High-impact low-likelihood climate scenarios for the UK

Scenario Report

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High-impact low-likelihood climate scenarios for the UK

Executive Summary

This report presents two sets of high-impact low-likelihood (HILL) climate scenarios for the UK. The scenarios are designed to supplement and contextualise the UKCP18 climate projections, and to meet requirements of users for plausible high-end or worst-case climate scenarios.

One of the sets of scenarios – **transient scenarios** - describe the evolution of change in climate to 2100. This set consists of six plausible and distinctive narrative storylines describing qualitatively different potential drivers of high-impact, low-likelihood changes in UK climate and sea level. The storylines are designed to describe changes outside the extreme range conventionally assumed, taken here to be *either* a world reaching an increase of 4^{o}C above pre-industrial levels by 2100 *or* one where changes in climate are outside the range as represented by the majority of current climate models. Such changes could occur because the ***forcings*** of climate change are outside the conventional range, or because the large-scale ***climate system response*** is outside the range projected by most current climate models. The scenarios are similar in principle to conventional climate change scenarios. Each is presented as a single quantification. Two (enhanced global warming and enhanced sea level rise) are defined as standalone scenarios, and the other four are presented as perturbations to be applied to UKCP18 climate projections from any strand with any emissions scenario. The transient scenarios provide a high-level picture of how future UK climate could be different to that implied by conventional UKCP18 climate projections. They can be applied individually or in combination.

The second set consists of a number of **extreme anomaly scenarios** representing plausible extreme monthly and seasonal temperature, rainfall and windspeed anomalies, both individually and in combination. These scenarios are designed to be applied to a long-term climate mean to represent an individual month or season, or sequence of months. They can be applied to conventional climate projections or the high-impact low-likelihood transient scenarios developed here to define plausible extreme months or seasons. Each is associated with a ‘backstory’ describing plausible circulation patterns (such as jet stream position) that generate the anomalous extremes. This set of scenarios allows an assessment of risks from plausible extreme months and seasons. They are not intended to replace sector-specific worst case event scenarios.

Both the transient and extreme anomaly scenarios are developed through a combination of theory, historical experience, expert judgment and the interpretation of climate model output, including UKCP18 products. The scenarios are not assigned quantitative likelihoods, but their plausibility is characterised in terms of understanding of (i) the drivers of the scenario (forcing or large-scale response) and (ii) the consequences of the scenario for the UK if it were to occur.

The narrative storylines and backstories provide a framework for further elaboration, for example to add specific detail relevant to a user or to develop narrative descriptions of potential consequences. The quantitative characterisations of the scenarios presented here can be used in quantitative risk assessments but are not to be interpreted too literally. They can be updated or supplemented within the framework presented here as new information becomes available.

This report describes the transient and extreme anomaly scenarios in Parts A and B respectively. A separate technical report outlines the use and interpretation of high-impact low-likelihood climate scenarios in the UK, describes the framework developed for constructing the scenarios, and summarises the evidence used to construct them.

