

Climate Analysis of Potential evapotranspiration deficit

Horizons Region, New Zealand

Climate Change Projections from CCAM-Downscaled CMIP6 Simulations

Prepared by

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1 Executive Summary

Potential evapotranspiration deficit (PED) is a critical climate variable for the Horizons region, encapsulating the net difference between evaporative demand and actual evapotranspiration, and serving as a primary indicator of climatic moisture stress. PED represents a synthesis of temperature, humidity, solar radiation, wind, and precipitation interactions, making it highly relevant for water resource management, agriculture, ecosystems, and drought risk assessment. An increase in PED implies an elevated likelihood and severity of hydrological drought, challenges for crop and pasture productivity, and stress on natural systems dependent on available water.

The comprehensive multi-model analysis synthesised for this report shows that, historically (1986–2005), PED exhibits a robust north–south and inland–coastal gradient, with higher values concentrated in southern and eastern (leeward) parts of the Horizons region. There is extremely high inter-model agreement (>99% probability, virtually certain) about this spatial structure, and differences between models are much smaller than the absolute variation observed in the baseline climatology.

Looking ahead, it is virtually certain that PED will increase across the region under all future greenhouse gas emission scenarios, with higher warming scenarios (SSP3-7.0, SSP5-8.5) producing larger, more widespread, and more spatially coherent increases. By the late 21st century, ensemble mean PED increases of over 100 mm are projected in the highest-emission scenario, with the largest absolute increases consistently affecting sub-regions such as Puketoi ki Tai, Tararua, and Turakina. These areas already experience the highest baseline deficits and are thus likely to be most vulnerable to further moisture stress and associated impacts. Even under the most optimistic scenario (SSP1-2.6), PED increases are likely region-wide, though of smaller magnitude (~25–40 mm on average). Local exceptions exist in some wetter or highland sub-regions, where smaller or infrequent decreases remain about as likely as not.

Uncertainty analysis demonstrates that while the magnitude and fine-scale pattern of change remain somewhat model-dependent, the direction and broad regional structure of the projected increase are highly robust (very likely to extremely likely). Model ensemble maxima provide reliable proxies for upper-end (dry extreme) projections, guiding planning for worst-case scenarios.

These findings underscore an urgent need for adaptive management of water supplies, agricultural strategies, and natural ecosystems to mitigate the risks posed by a drier climate, with a particular focus on the most affected sub-regions. The available sub-reports from Bodeker Scientific provide further scenario, sub-region, and season-specific detail for decision-makers as required.

2 Introduction

The present synthesis aims to provide a comprehensive evaluation of baseline and projected future changes in potential evapotranspiration deficit (PED) across the Horizons region of New Zealand. PED is a key indicator for assessing landscape-level moisture limitation, agricultural drought risk, ecosystem stress, and long-term sustainability of water resource systems. It serves as an integrated measure of the excess of atmospheric moisture demand over supply and actual surface evapotranspiration, making it critical for a region such as Horizons, characterised by diverse topography, climate gradients, and economic dependence on rain-fed agriculture and natural resources.

The objectives of this synthesis are sixfold:

1. to characterise the historical spatial distribution of PED for 1986–2005 across the region.
2. to assess model-based projections of PED under multiple Shared Socioeconomic Pathways (SSPs) out to 2099.
3. to examine how spatial patterns and magnitude of PED change evolve through three distinct future



periods (2021–2040, 2041–2060, 2080–2099).

4. to evaluate cross-model agreement and ensemble spread.
5. to identify hotspots—in terms of both high baseline values and projected increases—where vulnerability to moisture deficit and drought is greatest, and.
6. to characterise the various sources and scales of uncertainty present in these projections.

PED is relevant for land managers, farmers, urban planners, and environmental agencies, given its direct connection to soil moisture, irrigation demand, pasture growth, and river/stream flows. As climate change progresses, increases in PED signal heightened risk of drought frequency, duration, and severity, with accompanying threats to crop yields, biodiversity, and the economic wellbeing of rural communities. Adaptation strategies, such as the implementation of resilient crop varieties, soil moisture conservation, targeted water storage solutions, and changes to livestock management, should thus be prioritised in areas projected to see the greatest increases in PED.

This synthesis leverages an ensemble of downscaled climate projections (via the CCAM model), which assimilate boundary conditions from six CMIP6 global models, across four emissions scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5). The analyses are both region-wide and sub-regional, with full scenario, period, and sub-region results available upon request from Bodeker Scientific. The intent is to deliver a clear understanding of how the PED baseline is expected to evolve, where the greatest risks are likely to emerge, the confidence that can be placed in these projections, and what policy, planning, and practical responses may be warranted.

3 Understanding Potential Evapotranspiration Deficit

Potential evapotranspiration deficit (PED) quantifies the accumulated shortfall between atmospheric evaporative demand (potential evapotranspiration, PET) and the actual evapotranspiration (AET) realised from a surface, typically assessed over the growing season. Mathematically, PED is calculated as the sum (over a period, usually days-to-months) of $(PET - AET)$ for intervals where PET exceeds AET, and is expressed in millimetres (mm).

PET itself is typically calculated using formulae such as the Penman-Monteith equation, which incorporates solar radiation, air temperature, wind speed, and relative humidity—variables that determine the evaporative power of the atmosphere. Actual evapotranspiration is usually a function of PET constrained by soil moisture availability and precipitation inputs. Thus, PED increases when atmospheric demand rises (due to warming, windiness, lower humidity, or greater solar radiation) and/or when realised precipitation and soil moisture decline.

The primary climatic drivers of a rising PED are increasing air temperatures (which amplify PET), declining precipitation (reducing AET), or both. Wind speed, humidity, and solar radiation can modulate PED's magnitude, as can land-cover and soil changes, but climate trends in temperature and precipitation dominate longer-term changes. PED is particularly sensitive to persistent rainfall deficits, high-frequency heat events, or prolonged warm-dry conditions, making it a robust metric for capturing climate change impacts on agricultural and ecological drought risk. Changes in PED thus respond to a combination of warming and drying trends—both of which are projected under most climate change scenarios for New Zealand's east and central regions.

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.

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

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

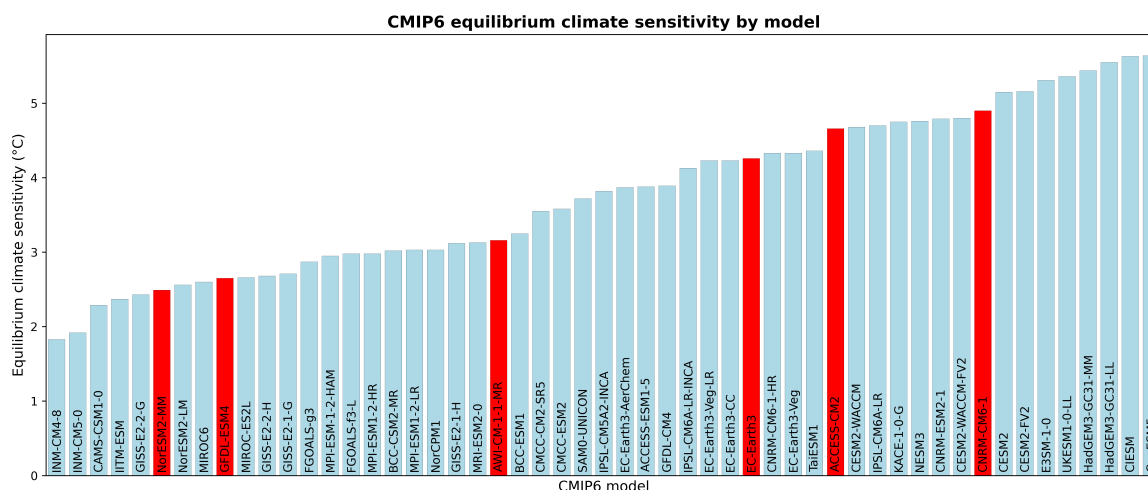


Figure 1: The location of the six guiding CMIP6 models across the full range of equilibrium climate sensitivities (ECSs) of all 53 CMIP6 models. The original of this figure can be downloaded [here](#).

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

Three future periods were examined:

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

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

A key strength of the modelling framework is the use of an ensemble of climate models rather than reliance on a single simulation. Ensemble approaches allow both the central tendency and uncertainty of projected changes to be assessed. That said, an ensemble of six models does not capture the potential full range of variability. By considering the ECS of each of these models in the context of the much wider range of 53 CMIP6 models (see Figure 1), a method was developed to generate a more complete picture of the potential uncertainty in projected changes. That method is discussed in the companion “overview” report to this PED-specific report. Uncertainty probability density functions (PDFs) generated using this method appear in many of the plots shown herein.

5 Potential Evapotranspiration Deficit Climatology: 1986 to 2005

The CCAM simulated potential evapotranspiration deficit fields, averaged over the period 1986–2005, are shown in Figure 2. This variable is not seasonally disaggregated and so the fields shown in Figure 2 are representative of the whole year. Because the differences between these fields are not readily apparent, differences between each field and the multi-model mean are shown in Figure 3.

For the baseline period (1986–2005), the climatology of potential evapotranspiration deficit (PED) in the Horizons region is defined by a pronounced spatial gradient, robustly reproduced across all six CCAM-driven model simulations. PED values are lowest in the northern and western sub-regions, particularly Horowhenua, Volcanic Plateau, and Taumarunui, reflecting coastal proximity, prevailing westerlies, and higher baseline rainfall. In these areas, mean PED values can fall below 100 mm, indicating limited cumulative moisture stress and a climate generally more favourable for pastoral and cropping activities reliant on rain-fed systems.

By contrast, the central, southern, and especially southeastern coastal and upland parts of the region—such

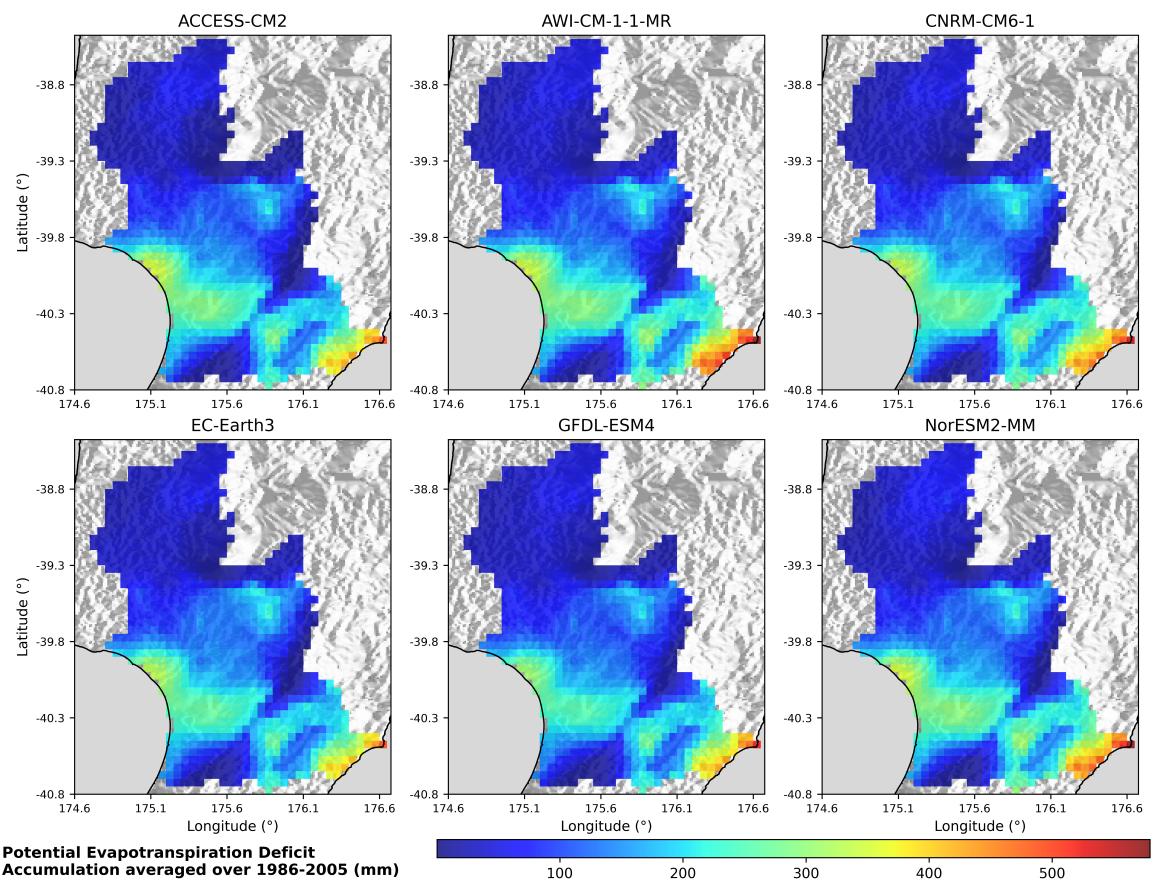


Figure 2: Potential evapotranspiration deficit fields as simulated by the CCAM model and averaged over the period 1986 to 2005. The original of this figure is available [here](#).



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

as Puketoi ki Tai, Tararua, and southern Middle Manawatū-Rangitīkei—record much higher PED values, with annual accumulations at or above 400–500 mm in the model ensemble. These zones lie in the lee of the major ranges, receive lower precipitation due to regional rain shadows, and frequently experience higher summer temperatures and evaporation rates. The persistence of this spatial gradient is evident in all six CCAM model simulations, with mean spatial R^2 values approaching 0.99 (virtually certain agreement) and inter-model spread typically small compared to the overall range. Differences from the multi-model mean exceed ± 40 mm only at a few isolated locations, usually near complex topography such as the eastern escarpment, and do not undermine the robust identification of regional hotspots of moisture deficit.

The consistency of the spatial pattern across climate models provides high confidence in the baseline structure: the southern/eastern zones are more vulnerable to seasonal and interannual drought due to higher PEDs, while the northern/western zones remain relatively buffered by higher rainfall and lower evaporative demand. This strong underlying gradient forms the reference against which all future PED changes are assessed.

6 Near-Future Projections (2021–2040)

In the near future (2021–2040), the Horizons region is projected to experience a general increase in potential evapotranspiration deficit (PED), a proxy for seasonal moisture deficit and drought risk. This increase is a consistent signal found across all four emissions scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5) and is evident in the majority of global climate models considered. The scale of projected change is typically moderate, with ensemble mean increases in PED ranging from just under 10 mm to around 50 mm regionally. The largest increases tend to occur in the eastern and central sub-regions, notably in areas like Puketoi ki Tai and Tararua, which are already more prone to dryness in the baseline climate. In these locations, localised max-



imum changes may exceed 100 mm in some model runs, although spatial averages tend to be considerably lower.

Model agreement is generally moderate: most models show increases in PED, but one or two models within each scenario occasionally simulate either negligible change or small decreases in specific sub-regions. Agreement is stronger on the direction of change (increases) than on the precise magnitude or spatial structure, especially at finer scales. The likelihood of regionally widespread increases is high (at least likely in IPCC terms), though confidence in exact local-scale impacts is somewhat limited by inter-model variability. Compared to baseline, this projected increase in PED implies an escalating risk of seasonal water stress—an important consideration for water resource planning, agriculture, and ecosystem management.

Spatial uncertainty remains, with variability in both the extent and magnitude of PED change across the region. Some western or high-elevation areas may see relatively stable conditions, but the overwhelming regional signal is a modest movement toward greater moisture deficit by 2040. The regional signal is robust enough to inform adaptation discussion, noting that increases are not uniform and local conditions may differ substantially. Further detail and model-specific nuances are available in dedicated sub-reports, held by Bodeker Scientific.

6.1 SSP1-2.6: Very likely region-wide small increases, highest in eastern areas

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP1-2.6 scenario, as simulated by the six different models, are shown in Figure 4.

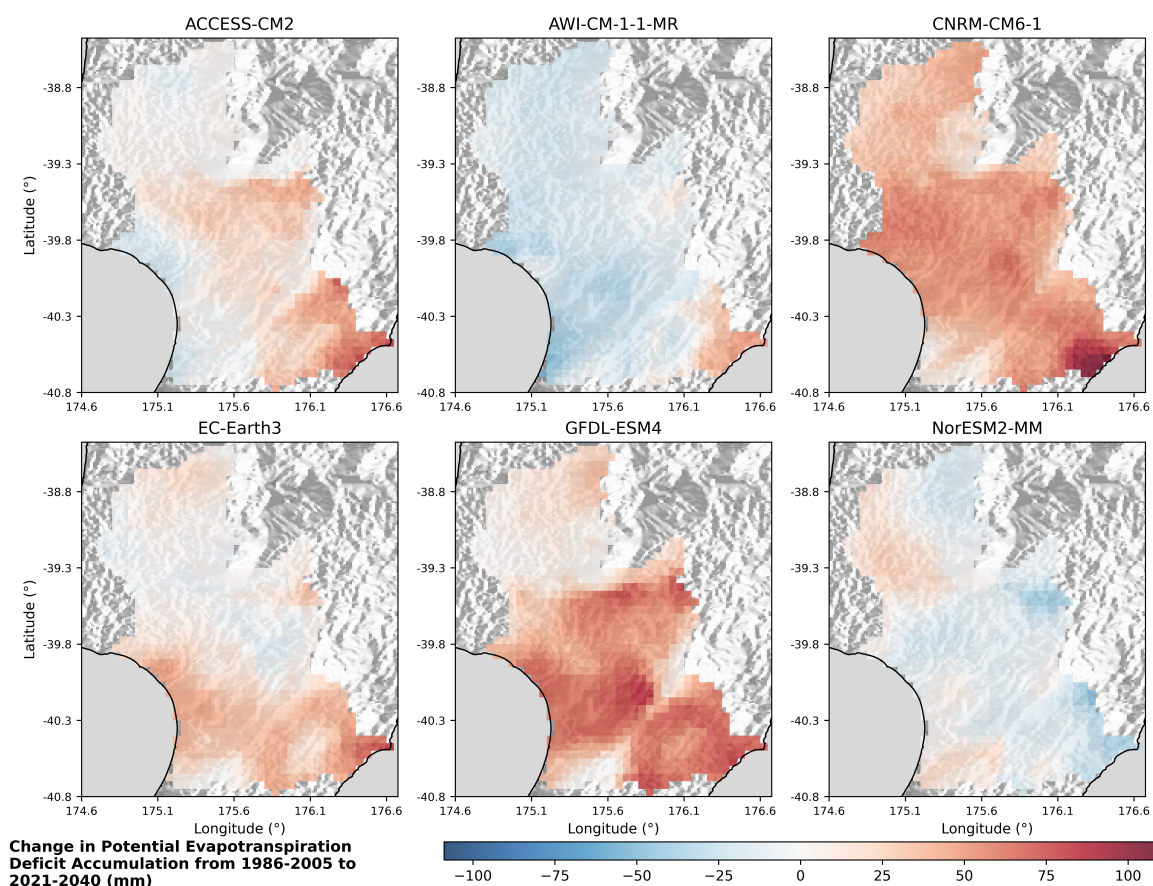


Figure 4: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP1-2.6 scenario. The original of this figure is available [here](#).

Under the low-emissions scenario SSP1-2.6, projections for 2021–2040 show a likely, though relatively mod-



est, increase in potential evapotranspiration deficit (PED) across most of the Horizons region. This signal is widespread but of moderate magnitude: ensemble mean PED increases are generally around 15 mm, with localised maxima above 70 mm in some model fields. The most pronounced increases are expected in eastern and southeastern sub-regions, such as Puketoi ki Tai and Tararua, areas already exhibiting higher baseline PED. Model agreement is good on the overall direction of change—most models agree on increases—but consensus wanes regarding the precise geography or local magnitude, reflected in modest spatial R^2 values (average ~ 0.26). Inter-model spread is evident, with some models (e.g., AWI-CM-1-1-MR) simulating minimal change or even slight PED decreases in central or western areas. However, across the ensemble as a whole, there is high confidence that increased PED is more likely than not, especially in historically drier areas.

Statistical analyses of uncertainty indicate that the range of ensemble projections is moderate, with notable differences between minimum, mean, and maximum values across models—maximum values provide a robust estimate of upper-end outcomes (P95), while minima may underrepresent or exaggerate potential decreases. For regional adaptation planning, it is important to note that while overall increases in evaporative deficit are very likely, precise local responses remain more uncertain. The narrative and figures supporting these findings, as well as any sub-regional details, are available upon request through Bodeker Scientific.

6.2 SSP2-4.5: Likely moderate, widespread PED increases, strongest east and central

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP2-4.5 scenario, as simulated by the six different models, are shown in Figure 5.

