A1 Birtley to Coal House

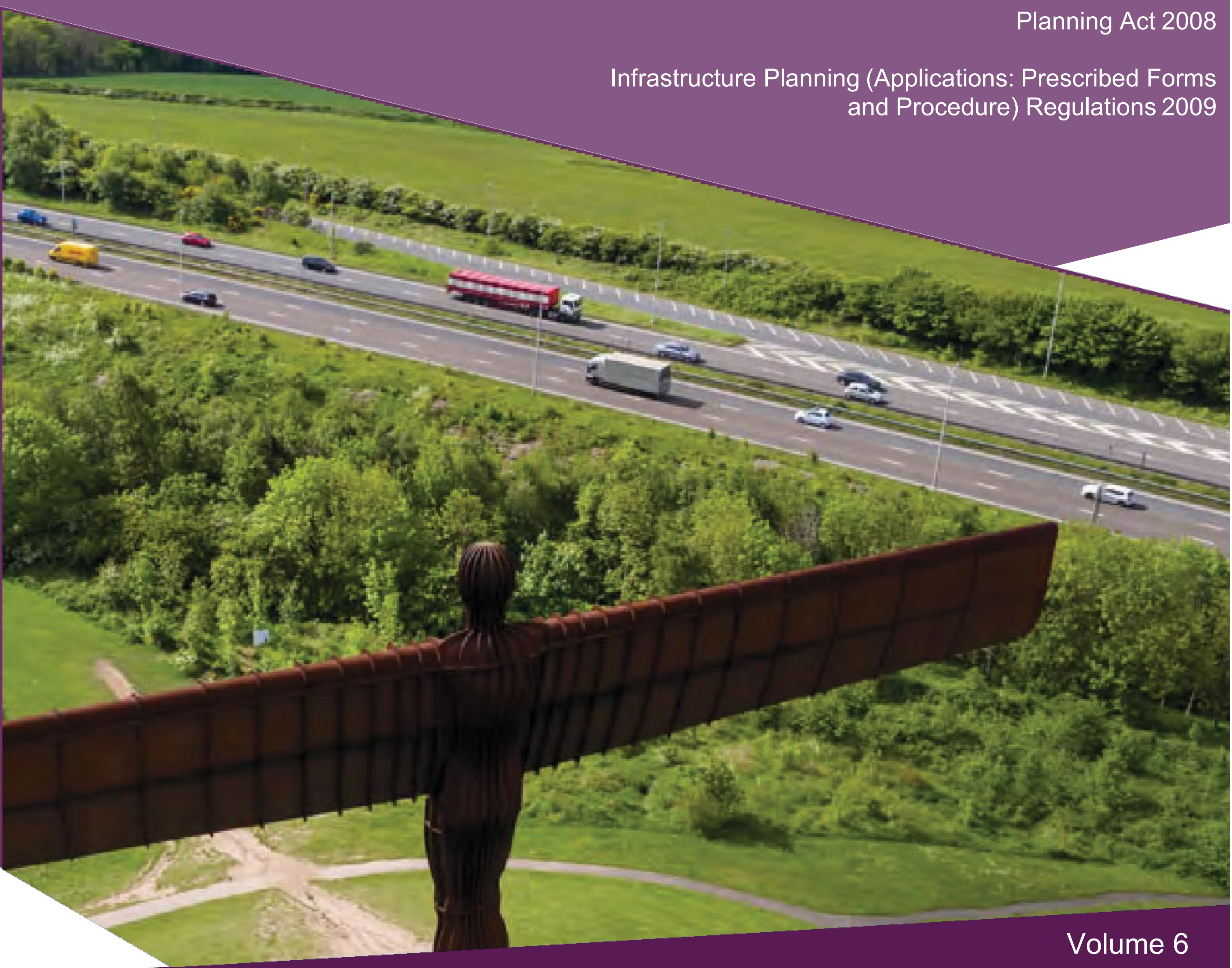
Scheme Number: TR010031

6.3 Environmental Statement – Appendix 14.1 Description of the Climate Baseline

APFP Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009



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The Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009

A1 Birtley to Coal House

Development Consent Order 20[xx]

Environmental Statement - Appendix

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1 DESCRIPTION OF THE CLIMATE BASELINE

1.1.1. This Appendix provides a description of the climate baseline for the Study Area, as referred to in the Birtley to Coal House Environmental Statement (ES) **Chapter 14 Climate** Assessment of the Vulnerability of the Scheme to Climate Change (**Application Document Reference: TR010031/APP/6.1**).

1.1.2. UK Climate Projections (2018) (UKCP18) (Met Office, 2019) have been used to infer future changes in a range of climate variables that may affect the vulnerability of the Scheme to climate change. At the time of writing, these represent the most up-to-date representation of future climate in the UK.

1.1.3. The Representative Concentration Pathways (RCPs) (from UKCP18) specify the concentrations of Greenhouse Gases (GHGs) that would result in target amounts of radiative forcing at the top of the atmosphere by 2100, relative to preindustrial levels. Four forcing levels have been set: 2.6, 4.5, 6.0 and 8.5 W/m2. These create four RCPs that are used in UKCP18; RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. RCP8.5 broadly corresponds to a high emissions scenario.

1.1.4. However, the UKCP18 data currently available does not provide data from extreme precipitation, drought, snow and ice, extreme temperature, solar radiation, wind or relative humidity. Data for these aspects has been taken from UK Climate Projections (2009) (UKCP09) (Met Office, 2009).

1.2 OVERVIEW OF CLIMATE FOR THE NORTH EAST REGION

1.2.1. The climate of the North East is relatively warm and temperate, although rainfall is significant, even in the driest month (typically February in Tynemouth which is the nearest meteorological station to Birtley). The climate is defined as Cfb, as described according to the Koppen-Geiger climate classification, such that:

- Temperature of the warmest month is greater than or equal to10 °C, and temperature of coldest month is less than18 °C but greater than –3 °C.
- Precipitation is evenly distributed throughout the year.
- The temperature of the warmest month has an average mean daily temperature of less than 22 °C.

1.2.2. The sections that follow describe historical trends and future projections in the climate variables as a function of different timeslices and a high emissions scenario.

1.3 PRECIPITATION

1.3.1. Rainfall in the UK tends to be associated with Atlantic depressions or with convection. The Atlantic lows are more vigorous in autumn and winter and bring most of the rain that falls in these seasons. In summer, convection caused by solar surface heating can form shower clouds and a large proportion of rain falls from showers and thunderstorms in the region during this time (Met Office, 2017).

