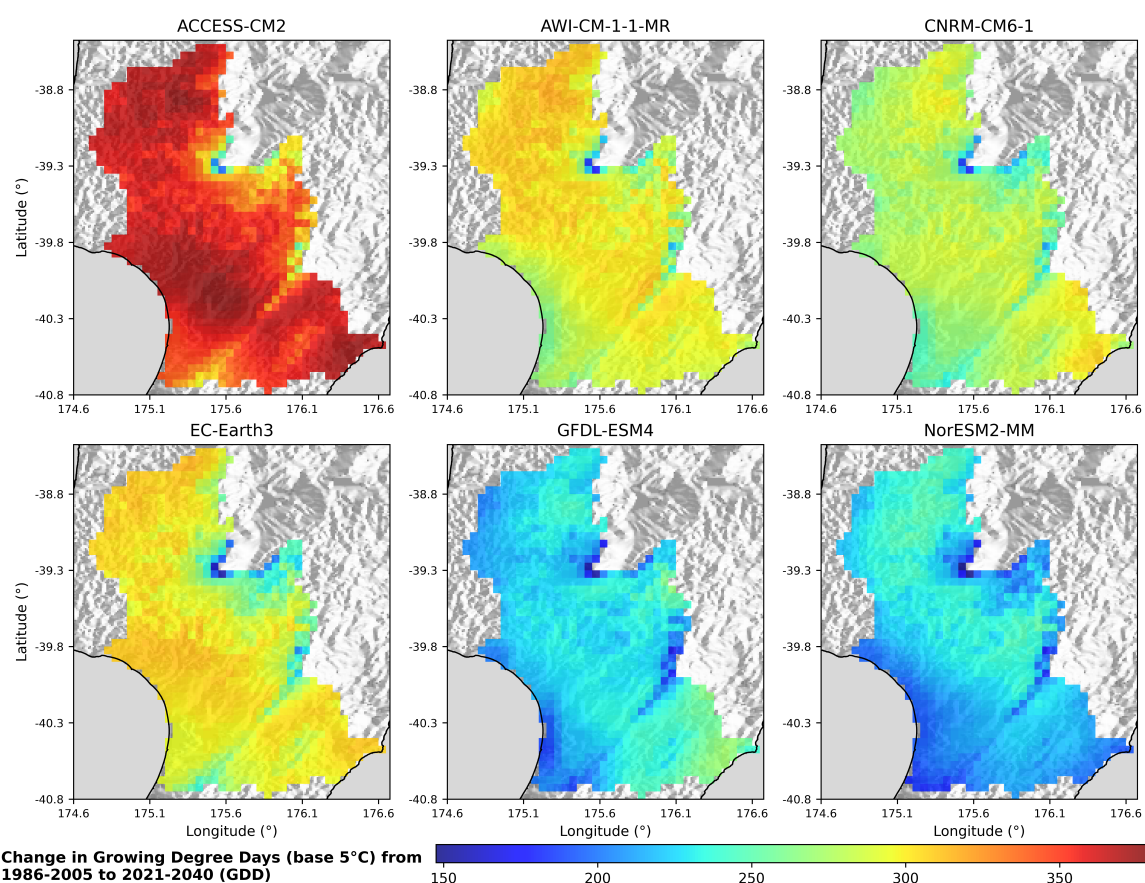


Figure 5: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2021-2040 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

For the intermediate emissions scenario SSP2-4.5, the near-term period (2021–2040) indicates a very likely and spatially widespread increase in GDD5 for all parts of the Horizons region. The model ensemble projects a typical regional mean increase of around 280 GDD, with individual model means ranging from approximately 220 to 350 GDD. All models exhibit a positive trend, and minimum modelled values for change in most sub-regions consistently exceed 180 GDD.

The spatial distribution of change is largely congruent across models: the western lowlands and low-elevation plains experience the largest increases, while higher elevations and the eastern hill country show lower but still marked increases. Inter-model spread for regional means is about 45 GDD, and spatial standard deviation within models ranges from 15 to 22 GDD, suggesting moderate uncertainty. Average spatial R^2 across models is 0.45, indicating reasonable but not perfect coherence in local spatial structure amongst models, with



individual models varying substantially in their spatial patterning accuracy.

Uncertainty analysis indicates that while maxima can serve as robust proxies for the 95th percentile of change ($R^2 \approx 0.99$), minima under-represent the 5th percentile, signalling a need for caution when using the lower bound as a confidence limit. Across all sub-regions, the direction and scale of the increase are robust, and the likely outcome (IPCC) is a substantial and regionally uniform enhancement of thermal time available for plant growth. Differences in scenario outcome for SSP2-4.5 versus lower-forcing trajectories are primarily evident in the somewhat larger scale of change and slightly wider ensemble spread.

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

The projected changes in growing degree days (base 5°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.

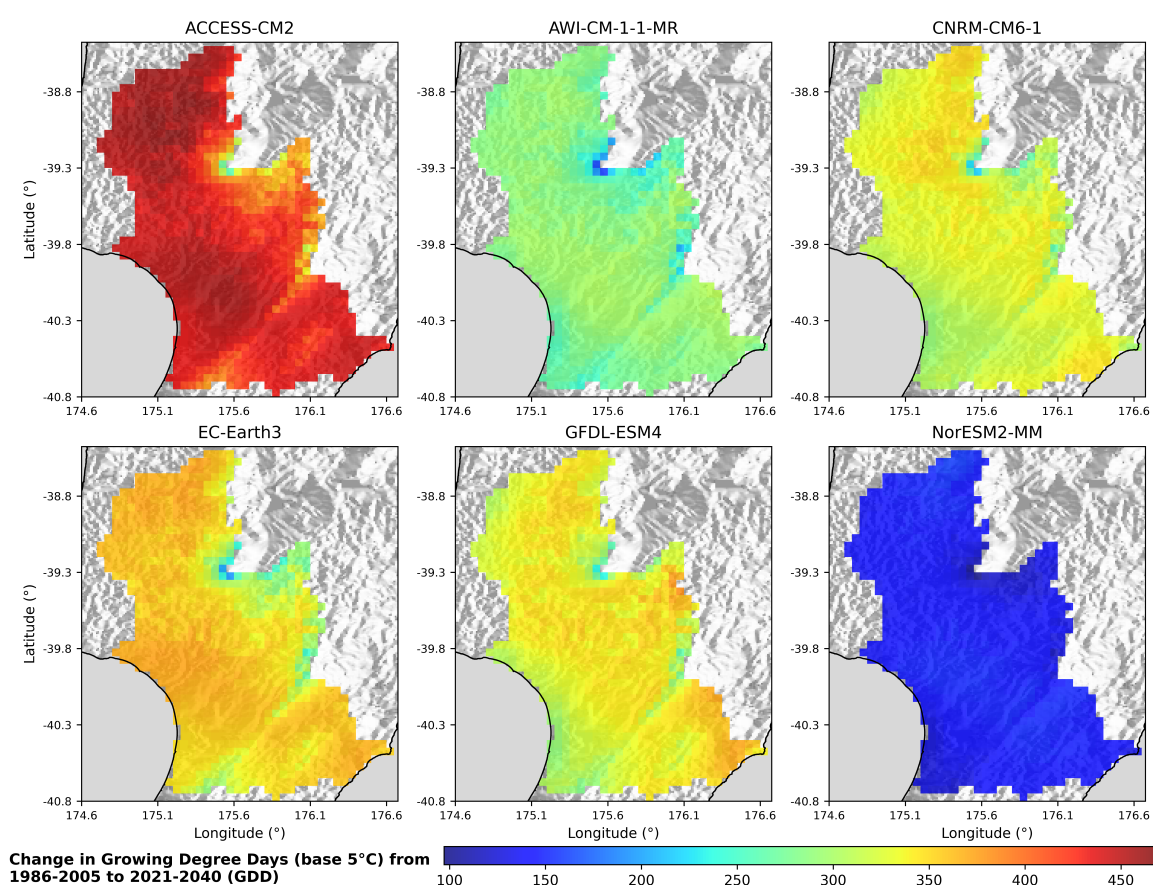


Figure 6: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2021-2040 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

Under SSP3-7.0, a higher emissions scenario, the near-term period (2021–2040) is associated with a larger and still spatially homogeneous increase in GDD5, supporting an extremely likely regional warming signal. Ensemble mean increases are about 310 GDD, with the range of individual model means spanning from about 140 to 435 GDD. All six models show a positive signal for all sub-regions, with only minor spatial variability in the magnitude of this increase relative to inter-model spread.

Spatial agreement remains strong regionally, with a mean spatial R^2 around 0.48 but individual models ranging from approximately 0.17 to over 0.9, reflecting some differences in model ability to capture topographic gradients and microclimate complexities. The largest increases occur in lowland regions, with higher-elevation areas showing smaller but still positive changes. The inter-model standard deviation in mean projected change



is approximately 88 GDD, but the entire ensemble lies well outside the bounds of historical variability in most regions. Minimum and maximum projections for each sub-region show that even conservative (5th percentile) estimates exceed 200 GDD, while upper bounds are above 400 GDD.

Uncertainty analysis demonstrates that the maximum ensemble value is a high-confidence proxy for the 95th percentile ($R^2 \approx 0.94$), while the minimum underestimates the 5th percentile and should be used more cautiously ($R^2 \approx 0.82$). In practical terms, the confidence in a warming-driven lengthening of the growing season is very high. This is mirrored in detail within the supporting sub-reports, which consistently endorse a virtually certain signal of widespread increase.

6.4 SSP5-8.5: Extremely likely widespread, moderate regional increases

The projected changes in growing degree days (base 5°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.

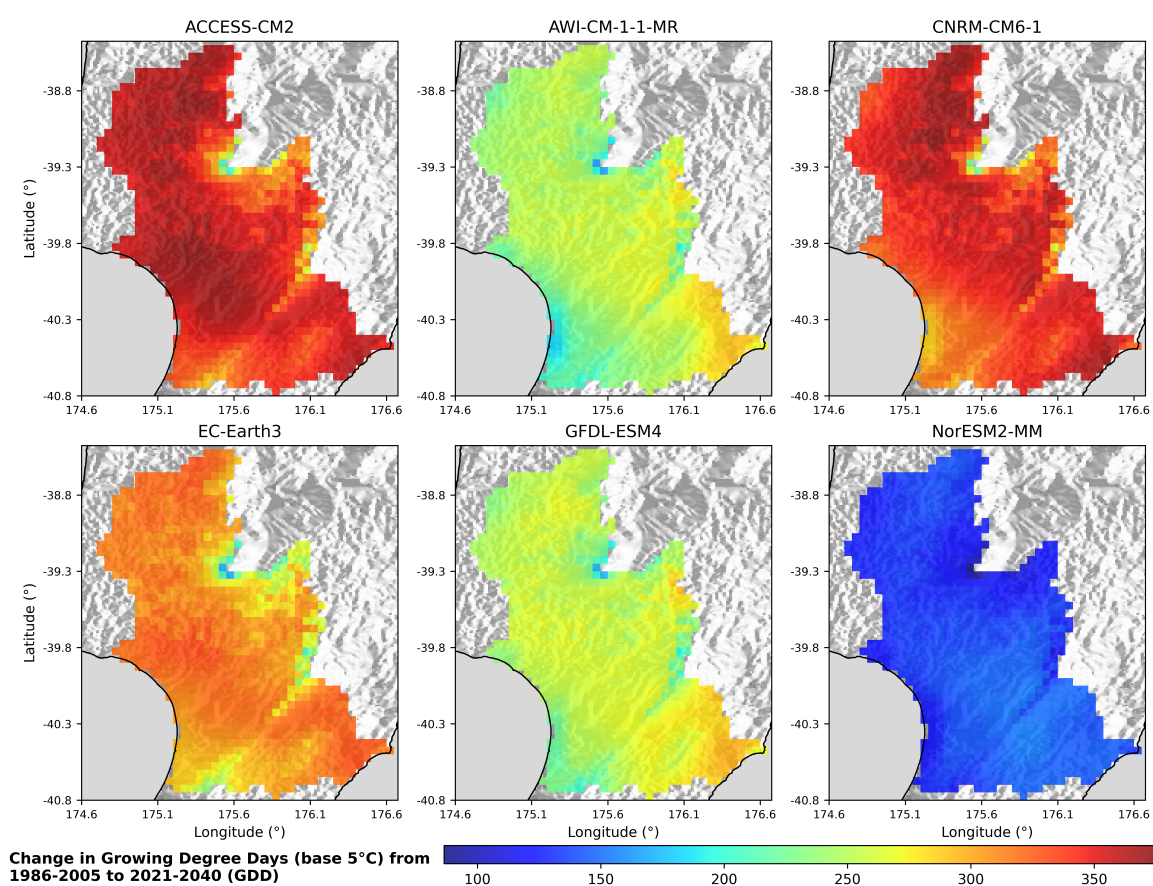


Figure 7: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2021-2040 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

The high emissions scenario SSP5-8.5 also projects an extremely likely, robust increase in GDD5 throughout the Horizons region for the near-term period (2021–2040). Ensemble mean increases are just below 275 GDD, and all individual model projections indicate a rise, with model means spanning from approximately 135 to 350 GDD. This projected increase is both spatially and quantitatively consistent, with higher elevations experiencing somewhat smaller gains than lowland and coastal locations, in line with temperature gradients.

Inter-model agreement is high for the sign and broad magnitude of change (spatial $R^2 \approx 0.43$ – 0.49), though there is more variation in the fine detail of spatial patterns (i.e., at sub-regional and farm scale). The standard deviation of model means is roughly 72 GDD, which is minor compared to the scale of change observed in the



ensemble mean.

Uncertainty analysis shows that maximum model projections serve as reliable indicators for the 95th percentile ($R^2 \approx 0.93$), but the minimum fields should not be interpreted as exact lower statistical bounds since they systematically underestimate the 5th percentile and thus the lower envelope of plausible outcomes. All data indicate that the probability of an increase in GDD5 in any part of the region is extremely likely.

Local variation in the magnitude of increase is present but modest compared with the overall regional trend. Even conservative (5th percentile) estimates for all sub-regions are well above zero, underscoring high confidence in the sign and broad spatial uniformity of GDD5 increases due to climate change.

6.5 Comparison Across Scenarios

Across all SSP scenarios in the near-term (2021–2040), there is extremely high confidence that the Horizons region will experience widespread and substantial increases in growing degree days (base 5°C). The direction of change is universally positive, and although some inter-model spread in magnitude and spatial details exists, all scenario analyses consistently indicate longer, warmer growing seasons. The differences among scenarios at this horizon are mainly in the exact scale of change, with higher-forcing pathways (SSP3-7.0 and SSP5-8.5) producing slightly larger increases than lower-forcing scenarios (SSP1-2.6). The spatial gradients of projected change align with established topographic influences, and there is only modest sensitivity of the results to emissions pathway in the near term. All minimum model projections remain positive, and the agreement in sign and substantial interquartile range supports a near-universal assessment of extremely likely increases across the region.

7 Mid-Century Projections (2041–2060)

By mid-century (2041–2060), climate model ensemble projections unanimously signal a strong, widespread increase in growing degree days (GDD5, base 5°C) across the Horizons region. The projected changes are larger than in the near term, and the regionally averaged increases become increasingly distinct among scenarios. The robustness of the signal is extremely high: every model, over every emissions scenario, produces positive change, highlighting a virtually certain warming-driven enhancement of the region's thermal growing season.

Spatially, projected increases are more pronounced in lowland and coastal districts, but even upland and cooler sub-regions show large, positive shifts in GDD5. This indicates a broad extension in the length and intensity of the growing season across all landscapes. Inter-model agreement is very high for the sign and core magnitude of change—supported by high mean spatial R^2 values (commonly 0.55–0.85)—though some uncertainty in the precise spatial structure remains, particularly in terrain-influenced areas.

Standard deviations among model mean changes are larger than in the near-term, rising to typically 75–110 GDD depending on scenario, but always small relative to the scale of projected increases. Uncertainty analyses reinforce that ensemble minima and maxima align very closely with the 5th and 95th percentiles, further supporting their use as pragmatic markers for lower and upper bounds (R^2 values generally above 0.9). Sub-regional analyses consistently show all areas experiencing robust increases, with only minor differences in the magnitude and spatial coherence of change.

These outcomes, mirrored consistently across the 12 detailed sub-reports (available on request to Bodeker Scientific), indicate a strong, actionable signal for regional adaptation to changing thermal regimes.



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

The projected changes in growing degree days (base 5°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.

