A83 Rest and Be Thankful

LTS EIAR VOLUME 4, APPENDIX 17.3 - CLIMATE VULNERABILITY BASELINE

Transport Scotland

A83AAB-AWJ-EAC-LTS_GEN-RP-LE-000380

A17-3. Baseline Conditions

A17-3.1. Study Area Context

A17-3.1.1. The climate change vulnerability baseline for the study area, which is defined in Volume 2, Chapter 17 Climate Vulnerability, Section 17.2, is presented in two parts:

- the first describes the current climatic conditions in the study area and
- the second presents a range of possible future climate projections in the study area.

A17-3.1.2. It should be noted that climate change is not only a challenge for the future. The UK is already observing changes in its climate.

A17-3.2. Current Climate Baseline

A17-3.2.1. The Proposed Scheme is situated within the Argyll River Basin. To inform adaptation decisions this section presents data from the Meteorological Office (Met Office) to summarise the Argyll River Basin current climate. The Met Office's UK Climate Averages are used, they show the latest set of 30-year averages covering the period 1981-2010. Context to this is provided by including comparison to the equivalent national result (UK minimum, average and maximum temperatures).

A17-3.2.2. To support the above average regional data a local dataset has also been collected from the closest long running climate station to the Proposed Scheme. The closest climate station is located at Dunstaffnage (188100E 734000N – approximately 25 miles northwest of the Proposed Scheme) and has been recording observations since 1972.

Current temperature

A17-3.2.3. The climate in the Argyll River Basin is one of relatively mild winters and warm summers. As shown in Plate 17-3-1 and Plate 17-3-2, monthly average and mean maximum temperatures are between the UK average and minimum.

Across the timeseries, 1981-2010, peak summer (July) average maximum temperatures of 13.1 °C in the Argyll River Basin are below the average, but slightly above the minimum (12.7 °C) across the UK. Note that mean maximum temperatures are calculated as the monthly average of daily maximums – as such some individual days are likely to have recorded hotter temperatures than those stated.

Plate 17-3-1 - Long-term average monthly mean temperature (°C) (1981-2010)

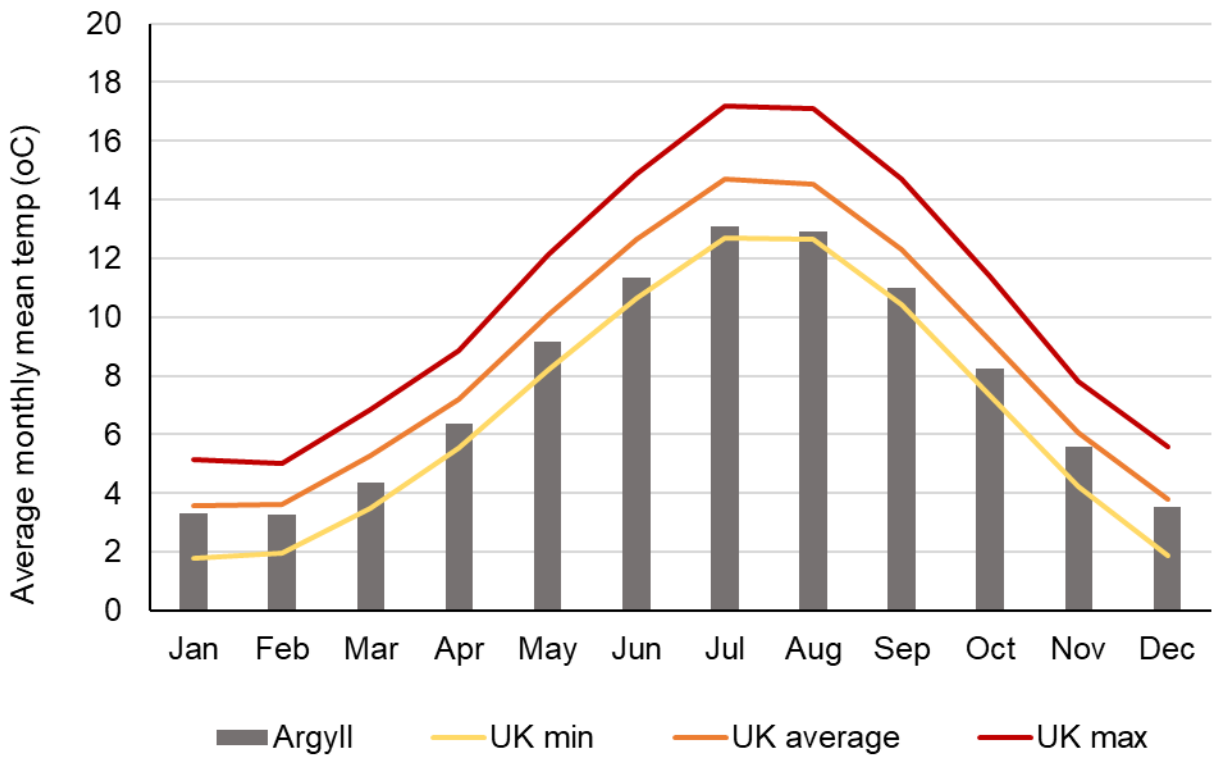
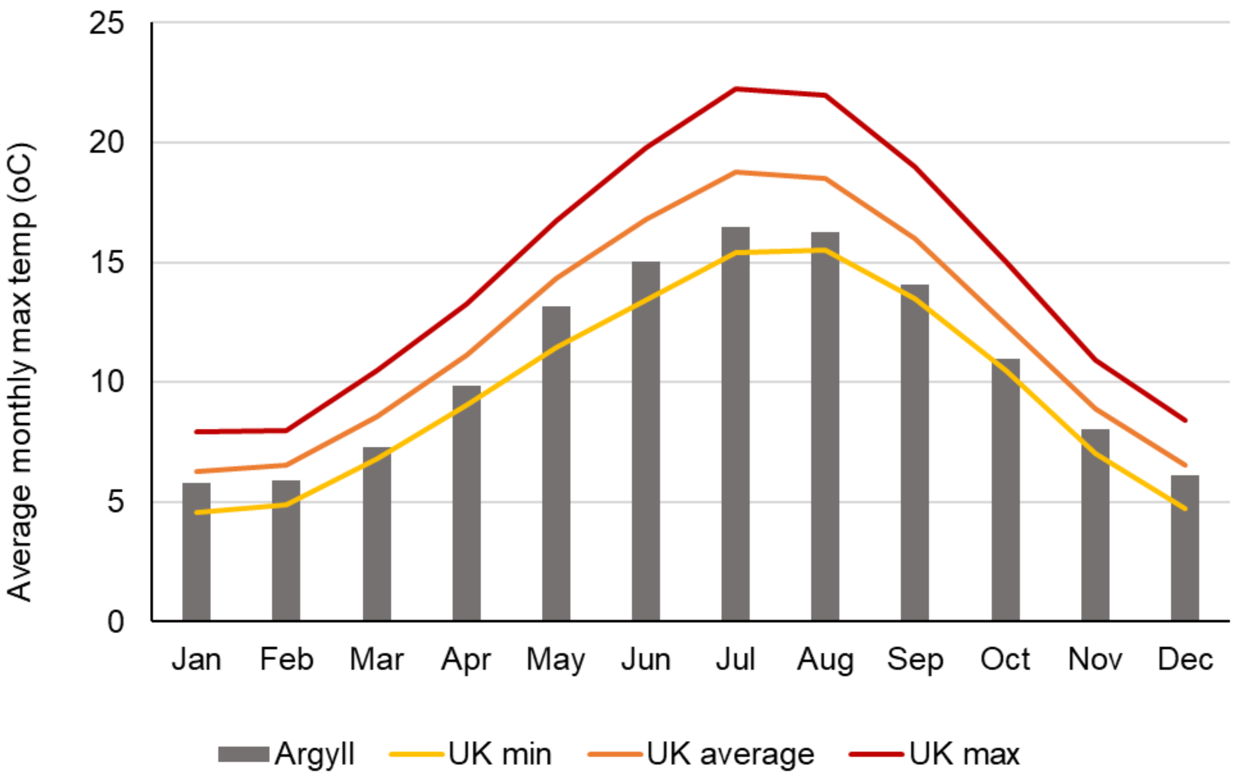