1.3.2. Altitude also greatly affects rainfall in the North East region. The average annual rainfall exceeds 1500 mm in the higher parts of the Pennines. There is a decrease as the land falls eastwards, such that the east coast is one of the driest parts of the UK with less than 600mm in places such as Teesside and the Northumbrian coast. These values can be compared with annual totals around 500 mm in parts of eastern England and over 4000 mm in the western Scottish Highlands.

1.3.3. At the Tynemouth meteorological station (located approximately 15 miles North East of Birtley), an average of 597.2 mm of rain fell annually from 1981-2010. The driest month is February and the wettest month is November. **Table 1-1** shows total mean monthly rainfall at Tynemouth.

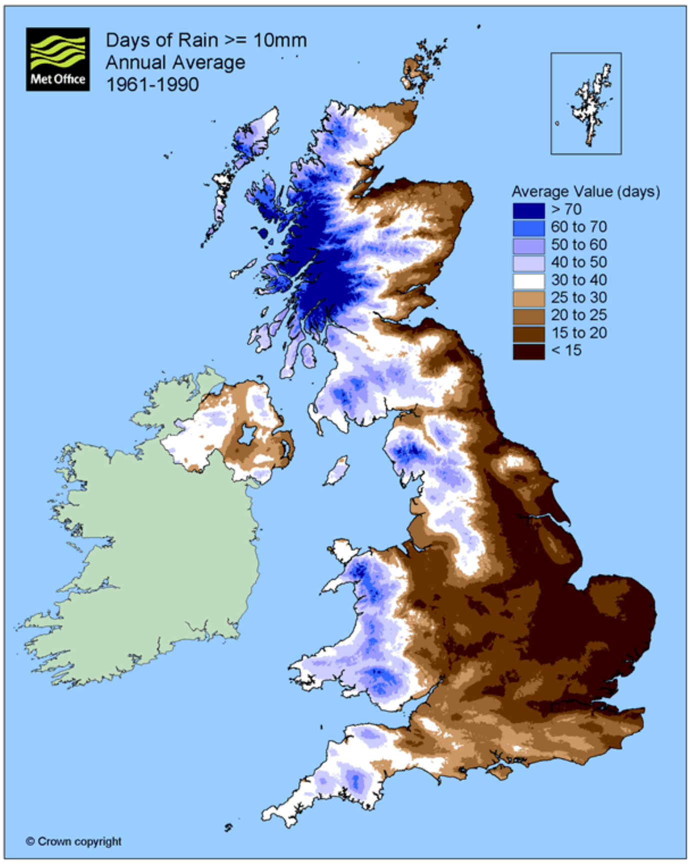
Table 1-1 - Total monthly mean rainfall at the Tynemouth station (1981-2010)

Precip (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	45.5	37.8	43.9	45.4	43.2	51.9	47.6	59.6	53.0	53.6	62.8	52.9

1.3.4. Over much of the North East region, the number of days with rainfall totals of 1mm or more ('wet days') tends to follow a pattern similar to the monthly rainfall totals. In the higher parts in winter (December-February), 45-50 days is the norm but this decreases to about 35 days in summer (June-August). In the drier areas closer to the coast, about 30 days in winter and about 25 days in summer are typical (Met Office, 2017). Periods of prolonged rainfall are often associated with east or North East winds on the northern flank of depressions passing to the south of the area.

1.3.5. **Figure 1-1** shows annual average days of heavy rainfall (>= 10 mm). In summary, the Study Area experiences a higher number of 'wet days' in winter than in summer, and as the site is located relatively close to the coast (around nine miles), it may experience fewer wet days than the rest of North East region.

Figure 1-1 - Days of rain >= 10 mm (1961-1990)



1.3.6. Thunderstorms are most likely to occur from May to September, reaching their peak in July and August, but are less frequent than in areas further south of the UK. The north of the region can expect only 5 to 8 days with thunder each year. The heaviest falls of rain in the UK are often associated with these summer thunderstorms (Met Office, 2017).

1.3.7. With regard to future projections, UKCP18 suggests that climate change is projected to lead to wetter winters and drier summers, with more extreme rainfall events.

1.3.8. Using data from UKCP18, **Figure 1-2** shows projections (RCP8.5 emission scenario only) of mean summer precipitation across three timeslices, namely: 2020s, 2050s and 2080s. The changes projected by UKCP18 are calculated against the baseline from HadUK-Grid Climate Observations on a 60km grid from 1961-1990.

Table 1-2 - Baseline total seasonal rainfall data from 1961-1990

Variable	Winter	Summer
Total Rainfall (mm)	249.05	228.64

1.3.9. By the 2020s, mean summer precipitation is expected to have 0% change (50th percentile), with the range of estimates from a 14% decrease to a 17% increase (represented by the 10th and 90th percentile respectively). By the 2050s, the central estimate (50th percentile) for mean summer precipitation rate is a 13% decrease and the 10th and 90th percentile projections range from 31% decrease and 7% increase. By the 2080s, this decreases further to 22% (50th percentile), with the 10th percentile at 41% decrease and the 90th percentile at 2% decrease.

1.3.10. **Figure 1-2** also shows projections (RCP8.5 only) of mean winter precipitation across the same timeslices. By the 2020s, this is expected to be a 7% increase (50th percentile), with the range from 6% decrease at the 10th percentile to 21% increase at the 90th percentile. By the 2050s, the central estimate (50th percentile) is projected to increase by 14%, with the 10th and 90th percentile projections ranging from 1% decrease and 32% increase respectively; and by the 2080s, this is increased to 27% (50th percentile), with the range from 7% increase to 52% increase (represented by the 10th and the 90th percentile) under RCP8.5. **Figure 1-2** summarises mean winter and summer precipitation for the 2020s, 2050s and 2080s under RCP8.5.

1.3.11. **Table 1-3** summarises change in mean winter and summer precipitation for the 2020s, 2050s and 2080s under RCP8.5.

Figure 1-2 - Change in seasonal mean precipitation (mm/day) for the 2020s, 2050s and 2080s in the 25km^2 grid square (437500.00, 562500.00), under RCP8.5.