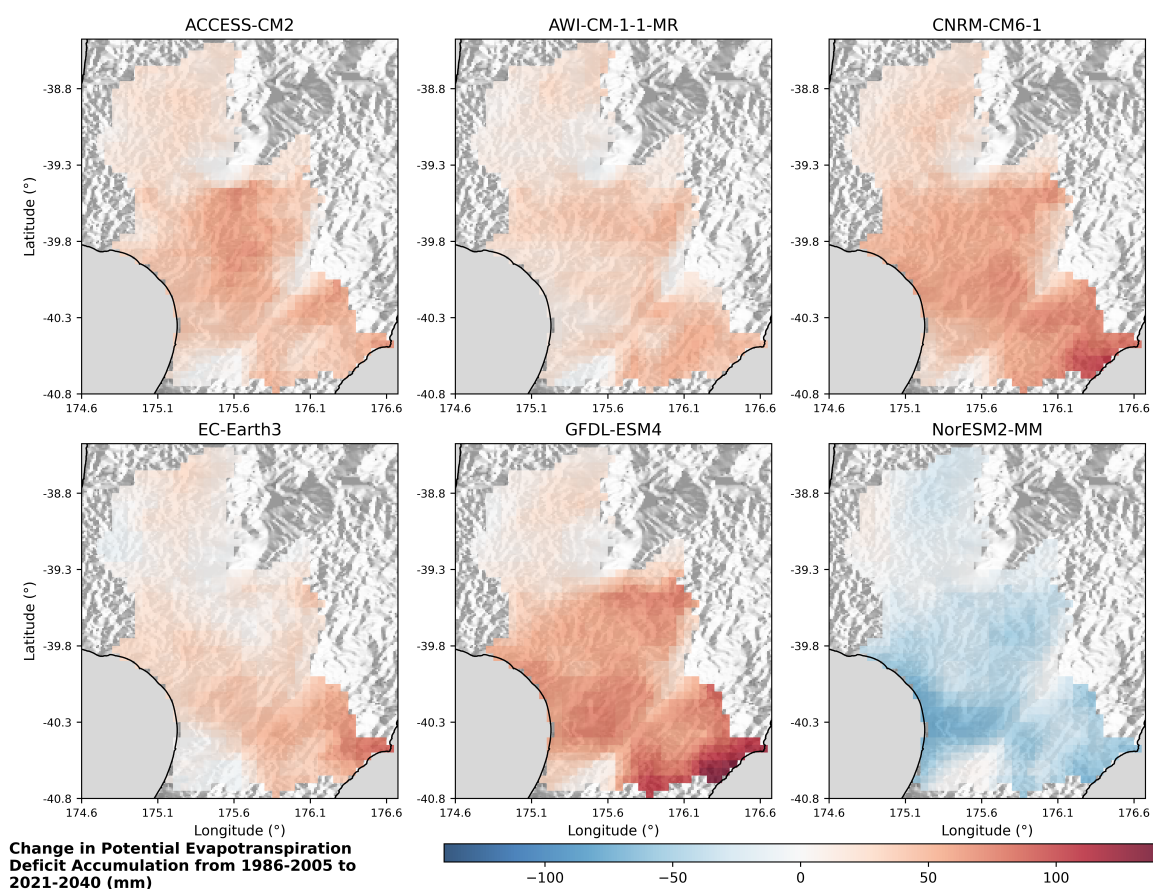


Figure 5: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

For the SSP2-4.5 scenario, representing intermediate emissions, projections for PED in the Horizons region by 2021–2040 indicate a likely and spatially robust increase. The ensemble mean increase is typically moderate,



ranging up to 50 mm in affected sub-regions; some models even simulate local maxima near 140 mm, but these are not widespread. The spatial signal of increased PED is clearest in the eastern lowlands and central uplifted areas, which correspond closely to baseline zones of higher PED. By contrast, areas such as Horowhenua and Volcanic Plateau are projected to see the smallest increases, with some localised exceptions showing almost negligible change, but no robust evidence for widespread decreases.

Inter-model agreement is moderately high, with most models simulating increased PED, a spatial R^2 around 0.5, and consistent median (50th percentile) and upper percentile (95th percentile) values. One model (NorESM2-MM) occasionally diverges, especially in the west, lending further nuance to the ensemble mean. The uncertainty analysis confirms that ensemble minima and maxima, while not perfect, provide reasonable first-order estimates for lower and upper bound PED changes, although dedicated percentile fields offer more scientifically robust quantification. Broad agreement on the regional signal supports high confidence, at least likely to very likely, that water deficits will worsen during the period for most sub-regions, and that this tendency is more pronounced in already dry eastern and interior zones. Sub-reports with detailed spatial findings and supportive figures are maintained by Bodeker Scientific and can be requested for further local assessment.

6.3 SSP3-7.0: Very likely modest regional PED increases, peak in eastern hotspots

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP3-7.0 scenario, as simulated by the six different models, are shown in Figure 6.

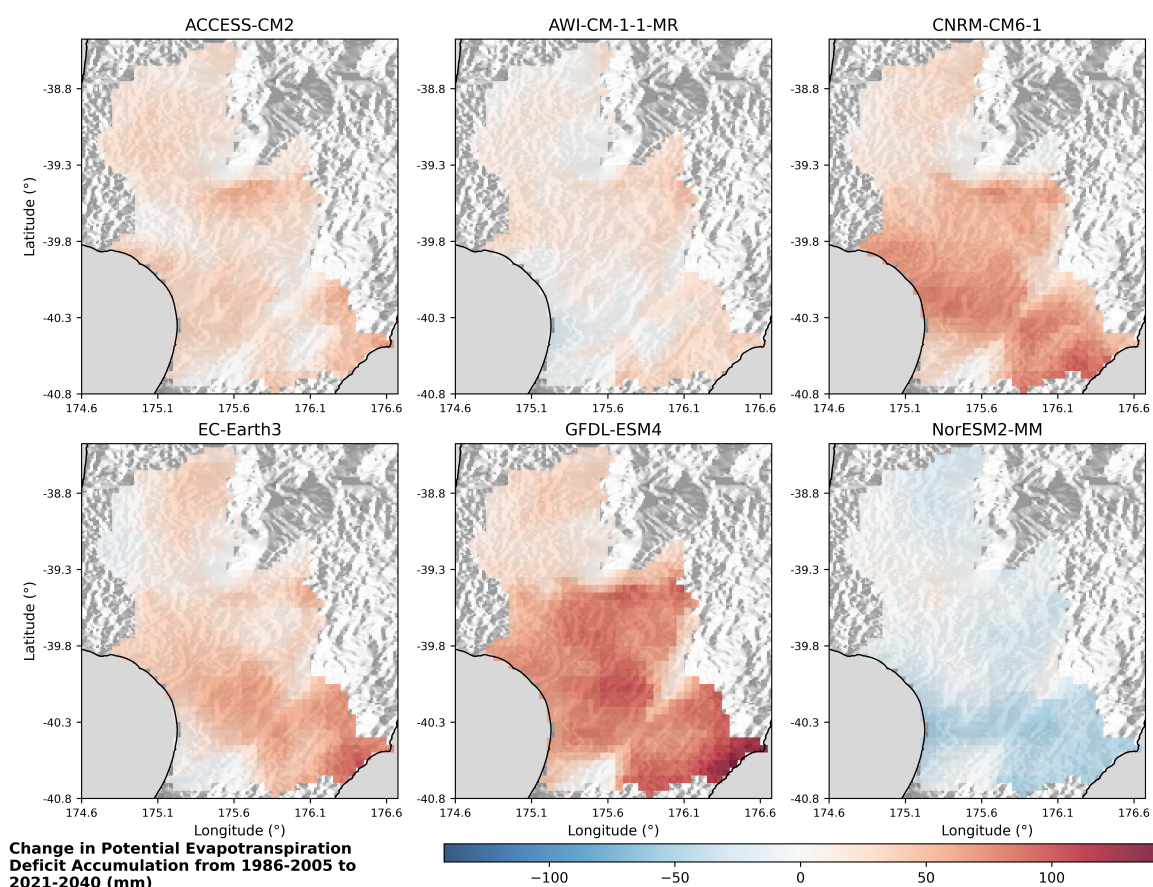


Figure 6: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

Under the high–intermediate emissions scenario SSP3-7.0, the near-future change (2021–2040) in PED across the Horizons region is also characterised by likely and spatially widespread increases. Ensemble mean PED rises of around 25 mm are common, but substantial local and model-dependent variation remains (individual means



range from decreases of ~ 18 mm to increases above 55 mm, maxima exceeding 120 mm in some runs). The general trend is that eastern, southeastern, and central parts of the region will face greater increases, while Horowhenua and other western sub-regions tend to show the smallest changes.

Model agreement is high on the sign of regional change—five out of six models project increases over most of the area, implying a robust regional response. However, the spatial R^2 is relatively low (~ 0.28), reflecting limited consensus at more local scales regarding where changes will be most pronounced. Inter-model spread in fine-scale response remains moderate, but all ensemble means are positive, except for one model (NorESM2-MM), which simulates near-neutral or slight decreases in PED for some sub-regions. The overall risk of increasing seasonal water stress due to climate change is thus high, and it is very likely that the Horizons region will experience greater PED by 2040, particularly in eastern or more drought-prone sub-regions. Minimum and maximum ensemble projections are consistent with the 5th–95th percentile spread, supporting very high confidence in the upper bounds of possible increases. Interested readers may request detailed sub-reports from Bodeker Scientific for more granular analysis.

6.4 SSP5-8.5: Likely moderate, regionally consistent PED increases, especially east

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP5-8.5 scenario, as simulated by the six different models, are shown in Figure 7.

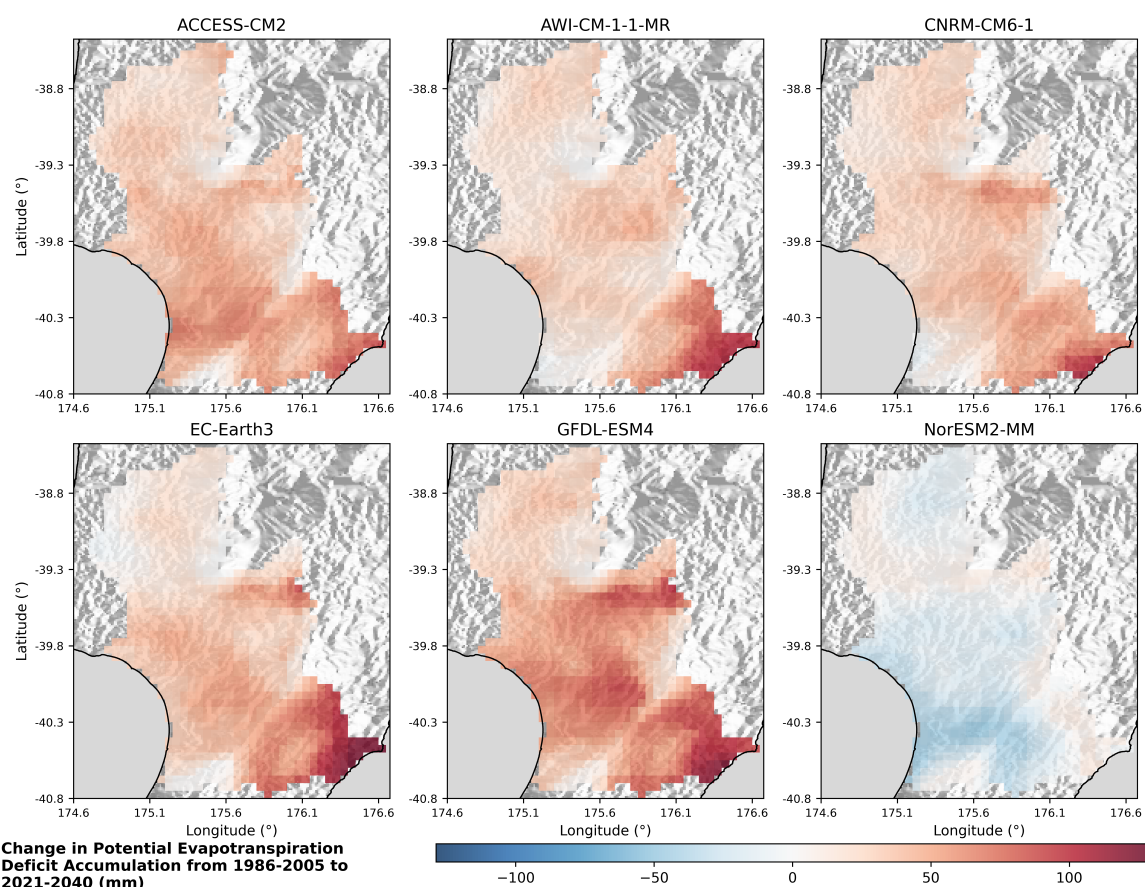


Figure 7: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2021-2040 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

The highest-emissions scenario, SSP5-8.5, yields a near-future (2021–2040) projection of likely and regionally coherent increases in PED for Horizons. The spatial signal is clear: ensemble mean increases in PED are typically about 30 mm, occasionally exceeding 100 mm at local gridpoints, but with a moderate range across models, including some local decreases or minimal increases in one ensemble member. The projected increases are



generally broad-based but exhibit the greatest magnitude in the central and eastern lowlands, scaling with baseline sensitivity.

Inter-model spread is present but does not obscure the dominant trend; five of six models show consistent increases in most areas, while one model projects more muted changes or slight decreases. The mean spatial R^2 (~ 0.41) indicates only moderate agreement on local patterns but strong agreement on overall direction. Uncertainty assessment demonstrates very likely (probability $>66\%$) increases in most sub-regions, and extremely likely robust upper limits on ensemble projections. Areas with previously low PED experience the smallest changes, while already stressed zones (e.g., Puketoi ki Tai) see relative amplification of deficit. This scenario highlights the expected sensitivity of PED responses to emissions pathway, even at short time scales. Detailed, model-by-model and sub-regional narratives supporting all findings can be obtained from Bodeker Scientific.

6.5 Comparison Across Scenarios

Across all scenarios (SSP1-2.6 through SSP5-8.5), the regional signal for the near term (2021–2040) is a likely, modest increase in PED, with the most robust signals and highest magnitude of change concentrated in the eastern and central sub-regions. The overall pattern holds across emissions pathways, though the degree of increase and local variability grows with higher-emissions scenarios. Model agreement is highest for the sign of change (increased PED), but less so for fine-scale patterns or magnitude. The lowest-emissions pathways yield smaller and more spatially contained changes, while higher scenarios amplify both the mean trend and the spatial extent. No scenario exhibits region-wide decreases. Confidence in the overall direction of change is very likely or higher, though local details must be interpreted with care.

7 Mid-Century Projections (2041–2060)

For the mid-century period (2041–2060), robust increases in potential evapotranspiration deficit (PED) are projected for the Horizons region across all emission scenarios. The signal of intensifying regional moisture deficit strengthens relative to the near-future period, with ensemble mean increases in PED typically ranging from 35 mm to over 50 mm, and local maxima for some models and grid points exceeding 150 mm. The most prominent increases are expected in sub-regions that are already dry or moisture-limited, particularly in the east, south, and central lowlands—such as Puketoi ki Tai, Tararua, and Turakina. Ensemble mean projections indicate widespread regional increases, while sub-regional variability in magnitude persists, reflecting underlying topography and rainfall gradients.

Model agreement becomes progressively stronger by mid-century, especially on the sign of regional change. All models simulate positive PED changes in most areas, though the spatial detail (i.e., which gridpoints see the largest increases) varies, as indicated by moderate spatial R^2 values—from about 0.4 up to 0.5 or higher depending on scenario. Inter-model spread remains substantial for local extremes, but agreement is robust for the overall drying trend. The upper bound estimates (ensemble maxima) reliably indicate the scale of possible extreme increases in PED, while minima still show some potential for isolated, modest reductions (generally in the wettest sub-regions, e.g., Horowhenua), but these declines are rare.

The mid-century intensification of PED reflects amplified climate change signals: greater evaporative demand and/or reduced precipitation. The likelihood of increased moisture deficits at this timescale is high (very likely to extremely likely), with the greatest vulnerabilities focused in the sub-regions that are arid at baseline. These findings reinforce the importance of ongoing water resource and drought adaptation planning for the region. Detailed scenario- and sub-region-specific findings are available in the supplementary sub-reports held at Bodeker Scientific.



7.1 SSP1-2.6: Very likely moderate, widespread PED increases, strongest in east

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP1-2.6 scenario, as simulated by the six different models, are shown in Figure 8.

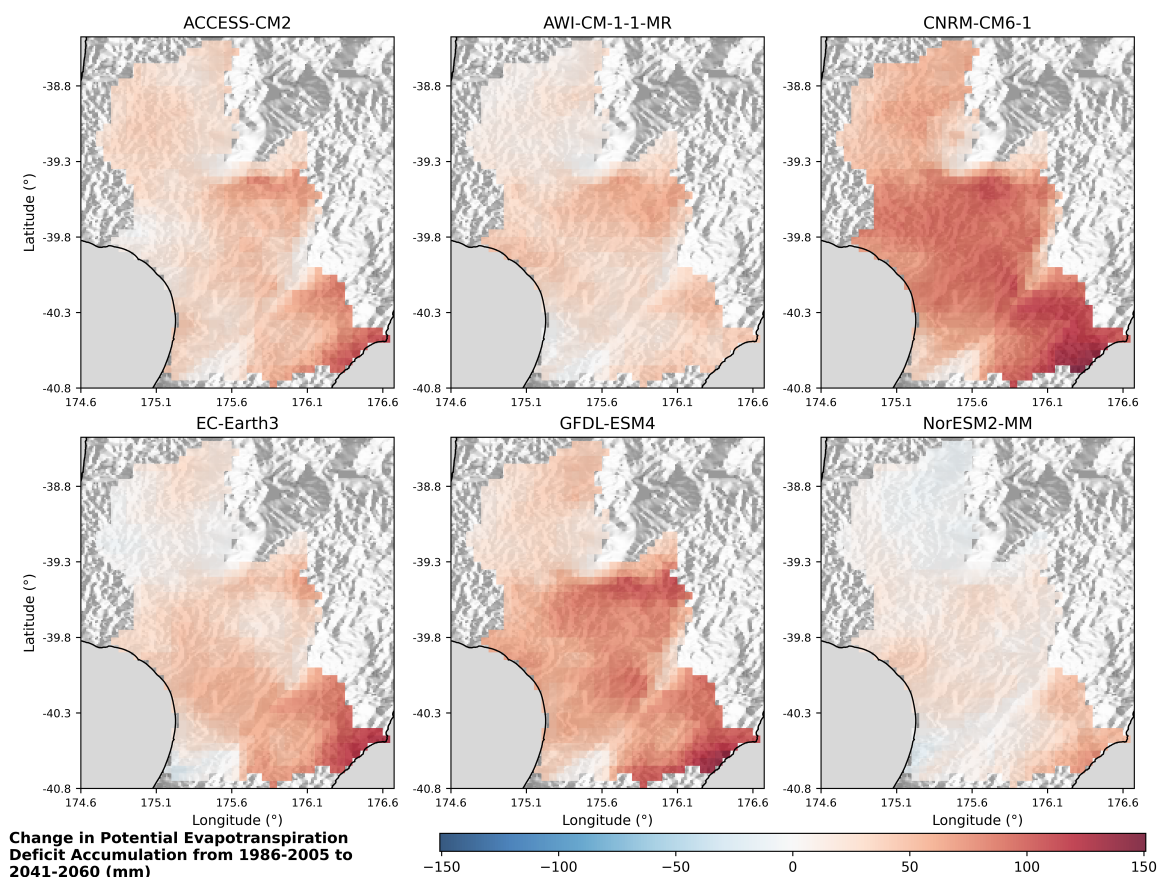


Figure 8: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP1-2.6 scenario. The original of this figure is available [here](#).

Under SSP1-2.6, the mid-century period (2041–2060) shows a widespread, moderate increase in PED across the Horizons region. Ensemble mean increases typically centre around 40 mm, with model means extending from roughly 13 to 73 mm and sub-regional maxima exceeding 100 mm in a few localities. Largest changes are found in eastern and upland areas (e.g., Puketoi ki Tai, Tararua), with coastal and lowland areas (Horowhenua, Whanganui-Manawātū Lakes) experiencing more modest changes. All models agree on increases in PED regionally, so the likelihood of a positive shift is high and confidence in the sign of change is very likely.

However, fine-scale spatial agreement is lower, with moderate spatial R^2 (~ 0.52 on average) and localised model-to-model variability in where the greatest changes occur. Minimum and lower percentile projections suggest the possibility of little or no change in some wetter sub-regions, but these are not central tendencies and, for eastern or central sub-regions, all models project increases above zero. The percentile spread is relatively tight for high-PED zones, providing extremely likely confidence in persistently increasing water deficits for the most at-risk locales.

Statistical analyses endorse the use of extremes from the ensemble as proxies for percentile bounds, with both minimum and maximum fields highly correlated to their 5th and 95th percentiles, respectively. The overall conclusion is that a region-wide, moderate increase in PED is very likely by mid-century under SSP1-2.6, with local magnitude and pattern shaped by underlying climate and geography. Sub-report figures and details are available for deeper review from Bodeker Scientific.



7.2 SSP2-4.5: Extremely likely region-wide PED increases, highest in east/central

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP2-4.5 scenario, as simulated by the six different models, are shown in Figure 9.