Plate 17-3-2 - Long-term average monthly maximum temperature (°C) (1981-2010)

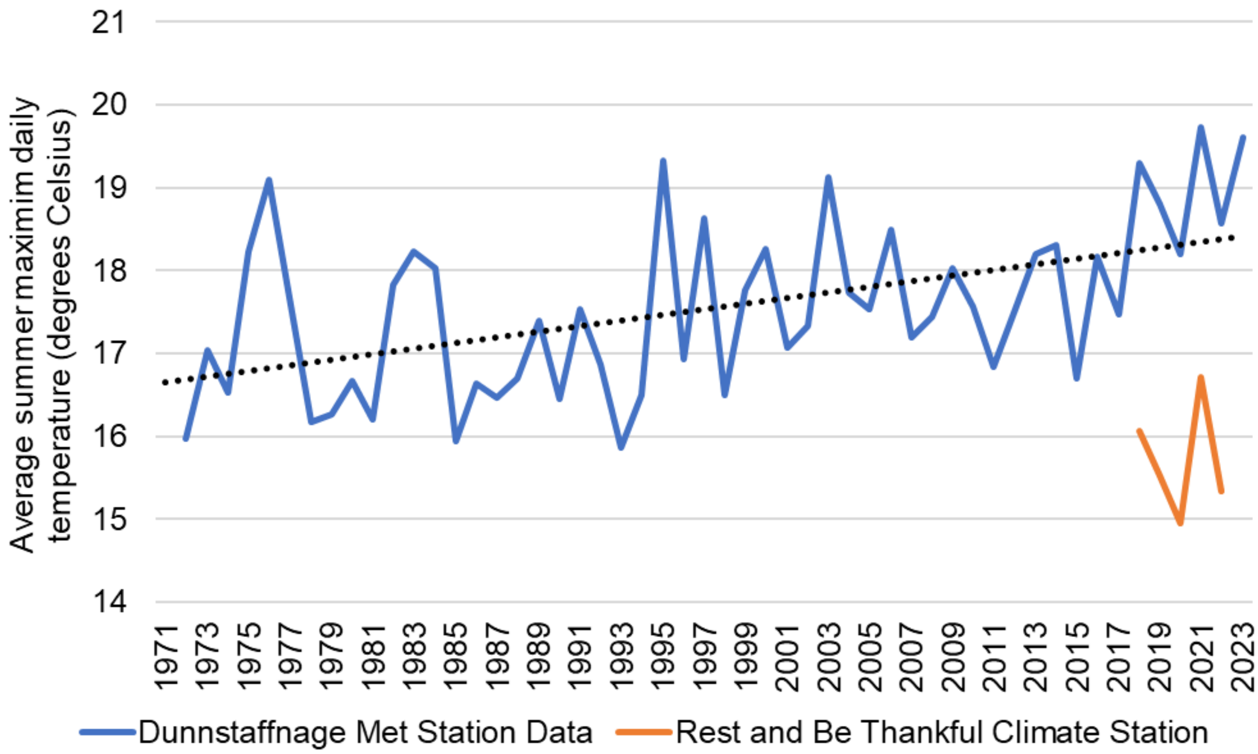


Note: the maximum data presented is a monthly average of daily maximums.

A17-3.2.4. Observations for the UK show that the decade leading up to the publication of UKCP18 (2008-2017) was on average 0.3°C warmer than the 1981-2010 average and 0.8°C warmer than 1961-1990. All of the top ten warmest years have occurred since 2002.

A17-3.2.5. The summer of 1976 was one of the hottest recorded in the UK and this is reflected in the temperature record at the Dunstaffnage climate station (Plate 17-3-3). It was one of the driest, sunniest and warmest summers (June/July/August) in the 20th century. 2022 is the joint (with 2018) hottest summer on record. While a 2022 peak doesn't stand out for the Dunstaffnage climate station, 2018 is reflected in the temperature record showing an average summer maximum daily temperature of 19.3°C. The highest peak is recorded in 2021 where an average summer maximum daily temperature was 19.7°C, closely followed by 2023 at 19.6°C – the final two peak shown on Plate 17-3-3. Temperature data from the more local Rest and Be Thankful climate station suggest similar patterns to the Dunstaffnage climate station, although at approximately 3°C cooler (Plate 17-3-3 and Plate 17-3-4). It is noted that the Dunstaffnage climate station is 3m above Average Mean Sea Level (AMSL), by comparison the Rest and Be Thankful car park is approximately 275m AMSL and only started recording in recent years (2018).

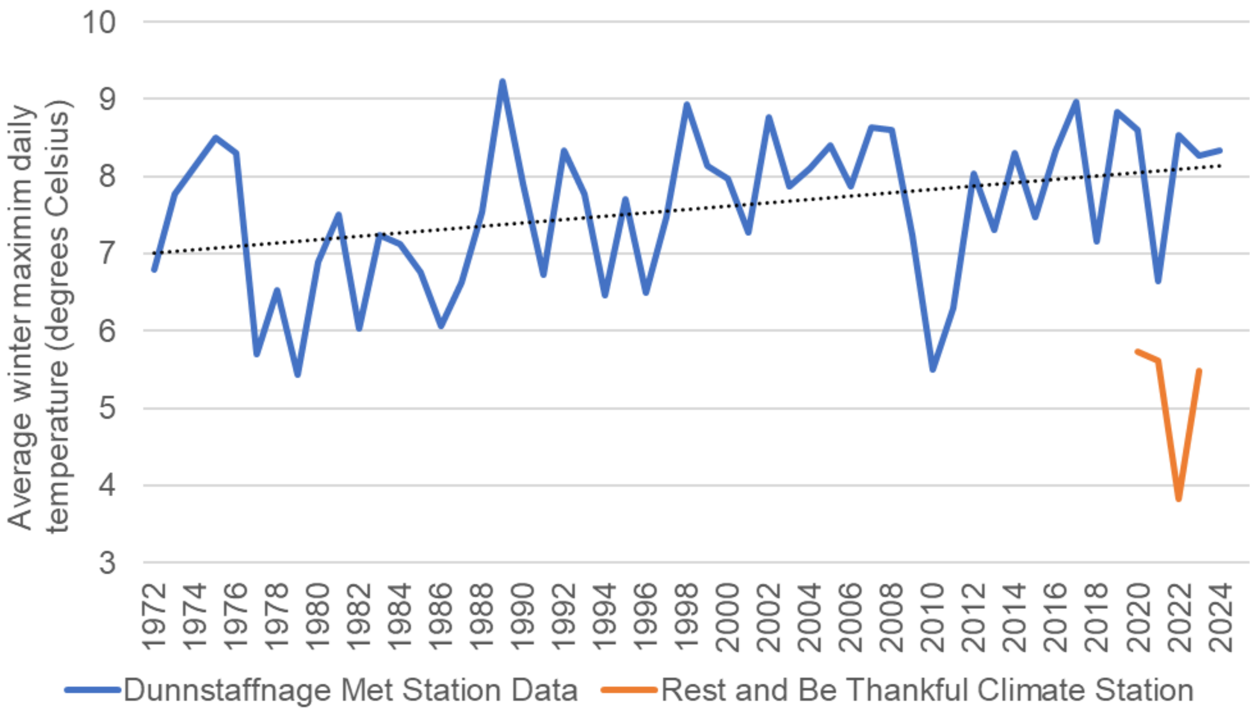
Plate 17-3-3 - Average summer maximum daily temperature for the closest historic climate station (Dunstaffnage) and local climate station (Rest and Be Thankful).