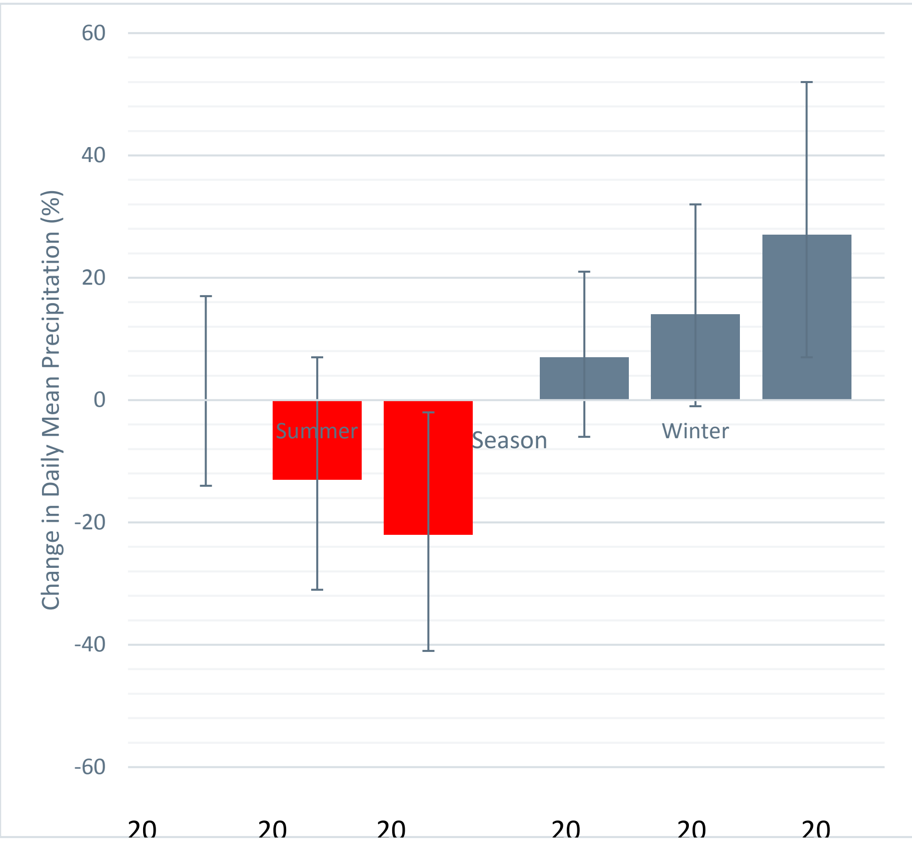


Table 1-3 - Change in seasonal precipitation (%) for the 2020s, 2050s and 2080s in the 25km^2 grid square (437500.00, 562500.00)

Period	Probability of being less than		
	10th	50th	90th
Summer (change in average precipitation, %)			
2020s	-14	0	17
2050s	-31	-13	7
2080s	-41	-22	7
Winter (change in average precipitation, %)			
2020s	-6	7	21
2050s	-1	14	32
2080s	7	27	52

1.3.12. The central estimate projections for RCP8.5 for mean daily precipitation as shown in **Figure 1-3** suggest that winter precipitation will increase, and summer precipitation will decrease over the 21st Century.

1.3.13. **Figure 1-3** shows the UKCP09 projections for changes in extreme precipitation in winter in the Birtley 25km grid square (grid location: 1004) in the 2020s, 2050s and 2080s under High emissions scenarios. By the 2020s, precipitation on the wettest day in winter is expected to increase by approximately 7.1%. However, there is considerable uncertainty around this central estimate, which ranges from approximately -6.4% to 22.5% (represented by the 10th and 90th percentile). By the 2050s, the central estimate projects an increase of 14.8%, with large uncertainty (ranging from -1.5%, 10th percentile, to 34.7%, 90th percentile). By the 2080s, an increase in precipitation on the wettest day of approximately 25.1% is predicted by the central estimate, with the 10th percentile at 3.7% and the 90th percentile at 53.9%.

1.3.14. **Table 1-4** summarises the projected changes in precipitation on the wettest day in winter in the 2020s, 2050s and 2080s under the High emissions scenario.

Figure 1-3 - Percentage change in precipitation on the wettest day in winter in grid square 1004 for the 2020s, 2050s and 2080s under the High emissions scenario

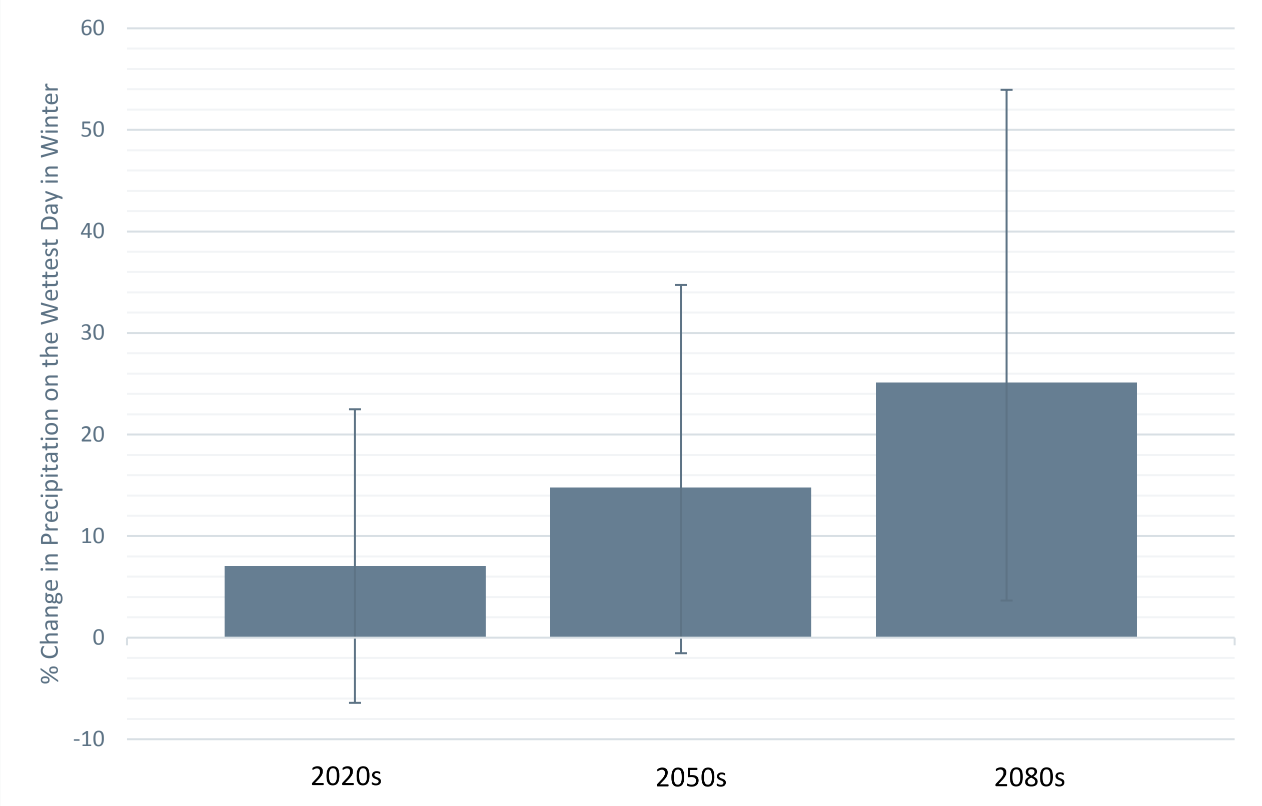


Table 1-4 - Change in precipitation on the wettest day in winter in the 1004 grid square for the 2020s, 2050s and 2080s under the High emissions scenario