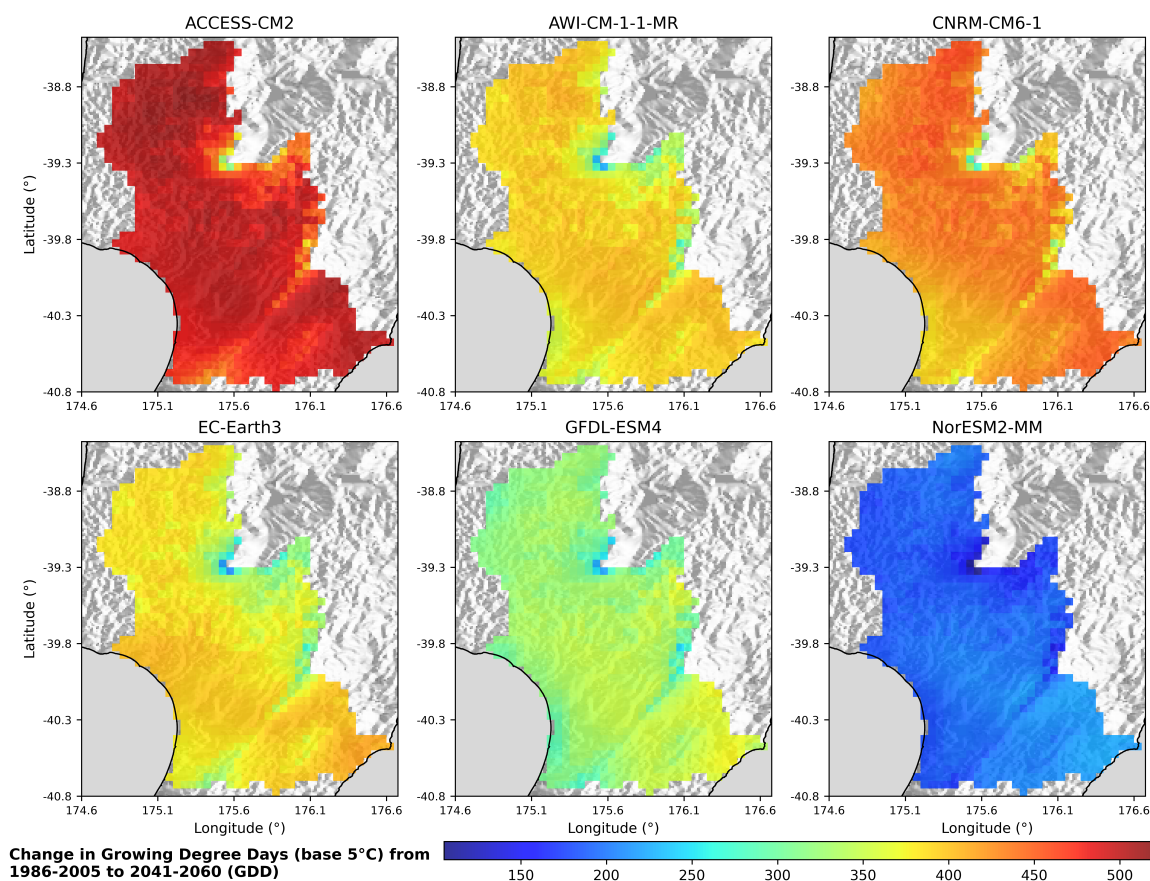


Figure 8: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2041-2060 under the SSP1-2.6 scenario. The original of this figure is available [here](#).

The low-emissions SSP1-2.6 scenario for mid-century (2041–2060) reinforces the robust, regionally coherent warming signal in GDD5. All models project increases, with typical regional mean changes of approximately 370 GDD, and model means spanning 200–490 GDD. Model agreement is extremely high in the sign of change and strong in spatial pattern, though there is moderate inter-model spread in absolute magnitude (standard deviation of regional means ≈ 90 GDD).

Spatial patterns are consistent across models, with lowland and coastal sub-regions experiencing the largest increases and elevation modulating absolute values. Sub-regional differences are minimal: most areas are projected to gain between 345–390 GDD. The lowest GDD5 increases are seen in highland areas, but no sub-region shows likely decreases. Spatial R^2 values average around 0.55, confirming moderate model consensus on the fine-scale spatial expression of change, but with strong agreement in region-wide totals.

Uncertainty quantification demonstrates that ensemble minima and maxima are very strong proxies for the 5th and 95th percentiles of change ($R^2 \approx 0.96$ for both). This means the full suite of models brackets plausible regional outcomes, with narrow uncertainty on the direction and magnitude of projected change. Even the most conservative projections show significant increases in GDD5. In summary, the signal for increased GDD5 is extremely likely, regionally coherent, and robust across sub-regions—offering clear guidance for sector planning and adaptation.



7.2 SSP2-4.5: Extremely likely widespread, substantial regional increases

The projected changes in growing degree days (base 5°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.

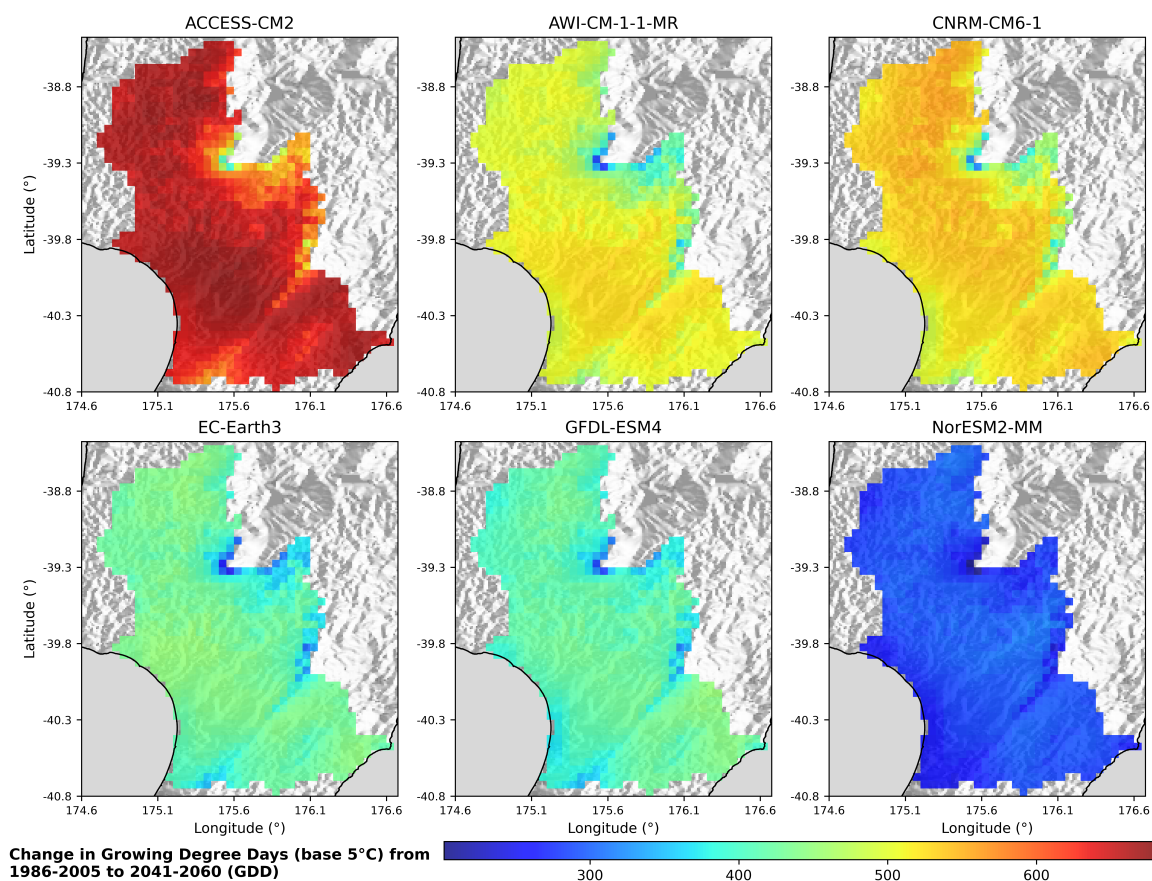


Figure 9: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2041-2060 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

Under the mid-range scenario SSP2-4.5, mid-century (2041–2060) projections show a robust and spatially extensive increase in GDD5. The regional mean increase is approximately 465 GDD, with model means ranging from about 290 to 650 GDD. All models consistently signal an increase, and spatial structure of the change exhibits high agreement, particularly in the lowland and coastal parts of Horizons, though elevated areas still experience pronounced gains.

Spatial coherence is confirmed by high spatial R^2 values (mean ≈ 0.65), supporting uniformity in the underlying regional response, with little intra-regional divergence. Sub-regional analyses reveal increases tightly clustered around 450–480 GDD, with standard deviations for mean changes typically less than 40 GDD, and narrow percentile (P5–P95) spreads reinforcing high inter-model consensus (extremely likely outcome). Coastal regions and basins see the largest increases, but even historically cool areas display substantial enhancement in GDD5, supporting the interpretation of a widespread, actionable warming signal.

Uncertainty analysis shows the minimum and maximum ensemble values closely track the 5th and 95th percentiles of change ($R^2 \approx 0.89$ for min/P5 and 0.99 for max/P95), supporting their use for bounding uncertainty. Sectoral and spatial implications are clear: all areas will see major warming-driven gains by mid-century. No model projects a decrease, giving very high confidence for planners and stakeholders.



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

The projected changes in growing degree days (base 5°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.

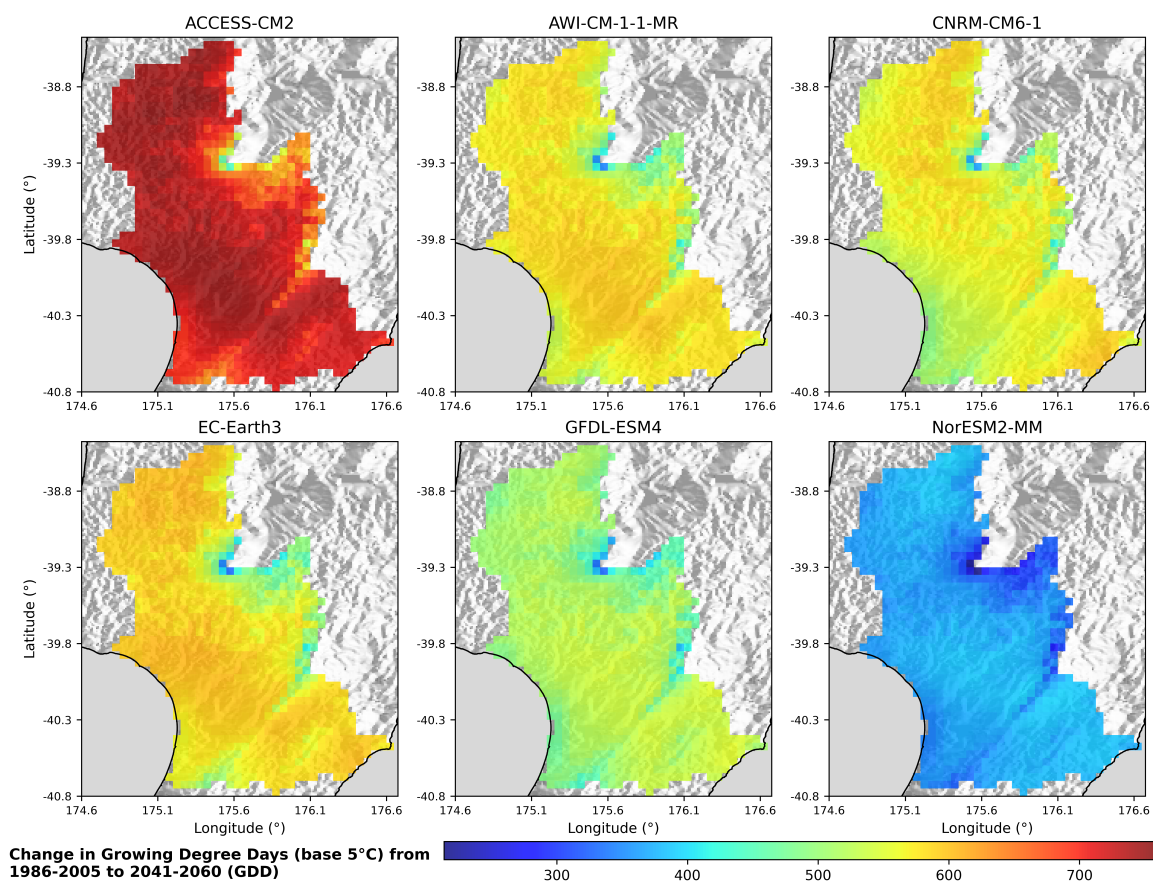


Figure 10: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2041-2060 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

Mid-century (2041–2060) under SSP3-7.0 brings a substantial, spatially consistent increase in GDD5 to the Horizons region. All models project positive changes, with regional mean increases close to 550 GDD, and individual model means spanning from 370 to over 700 GDD. The magnitude of projected change in the region robustly exceeds inter-annual variability and historical baseline differences.

Spatial R^2 averages approximately 0.73, providing strong evidence of consensus on where—and how much—the growing season will lengthen most. The dominant pattern is one of region-wide increases, particularly pronounced in the lowland and west, but upland and traditionally cooler regions also exhibit meaningful absolute changes. Sub-regional projections indicate increases between approximately 520 and 560 GDD for nearly all areas, with small spreads among models (typically under 10% of the mean value).

Estimated uncertainty ranges are well captured by ensemble minimum and maximum, confirmed by their excellent alignment with the 5th and 95th percentiles ($R^2 \approx 0.95$ – 0.98). This supports the use of ensemble extrema as operational lower/upper bounds. No scenario or model member suggests decreases in any sub-region. These results support a robust, actionable conclusion for practitioners: by 2041–2060 under SSP3-7.0, the entire region will experience an extremely likely, strong warming-driven enhancement of the thermal growing season.



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

The projected changes in growing degree days (base 5°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.

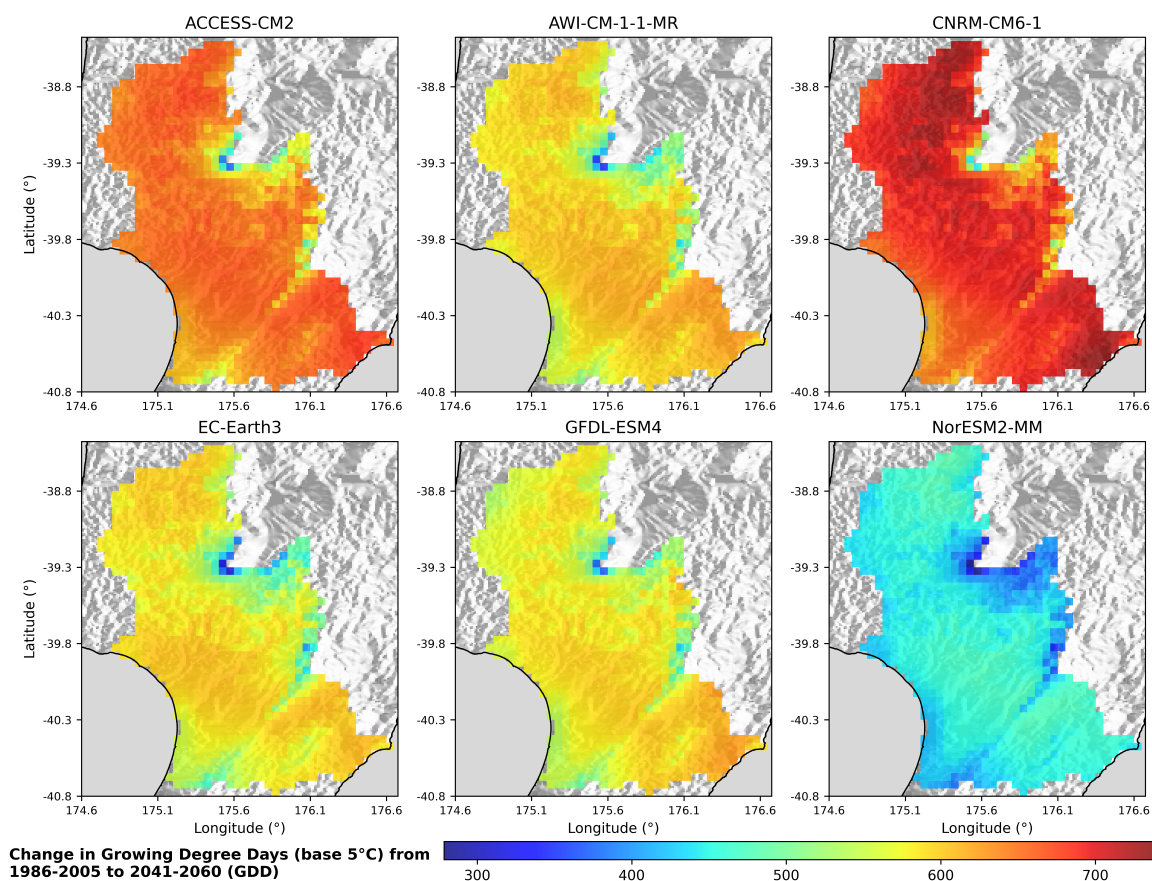


Figure 11: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2041-2060 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

The high-emissions scenario SSP5-8.5 projects a strong, regionally coherent rise in GDD5 by mid-century (2041–2060), with all models agreeing on the direction and broad spatial patterns of change. Model ensemble means place the average regional increase at around 585 GDD, with model means between 450 and nearly 685 GDD and only moderate spread (standard deviation ≈ 74 GDD).

Spatial coherence is high, as reflected by spatial R^2 coefficients averaging 0.82, confirming consistent patterns of stronger increases in lower elevations and the east/north, but with marked gains even in the coolest, highest sub-regions. No grid cell anywhere in the Horizons region is projected to see a decrease, making the probability of a region-wide increase in GDD5 extremely likely under this scenario.

Minimum and maximum projections align closely with the 5th and 95th percentiles ($R^2 \approx 0.95$ – 0.94 , respectively), validating their use as operational uncertainty bounds. Sub-regions uniformly display mean gains between 550 and 610 GDD, with narrow spreads across and within regions. The entire region can therefore prepare for a significant and robust increase in GDD5, with little model disagreement about the qualitative outcome, although fine local-scale variability remains an uncertainty. This powerful and spatially extensive regional warming signal forms a clear basis for long-term climate adaptation strategies.



7.5 Comparison Across Scenarios

At mid-century (2041–2060), all scenarios project extremely likely and robust region-wide increases in GDD5 for the Horizons region. While magnitude varies with emissions pathway—ranging from approximately 370 GDD for SSP1-2.6 to nearly 585 GDD under SSP5-8.5—the sign is universally positive. Inter-model and inter-scenario agreement is high for both spatial structure and magnitude, providing confidence in the direction and general size of change. All sub-regions and grid cells are projected to experience substantial increases, with ensemble uncertainty bounds tightly bracketed by model minima and maxima. Differences among scenarios become more pronounced than in the near-term, reflecting a growing influence of emissions trajectory, but the common outcome of widespread, substantial regional increase is extremely likely.

8 Late-Century Projections (2080–2090)

For the late-century period (2080–2099), model ensembles under all scenarios signal extremely likely and large increases in growing degree days (GDD5, base 5°C) across the Horizons region. Scenario divergence is most pronounced by this horizon, with regional mean increases under SSP1-2.6 still robust (mean change $\approx$ 355 GDD), but escalating to 1,440 GDD or more under SSP5-8.5, depending on scenario and location. This represents a transformative change in the region’s heat accumulation characteristics, with potential to significantly alter the length and productivity of the thermal growing season.