A17-3.2.6. Observation from the Dunstaffnage climate station reveal that seven of the 10 highest monthly mean daily maximum temperatures (t-max) it has recorded have been since 2006.

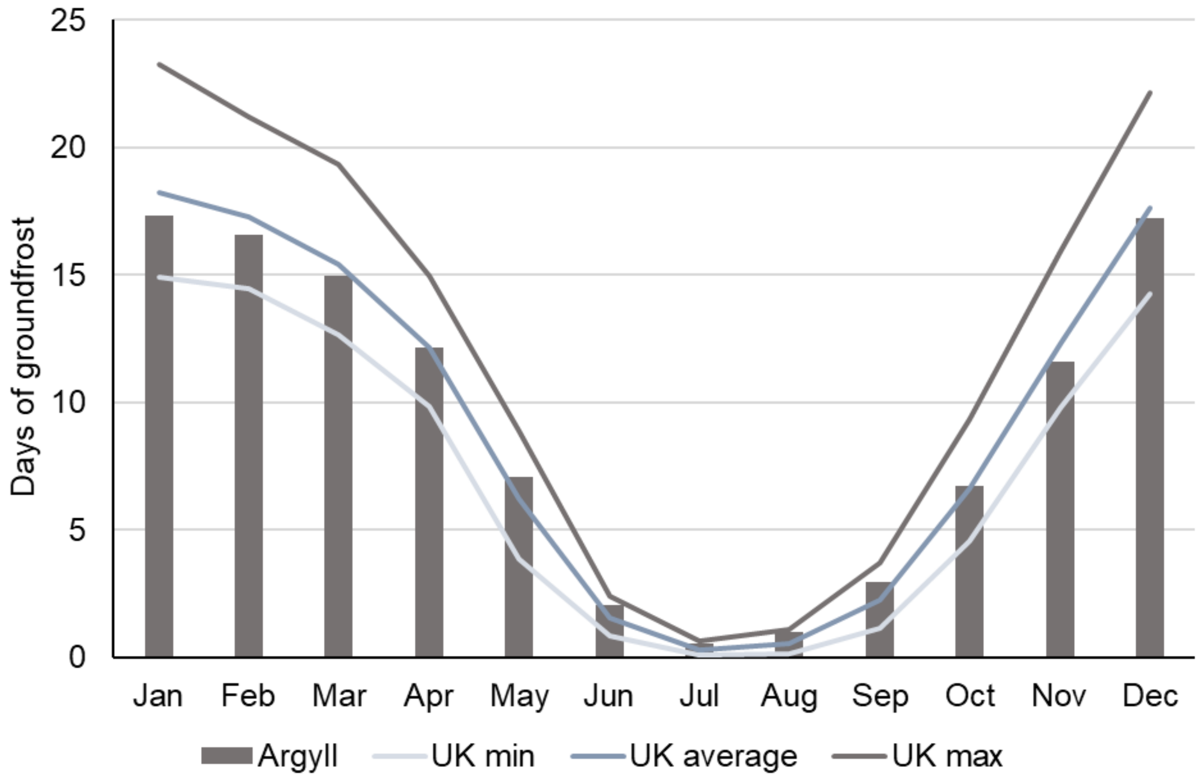
A17-3.2.7. The data from the Dunstaffnage met station also shows that over the period 1930 to 2022 both the average daily summer maximum temperatures and average daily winter maximum temperatures have been increasing (conclusion based on linear trendlines on Plate 17-3-3 and Plate 17-3-4).

Plate 17-3-4 - Average winter maximum daily temperature for the closest historic climate station (Dunstaffnage) and local climate station (Rest and Be Thankful).



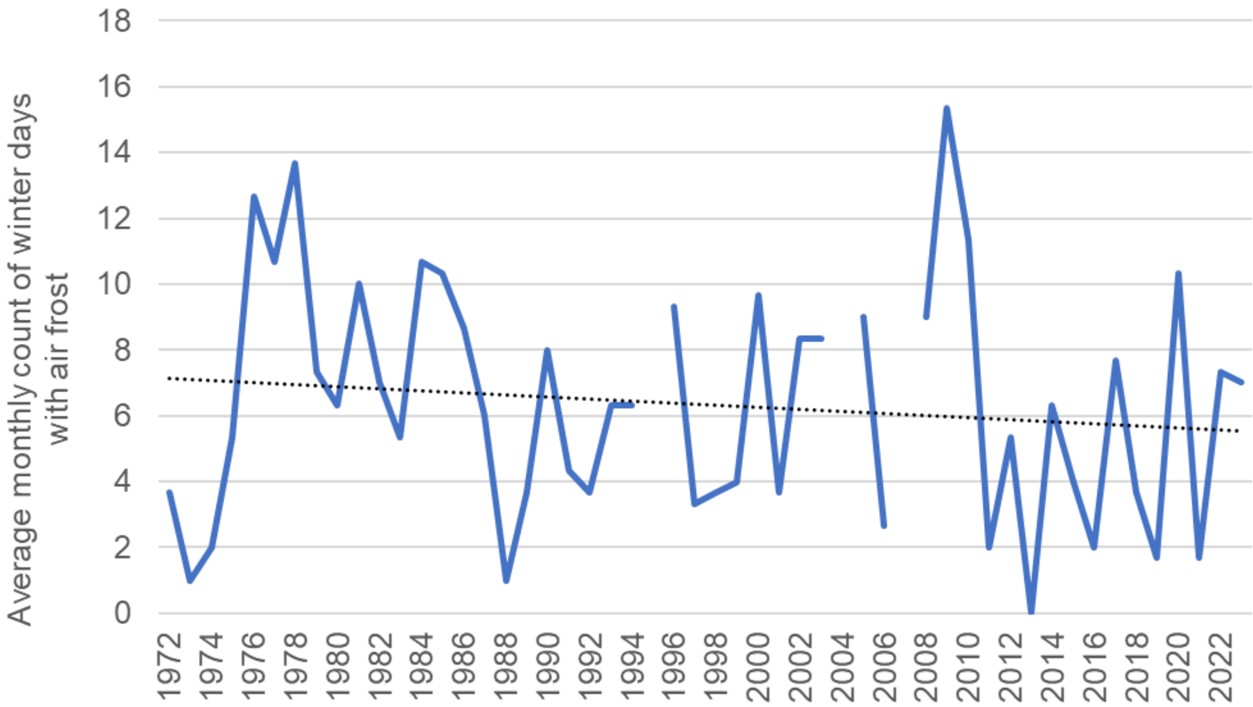
A17-3.2.8. As shown in Plate 17-3-5 the long-term average days with ground frost (1981-2010) in the Argyll River Basin are similar to the UK average.

Plate 17-3-5 - Long-term average days with ground frost (1981-2010)



A17-3.2.9. In accordance with the observed increasing winter temperatures (Refer to Plate 17-3-4), the linear trendline on Plate 17-3-6 shows that at the nearest long running climate station, the number of days with air frost each winter has been reducing since 1972.

Plate 17-3-6 – Average count of winter days with air frost at the Dunstaffnage climate station.