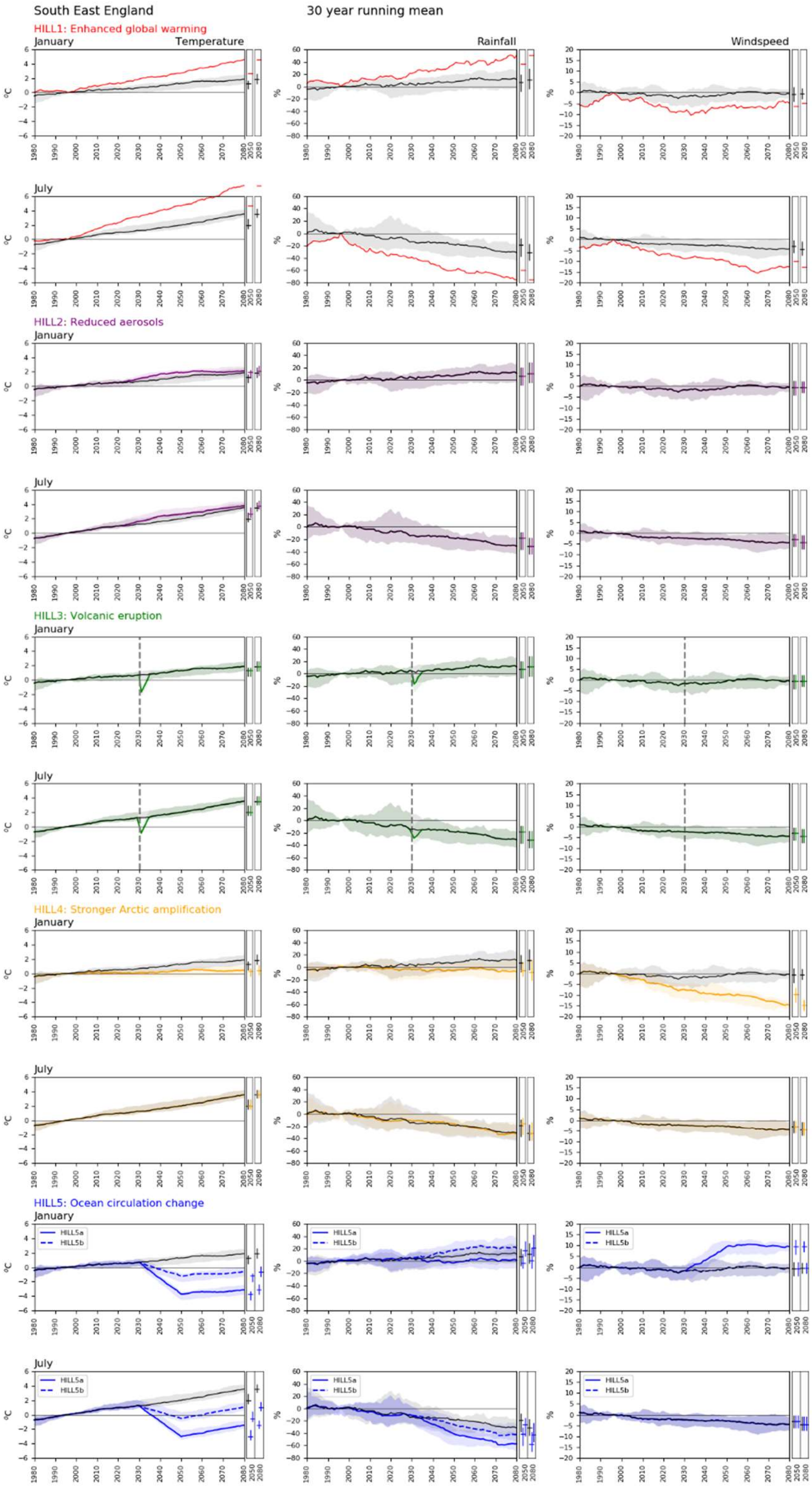
The transient and extreme anomaly scenarios describe plausible high-impact low-likelihood changes in average temperature, rainfall and windspeed (and sea level for the transient scenarios). Plausible changes in other climate variables (such as humidity) can be inferred if necessary from the narrative storylines.