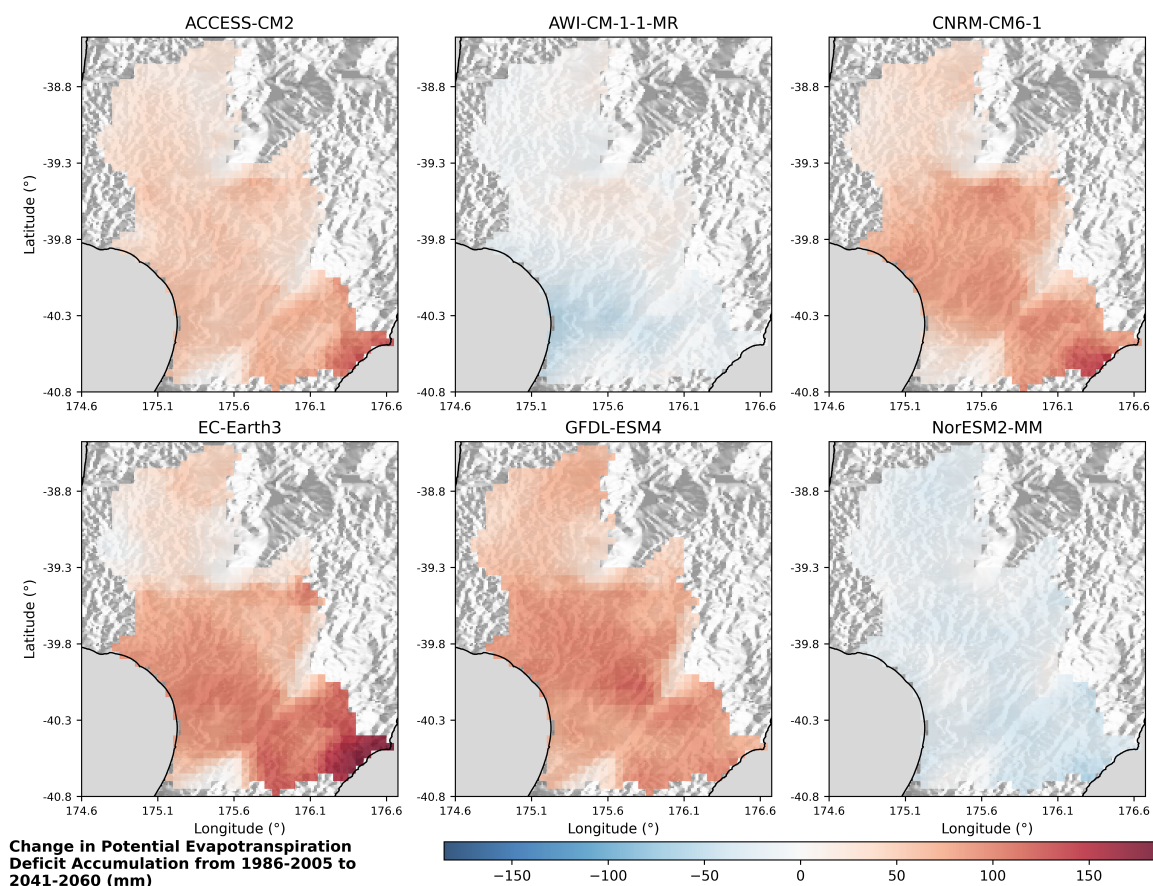


Figure 9: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

For SSP2-4.5, the mid-century (2041–2060) projection is of a likely and robust increase in PED across almost all of the Horizons region. The mean regional increase is about 36 mm, with sub-regional means spanning from roughly -18 mm up to ~72 mm, and model local maxima in excess of 100 mm at a few sites, especially in central and eastern lowland or hill country zones. The broad spatial pattern mirrors both the baseline and near-future shifts, reinforcing the eastern and central sub-regions as the most moisture-stressed. All models, except occasional isolated grid points, project increased PED throughout the domain, and percentile spreads support high confidence: minima are generally negative or near-zero only in the wettest sub-regions.

Model agreement is extremely high regarding the direction of change (regional increases)—all but minor local exceptions indicate drying. However, moderate inter-model spread persists on exact spatial detail and magnitude, as reflected by spatial R^2 values (mean ~0.38) and substantial standard deviations among ensemble means. The upper percentile bounds (P95) are robustly captured by ensemble maxima, offering very high confidence in the estimate of extreme PED increase. The collective evidence indicates that intensified evaporative deficit by mid-century is extremely likely for the Horizons region, supporting confident planning for heightened drought and water loss risks across sub-regions. Sub-report documentation and supporting analysis are available on request.



7.3 SSP3-7.0: Very likely moderate-to-large PED increases, especially east/south

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP3-7.0 scenario, as simulated by the six different models, are shown in Figure 10.

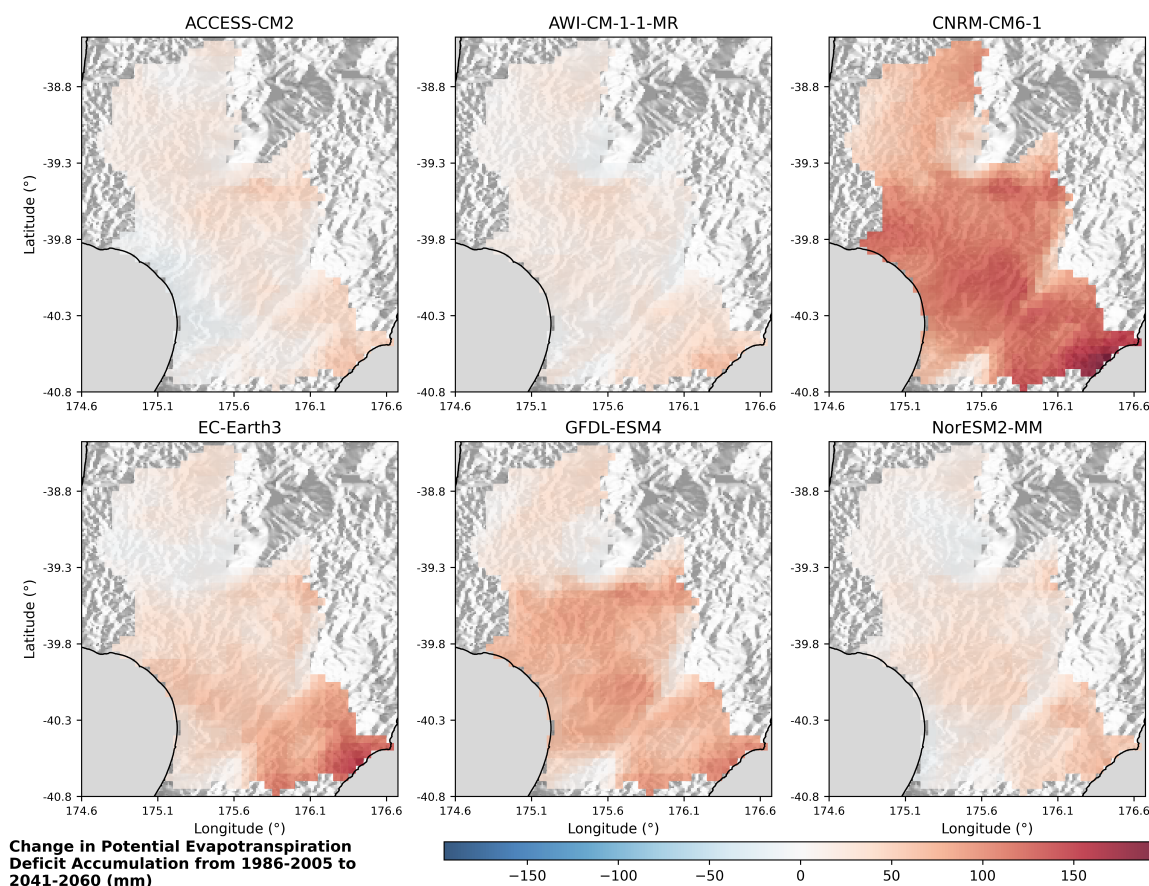


Figure 10: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

Under SSP3-7.0, mid-century (2041–2060) projections show a strong, region-wide increase in PED accumulation, signalling a further intensification of moisture deficit. Sub-regional means for PED change range from modest (as low as 17 mm in Horowhenua/Volcanic Plateau) to significant (above 80 mm in Puketo ki Tai and more than 45–55 mm in Taranaki, Turakina, Western Ruahine, and Middle Whangape-Whanganui). All models project a positive PED shift, with the largest increases in the south and east, mirroring topographically and climatically driven gradients. Localised maxima in individual models can exceed 200 mm. The median and upper percentiles (P50 and P95) in almost all sub-regions are positive, offering extremely likely confidence in the sign and regional extent of PED increase.

Inter-model agreement on overall magnitude and broad spatial pattern is high, reflected in moderate-to-high spatial R^2 values (mean ~ 0.45 , none below 0.12, occasionally above 0.8). Local-level uncertainty remains, particularly in sub-regions with more variable rainfall regimes or topography, but region-wide, the consensus is for increased PED. This pattern signals heightened drought risk and potential impacts on agriculture and natural systems, with the most marked vulnerability in already dry, eastern and southern sub-regions. The results, with supporting statistical analysis and figures, are available for further inspection via Bodeker Scientific.



7.4 SSP5-8.5: Very likely large, widespread PED increases, especially in dry sub-regions

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP5-8.5 scenario, as simulated by the six different models, are shown in Figure 11.

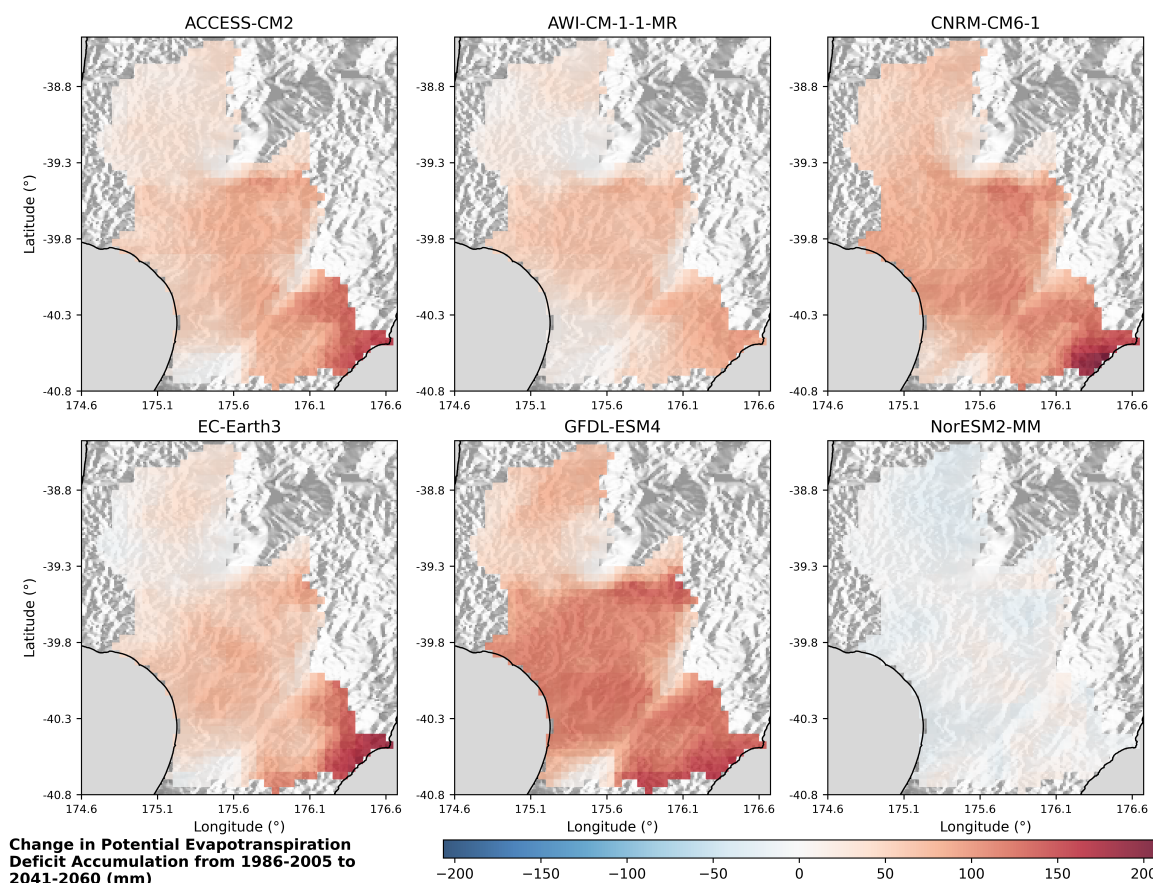


Figure 11: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2041-2060 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

For the high-emissions pathway SSP5-8.5, projections to mid-century (2041–2060) indicate a very likely, robust regional increase in PED. The ensemble mean PED change is approximately 50 mm, with sub-regional means varying from 17–24 mm (Horowhenua/Volcanic Plateau) to over 100 mm in Puketoi ki Tai. All models simulate a positive change across nearly the entire region, though some localised areas (in the west, e.g. Horowhenua or Whanganui-Manawatū Lakes) may see a few gridpoints with negligible or even slightly negative change, but these are outliers. The spatial agreement is moderate, with spatial R^2 values near 0.5 on average, but the regional mean and P50/P95 percentiles are all positive and consistently increasing for the highest change areas.

Model spread is greatest in already dry eastern or hill-country sub-regions—standard deviations are highest here and maxima at individual gridpoints exceed 140 mm. The minimum model fields are less reliable for percentile estimates at this time horizon and scenario, while the maximum remains a robust upper bound (very high R^2 with the P95 field).

Across almost all of the region, it is very likely that seasonal and annual moisture deficits will intensify. The highest confidence in this conclusion is in the central, southern, and eastern sub-regions, which combine the greatest baseline PED and the largest projected increases. Supporting figures and extended analysis can be accessed for review in sub-reports from Bodeker Scientific.



7.5 Comparison Across Scenarios

Across all scenarios, the mid-century PED projections for the Horizons region reveal a very likely, region-wide signal of intensifying moisture deficit. The greatest increases are concentrated in eastern and central sub-regions, but all areas except possibly the wettest western zones exhibit significant upward shifts. The sign of regional change is robustly positive, with only modest local variation in the lowest-emissions scenario and amplified responses under high-emissions. While spatial agreement on local extremes varies (R^2 values moderate), upper bound projections (P95) are highly reliable, and the confidence in future drying is high, especially in areas already at risk.

8 Late-Century Projections (2080–2090)

By late-century (2080–2099), the magnitude and regional extent of projected increases in potential evapotranspiration deficit (PED) in Horizons become even more pronounced, especially under higher-emissions scenarios. Across all four SSP pathways, ensemble mean increases typically exceed those from the mid-century period, reaching as much as 100 mm or more in the driest sub-regions—most notably, Puketoi ki Tai and other eastern and central zones. Maximum local changes in individual model runs can far exceed this, with projections indicating local increases above 200 mm or even 300 mm in some high-emissions scenarios and grid points. Model agreement remains strong—especially regarding the direction of regional change (PED increases)—and becomes tighter on the pattern of spatial intensification, as the climate signal strengthens relative to natural variability.

Inter-model spread persists, reflecting both variable model responses and nuanced spatial drivers (e.g., terrain, rainfall shadow zones), but the range narrows relative to the definitiveness of the overall trend. In high-emissions pathways (SSP3-7.0 and SSP5-8.5), changes are substantial and spatially extensive; even the lowest values in the ensemble are almost always positive except in a handful of grid points (usually already moist, westerly sub-regions with occasionally negligible change). Lower-emissions scenarios (SSP1-2.6) project smaller increases but maintain the same spatial ordering, with highest deficits east and central.

By this horizon, upper bound uncertainty (ensemble max/P95) is extremely well characterised, as all models converge on both the sign and location of highest risk. The regional hydrological and agricultural implications are therefore substantial, as widely amplified evaporative demand and declining moisture supply will combine to heighten drought vulnerability, especially in areas already stressed under historical climate. Sub-reports and all supporting figures are available for review at Bodeker Scientific.

8.1 SSP1-2.6: Likely small to moderate PED increases, strongest east/central

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP1-2.6 scenario, as simulated by the six different models, are shown in Figure 12.

In late-century projections for SSP1-2.6 (2080–2099), a further increase in PED is likely for Horizons, though the overall magnitude of change is smaller than for higher emissions scenarios. Mean regional increases are generally around 27 mm, with ensemble means ranging from small decreases to increases of about 44 mm. Maximum increases, in some grid points, still exceed 100 mm, typically focused in the eastern lowlands and south. The sign of regional change remains robustly positive, though confidence is somewhat reduced at fine scales due to moderate-to-large inter-model spread and modest spatial R^2 (~ 0.37). Model agreement is tightest in central-eastern and lowland areas, with high confidence for increased PED, and looser in wetter, western sub-regions.

Minimum and P5 projections diverge in the late-century sample, suggesting only moderate confidence in the use of ensemble minimum as a lower percentile approximation, but maximum fields reliably indicate upper-

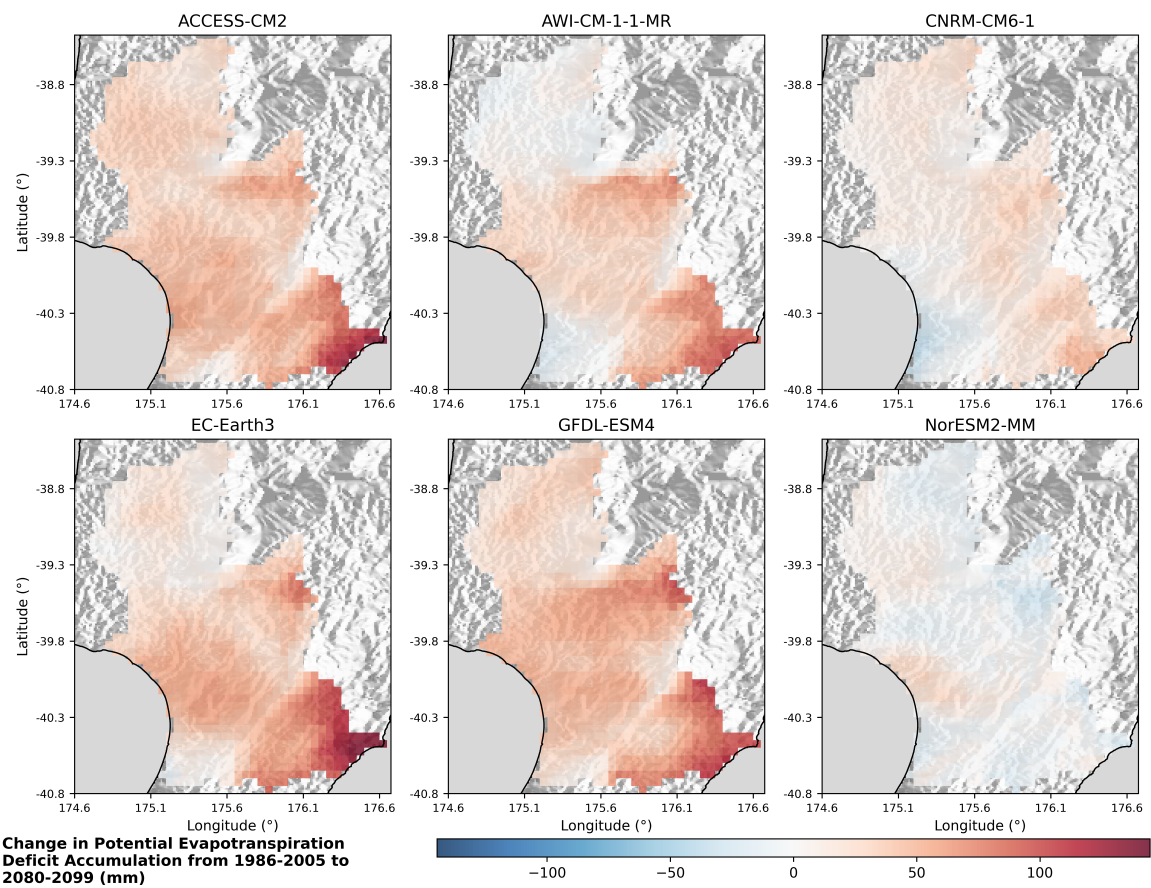


Figure 12: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP1-2.6 scenario. The original of this figure is available [here](#).



bound change (P95). The sub-region of Puketoi ki Tai again stands out for both baseline and future increases, facing the largest absolute and percentage rise in every model. Horowhenua and other wet, westerly areas may experience negligible or slightly negative PED changes, but these are isolated and not regionally representative.

Overall, Horizons is very likely to face increased PED by 2100—even under low emissions—but with more modest changes than for higher scenarios. Supporting details, including uncertainty metrics, are documented in sub-reports available from Bodeker Scientific.

8.2 SSP2-4.5: Very likely moderate-to-large PED increases, most in dry sub-regions

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP2-4.5 scenario, as simulated by the six different models, are shown in Figure 13.

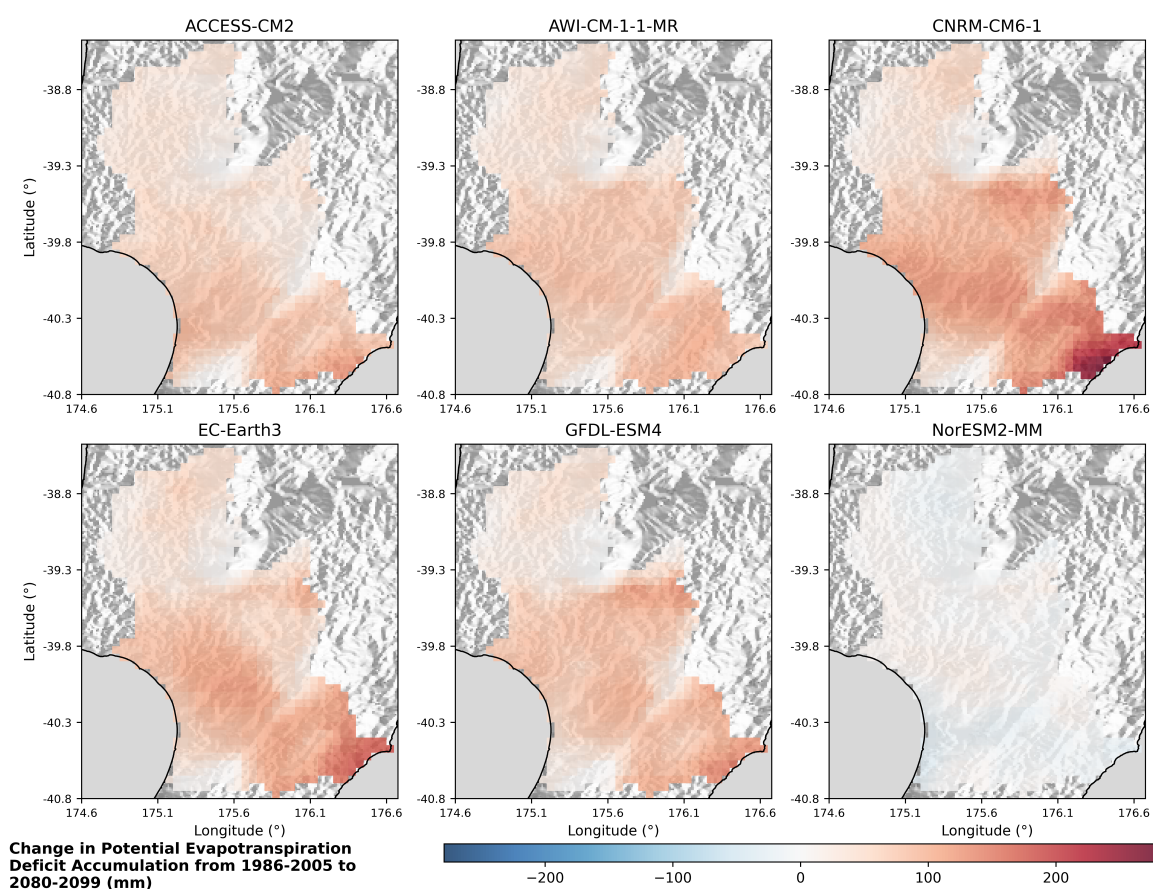


Figure 13: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP2-4.5 scenario. The original of this figure is available [here](#).

