



Climate Change: Method Statement



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1. Introduction

Jersey Water has commissioned AtkinsRéalis to support the update of their Water Resources and Drought Management Plan (WRDMP) to ensure a resilient, secure water supply up to 2065. To develop the plan an assessment of baseline water availability and the impacts of climate change on future water supply and demand is required. The UK Climate Projections 2018 (UKCP18), provide a range of modelling products with the most emphasis on Representative Concentration Pathway 8.5 (RCP8.5) which is a higher emissions scenario. This scenario indicates warming of 1.4 to 4.1 °C in the 2070s above the 1981-2000 baseline for England and Wales¹ (therefore 2 to 5 °C above pre-industrial average temperatures).

This method statement:

- 1) reviews which UKCP18 data products and RCP's are available for Jersey Water,
- 2) provides a comparison of their projected climate changes,
- 3) outlines a pragmatic sampling approach that has been adopted to select and recommend a sub-sample of climate change factors that can be applied to baseline and stochastic weather data to assess the impact of a range of possible climate futures on supply, and
- 4) provides a suggested update to align the modelling of the impact of climate change on demand with supply.

2. Jersey's Climatology

Jersey is the largest of the Channel Islands, neighboured by Guernsey Island and is a short distance from the French coast of Lower Normandy. This means it is influenced by prevailing winds bringing conditions from continental France and influenced by the warm jet stream in the winter months leading to relatively warm seawater.

¹ Based on 10th and 90th percentile of the UKCP probabilistic data for 2060-2079.

As shown in

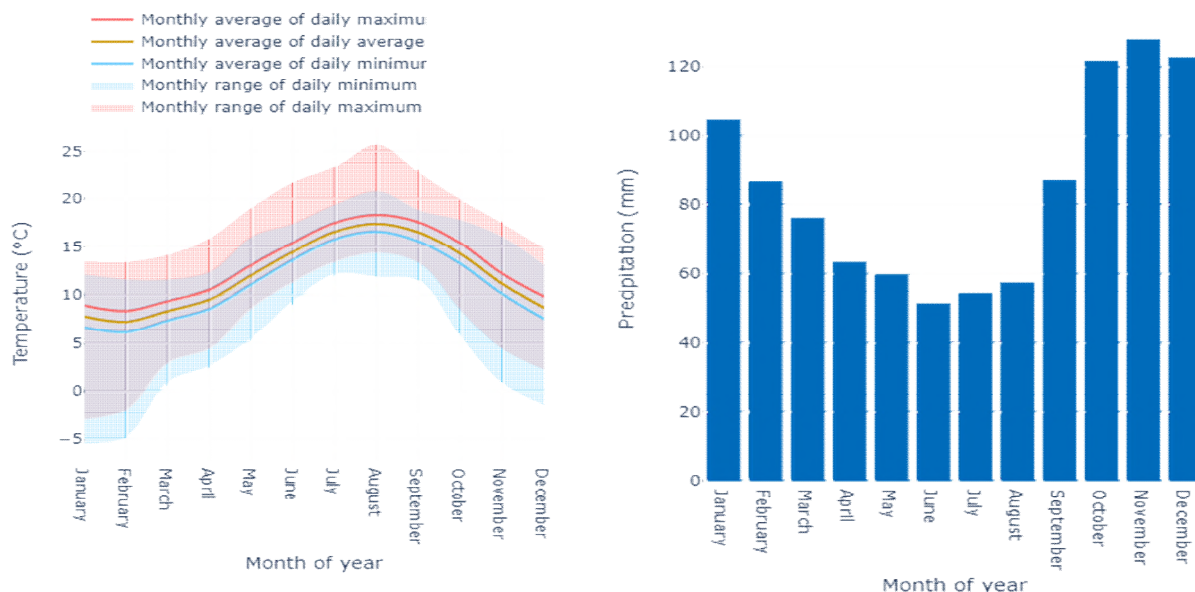


Figure 2-1 below Jersey's climatology is typified by mild winters and warm summers with monthly average temperatures ranging from approximately 7°C to 15°C throughout the year with warmer summers and cooler winters. The wettest months are September through to February. Jersey's mean daily air temperature is 12.31°C with an annual total rainfall of 918mm (1991 to 2020 30-year average).

In 2022, Jersey Met recorded several new extreme temperature records including:

- the hottest year since official records began with an average annual temperature of 13.56°C
- an all-time highest daytime maximum of 37.9°C on 18th July
- new highest night-time minimum temperature of 25.5°C on 19th July
- the most days within a single year that reach 30°C, and
- the warmest summer on record exceeding the 1976 summer.

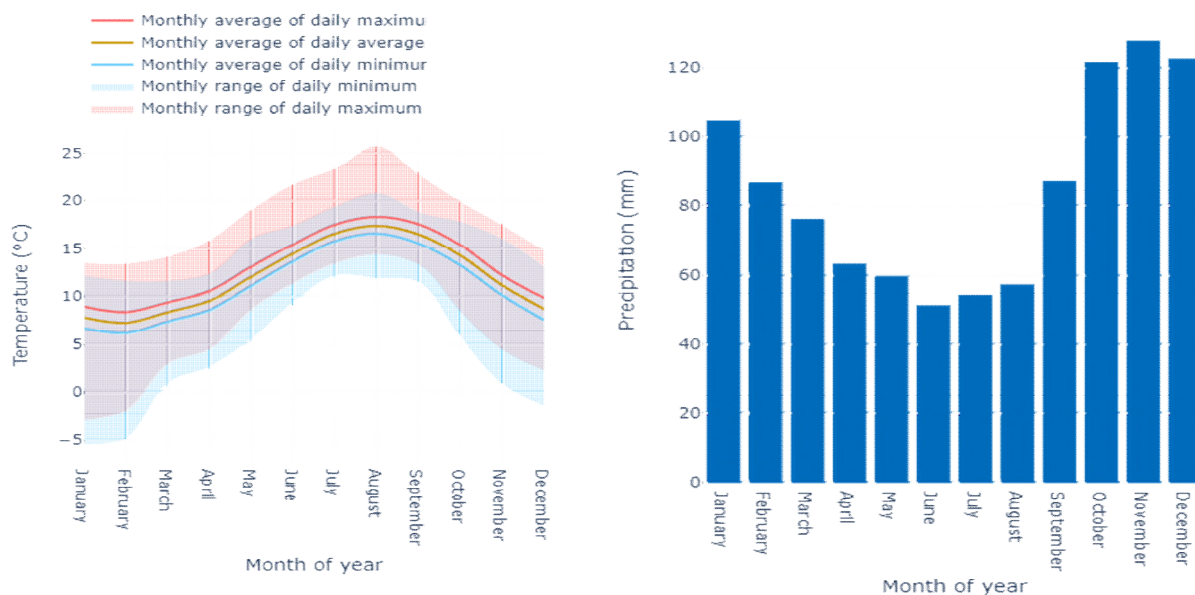


Figure 2-1 – Jersey monthly average temperatures and precipitation 1981-2010².

Many of the climate change data products that are available are for a regional average covering Jersey and Guernsey Islands. Therefore, to explore whether Jersey island has similar climate to its neighbouring islands we present temperature and rainfall data for Guernsey Island below. As shown in Figure 2-2, Guernsey Island has similar rainfall in winter months but is drier in the summer months. The average daily temperatures are similar for each of the islands however, Jersey experiences higher average maximum daily temperatures than Guernsey.