Change in precipitation on the wettest day in winter (%)	Probability of being less than		
	10%	50%	90%
2020s	-6.42	7.06	22.49
2050s	-1.53	14.76	34.73
2080s	3.65	25.11	53.94

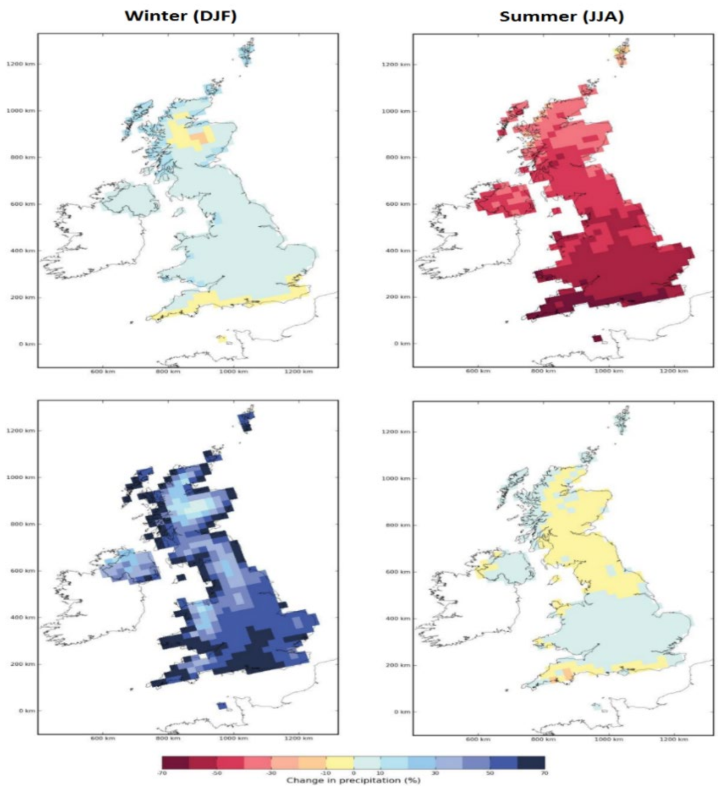
1.4 DROUGHT

1.4.1. A combination of higher summer temperatures and reduced summer rainfall could see increases in the risk of drought in the UK. UKCP09 is not suitable for the analysis of multi-year droughts, however, it does contain some information on changes at the seasonal timescale.

1.4.2. **Figure 1-4** shows projected changes in winter (left panels) and summer (right panels) precipitation totals expected by 2070-2099 under the UKCP09 High emissions scenario. The upper panels represent changes at the 10% probability (i.e. driest) level of the probabilistic range. The lower panels represent changes at the 90% probability (i.e. wettest) level.

1.4.3. The overall pattern is a move toward wetter winters and drier summers suggesting that short-term summer droughts may increase in frequency. The range of the projected changes varies considerably across the probability ranges from almost no change through to shifts of greater than 70% of the 30-year average value, therefore there is large uncertainty in the magnitude of change although the direction is agreed (droughts are likely to become more frequent). Other studies, including the recent UK Climate Change Risk Assessment (CCRA) Evidence Report[i] suggest that the North East region, including the Study Area, is expected to experience a water surplus, of between100 and 1,000 Ml/day by the 2080s under a High emissions scenario. Therefore, risk from drought is likely to be lower than other parts of the country but may still pose a threat, particularly in the summer months.

Figure 1-4 - Projected changes in winter (left) and summer (right) total precipitation by 2080s



Under the UKCP09 High emissions scenario. The top panel represents changes at the 10% probability (i.e. driest) level of the probabilistic range. The bottom panels represent changes at the 90% probability (i.e. wettest) level.

1.5 SNOW AND ICE

1.5.1. Snowfall is closely linked with temperature, with falls rarely occurring if the temperature is higher than 4 °C. For snow to lie for any length of time, the temperature normally has to be lower than this. Over most of the North East region, snowfall is normally confined to the months from November to April, but upland areas can often have falls in October and May. Snow rarely lies on low ground outside the period from November to March but over higher ground lying snow can also occur in October and as late as May.

1.5.2. The degree of exposure to northerly winds is critical, and the North York Moors can receive nearly as much snow as the higher ground of the Pennines. Often this is of a showery nature, triggered by the passage of a cold airstream over the North Sea. On average, the number of days with snow falling is about 20 per year near the coast and in low lying areas of south Yorkshire and as much as 50 days over the higher Pennines.

1.5.3. An average increase of about five days of snow falling per year for every 100 m increase in altitude has been found to be typical (Jebson et al., 2007). The number of days with snow lying is also mainly dependent upon altitude but partly upon proximity to the sea. The number therefore varies from about 10 days per year near the east coast and in low lying areas of south Yorkshire to over 40 days in the higher Pennines. These averages can be compared with parts of the Scottish Highlands, which have about 60 days with snow lying on average and with the coasts of South West England, with less than three days per year. In most places, January is the month with most days of both snow lying and snow falling.

1.5.4. With regards to future changes, rising winter temperatures are likely to reduce the amount of precipitation that falls as snow in winter. UKCP09 projects a reduction of mean snowfall, the number of days when snow falls and heavy snow events by the end of the 21st century (Brown et al., 2010). UKCP09 does not provide projections for the nearer-term for snow. While there is less certainty in the magnitude of projected change, there is confidence that snow fall is generally expected to decrease compared with the baseline (Jylhä et al., 2008). Projections indicate substantial reductions in snowfall days for all regions in winter, and this is also expected to be the case in the Study Area (Brown et al., 2010; McColl et al., 2012).