Spatial patterning remains consistent: the largest increases are found in lowland and coastal locations, with more moderate gains over upland and topographically complex terrain. The core regional signal is nearly universal, with all models and scenarios agreeing on positive, spatially extensive, and substantial increases. Inter-model agreement is excellent in the sign and broad magnitude of change (spatial R^2 for late-century projections are routinely above 0.8 in higher-forcing scenarios), though fine-scale local magnitude retains some uncertainty.

Uncertainty analyses confirm that ensemble minimum and maximum are pragmatic proxies for the 5th and 95th percentiles ($R^2 \gtrsim 0.96$). Even conservative projections show increases substantially outside historical variability, and all sub-regions exhibit coherent positive shifts. The regional coherence and scale of change are so pronounced that confidence in widespread, significant GDD5 increase is virtually certain under all plausible emission pathways. These findings, summarised in further depth in the 12 available sub-reports, reinforce the urgency of future-proofing land use and ecosystem management in the region.

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

The projected changes in growing degree days (base 5°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.

Late-century (2080–2099) projections for SSP1-2.6 maintain a robust, spatially coherent and extremely likely signal of increasing GDD5 across all sub-regions of the Horizons region. The ensemble mean increase is approximately 355 GDD, with model means typically between 290 and 540 GDD. All models support positive change, and spatial patterns are consistently determined by topography, with lowland and coastal sub-regions showing the largest gains, while higher areas see smaller, though still meaningful, increases.

Inter-model standard deviations for regional means are about 89 GDD, and spatial R^2 averages around 0.61, reflecting moderate to high consistency in spatial patterns across models. Sub-regional analyses indicate mean increases of 330–380 GDD, with minimal spread, and the minimum change projected by any model in any grid cell is still substantially positive, making any decrease in GDD5 virtually impossible within the modelled ensemble.

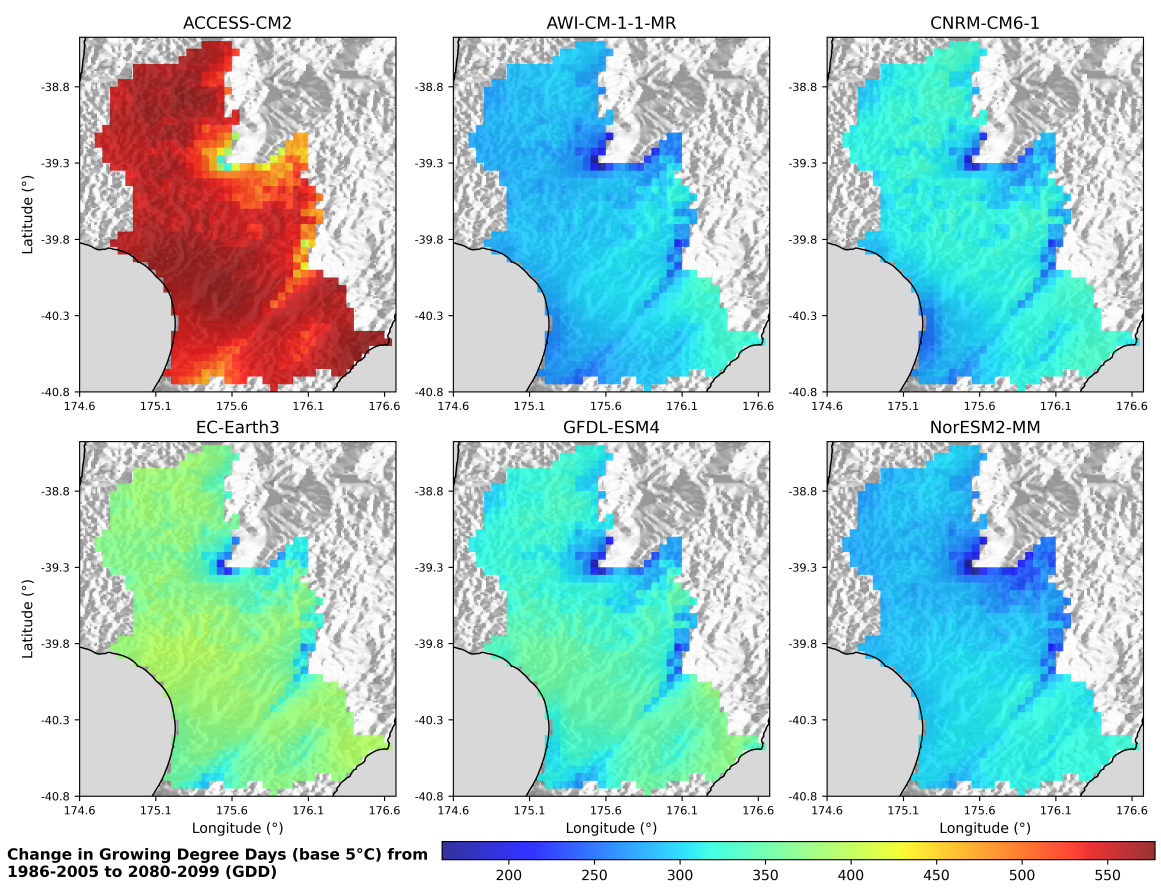


Figure 12: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2080-2099 under the SSP1-2.6 scenario. The original of this figure is available [here](#).



Uncertainty fields show ensemble minima and maxima closely aligned with the statistical 5th and 95th percentiles ($R^2 \approx 0.86$ –1.00), supporting very high confidence in using model spread as a proxy for range. The late-century GDD5 increase is thus extremely likely region-wide, even under a low-emissions scenario. Differences among sub-regions in either direction or scale of change are minor, meaning the entire region can expect a pronounced extension and intensification of the thermal growing season by century's end.

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

The projected changes in growing degree days (base 5°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.

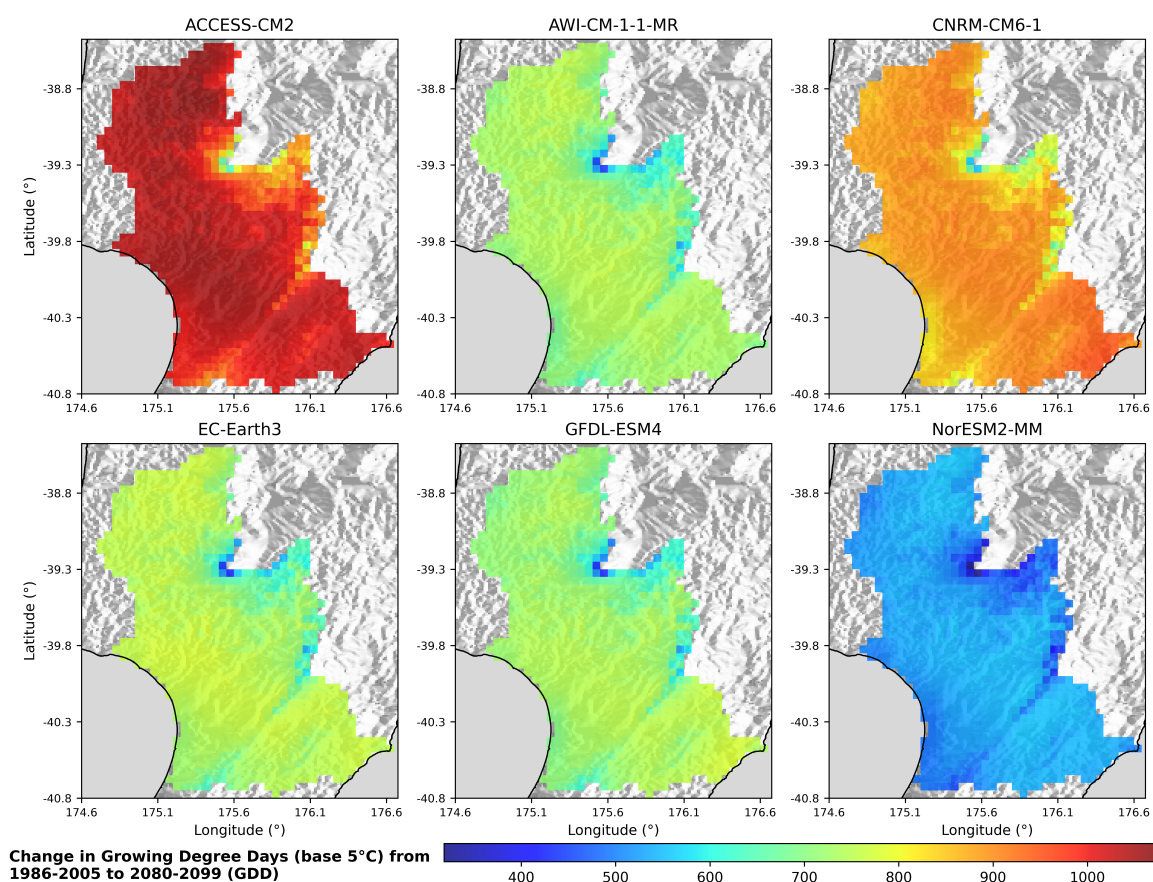


Figure 13: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2080-2099 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

For SSP2-4.5, late-century (2080–2099) projections show a robust and spatially extensive increase in GDD5, with model mean increases over the Horizons region averaging about 770 GDD, with a model range of approximately 530–1,000 GDD. All models demonstrate positive changes, and spatial coherence is excellent across the region, with spatial R^2 averaging 0.86 and all models above 0.75. Sub-regionally, mean gains lie between 720 and 790 GDD, and the smallest subregional increase is still substantial, supporting an extremely likely signal for widespread extension of the thermal growing season.

Uncertainty analyses confirm ensemble minimum and maximum as proxies for the lower and upper percentiles ($R^2 \approx 0.96$ –0.98). Sub-regional variability is modest compared with baseline spatial gradients, and intra-regional spread is lowest in warmer, lowland areas. The fewest increases occur in upland areas (e.g., Volcanic Plateau), but their percentage increase relative to baseline is large. No sub-region or grid cell displays a projected decrease in any model, making the outcome for late-century under mid-range emissions virtually certain: a strong and regionally coherent increase in GDD5, with only moderate uncertainty as to the specifics



of local change.

8.3 SSP3-7.0: Extremely likely widespread, significant regional increases

The projected changes in growing degree days (base 5°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.

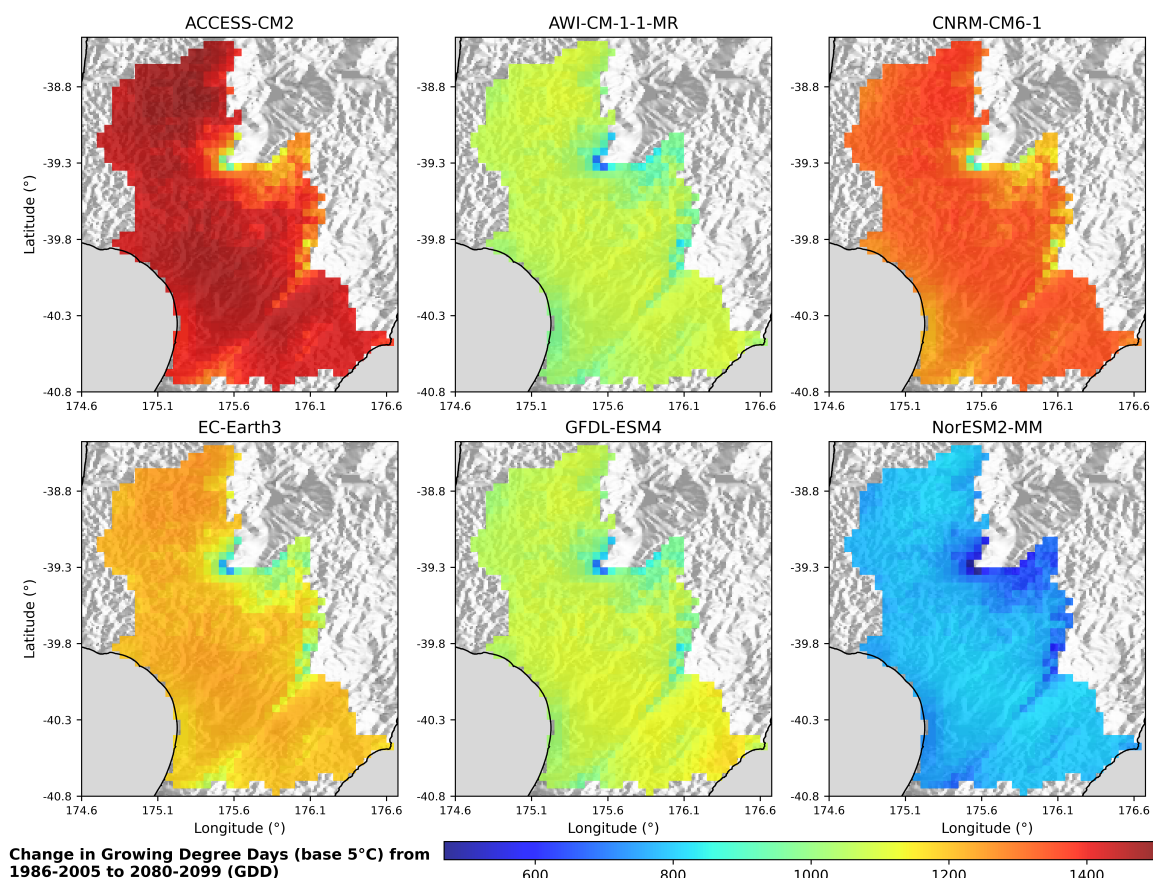


Figure 14: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2080-2099 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

The late-century period under the higher emissions scenario SSP3-7.0 projects extremely large increases in GDD5 for the Horizons region. The multi-model mean is just above 1,100 GDD, with individual model mean changes spanning approximately 770–1,420 GDD. Spatial patterning shows the largest changes remain focused in lowland and warm districts, but substantial increases occur everywhere, including highland sub-regions and those traditionally cooler, where relative change is even more pronounced.

Spatial coherence and inter-model agreement are very high (mean spatial $R^2 \approx 0.83$), and all models agree on the direction and qualitative scale of change. The standard deviation of model mean changes is about 207 GDD—substantial, but small compared to the overall signal, confirming high robustness. Even the most conservative model scenarios indicate large increases, with envelope bounds and percentiles confirming that all plausible outcomes are for region-wide, substantial gain in thermal time available for growth.

Sub-regional differences are apparent but do not disrupt the core regional signal: every sub-region gains more than 1,000 GDD on average, with the Volcanic Plateau displaying slightly greater spatial variability. Uncertainty analyses reinforce the extremely likely nature of this response. The late 21st century under SSP3-7.0 will see transformative, spatially extensive increases in GDD5—with high confidence in both magnitude and pattern.



8.4 SSP5-8.5: Extremely likely widespread, significant regional increases

The projected changes in growing degree days (base 5°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.

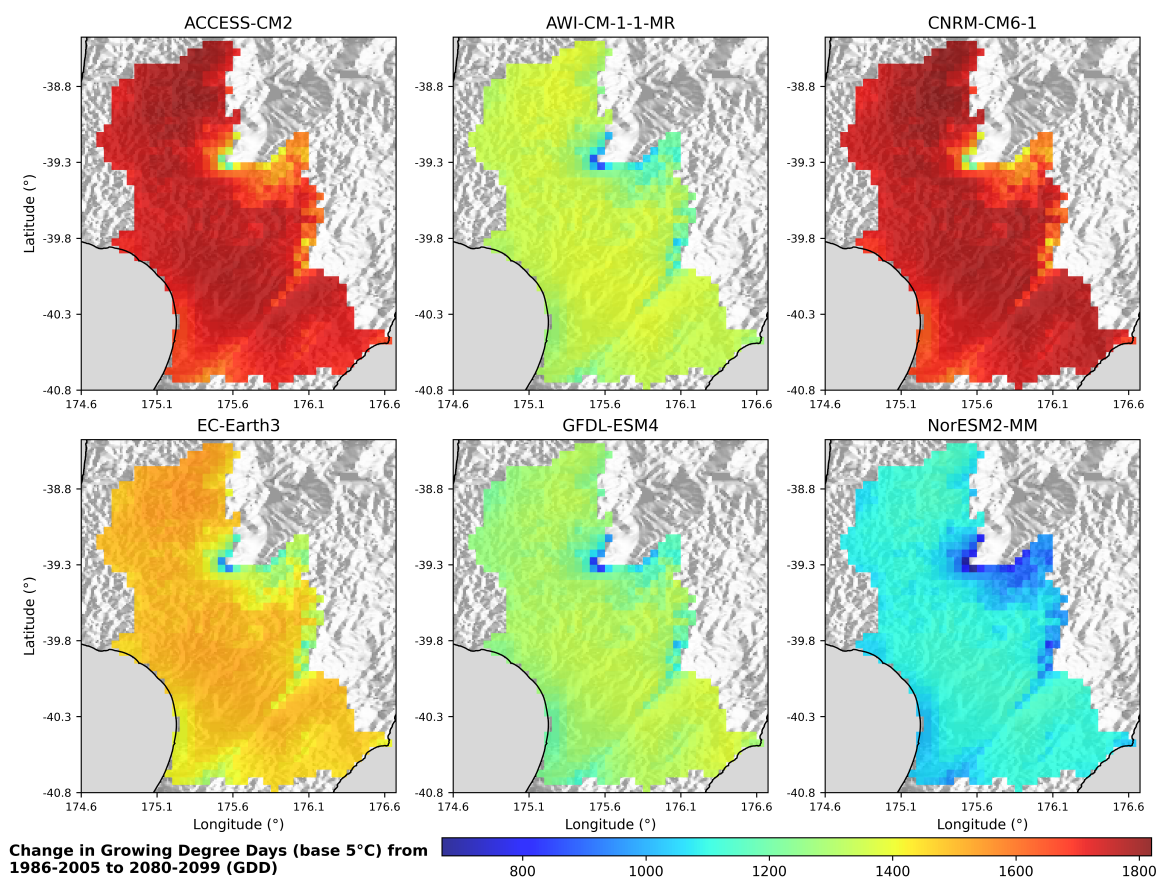


Figure 15: Projected changes in growing degree days (base 5°C) from 1986-2005 to 2080-2099 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

Under the highest emissions scenario SSP5-8.5, late-century (2080–2099) projections depict extremely large, spatially coherent increases in GDD5, with mean projected regional increases of about 1,440 GDD, and a spread among models of about 234 GDD. All models indicate positive, substantial changes, with high inter-model agreement (mean spatial $R^2 \approx 0.88$, range 0.71–0.99). Spatial distribution of change follows expected topographic gradients, with the highest increases in warmer, lower elevation regions and smaller (though still very large) increases at higher elevations.