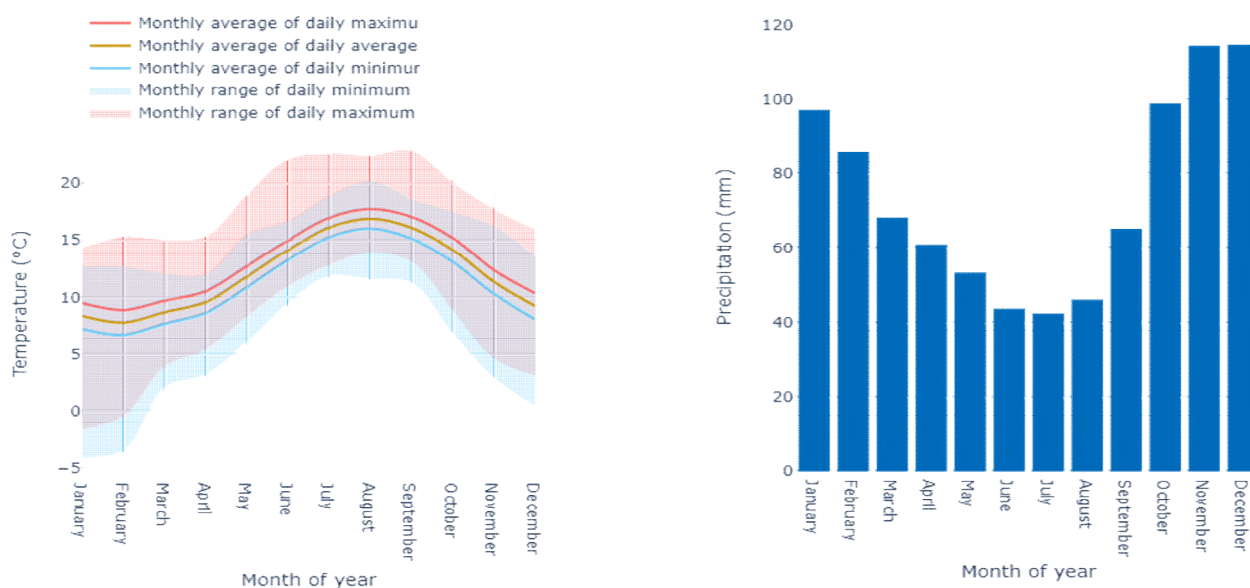


Figure 2-2 - Guernsey monthly average temperatures and precipitation 1981-2010³.

² Sourced from: ERA5 (ECMWF). Contains modified Copernicus Climate Change Service information. ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate. It is not observed data.

³ Sourced from: ERA5 (ECMWF). Contains modified Copernicus Climate Change Service information. ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate. It is not observed data.

Figure 2-3 shows climatological data that has been recorded at Maison St Louis Observatory, Jersey Island since 1894. As shown, average temperatures on the island are increasing with the average temperature for the 2010s averaging as 12.5°C which was approximately 1.5°C increase since the 1900s. The records show that 16 of the top 20 warmest years in Jersey have occurred within the last 30 years.

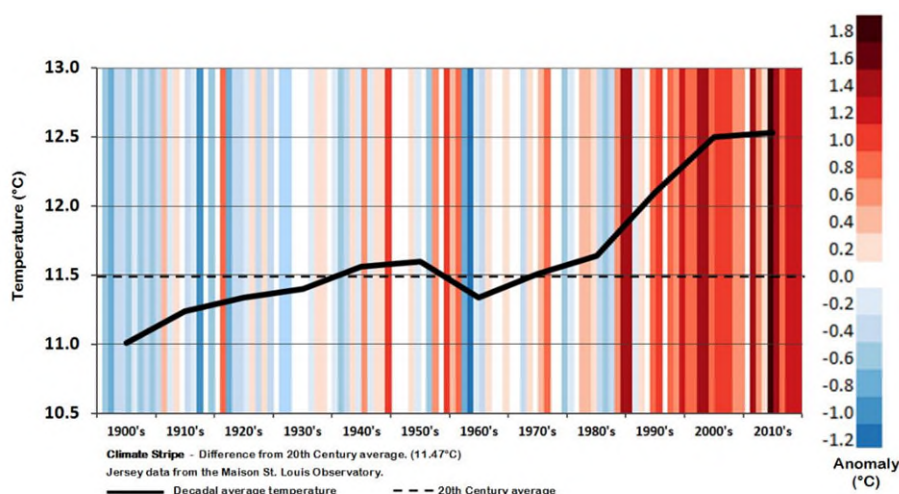


Figure 2-3 – Warming stripes showing annual average air temperatures in Jersey since 1990. Sourced from: Jersey Met.

3. Available Climate Change Data

Table 3-1 below details the available Met Office UK Climate Change Impacts Programme 2018 (UKCP18) products that are available for Jersey Island. As shown, some products are only available for a regional spatial scale that captures the whole Channel Islands than grid cells which is the spatial disaggregation more widely available for England. Further details about the products are provided in the sections following the table below.

Table 3-1 - UKCP18 products and their availability for Jersey

Model/product	Available RCPs	Available Period(s) of Data	Spatial resolution available for Jersey Water	Number of runs in ensemble
HadUK observed data	N/A	1900-2020	Not available for Jersey	1
Global Climate Model (GCM)	2.6 and 8.5	1900-2100	Not available for Jersey – grid cell over Jersey captures the ocean area only and returns no data.	15 produced by the Met Office Hadley Centre, 13 from CMIP5 modelling
Probabilistic Climate Model	2.6, 4.5, 6.0 and 8.5	1961-2100	25km grid cell centred over Guernsey (significant ocean coverage included). Admin region and country average covering all Channel Islands.	3000
Regional Climate Model (RCMs)	8.5	1980-2080	12km grid cell centred over Jersey (some ocean coverage included). Admin region and country average covering all Channel Islands.	12

3.1.1 Probabilistic climate model

The future probabilistic projections in UKCP18 capture climate changes for various probabilities which indicate how much the evidence from models and observations taken together support a particular future climate outcome. The projections are available for four different RCPs – 2.6, 4.5, 6.0 and 8.5. In UKCP18 probabilistic data there are 3000 possible climate outcomes for each RCP and future time-period.

For Jersey the probabilistic data are available at either the grid cell or regional spatial resolution. As such, we undertook a comparison of the projections from both and the values are identical.

3.1.2 Regional climate model

Regional climate models (RCM) can have systematic biases, which mean they have limited skill in reproducing important hydrological characteristics, such as the magnitude and frequency of very wet days and the length of dry periods. In addition, some models may be too warm/dry and/or too wet in specific months or seasons to accurately reproduce catchment water balances.

To use the RCM absolute values directly in hydrological modelling, the application of bias correction to correct the baseline period and future scenarios is required based on the assumption that these biases carry through to the future modelling periods. As part of work undertaken to support the UK Water Industry for the recent Regional Plans, AtkinsRéalis created a methodology to bias correct the UKCP18 Regional Climate Models, based on published 'quantile mapping' bias correction methods (e.g. Li *et al.*, 2010⁴). The specific method developed is referred to as Equidistant CDF mapping (EDCDF) in the scientific literature and involves correcting daily, seasonal and annual bias using 31 day moving window on daily RCM data independently for each variable and ensemble member. This removes systematic bias in the models, which ensures more realistic seasonal and daily variations in rainfall.

To provide the flexibility to use the data directly, if required, and to remove systematic biases we have applied the AtkinsRéalis bias correction technique to the RCM data using weather data for 1981-2000 from Jersey Met for the Maison St Louis weather station. This has produced bias corrected RCM data for Jersey.

4. Climate Change Data Comparison

4.1 Baseline periods

For evaluating the impact of future climate change, there are a range of baseline periods (e.g. 1981-2000, 1920-1990 etc.) that can be used and each differ in their average climatology. The baseline period of 1981-2000 is commonly used for determining anomalies within UKCP18 climate projections so this climate change baseline is recommended for use in Jersey Water's plan to calculate the climate change factors/anomalies that will be applied to the hydrological modelling inputs.

However, it will be important to ensure that any misalignment between the climate change baseline period and historical baseline period or stochastic weather dataset are accounted before being used in Jersey Water's rainfall-

⁴ Li, H., J. Sheffield, and E. F. Wood (2010), Bias correction of monthly precipitation and temperature fields from Intergovernmental Panel on Climate Change AR4 models using equidistant quantile matching, J. Geophysical Research, 115, D10101, doi:10.1029/2009JD012882.

runoff modelling so that climate changes are double counted or misrepresented, particularly for temperature and potential evapotranspiration.