1.5.5. Reductions of 70 to 80 % are projected for the majority of England in winter, and similar magnitude changes are also projected for spring (not shown). Ensemble projections for the 2080s suggest that for most of the UK, the intensity of winter and spring 'heavy' snow events (the 90th percentile of snowfall rate) could decrease by over 80 % (Brown *et al*., 2010). Reductions are greatest in East and North East regions of England, and therefore the Study Area and the Scheme is likely to experience a reduction in snowfall and heavy snow days.

1.6 TEMPERATURE

1.6.1. Mean annual temperatures depend strongly on altitude, with a decrease of about 0.5 °C for each 100 m increase in altitude, and, to some extent, proximity to coast (Jebson et al., 2007). The coldest waters around the UK are found off North East England This, coupled with extensive areas of upland, means that temperatures in the Study Area, relative to elsewhere in England, are generally cool throughout the year.

1.6.2. At the Tynemouth meteorological station (located approximately 15 miles North East of Birtley), the annual average minimum temperature from 1981-2010 was 6.7 °C whilst the annual average maximum temperature was 12.1 °C. **Table 1-5** shows minimum and maximum mean monthly temperatures at Tynemouth.

Table 1-5 - Minimum and maximum monthly mean temperatures at the Tynemouth station (1981-2010)

Temp. (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	2.2	2.2	3.3	4.8	7.2	10.0	12.3	12.3	10.4	7.7	4.9	2.5
Max	7.2	7.3	9.0	10.3	12.7	15.6	18.1	18.1	16.1	13.2	9.7	7.4

1.6.3. From 1961-2006 the North East region experienced an increase in mean annual temperature of 1.46°C. **Table 1-6** summarises changes in daily mean annual temperature in each season for the period 1961-2006.

Table 1-6 - Change in daily mean temperature (°C) from 1961 to 2006 by season in the North East region

Spring	Summer	Autumn	Winter	Annual
1.43°C	1.57°C	1.13°C	1.86°C	1.46°C

1.6.4. With regard to future projections, climate change is projected to lead to hotter summers and warmer winters, with more extreme high temperature events.

1.6.5. The following baseline from HadUK-Grid Climate Observations on a 60 km grid from 1961-1990 was used to show the projected changes by UKCP18.

Table 1-7 - Baseline temperature data from 1961-1990

Variable	Winter	Summer
Mean air temperature (ºC)	2.21	12.75
Daily minimum temperature (ºC)	-0.41	8.62
Daily maximum temperature (ºC)	4.82	16.95

1.6.6. As shown in **Figure 1-5**, by the 2020s, mean air temperature in the 25 km^2 grid square (437500.00, 562500.00) in the summer is projected increase by 1.2 ºC at the central estimate (50th percentile). The 10th and 90th percentile projections (represented by the error bars in **Figure 1-5**) represent the uncertainty around the central estimate and range from 0.4 °C to 2.0 °C.

1.6.7. The UKCP18 projections for change in mean temperature rise are higher for the 2050s and 2080s respectively. Under RCP8.5, by the 2050s, mean air temperature in the summer is projected to increase by 2.4 °C at the central estimate (50th percentile). The 10th and 90th percentile range from 0.9 °C and 4.0 °C respectively.

1.6.8. By the 2080s, under RCP8.5, mean air temperature in the summer is projected to increase by 4.4 °C at the central estimate (50th percentile) with the 10th and 90th percentile ranging from 1.9 °C to 7.10 °C.

1.6.9. **Figure 1-5** also shows that mean air temperature in the winter is projected to increase by 1.0 °C at the central estimate (50th percentile), by the 2020s. The 10th and 90th percentile projections show lower and upper estimates of 0.2 °C and 1.9 °C respectively.

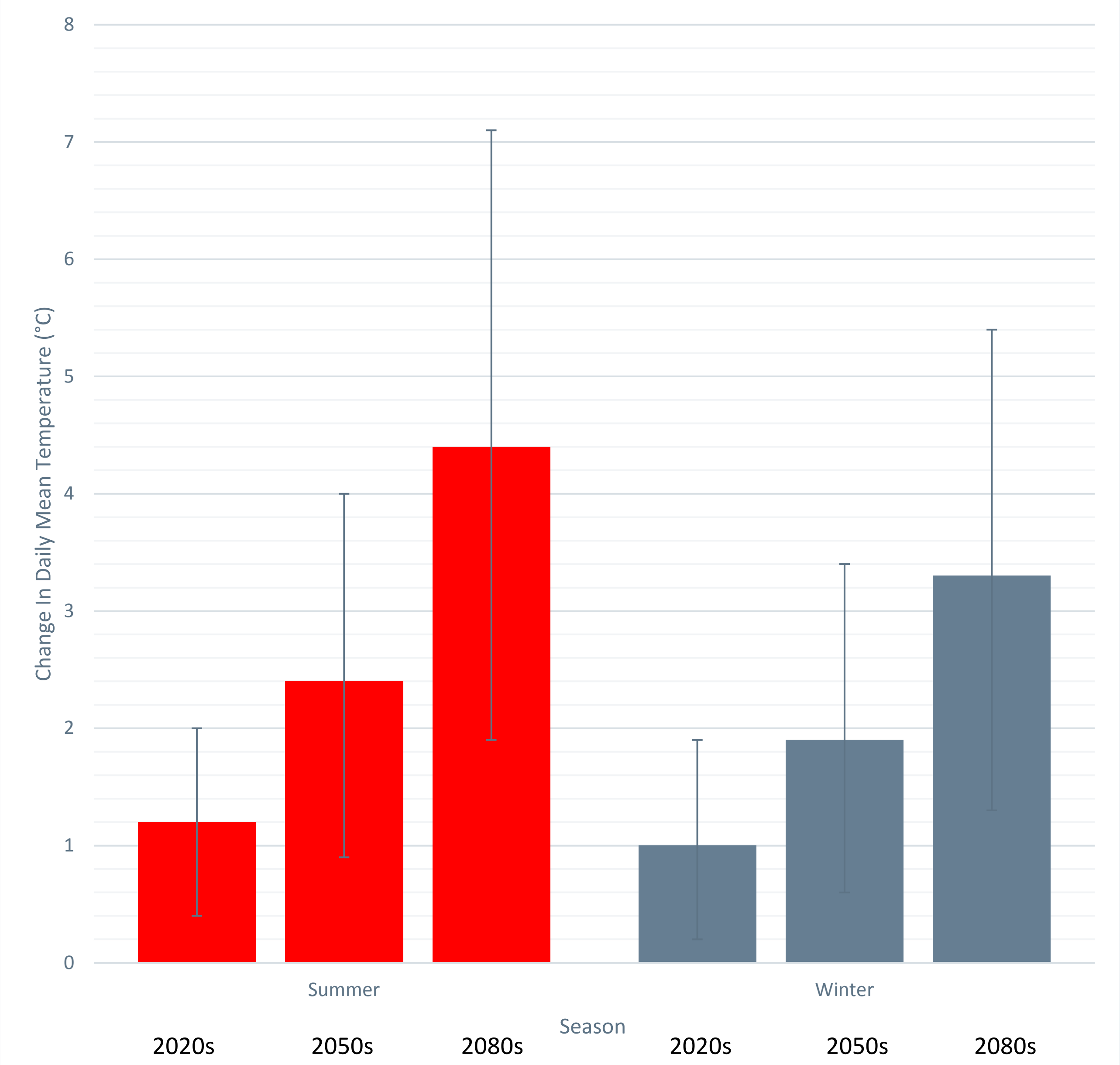
1.6.10. The projections from UKCP18 show higher temperature increases for the 2050s and the 2080s respectively. By the 2050s, under RCP8.5, mean air temperature in the winter is expected to be 1.9 °C higher at the central estimate (50th percentile). The 10th and 90th percentile projections range from 0.6 °C to 3.4 °C.