By 2080–2099 under SSP2-4.5, the Horizons region is very likely to experience a substantial, region-wide increase in PED. The mean change is about 55 mm across the region, with sub-regional means ranging from roughly 20 mm in Horowhenua/Volcanic Plateau up to more than 110 mm in Puketoi ki Tai. Maximum grid-point increases approach 280 mm in certain models and sub-regions—again, the largest increases and highest agreement centre on eastern and southern lowlands and hill-country sub-regions.

All models simulate widespread PED increases, with only slight or negligible decreases in a handful of gridpoints—these, generally, are not regionally significant. The spatial consistency of model projections is strong, with mean spatial R^2 values near 0.47 and some exceeding 0.8, denoting high agreement on the geographic pattern of drying, though magnitude differences remain. The overwhelming consensus (all models, means, medians, and most percentiles positive) supports a very likely outcome of intensified water stress throughout Horizons,



with the scale greatest in more arid zones.

Uncertainty statistics reinforce high confidence at the upper bound (maxima correlate extremely tightly to P95), while the lower bound (minima vs P5) is only moderately reliable. These results affirm that, absent deliberate adaptation, heightened PED will become the norm, necessitating ongoing water management innovation. All supporting narrative, images, and scenarios can be supplied by Bodeker Scientific.

8.3 SSP3-7.0: Extremely likely large, region-wide increases, with robust hotspots

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP3-7.0 scenario, as simulated by the six different models, are shown in Figure 14.

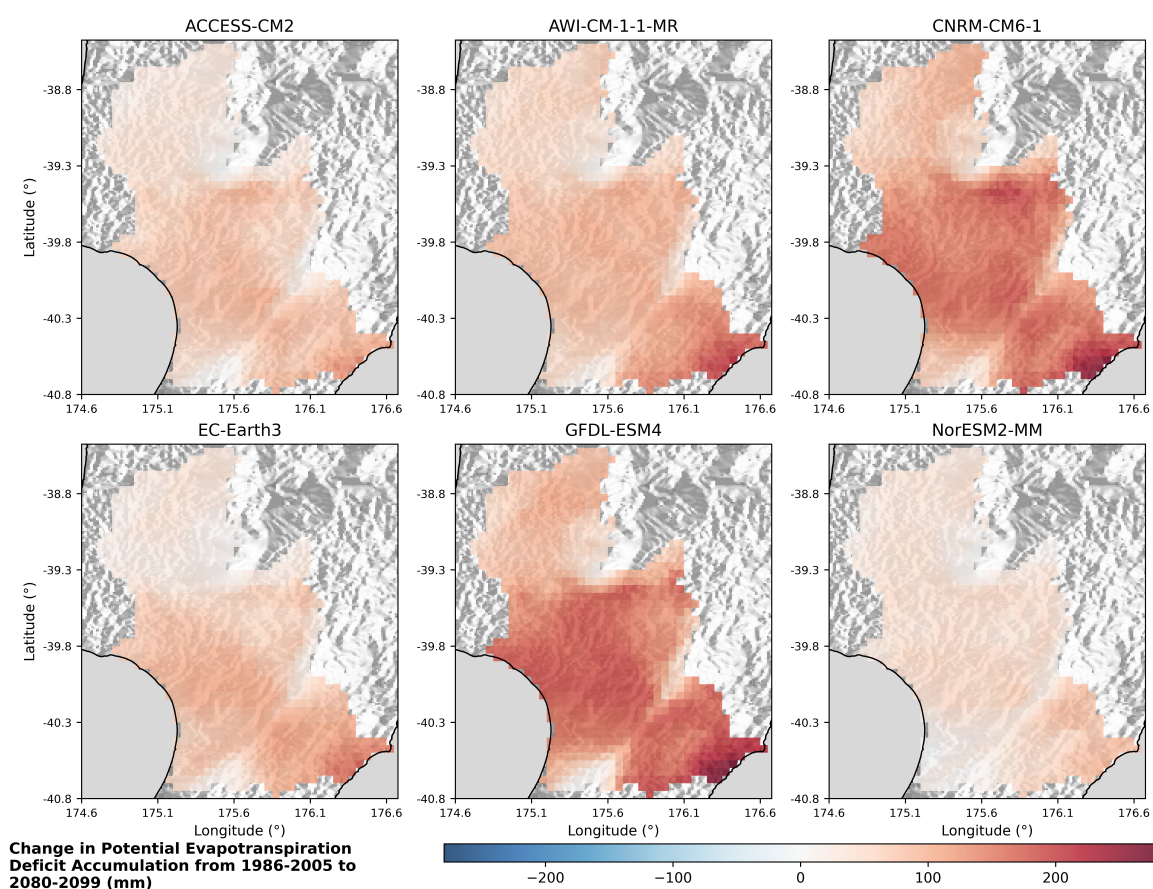


Figure 14: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP3-7.0 scenario. The original of this figure is available [here](#).

Late-century projections under SSP3-7.0 show an extremely strong and regionally consistent signal of PED increase in Horizons. Ensemble mean increases approach 85 mm, with model means for sub-regions ranging from a little over 40 mm to near 135 mm for the highest-response models. The eastern and central lowlands see the largest overall shifts, while upland and northern regions register the smallest absolute rises but still positive mean increases (~ 44 – 47 mm minimum). Maximum local increases, as shown in the modelled gridpoints, often exceed 200 mm. Consistency among models is high, with mean spatial R^2 near 0.73 and no model below 0.5, signifying very high confidence in the spatial pattern, if not always the local magnitude.

Every model projects the largest PED increases in central, southern, or eastern sub-regions, confirming robust, scenario-invariant hotspots repeatedly identified in earlier periods. Even sub-regions typically less drought-prone (Horowhenua or Volcanic Plateau) see increases, and there are no widespread simulated declines. The relationship between ensemble maxima and P95 percentiles is extremely tight—suggesting very likely rela-



bility in plausible upper bounds—while minima, although correlated with the P5, show slightly greater spread and uncertainty.

These outcomes make it extremely likely that late-century Horizons will be characterised by substantial, spatially extensive increases in moisture deficit, with important implications for ecosystem resilience and resource planning. Full details and supporting analyses can be accessed from Bodeker Scientific sub-reports.

8.4 SSP5-8.5: Extremely likely large, spatially extensive PED increases everywhere

The projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP5-8.5 scenario, as simulated by the six different models, are shown in Figure 15.

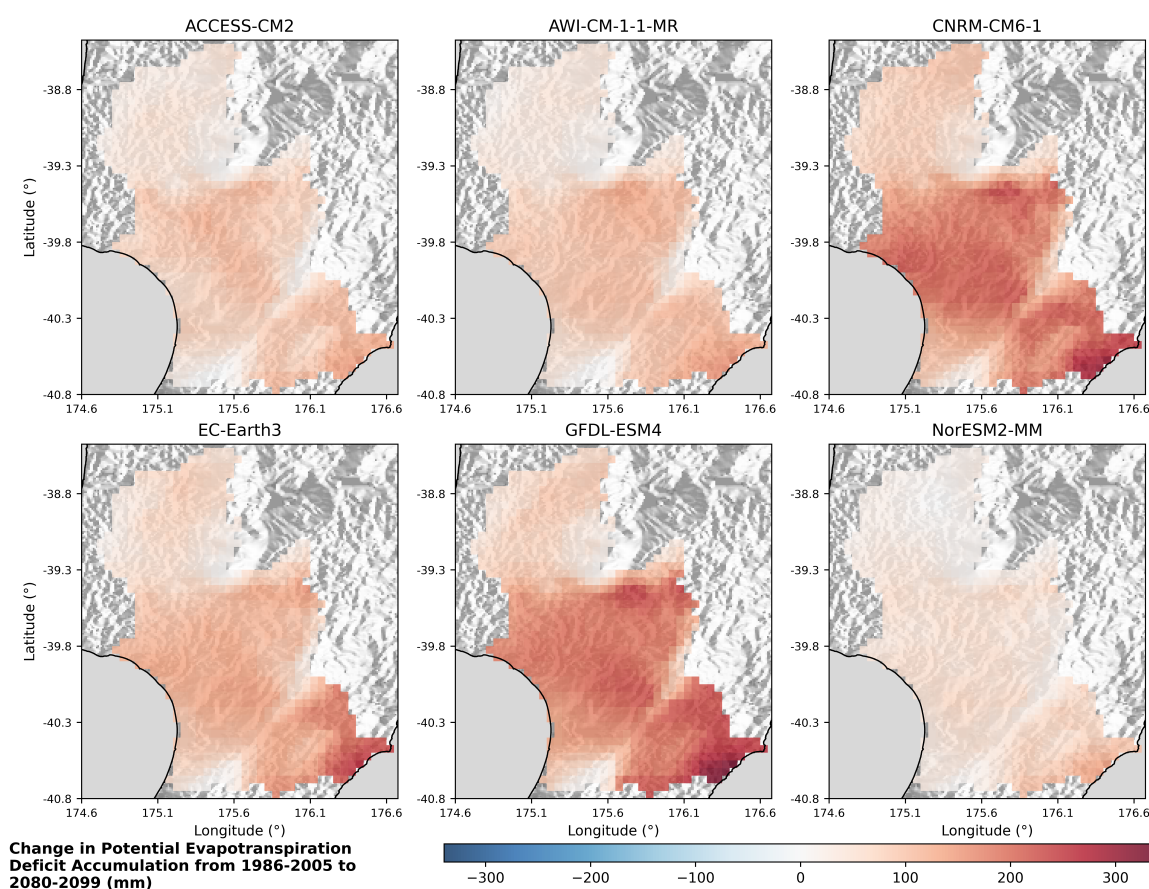


Figure 15: Projected changes in potential evapotranspiration deficit from 1986-2005 to 2080-2099 under the SSP5-8.5 scenario. The original of this figure is available [here](#).

For SSP5-8.5, the highest emission scenario, projections for 2080–2099 imply an extremely likely, robust, and spatially coherent increase in PED for the Horizons region. Model consensus is unmatched—ensemble mean increases of around 100 mm, with model means from 45 mm to nearly 150 mm depending on scenario response and gridpoint. The largest increases again attend the central, southern, and especially eastern lowlands—Puketoi ki Tai is the local and regional outlier, with increases surpassing 180 mm in some models. No region is simulated to see net declines at any model median or mean, although minima at isolated gridpoints may be near zero or marginally negative.

Spatial model agreement is very high throughout, with mean spatial R^2 values around 0.82, supporting an extremely likely confidence level for pattern and sign of regional change. Model spread in magnitude persists (standard deviation of means ~ 39 mm), but the minimum and maximum ensemble projections bracket uncertainty robustly: maxima match P95 almost exactly, minima serve as good proxies for P5, and percentile spreads



are well bounded. Across all sub-regions, the probability of increased PED approaches virtual certainty, with especially high risks in drought-prone or already dry areas. The broad spatial coherence and magnitude of late-century increases demand continued adaptation and policy attention. For supporting documents, sub-regionally detailed tables, and specialist figures, contact Bodeker Scientific.

8.5 Comparison Across Scenarios

Late-century projections reinforce an unequivocal regional trend: substantial increases in PED are nearly certain, especially under higher emission scenarios, with the largest impacts in eastern, southern, and central lowlands—areas with historical moisture deficit. All scenarios, except perhaps the lowest, show robust upper-bound extremes, and no models display widespread decreases anywhere. Confidence in the direction and broad spatial pattern of change is extremely high, with modest model spread persisting only in magnitude and the lowest-change sub-regions.

9 Evolution of Regional Hot-spots

A full breakdown on projected changes in potential evapotranspiration deficit by region is given in the Appendices. What follows below is a brief overview of those results.

Analysis of both the baseline climatology and projected PED changes consistently identifies a suite of sub-regions within Horizons—but especially Puketoi ki Tai, Tararua, Turakina, and to a lesser extent, Middle Manawātū-Rangitīkei and Coastal Whanganui—as focal hotspots for high and increasing potential evapotranspiration deficit. These zones are typified by already elevated baseline PED values, reflecting the interplay between lower precipitation, exposure to warm-dry airflow, and topographically mediated rain shadows.

Over the coming century, all emission scenarios project that these existing hotspots will not only maintain but often amplify their pre-eminence in terms of accumulated water deficit. Projections for late-century under moderate to high emission scenarios (SSP2-4.5, SSP3-7.0, SSP5-8.5) show mean increases in Puketoi ki Tai exceeding 100–180 mm, with the highest scenario (SSP5-8.5) projecting ensemble means above 180 mm and percentile maxima approaching or surpassing 280 mm. Tararua, Turakina, and Coastal Whanganui frequently project mean increases of 60–130 mm depending on scenario and period, again with very high ensemble agreement (virtually certain in some cases).

What distinguishes these hotspots is not just their absolute PED, but also the model agreement on direction, magnitude, and spatial persistence of the signal. Even where inter-model spread is greater, particularly in these higher-deficit sub-regions, the lower ensemble percentiles remain above zero, underlining the very likely or extremely likely prospect of further PED increase. Conversely, sub-regions such as Horowhenua, Volcanic Plateau, and NorthernZone-Taumarunui show persistently smaller PED increases and in some scenarios or models, even potential for near-neutral or negative changes. These western and upland areas are thus notable as localised zones of relatively low risk, but seldom as regional outliers in the opposite direction.

Temporal evolution indicates that hotspots emerge early and intensify with time and emissions pathway strength. By mid-century, hotspots see moderate increases under lower scenarios and much more pronounced rises under higher ones. By 2080–2099 in high-emission scenarios, these regions effectively define the upper envelope of water deficit risk and will likely require bespoke adaptation responses (e.g., targeted irrigation development, major shifts in land use or stocking rates, and enhanced drought planning).

The resilience and vulnerability of these hotspots will also be shaped by local soil profiles, irrigation infrastructure, and economic context, but climate-driven PED increases make these locations a priority for regional adaptation planning. The ability to distinguish both extremely likely hotspots of high risk and localised areas of relative resilience is a unique advantage of ensemble-based, spatially explicit PED projections such as those



synthesised herein.

10 Understanding Projection Uncertainty

10.1 Why uncertainty matters

Uncertainty in climate projections is a fundamental feature of climate change assessment, especially for variables such as potential evapotranspiration deficit (PED) that integrate several climatic and surface processes. PED projections are not precise predictions of a single future outcome but rather represent a spectrum of plausible developments conditional on greenhouse gas (GHG) emissions pathways, model formulation, and natural climate variability. Understanding and communicating projection uncertainty is essential because it shapes how regional planners, sectoral managers, and policymakers weigh risks, decide between mitigation and adaptation options, and identify areas where additional information or flexibility in response is necessary. The stakes for water availability, ecosystem sustainability, and drought resilience are high, and real-world decisions must be robust to potentially differing manifestations of future PED.

In the Horizons region, uncertainty varies through time—in near-term projections (2021–2040), internal climate variability and differences in how individual models simulate physical processes are the dominant sources. By later decades, especially under higher-emission scenarios, scenario uncertainty and divergent model sensitivity to radiative forcing assume greater importance. Importantly, while the exact rate or geographic focus of PED increases is sometimes uncertain, confidence in the direction of change (towards increasing deficit) strengthens steadily through the century, especially at regional scales. Characterising and interpreting the envelope of plausible outcomes therefore underpins sound and adaptive regional planning.

10.2 Interpreting Ensemble Spread

The six-model ensemble structure underpinning the Horizons region PED analysis provides both a central tendency and a diagnostic of uncertainty. Where all (or most) models project changes of the same sign and similar magnitude, confidence in the projection is high; where models diverge in direction or spatial focus, lower confidence results. For the historical baseline, ensemble spatial R^2 values near 0.99 signal virtually perfect agreement on large-scale PED climatology. In projections, ensemble spread reflects emerging climate change signals compared to natural variability—model agreement on spatial patterns is highest for the strongest scenarios and latest periods (e.g., mean spatial $R^2 > 0.7$ for SSP5-8.5 late-century), indicating a robust emergence of anthropogenic signals from noise.

Conversely, ensemble spread is largest in the near term and under weaker scenarios, where noise from model differences and natural variability can obscure or modulate the forced signal. For localised projections, disagreement in pattern detail (mean spatial $R^2 < 0.4$ in some near-term projections) reduces spatial confidence, meaning only regional or sub-region mean changes should be trusted for adaptation planning in those cases. Hotspot regions, especially those already identified as PED maxima, tend to show the greatest spread largely due to larger absolute signal—yet all models agree on their continued status as risk foci. This ensemble approach allows for an explicit, evidence-based attribution of which regions and signals are robust (high-concordance) versus where model uncertainty still dominates.

10.3 Minimum, Maximum and Percentile Fields

Interpreting minima and maxima of ensemble projections as bounds on plausible future change is tempting but requires nuance. In these analyses, maximum PED changes across models correspond closely to the 95th percentile (95th percentile) field, often with R^2 values in regression analysis exceeding 0.95. This means the



maximum can be regarded as an extremely likely estimate of the upper-bound risk, suitable for conservative planning in sectors with low risk tolerance (e.g., municipal water supply).

Minimum values, however, are only moderately well aligned with the fifth percentile (5th percentile), with R^2 variably between 0.5 and 0.9 depending on period and scenario. Minima tend to underestimate the P5, possibly overstating dry-side uncertainty where model spread is small or models cluster. For robust risk assessment and communication, percentile-based fields are scientifically preferable, but in resource-constrained or decision-urgency cases, max fields can still serve as proxies for identifying where and when interventions against worst-case outcomes are most justified. For large-scale regional planning, the ensemble mean, together with P95, is a reliable basis for scenario-neutral adaptation, while more localised or minimum-based actions should be viewed as less robust.

Overall, high confidence can be assigned to means and maxima for risk framing, whereas minima should always be interpreted in the context of ensemble sample size and P5-minus-min differences.

11 Equilibrium Climate Sensitivity and Potential evapotranspiration deficit Change

11.1 Understanding ECS

Equilibrium Climate Sensitivity (ECS) refers to the change in global mean surface temperature expected from a doubling of atmospheric carbon dioxide, and it is a foundational characteristic distinguishing the response of different climate models. In the downscaled ensemble utilised here, differences in ECS among the six global models partially drive the diversity of projected PED outcomes, particularly under higher emission scenarios and by the late 21st century. Models with higher ECS tend to produce greater warming and thus higher potential evapotranspiration rates, all else being equal—subsequently amplifying projected PED increases where precipitation does not compensate for additional evaporative demand.

However, in the Horizons region, while there is a discernible relationship between model ECS and the regional magnitude of PED change (especially for hotspot sub-regions in high emissions scenarios), it is not the only explanatory factor. Spatial heterogeneity in projected precipitation trends, model-specific representations of cloud, land–surface feedbacks, and downscaling artefacts also contribute. As such, ECS is an important but incomplete descriptor; it helps explain why some models (e.g., GFDL-ESM4, EC-Earth3) often lie above or below the ensemble mean but does not, by itself, determine sub-regional or local outcomes. Highest confidence in an ECS-based ordering of PED change applies to scenario and period combinations where temperature-driven evaporative demand unambiguously dominates moisture balance.

12 Sources of Uncertainty

12.1 Emissions Uncertainty

By the late 21st century, the greatest source of uncertainty in PED projections is the emissions pathway followed globally—reflected here as divergence between SSP1-2.6 (mitigation) and SSP5-8.5/SSP3-7.0 (high/very high emissions) scenarios. Emissions uncertainty is minor for the near-term, where scenario choice produces only modest differences, but becomes dominant later in the century, as PED increases are 2–4 times greater in the highest compared to lowest scenarios. This uncertainty is structural: only societal choices and international action on climate change mitigation can reduce it. The range between plausible emissions futures translates directly into the range of PED risk, and adaptation planning for Horizons must therefore remain dynamic, tracking real-world emissions developments over the coming decades.



12.2 Climate Model Uncertainty

Climate model uncertainty arises from systematic differences in the representation of complex atmospheric, surface, and hydrological processes in each participating global model and in the downscaling system. These uncertainties manifest as differences in magnitudes, timing, and spatial distribution of PED change—even under identical emissions assumptions. In the Horizons region, model uncertainty is most tangible in near-term and mid-century projections, and in sub-regional pattern detail. The six-model ensemble samples a reasonable but not exhaustive range of such uncertainty, and increased model diversity would further refine risk bounds. Nonetheless, the consistency of main findings—a region-wide increase in PED, with eastern and central hotspots—suggests the ensemble captures the core robust features of climate change effects on moisture deficit.