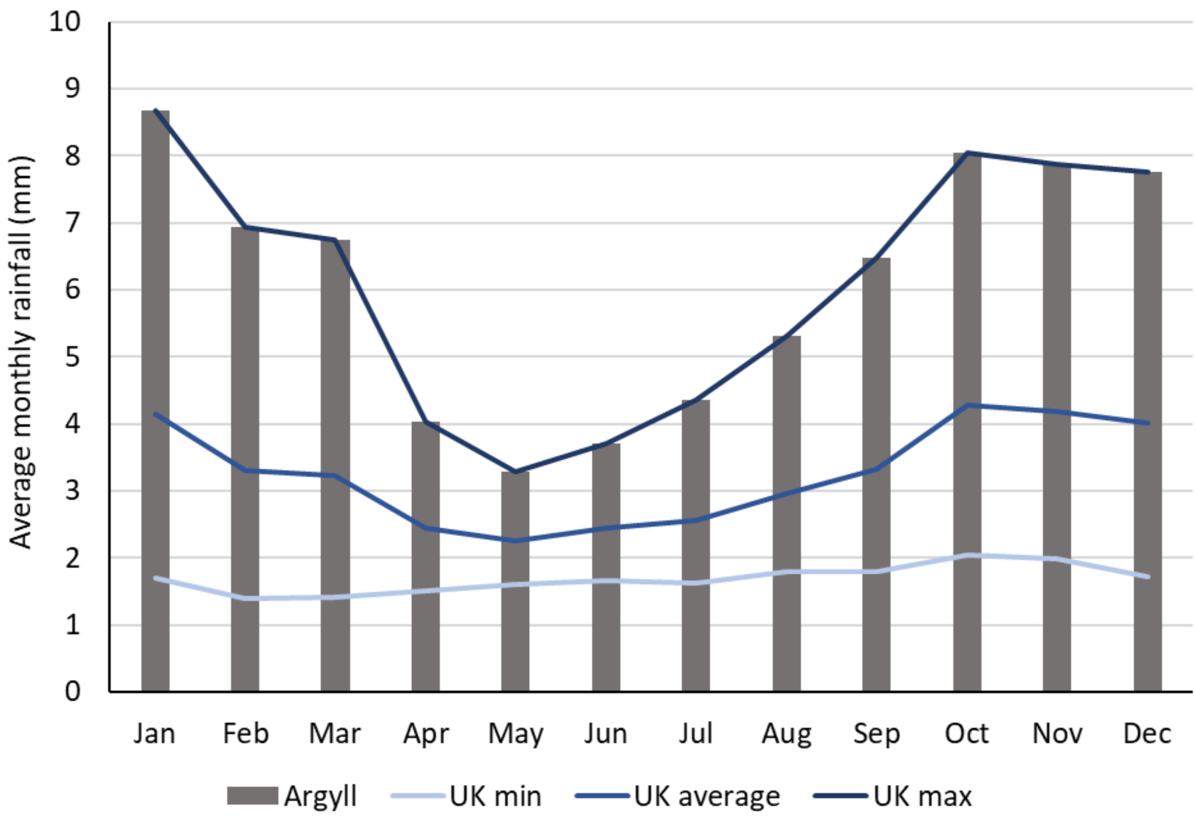


Current Precipitation

A17-3.2.10. Observations across the UK show a high level of variability in precipitation from year to year, with a slight overall increase in UK winter precipitation in recent decades.

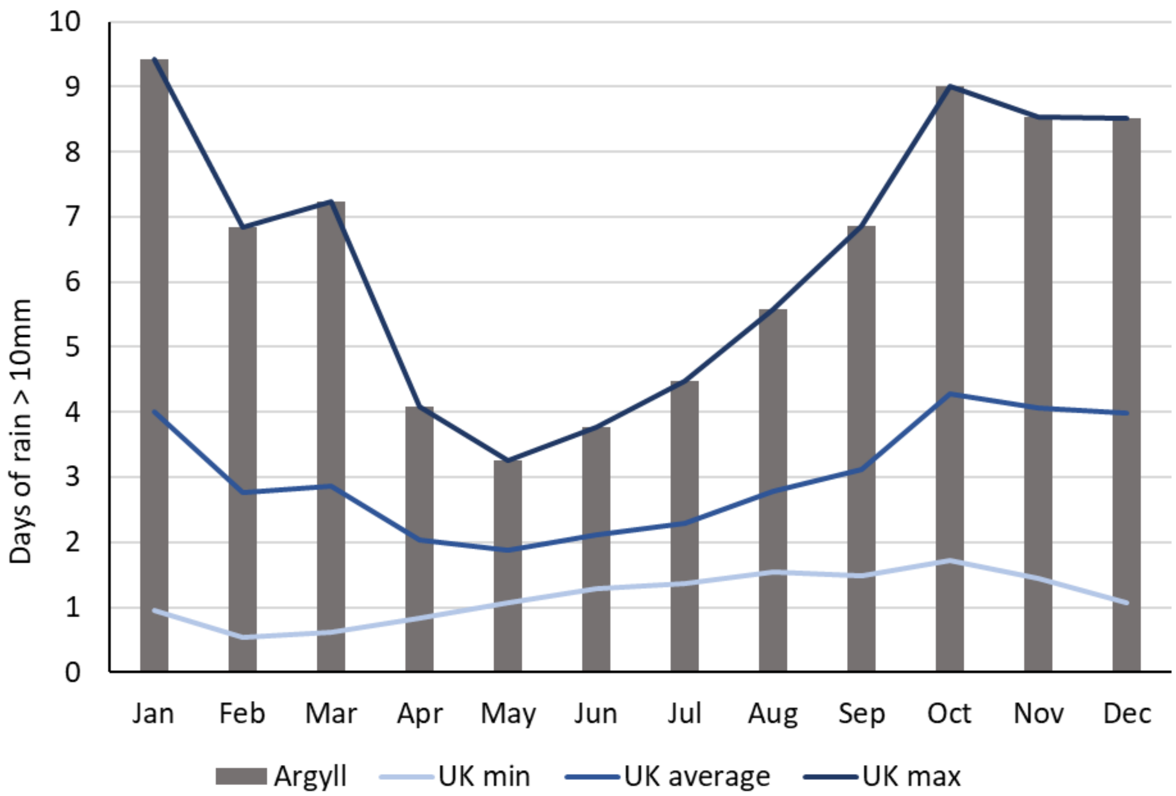
A17-3.2.11. As shown in Plate 17-3-7, long-term average daily rainfall for each month (1981-2010) in the Argyll River Basin is in line with the maximum for the UK.

Plate 17-3-7 - Long-term average daily rainfall for each month (1981-2010)



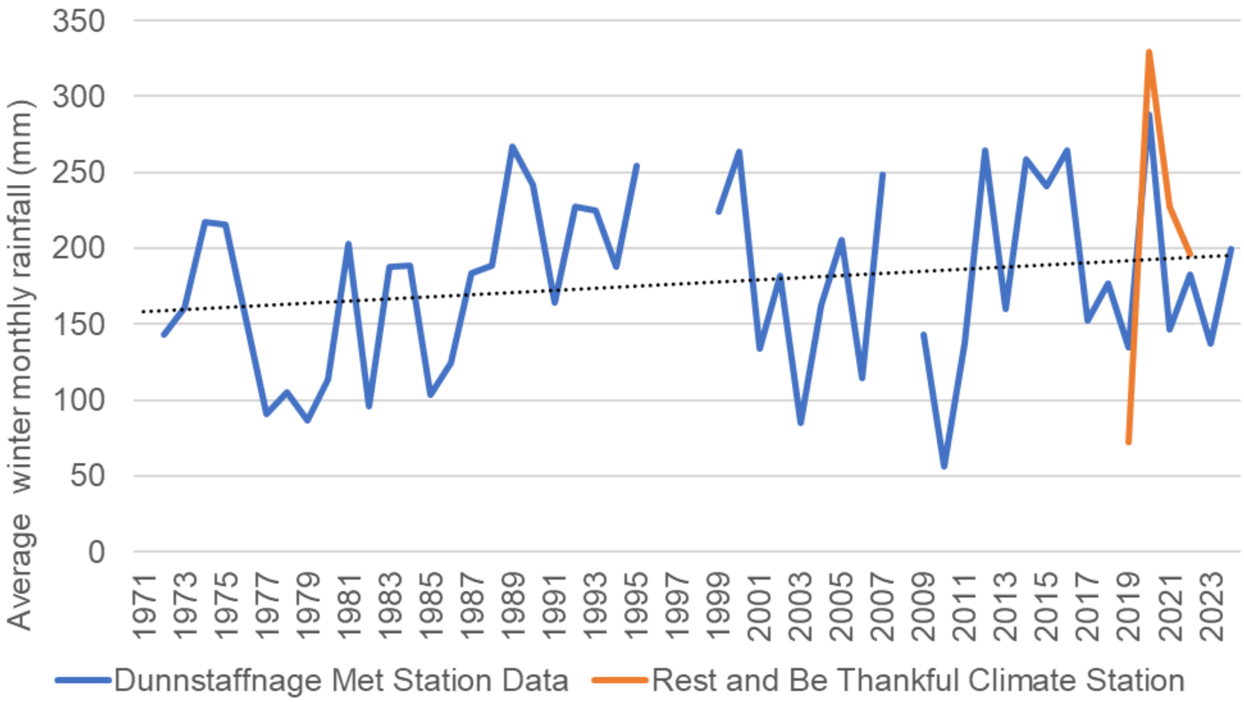
A17-3.2.12. Plate 17-3-8 shows the long-term average number of days that had rainfall over 10mm. It shows that the Argyll River Basin experiences the maximum heavy rainfall days for the UK.