1.6.11. By the 2080s, mean air temperature in the winter is projected to increase by 3.3 °C at the central estimate (50th percentile), with the 10th and 90th percentile projects, representing the uncertainty, range from 1.3 °C to 5.4 °C.

Table 1-8 – Change in mean summer and winter temperature (°C) in the 25 km^2 grid square (437500.00, 562500.00) for the 2020s, 2050s and 2080s

Period	**Probability of being less than**		
	10th	**50th**	**90th**
Change in summer (mean temperature, °C)			
2020s	0.4	1.2	2.0
2050s	0.9	2.4	4.0
2080s	1.9	4.4	7.1
Change in winter (mean temperature, °C)			
2020s	0.2	1.0	1.9
2050s	0.6	1.9	3.4
2080s	1.3	3.3	5.4

Figure 1-5 – Change in Seasonal average daily mean temperature (°C) for the 2020s, 2050s and 2080s in the 25 km2 grid square (437500.00, 562500.00) under RCP8.5



1.6.12. Temperature shows both a seasonal and a diurnal variation. January is usually the coldest month, with mean daily minimum temperatures varying from below -0.5 °C on the highest ground to ~2 °C along the coast and in South Yorkshire. Minimum temperatures usually occur around sunrise and extreme minima have been recorded in winter, most often in January or February.

1.6.13. With regards to changes in minimum and maximum temperatures, from 1961-2006 the North East region has experienced an increase in mean minimum temperatures of ~1.35

°C. **Table 1-9** summarises the changes in mean annual minimum temperature for each season for the period 1961-2006 for the North East region.

Table 1-9 - Change in daily minimum temperature (°C) from 1961-2006 by season in the North East region

Spring	Summer	Autumn	Winter	Annual
1.19°C	1.42°C	1.13°C	1.78°C	1.35°C

1.6.14. From 1961-2006, the North East region has also experienced an increase in mean maximum temperature of 1.55 °C. **Table 1-10** summarises the changes in mean annual maximum temperature for each season for the period 1961-2006 for the North East region.

Table 1-10 - Change in daily maximum temperature (°C) from 1961-2006 by season in the North East region

Spring	Summer	Autumn	Winter	Annual
1.63°C	1.72°C	1.11°C	1.92°C	1.55°C

1.6.15. As shown in **Figure 1-6** by the 2020s, the central estimate (50th percentile) projections under RCP8.5 suggest that mean daily maximum temperature in the summer will increase by 1.2 °C. There is large uncertainty around these central estimates (represented by the 10th and 90th percentile), ranging from 0.4 °C to 2.1 °C. By the 2050s, mean maximum temperature in the summer is expected to increase by 2.5°C, with the 10th and the 90th percentile ranging from 0.8 °C to 4.4 °C. By the 2080s, projections for daily maximum summer temperature for the 25km^2 grid square (412500.00, 587500.00) are an increase of 4.7 ºC for the central estimate (50th percentile), with uncertainty ranging from 1.9 ºC (10th percentile) to 7.7 ºC (90th percentile).

1.6.16. Mean daily minimum temperatures in the winter are projected to increase by 1.0 ºC for the central estimate (50th percentile), by the 2020s. The 10th and 90th percentile projections suggest lower and upper estimates of 0.0 °C and 2.0 °C respectively. By the 2050s, projections for daily minimum winter temperature increase by 1.9 °C for the central estimate (50th percentile) and the 10th and 90th percentile projections range from 0.5 °C to 3.5 °C. By the 2080s, projections show an increase of 3.3 °C for the central estimate (50th percentile), with the uncertainty ranging from 1.0 °C (10th percentile) and 5.8 °C (90th percentile).

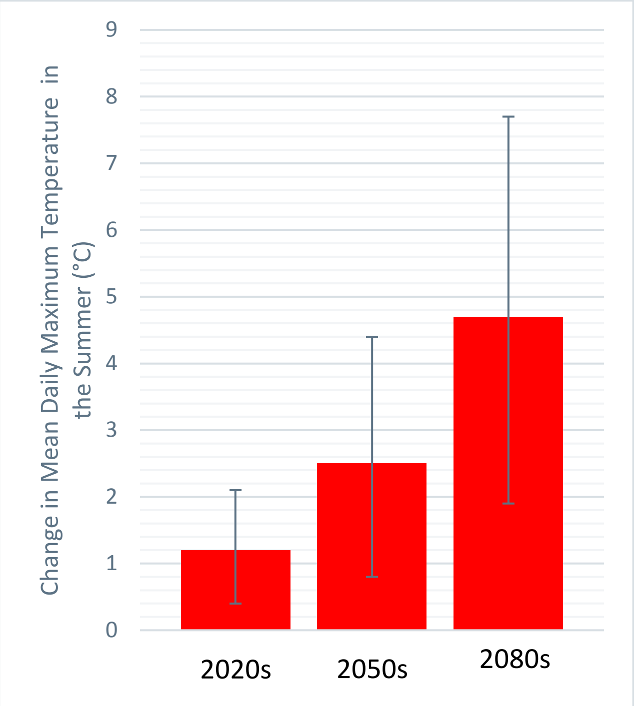
1.6.17. **Table 1-11** show the UKCP09 projections for changes in maximum temperatures in the summer and minimum temperatures in the winter in the Birtley 25 km grid square in the 2020s, 2050s and 2080s under RCP8.5.