12.3 Natural Climate Variability

Decadal-to-multidecadal climate variability—such as El Niño–Southern Oscillation (ENSO), Southern Annular Mode (SAM), and other internal oscillations—remains a significant source of ped uncertainty, especially in the earlier decades of the projection horizon (2021–2040). These natural fluctuations can temporarily amplify or dampen long-term change signals, producing periods of unexpected respite or accentuated stress on water resources and land. Over longer periods or toward the end-of-century, the forced climate signal increasingly dominates, but early-decade planning should remain alert to the possibility of misleading decadal swings in PED, not solely the mean trend.

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

Across the analyses for the Horizons region, there is extremely high confidence (virtually certain, >99% probability) in the spatial pattern and magnitude of historical PED gradients, given ensemble R^2 near or above 0.99 and minimal spread between models. For future projections, confidence increases with time and with emissions scenario strength. For the near-term (2021–2040), a likely to very likely (66–99%) regional increase in PED is assessed, with very high model agreement on the sign but moderate regional-scale uncertainty in the exact magnitude and sub-regional pattern due to natural variability and model process differences.

By mid-century and especially by 2080–2099, confidence that PED will increase becomes very likely (high emissions) to extremely likely (very high emissions): all models agree on the direction of change, and spatial R^2 values in scenario high-end cases (>0.7) indicate robust coherence in regional patterning. Estimates for upper-end impacts (using ensemble maxima or P95) are extremely likely to capture the risk envelope needed for adaptation planning, while minima provide about as likely as not to likely correspondence to lower-end scenarios.

Confidence in local detail (e.g., sub-regional hotspots, fine-scale pattern shifts) remains somewhat lower (about as likely as not to likely) due to model spread and downscaling artefacts. Nonetheless, ensemble and percentile



analysis ensures that adaptation can proceed with high confidence in where and for whom change is greatest, and in the maximally plausible increases to which planning should be attuned.

14 Conclusions

This synthesis confirms that PED is a robust and policy-relevant indicator for water stress, drought risk, and climate impacts in the Horizons region. The historical PED pattern is highly consistent across models—southern and eastern sub-regions experience substantially higher deficits, which are expected only to intensify under projected climate change. Regional projections indicate virtually certain, widespread increases in PED throughout the 21st century, with the magnitude and spatial coherence of increases scaling directly with greenhouse gas emissions pathway.

The most vulnerable sub-regions correspond to those with already high baseline PED, notably Puketoi ki Tai, Tararua, and Turakina, where ensemble mean increases by late-century in high-emission scenarios exceed 150 mm, and upper percentile maxima can approach or surpass 280 mm. These areas are priority candidates for adaptation planning, given their exposure to intensifying moisture stress and associated challenges for water supply, agriculture, and ecosystems. By comparison, areas such as Horowhenua and Plateau regions remain relatively less affected, but even here significant increases are projected in most cases.

Projection uncertainty diminishes with time and emissions scenario strength: while local spatial and magnitude details retain notable variability, the direction and core regional pattern of PED increase are exceptionally robust. Upper-bound estimates from ensemble maxima provide reliable guidance for conservative risk management, while percentile and ensemble spread analysis allows for sound, nuanced adaptation planning. Future resilience will hinge on recognising the inevitability of drier, more water-stressed conditions in much of the region and acting proactively in both policy and practice—strengthening water resource management, investing in drought resilience, and prioritising the needs of the most affected communities and sectors. Detailed sub-reports providing further regional, temporal, and scenario breakdowns are available on request from Bodeker Scientific for supporting strategic planning.

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.

15.1 Region: NorthernZone-Taumarunui

Area: 5084.04 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 18. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 1. The projected changes in annual potential evapotranspiration deficit (PED) for



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

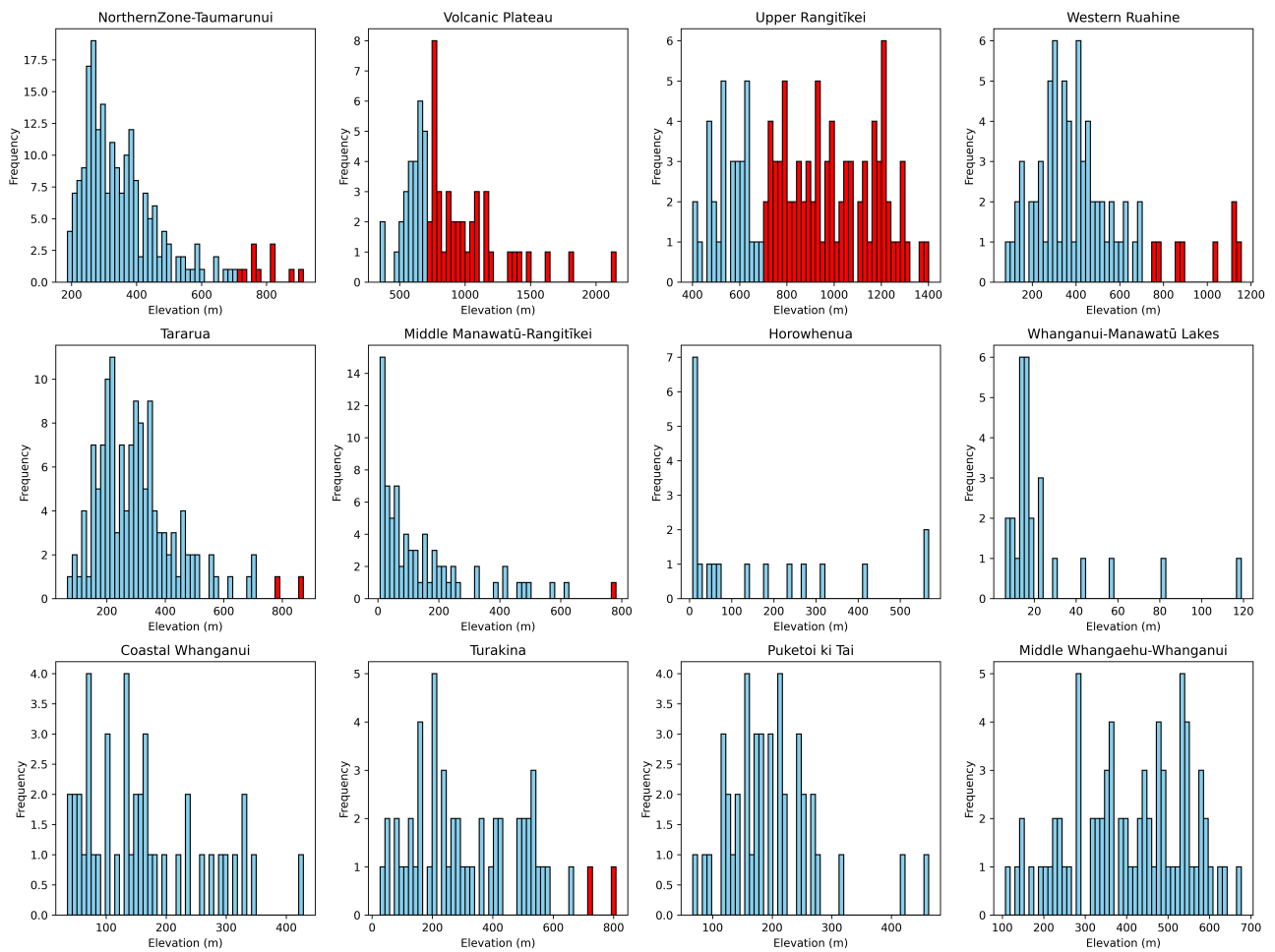


Figure 17: Histograms showing the number of CCAM model cells at each elevation. Histogram bars at elevations exceeding 700 m are shown in red. The original of this figure is available [here](#).



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	37.84 ± 12.76	37.84 ± 12.76	37.84 ± 12.76	37.84 ± 12.76
	2021-2040	6.97 ± 2.32	12.17 ± 3.55	14.53 ± 3.92	18.43 ± 3.35
	2041-2060	22.98 ± 4.34	22.02 ± 5.28	22.48 ± 6.92	27.24 ± 6.74
	2080-2099	14.54 ± 3.03	29.46 ± 7.30	53.99 ± 9.70	52.16 ± 11.32
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	7.23 ± 2.32	12.50 ± 3.65	14.77 ± 3.98	18.61 ± 3.41
	2041-2060	23.41 ± 4.38	22.31 ± 5.36	22.87 ± 6.97	27.57 ± 6.78
	2080-2099	14.71 ± 3.03	29.87 ± 7.40	53.91 ± 9.71	52.52 ± 11.33
Multi-model minimum	Baseline	32.22 ± 11.96	32.22 ± 11.96	32.22 ± 11.96	32.22 ± 11.96
	2021-2040	-16.74 ± 4.00	-10.75 ± 8.53	-8.61 ± 8.19	-3.65 ± 7.79
	2041-2060	-1.53 ± 5.04	-13.88 ± 6.62	3.74 ± 4.55	-9.92 ± 7.50
	2080-2099	-3.38 ± 6.68	-1.23 ± 8.39	26.61 ± 6.46	20.86 ± 11.53
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-18.59 ± 4.73	-5.60 ± 4.47	-4.92 ± 5.04	0.48 ± 3.86
	2041-2060	-4.11 ± 2.42	-13.61 ± 3.49	-7.47 ± 2.88	-7.53 ± 3.39
	2080-2099	-4.34 ± 3.52	6.23 ± 5.90	16.96 ± 4.18	17.06 ± 8.07
Multi-model maximum	Baseline	45.37 ± 15.57	45.37 ± 15.57	45.37 ± 15.57	45.37 ± 15.57
	2021-2040	35.19 ± 6.88	25.04 ± 6.38	29.27 ± 6.32	31.99 ± 6.24
	2041-2060	52.90 ± 8.80	57.06 ± 10.24	64.08 ± 17.01	59.72 ± 12.31
	2080-2099	33.38 ± 4.40	45.82 ± 11.20	89.88 ± 16.83	85.59 ± 15.33
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	34.91 ± 7.44	32.63 ± 10.26	36.06 ± 9.54	37.91 ± 8.30
	2041-2060	53.78 ± 8.25	60.28 ± 11.86	56.10 ± 14.76	64.98 ± 13.67
	2080-2099	34.94 ± 5.16	56.04 ± 15.55	90.32 ± 16.97	90.60 ± 17.85

Table 1: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).

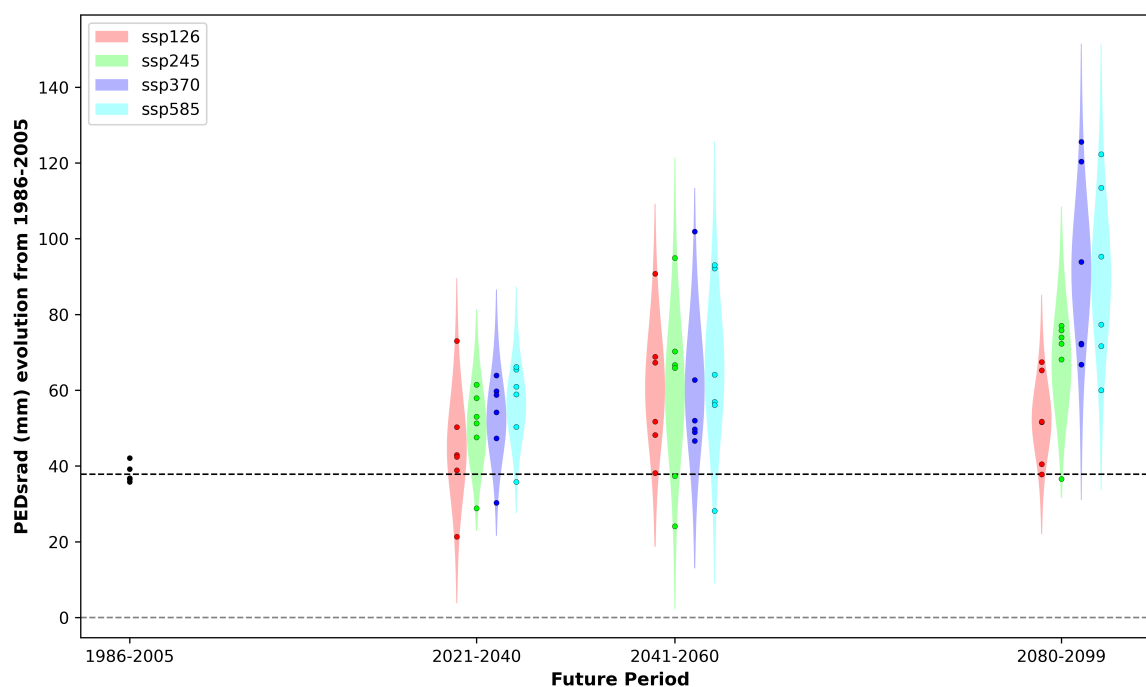


Figure 18: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the NorthernZone-Taumarunui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the 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 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](#).

the NorthernZone-Taumarunui sub-region show a robust signal of decrease relative to the 1986–2005 baseline across all future scenarios, but with increasing divergence in projections by late century. Multi-model means indicate a likely reduction in PED for 2021–2040 and 2041–2060, with changes ranging from roughly 7 to 18 mm in the near term and 22 to 27 mm by mid-century. Projections for 2080–2099 display more scenario dependence: under low emissions (SSP1-2.6), mean changes remain modest (~ 15 mm), whereas high emissions scenarios (SSP3-7.0, SSP5-8.5) could see substantially larger reductions (up to ~ 54 mm). High model agreement persists into mid-century (percentage agreement $>95\%$), providing high confidence in the direction of change, but inter-scenario agreement declines by late century ($\sim 70\%$), reducing confidence in the magnitude under stronger warming. The inter-model spread visible in the violin plots remains moderate, especially for mid-century, and spatial variability (stdv) is relatively low compared to the magnitude of change, indicating consistent regional responses. Overall, it is very likely that PED will decrease in NorthernZone-Taumarunui over the 21st century, with the largest uncertainties associated with late-century and high emissions outcomes.

15.2 Region: Volcanic Plateau

Area: 1664.65 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 19. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 2. The figure and supporting data indicate that the Volcanic Plateau is projected to experience a likely increase in annual potential evapotranspiration deficit (PED) relative to the 1986–2005 baseline, across all future periods and scenarios. For the near-term (2021–2040), increases are evident and consistent across scenarios, with multi-model means ranging approximately from 6 to 16 mm and high multi-scenario agreement ($\sim 85\%$). Over mid-century (2041–2060), further increases are projected, with mean increases of approximately 19–24 mm across scenarios, and extremely likely agreement (95%). By late century



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	31.15 ± 28.42	31.15 ± 28.42	31.15 ± 28.42	31.15 ± 28.42
	2021-2040	5.57 ± 5.81	10.36 ± 8.34	12.28 ± 11.51	16.30 ± 9.60
	2041-2060	22.19 ± 15.10	19.24 ± 12.35	19.49 ± 14.59	23.86 ± 17.75
	2080-2099	12.00 ± 8.20	21.46 ± 18.12	46.98 ± 25.92	46.70 ± 34.15
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	5.83 ± 5.85	10.64 ± 8.43	12.44 ± 11.56	16.50 ± 9.66
	2041-2060	22.48 ± 15.15	19.52 ± 12.58	19.96 ± 14.55	24.26 ± 17.81
	2080-2099	12.13 ± 8.15	21.77 ± 18.22	47.06 ± 25.96	46.96 ± 34.20
Multi-model minimum	Baseline	22.54 ± 27.71	22.54 ± 27.71	22.54 ± 27.71	22.54 ± 27.71
	2021-2040	-13.17 ± 2.30	-10.62 ± 6.25	-6.26 ± 5.81	-0.31 ± 4.52
	2041-2060	0.90 ± 7.73	-10.21 ± 4.77	1.35 ± 9.58	-8.31 ± 8.84
	2080-2099	-4.56 ± 5.01	-3.72 ± 5.26	18.11 ± 14.31	21.18 ± 16.22
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-15.28 ± 3.65	-7.39 ± 3.34	-4.89 ± 3.90	2.20 ± 3.64
	2041-2060	-1.12 ± 7.25	-9.89 ± 3.94	-10.62 ± 6.39	-4.83 ± 9.26
	2080-2099	-5.94 ± 5.41	0.27 ± 7.22	8.09 ± 10.26	17.32 ± 16.34
Multi-model maximum	Baseline	38.15 ± 29.25	38.15 ± 29.25	38.15 ± 29.25	38.15 ± 29.25
	2021-2040	29.56 ± 14.84	24.90 ± 15.25	28.41 ± 20.88	27.92 ± 16.73
	2041-2060	46.91 ± 24.93	46.82 ± 17.60	60.02 ± 26.24	49.20 ± 26.79
	2080-2099	29.85 ± 12.01	39.30 ± 27.39	85.73 ± 41.02	77.21 ± 49.50
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	28.78 ± 15.02	30.37 ± 19.53	30.87 ± 20.74	32.00 ± 17.75
	2041-2060	48.16 ± 24.61	50.84 ± 24.76	53.76 ± 24.01	55.99 ± 29.02
	2080-2099	31.12 ± 13.37	45.25 ± 30.51	86.62 ± 42.50	78.46 ± 52.75

Table 2: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).

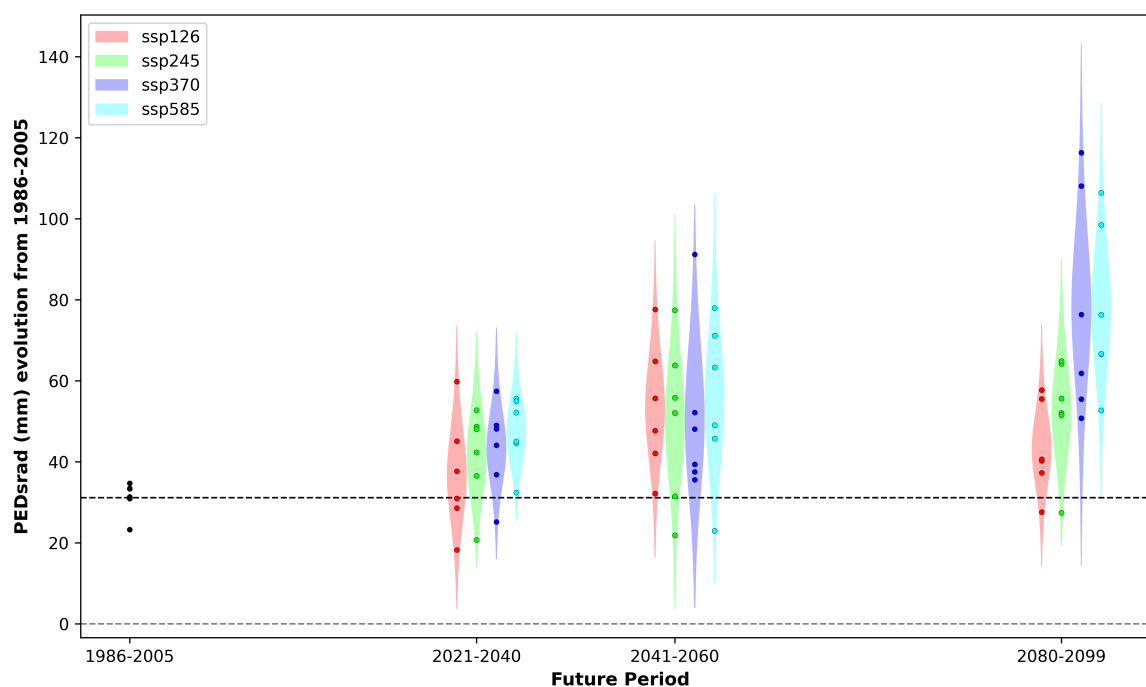


Figure 19: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Volcanic Plateau region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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 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](#).

(2080–2099), scenario divergence becomes more pronounced: modest increases endure under SSP126 and SSP245 (means near 12 and 21 mm, respectively), but much larger deficits (near 47 mm) become very likely under higher emissions (SSP370, SSP585). Inter-model spread within each scenario remains moderate relative to the projected signal, supporting moderate to high confidence in these projections, especially through mid-century. However, spatial variability within the sub-region is large relative to projected changes, and late-century scenario agreement drops (70%), indicating reduced confidence in the most distant projections. Overall, it is very likely that the Volcanic Plateau will experience greater PED, with the magnitude of change strongly dependent on emissions pathway, especially after 2060.

15.3 Region: Upper Rangitīkei

Area: 2694.06 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 20. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 3. Projected changes in annual potential evapotranspiration deficit (PED) for the Upper Rangitīkei indicate a likely increase across all emissions scenarios (SSPs) relative to the 1986–2005 baseline. By 2021–2040, multi-model mean PED increases across scenarios range from approximately 15 to 30 mm, with high inter-scenario agreement (c. 88%; very likely). Substantial increases persist and intensify through mid-century, with 2041–2060 mean increases of 34–55 mm. By 2080–2099, scenario dependence becomes clearer: under low emissions (SSP1-2.6), PED increases remain moderate (~31 mm), while under high emissions (SSP5-8.5), the projected increase approaches 103 mm, effectively doubling the baseline mean PED (virtually certain for increase; magnitude very likely scenario-dependent).