Sub-regional projections show mean increases ranging 1,350–1,470 GDD, tightly clustered around the ensemble mean, and inter-model spreads remain modest for such large absolute changes. All models and percentiles (P5–P95) project increases well beyond historical variability. Minimum ensemble projections for every sub-region are well above zero, and even lower bound estimates (5th percentile) are robust proxies for smallest likely outcome ($R^2 \approx 0.98$). The magnitude of the projected increase is so pronounced that even inter-model uncertainty does not challenge the qualitative outcome: it is extremely likely that the region will experience a transformative increase in thermal growing days,

This result supports high-confidence planning for major agricultural and ecological adaptation across the region, as lengthened growing seasons and enhanced thermal resources will be a near-certain outcome by century's end under SSP5-8.5.



8.5 Comparison Across Scenarios

In the late-century horizon (2080–2099), all SSP scenarios project extremely likely and spatially extensive increases in GDD5, with regional mean changes ranging from about 355 GDD (SSP1-2.6) to 1,440 GDD (SSP5-8.5) or higher. The magnitude of warming-driven gains is scenario-dependent, and inter-model spread is evident, but the likelihood of region-wide increase is virtually certain throughout. Sub-regional differences exist in the absolute value but not in the sign, and ensemble minima and maxima remain excellent proxies for the tails of the projection distribution. The projected heat accumulation changes will transform the region's thermal landscape, supporting confidence in the need for future-oriented adaptation in land use, ecosystems, and agricultural planning.

9 Evolution of Regional Hot-spots

A full breakdown on projected changes in growing degree days (base 5°C) by region is given in the Appendices. What follows below is a brief overview of those results.

Hotspots for changes in GDD5 are generally found in the lower-elevation western and coastal sub-regions of the Horizons region, where both the baseline climatology and the projected increases are most pronounced. Across all SSP scenarios and future time periods, models display spatially coherent patterns of GDD5 response, and the locations of largest absolute change are persistent through the 21st century.

In the near term (2021–2040), the largest projected increases in GDD5 cluster in lowland and northern areas such as Whanganui–Manawatu Lakes, Coastal Whanganui, and Puketoi ki Tai. For these sub-regions, even under low emissions (SSP1-2.6), projected mean increases approach or exceed 240–290 GDD, with moderate inter-model spread. Higher-elevation and inland areas, such as the Volcanic Plateau and Upper Rangitikei, start with a much lower baseline (ca. 1,660 GDD) and register slightly reduced absolute increases (220–230 GDD), though the proportional rise there is still notable. This pattern of hotspots aligned with existing warm, low-lying locations persists through mid-century (2041–2060) and late-century (2080–2099) in every scenario, with the absolute signal becoming progressively steeper.

Under mid-century and late-century future periods, both the spatial extent and magnitude of hotspot increases escalate. By 2080–2099 under intermediate to high emissions (SSP2-4.5, SSP3-7.0, SSP5-8.5), projected increases in GDD5 routinely exceed 750–1,400 GDD in the warmest/widest sub-regions and still climb above 500 GDD even in the cooler plateau and interior northern ranges. The multi-model ensemble signals a very high degree of spatial agreement, especially in the direction of change: all models and scenarios show positive increases everywhere. The regional intensification of hotspots is linked both to local radiative forcing (warming) and to underlying geographic controls (e.g., topographically induced temperature fields, maritime moderation).

While the hotspots remain generally proportional to present-day warmest sub-regions, the spatial gradients may flatten slightly over time as cooler, more elevated areas catch up in absolute increases—though their baseline disadvantage ensures they never overtake established lowland and coastal hotspots in total thermal time.

It is rare for any model or scenario to indicate a location with either negligible or negative change; at worst, hotspot boundaries show moderate spatial uncertainty, sometimes broadened or contracted by up to 50–100 GDD between models. This spread is largest in the areas of steepest terrain or microclimatic variability, especially in the Volcanic Plateau and in localised river basins adjacent to upland divides. Nonetheless, the overwhelming consensus—even at model and grid-point level—is one of hotspot reinforcement: areas warmest now become even more favourable for growing season accumulation, while historically cooler sub-regions are not left behind but rather experience strong proportional gains.



For agricultural and economic planning, these evolving hotspots signal both opportunities (potential for expanded high-value crop or pasture productivity, longer growing seasons, double-cropping potential) and risks (increased evapotranspiration demand, greater pest pressure, heat stress for temperature-sensitive species). Adaptive management in these areas will become increasingly important as the magnitude of change pushes baseline thermal conditions well beyond current experience.

10 Understanding Projection Uncertainty

10.1 Why uncertainty matters

Uncertainty in climate projections is intrinsic and essential to interpreting and acting on GDD5 change for the Horizons region. Projections are not deterministic predictions, but span plausible outcomes conditioned by emissions trajectories, model structural differences, and internal variability of the climate system. Understanding the envelope of possible GDD5 futures is vital for risk management and adaptation decisions in sectors reliant on thermal time (agriculture, forestry, pest management, etc.).

In the near term (2021–2040), natural climate variability and model formulation are the predominant sources of uncertainty—while emissions pathway differences are still emerging, model spread can rival the forced signal locally, especially in areas of complex terrain. By mid-century and especially late-century, however, uncertainty becomes dominated by scenario choice, as the magnitude of warming under higher greenhouse gas concentrations increasingly diverges between low and high emissions pathways. Inter-model uncertainty remains important at all time horizons, but agreement on the direction of GDD5 change is exceptionally strong.

Recognising, characterising, and communicating the nature of this uncertainty means that stakeholders can prepare for a range of credible futures, identify early adaptation priorities robust to multiple outcomes, and update planning as new knowledge or emissions pathway evidence emerges.

10.2 Interpreting Ensemble Spread

The spatial and temporal spread among the six-model ensemble provides a direct measure of the uncertainty in GDD5 projections. High agreement among models (i.e., low standard deviation or high R^2) implies strong confidence in the projected direction, pattern, and magnitude of change, whereas significant divergence signals areas where caution and more flexible adaptation are warranted.

In the historical period, ensemble spread is extremely low: R^2 values for baseline spatial means routinely exceed 0.99, confirming that the physical controls underpinning present-day GDD5 are robustly resolved by all models. For future projections, agreement on the direction (an increase in GDD5) remains ubiquitous but the magnitude and local spatial detail introduce more uncertainty, particularly in upland or complex terrain. Spread between maximum and minimum model projections for a given period or scenario ranges widely (sometimes over 1,000 GDD under high emissions at century's end), but the ensemble mean and median values preserve the regional warming signal.

Percentile-based analysis (P5, P50, P95) and statistical diagnostics (spatial standard deviation, R^2 of ensemble spread fields) support interpreting the spread as a practical, meaningful characterisation of uncertainty for risk-based decision-making. Where models agree closely, confidence is high and adaptive decisions (e.g., cultivar change, irrigation investment) can lean on mean projections. Where the spread is wide, planning should emphasise flexibility, no-regrets options, and ongoing monitoring.



10.3 Minimum, Maximum and Percentile Fields

Minimum and maximum values within the model ensemble are often used as pragmatic lower and upper uncertainty bounds when assessing the full envelope of GDD5 change. In this study, regression analyses show that maximum values are extremely strong proxies for the P95 field (R^2 typically 0.98 or higher), meaning that decision-makers can treat the upper bound of the ensemble as a robust marker for high-end risk assessment. Minimum values are also strongly related to the P5 field, with R^2 usually at or above 0.95, although minima tend to slightly underestimate the true 5th percentile—so there is a conservative bias for low-end scenarios.

This relationship holds across periods, scenarios, and spatial scales, aided by the ensemble's size and the statistical structure of model spread. Nevertheless, users should be cautious about treating minima as exact surrogates for risk thresholds: the presence of an outlier or model-specific bias can lower the minimum further than is statistically warranted for a representative “worst case.” For formal likelihood interpretation, P5 and P95 fields should be preferred, but minimum and maximum values are suitable for rapid screening and communication of ensemble uncertainty in most practical contexts.

In summary, decision makers can reasonably use maximum ensemble values as high-confidence (extremely likely) upper bounds on projected GDD5 increases, but should interpret minimum values as slightly conservative, underscoring the need for flexibility and resilience in adaptation responses.

11 Equilibrium Climate Sensitivity and Growing degree days (base 5°C) Change

11.1 Understanding ECS

Equilibrium Climate Sensitivity (ECS)—the long-term response of global temperature to a doubling of atmospheric CO₂—partly explains differences among projected GDD5 changes from the six-model ensemble. Models with higher ECS values tend to yield larger temperature increases, which directly amplify GDD5 through increased mean temperatures, longer frost-free periods, and more frequent exceedance of the 5°C threshold.

That said, GDD5 is modulated by more than just mean temperature: changes in the diurnal cycle, variability, the seasonal profile of warming, and feedbacks linked to cloudiness, soil moisture, and local convection can all influence how efficiently increases in greenhouse gas concentrations translate to growing degree day accumulation. The relationship between ECS and the spatial/magnitude divergence in GDD5 is therefore strong at regional means and across high/low emissions scenarios but less deterministic at fine scales or in areas where model parameterisation of land–atmosphere exchange differs.

The pattern emerging in the Horizons region is consistent with broader findings: models with higher ECS (e.g., ACCESS-CM2, CNRM-CM6-1) project the largest GDD5 increases, while those with lower ECS (e.g., NorESM2-MM, GFDL-ESM4) tend toward the lower envelope of change. However, spatial detail and model structure maintain a secondary but important role—highlighting why ensemble-based projections, rather than reliance on any single model, remain the gold standard for regional climate synthesis.

12 Sources of Uncertainty

12.1 Emissions Uncertainty

By late century, emissions uncertainty (the choice and realisation of future atmospheric greenhouse gas concentrations) becomes the major driver of divergence in GDD5 projections. The contrast between outcomes under SSP1-2.6 (strong mitigation) versus SSP5-8.5 (continued high emissions) is dramatic: the difference in regional mean GDD5 increases is routinely 700 GDD or more, far outstripping inter-model spread at any sin-



gle scenario. In the near term (2021–2040), pathway divergence is less pronounced, but from mid-century onwards, emissions uncertainty dominates the range of plausible outcomes. This underscores the strategic importance of global mitigation efforts, as well as the need to plan for a broad envelope of future thermal conditions in the absence of clear and binding emissions commitments.

12.2 Climate Model Uncertainty

Climate model uncertainty arises from differing representations of fundamental climate processes—clouds, convection, surface energy exchange, and large-scale circulation. Although the six-model ensemble shows extremely high agreement on baseline GDD5 and robust consensus on the sign of future change, differences in projected magnitude and local spatial expression do remain, especially in areas of complex topography. Ensemble spread in means can reach over 200 GDD under high emissions by late century, and R^2 diagnostic values highlight moderate model-to-model coherence in spatial detail. As such, ensemble-based synthesis supports robust interpretation of regional trends, while reminding users to interpret site-specific or model-specific projections with ongoing caution.

12.3 Natural Climate Variability

Natural variability—arising from internal climate modes such as ENSO—remains a substantial contributor to uncertainty over the next several decades, especially for near-term projections (2021–2040). Year-to-year and decadal variability can obscure or exaggerate the forced warming signal, particularly at local and sub-regional scales. By late century, however, increases in mean GDD5 overwhelm natural variability in all scenarios, shifting the balance of uncertainty from internal climate noise to emissions pathway and model structural differences. For planning horizons beyond 2040, climate change signal to noise is high, justifying increased confidence in robust regional warming signals.

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

The synthesis of baseline and future GDD5 projections for the Horizons region supports several strong confidence statements using IPCC terminology. There is virtually certain confidence (>99% probability) in the model ensemble's characterisation of present-day GDD5 climatology and spatial distribution, as indicated by extremely high inter-model R^2 values and low ensemble spread. For future projections, direction of change is also virtually certain: every model, scenario, and future period examined projects widespread and substantial increases in GDD5, regardless of underlying uncertainties.

By mid-century (2041–2060) and especially by late century (2080–2099), there is extremely high confidence (extremely likely, >95%) that both the magnitude and spatial extent of GDD5 increases will be substantial under all emissions scenarios, with greatest absolute gains in lowland and coastal regions and largest proportional



changes in currently cooler areas. The spatial pattern of increases and the ranking of hotspots are extremely likely to be robust, even though some uncertainty persists in precise local values or microclimate detail. The largest uncertainties remain in the magnitude of change under specific high/low emissions trajectories and in the expression of local spatial detail, especially in upland or complex topography.

Confidence is slightly lower (likely to very likely) for estimates of uncertainty bounds at individual grid cells or in the fine detail of change, with model-specific and natural variability playing a more prominent role at these scales. Nevertheless, the ensemble mean and percentile-based fields provide a scientifically credible basis for adaptation planning. No sub-region is projected with even moderate likelihood of seeing a decrease in GDD5 under any scenario, highlighting the remarkable robustness of the warming signal in this context.

14 Conclusions

The synthesis of GDD5 projections for the Horizons region demonstrates an unequivocal, regionally consistent, and progressively intensifying signal of increased thermal accumulation, extending the growing season and altering land-use opportunities throughout the 21st century. This finding is robust to model choice, downscaling approach, and emissions pathway, with particularly strong increases projected under mid- to high-emissions futures. While absolute increases are maximal in lowland and coastal sub-regions, all areas—including the traditionally cooler and higher-elevation locales—are projected to experience substantial gains.

Model agreement on both the baseline and the direction of future change is exceptionally high, supporting virtually certain confidence in qualitative regional messages, and extremely high confidence in the quantitative outlook for long-term planning. Emissions uncertainty becomes the dominant driver of projection spread by mid-century and beyond, but for all plausible scenarios, a large and spatially pervasive increase in GDD5 is expected.

From a management perspective, these projected changes present both opportunities and risks: potential for increased and more diverse agricultural output, but also for greater pest and disease pressure, altered irrigation demand, and increased risk of heat-related or water-limited crop stress. Effective adaptation will require a proactive approach to crop variety selection, planting and harvesting schedules, water resource stewardship, and ecosystem support strategies. Ongoing monitoring and flexible, robust planning will be essential to ensure that regional stakeholders—not only in agriculture but also in conservation, forestry, and public health—are able to respond effectively to a rapidly evolving thermal regime.

15 Appendices

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

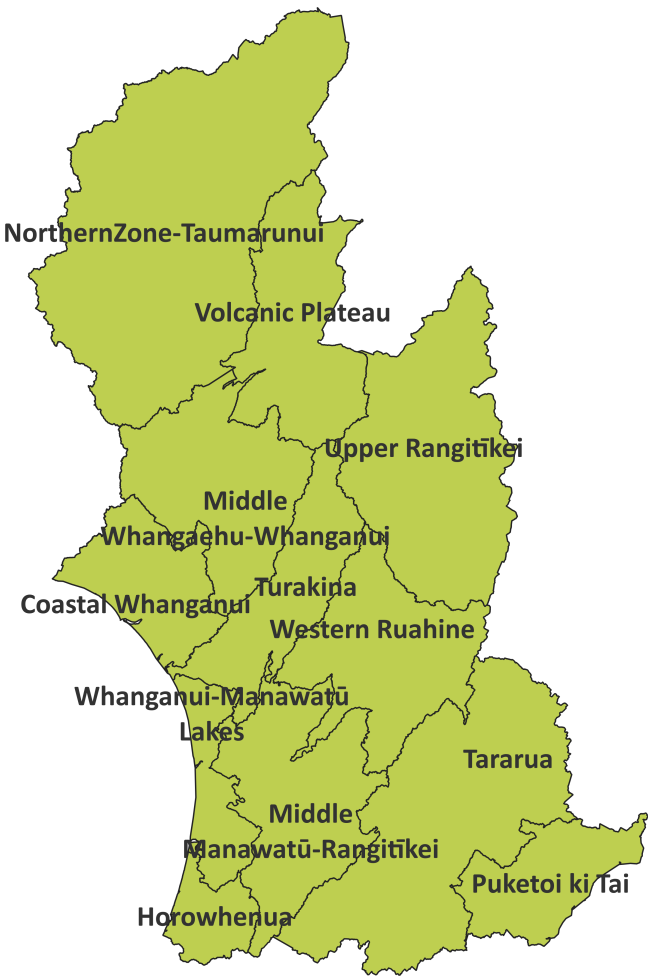


Figure 16: A map of the regions reported on in these appendices.