Plate 17-3-8 - Long-term average days with rainfall above 10mm (1981-2010)



A17-3.2.13. Data from the Dunstaffnage climate station shows winter to have variable precipitation and that rainfall has been increasing since 1971 (conclusion based on it of linear trendline on Plate 17-9). The four years of available data at the Rest and Be Thankful climate station also shows variable precipitation, with similar patterns to that observed at Dunstaffnage.

Plate 17-3-9 - Average winter monthly rainfall for the closest historic climate station (Dunstaffnage) and local climate station (Rest and Be Thankful).



Extreme weather events

A17-3.2.14. Across the UK, the amount of rain from extremely wet days has increased by 17% when comparing the period 2008-2017 to 1961-1990 period (Met Office, 2018). These changes are largest for Scotland and less significant for England. Other extreme rainfall indices exhibit large inter-annual variability but are broadly consistent with increased rainfall over the UK.

A17-3.2.15. In the study area, impacts from extreme weather have been recorded. Winter *et al.*, (2019) discusses the economic impacts of landslides and floods on a road network using the A83 as a case study. It highlights the regular occurrence of landslide events associated with monthly average rainfall substantially in excess of the average in Scotland. The section of the A83 within the Proposed Scheme boundary through Glen Croe is identified as being extremely active in recent years with multiple debris flow events and road associated closures. Between 2007 and 2019, nine of those years had at least one event that had an adverse effect on the travelling public.

A17-3.2.16. Regular monitoring and risk reviews from BEAR Scotland have also shown the relationship between excessive rainfall and landslide occurrence. Alert Levels are applied to trigger management actions across section of the A83 within the Proposed Scheme boundary to manage the risk. The levels are linked to predicted rainfall and saturation of the hillside. Between 2018 and early 2023, the slope failures that resulted in debris reaching the road ranged from Alert Levels 3 to 6 (where six is the highest risk). All these events were >15mm daily rainfall, with four of the six being >35mm daily rainfall.

A17-3.2.17. Recent examples of extreme weather impacting road users include:

- In November 2020, the A83(T) had barely been open for three weeks since early August 2020 due to the occurrence of major landslides, when another landslide brought about by rain blocked the road. It left motorists with a 60 mile diversion as the single track alternative route (the Old Military Road) was also closed that evening due to heavy rain forecasted and associated landslide risks.
- In October 2023, a month's worth of rainfall (approximately 160mm) was observed over 36 hours. As a result, BEAR Scotland reported seven landslides occurred requiring approximately 12,000 tonnes of mud and rock to be removed from the A83(T) Rest and Be Thankful. The road was closed on 7 October 2023 and reopened on 11 October 2023 and 10 people had to be airlifted from their vehicles.
- For this year, up to June 2024, the A83(T) has been diverted due to landslide risk on three occasions.

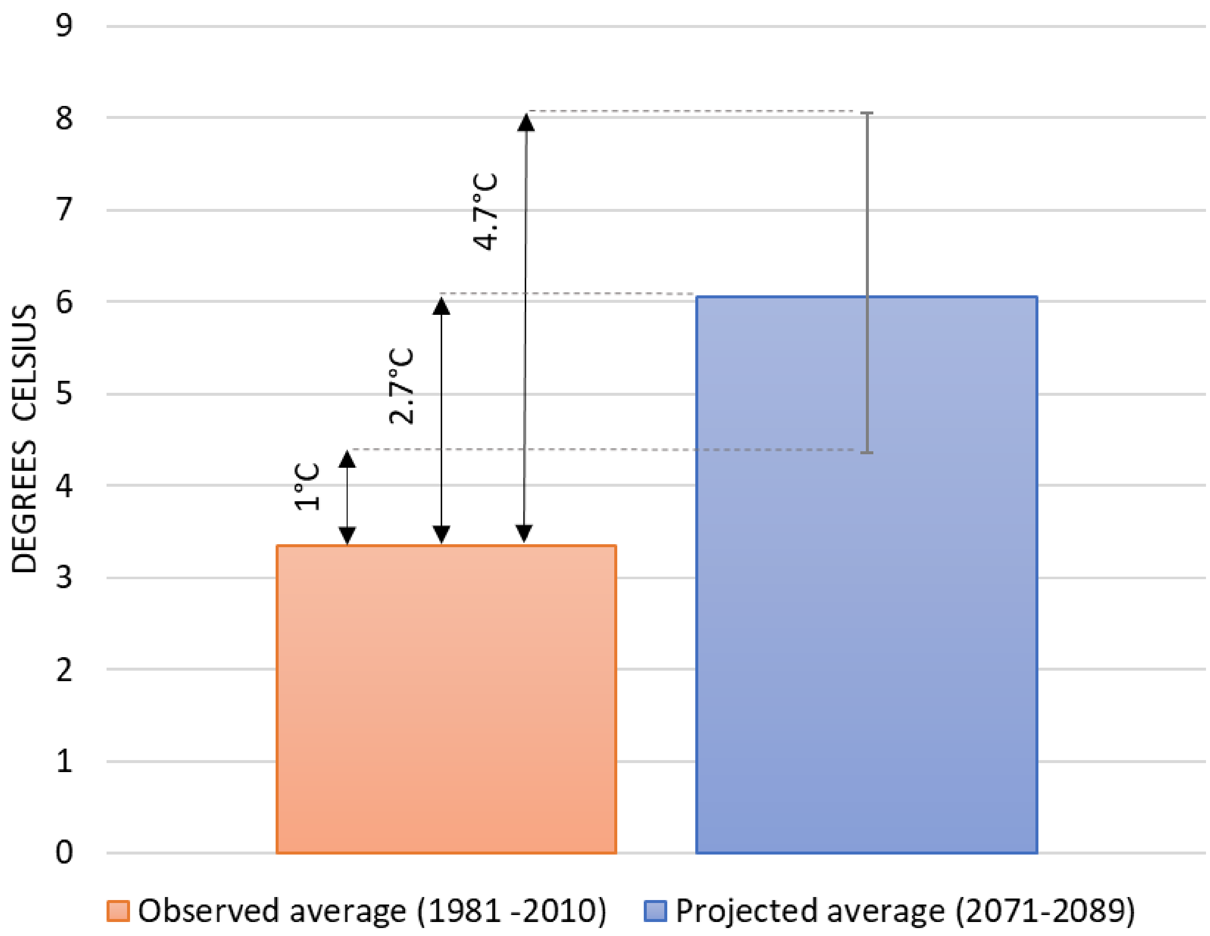
A17-3.2.18. With regard to storminess, across the UK historical data provides no compelling trends as determined by maximum gust speeds from the UK wind network over the last four decades (UKCP18).