Part A: Transient high-impact low-likelihood scenarios

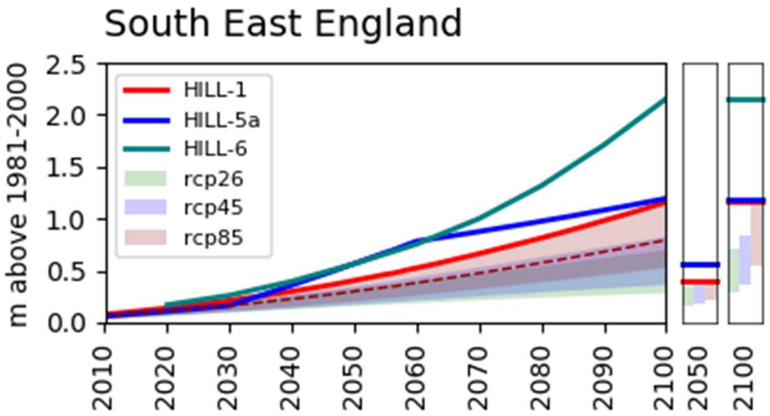
Summary

	Scenario	Summary
HILL-1	Enhanced global warming	Global temperature increases well above 4°C due to very high emissions, stronger carbon cycle feedbacks and/or high climate sensitivity.
HILL-2	Rapid aerosol reductions	Lower aerosol emissions increase warming. This scenario can be applied with any emissions scenario.
HILL-3	Volcanic eruption	Cooling follows major volcanic eruption (VEI7). This scenario can be applied with any emissions scenario.
HILL-4	Stronger Arctic Amplification	A strong increase in Arctic warming leads to circulation changes which increase the frequency of occurrence of cold periods. This scenario can be applied with any emissions scenario.
HILL-5	Ocean circulation change	Changes in the North Atlantic Ocean lead to cooling across the UK. Two variants (HILL-5a collapse of the Atlantic Meridional Overturning Circulation and HILL-5b collapse of the sub-Polar Gyre) describe different levels of cooling. This scenario can be applied with any emissions scenario.
HILL-6	Enhanced sea level rise	Rapid deglaciation in Greenland and Antarctica leads to an increase in sea level around the UK of up to 2.2m relative to current levels by 2100. Two standalone scenarios are presented representing enhanced sea level rise with high and low emissions.

An illustration of the effect of the transient HILL scenarios on temperature, precipitation and windspeed in January and July for an example location in south east England, together with changes in a 4°C world (the thick black line). Scenarios HILL-2 to HILL-5 are defined as differences from the 4°C projections, whilst scenario HILL-1 is based on the most extreme RCP8.5 projections. The panels to the right of each plot show changes in 2050 and 2080. Note that not all scenarios define changes in all variables. The vertical line in HILL-3 represents the assumed date of the volcanic eruption.



An illustration of the effect of the transient HILL scenarios on sea level rise for south east England. The plot shows the increase in mean sea level with the HILL-1, HILL-5a and HILL-6 scenarios, together with the 5 to 95th percentile ranges for the UKCP18 scenarios with RCP2.6, RCP4.5 and RCP8.5 emissions. The HILL-5a scenario is applied here to the median UKCP18 RCP8.5 estimate shown by the dashed line.



HILL-1
Enhanced global warming

Storyline narrative

The rate and magnitude of climate change is greater than assumed, resulting in global warming in excess of 4°C above pre-industrial levels by 2100.

Description

Future global warming is considerably greater than 4°C by 2100. This is because future emissions increase more rapidly than anticipated, because the climate system is more sensitive to emissions than conventionally assumed and/or because positive feedbacks which release stored carbon and methane are stronger than conventionally assumed.

Storyline type

The storyline describes a **forcing of climate change** outside the conventional range and/or a **climate system response** outside the conventional range.

Variants

There are no variants to this storyline, although there are several options for its application.

Links to other scenarios

This scenario affects the plausibility of HILL-4, HILL-5 and HILL-6, and affects the consequences of HILL-2 and HILL-3.

Implications for UK climate and sea level

An increase in winter and summer average temperature of up to 4.2 and 5.6°C above the 1981-2000 average respectively by the 2050s, an increase in winter precipitation of up to 60%, a decrease in summer precipitation of up to 65%. Mean windspeed up to 9% stronger in winter by 2050, and up to 10% weaker in summer. Increase in mean sea level by up to 40cm by the 2050s.

Confidence in UK effects

Increase in temperature: High
Increase in winter precipitation: Med
Increase in summer precipitation: Low
Decrease in winter precipitation: Low
Decrease in summer precipitation: Med
Increase in winter windspeed: Med
Increase in summer windspeed: Low
Increase in sea level: High

Sources of evidence

The specific scenario is based on the UKCP18 RCP8.5 projections. Plausibility and confidence are based on a combination of historical experience, theory and climate model simulations.