Across all time periods, the projected signal rises above baseline in all models, with only modest spatial variability relative to baseline, as reflected by lower standard deviations. Agreement between models and scenarios



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	92.8 ± 60.7	92.8 ± 60.7	92.8 ± 60.7	92.8 ± 60.7
	2021-2040	15.5 ± 6.9	24.5 ± 9.2	26.2 ± 10.4	30.2 ± 11.1
	2041-2060	46.2 ± 15.3	33.6 ± 12.6	40.8 ± 14.1	55.3 ± 19.4
	2080-2099	31.1 ± 10.7	52.8 ± 18.9	82.8 ± 24.1	103.3 ± 35.3
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	15.9 ± 7.0	25.0 ± 9.4	26.4 ± 10.6	30.4 ± 11.2
	2041-2060	46.5 ± 15.4	34.2 ± 12.9	41.3 ± 14.2	55.8 ± 19.6
	2080-2099	31.3 ± 10.7	53.1 ± 19.0	83.1 ± 24.3	103.6 ± 35.5
Multi-model minimum	Baseline	77.0 ± 60.3	77.0 ± 60.3	77.0 ± 60.3	77.0 ± 60.3
	2021-2040	-16.5 ± 9.6	-27.7 ± 13.7	-15.0 ± 6.8	-3.4 ± 10.0
	2041-2060	11.9 ± 7.8	-13.4 ± 6.9	10.2 ± 9.1	-3.7 ± 10.9
	2080-2099	-10.5 ± 10.0	2.5 ± 7.4	37.1 ± 13.5	38.3 ± 15.8
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-20.4 ± 4.9	-15.3 ± 7.9	-9.9 ± 4.9	2.5 ± 5.2
	2041-2060	12.7 ± 7.6	-10.0 ± 5.6	-1.6 ± 5.7	9.2 ± 6.8
	2080-2099	-2.0 ± 6.1	7.5 ± 6.7	23.6 ± 11.7	35.5 ± 15.1
Multi-model maximum	Baseline	104.8 ± 61.5	104.8 ± 61.5	104.8 ± 61.5	104.8 ± 61.5
	2021-2040	48.7 ± 14.7	52.5 ± 19.3	61.6 ± 21.3	54.2 ± 22.8
	2041-2060	78.3 ± 23.2	68.7 ± 21.3	93.5 ± 25.1	92.3 ± 32.2
	2080-2099	56.7 ± 18.2	91.8 ± 33.1	143.3 ± 38.4	168.6 ± 54.1
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	54.5 ± 18.5	68.2 ± 26.7	63.8 ± 21.8	59.3 ± 23.2
	2041-2060	81.8 ± 25.5	82.0 ± 28.2	87.7 ± 24.8	105.9 ± 38.1
	2080-2099	65.9 ± 22.4	101.5 ± 35.1	144.2 ± 39.2	173.7 ± 58.9

Table 3: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).

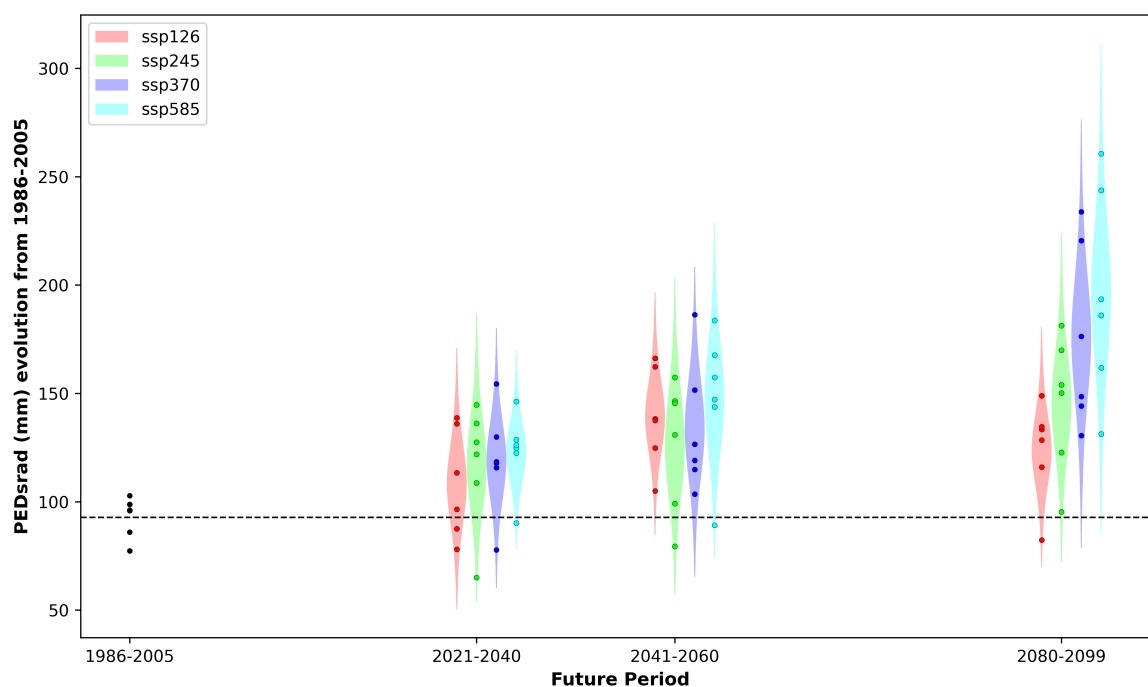


Figure 20: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Upper Rangitikei region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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](#).

remains strong through mid-century and decreases only by late century (c. 70%; likely), owing to widening inter-scenario and inter-model spread. These results indicate high confidence in increasing annual PED for Upper Rangitikei, with the magnitude of change highly sensitive to emissions pathway. The projections imply increased atmospheric water demand, which is extremely likely to have implications for hydrology, drought risk, and water management in the region.

15.4 Region: Western Ruahine

Area: 1758.32 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 21. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 4. Projected changes in annual potential evapotranspiration deficit (PED) for Western Ruahine indicate a likely increase across all future scenarios and periods when compared to the 1986–2005 baseline. By mid-century (2041–2060), multi-model means show increases of approximately 40–60 mm depending on the scenario, and by late century (2080–2099), these increases range from around 30 mm (SSP1-2.6) to about 120 mm (SSP5-8.5), indicating greater increases under higher emissions pathways. This regional signal is robust, with high inter-model consistency: percentage agreement across scenarios exceeds 89% through mid-century, giving high confidence in the direction of change. By late century, agreement declines to 66%, demonstrating a broader spread in scenario outcomes, but increases remain likely under all pathways.

Inter-model spread within each scenario is evident but does not obscure the overall tendency for PED to increase, with spatial variability (stdv) generally rising in higher emission and later periods. The magnitude of change and agreement suggest that increases are extremely likely for all but the lowest emission future. These results suggest a regionally significant drying tendency in Western Ruahine, with implications for water re-



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	123.6 ± 67.6	123.6 ± 67.6	123.6 ± 67.6	123.6 ± 67.6
	2021-2040	17.0 ± 5.4	29.7 ± 7.7	29.4 ± 9.7	31.9 ± 9.1
	2041-2060	45.6 ± 10.1	41.7 ± 11.8	47.5 ± 12.9	61.6 ± 15.5
	2080-2099	28.0 ± 8.0	65.2 ± 21.4	100.2 ± 25.1	116.4 ± 31.5
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	17.3 ± 5.4	30.4 ± 7.9	29.8 ± 9.8	32.2 ± 9.3
	2041-2060	46.0 ± 10.3	42.4 ± 12.1	47.9 ± 12.9	62.2 ± 15.6
	2080-2099	28.2 ± 8.0	66.0 ± 21.6	100.5 ± 25.1	116.9 ± 31.7
Multi-model minimum	Baseline	111.1 ± 63.3	111.1 ± 63.3	111.1 ± 63.3	111.1 ± 63.3
	2021-2040	-21.1 ± 6.6	-34.2 ± 14.9	-19.6 ± 12.5	-14.2 ± 12.2
	2041-2060	13.5 ± 4.7	-20.9 ± 9.9	11.9 ± 6.4	3.2 ± 6.3
	2080-2099	3.5 ± 4.7	3.7 ± 7.8	47.0 ± 14.8	45.1 ± 15.9
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-25.4 ± 6.8	-17.8 ± 8.1	-15.7 ± 9.1	-4.1 ± 6.9
	2041-2060	7.3 ± 3.9	-21.9 ± 10.4	-4.8 ± 3.4	14.5 ± 6.7
	2080-2099	6.5 ± 3.6	16.1 ± 10.3	38.1 ± 15.0	38.5 ± 19.0
Multi-model maximum	Baseline	134.9 ± 69.3	134.9 ± 69.3	134.9 ± 69.3	134.9 ± 69.3
	2021-2040	59.2 ± 16.2	58.4 ± 14.8	71.6 ± 25.6	62.4 ± 22.9
	2041-2060	87.1 ± 16.6	92.1 ± 26.4	113.5 ± 24.4	101.4 ± 23.3
	2080-2099	45.2 ± 11.8	105.5 ± 29.0	163.0 ± 33.5	188.3 ± 41.4
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	62.3 ± 16.8	82.9 ± 23.8	77.8 ± 27.8	71.1 ± 25.4
	2041-2060	88.0 ± 18.7	112.0 ± 36.0	103.7 ± 23.6	113.7 ± 27.1
	2080-2099	51.0 ± 14.2	121.1 ± 36.4	164.7 ± 36.3	198.4 ± 46.2

Table 4: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).

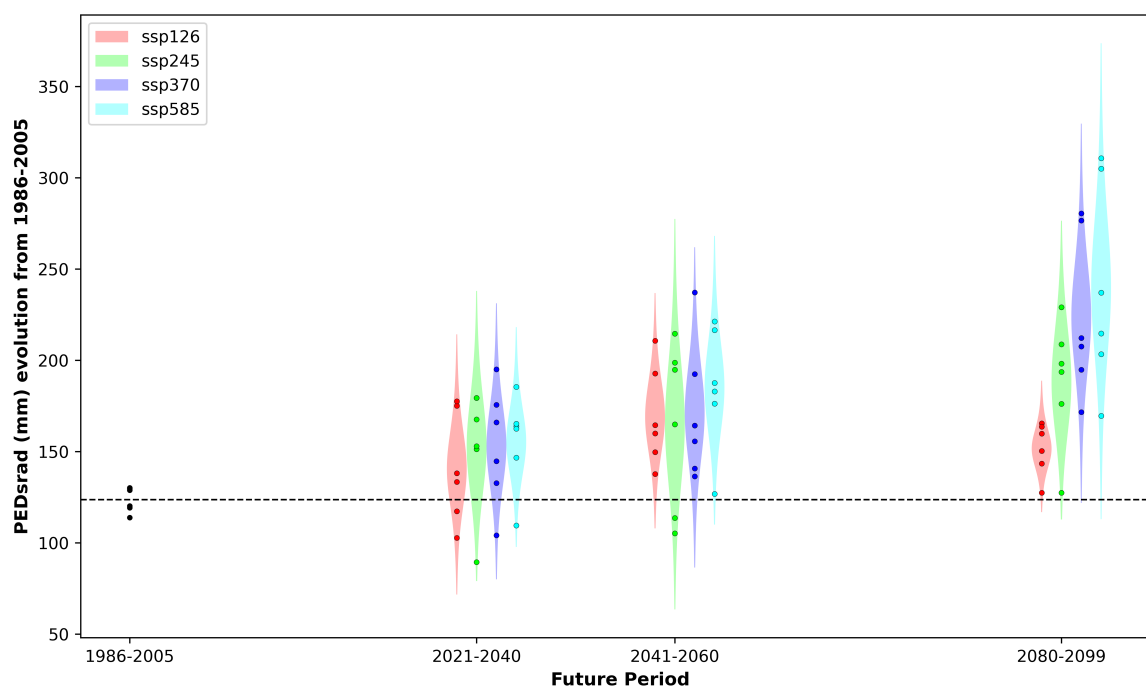


Figure 21: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Western Ruahine region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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 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](#).

source management that are very likely to intensify toward the end of this century as emissions rise.

15.5 Region: Taranua

Area: 3155.23 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 22. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 5. Projected changes in annual potential evapotranspiration deficit (PED) for Taranua show an overall increase compared to the 1986–2005 baseline, reflecting enhanced water demand or moisture deficits under all emission scenarios. The multi-model mean PED increases by around 25–45 mm for 2021–2040 and 45–70 mm for 2041–2060, depending on the scenario, indicating likely increases in climate-driven water stress across the sub-region. For 2080–2099, projected changes range more widely: under low-emission SSP1-2.6, the increase stabilises (~40 mm), while higher emission scenarios (SSP2-4.5 to SSP5-8.5) indicate much greater increases (~75–120 mm), reflecting a scenario-dependent response.

There is very high inter-scenario agreement for the near- and mid-term periods (>88% and >90%, respectively), supporting high confidence in the projected direction of change through mid-century. However, by late century, scenario divergence grows (agreement decreases to ~69%), particularly under higher emissions, and model spread also increases, so projections become less certain but remain very likely to indicate increasing deficits. Spatial variability is lower than the projected mean change, and no scenario-mean or median suggests a reduction in PED deficit (i.e., a wetter regime), so it is extremely likely Taranua will experience amplified PED, increasing drought risk, especially under higher emission trajectories.



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	160.9 ± 72.5	160.9 ± 72.5	160.9 ± 72.5	160.9 ± 72.5
	2021-2040	24.5 ± 8.5	34.9 ± 9.3	29.9 ± 9.3	42.7 ± 14.4
	2041-2060	55.3 ± 16.7	45.6 ± 11.9	55.1 ± 14.7	70.0 ± 20.4
	2080-2099	40.1 ± 14.9	74.8 ± 20.7	106.7 ± 25.6	122.2 ± 32.2
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	24.9 ± 8.6	35.6 ± 9.5	30.4 ± 9.4	43.2 ± 14.4
	2041-2060	55.9 ± 16.8	46.8 ± 12.3	55.7 ± 14.8	70.6 ± 20.6
	2080-2099	40.3 ± 15.0	75.9 ± 21.0	106.7 ± 25.6	122.4 ± 32.3
Multi-model minimum	Baseline	143.2 ± 69.5	143.2 ± 69.5	143.2 ± 69.5	143.2 ± 69.5
	2021-2040	-16.0 ± 8.6	-35.6 ± 13.4	-36.9 ± 12.6	-14.8 ± 17.2
	2041-2060	23.9 ± 14.8	-28.4 ± 8.0	15.9 ± 8.8	2.1 ± 8.6
	2080-2099	-4.4 ± 6.8	-3.5 ± 7.9	53.6 ± 19.9	61.7 ± 22.3
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-14.4 ± 5.6	-16.5 ± 7.8	-24.1 ± 9.0	1.0 ± 12.6
	2041-2060	20.1 ± 13.8	-27.5 ± 7.7	6.3 ± 9.2	15.6 ± 11.2
	2080-2099	2.5 ± 6.2	16.1 ± 7.6	49.8 ± 17.0	51.7 ± 19.8
Multi-model maximum	Baseline	177.2 ± 75.7	177.2 ± 75.7	177.2 ± 75.7	177.2 ± 75.7
	2021-2040	56.9 ± 15.2	69.7 ± 19.4	73.1 ± 21.4	68.4 ± 20.6
	2041-2060	91.1 ± 23.1	101.2 ± 24.7	111.2 ± 24.5	113.1 ± 27.4
	2080-2099	69.4 ± 23.2	117.9 ± 33.8	159.5 ± 35.1	192.8 ± 45.6
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	67.2 ± 17.7	91.6 ± 24.5	88.6 ± 26.0	88.3 ± 24.1
	2041-2060	95.4 ± 23.6	128.5 ± 32.5	109.3 ± 25.2	129.9 ± 34.5
	2080-2099	79.9 ± 27.8	142.6 ± 39.5	164.0 ± 35.8	195.1 ± 47.9

Table 5: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).

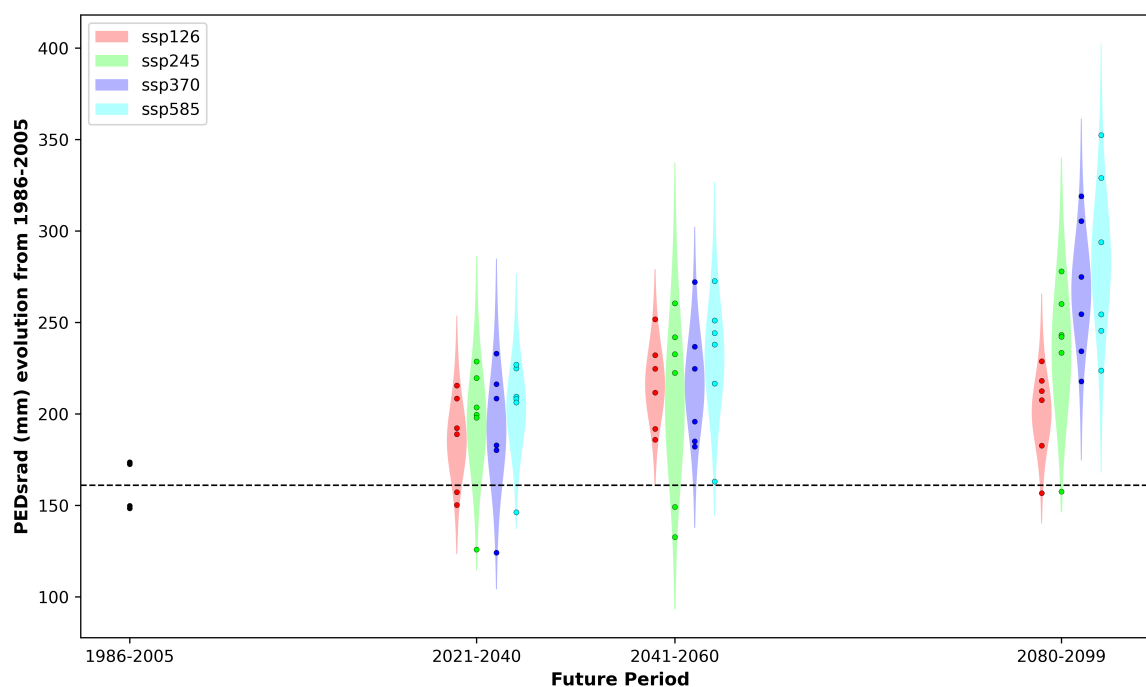


Figure 22: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Taranaki region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty 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](#).

15.6 Region: Middle Manawatū-Rangitīkei

Area: 1838.51 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 23. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 6. The ensemble projections for potential evapotranspiration deficit (PED) in Middle Manawatū-Rangitīkei indicate a likely increase relative to the 1986-2005 baseline under all emissions scenarios. For 2021-2040, the multi-model mean change in PED is around 17–28 mm, increasing to 37–49 mm for 2041-2060, and for 2080-2099, the range expands considerably: from ~24 mm under SSP1-2.6 (low emissions) to 99 mm under SSP5-8.5 (high emissions). This demonstrates a robust positive trend in PED, consistent with warming and drying scenarios, with the magnitude of change scaling with emissions pathway.

Model agreement across scenarios is very high through mid-century (>90%), decreasing to about 66% agreement late in the century as scenario divergence becomes more pronounced. This is reflected in wider distribution and greater interquartile spread for higher-emission scenarios, especially by 2080-2099, suggesting increased uncertainty and scenario dependence for later periods. Spatial variability in projections, indicated by regional standard deviation, also rises with time and emissions level, especially under SSP3-7.0 and SSP5-8.5.

It is very likely that PED will increase, with magnitude depending on future emissions. There is high confidence in a persistent trend towards higher PED for the region, signalling intensification of annual water deficits by late century, especially for unabated emissions trajectories.

15.7 Region: Horowhenua

Area: 448.71 km²



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	185.3 ± 87.8	185.3 ± 87.8	185.3 ± 87.8	185.3 ± 87.8
	2021-2040	17.0 ± 5.5	24.5 ± 8.6	26.3 ± 10.7	27.6 ± 9.5
	2041-2060	36.7 ± 12.3	36.7 ± 10.2	41.3 ± 12.7	48.9 ± 17.2
	2080-2099	23.9 ± 10.3	61.3 ± 21.6	89.1 ± 27.4	98.6 ± 33.1
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	17.1 ± 5.5	25.1 ± 8.9	26.8 ± 10.9	28.2 ± 9.6
	2041-2060	37.0 ± 12.4	37.7 ± 10.5	41.7 ± 12.7	49.4 ± 17.4
	2080-2099	24.0 ± 10.3	62.3 ± 21.9	89.4 ± 27.5	99.0 ± 33.2
Multi-model minimum	Baseline	165.7 ± 81.2	165.7 ± 81.2	165.7 ± 81.2	165.7 ± 81.2
	2021-2040	-24.3 ± 6.2	-45.8 ± 21.9	-27.9 ± 13.5	-31.5 ± 13.8
	2041-2060	10.8 ± 9.0	-32.1 ± 13.0	3.1 ± 7.5	-6.8 ± 5.2
	2080-2099	-2.0 ± 7.2	-6.8 ± 9.1	31.3 ± 14.5	47.0 ± 16.9
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-23.0 ± 7.2	-27.5 ± 13.8	-21.7 ± 10.3	-16.8 ± 8.6
	2041-2060	6.1 ± 5.9	-32.1 ± 10.9	-9.8 ± 5.9	-2.8 ± 7.4
	2080-2099	-4.6 ± 8.6	11.2 ± 7.6	32.5 ± 13.0	40.3 ± 15.7
Multi-model maximum	Baseline	198.8 ± 91.9	198.8 ± 91.9	198.8 ± 91.9	198.8 ± 91.9
	2021-2040	53.9 ± 18.9	61.4 ± 18.5	65.6 ± 23.6	59.3 ± 18.7
	2041-2060	68.7 ± 20.3	86.9 ± 22.0	101.2 ± 27.4	98.6 ± 28.3
	2080-2099	48.0 ± 14.1	95.4 ± 34.6	143.5 ± 43.0	153.6 ± 48.9
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	58.4 ± 17.6	81.8 ± 27.7	79.2 ± 30.2	77.0 ± 24.5
	2041-2060	70.6 ± 20.9	113.7 ± 32.4	96.2 ± 26.7	105.0 ± 31.8
	2080-2099	53.2 ± 16.2	120.0 ± 41.4	149.1 ± 43.5	160.7 ± 52.3

Table 6: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).