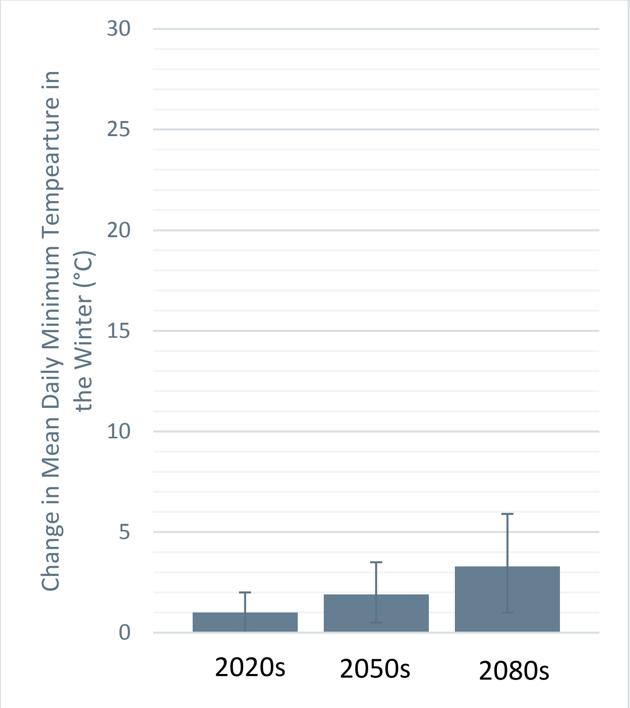
Table 1-11 - Seasonal temperature variables in the Birtley 25 km grid square in 2020s, 2050s, and 2080s under RCP8.5

Change in summer mean maximum temperature (°C)	Probability of being less than		
	10%	50%	90%
2020s	0.4	1.2	2.1
2050s	0.8	2.5	4.4
2080s	1.9	4.7	7.7

Change in winter mean minimum temperature (°C)	Probability of being less than		
	10%	50%	90%
2020s	0.0	1.0	2.0
2050s	0.5	1.9	3.5
2080s	1.0	3.3	5.9

Figure 1-6 - Seasonal temperature variables for the 2020s, 2050s and 2080s in the 25km² grid square (437500.00, 562500.00) under the High emissions scenario





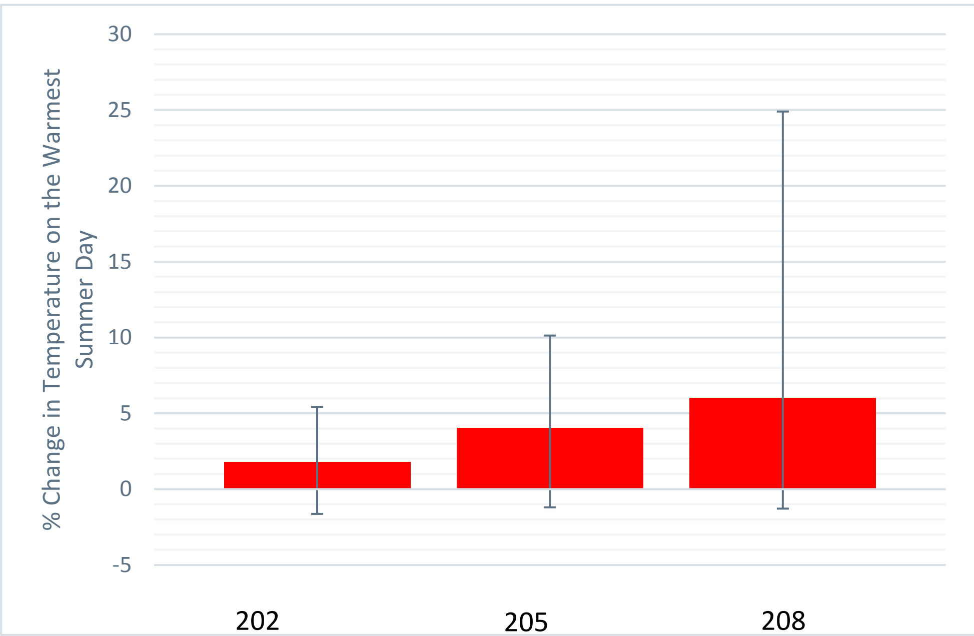
1.6.18. **Table 1-12** shows the UKCP09 projections for changes in extreme temperatures in summer in the Birtley 25km grid square (ID: 1004) in the 2020s, 2050s and 2080s under High emissions scenarios.

1.6.19. **Figure 1-7** shows the UKCP09 projections for changes in extreme temperatures in summer in the Birtley 25km grid square (1004) in the 2020s, 2050s and 2080s under High emissions scenarios. By the 2020s, temperature on the warmest summer day is expected to increase by approximately 1.8%. However, the uncertainty around this central estimate ranges from approximately -6.4% to 5.4% (represented by the 10th and 90th percentile). By the 2050s, the central estimate has predicted an increase of 4.0%, with the uncertainty ranging from -1.2% (10th percentile) to 10.1% (90th percentile). By the 2080s, an increase of approximately 6.0% is predicted by the central estimate, with the 10th percentile at -1.3% and the 90th percentile at 24.9%.

Table 1-12 - Changes in extreme temperature variables in the Birtley 25km grid square in 2020s, 2050s and 2080s under a HIGH emissions scenario

Change in temperature on the warmest summer day (°C)	Probability of being less than		
	10%	50%	90%
2020s	-1.6	1.8	5.4
2050s	-1.2	4.0	10.1
2080s	-1.3	6.0	24.9

Figure 1-7 - Changes in extreme temperature in summer for the 2020s, 2050s and 2080s in the 25km^2 grid square 1004 under the High emissions scenario



1.6.20. With regard to heat waves, research published by the Met Office Hadley Centre suggests the European summer heat wave in 2003 could become a normal event by the 2040s. By the 2060s, such a summer would be considered cool according to some climate models (Highways Agency, 2011). It is very likely (confidence level >90%) that human influence has at least doubled the risk of a heatwave exceeding mean summer temperatures experienced in 2003 (Stott et al., 2004). In a study for Australia, Lewis and Karoly (2013) concluded that it was very likely (>90% confidence) that there was a fivefold increase in the odds of extreme heat occurring in the country due to human influences using simulations for 2006-2020.