A17-3.3. Future Climate Projections

Temperature projections – warmer winters

A17-3.3.1. Plate 17-3-10 shows that under Representative Concentration Pathway 8.5 (RCP8.5) (described in Volume 2, Chapter 17: Climate Vulnerability, Section 17.2) average winter temperatures in the Argyll River Basin are expected to increase from 3.4ºC (observed average 1981-2010) to 6.1ºC (projected average 2071-2089), an increase of 2.7ºC (based on the central estimate, i.e. 50th percentile). The uncertainty around this estimate of change ranges from 1.0ºC to 4.7ºC (represented by the 10th and 90th percentiles respectively).

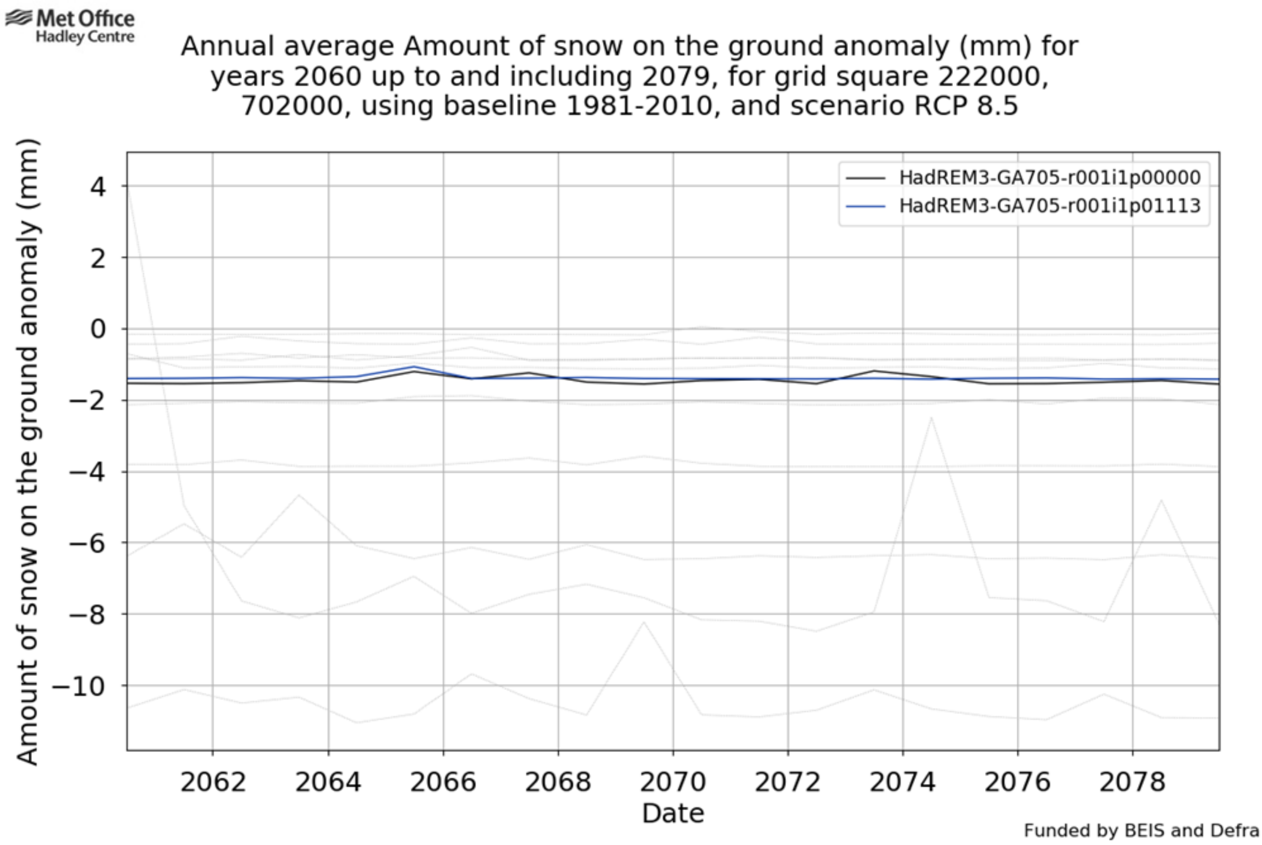
Plate 17-3-10 - Projected average mean winter temperatures (2071-2089)



NB: The projected data is probabilistic. It shows the central estimate (50th percentile) with error bars that indicate the 10th & 90th percentiles.

A17-3.3.2. In the UK, the heaviest snowfalls tend to occur when the air temperature is between zero and 2°C . The projected increase in winter temperatures is therefore expected to reduce mean snowfall, number of snow days and heavy snow events. While there is less certainty in the magnitude of these changes, there is confidence in the negative direction of the change . This is supported by the fact that the decade leading up to the publication of UKCP18 (2008-2017) had 5% fewer days of air frost and 9% fewer days of ground frost compared to the 1981-2010 average, and 15% and 14% respectively compared to 1961-1990. Plate 17-3-11 shows a plume plot containing regional results (12km resolution) of RCP 8.5 projections for surface snow amount anomaly (mm), the middle model projections are highlighted. Only one of the twelve model outputs presented show positive values; and it is only within one year of the twenty-year time period presented. For the period 2060-2079, under a high emissions scenario (RCP8.5), the Regional (12km) and Local (2.2km) projections show a decrease in both falling and lying snow across the UK relative to the 1981-2000 baseline.

Plate 17-3-11 - Annual average amount of snow on the ground anomaly (mm) for years 2060 up to and including 2079 for the 12km grid square containing the Proposed Scheme (222000, 702000)

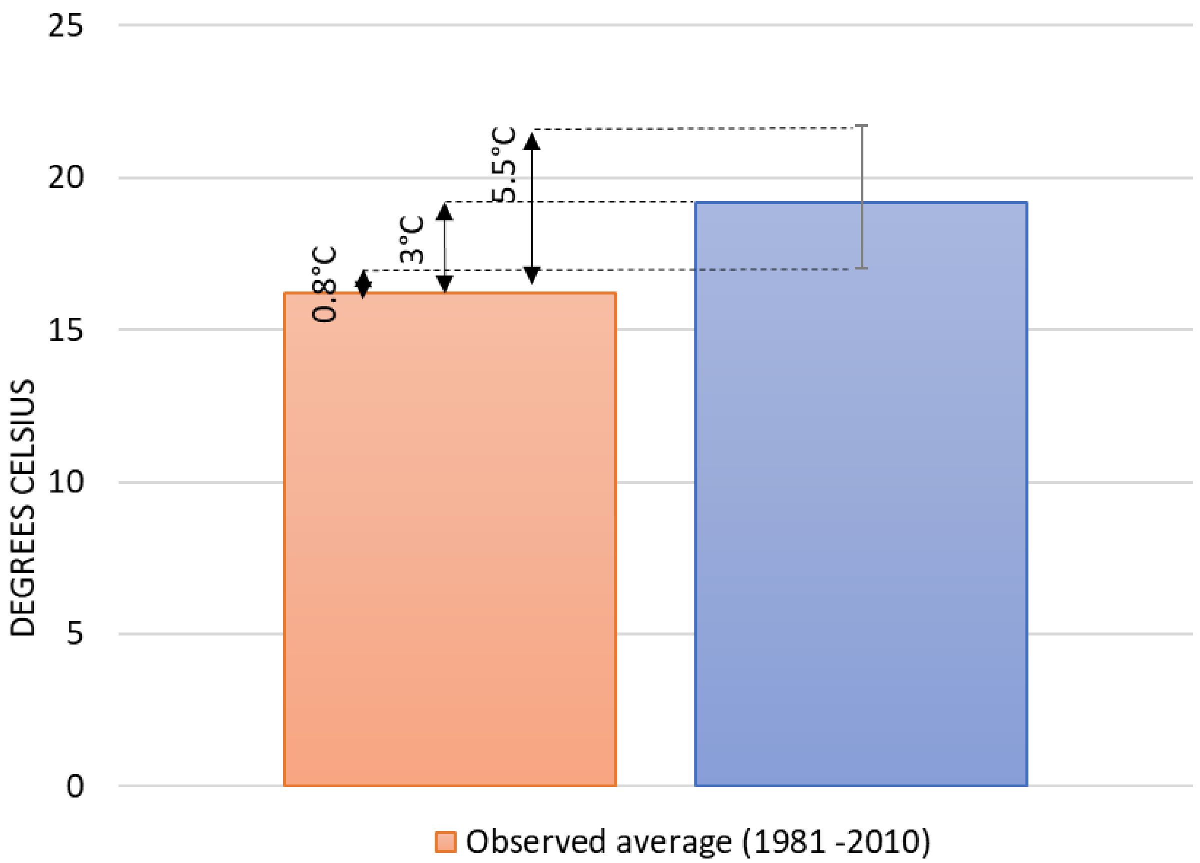


Temperature projections - hotter summers

A17-3.3.3. In the recent past (1981-2000) the probability of seeing a summer as hot as 2018 in the UK was low (<10%). This probability has already increased due to climate change and is now estimated to be between 10-25%. With future warming, hot summers by the mid-century could become even more common (with probabilities of the order of 50% depending on the emissions scenario followed). The warmest summer recorded in Scotland was in 2003 (average 14.07 °C) and the coolest was in 1922 (average 10.64 °C).