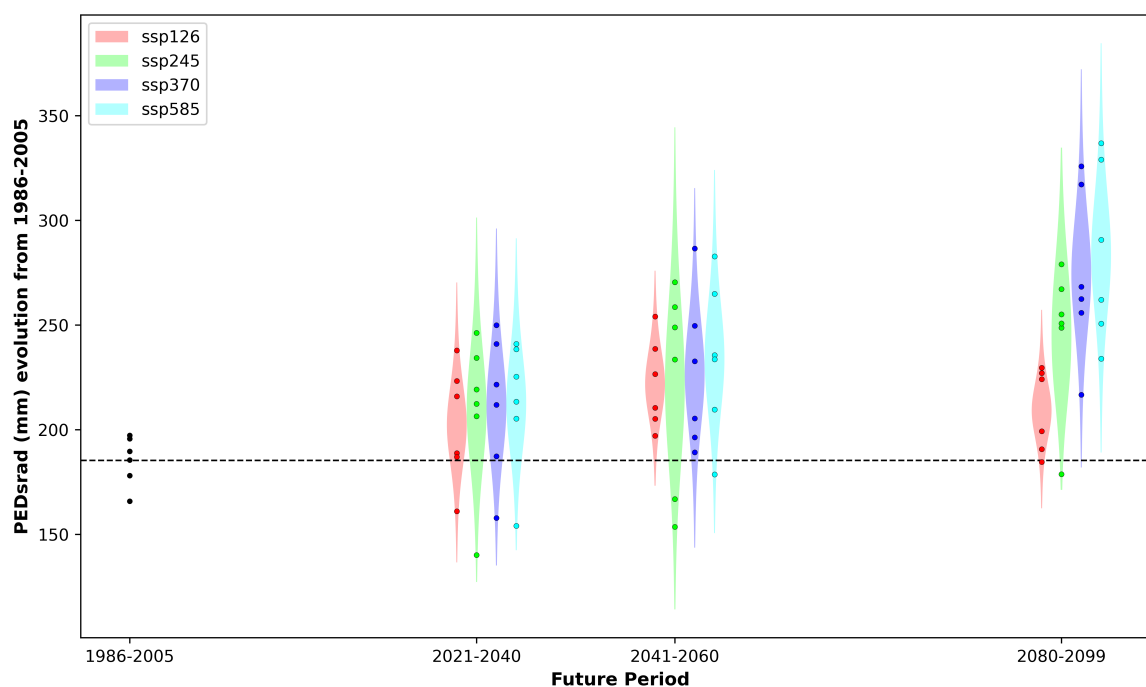


Figure 23: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Middle Manawatū-Rangitikei region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty analysis explained in the main report. Small circles show the individual model values extracted from the data files provided by MfE. The projections under the different SSP scenarios are shown in 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 potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 24. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 7. Projections for potential evapotranspiration deficit (PED) in Horowhenua indicate an overall increase relative to the 1986–2005 baseline, with the magnitude of change closely linked to emissions scenario and time horizon. By 2021–2040, multi-model means show modest PED rises across all scenarios (from approximately 4 to 10 mm above baseline), with very high scenario agreement (>93%), suggesting it is very likely there will be a small PED increase in early decades. Mid-century (2041–2060) projections indicate further increases, with means of 14–17 mm above baseline under most scenarios, and agreement remains extremely likely (>93%), supporting high confidence in continued drying, albeit with moderate spatial variability (stdv $\sim$ 6 mm).

By 2080–2099, stronger scenario dependence emerges. While SSP1-2.6 remains close to baseline (mean $\sim$ 3 mm), higher emissions pathways (SSP3-7.0, SSP5-8.5) project PED increases exceeding 40 mm, indicating it is likely higher emissions will drive substantial increases in PED by century's end. Scenario agreement drops notably (to $\sim$ 69%), reflecting growing model and scenario divergence. Spatial variability within the region also increases under these scenarios (stdv up to $\sim$ 18 mm for SSP5-8.5).

In summary, it is extremely likely Horowhenua will experience at least modest increases in PED through mid-century, with large, scenario-dependent increases possible late in the century under high emissions, but with declining inter-model agreement.

15.8 Region: Whanganui-Manawatū Lakes

Area: 623.11 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	81.13 ± 58.16	81.13 ± 58.16	81.13 ± 58.16	81.13 ± 58.16
	2021-2040	4.06 ± 2.88	5.99 ± 3.39	5.92 ± 4.20	9.52 ± 4.00
	2041-2060	13.64 ± 5.89	16.06 ± 5.88	17.38 ± 6.72	17.00 ± 6.32
	2080-2099	3.37 ± 3.78	20.01 ± 10.22	43.69 ± 15.77	42.66 ± 17.89
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	3.96 ± 2.92	6.20 ± 3.46	6.12 ± 4.30	9.75 ± 4.08
	2041-2060	13.80 ± 5.95	16.37 ± 6.05	17.69 ± 6.83	16.98 ± 6.31
	2080-2099	3.32 ± 3.82	20.49 ± 10.55	43.97 ± 15.73	42.85 ± 17.96
Multi-model minimum	Baseline	65.91 ± 49.41	65.91 ± 49.41	65.91 ± 49.41	65.91 ± 49.41
	2021-2040	-27.89 ± 13.84	-25.42 ± 19.94	-16.13 ± 10.13	-16.47 ± 17.39
	2041-2060	-8.99 ± 8.25	-22.00 ± 13.42	-1.48 ± 5.83	-3.91 ± 4.83
	2080-2099	-16.38 ± 11.89	-12.03 ± 13.09	10.42 ± 7.50	17.55 ± 10.86
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-23.98 ± 12.66	-19.43 ± 11.79	-16.48 ± 8.73	-15.76 ± 13.42
	2041-2060	-8.74 ± 5.91	-23.61 ± 12.92	-9.06 ± 5.36	-11.48 ± 5.36
	2080-2099	-19.68 ± 12.47	-6.61 ± 9.06	12.45 ± 9.73	10.96 ± 7.95
Multi-model maximum	Baseline	91.93 ± 60.62	91.93 ± 60.62	91.93 ± 60.62	91.93 ± 60.62
	2021-2040	24.95 ± 10.89	25.90 ± 10.41	27.05 ± 14.85	32.74 ± 14.68
	2041-2060	32.91 ± 12.04	50.65 ± 15.00	51.03 ± 18.37	51.01 ± 19.39
	2080-2099	25.42 ± 8.30	42.98 ± 24.80	73.51 ± 23.98	76.23 ± 26.08
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	31.11 ± 12.06	33.24 ± 16.59	30.31 ± 16.54	36.91 ± 18.13
	2041-2060	37.60 ± 14.42	58.71 ± 23.58	46.77 ± 16.39	45.29 ± 16.50
	2080-2099	26.00 ± 8.81	50.73 ± 29.19	77.47 ± 24.46	76.14 ± 28.94

Table 7: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).

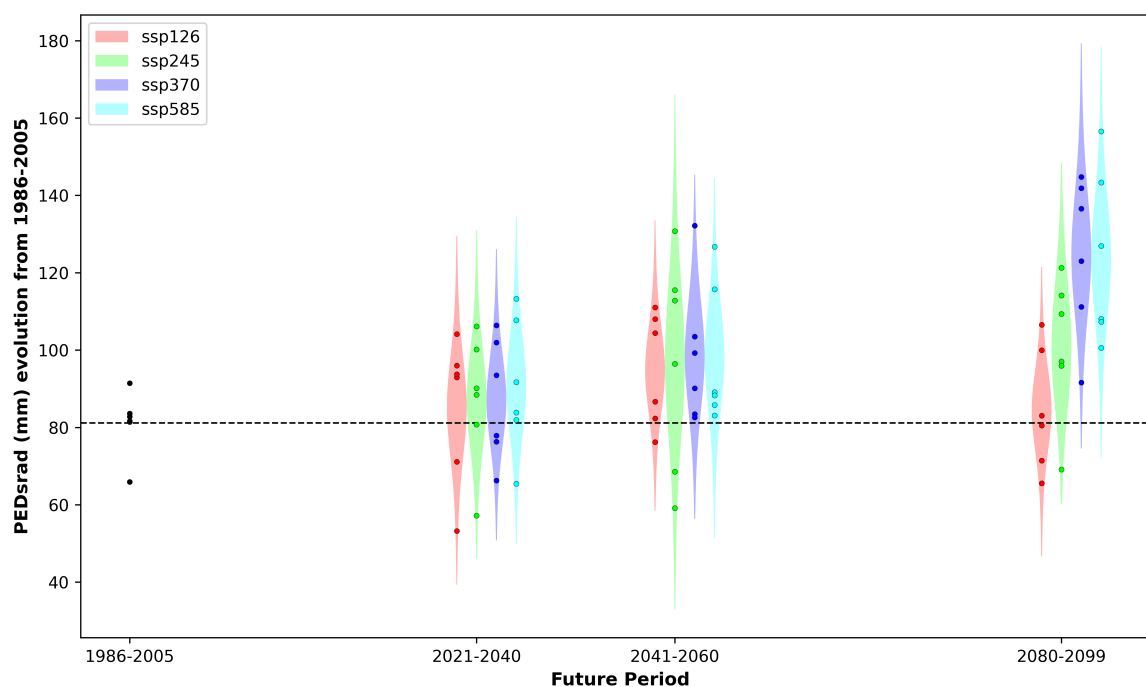


Figure 24: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Horowhenua region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty 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](#).

shown in Figure 25. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 8. Projections for the Whanganui-Manawātū Lakes sub-region indicate a likely increase in annual potential evapotranspiration deficit (PED) across all scenarios relative to the 1986–2005 baseline. By mid-century (2041–2060), multi-model means show moderate rises in PED of about 32–43 mm, depending on the emissions pathway, with lower emissions (SSP1-2.6) showing smaller changes compared to high emissions (SSP5-8.5). This increase continues to strengthen towards the late century under medium to high emission scenarios, and by 2080–2099, the projected increase in PED is largest under SSP5-8.5 (about 91 mm) and SSP3-7.0 (about 84 mm), while SSP2-4.5 also shows an increase (about 54 mm). Under the strong mitigation scenario (SSP1-2.6), the increase is considerably less (about 17 mm), suggesting emission pathways meaningfully influence outcomes.

The multi-model spread is moderate, indicating generally good agreement among models, particularly for near-term periods, with percentage inter-scenario agreement above 90% before late century. By 2080–2099, agreement drops to around 68%, reflecting increasing spread, particularly under higher emission scenarios. The spatial variability of each scenario remains low relative to the projected change, giving high confidence that increased PED is a robust signal. It is extremely likely that the Whanganui-Manawātū Lakes will experience increased PED, with the magnitude and variability rising under higher emissions, implying a higher likelihood of future water deficit stress, especially under limited mitigation.

15.9 Region: Coastal Whanganui

Area: 1048.57 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986-2005 baseline over this region is shown in Figure 26. The statistical summary of projected changes in potential evapotranspiration deficit over this region is shown in Table 9. Projections for potential evapotranspiration deficit (PED) in the Coastal

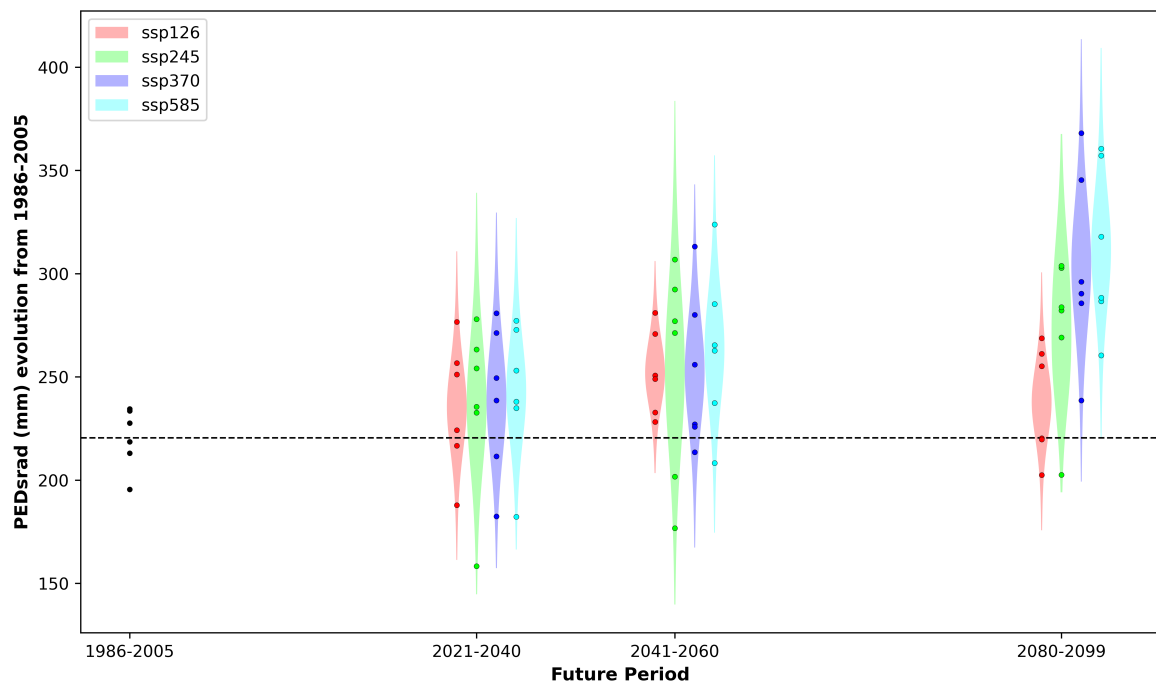


Figure 25: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Whanganui-Manawatu Lakes region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the 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 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](#).

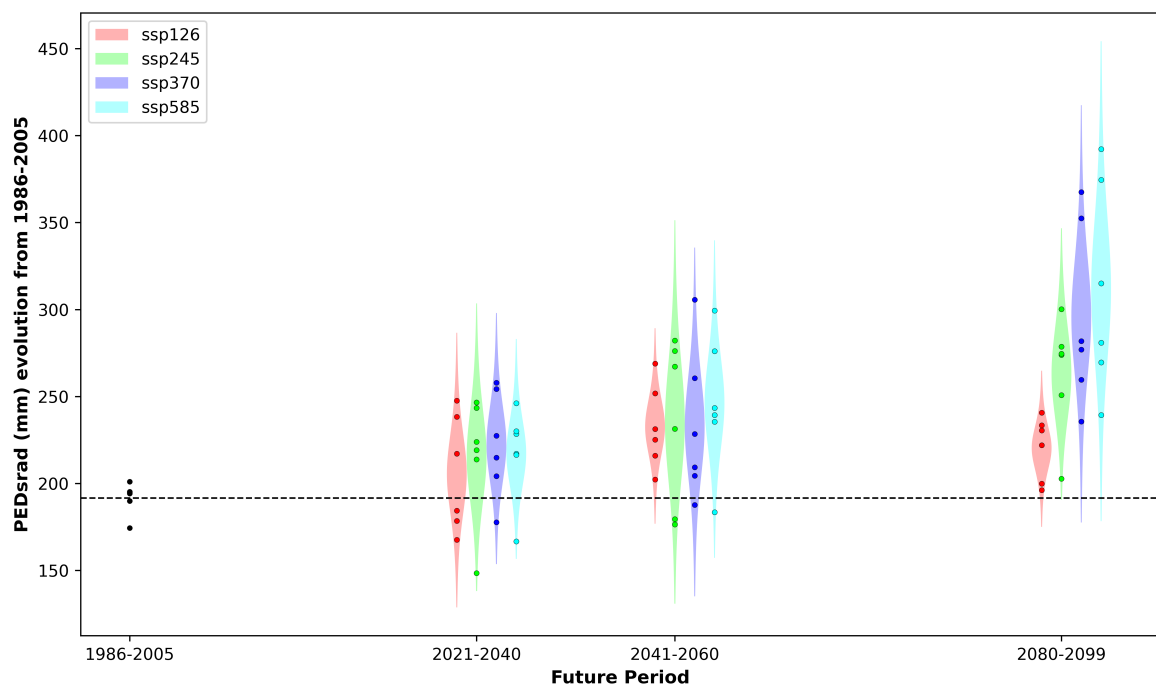


Figure 26: The time evolution of potential evapotranspiration deficit from the 1986-2005 baseline in units of mm over the Coastal Whanganui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based 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 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	220.5 ± 53.1	220.5 ± 53.1	220.5 ± 53.1	220.5 ± 53.1
	2021-2040	15.1 ± 5.6	16.5 ± 4.9	18.5 ± 6.9	22.6 ± 6.2
	2041-2060	31.6 ± 8.4	33.8 ± 7.7	32.1 ± 6.3	43.3 ± 10.2
	2080-2099	17.4 ± 10.9	53.6 ± 12.1	83.6 ± 16.7	91.4 ± 15.7
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	15.1 ± 5.8	17.2 ± 5.1	19.2 ± 7.0	23.1 ± 6.2
	2041-2060	32.0 ± 8.4	34.8 ± 7.9	32.5 ± 6.4	43.6 ± 10.4
	2080-2099	17.5 ± 10.9	54.8 ± 12.2	83.9 ± 16.7	91.8 ± 15.8
Multi-model minimum	Baseline	195.5 ± 53.0	195.5 ± 53.0	195.5 ± 53.0	195.5 ± 53.0
	2021-2040	-32.6 ± 7.0	-62.1 ± 10.5	-38.1 ± 8.9	-38.2 ± 5.3
	2041-2060	5.4 ± 11.6	-43.8 ± 7.6	-7.4 ± 4.1	-12.2 ± 3.1
	2080-2099	-18.0 ± 12.0	-17.9 ± 7.2	18.2 ± 15.8	39.9 ± 8.4
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-30.2 ± 4.5	-41.5 ± 7.2	-32.8 ± 8.0	-25.2 ± 7.4
	2041-2060	1.1 ± 7.6	-38.7 ± 5.0	-20.2 ± 5.5	-11.3 ± 5.5
	2080-2099	-20.5 ± 14.6	-0.4 ± 8.3	19.8 ± 12.1	35.1 ± 7.2
Multi-model maximum	Baseline	235.4 ± 54.4	235.4 ± 54.4	235.4 ± 54.4	235.4 ± 54.4
	2021-2040	56.2 ± 9.9	57.5 ± 9.8	63.9 ± 11.1	60.9 ± 7.7
	2041-2060	62.5 ± 14.5	86.3 ± 10.2	92.7 ± 15.5	103.3 ± 13.7
	2080-2099	49.1 ± 9.6	95.6 ± 17.5	147.6 ± 24.8	147.8 ± 29.0
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	60.8 ± 8.9	80.8 ± 15.0	75.4 ± 15.1	75.3 ± 9.3
	2041-2060	65.5 ± 9.5	115.0 ± 15.2	88.1 ± 12.6	101.0 ± 18.5
	2080-2099	55.6 ± 10.0	117.6 ± 18.0	150.3 ± 24.8	151.9 ± 27.2

Table 8: The statistics of the projected changes in potential evapotranspiration deficit in units of mm over the Whanganui-Manawātū 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).



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	191.6 ± 79.5	191.6 ± 79.5	191.6 ± 79.5	191.6 ± 79.5
	2021-2040	13.9 ± 3.8	24.3 ± 1.7	31.1 ± 2.4	25.9 ± 2.7
	2041-2060	40.9 ± 3.5	43.9 ± 3.9	41.0 ± 2.9	54.6 ± 4.1
	2080-2099	28.8 ± 4.1	71.9 ± 5.3	104.0 ± 7.0	120.3 ± 7.9
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	14.2 ± 3.7	25.0 ± 1.8	31.5 ± 2.5	26.2 ± 2.7
	2041-2060	41.0 ± 3.4	44.6 ± 4.0	41.4 ± 2.8	54.9 ± 4.0
	2080-2099	28.7 ± 4.0	72.6 ± 5.4	104.2 ± 7.0	121.0 ± 8.0
Multi-model minimum	Baseline	174.4 ± 72.0	174.4 ± 72.0	174.4 ± 72.0	174.4 ± 72.0
	2021-2040	-26.2 ± 6.4	-43.2 ± 11.5	-13.9 ± 6.5	-24.9 ± 5.8
	2041-2060	10.6 ± 6.4	-16.8 ± 3.0	-4.0 ± 6.2	-8.1 ± 5.3
	2080-2099	-1.5 ± 4.6	11.2 ± 4.2	44.0 ± 9.2	47.7 ± 6.8
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-33.2 ± 3.0	-25.0 ± 8.4	-11.9 ± 5.5	-11.8 ± 4.2
	2041-2060	6.9 ± 8.5	-21.5 ± 2.8	-18.7 ± 5.8	0.2 ± 5.1
	2080-2099	1.1 ± 2.8	25.3 ± 4.0	31.9 ± 8.8	37.9 ± 3.7
Multi-model maximum	Baseline	201.4 ± 80.8	201.4 ± 80.8	201.4 ± 80.8	201.4 ± 80.8
	2021-2040	59.7 ± 3.5	56.3 ± 6.6	66.8 ± 6.3	54.9 ± 8.6
	2041-2060	77.4 ± 7.7	90.9 ± 4.9	114.0 ± 9.5	107.8 ± 8.1
	2080-2099	50.9 ± 3.8	108.7 ± 11.8	176.6 ± 10.4	200.7 ± 16.7
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	63.8 ± 5.9	79.2 ± 10.9	78.0 ± 9.2	66.6 ± 5.8
	2041-2060	75.6 ± 4.1	116.5 ± 9.3	104.5 ± 4.9	111.7 ± 4.6
	2080-2099	55.9 ± 6.0	124.3 ± 9.6	177.9 ± 8.2	208.7 ± 13.9

Table 9: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).