1.7 SOLAR RADIATION

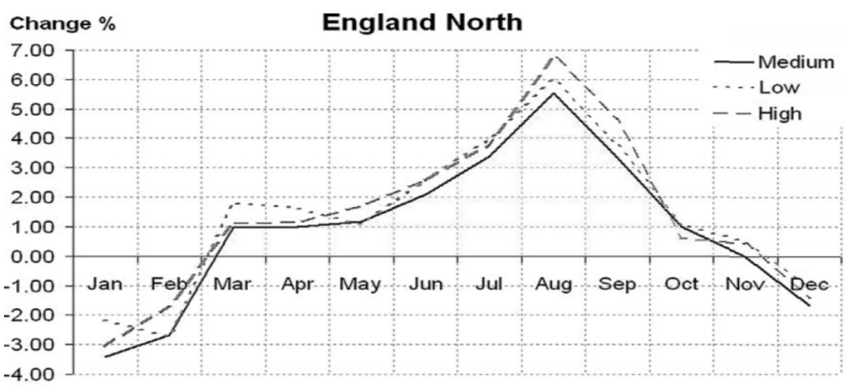
1.7.1. A recent (regional) study (Burnett et al., 2014) suggests that the north of the UK, including the North East region and the Study Area, is likely to see an increase in annual solar radiation by the 2050s of 3.8 Wm-2 and by the 2080s of 4.6 Wm-2 under the central (50th percentile) estimate, under the High emissions scenario. **Table 1-13** outlines the changes in annual solar radiation for the 2050s and 2080s under the UKCP09 emissions scenarios.

1.7.2. All regions of the UK are likely to have increased cloud cover (although there is large uncertainty around future projections of cloud cover) and therefore slightly less solar radiation during the winter. **Figure 1-8** describes the change (%) in solar radiation from the baseline for the 2050s for the north of England, which encompasses the Study Area. The results suggest that increases in solar radiation are more likely in the spring and summer than in autumn and winter.

Table 1-13 - Changes in annual solar radiation (Wm^{-2})

Period	High		
	10th	50th	90th
2050s	-0.6	3.8	8.5
2080s	-1.5	4.6	11.3

Figure 1-8 - Projected regional average change (%) of solar radiation (2050s)



Source: Burnett *et al.,* (2014)

1.8 WIND

1.8.1. The UKCP09 projections depict a wide spread of future changes in mean surface wind speed, however, there is large uncertainty in projected changes in circulation over the UK and natural climate variability contributes much of this uncertainty (Brown et al., 2012). It is therefore difficult to represent regional wind extreme winds and gusts within regional climate models (Brown et al., 2008).

1.8.2. Central estimates of change in mean wind speed for the 2050s are small in all ensemble runs (<0.2ms-1). A wind speed of 0.2 ms−1 (~0.4 knots) is small compared with the typical magnitude of summer mean wind speed of about 3.6–5.1 ms-1 (7–10 knots) over much of England (Jenkins et al., 2008). Seasonal changes at individual locations across the UK lie within the range of –15% to +10%. Results suggest that there could be a future reduction in the summer westerly wind flows over the southern half of the UK. There may be an increase in westerly flows in the north during summer and also an increase in southerly flows over the UK in winter.

1.8.3. With regards to storms, the analysis presented here is a summary of expected changes in storm patterns under a changing climate. A storm is defined by the Met Office as a wind event measuring 10 or higher on the Beaufort scale (equivalent to a wind speed of 24.5 m/s or 55 mph).

1.8.4. Studies suggest that climate-driven storm changes are less distinct in the Northern than Southern hemisphere (Bengtsson et al., 2006). There is some agreement of a projected poleward shift in storm tracks across the Atlantic Ocean; however, for mid-Atlantic storms the signal is more complex (Slingo et al., 2014). Potentially, mid-Atlantic storms may become more intense, particularly with the long-term warming of the sub-tropical Atlantic that could increase the amount of moisture that those storms carry (ibid). However, such is the wide range of inter-model variation, robust projections of changes in storm track 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.

1.9 RELATIVE HUMIDITY

1.9.1. Relative Humidity is the most common measure of humidity. It measures how close the air is to being saturated. From 1961-2006 the North East region has experienced a decrease in relative humidity of ~2.7%. **Table 1-14** summarises the changes in relative humidity in each season for the period 1961-2006 in the North East region.

Table 1-14 - Change in mean relative humidity from 1961-2006 by season in the North East region

Spring	Summer	Autumn	Winter	Annual
-2.8%	-2.8%	-2.3%	-2.6%	-2.7%

1.9.2. **Table 1-15** shows the UKCP09 projections for changes in seasonal mean relative humidity in the 25km^2 grid square 1004 in 2080 under High emissions scenarios, respectively.

Table 1-15 - Change in seasonal mean relative humidity in the 25km^2 grid square 1004 in 2080 under High emissions scenario

Climate variable: HIGH emissions	Probability of being less than		
	10%	50%	90%
Summer mean relative humidity (%)	-10 to -5	-5 to 0	0 to 5
Winter mean relative humidity (%)	-5 to 0	0	0 to 5

1.10 EXTREMES (PRECIPITATION AND TEMPERATURE EVENTS)

1.10.1. A range of 'extreme' climate change scenarios (produced by Wade et al., 2015) have also been reviewed. The H++ scenarios represent the margins or beyond the 10th to 90th percentile range of the 2080s UKCP09 High emissions scenario as presented in the UKCP09 projections (Murphy et al., 2009) and reported here. These scenarios provide a high-impact, low-likelihood event to compare against more likely outcomes.

1.10.2. The H++ scenarios suggest that average summer maximum temperatures will exceed 30 °C across most of the UK, with temperatures of the hottest days are also likely to exceed 40 °C (Wade et al., 2015). The H++ scenarios for heavy daily and sub-daily rainfall suggest that, for the same period, there is a 60% to 80% increase in rainfall for summer or winter events based on a consideration of new high-resolution modelling and physical processes.

1.10.3. Wade *et al*., (2015) recommend that a plausible H++ windstorm scenario is a 50-80% increase in the number of windstorms over the UK by 2070-2100 compared to 1975-2005. However, it is important to note that this scenario is based on the CMIP5 climate model simulations, which contain biases in the position of the North Atlantic storm track and systematically under-represents the number of intense cyclones.

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