4.2 Future Climate Changes

For the recent UK Water Resource Management Planning, the industry has generally used the 'delta change' or change factor approach to assess the impacts of climate change. This involves factoring a historical record for a baseline period (1920-present, 1961-1990, 1981-2000), with monthly precipitation, temperature, or potential evapotranspiration factors to assess impacts. This was also the approach adopted in Jersey Water's previous plan and therefore is the approach recommended for this Water Resources and Drought Management Plan (WR&DMP).

In the recent round of UK water company plans stochastic data were also used to explore natural variability and estimate severe droughts (using a 1950-1997 baseline). Monthly rainfall and temperature change factors were applied to the baseline stochastic datasets for each of the climate scenarios before generating climate perturbed stochastic flows and then assessing the change in deployable output in the water resources model.

To inform the selection of the most appropriate data product for assessing the impact of climate change for Jersey Water this section of the Method Statement presents a comparison of climate changes (from 1981-2000 baseline conditions) in precipitation (%) and temperature (°C) that capture the:

- Long-term annual changes through time
- Intra-annual (seasonal) changes, and
- Interaction of change factors for both variables at a given timepoint.

4.2.1 Long-term annual changes through time

UKCP18 projections are based on the concentration of greenhouse gases in the atmosphere; the scenarios are referred to as Representative Concentration Pathways (RCPs) 2.6, 4.5, 6.0 and 8.5. These are outlined in Table 4-1 below.

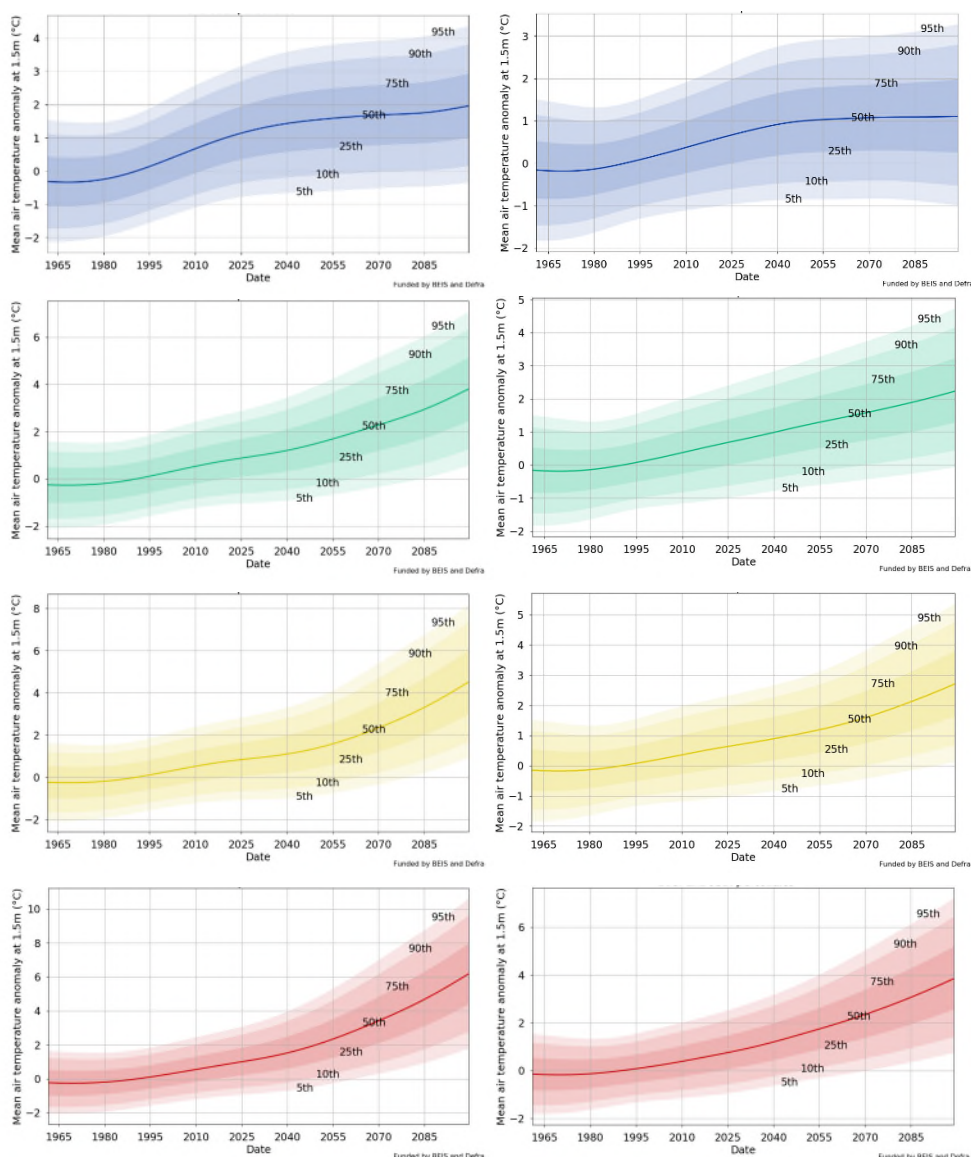
Table 4-1 – Summary of UKCP18 Representative Concentration Pathways

RCP	Description of pathway	Change in global temp. (°C) by 2080-2100 ⁵
2.6	GHG emissions strongly reduced.	1.6 (0.9 – 2.3)
4.5	Medium stabilisation pathway with mitigation.	2.4 (1.7 – 3.2)
6.0	Medium stabilisation pathway with mitigation.	2.8 (2.0 – 3.7)
8.5	GHG emissions continue to grow unmitigated.	4.3 (3.2 – 5.4)

⁵ The increase in global mean surface temperature averaged over 2081-2100 compared to the pre-industrial period (average between 1850-1900) for the RCP pathways (best estimate, 5-95% range). Sourced from: [ukcp18-guidance-representative-concentration-pathways.pdf](https://www.metoffice.gov.uk/publications/ukcp18-guidance-representative-concentration-pathways.pdf) ([metoffice.gov.uk](https://www.metoffice.gov.uk)).

The RCP2.6 scenario is closest to limiting warming to below 2 degrees consistent with Paris Agreement but RCP8.5 is often used for risk assessment purposes as it presents a lower probability / higher consequence scenario. The average temperature in England and Wales has already risen 1.1°C above pre-industrial temperatures and although some authors argue that the likelihood of RCP8.5 is reducing due to our efforts to reduce emissions⁶ observed carbon concentrations in the atmosphere continue to rise at a rate consistent with this scenario⁷.

As shown by Figure 4-1 all scenarios show an increasing rate of warming (the classic “hockey stick”) over time except RCP2.6 which plateaus from the 2040s onwards. Precipitation projections are shown in Figure 4-2 show a weaker long-term trend with slight drying in summer months and wetting in winter months but a wide range of uncertainty. These seasonal trends are explored further in the following section (see Section 4.2.2)



⁶ <https://www.nature.com/magazine-assets/d41586-020-00177-3/d41586-020-00177-3.pdf>

⁷ <https://www.esrl.noaa.gov/gmd/ccgg/trends/>

Figure 4-1 - Plume plots of 3-month summer (left) and 3 month winter (right) average probabilistic temperature change (degrees Celsius) factor projections relative to 1981-2000 baseline. RCP2.6 (blue), RCP4.5 (green), RCP6.0 (yellow) and RCP8.5 (red).