A17-3.3.4. In the Argyll River Basin, within which the Proposed Scheme is located, projected mean daily maximum summer temperatures have been obtained from the UKCP18 probabilistic projections for 2071-89. Since these are an average of summer daily maximum temperatures it should be noted that some days in this period are likely to be hotter than the values indicated below. Plate 17-3-12 shows that an increase in summer temperatures is expected by the 2080s under RCP8.5. The central estimate (i.e. 50th percentile) projects an increase of 3ºC in summer mean daily maximum temperatures by 2071-89.

Plate 17-3-12 - Projected average maximum summer temperature (2071-2089)

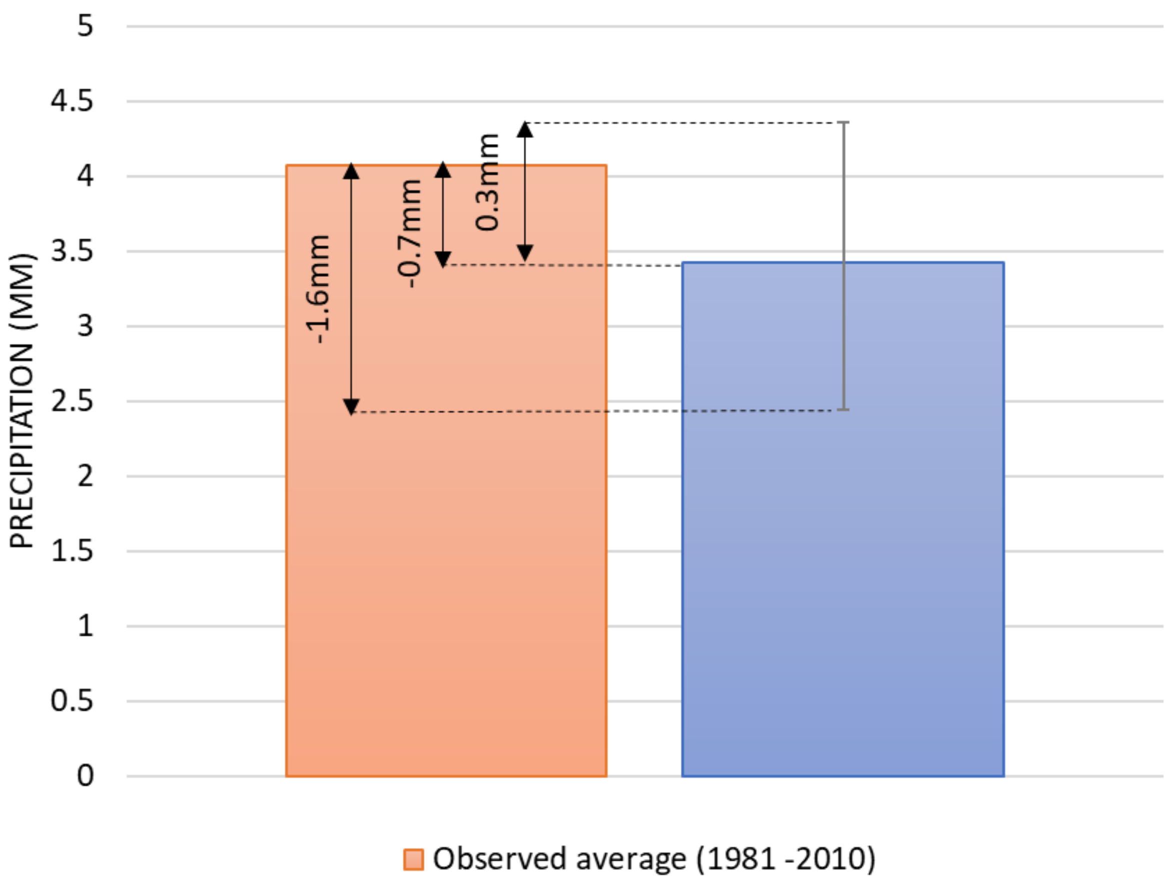


NB: The projected data is probabilistic. It shows the central estimate (50th percentile) with error bars that indicate the 10th & 90th percentiles

Precipitation projections - drier summers

A17-3.3.5. Projected precipitation levels for RCP 8.5 have been averaged across the Argyll River basin, within which the Proposed Scheme is located, to give a range of projected average rainfall change between the 10% and 90% probability levels. As shown in Plate 17-3-13, by 2071-89 this range falls between a +0.3mm to -1.6mm change to rainfall. The central estimate of change (i.e. 50th percentile) in mean summer precipitation for the same period is a 0.7mm (16%) reduction. These projections suggest that future average rainfall trends are uncertain, but it is more likely than not that summer rainfall will decrease.

Plate 17-3-13 - Projected average summer precipitation (2071-2089)