HILL-1 Enhanced global warming

1. Description

Climate change leads to an increase in global average temperature considerably greater than 4°C by the end of the 21st century. There are three potential reasons why global average warming might be greater than assumed under current policy scenarios or a 4°C world (Figure HILL1-1):

- emissions might be higher than assumed in current policy scenarios;
- the climate system might respond more strongly to a forcing than conventionally assumed (high climate sensitivity);
- accelerated feedbacks mean that more greenhouse gases are released from the earth surface to enhance the greenhouse effect.

The first is a *forcing* of change outside the conventional range, whilst the other two are system *responses* outside the conventional range.

The scenario is defined as a specific ‘high end’ interpretation of the UKCP18 RCP8.5 climate and marine projections.

2. Consequences for weather and sea level in the UK

The scenario results in increases across the UK in average winter and summer temperature of up to 4.2°C and 5.6°C respectively above the 1981-2010 average by the 2050s and increases of up to 5.6°C and 7.7°C by the end of the century. Winter rainfall increases by up to 60% by the 2050s and 70% by the end of the century, and summer rainfall decreases by up to 65% and over 70% by the 2050s and end of the century respectively.

Indicative national average changes in seasonal climate indicators are summarised in Tables HILL1-1 and HILL1-2, for the 2050s and the 2070s: note that changes in individual regions may be larger or smaller than the national average changes. Table HILL1-1 shows change in 20-year mean climate, whilst Table HILL1-2 shows frequencies over 30-year periods. Specific guidance on constructing HILL-1 scenarios from UKCP18 products is given in Section 5.

All climate projections based on RCP8.5 show an increase in temperature across the UK throughout the year, with greatest increases in the south and in summer. There is, however, greater uncertainty in the direction of change in precipitation and, to a lesser extent, windspeed across the UK. Although the general picture is of increased precipitation in winter and less in summer, some individual models project less precipitation in winter than at present and some project more precipitation in summer. Similarly, some models project an increase in mean windspeed and storminess, and others a decrease. Some users will be vulnerable to increases in precipitation and some to decreases, and similarly some users will be vulnerable to increases in windspeed and others to reductions. Tables HILL1-1 and HILL1-2 therefore show ‘wet’, ‘dry’, ’windy’ and ‘still’ versions of HILL-1 alongside the increase in temperature.

The 95th percentile UKCP18 RCP8.5 sea level rise (relative to 1981-2000) ranges from 28cm in the north west to up to 40cm in the south west by 2050, and between 84 and 109cm by 2100. More extreme sea level rise scenarios are described in Scenario HILL-6.

3. Confidence in projected consequences for the UK

The confidence in the magnitude of the projected changes in temperature, precipitation, windspeed and sea level for the UK under the HILL-1 scenario is summarised in Figure HILL1-2. Confidence is based on the degree of evidence (from observations, theory and models) and the agreement amongst the sources of evidence. For this scenario, most of the evidence comes from climate model simulations using RCP8.5 emissions scenarios, as contained in UKCP18 products. There is low confidence that average summer precipitation will increase and average winter precipitation decrease because few models project such changes. Nevertheless, they are still regarded as possibilities.

It is possible that the models used to construct UKCP18 projections underestimate the likelihood of significant step changes in UK weather and climate at very high levels of warming.

4. Applying the scenario

The scenario uses UKCP18 RCP8.5 land and marine projections available through the UKCP18 user interface (https://ukclimateprojections-ui.metoffice.gov.uk/ui/home) or CEDA catalogue, and can be implemented in four ways depending on (i) whether the user is interested in just one climate variable and month/season and or in several variables or months/seasons, and (ii) whether the user uses the probabilistic strand or the global, regional or local strands. The methods outlined here can be used to create scenarios defining change over time or change for specific time slices.