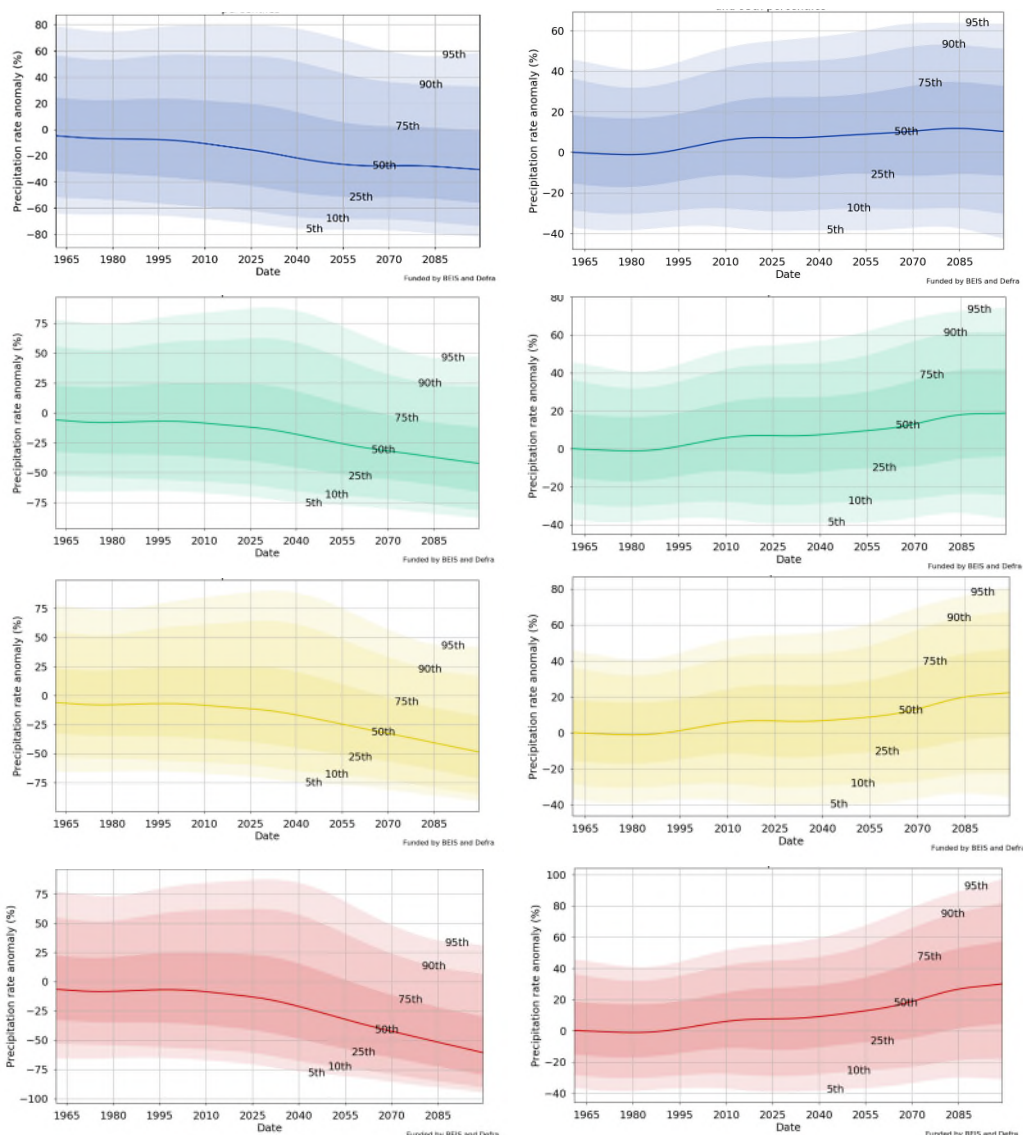


Figure 4-2 - Plume plots of 3-month summer (left) and 3 month winter (right) average probabilistic precipitation change (%) factor projections relative to 1981-2000 baseline. RCP2.6 (blue), RCP4.5 (green), RCP6.0 (yellow) and RCP8.5 (red).

4.2.2 Seasonal and monthly change factors

This section summarises the intra-annual pattern of the median and interquartile range of change factors for the 2070s period (20year time slice). Figure 4-3 shows:

- The intra-annual pattern for temperature change is consistent between all models with future warming predicted throughout the year and more pronounced warming expected in the summer months.
- Across the probabilistic projections the 'peakiness' of the expected summer temperature rise becomes more pronounced with increasing RCP.

- The interquartile range ribbons demonstrate significant overlap in the distribution between all probabilistic models but particularly between RCP4.5 and RCP6.0. Although there is significant overlap of the interquartile range for RCP8.5 and all other probabilistic models, RCP8.5 projects warmer conditions throughout the year but particularly in the summer months.
- The median projection of the bias corrected RCM RCP8.5 data is warmer than the median probabilistic projection for the equivalent RCP and is significantly warmer than the probabilistic projections for all other RCPs across all months with the interquartile range even sitting above the interquartile range of the probabilistic RCP2.6 to 6.0 projections.
- The bias corrected RCM data captures a smaller range of future uncertainty than the probabilistic projections demonstrated by the narrower ribbons.
- The 5th to 95th percentile range of the probabilistic RCP8.5 models encapsulates the projections from all other models including the bias corrected RCM RCP8.5 projections.

Figure 4-4 shows:

- Relative to temperature change, there is much greater overlap in the distributions of precipitation change between all models presented.
- The patterns of intra-annual change are similar across all data products, where winter months and summer months are projected to become wetter and drier respectively. However, the bias corrected RCM RCP8.5 project more pronounced summer warming than the probabilistic projections.
- The interquartile range ribbons also show that there is significant overlap in range of projected conditions across all models.
- As was identified by the temperature change plots, the bias corrected RCM RCP8.5 projections capture a smaller range of future uncertainty across the ensembles than the probabilistic models.

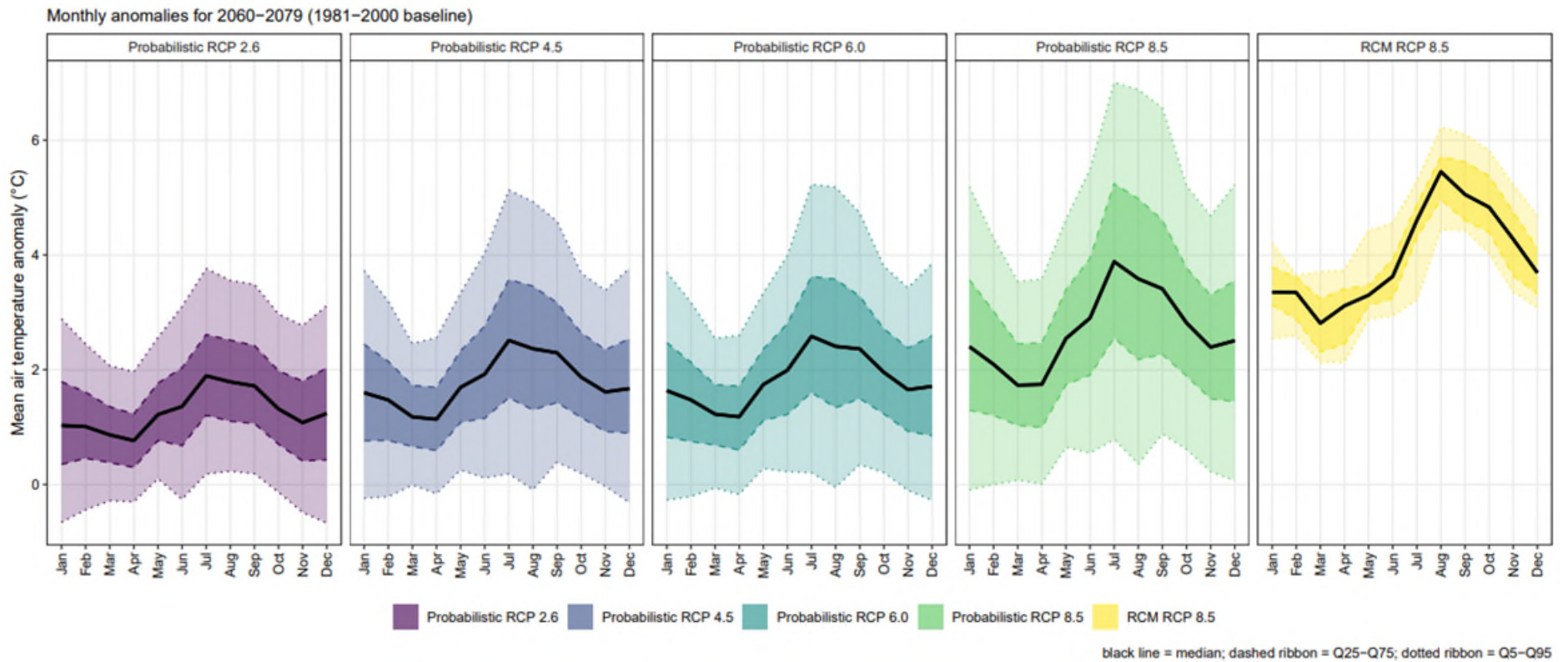


Figure 4-3 – Jersey catchment intra-annual temperature change factors (°C) for the 2070's period. Changes shown from a 1981-2000 baseline conditions. The line indicates the median of each model, whereas the ribbon denotes the interquartile range.