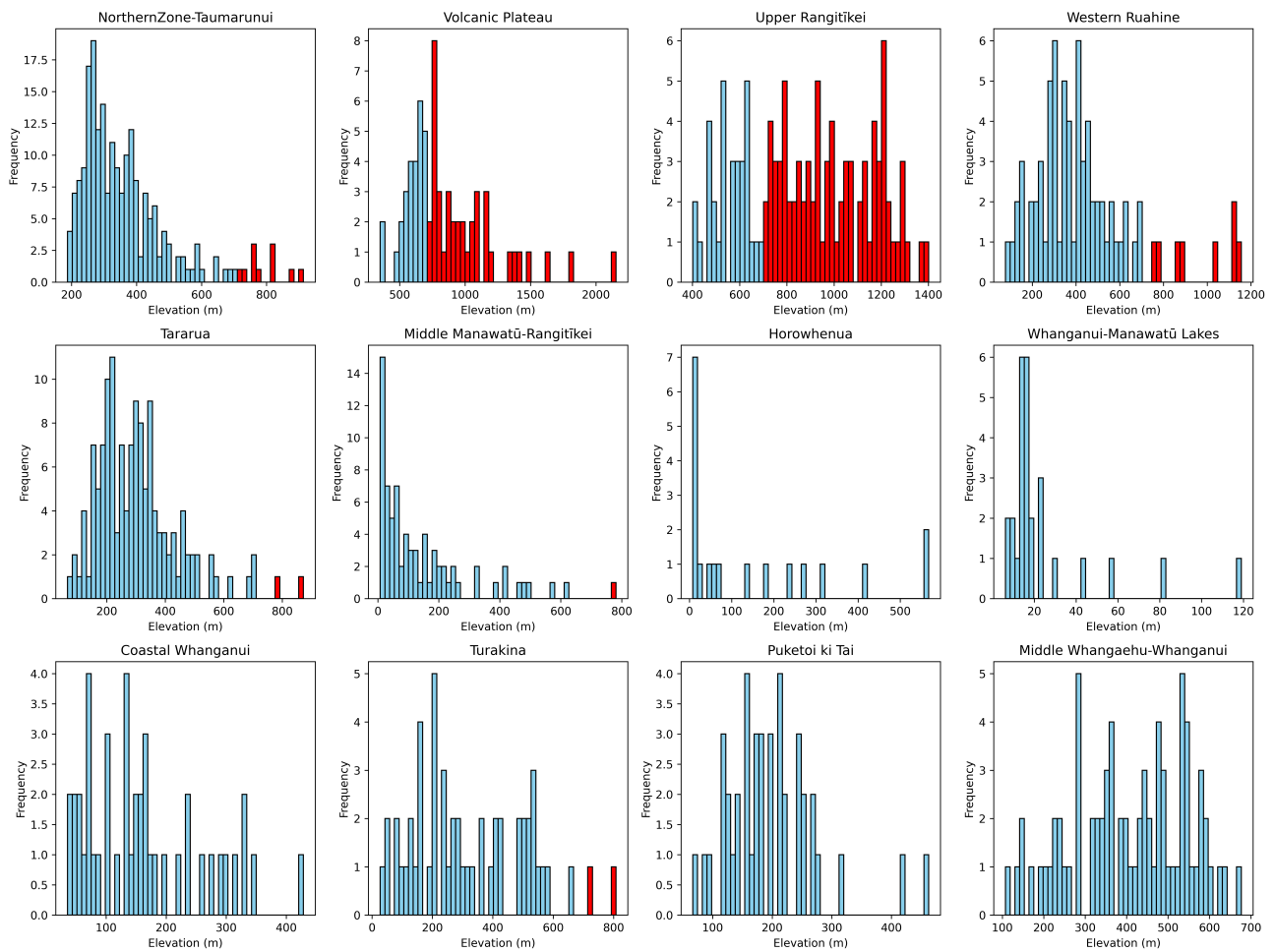


Figure 17: Histograms showing the number of CCAM model cells at each elevation. Histogram bars at elevations exceeding 700 m are shown in red. The original of this figure is available [here](#).



15.1 Region: NorthernZone-Taumarunui

Area: 5084.04 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region

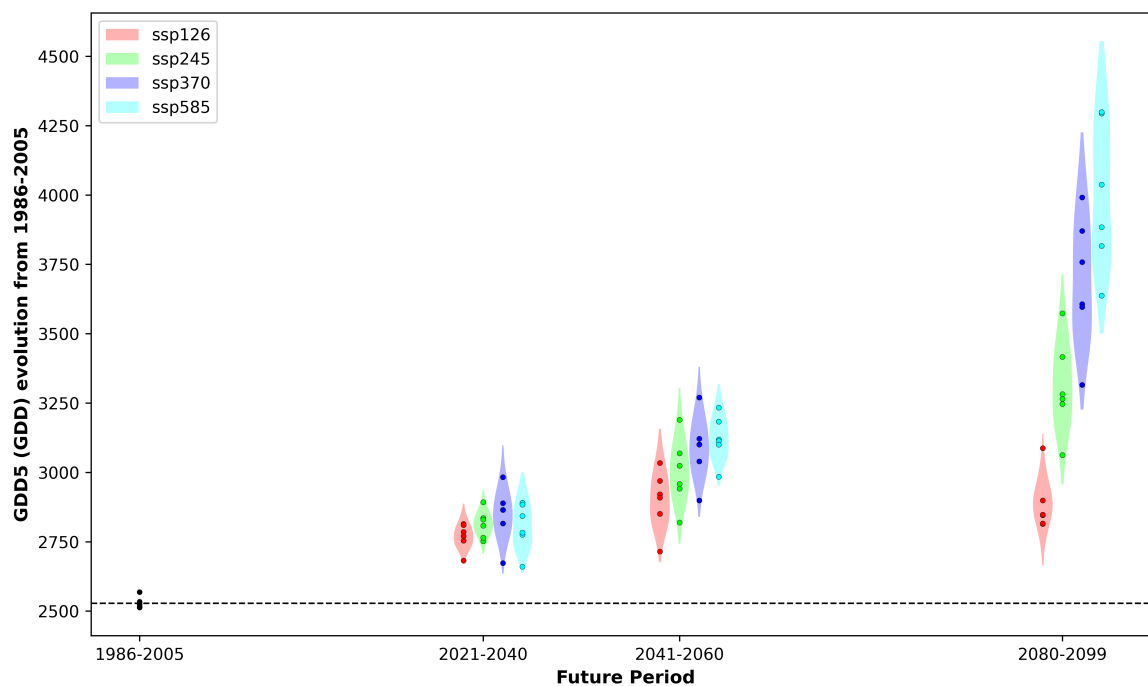


Figure 18: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the NorthernZone-Taumarunui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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](#).

is shown in Table 1. Projected annual growing degree days (GDD5) for the NorthernZone-Taumarunui region show a clear increasing trend across all future scenarios. Compared with the historical baseline (mean ~2528 GDD), all SSPs project likely increases throughout the 21st century. By 2021-2040, multi-model means show GDD5 increases of approximately 240–320, depending on scenario; by 2041-2060, this rises to increases of 370 under SSP1-2.6, up to 590 under SSP5-8.5. The divergence between scenarios becomes pronounced by 2080-2099, with SSP1-2.6 projecting a mean increase near 360 GDD, while the highest-emission scenario (SSP5-8.5) projects a very likely increase approaching 1470 GDD. This spread indicates extremely likely and substantial scenario dependence by late century.

Inter-model agreement is strong in the near term, with limited spread within each scenario and only modest separation between scenarios. However, agreement declines over time; scenario divergence increases (agreement across scenarios falls from 40% in 2021-2040 to 0% by 2080-2099), indicating that late-century GDD5 changes are very likely to depend strongly on emission pathways. Across scenarios and periods, intra-region spatial variability (stdv) remains low relative to the mean change, suggesting robust regional signals. Taken together, it is virtually certain that annual GDD5 will rise in NorthernZone-Taumarunui, with the magnitude of increase extremely likely to be driven by the emissions pathway, especially after mid-century.

15.2 Region: Volcanic Plateau

Area: 1664.65 km²



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2528 ± 290	2528 ± 290	2528 ± 290	2528 ± 290
	2021-2040	241 ± 6	286 ± 7	320 ± 7	278 ± 7
	2041-2060	372 ± 8	472 ± 10	560 ± 11	594 ± 13
	2080-2099	357 ± 8	780 ± 15	1162 ± 20	1467 ± 24
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	243 ± 6	287 ± 7	323 ± 7	282 ± 7
	2041-2060	376 ± 8	476 ± 10	564 ± 11	597 ± 13
	2080-2099	359 ± 8	786 ± 15	1174 ± 20	1486 ± 24
Multi-model minimum	Baseline	2512 ± 290	2512 ± 290	2512 ± 290	2512 ± 290
	2021-2040	154 ± 5	224 ± 9	145 ± 6	132 ± 5
	2041-2060	187 ± 7	291 ± 9	371 ± 10	456 ± 13
	2080-2099	286 ± 7	534 ± 14	787 ± 17	1109 ± 24
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	174 ± 5	215 ± 9	179 ± 6	157 ± 6
	2041-2060	218 ± 7	297 ± 9	393 ± 11	475 ± 12
	2080-2099	215 ± 7	537 ± 13	827 ± 18	1098 ± 23
Multi-model maximum	Baseline	2569 ± 291	2569 ± 291	2569 ± 291	2569 ± 291
	2021-2040	287 ± 7	364 ± 8	455 ± 10	363 ± 7
	2041-2060	506 ± 8	662 ± 12	742 ± 13	705 ± 17
	2080-2099	559 ± 11	1045 ± 17	1463 ± 23	1772 ± 27
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	322 ± 8	369 ± 8	486 ± 9	425 ± 9
	2041-2060	556 ± 10	680 ± 13	759 ± 13	737 ± 15
	2080-2099	518 ± 11	1069 ± 17	1568 ± 24	1924 ± 27

Table 1: The statistics of the projected changes in growing degree days (base 5°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).



A plot of the evolution in growing degree days (base 5°C) from the 1986-2005 baseline over this region is shown in Figure 19. The statistical summary of projected changes in growing degree days (base 5°C) over this region is

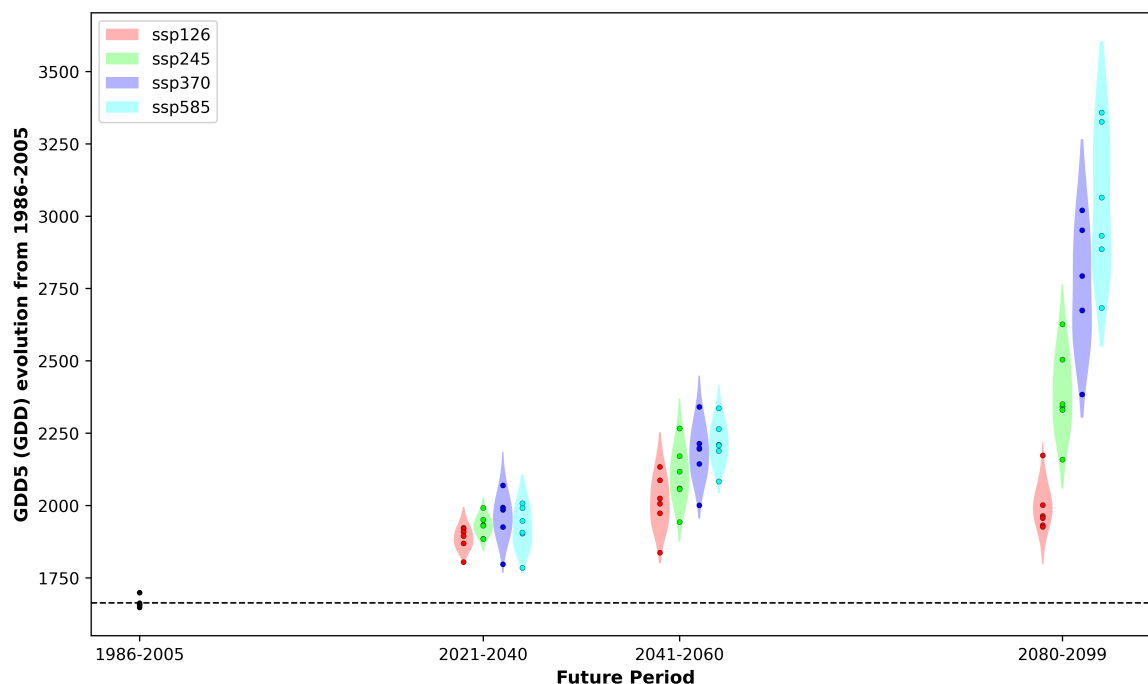


Figure 19: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Volcanic Plateau region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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](#).

shown in Table 2. Projected changes in growing degree days (GDD, base 5°C) for the Volcanic Plateau indicate a consistent and robust warming-related signal across all future periods and emissions scenarios. Multi-model means show a clear and sustained increase relative to the 1986-2005 baseline (1664 GDD). By 2021-2040, all scenarios project increases of roughly 220–300 GDD, rising to 350–550 GDD by mid-century (2041-2060), and thereafter diverging strongly: low emissions (SSP1-2.6) yields a modest total increase (~330 GDD by 2080-2099), whereas high emissions (SSP5-8.5) drives a substantial increase (~1380 GDD). The violin plots show strong inter-model agreement on the direction of change (virtually certain), with spread increasing especially for high-end scenarios and longer lead times. This divergence is confirmed by the percentage scenario agreement: moderate for the near term (~40% for 2021-2040), dropping to zero by late century as scenario dependence dominates. Spatial variability in GDD5 values increases, especially under high emissions, reflecting both expanded regional warmth and emerging sub-regional contrasts (standard deviation grows from ~24 to ~115 GDD by 2100 in SSP5-8.5). In summary, it is extremely likely that the Volcanic Plateau will experience increasing thermal accumulation under all scenarios, with the magnitude of change strongly dependent on global emissions trajectories.

15.3 Region: Upper Rangitīkei

Area: 2694.06 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 3. Projections indicate a substantial and likely increase in annual growing degree days (GDD, base 5°C) in the Upper Rangitīkei sub-region through the 21st century. Compared to the 1986-2005



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	1664 ± 419	1664 ± 419	1664 ± 419	1664 ± 419
	2021-2040	223 ± 22	266 ± 26	297 ± 28	260 ± 24
	2041-2060	347 ± 33	439 ± 42	519 ± 50	551 ± 54
	2080-2099	329 ± 34	722 ± 71	1086 ± 94	1378 ± 115
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	225 ± 23	267 ± 26	299 ± 28	264 ± 25
	2041-2060	351 ± 33	442 ± 43	522 ± 50	554 ± 55
	2080-2099	331 ± 34	728 ± 71	1097 ± 95	1395 ± 116
Multi-model minimum	Baseline	1648 ± 421	1648 ± 421	1648 ± 421	1648 ± 421
	2021-2040	141 ± 12	219 ± 20	134 ± 10	121 ± 10
	2041-2060	174 ± 18	280 ± 22	337 ± 34	419 ± 40
	2080-2099	263 ± 28	495 ± 50	720 ± 71	1019 ± 101
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	160 ± 15	209 ± 18	169 ± 15	147 ± 12
	2041-2060	202 ± 21	284 ± 24	364 ± 36	434 ± 45
	2080-2099	202 ± 21	495 ± 52	765 ± 74	1012 ± 100
Multi-model maximum	Baseline	1699 ± 423	1699 ± 423	1699 ± 423	1699 ± 423
	2021-2040	263 ± 25	328 ± 36	406 ± 42	344 ± 32
	2041-2060	470 ± 41	603 ± 59	677 ± 65	672 ± 61
	2080-2099	509 ± 53	963 ± 90	1357 ± 114	1695 ± 125
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	298 ± 31	333 ± 36	446 ± 44	396 ± 41
	2041-2060	519 ± 47	622 ± 64	702 ± 66	691 ± 66
	2080-2099	474 ± 49	992 ± 93	1475 ± 119	1829 ± 134

Table 2: The statistics of the projected changes in growing degree days (base 5°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	1670 ± 401	1670 ± 401	1670 ± 401	1670 ± 401
	2021-2040	227 ± 18	267 ± 18	297 ± 18	265 ± 17
	2041-2060	353 ± 23	440 ± 32	518 ± 36	556 ± 38
	2080-2099	337 ± 25	723 ± 51	1081 ± 67	1376 ± 84
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	228 ± 18	268 ± 18	299 ± 19	268 ± 17
	2041-2060	356 ± 23	443 ± 32	521 ± 36	558 ± 39
	2080-2099	339 ± 26	728 ± 51	1091 ± 67	1391 ± 85
Multi-model minimum	Baseline	1655 ± 402	1655 ± 402	1655 ± 402	1655 ± 402
	2021-2040	142 ± 11	220 ± 14	135 ± 7	130 ± 10
	2041-2060	182 ± 14	288 ± 17	341 ± 26	419 ± 30
	2080-2099	268 ± 22	506 ± 37	718 ± 53	1013 ± 76
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	165 ± 14	213 ± 13	175 ± 10	160 ± 10
	2041-2060	214 ± 16	293 ± 19	371 ± 29	443 ± 33
	2080-2099	214 ± 18	509 ± 38	774 ± 54	1020 ± 73
Multi-model maximum	Baseline	1699 ± 405	1699 ± 405	1699 ± 405	1699 ± 405
	2021-2040	263 ± 20	326 ± 24	396 ± 27	338 ± 21
	2041-2060	473 ± 27	601 ± 43	671 ± 45	657 ± 42
	2080-2099	512 ± 36	947 ± 64	1335 ± 79	1677 ± 95
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	299 ± 23	329 ± 25	438 ± 29	392 ± 26
	2041-2060	518 ± 31	613 ± 48	692 ± 45	689 ± 46
	2080-2099	476 ± 34	978 ± 66	1452 ± 82	1812 ± 97

Table 3: The statistics of the projected changes in growing degree days (base 5°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).