4.1 Single variable and month/season

This method is appropriate where interest is in just one variable and temporal averaging period (e.g. summer maximum temperatures), or where there is interest in more than one variable and averaging period but each can be assumed independent (e.g. interested in both summer temperature and winter rainfall, but not together). This method is appropriate for sea level rise.

HILL-1-1a Probabilistic strand

Where focus is on the largest increase in a climate variable (e.g. largest increase in rainfall) or sea level rise, select the 95th percentile from the RCP8.5 probabilistic strand. If the focus is on the greatest decrease (e.g. largest decrease in rainfall), select the 5th percentile. Note that whilst it is possible to extract joint probabilities of two indicators from the UKCP18 user interface, these use the 90th percentiles to define the extreme range. The UKCP18 probabilistic projections do not include windspeed.

The use of UKCP18 percentiles does not imply that probabilities can be attached to the HILL-1 scenarios.

HILL-1-1b Global, regional or local strand

Use the full HadGEM3-GC3.05 PPE ensemble (for the global or regional strands) or HadREM3-RA11M PPE ensemble (local strand). For temperature, select the member with the largest temperature increase. For rainfall or windspeed, select the member either with the largest increase or the largest decrease, depending on whether focus is on increase or decrease. Note that the lowest and highest members will vary between climate variable, time period and location: no one ensemble member is consistently high or low across all variables, time periods and places.

4.2 Multiple variables and months

This method is appropriate where impact is dependent on more than one climate variable (e.g. temperature and rainfall), on more than one time period (e.g. on all months), or on changes in several places. In this case, impact must be estimated using a model with climate inputs defined by a climate scenario. There are several potential ways of applying UKCP18 climate data with an impact model: this guidance here focuses on which climate information to use, not on how to use it.

HILL-1-2a Probabilistic strand

Use the full set of 3000 individual probabilistic strand ensemble members (or, if this is not practical, a large subset) with an appropriate impact model. Select the 95th percentile (or 5th percentile for largest decrease) from the model output. The use of UKCP18 percentiles does not imply that probabilities can be attached to the HILL-1 scenarios.

HILL-1-2b Global, regional or local strand

Use the full set of global, regional or local strand ensemble members with a model, and select the largest increase (or greatest decrease, as appropriate). No one ensemble member will consistently produce the most extreme impact. Where a model has already been applied (e.g. in the eFLaG River Flow and Groundwater dataset: https://www.ceh.ac.uk/our-science/projects/eflag-enhanced-future-flows-and-groundwater), extract the largest increase or greatest decrease as appropriate.