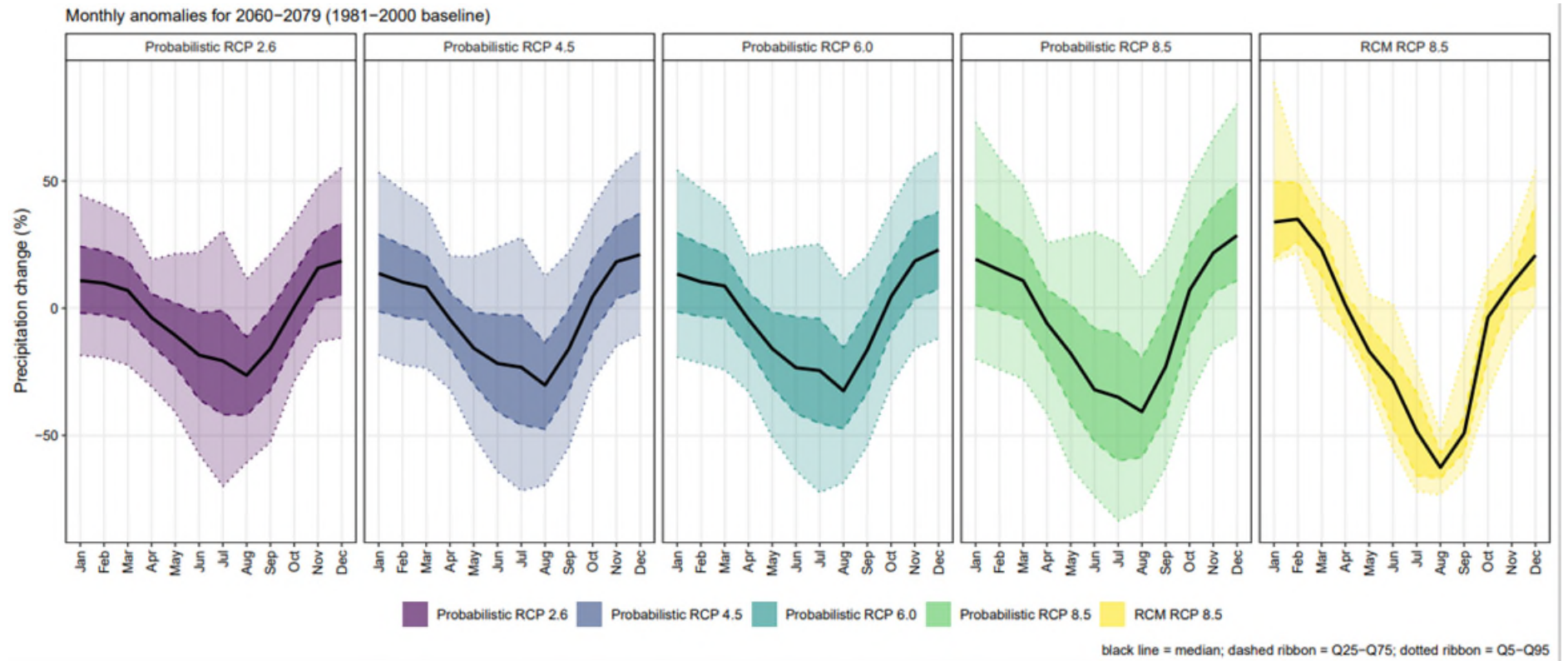


Figure 4-4 – Jersey catchment intra-annual precipitation change factors (%) for the 2070's period. Changes shown from a 1981-2000 baseline conditions. The line indicates the median of each model, whereas the ribbon denotes the interquartile range.

4.2.3 Temperature-precipitation interaction

This section outlines the interaction between precipitation change and temperature change for the 2070 period. Cross hair plots (shown in Figure 4-5) indicate the median and range of uncertainty (captured by the interquartile range and 5th to 95th percentile) of each climate model.

As shown, typically, the median point of all models falls within the same quadrant (i.e. wetting and warming, or drying and warming) with the exception of April and October, where the bias corrected RCM RCP8.5 data projects a slight wetting rather than drying for April and a slight drying rather than wetting for October. In all cases the bias corrected RCM RCP8.5 data projects a more extreme trend per month than the probabilistic data, for example, more extreme drying and warming in August than the probabilistic projections. For most months, the plots demonstrate greater overlap within precipitation change than temperature change.

The scale of the crosshair can be used to determine the level of uncertainty associated with each model. Here, the 3000 replicates of the probabilistic models produce the greatest ranges, with Q05-Q95 crosshairs spanning multiple quadrants in some months (i.e. December or January could be wetter and warmer, warmer and drier or wetter and cooler). In contrast RCMs produce the smallest cross hairs with Q05-Q95 often all within one quadrant. Nonetheless, for the majority of months, the interquartile range sits within one quadrant.

In winter and summer months, changes in precipitation interact clearly with temperature compounding potential impacts of warm wet winters and hot dry summers; in catchments or water resources systems with limited storage this is likely to lead to significant impacts.

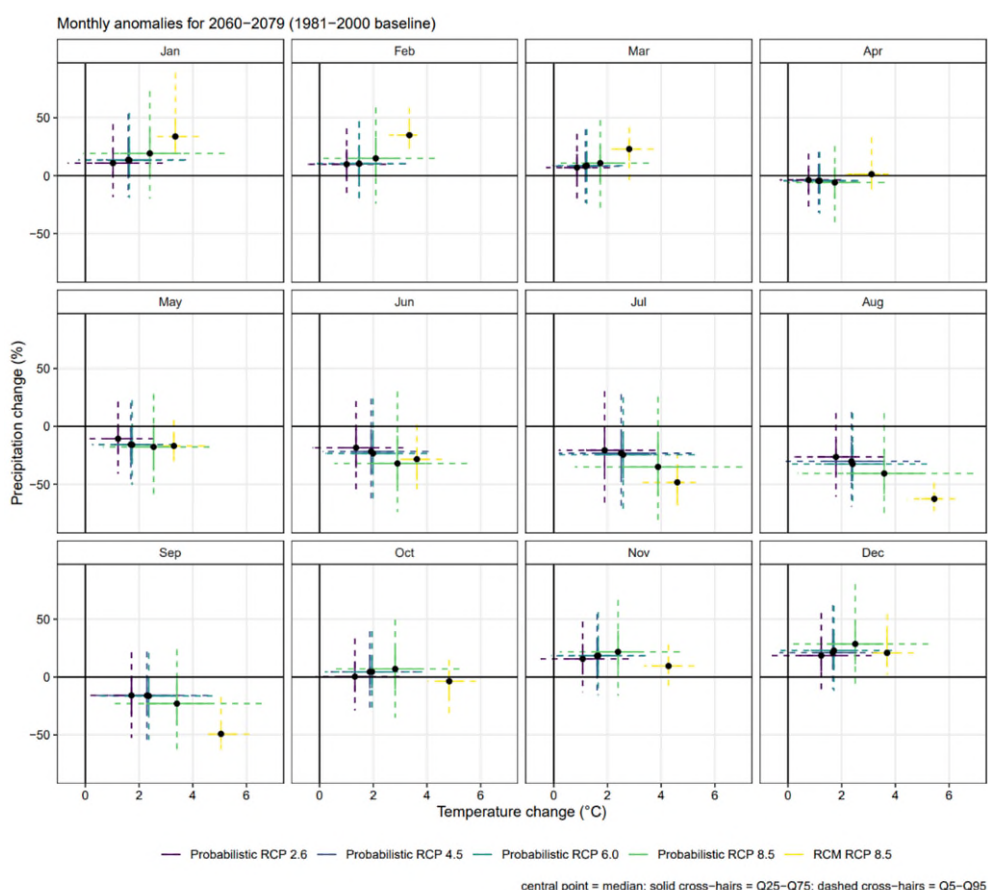


Figure 4-5 - Monthly temperature (°C) and precipitation (%) change factors for Jersey catchment in the 2070s. The point indicates Q50 of each model, the solid cross denotes the Q25–Q75 and the dashed cross denotes Q05–Q95.