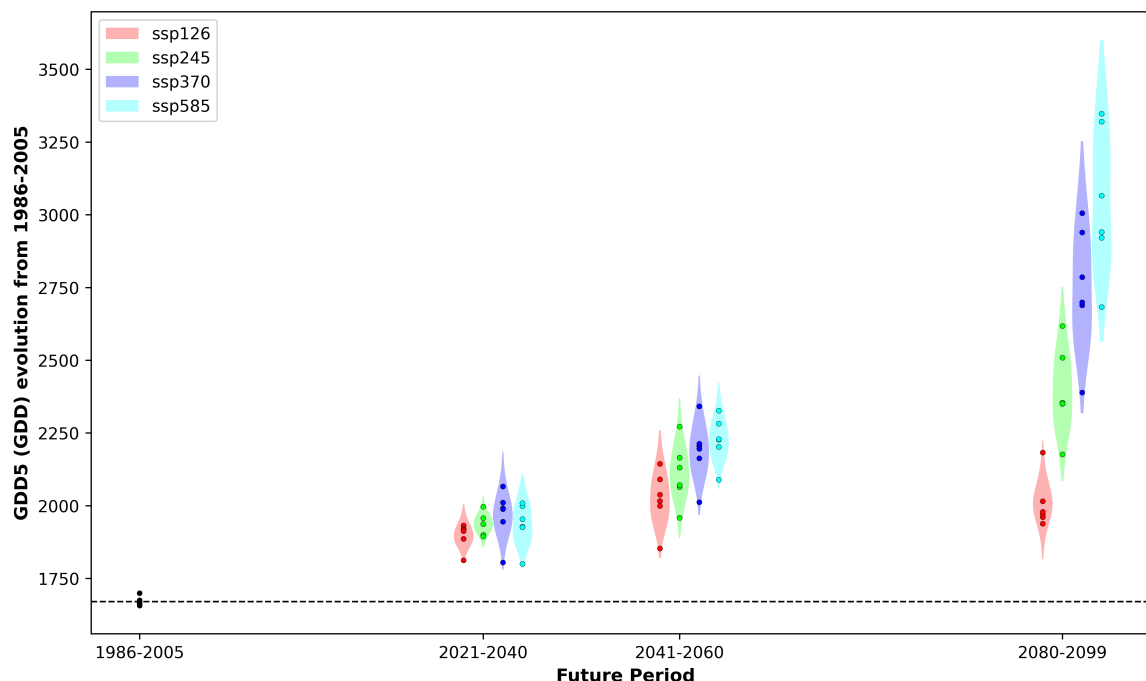


Figure 20: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Upper Rangitikei region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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](#).

baseline (~1670 GDD), multi-model mean GDD increases are projected for all future periods and emission scenarios (SSPs). By mid-century (2041-2060), increases range from about 350 GDD (SSP1-2.6) to over 550 GDD (SSP5-8.5), with a further acceleration towards century's end under higher emissions. For 2080-2099, projected mean increases span from around 340 GDD (SSP1-2.6) to nearly 1400 GDD (SSP5-8.5), a major rise that is extremely likely under high-emission scenarios.

Model agreement is highest in the near term (2021-2040, ~38% agreement), but inter-scenario divergence grows sharply later (agreement drops to 0% by 2080-2099), reflecting increasing scenario dependence. The spread among models within each scenario remains relatively moderate, indicating robust intra-scenario agreement, especially in the near term. Spatial variability (standard deviation) across Upper Rangitikei stays low to moderate (below 85 GDD even in late century extreme scenarios), suggesting consistent changes across the region.

Overall, it is virtually certain that Upper Rangitikei will experience marked increases in GDD, supporting longer or more productive growing seasons, with the magnitude of change very likely dependent on global emissions trajectories.

15.4 Region: Western Ruahine

Area: 1758.32 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 4. Projected changes in annual growing degree days (GDD, base 5°C) for Western Ruahine indicate a consistent and robust increase throughout the 21st century, with the magnitude of change strongly dependent on emissions scenario (SSP). All models and scenarios show a likely to very likely increase relative



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2316 ± 398	2316 ± 398	2316 ± 398	2316 ± 398
	2021-2040	243 ± 12	280 ± 13	314 ± 13	278 ± 12
	2041-2060	371 ± 16	472 ± 21	556 ± 24	593 ± 26
	2080-2099	360 ± 18	776 ± 33	1152 ± 42	1461 ± 47
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	245 ± 12	282 ± 13	317 ± 13	282 ± 13
	2041-2060	375 ± 16	475 ± 21	559 ± 24	595 ± 26
	2080-2099	362 ± 18	782 ± 33	1163 ± 42	1477 ± 48
Multi-model minimum	Baseline	2296 ± 399	2296 ± 399	2296 ± 399	2296 ± 399
	2021-2040	161 ± 7	223 ± 10	147 ± 5	146 ± 6
	2041-2060	202 ± 10	295 ± 11	376 ± 14	459 ± 20
	2080-2099	299 ± 13	540 ± 21	791 ± 33	1109 ± 40
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	182 ± 8	212 ± 9	184 ± 6	172 ± 7
	2041-2060	234 ± 13	303 ± 13	402 ± 17	484 ± 24
	2080-2099	228 ± 12	546 ± 25	838 ± 34	1107 ± 43
Multi-model maximum	Baseline	2353 ± 400	2353 ± 400	2353 ± 400	2353 ± 400
	2021-2040	282 ± 14	357 ± 20	434 ± 24	355 ± 15
	2041-2060	490 ± 19	654 ± 30	724 ± 32	688 ± 25
	2080-2099	550 ± 27	1022 ± 41	1430 ± 51	1758 ± 48
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	315 ± 17	361 ± 19	467 ± 22	408 ± 19
	2041-2060	534 ± 21	670 ± 32	737 ± 32	723 ± 28
	2080-2099	508 ± 26	1051 ± 43	1533 ± 51	1897 ± 53

Table 4: The statistics of the projected changes in growing degree days (base 5°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).

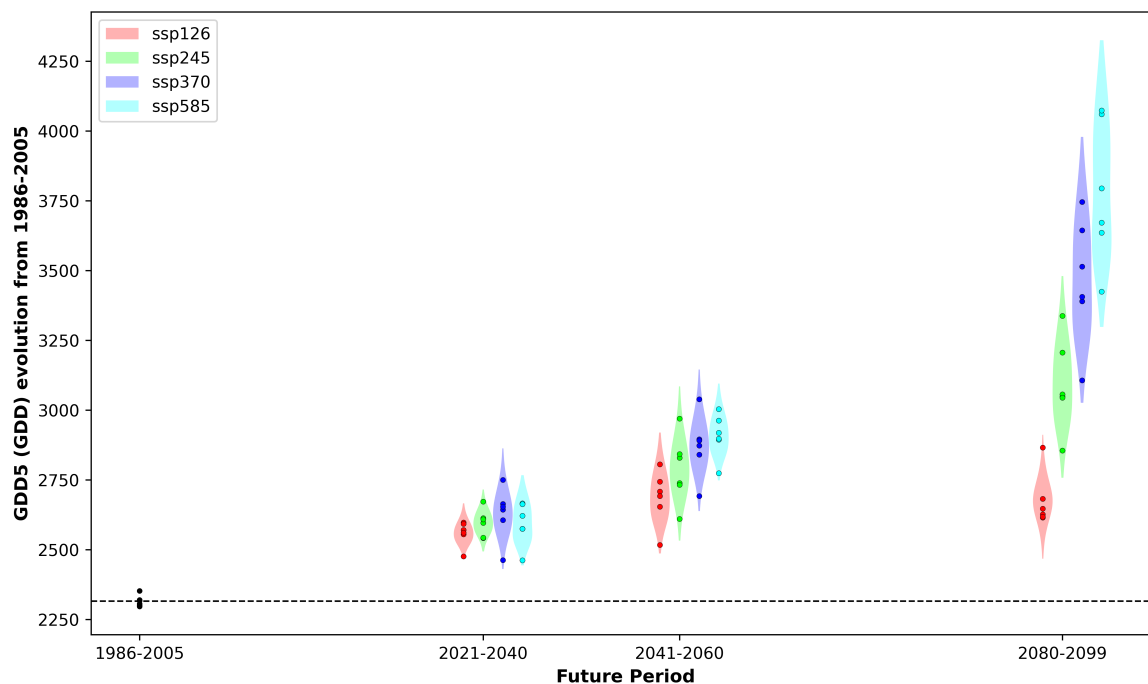


Figure 21: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Western Ruahine region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty 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](#).

to the 1986–2005 baseline (multi-model mean: ~ 2316 GDD).

By mid-century (2041–2060), the projected multi-model mean increase in GDD ranges from about 370 (SSP1-2.6) to nearly 600 (SSP5-8.5), with even greater increases by late century (2080–2099), from ~ 360 (SSP1-2.6) up to 1460 (SSP5-8.5). These projections are supported by the medians and percentiles across models, and the distributions indicate that an increase is virtually certain under all scenarios, with higher emissions scenarios yielding substantially greater increases in heat accumulation.

Inter-model agreement is high within scenarios, but the spread between scenarios grows substantially by 2080–2099, and scenario agreement drops to zero, reflecting strong scenario dependence and thus a high sensitivity to emissions pathways. The spatial variability (standard deviation) is small compared with the magnitude of projected change, suggesting the regional signal is spatially consistent. Overall, it is virtually certain that Western Ruahine will see increased growing degree days this century, with the magnitude very likely to depend strongly on future greenhouse gas emissions.

15.5 Region: Tararua

Area: 3155.23 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 5. The figure and accompanying statistics show a clear, consistent trend towards increasing growing degree days (GDD, base 5°C) in Tararua through the 21st century, with the magnitude of change strongly dependent on emissions pathway. All scenarios project higher annual GDD relative to the 1986-2005 baseline (mean: ~ 2536 GDD), with increases becoming particularly pronounced from mid-century onward. By 2080-2099, projected mean increases range from approximately 364 GDD under the very low



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2536 ± 251	2536 ± 251	2536 ± 251	2536 ± 251
	2021-2040	244 ± 9	281 ± 9	314 ± 9	278 ± 11
	2041-2060	375 ± 12	470 ± 12	557 ± 14	597 ± 18
	2080-2099	364 ± 12	779 ± 18	1154 ± 21	1454 ± 27
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	245 ± 9	282 ± 9	316 ± 9	281 ± 11
	2041-2060	379 ± 12	474 ± 12	560 ± 14	599 ± 18
	2080-2099	366 ± 12	786 ± 18	1163 ± 21	1469 ± 28
Multi-model minimum	Baseline	2514 ± 251	2514 ± 251	2514 ± 251	2514 ± 251
	2021-2040	164 ± 4	217 ± 7	147 ± 4	147 ± 5
	2041-2060	210 ± 7	290 ± 8	378 ± 10	457 ± 15
	2080-2099	300 ± 12	541 ± 13	796 ± 18	1113 ± 23
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	185 ± 6	213 ± 7	183 ± 6	174 ± 7
	2041-2060	244 ± 9	303 ± 10	406 ± 11	486 ± 17
	2080-2099	238 ± 10	550 ± 15	846 ± 19	1111 ± 25
Multi-model maximum	Baseline	2575 ± 251	2575 ± 251	2575 ± 251	2575 ± 251
	2021-2040	282 ± 10	355 ± 12	432 ± 10	345 ± 10
	2041-2060	487 ± 13	649 ± 16	720 ± 18	691 ± 16
	2080-2099	547 ± 14	1015 ± 20	1422 ± 24	1749 ± 28
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	313 ± 13	361 ± 11	465 ± 12	402 ± 15
	2041-2060	532 ± 15	667 ± 15	735 ± 18	728 ± 20
	2080-2099	506 ± 15	1053 ± 22	1524 ± 24	1875 ± 31

Table 5: The statistics of the projected changes in growing degree days (base 5°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).

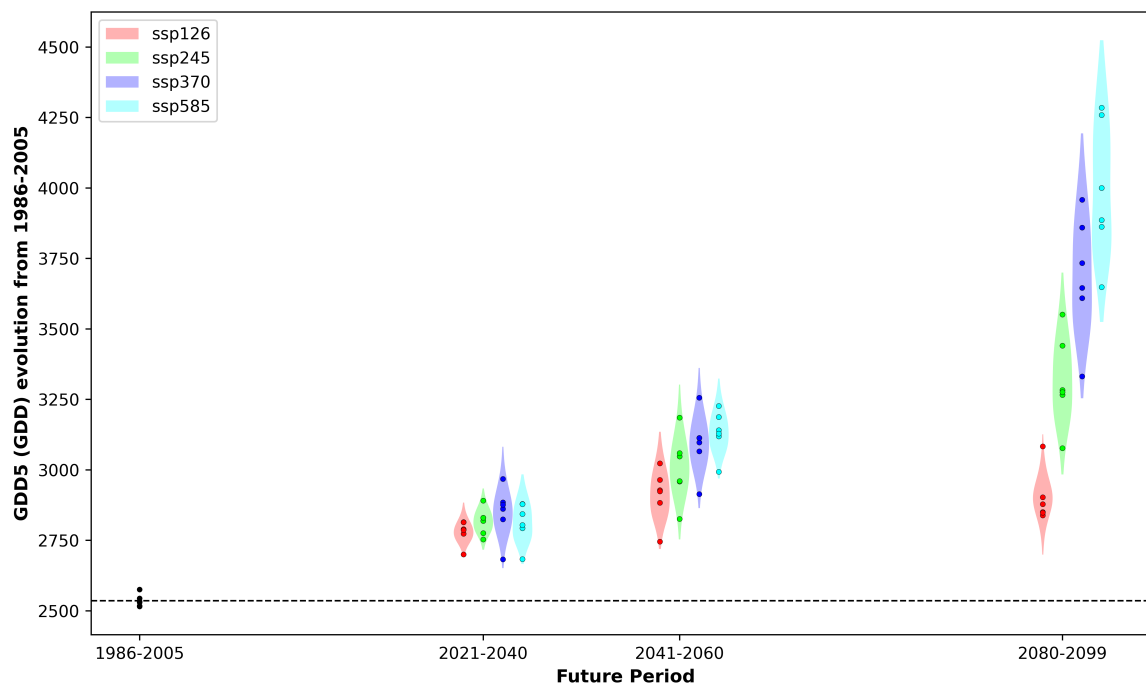


Figure 22: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Tararua region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty 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 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](#).

emissions pathway (SSP1-2.6) to over 1450 GDD for the very high pathway (SSP5-8.5). This amounts to likely increases of about 15–57% over baseline, depending on scenario, with higher emissions resulting in larger increases.

The visual spread among models within each scenario is modest compared to the differences between scenarios, especially by century's end, giving high confidence in the direction and relative magnitude of change. Inter-model agreement within scenarios is high, yet agreement across scenarios drops from the 2021-2040 period (about as likely as not agreement) to near zero by 2080-2099, reinforcing emissions-dependence as the dominant factor shaping future GDD. The spatial variability within Tararua is low relative to the regional signal, suggesting robust, area-wide increases. These projections are very likely robust for at least the first half of the century, with higher confidence attached to near-term changes.

15.6 Region: Middle Manawatū-Rangitīkei

Area: 1838.51 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 6. The Middle Manawatū-Rangitīkei sub-region is projected to experience substantial increases in annual growing degree days (GDD5, base 5°C) across all future scenarios compared to the 1986–2005 baseline. All scenarios indicate a very likely increase by 2021–2040, with mean changes ranging from about 240 GDD (SSP1-2.6) to over 300 GDD (SSP3-7.0). This warming signal intensifies through the century. By 2080–2099, under the highest emissions pathway (SSP5-8.5), the mean increase reaches around 1450 GDD, while the low emissions pathway (SSP1-2.6) shows a smaller but still marked rise (~360 GDD). The magnitude of change is scenario-dependent, with multi-model means diverging sharply after mid-century. This divergence indicates very low scenario agreement by 2080–2099 (0% inter-SSP agreement), and the regional spread is



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2763 ± 331	2763 ± 331	2763 ± 331	2763 ± 331
	2021-2040	238 ± 10	274 ± 11	309 ± 11	268 ± 12
	2041-2060	366 ± 13	467 ± 16	552 ± 18	585 ± 20
	2080-2099	358 ± 14	773 ± 24	1146 ± 29	1446 ± 36
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	239 ± 10	275 ± 11	312 ± 11	272 ± 12
	2041-2060	369 ± 13	471 ± 16	555 ± 18	587 ± 20
	2080-2099	359 ± 14	779 ± 24	1156 ± 29	1462 ± 37
Multi-model minimum	Baseline	2740 ± 331	2740 ± 331	2740 ± 331	2740 ± 331
	2021-2040	153 ± 4	209 ± 8	142 ± 6	142 ± 6
	2041-2060	195 ± 6	281 ± 10	367 ± 11	450 ± 16
	2080-2099	290 ± 12	525 ± 16	785 ± 25	1098 ± 29
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	173 ± 5	199 ± 7	174 ± 7	162 ± 8
	2041-2060	230 ± 9	293 ± 11	391 ± 12	480 ± 19
	2080-2099	223 ± 9	538 ± 18	831 ± 24	1098 ± 32
Multi-model maximum	Baseline	2804 ± 327	2804 ± 327	2804 ± 327	2804 ± 327
	2021-2040	284 ± 13	359 ± 18	442 ± 17	350 ± 19
	2041-2060	488 ± 17	654 ± 24	728 ± 25	667 ± 17
	2080-2099	551 ± 23	1025 ± 31	1433 ± 37	1735 ± 35
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	312 ± 17	362 ± 17	467 ± 16	396 ± 19
	2041-2060	527 ± 18	673 ± 22	739 ± 25	709 ± 22
	2080-2099	509 ± 22	1053 ± 31	1525 ± 35	1875 ± 42

Table 6: The statistics of the projected changes in growing degree days (base 5°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).

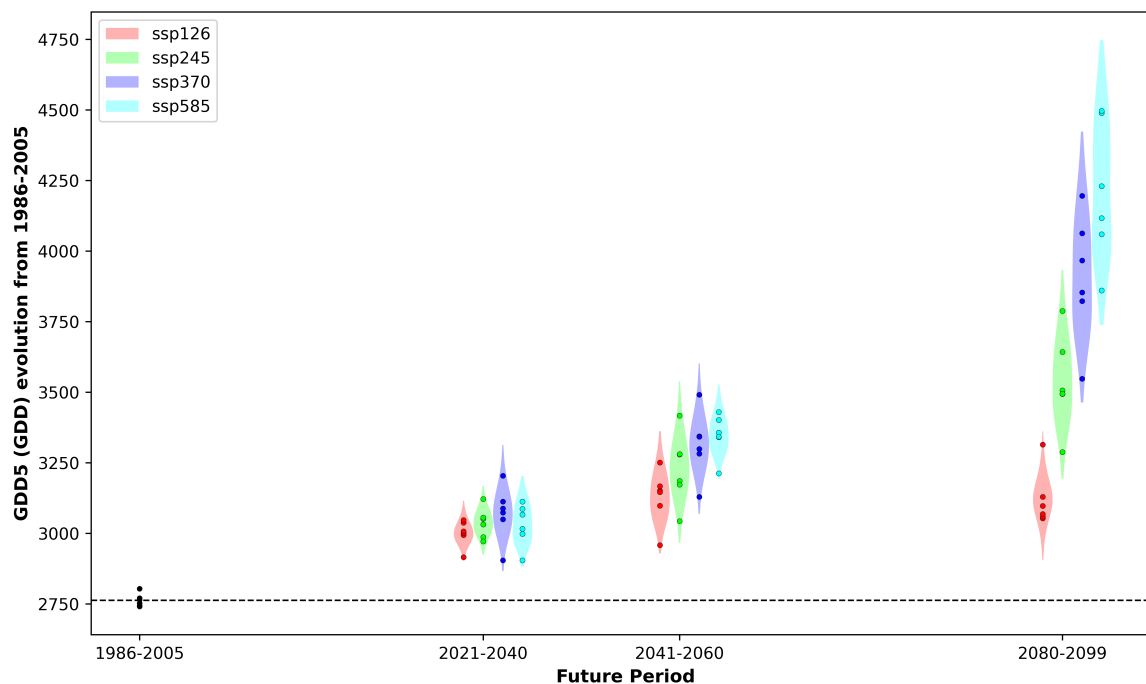


Figure 23: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Middle Manawātū-Rangitīkei region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the 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](#).

greatest for higher emissions.