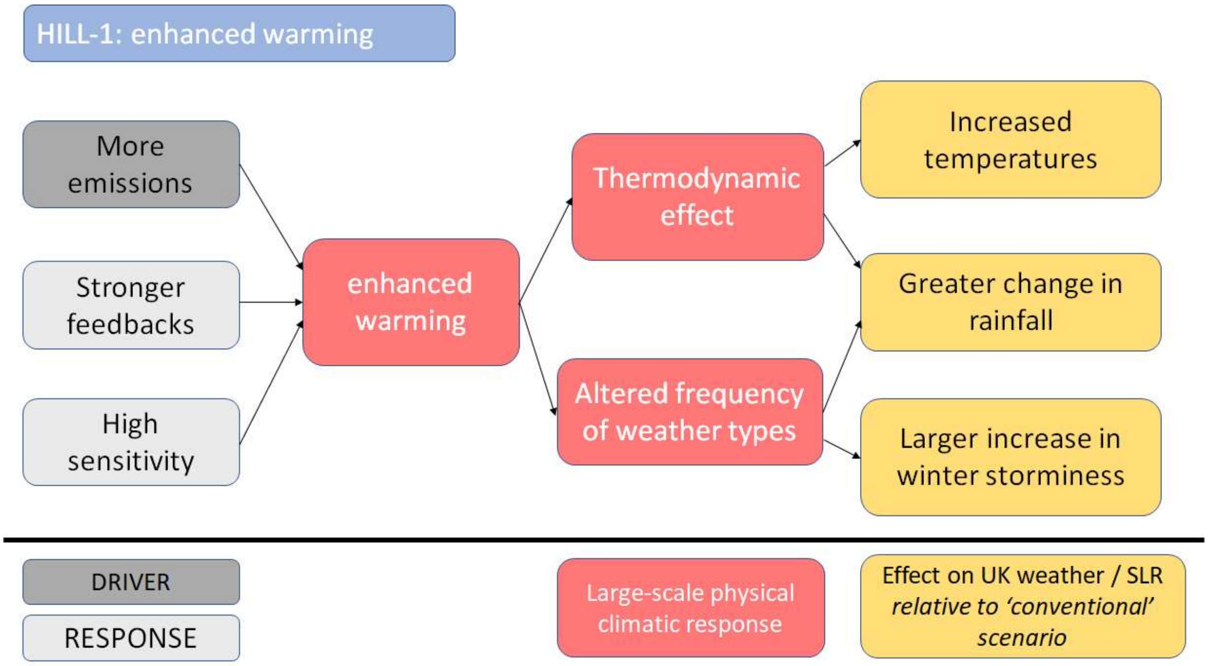


Figure HILL1-1: Causal loop diagram for the enhanced warming scenario. The red boxes describe the large-scale climate processes affected by the storyline, and the yellow boxes describe the consequences for the UK.

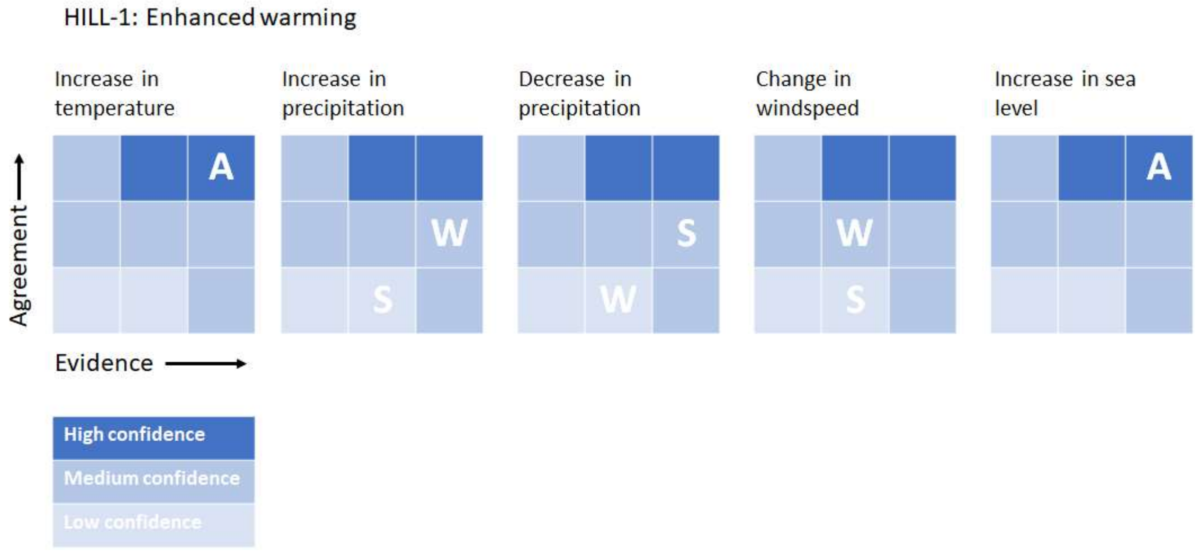


Figure HILL1-2: Confidence in the magnitude of changes in weather and sea level for the UK under the HILL-1 scenario. A: annual, W: winter, S: summer