5. Scenario selection

As shown in Section 4, there is considerable overlap between UKCP18 probabilistic data and the RCM RCP8.5 data. Although the median RCM projection exhibits higher rates of warming than the median probabilistic data, the RCP8.5 probabilistic projections capture the full range of changes expressed by almost all other scenarios and the RCM RCP8.5 data.

Our recommendation is to sample from the RCP8.5 probabilistic projections for the following reasons:

- During the scoping stage it was identified that Jersey Water would like to capture climate changes that represent the range of uncertainty in future projections and the range of possible outcomes in UKCP18 RCP8.5 probabilistic data cover almost all other RCPs.
- RCP8.5 is often used for risk assessment purposes as it presents a lower probability / higher consequence scenario.
- In 2019, the UK Government set its target to bring greenhouse gas emissions to net zero by 2050⁸ (compared with the previous target of at least 80% reduction from 1990 levels). However, the UK's Climate Change Committee (CCC) have stated that up to at least 2050, temperatures in the UK are expected to increase regardless of how strongly emissions are reduced globally, and sea level will continue to increase for centuries even on a low emissions pathway⁹. The CCC's view is that it is prudent for the UK to consider the risks from a scenario of 4°C warming by 2100 in adaptation planning¹⁰ and RCP8.5 is the only scenario that reaches 4 degrees.

Typically, a sub-sample of probabilistic data (e.g. 20 scenarios) are used for hydrological and water resources systems modelling. The sub-sample can be selected using various methods of sub-sampling that are based on either:

- **Climatology** – using techniques applied to the climate change factors e.g.
 - Ranking methods based on drought indices that are relevant to the drought vulnerabilities of the water company to inform selection of a sample that represents a drier future, a wetter future and median future conditions.
 - Latin hypercube sampling to select a random sample of parameter values.
- **System response**– involves modelling all scenarios through hydrological modelling and using the system response to inform the sampling.

Based on discussions with Jersey Water during the scoping stage we have opted for a pragmatic approach that samples based on the climatology. We undertook a two-step sampling methodology:

- Sampled from 3000 to 30 samples using a ranking approach based on an aridity index and drought durations relevant to Jersey Water's system.

⁸ <https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law>

⁹ <https://www.theccc.org.uk/publication/progress-in-preparing-for-climate-change-2019-progress-report-to-parliament/>

¹⁰ <https://www.theccc.org.uk/publication/progress-in-preparing-for-climate-change-2019-progress-report-to-parliament/>

- Manually sampled from 30 to 12 samples using expert judgement.

5.1 Sub-sampling

Jersey Water's previous WR&DMP Appendix H (Drought Management)¹¹ identified that the Jersey Water system has approximately 130 days of storage and is not vulnerable to short duration droughts but is vulnerable to dry summers followed by dry winters. Therefore, we uplifted Jersey's monthly meteorological record for Maison St. Louis using the 3000 climate change factors and calculated an aridity index¹² that incorporates temperature and precipitation to calculate aridity for the following durations:

- average of the summer, autumn and winter seasons (June-February), and
- annual average.

For each duration the aridity index was ranked across all 3000 probabilistic projections. Samples were selected using the following percentile bands to capture the range of uncertainty represented by the probabilistic projections. The upper and lower tails of the distribution (0th to 10th percentiles and 90th to 100th) were removed as these represent a less likely and extreme outcome that may be influenced by outliers. This is also in line with how data is reported by UKCP18¹³:

- 80th to 90th percentile – to represent the high aridity samples.
- 45th to 55th percentile – to represent the median aridity samples.
- 10th to 20th percentile – to represent the low aridity samples.

Each of these percentile bands contained approximately 300 samples. From the 300 samples, a sub-sample of 5 were systematically selected (as the maximum, 75th percentile, median, 25th percentile and minimum) that represented the full range of the 300 samples. This resulted in 15 samples per aridity duration and a total of 30 samples across the two aridity durations.

As shown in Figure 5-1 and

¹¹ Available at: [JW-WRMP-DP-Appendix-H.-Drought-Management.pdf \(jerseywater.je\)](#)

¹² Taken from: Marsh, 2004. *The UK drought of 2003: A hydrological review*. Weather – August 2004, Vol.59, No.8

¹³ Murphy et al., 2018. UKCP18 Land Projections: Science Report, November 2018 (updated March 2018) and Lowe et al., 2018. UKCP18 Science Overview Report, November 2018 (updated March 2019).

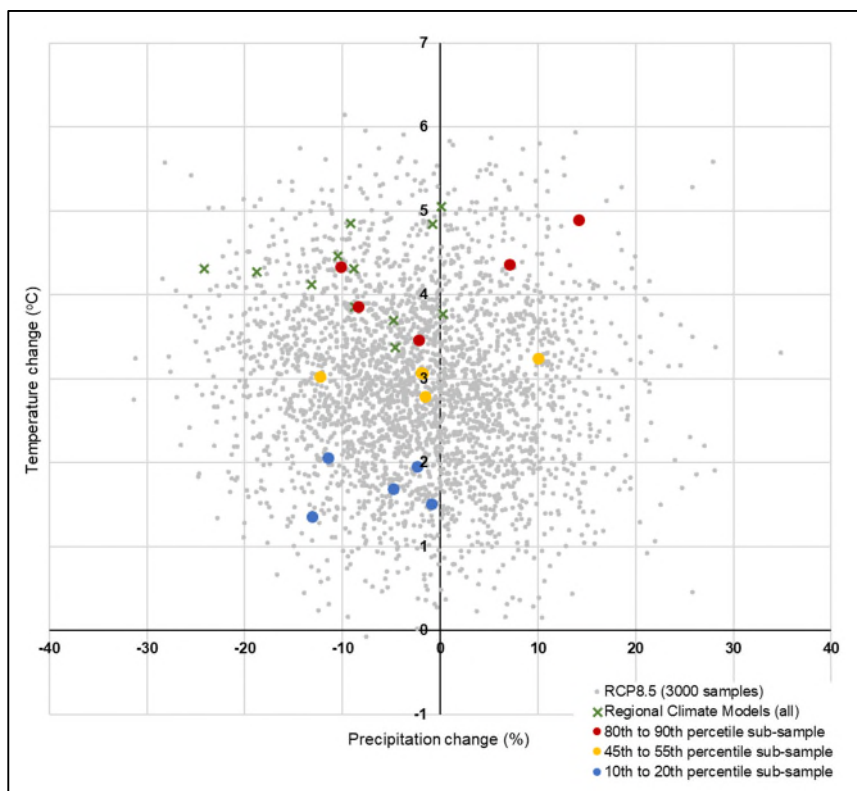


Figure 5-2, the sampling process has resulted in sub-samples that, for each percentile band, are evenly distributed across the range of precipitation changes projected by the full 3000 probabilistic projections and also samples temperature increases at approximately 2, 3 and 4°C warming.