Whanganui sub-region indicate a likely increase throughout the 21st century, compared to the 1986–2005 baseline. For all emission scenarios (SSP126 to SSP585), multi-model means show positive PED anomalies, with the magnitude of change strongly dependent on emissions pathway and time period. Near-term increases (2021–2040) are moderate (around 15–30 mm above baseline), and inter-scenario agreement is high, reflecting high confidence in a positive change. Mid-century (2041–2060), all scenarios project further increases, with the highest emissions scenario (SSP585) reaching a multi-model mean change of approximately 55 mm. By late century (2080–2099), scenario divergence is pronounced: SSP585 and SSP370 indicate substantial increases (about 120 mm and 104 mm, respectively), while SSP126 shows a smaller increase (around 29 mm), and inter-scenario agreement drops to about as likely as not, reflecting increased uncertainty for high emissions paths.

Model spread (across-model mean standard deviations) is modest throughout, indicating consistent spatial signals within the region. The likelihood of increased PED by century's end is very likely for medium-to-high emissions pathways, and likely even under strong mitigation. These changes suggest greater annual water deficits for Coastal Whanganui under most future scenarios. Confidence in a persistent upward trend is high, particularly out to mid-century.

15.10 Region: Turakina

Area: 1237.15 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986–2005 baseline over this region is shown in Figure 27. The statistical summary of projected changes in potential evapotranspiration deficit

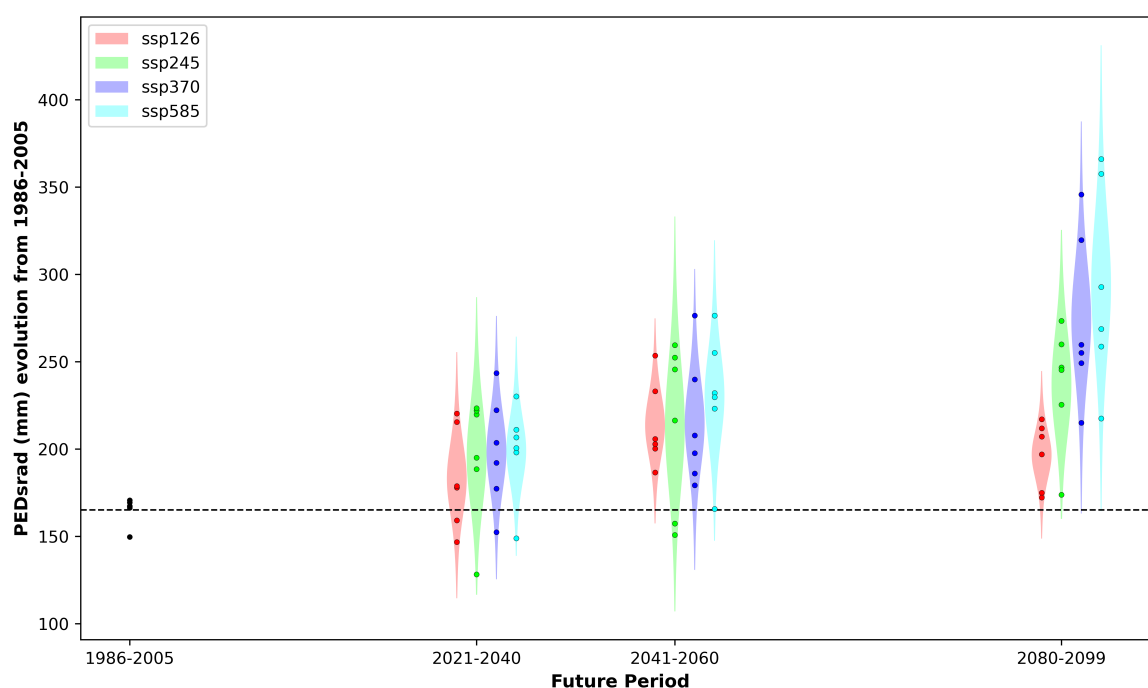


Figure 27: The time evolution of potential evapotranspiration deficit from the 1986–2005 baseline in units of mm over the Turakina region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based uncertainty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

over this region is shown in Table 10. Projected changes in annual potential evapotranspiration deficit (PED) in Turakina show a robust and consistent increase across all scenarios for the coming decades. Relative to the 1986–2005 baseline, mean PED is very likely to increase by 18 to 34 mm by 2021–2040 across all emissions



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	165.2 ± 53.3	165.2 ± 53.3	165.2 ± 53.3	165.2 ± 53.3
	2021-2040	17.9 ± 2.6	31.0 ± 2.8	33.4 ± 3.4	34.1 ± 2.6
	2041-2060	48.5 ± 4.5	48.5 ± 2.1	49.4 ± 3.4	65.2 ± 5.1
	2080-2099	31.6 ± 3.0	72.3 ± 7.2	108.9 ± 4.9	128.4 ± 5.5
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	18.2 ± 2.5	31.8 ± 2.7	33.7 ± 3.5	34.5 ± 2.6
	2041-2060	48.9 ± 4.5	49.4 ± 2.1	49.7 ± 3.4	65.7 ± 5.2
	2080-2099	31.6 ± 2.9	73.1 ± 7.4	109.1 ± 4.9	129.1 ± 5.6
Multi-model minimum	Baseline	149.3 ± 48.7	149.3 ± 48.7	149.3 ± 48.7	149.3 ± 48.7
	2021-2040	-18.5 ± 5.3	-36.9 ± 9.3	-12.7 ± 7.7	-16.2 ± 5.0
	2041-2060	20.0 ± 4.2	-21.0 ± 6.0	12.8 ± 11.8	0.6 ± 5.9
	2080-2099	0.0 ± 3.9	8.7 ± 6.9	49.8 ± 5.7	52.4 ± 5.1
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-24.1 ± 2.1	-19.8 ± 7.2	-11.6 ± 5.6	-3.3 ± 3.9
	2041-2060	13.6 ± 4.3	-18.6 ± 5.5	-1.8 ± 6.6	14.0 ± 8.1
	2080-2099	2.3 ± 3.6	22.4 ± 6.6	41.5 ± 7.4	48.8 ± 7.9
Multi-model maximum	Baseline	176.9 ± 53.6	176.9 ± 53.6	176.9 ± 53.6	176.9 ± 53.6
	2021-2040	57.0 ± 5.1	61.5 ± 3.2	78.6 ± 6.6	65.0 ± 6.7
	2041-2060	88.3 ± 6.3	96.6 ± 4.8	111.2 ± 8.4	111.3 ± 4.8
	2080-2099	56.3 ± 4.7	109.4 ± 12.0	180.5 ± 5.9	202.0 ± 7.9
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	62.7 ± 4.6	88.2 ± 5.3	81.3 ± 6.3	74.5 ± 4.9
	2041-2060	86.7 ± 7.4	123.4 ± 7.0	103.7 ± 5.9	120.8 ± 5.5
	2080-2099	60.9 ± 3.6	129.1 ± 12.2	177.9 ± 5.2	213.8 ± 8.0

Table 10: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).



pathways, with negligible inter-model variability and high agreement among scenarios (about 89% agreement). The trend persists into 2041–2060, with mean PED changes expanding to approximately 49 mm even under low-emissions (SSP1-2.6) and reaching up to 65 mm for high-emissions (SSP5-8.5). By 2080–2099, strong scenario dependence emerges: under SSP1-2.6, the projected increase is modest (32 mm), while under higher emissions (SSP3-7.0, SSP5-8.5) mean increases are in the range of 109–128 mm—almost doubling the deficit relative to the baseline. This escalation is extremely likely under higher emission scenarios, though agreement among scenarios drops to ~65%, indicating increased uncertainty by late-century.

Inter-model spread within each scenario remains low for most periods, indicating high confidence in the direction of change. The spatial variability of PED values across Turakina is also low compared to the magnitude of the trend. In summary, it is very likely that PED will increase substantially in Turakina, with the greatest changes projected under high-emissions scenarios by the end of the century.

15.11 Region: Puketoi ki Tai

Area: 966.64 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986–2005 baseline over this region is shown in Figure 28. The statistical summary of projected changes in potential evapotranspiration deficit over

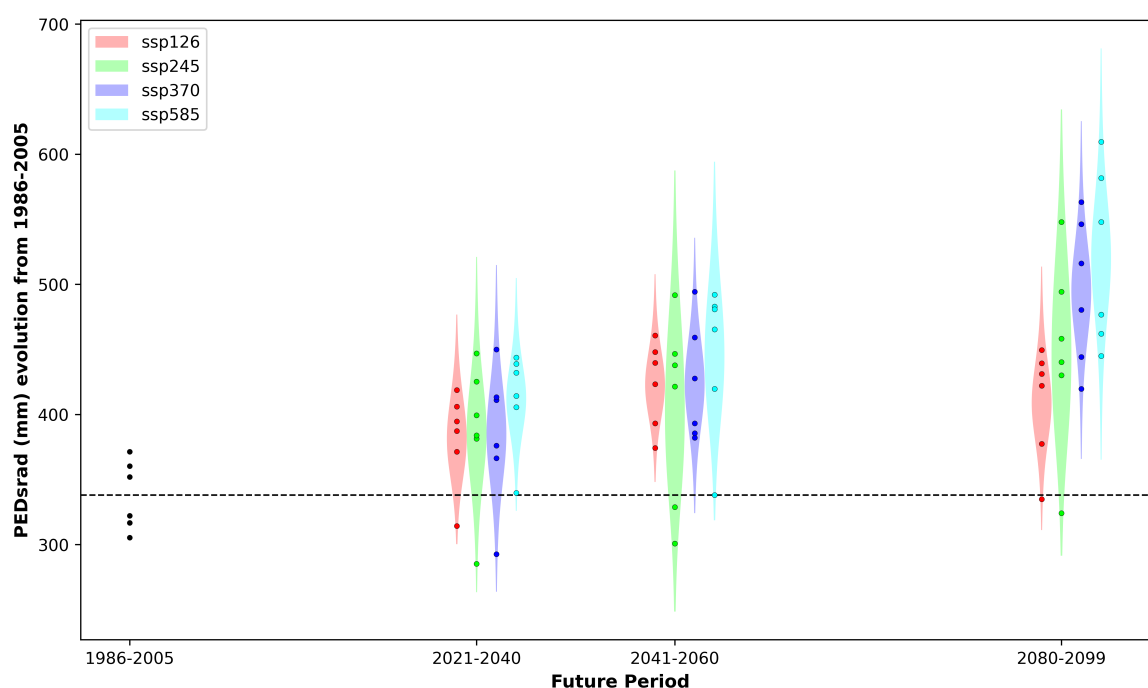


Figure 28: The time evolution of potential evapotranspiration deficit from the 1986–2005 baseline in units of mm over the Puketoi ki Tai region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using the ECS-based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

this region is shown in Table 11. Projected annual potential evapotranspiration deficit (PED) in Puketoi ki Tai indicates an overall increase compared to the 1986–2005 baseline under all emissions scenarios (SSPs). By mid-century, increases in annual PED are likely across all scenarios, with multi-model mean changes between approximately 45 mm (SSP126) and 74 mm (SSP585) for 2021–2040, climbing to between 85 mm (SSP126) and 108 mm (SSP585) in 2041–2060, and reaching 71 mm (SSP126) to 183 mm (SSP585) for 2080–2099. These results point to a very likely increase in PED, with larger increases under higher emissions pathways.



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	338.0 ± 94.5	338.0 ± 94.5	338.0 ± 94.5	338.0 ± 94.5
	2021-2040	44.1 ± 8.0	49.0 ± 5.5	46.9 ± 6.4	74.4 ± 13.4
	2041-2060	85.2 ± 11.4	66.5 ± 8.5	85.7 ± 12.5	108.5 ± 15.3
	2080-2099	71.0 ± 12.0	111.1 ± 13.8	157.0 ± 20.0	182.5 ± 25.2
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	45.0 ± 8.2	49.8 ± 5.6	47.5 ± 6.5	74.9 ± 13.5
	2041-2060	85.8 ± 11.5	68.7 ± 8.9	86.5 ± 12.6	110.0 ± 15.8
	2080-2099	71.6 ± 12.2	113.3 ± 14.3	157.1 ± 20.1	182.9 ± 25.3
Multi-model minimum	Baseline	304.5 ± 88.1	304.5 ± 88.1	304.5 ± 88.1	304.5 ± 88.1
	2021-2040	-23.8 ± 9.6	-52.8 ± 8.2	-45.3 ± 3.3	1.7 ± 9.2
	2041-2060	36.1 ± 5.6	-37.1 ± 10.1	41.1 ± 11.6	0.0 ± 5.9
	2080-2099	-3.2 ± 8.6	-13.9 ± 5.6	81.6 ± 10.4	106.9 ± 20.4
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-8.9 ± 2.7	-27.8 ± 8.2	-27.9 ± 2.6	21.0 ± 9.3
	2041-2060	37.6 ± 7.7	-36.9 ± 5.7	22.8 ± 7.4	25.2 ± 3.0
	2080-2099	10.6 ± 9.4	6.1 ± 8.2	78.4 ± 10.4	88.0 ± 14.7
Multi-model maximum	Baseline	372.5 ± 104.0	372.5 ± 104.0	372.5 ± 104.0	372.5 ± 104.0
	2021-2040	83.2 ± 15.1	108.9 ± 18.5	111.9 ± 17.0	109.2 ± 18.4
	2041-2060	125.0 ± 11.1	153.8 ± 23.6	156.4 ± 17.9	165.2 ± 22.2
	2080-2099	114.5 ± 22.4	209.9 ± 39.1	225.3 ± 28.4	271.7 ± 34.6
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	104.7 ± 16.8	132.9 ± 16.2	127.8 ± 14.5	131.8 ± 19.0
	2041-2060	138.4 ± 16.3	188.1 ± 24.7	156.0 ± 18.9	204.9 ± 33.0
	2080-2099	136.3 ± 25.5	234.7 ± 36.2	236.3 ± 31.2	280.6 ± 37.2

Table 11: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).



The inter-model spread is moderate for early periods and broadens by late-century, particularly under higher emission scenarios, reflecting reduced agreement (from $\sim 86\text{--}88\%$ for 2021–2060 to $\sim 70\%$ by 2080–2099). Spatial variability (regional standard deviation) is substantially lower in future periods than the baseline, indicating the increase in PED is relatively spatially uniform across Puketoi ki Tai, but variability grows with emission scenario by century's end.

Model agreement is high, supporting robust confidence in the direction of change. It is virtually certain that PED will rise in Puketoi ki Tai, with extremely likely increases under all future scenarios, and the magnitude of increase will be greatest under stronger warming, especially by late-century.

15.12 Region: Middle Whangaehu-Whanganui

Area: 1816.56 km²

A plot of the evolution in potential evapotranspiration deficit from the 1986–2005 baseline over this region is shown in Figure 29. The statistical summary of projected changes in potential evapotranspiration deficit

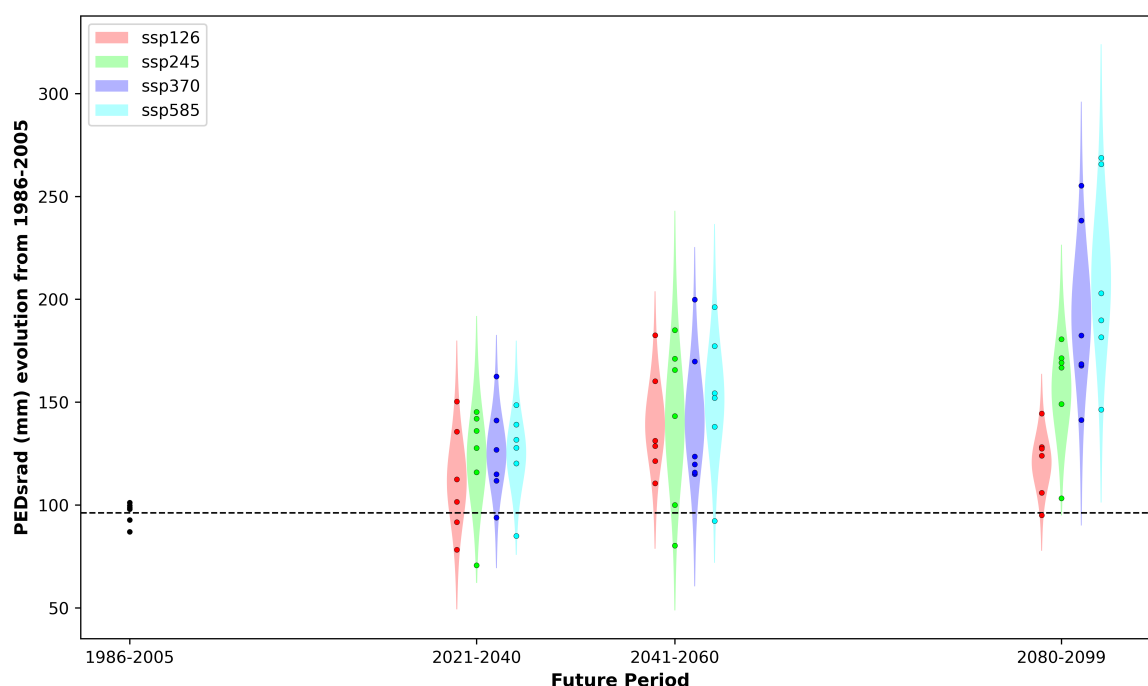


Figure 29: The time evolution of potential evapotranspiration deficit from the 1986–2005 baseline in units of mm over the Middle Whangaehu-Whanganui region. This variable is not seasonal and so the results shown here are for the whole year. The violin plots show indicative uncertainties derived using 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](#).

over this region is shown in Table 12. The projections for annual potential evapotranspiration deficit (PED) in the Middle Whangaehu-Whanganui region signal increases across all emission scenarios (SSPs) relative to the 1986–2005 baseline. For the near-term (2021–2040), all SSPs exhibit a likely increase in PED, with mean anomalies ranging from approximately 15 mm (SSP1-2.6) to 29 mm (SSP5-8.5). The signal strengthens for mid-century (2041–2060), with mean anomalies spanning 43–55 mm, indicating it is very likely PED increases persist. By late century (2080–2099), higher-emission scenarios show much larger increases: mean PED under SSP3-7.0 and SSP5-8.5 nearly matches or exceeds the historical mean, reaching around 100–113 mm, whereas lower-emission pathways show smaller or even reduced anomalies (SSP1-2.6: 25 mm, which is close to mid-century values).



Metric	Period	SSP scenario			
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Multi-model mean	Baseline	96.2 ± 36.0	96.2 ± 36.0	96.2 ± 36.0	96.2 ± 36.0
	2021-2040	15.4 ± 2.8	26.7 ± 4.7	29.0 ± 4.9	29.2 ± 4.0
	2041-2060	42.9 ± 6.9	44.7 ± 5.2	44.4 ± 6.3	55.5 ± 9.6
	2080-2099	24.6 ± 4.2	60.5 ± 11.0	96.1 ± 12.1	113.0 ± 17.0
Multi-model P50	Baseline	N/A	N/A	N/A	N/A
	2021-2040	15.9 ± 2.8	27.3 ± 4.8	29.1 ± 5.0	29.6 ± 4.0
	2041-2060	43.2 ± 6.9	45.4 ± 5.3	44.7 ± 6.3	55.8 ± 9.6
	2080-2099	24.6 ± 4.3	61.1 ± 11.1	96.2 ± 12.1	113.5 ± 17.1
Multi-model minimum	Baseline	86.4 ± 33.3	86.4 ± 33.3	86.4 ± 33.3	86.4 ± 33.3
	2021-2040	-18.5 ± 3.7	-25.5 ± 9.9	-2.4 ± 5.9	-11.2 ± 7.3
	2041-2060	13.6 ± 4.5	-16.2 ± 6.3	14.5 ± 7.9	-4.0 ± 6.1
	2080-2099	-2.2 ± 6.1	7.0 ± 5.3	44.1 ± 6.7	50.0 ± 5.4
Multi-model P5	Baseline	N/A	N/A	N/A	N/A
	2021-2040	-23.3 ± 4.0	-11.9 ± 6.0	-5.0 ± 4.9	-1.8 ± 3.8
	2041-2060	5.6 ± 5.8	-13.1 ± 3.5	-4.6 ± 7.0	6.4 ± 7.1
	2080-2099	-1.7 ± 3.3	21.3 ± 5.5	34.0 ± 7.9	46.5 ± 9.4
Multi-model maximum	Baseline	103.7 ± 36.9	103.7 ± 36.9	103.7 ± 36.9	103.7 ± 36.9
	2021-2040	55.7 ± 5.1	50.3 ± 7.9	66.3 ± 15.1	52.6 ± 9.9
	2041-2060	86.3 ± 7.1	88.9 ± 7.9	103.6 ± 10.9	101.2 ± 13.2
	2080-2099	49.2 ± 8.9	84.9 ± 13.7	160.3 ± 21.4	174.4 ± 24.7
Multi-model P95	Baseline	N/A	N/A	N/A	N/A
	2021-2040	58.1 ± 7.5	70.1 ± 15.5	64.0 ± 13.5	63.2 ± 10.6
	2041-2060	83.2 ± 9.6	108.8 ± 13.8	96.5 ± 10.6	107.8 ± 13.9
	2080-2099	50.8 ± 10.9	104.5 ± 19.4	159.3 ± 18.4	184.2 ± 28.3

Table 12: The statistics of the projected changes in potential evapotranspiration deficit in units of mm 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).



Model agreement is very high for the first two future periods (agreement is >89%), supporting high confidence in increasing PED through mid-century. However, for 2080–2099, inter-scenario agreement drops to about 64% as scenario differences emerge, indicating medium confidence for late-century outcomes. Spatial variability (stdv) remains relatively low compared to baseline. Overall, it is very likely that PED will rise through at least mid-century, with the magnitude of increases largely dependent on future emissions, supporting adaptation planning for increased drought risk.