Table HILL1-1: HILL-1 enhanced warming scenario

Largest average temperature increase (°C)								
	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	4.2	3.5	5.6	4.5	5.6	4.7	7.7	6.2
Wales	4.1	3.5	5.4	4.4	5.4	4.7	7.6	6.1
Scotland	3.7	3.2	4.2	3.8	4.8	4.3	5.9	5.2
Northern Ireland	3.6	3.2	4.5	3.9	4.8	4.3	6.5	5.4
Largest increase in maximum temperature (°C)								
	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	4	3.9	6.7	5	5.3	5.2	9.1	6.7
Wales	3.9	3.8	6.4	4.7	5.2	5.1	8.9	6.4
Scotland	3.6	3.3	4.7	3.8	4.7	4.4	6.7	5.2
Northern Ireland	3.4	3.4	5.2	4	4.6	4.5	7.5	5.5
Wet: largest increase in precipitation (%)								
	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	52	45	46	50	64	46	33	58
Wales	59	47	44	59	69	50	33	64
Scotland	55	45	34	51	66	47	31	54
Northern Ireland	52	46	37	52	63	50	31	61
Dry: largest decrease in precipitation (%)								
	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	-28	-41	-64	-36	-26	-44	-70	-37
Wales	-32	-43	-65	-39	-29	-45	-72	-38
Scotland	-25	-31	-46	-32	-24	-32	-54	-32
Northern Ireland	-27	-37	-54	-35	-23	-39	-62	-36
Windy: largest increase in windspeed (%)								
	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	5	1	0	0	11	3	0	0
Wales	6	2.3	0	1	13	4	0	1
Scotland	8.5	2.8	0	4	14	5	0	3
Northern Ireland	2.1	0.2	0	0	7	0	0	0
Still: largest decrease in windspeed (%)								
	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	-5	-7	-8	-10	-5	-7	-10	-11
Wales	-5	-7	-11	-11	-6	-8	-13	-12
Scotland	-7	-8	-11	-9	-5	-7	-12	-8
Northern Ireland	-6	-8	-11	-10	-8	-7	-13	-10

Relative to 1981-2000 mean

Temperature and precipitation changes taken from the UKCP18 probabilistic strand

Windspeed changes taken from the UKCP18 PPE15 global strand

Table HILL1-2: HI-1 enhanced warming scenario: frequency of ‘extreme’ days

Hot days (% of days)	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	33	39	64	59	44	56	85	77
Wales	33	41	65	60	44	59	87	79
Scotland	35	39	59	59	50	55	84	78
Northern Ireland	29	38	60	58	38	54	84	76

Cold days (% of days)	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1
Wales	0.6	0.3	0.3	0.4	0.2	0.2	0.4	0.4
Scotland	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Northern Ireland	0.6	0.5	0.6	0.6	0.3	0.3	0.4	0.5

Wet days (% of days)	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	16	13	10	11	18	12	9	12
Wales	16	13	9	13	20	14	8	14
Scotland	15	14	12	15	19	14	10	14
Northern Ireland	15	14	12	13	17	14	11	14

Windy days (% of days)	2050s				2070s			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
England	14	12	9	12	14	13	9	11
Wales	14	13	9	13	14	13	9	13
Scotland	14	13	10	13	15	14	9	12
Northern Ireland	13	12	10	11	14	12	9	11

The 1981-2010 frequency is 10%
‘Hot’ days: greater than the 1981-2010 90th percentile daily average temperature
‘Cold’ days: less than the 1981-2010 10th percentile daily average temperature
‘Wet’ days: greater than the 1981-2010 90th percentile daily precipitation
‘Windy’ days: greater than the 1981-2010 90th percentile daily mean windspeed
The thresholds are calculated separately by month and region, and the frequencies of exceedance averaged by nation and season.
Based on UKCP18 PPE15 global strand

HILL-2

Rapid aerosol reductions

Storyline narrative

Air quality concerns result in large, rapid reduction to anthropogenic aerosol emissions, which accelerate greenhouse gas driven warming for a few decades.

Description

Anthropogenic aerosols act to cool the climate, primarily by scattering incoming solar radiation back to space, and by altering the properties of clouds to make them more reflective. Aerosols have offset some of the warming due to increases in greenhouse gases, and rapid reductions in their emissions will unmask this warming.