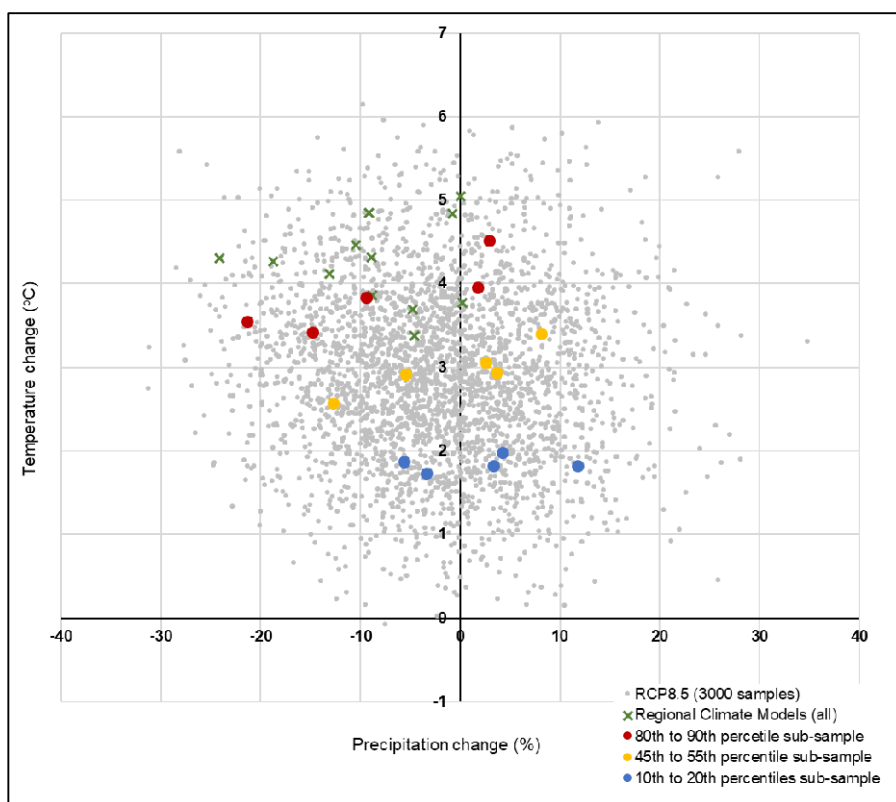


Figure 5-1 - Sub-sampling based on ranked aridity index (dry summer followed by dry winter)

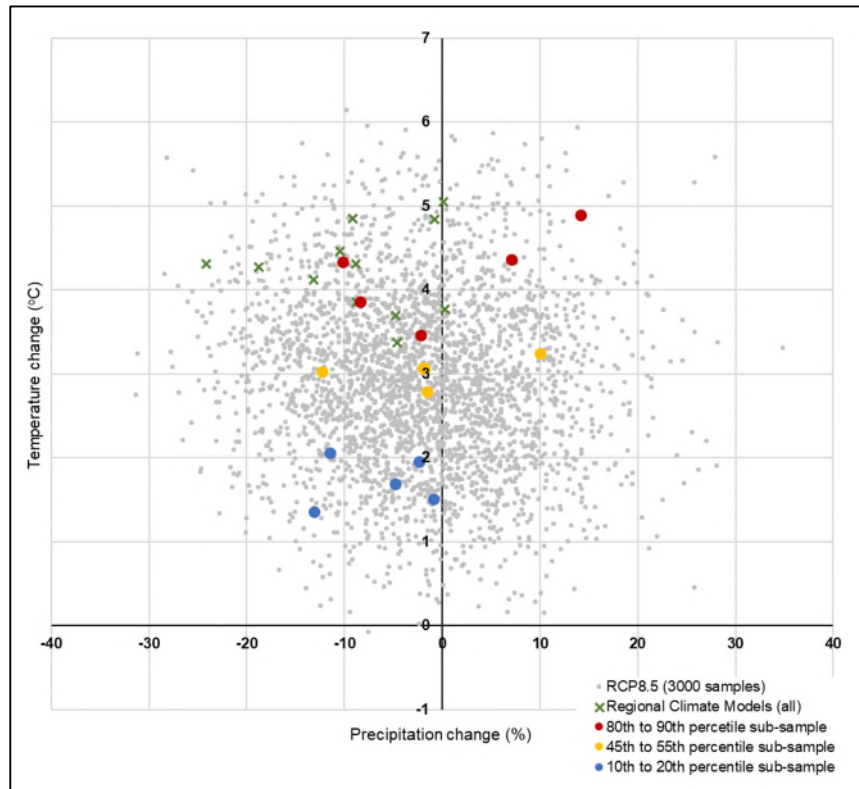


Figure 5-2 - Sub-sampling based on ranked aridity index (annual average)

As shown by Table 5-1, Table 5-2 and Table 5-3 the means and standard deviations of the sub-sample data and the full 3000 samples are very similar suggesting that the sub-samples provide a good representation of the full 3000 sample.

Table 5-1 - Summary descriptive statistics of the aridity index for sampling populations

		Mean	Standard deviation	Standard error
Dry summer followed by dry winter	Full 3000 probabilistic sample	6.40	0.52	0.01
	15 sub-sample	6.39	0.47	0.1
Annual average	Full 3000 probabilistic sample	6.03	0.47	0.01
	15 sub-sample	6.03	0.43	0.1

Table 5-2 - Summary descriptive statistics of temperature (°C) for sampling populations

		Mean	Standard deviation	Standard error
Dry summer followed by dry winter	Full 3000 probabilistic sample	2.92	1.04	0.01
	15 sub-sample	2.89	0.90	0.2

Annual average	Full 3000 probabilistic sample	2.92	1.04	0.01
	15 sub-sample	2.98	1.10	0.3

Table 5-3 - Summary descriptive statistics of precipitation (%) for sampling populations

		Mean	Standard deviation	Standard error
Dry summer followed by dry winter	Full 3000 probabilistic sample	-2.36	9.31	0.17
	15 sub-sample	-2.31	9.20	2.4
Annual average	Full 3000 probabilistic sample	-2.36	9.31	0.17
	15 sub-sample	-2.65	8.09	2.1

5.2 Recommended sub-sample selection

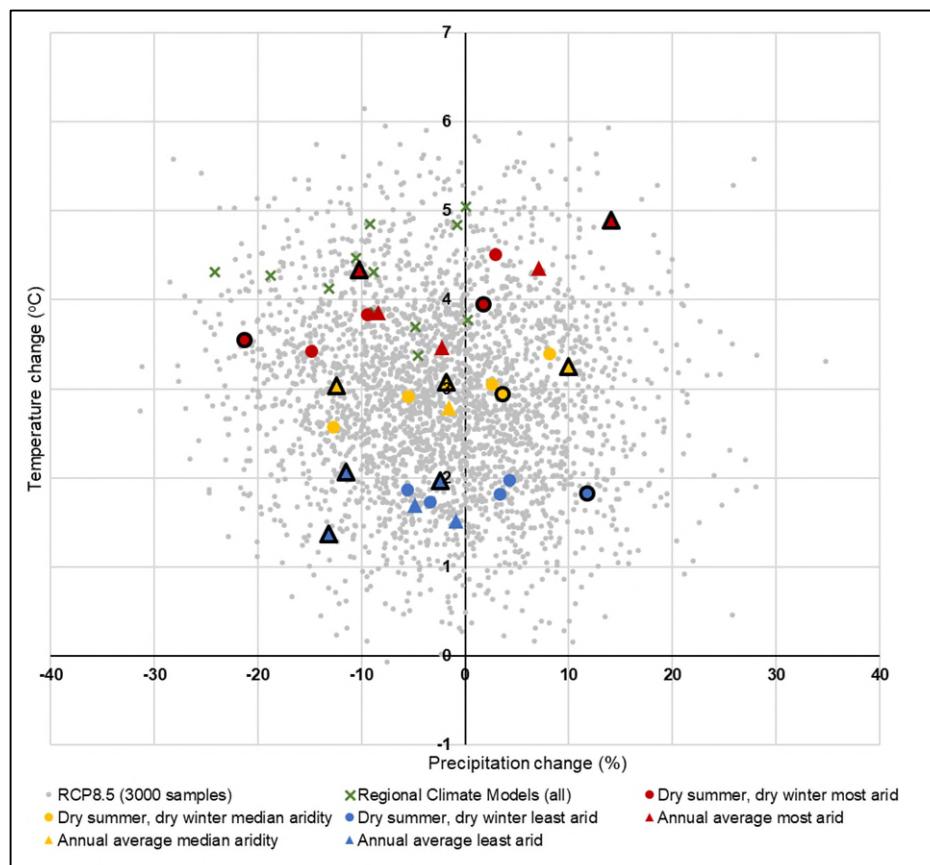


Figure 5-3 combines the sub-samples from each aridity duration. These have been reviewed to manually sample the sub-selection further and provide recommendations for 12 sub-samples to take through to hydrological and systems modelling to assess the impact of climate change on supply. Table 5-4 lists the recommended scenario

sub-sample and related precipitation and temperature changes. These are averaged over the sub-sampling duration so do not capture the monthly and seasonal profile that is important for water resources management.