The model agreement within each scenario remains strong: all models consistently indicate positive change, and the distribution of model results remains tightly clustered, especially in the near term. Spatial variability (stdv) is low relative to the magnitude of projected changes and does not materially affect the overall conclusion. These findings provide high confidence that GDD5 will rise, driving a longer and warmer effective growing season. The increase is virtually certain to be greater and more rapid under higher emission futures.

15.7 Region: Horowhenua

Area: 448.71 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 7. Projected changes in annual growing degree days (base 5°C) for Horowhenua indicate a robust warming signal through the 21st century, with magnitude increasing under higher emissions scenarios. Relative to the 1986–2005 baseline (mean ~2640 GDD), multi-model means show increases of around 220–293 GDD by 2021–2040 across all scenarios, rising to 346–549 GDD by mid-century, and diverging substantially by 2080–2099: from approximately 336 GDD (SSP1-2.6) to over 1380 GDD (SSP5-8.5). This progression suggests it is extremely likely that Horowhenua will experience more favourable thermal conditions for crop and pasture growth as the century progresses, with higher emission pathways resulting in virtually certain and much greater increases.

Model agreement is strong within each scenario, as evidenced by clustered model points and narrow spread in the figure, as well as low spatial standard deviations (generally <26 GDD by century's end, compared to inter-scenario increases exceeding 1000 GDD). However, the agreement between scenarios declines through



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2640 ± 393	2640 ± 393	2640 ± 393	2640 ± 393
	2021-2040	220 ± 7	255 ± 7	293 ± 7	246 ± 7
	2041-2060	346 ± 9	441 ± 12	521 ± 13	549 ± 14
	2080-2099	336 ± 10	736 ± 18	1096 ± 22	1383 ± 26
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	221 ± 7	256 ± 7	296 ± 7	250 ± 7
	2041-2060	349 ± 9	445 ± 12	524 ± 13	551 ± 14
	2080-2099	337 ± 10	741 ± 18	1106 ± 22	1399 ± 26
Multi-model minimum	Baseline	2614 ± 393	2614 ± 393	2614 ± 393	2614 ± 393
	2021-2040	150 ± 3	189 ± 6	127 ± 3	129 ± 5
	2041-2060	183 ± 5	254 ± 5	351 ± 8	422 ± 11
	2080-2099	267 ± 8	493 ± 11	740 ± 18	1045 ± 23
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	161 ± 3	180 ± 6	158 ± 4	144 ± 6
	2041-2060	213 ± 7	267 ± 7	370 ± 9	447 ± 14
	2080-2099	206 ± 7	506 ± 13	785 ± 18	1042 ± 24
Multi-model maximum	Baseline	2688 ± 391	2688 ± 391	2688 ± 391	2688 ± 391
	2021-2040	277 ± 14	333 ± 13	425 ± 15	322 ± 10
	2041-2060	463 ± 14	622 ± 19	687 ± 18	636 ± 13
	2080-2099	522 ± 18	981 ± 25	1379 ± 30	1671 ± 24
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	289 ± 12	343 ± 13	452 ± 13	369 ± 11
	2041-2060	503 ± 14	646 ± 19	698 ± 18	669 ± 15
	2080-2099	480 ± 17	1009 ± 24	1471 ± 26	1802 ± 27

Table 7: The statistics of the projected changes in growing degree days (base 5°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).

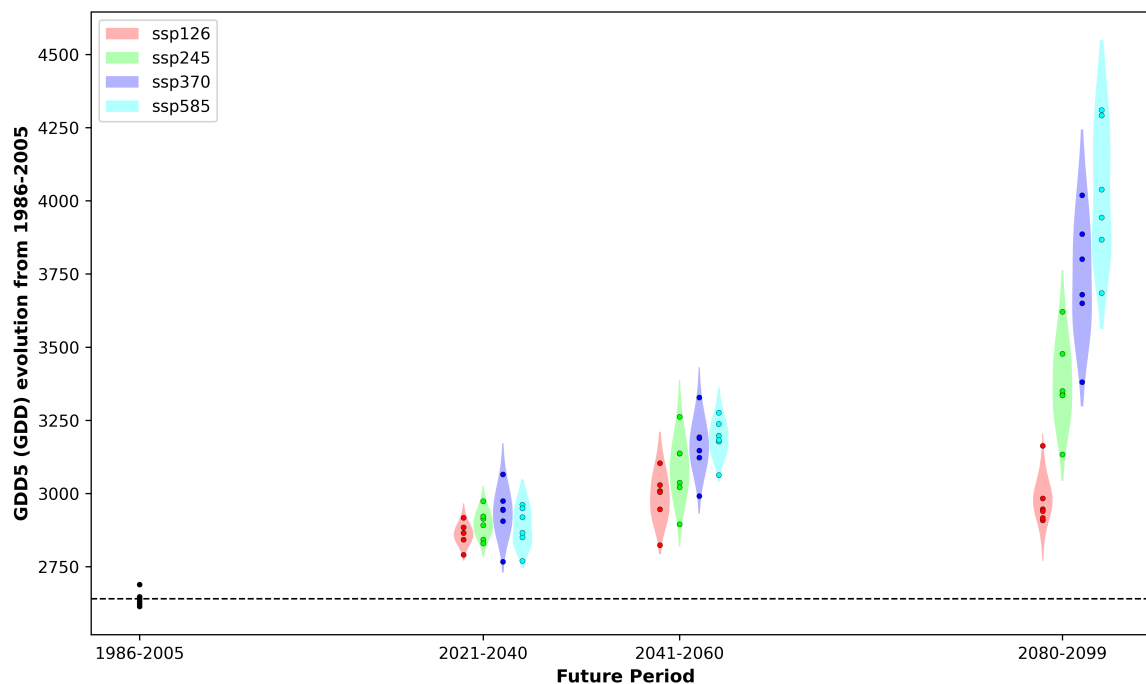


Figure 24: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Horowhenua region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty 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](#).

time, with scenario agreement virtually zero by late century, reflecting substantial uncertainty tied primarily to emissions trajectories rather than climate model spread. Overall, the signal-to-noise ratio is high, providing very high confidence in the direction and likely in the magnitude of change, especially under higher emission futures.

15.8 Region: Whanganui-Manawatū Lakes

Area: 623.11 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 8. Projected changes in annual growing degree days (GDD; base 5°C) for the Whanganui-Manawatū Lakes sub-region show a clear increase across all future scenarios. By mid-century (2041–2060), multi-model mean increases range from about 350 (SSP1-2.6, lower emissions) to over 560 GDD (SSP5-8.5, high emissions) above the 1986–2005 baseline. Late-century (2080–2099) projections diverge further, with a modest increase (~350 GDD) under SSP1-2.6, but rises of approximately 750, 1110, and 1400 GDD under SSP2-4.5, SSP3-7.0, and SSP5-8.5 respectively. These results indicate it is virtually certain that GDD will increase, but the magnitude is very likely to be scenario-dependent.

Model agreement on the sign of change is high (consistently positive), but the spread between scenarios grows markedly through the century, with inter-scenario agreement dropping from about 46% (2021–2040) to near zero by century's end, reflecting strong scenario sensitivity. Inter-model spread within each scenario is moderate, with higher spatial variability under higher forcing. The low intra-scenario spread relative to the large inter-scenario separation in later periods gives high confidence in the direction but only medium confidence in the magnitude of change under high emission pathways. In summary, increased heat availability for plant growth is extremely likely in the Whanganui-Manawatū Lakes, with the scale of increase depending strongly



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	3023 ± 56	3023 ± 56	3023 ± 56	3023 ± 56
	2021-2040	229 ± 7	263 ± 6	300 ± 7	253 ± 9
	2041-2060	355 ± 7	455 ± 9	534 ± 12	564 ± 13
	2080-2099	349 ± 8	753 ± 13	1111 ± 20	1402 ± 25
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	230 ± 7	265 ± 6	303 ± 7	257 ± 9
	2041-2060	359 ± 7	459 ± 8	537 ± 12	567 ± 13
	2080-2099	351 ± 8	759 ± 13	1121 ± 20	1418 ± 25
Multi-model minimum	Baseline	2998 ± 56	2998 ± 56	2998 ± 56	2998 ± 56
	2021-2040	152 ± 3	196 ± 5	132 ± 6	126 ± 7
	2041-2060	185 ± 4	263 ± 8	355 ± 7	434 ± 9
	2080-2099	271 ± 11	502 ± 10	754 ± 16	1058 ± 22
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	163 ± 5	181 ± 7	160 ± 7	140 ± 10
	2041-2060	213 ± 8	275 ± 10	372 ± 11	464 ± 10
	2080-2099	206 ± 9	514 ± 12	792 ± 20	1055 ± 24
Multi-model maximum	Baseline	3065 ± 54	3065 ± 54	3065 ± 54	3065 ± 54
	2021-2040	289 ± 4	355 ± 8	441 ± 5	347 ± 9
	2041-2060	487 ± 5	651 ± 8	713 ± 13	635 ± 15
	2080-2099	552 ± 10	1017 ± 13	1414 ± 17	1691 ± 23
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	305 ± 11	362 ± 8	465 ± 6	389 ± 11
	2041-2060	524 ± 8	668 ± 8	722 ± 14	685 ± 16
	2080-2099	509 ± 10	1037 ± 16	1495 ± 20	1829 ± 27

Table 8: The statistics of the projected changes in growing degree days (base 5°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).

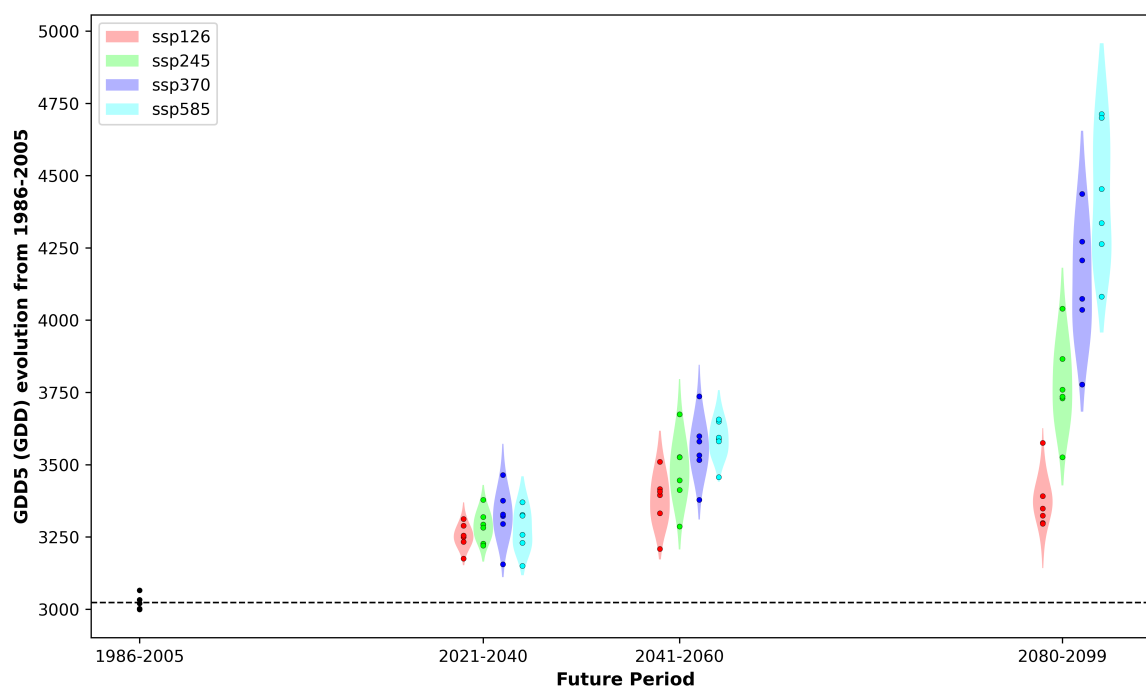


Figure 25: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Whanganui-Manawātū Lakes region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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](#).

on future emissions.

15.9 Region: Coastal Whanganui

Area: 1048.57 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 9. Projections for annual growing degree days (GDD5, base 5°C) in Coastal Whanganui indicate a robust and consistent warming-related increase throughout the 21st century. Compared to the 1986–2005 baseline, all scenarios (SSP126, SSP245, SSP370, SSP585) show very likely increases in GDD5, with the magnitude of change strongly dependent on emission pathway. By 2021–2040, multi-model mean increases range from approximately 240 to 320 GDD, which is likely given the close ensemble spread illustrated in the violin plots and narrow spatial standard deviations.

By 2041–2060, SSP370 and SSP585 indicate larger rises (about 560–590 GDD), while SSP126 remains lower (~370 GDD). By 2080–2099, projected increases diverge markedly: minimal under SSP126 (~360 GDD), moderate to large under SSP245 (~780 GDD), and very large under high-emission SSP370 and SSP585 scenarios (over 1100 and 1400 GDD, respectively). This widening spread reflects decreasing inter-scenario agreement over time, from around 45% for 2021–2040 to negligible agreement by century's end. However, within each scenario, model projections are consistent across the region, with low spatial variability.

It is virtually certain that Coastal Whanganui will experience increased heat accumulation this century. The magnitude of increase is extremely likely to depend on greenhouse gas emissions, with strong evidence for larger changes under higher forcing.



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2921 ± 192	2921 ± 192	2921 ± 192	2921 ± 192
	2021-2040	243 ± 5	279 ± 5	317 ± 4	275 ± 7
	2041-2060	370 ± 5	472 ± 8	559 ± 8	590 ± 9
	2080-2099	364 ± 5	781 ± 9	1148 ± 15	1447 ± 19
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	245 ± 5	281 ± 5	320 ± 4	279 ± 7
	2041-2060	374 ± 5	476 ± 8	562 ± 8	593 ± 9
	2080-2099	366 ± 5	787 ± 9	1159 ± 15	1465 ± 19
Multi-model minimum	Baseline	2902 ± 191	2902 ± 191	2902 ± 191	2902 ± 191
	2021-2040	149 ± 2	209 ± 9	144 ± 5	131 ± 6
	2041-2060	190 ± 5	275 ± 12	369 ± 6	446 ± 10
	2080-2099	287 ± 5	523 ± 11	779 ± 14	1093 ± 18
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	171 ± 4	196 ± 9	178 ± 6	155 ± 7
	2041-2060	224 ± 7	292 ± 11	391 ± 9	478 ± 9
	2080-2099	219 ± 6	536 ± 11	824 ± 16	1093 ± 18
Multi-model maximum	Baseline	2963 ± 191	2963 ± 191	2963 ± 191	2963 ± 191
	2021-2040	298 ± 4	368 ± 4	448 ± 4	364 ± 6
	2041-2060	494 ± 4	664 ± 6	743 ± 6	674 ± 13
	2080-2099	566 ± 6	1047 ± 7	1448 ± 12	1738 ± 17
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	328 ± 6	377 ± 3	480 ± 3	420 ± 6
	2041-2060	544 ± 4	686 ± 5	756 ± 6	724 ± 9
	2080-2099	527 ± 6	1072 ± 8	1540 ± 14	1886 ± 19

Table 9: The statistics of the projected changes in growing degree days (base 5°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).

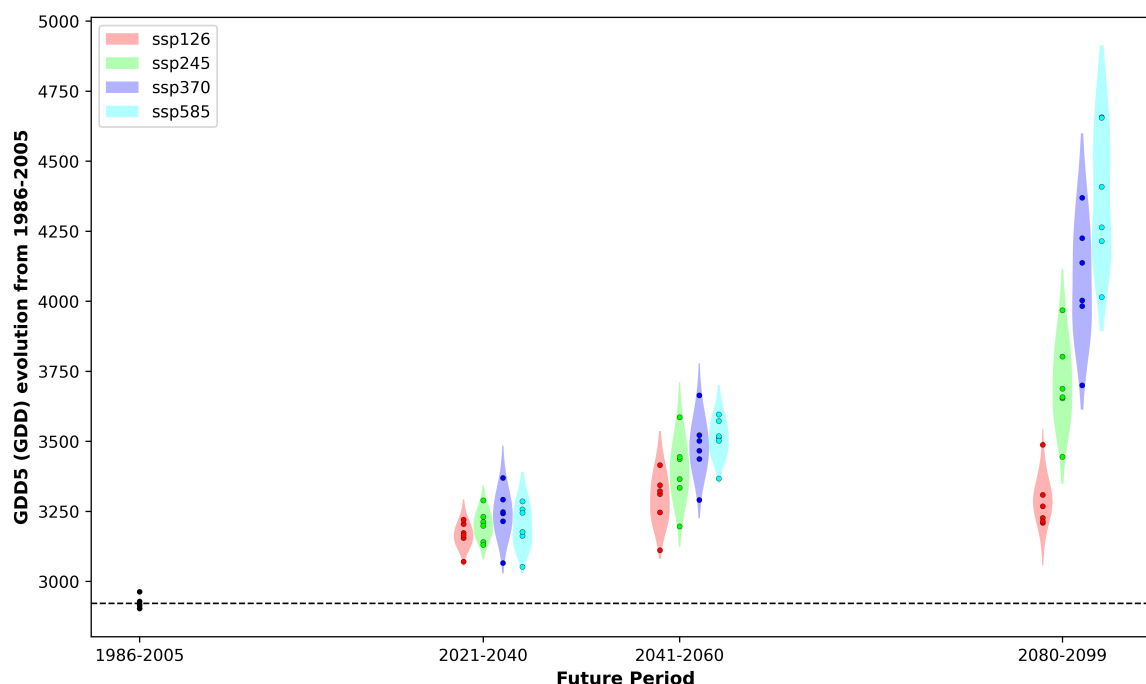


Figure 26: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Coastal Whanganui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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](#).