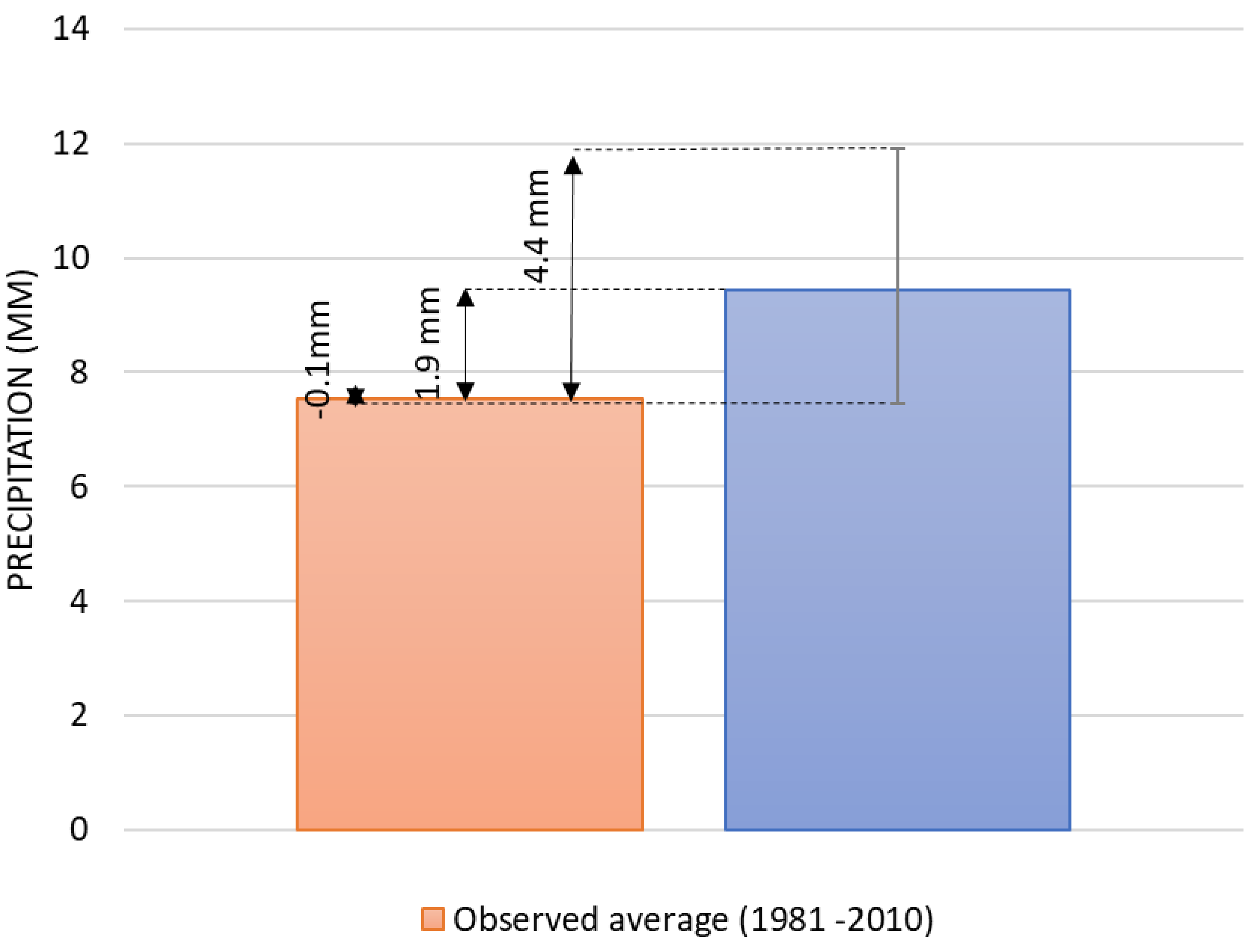


NB: The projected data is probabilistic. It shows the central estimate (50th percentile) with error bars that indicate the 10th & 90th percentiles

Precipitation projections - heavier rainfall and wetter winters

A17-3.3.6. Plate 17-3-14 shows that UKCP18 climate projections forecast that by 2071-89, under RCP 8.5 central estimate (i.e. 50th percentile), winter mean precipitation will increase by 1.9mm (over 661%). This aligns with the UK wide trend in UKCP18 data that points to an increase in frequency and intensity of rainfall. However, the variation in rainfall from year to year is still large and levels are expected to continue to vary widely.

Plate 17-3-14 - Projected average winter precipitation (2071-2089)

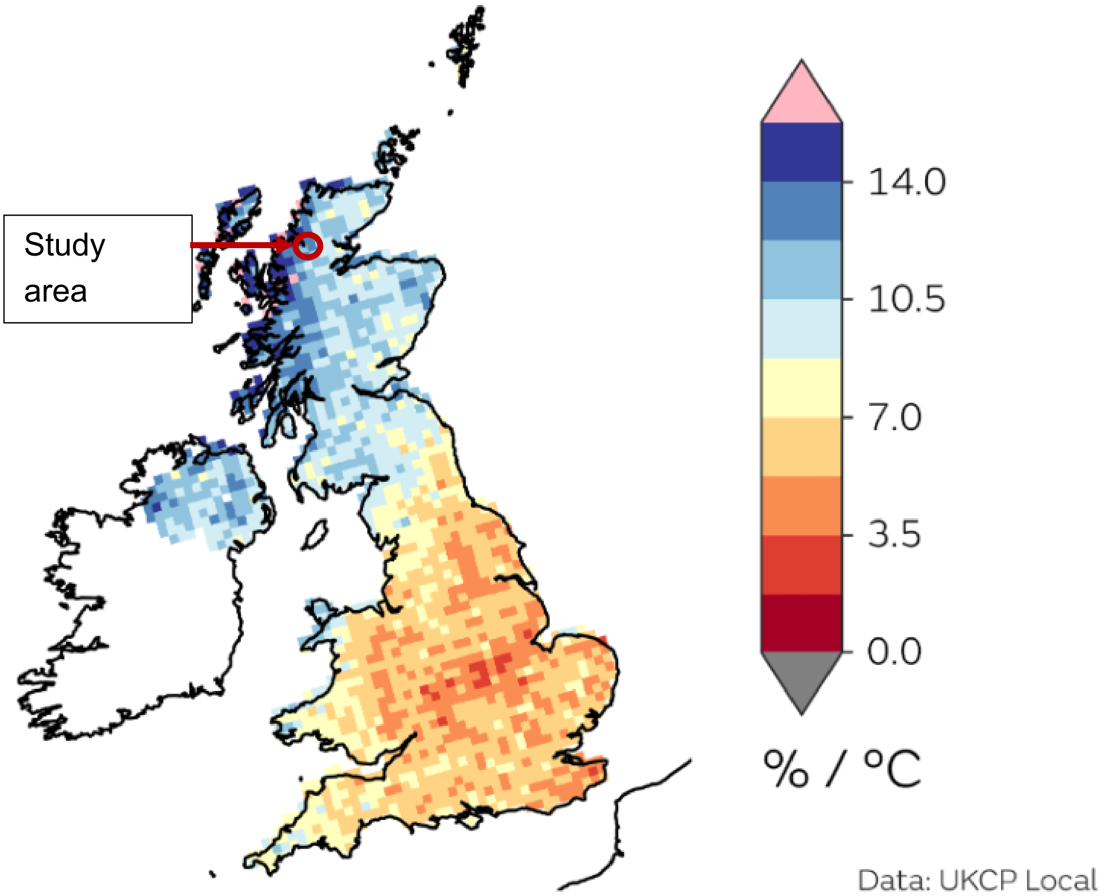


NB: The projected data is probabilistic. It shows the central estimate (50th percentile) with error bars that indicate the 10th & 90th percentiles

Extreme weather projections

A17-3.3.7. Under RCP 8.5, extreme rainfall events (exceeding 20mm/hr) in the UK could be four times as frequent by 2080 compared to the 1980s. When looking regionally, future changes in extreme rainfall events could be almost 10 times more frequent in Northwest Scotland in 2080 compared to the 1980s, whilst in the south of the UK the value is closer to three times more frequent (Plate 17-3-15). Despite the underlying projected trend, the number of events per year is projected to remain erratic (much like the observational record). This could mean that clusters of record-breaking intense rainfall events could be observed, followed by a prolonged period when no records are broken.

Plate 17-3-15 - Underlying change in intensity of extreme hourly precipitation for every degree of warming



A17-3.3.8. Since precipitation is a key driver for causing landslides, it is unsurprising that climate change, in areas with predicted increases in rainfall intensity, is expected to increase landslide activity. While there are uncertainties in the geographical and temporal details of climate projections, especially for extreme weather events, the study area is expected to see more intense rainfall (as discussed above). As a result, the number of landslide incidents in the study area is likely to increase. This finding is supported by a number of research studies.

A17-3.3.9. Future projections of storms and high winds are uncertain. They depict a wide spread of future changes in mean surface wind speed, refer to Plate 17-3-16 which shows UKCP18 data specific to the 12km grid square within which the Proposed Scheme is located. This uncertainty is partly due to large uncertainty in projected changes in circulation over the UK, and also because of wide ranging natural climate variability. It is therefore difficult to represent extreme winds and gusts within regional climate models. Global projections show an increase in near surface wind speeds over the UK for the second half of the 21st century for the winter season. These studies suggest that climate-driven storm changes are less distinct in the Northern than Southern hemisphere. There is some agreement of a projected poleward shift in storm tracks across the Atlantic Ocean. However, for mid-Atlantic storms, such as those that affected the UK in early 2014, projections are less certain. The wide range of inter-model variation (as shown in Plate 17-3-16), shows that robust projections of changes in storm tracks over the UK are not yet possible, and there is low confidence in the direction of future changes in the frequency, duration or intensity of storms affecting the UK.

Plate 17-3-16 - Projected seasonal average wind speed anomaly (1980-2079)