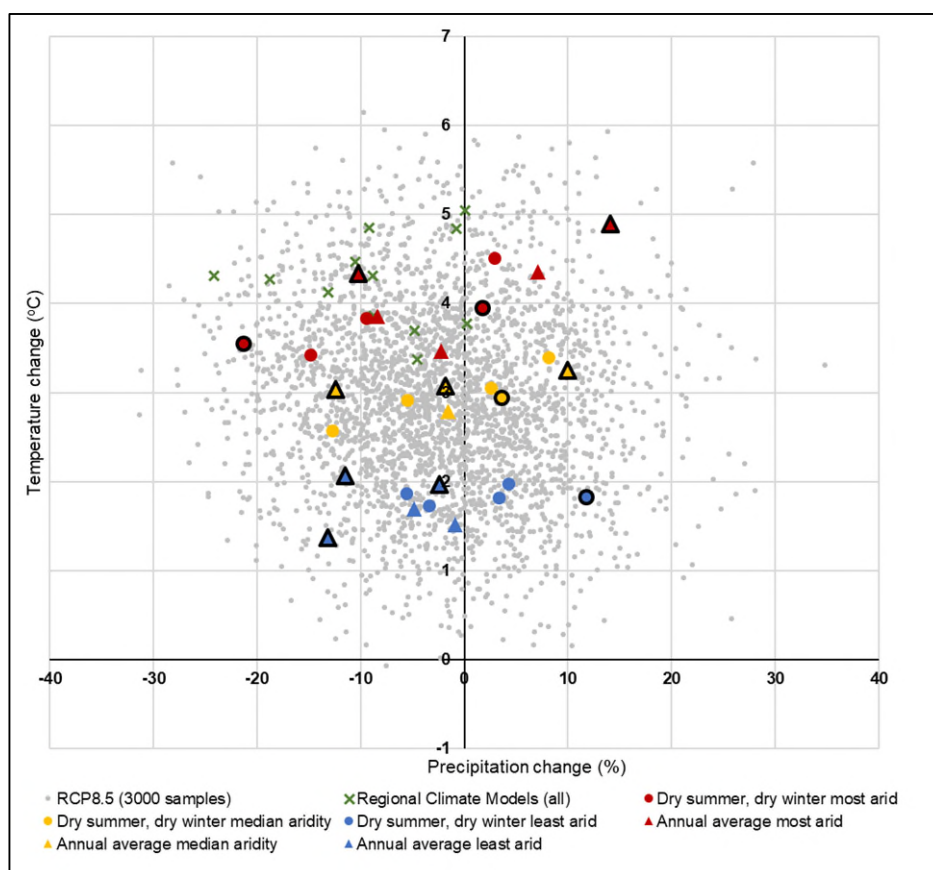


Figure 5-3 - Recommended sub-sample to assess impact of climate change on supply (shown with bold black outline).

Table 5-4 - Recommended sub-sample of UKCP18 probabilistic projections (RCP8.5)

	UKCP18 probabilistic ID	Temperature (°C)	Precipitation (%)
High aridity	594	3.6	-21
	749	4.3	-10
	1190	4.0	2
	2299	4.9	14
Median aridity	501	3.0	-12
	2182	3.2	10
	209	3.0	-2
	480	2.9	4
Low aridity	2995	1.4	-13
	1201	2.0	-2
	2380	1.8	12
	2302	2.1	-11

6. Impact of Climate Change on Supply

Both the historic and stochastic datasets will be used in the assessment of climate change impacts on deployable output. The monthly rainfall and temperature change factors will be applied to the baseline datasets for each of the

climate sub-sampled scenarios (shown in

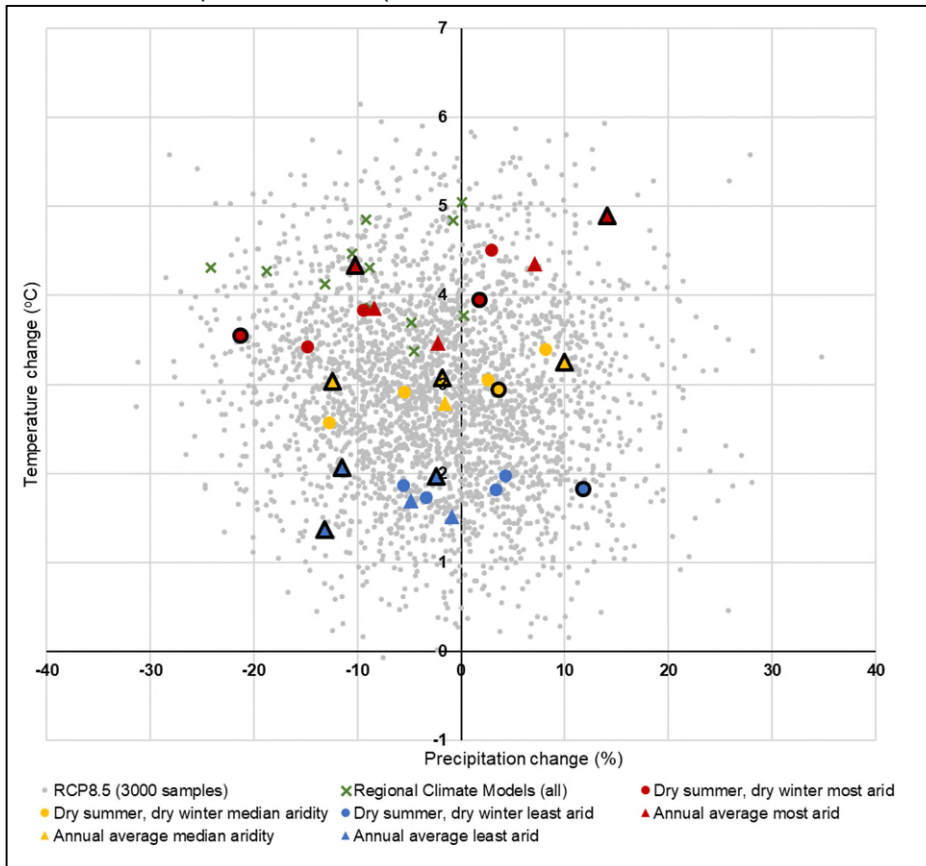


Figure 5-3) before generating climate perturbed historic and stochastic flows and assessing the change in deployable output in Pywr.

The impact on deployable output will be assessed for the 2070s and then the impacts scaled back to provide an annual profile of the impacts of climate change over the planning period. The profile of impact on deployable output throughout the planning period can be influenced by the type of scaling undertaken i.e. linear or non-linear time-based approach. The choice of approach will influence the time at which the climate change impacts influence Jersey Water's plan. Once the deployable output assessments are available, we can trial both a linear and non-linear time-based scaling approach to inform Jersey Water's selection of preferred scaling methodology.

7. Impact of Climate Change on Demand

Jersey Water's current demand model uses demand and climate change relationships that were derived by the UKWIR 2013 study¹⁴. This is still the most up to date study on climate change and demand and is widely used by water companies in England and Wales. We recommend that Jersey Water continues to use the relationships derived by the UKWIR 2013 study however currently the demand model only models a single climate change percentile. Instead, as demand is largely temperature driven, we will look to update this and sample a high, medium and low percentile from UKWIR 2013, that can be mapped to the temperatures sampled and modelled on the supply-side (e.g. the 2, 3 and 4 degree samples).

¹⁴ UKWIR, 2013. IMPACT OF CLIMATE CHANGE ON WATER DEMAND, Report Ref No. 13/CL/04/12