15.10 Region: Turakina

Area: 1237.15 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 10. Projected annual growing degree days (GDD, base 5°C) in Turakina show a clear increase across all future periods and scenarios compared to the baseline (1986–2005), with the magnitude of change dependent on emissions trajectory. For the near term (2021–2040), all scenarios project increases of around 250–320 GDD (multi-model means), which is likely based on the model spread and high consistency. By mid-century (2041–2060), projected increases range from about 375 under SSP1-2.6 to approximately 600 under SSP5-8.5, and by late century (2080–2099), the divergence between scenarios widens substantially, from around 365 for SSP1-2.6 to over 1,470 for SSP5-8.5. This spread in late-century projections is extremely likely, given the model-driven separation seen in the figure and supported by very low agreement across scenarios (0% for 2080–2099).

Within each scenario, inter-model agreement is high for both pattern and magnitude, as indicated by tight clustering in violin plots and low spatial standard deviations (<16 GDD for all periods and scenarios). The projected increases are robust and virtually certain through at least mid-century, with scenario differentiation becoming very likely after 2060. The increase in GDD reflects very high confidence that Turakina will experience longer or more intensive growing seasons, with the precise magnitude strongly dependent on the emissions pathway chosen.

15.11 Region: Puketoi ki Tai

Area: 966.64 km²



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2555 ± 363	2555 ± 363	2555 ± 363	2555 ± 363
	2021-2040	246 ± 4	283 ± 5	319 ± 5	280 ± 5
	2041-2060	375 ± 5	478 ± 7	564 ± 9	599 ± 9
	2080-2099	365 ± 7	786 ± 11	1163 ± 14	1471 ± 15
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	248 ± 4	285 ± 5	322 ± 5	283 ± 5
	2041-2060	379 ± 5	481 ± 7	567 ± 9	602 ± 9
	2080-2099	367 ± 7	792 ± 11	1174 ± 14	1488 ± 15
Multi-model minimum	Baseline	2536 ± 361	2536 ± 361	2536 ± 361	2536 ± 361
	2021-2040	157 ± 4	222 ± 9	148 ± 4	140 ± 5
	2041-2060	198 ± 6	294 ± 9	376 ± 8	460 ± 9
	2080-2099	294 ± 6	536 ± 10	794 ± 15	1113 ± 16
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	179 ± 4	210 ± 9	184 ± 4	165 ± 5
	2041-2060	232 ± 7	304 ± 7	403 ± 8	487 ± 10
	2080-2099	226 ± 5	547 ± 9	840 ± 13	1113 ± 16
Multi-model maximum	Baseline	2594 ± 364	2594 ± 364	2594 ± 364	2594 ± 364
	2021-2040	291 ± 7	366 ± 10	445 ± 13	363 ± 8
	2041-2060	499 ± 4	664 ± 13	738 ± 13	692 ± 12
	2080-2099	562 ± 12	1041 ± 16	1455 ± 18	1767 ± 16
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	326 ± 6	370 ± 10	478 ± 8	419 ± 7
	2041-2060	545 ± 5	683 ± 12	752 ± 11	732 ± 9
	2080-2099	522 ± 11	1071 ± 15	1554 ± 15	1913 ± 15

Table 10: The statistics of the projected changes in growing degree days (base 5°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).

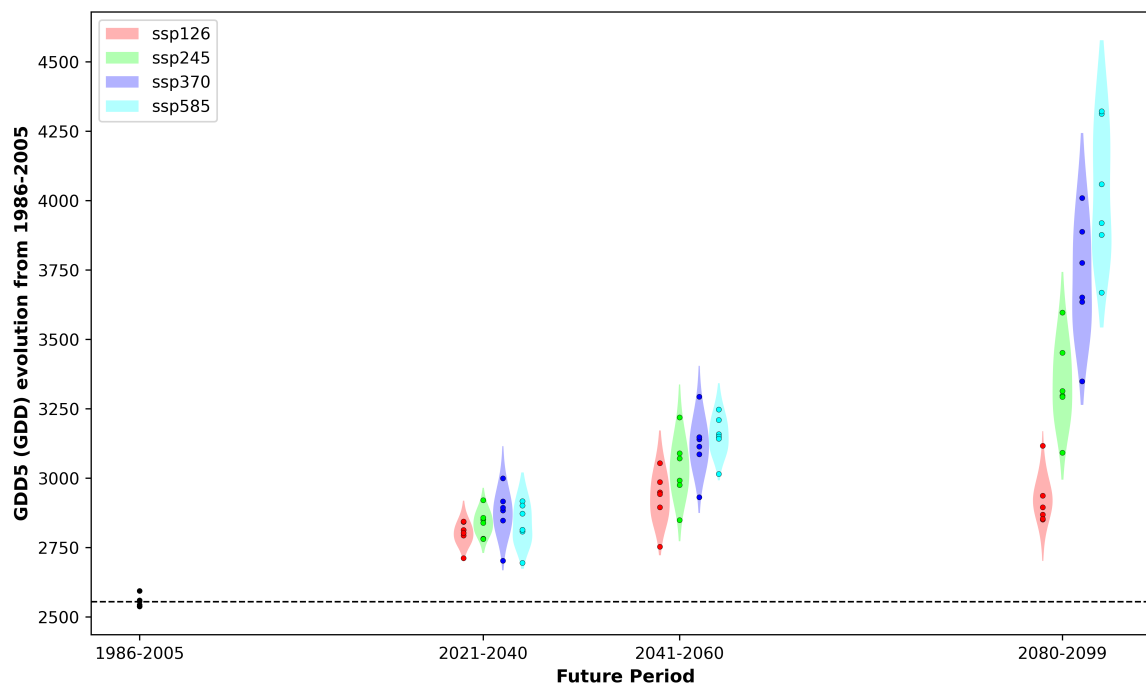


Figure 27: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Turakina region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty 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 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 5°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 5°C) over this region is shown in Table 11. Projected changes in growing degree days (base 5°C, GDD5) for Puketoi ki Tai indicate a clear, robust trend towards increasing thermal accumulation throughout the 21st century. Across all future periods and emissions scenarios (SSPs), modelled increases in GDD5 are evident relative to the 1986–2005 baseline (~2910 GDD), with the magnitude of change governed by emissions pathway and time period. By mid-century (2041–2060), GDD5 increases are likely for all SSPs, with multi-model means ranging from approximately 390 (SSP1-2.6, low emissions) to over 610 GDD (SSP5-8.5, high emissions), with very high confidence and inter-model consistency. For the late-century (2080–2099), projected GDD5 increases diverge substantially: a modest rise under SSP1-2.6 (~380 GDD), but a large enhancement under higher emissions (SSP2-4.5: ~790 GDD; SSP3-7.0: ~1160 GDD; SSP5-8.5: ~1450 GDD). This scenario-dependent spread, together with the negligible percentage agreement across SSPs by 2080–2099, suggests high dependence on emissions pathway (high confidence in direction, low confidence in magnitude). In all periods, spatial variability (intra-regional standard deviation) is small relative to the projected changes, reinforcing the robustness of these signals. Overall, it is virtually certain GDD5 will increase in Puketoi ki Tai, with the extent of increase very likely greatest under high-emissions scenarios.

15.12 Region: Middle Whangaehu-Whanganui

Area: 1816.56 km²

A plot of the evolution in growing degree days (base 5°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 5°C) over this region is shown in Table 12. Projections for annual growing degree days (GDD, base 5°C) in Middle Whangaehu-Whanganui indicate a robust and substantial increase relative to the 1986–2005 baseline. By mid-century,

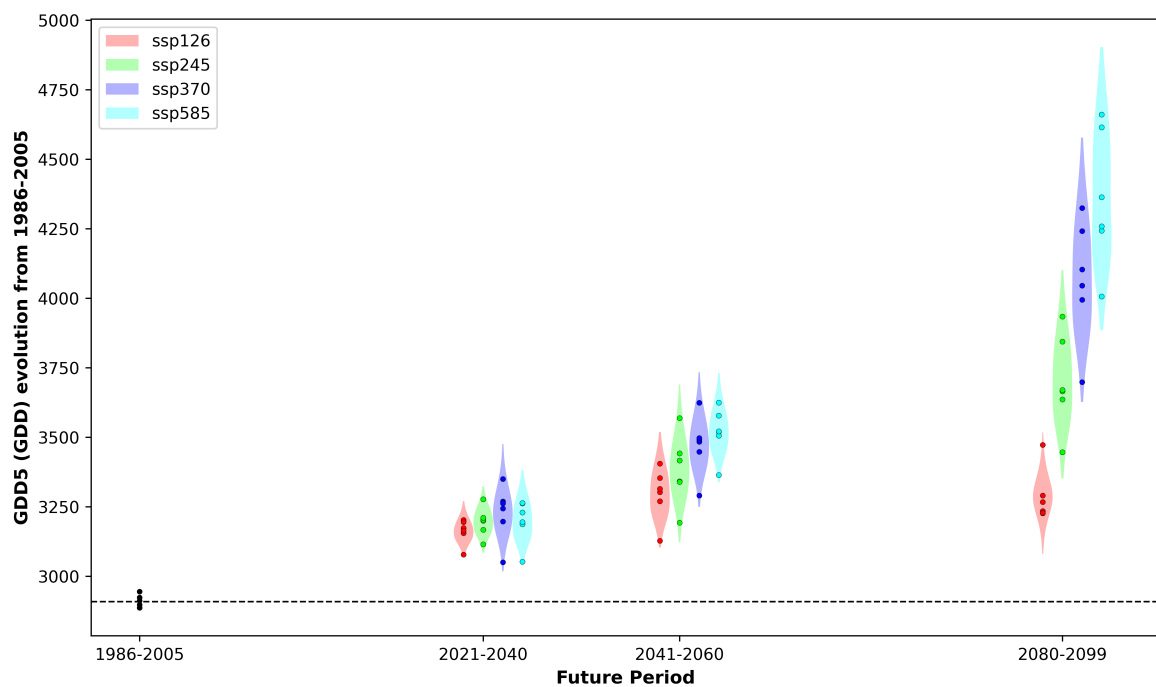


Figure 28: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Puketoi ki Tai region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty 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 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](#).

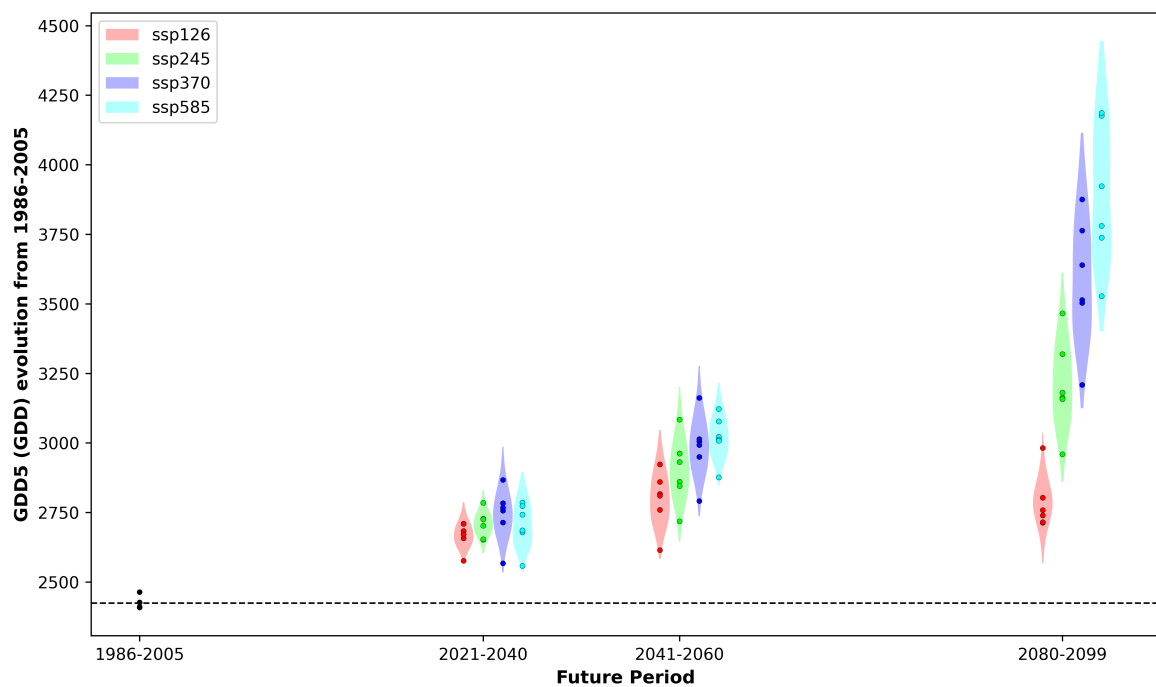


Figure 29: The time evolution of growing degree days (base 5°C) from the 1986-2005 baseline in units of GDD over the Middle Whangāehu-Whanganui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the 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 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](#).



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2908 ± 200	2908 ± 200	2908 ± 200	2908 ± 200
	2021-2040	253 ± 6	287 ± 6	320 ± 6	290 ± 8
	2041-2060	387 ± 7	475 ± 8	564 ± 9	610 ± 11
	2080-2099	378 ± 8	791 ± 11	1159 ± 16	1449 ± 18
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	254 ± 6	289 ± 6	323 ± 6	293 ± 8
	2041-2060	391 ± 7	479 ± 8	567 ± 9	613 ± 11
	2080-2099	380 ± 8	797 ± 11	1168 ± 16	1463 ± 18
Multi-model minimum	Baseline	2886 ± 200	2886 ± 200	2886 ± 200	2886 ± 200
	2021-2040	169 ± 3	206 ± 6	142 ± 4	144 ± 3
	2041-2060	219 ± 4	284 ± 9	382 ± 5	455 ± 6
	2080-2099	315 ± 7	537 ± 10	790 ± 14	1098 ± 19
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	190 ± 4	212 ± 6	182 ± 5	179 ± 5
	2041-2060	254 ± 6	301 ± 9	414 ± 7	487 ± 8
	2080-2099	248 ± 6	550 ± 9	852 ± 16	1104 ± 18
Multi-model maximum	Baseline	2945 ± 198	2945 ± 198	2945 ± 198	2945 ± 198
	2021-2040	294 ± 9	368 ± 7	441 ± 5	357 ± 8
	2041-2060	497 ± 8	660 ± 10	715 ± 8	716 ± 18
	2080-2099	564 ± 11	1025 ± 11	1416 ± 13	1752 ± 23
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	326 ± 10	376 ± 9	481 ± 9	422 ± 12
	2041-2060	545 ± 9	680 ± 10	740 ± 11	756 ± 17
	2080-2099	523 ± 11	1078 ± 16	1528 ± 16	1871 ± 18

Table 11: The statistics of the projected changes in growing degree days (base 5°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).



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	2424 ± 307	2424 ± 307	2424 ± 307	2424 ± 307
	2021-2040	244 ± 5	283 ± 5	318 ± 5	280 ± 5
	2041-2060	373 ± 6	476 ± 7	561 ± 8	595 ± 8
	2080-2099	361 ± 7	783 ± 10	1160 ± 12	1464 ± 13
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	245 ± 5	285 ± 5	321 ± 5	284 ± 5
	2041-2060	377 ± 6	480 ± 7	565 ± 8	598 ± 8
	2080-2099	363 ± 7	790 ± 10	1171 ± 12	1482 ± 13
Multi-model minimum	Baseline	2408 ± 306	2408 ± 306	2408 ± 306	2408 ± 306
	2021-2040	152 ± 5	227 ± 4	143 ± 4	134 ± 4
	2041-2060	191 ± 7	294 ± 5	367 ± 9	452 ± 9
	2080-2099	289 ± 5	534 ± 8	784 ± 12	1103 ± 14
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	175 ± 4	214 ± 5	181 ± 4	162 ± 4
	2041-2060	226 ± 7	304 ± 6	396 ± 8	478 ± 10
	2080-2099	221 ± 7	543 ± 10	832 ± 12	1103 ± 15
Multi-model maximum	Baseline	2464 ± 308	2464 ± 308	2464 ± 308	2464 ± 308
	2021-2040	288 ± 7	361 ± 7	443 ± 7	362 ± 6
	2041-2060	499 ± 5	660 ± 9	737 ± 9	698 ± 8
	2080-2099	558 ± 8	1042 ± 10	1451 ± 13	1762 ± 13
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	325 ± 6	365 ± 8	479 ± 6	422 ± 7
	2041-2060	549 ± 6	680 ± 9	756 ± 8	734 ± 8
	2080-2099	519 ± 8	1070 ± 10	1557 ± 12	1909 ± 13

Table 12: The statistics of the projected changes in growing degree days (base 5°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).



all future scenarios show a likely rise in multi-model mean GDDs, with increases ranging from roughly 240 under low emissions (SSP1-2.6) to over 590 under high emissions (SSP5-8.5) by 2041–2060. By 2080–2099, the range is larger: around 360 (SSP1-2.6) up to over 1460 (SSP5-8.5), making larger GDD increases very likely under higher emission scenarios.

The figure shows consistent inter-model agreement within each scenario, illustrated by tight violin plot widths for near and mid-term periods. However, scenario agreement declines over time, with future scenario spread increasing strongly by late century (agreement falls to 0%), indicating low confidence in emissions-independent projections after mid-century. Spatial variability across the sub-region (as represented by standard deviation) remains low relative to the signal size, supporting high confidence in the spatial coherence of the projected changes.

In summary, it is very likely that annual GDD will increase substantially in Middle Whangaehu-Whanganui, with the magnitude of change dominated by emissions pathway after mid-century. These changes are robust across models for each scenario, particularly in the near term, with very high confidence in the direction of change.