Storyline type

This storyline describes a **forcing of climate change** at the limit of conventional ranges.

Variants

There are no variants to this storyline

Links to other scenarios

The scenario is independent of the other scenarios.

Implications for UK and sea level

An increase in UK average temperature, of up to 0.75°C degree, relative to scenarios with present-day aerosol emissions. The maximum temperature effect is likely to be felt in the 2040s, when differences between aerosol pathways are largest. No clear effects on precipitation or storminess in the UK.

Confidence

Increase in temperature	Med
Change in rainfall	Low
Change in windspeed	Low

Sources of evidence

The scenario is based on climate model simulations with very different aerosol pathways to 2050 in three climate models. The models span a range of sensitivities to aerosol changes (indicated by their historical aerosol radiative forcing) in the more sensitive half of the CMIP5/6 distribution. The large responses seen in some figure panels likely represent an upper bound. Plausibility is based on technological ability, observed changes in emissions in recent decades, and past climate responses to aerosol changes. Confidence in UK effects is based on a comparison of model responses.

HILL-2 Rapid Aerosol Reductions

1. Description of the scenario

Rapid and major reductions in the emission of aerosols and their precursor gases into the atmosphere lead to more rapid warming across the globe and across the UK than projected in UKCP18 climate scenarios (Figure HILL2-1). The effect of lower aerosol emissions reduces to zero by 2100 because conventional scenarios assume substantial reductions by then.

2. Consequences for weather and sea level in the UK

Enhanced warming due to predominantly Asian aerosol reductions is larger over the Northern Hemisphere than the Southern, and larger over land than ocean. The warming over the UK is therefore slightly larger than the global mean, although there is greater variability between models and individual model runs at the UK scale than the global scale. The radiative effect of Northern Hemisphere aerosols is larger in summer, when incident solar radiation is larger, but the temperature changes over the UK in response to global aerosol reductions are also influenced by changes in the local atmospheric circulation. The UK warms more in winter than summer as anomalous northerlies in summer moderate the temperature increase, while anomalous southerlies enhance it in winter. By the 2040s average temperatures across the UK are 0.75^{o}C higher than in UKCP18 projections.

There is no robust signal from the model simulations of changes in precipitation, sea level pressure and windspeed: for each of the models used to inform the scenario, the effect of reductions in aerosols are small compared with multi-year variability and there are very large differences between individual model members. The consequences for UK weather of a rapid reduction in global aerosol emissions, beyond an increase in temperature, are therefore difficult to determine.

3. Confidence in projected changes in UK weather

Large, rapid aerosol reductions are technically feasible and are plausible. The large reductions included in the emissions scenario used to inform HILL-2 are based on uptake of existing technology and have been observed recently in China. Poor air quality is associated with health issues such as heart disease, lung cancer, lower-respiratory infections, and adverse birth outcomes, so human health is a strong motivation for reducing aerosol emissions. The lifetime of aerosols in the atmosphere is of order days to weeks, so any changes to emissions are rapidly reflected in aerosol burden and air quality. Unlike legislation to reduce greenhouse gas emissions, legislation to reduce aerosol emissions will likely yield results within a political term, which increases the likelihood of changes being made.

There is high confidence that aerosol reductions will result in positive radiative forcing and increases in temperature, both local to and far from the main aerosol emission regions. However, the large uncertainty in historical aerosol radiative forcing seen across CMIP6 and CMIP5 models indicates that there is low confidence in the precise magnitude of the response: there is therefore a medium confidence in change in approximate magnitude (Figure HILL2-2). Non-temperature impacts are uncertain over the UK, and not robust across models.

4. Applying the scenario

The HILL-2 scenario is defined as a temperature difference to be applied to any conventional UKCP18 temperature projection with any emissions scenario. The scenario assumes no difference in 2020, increasing to a maximum increase of 0.75°C in 2040, and decreasing to no difference again in 2100. Interpolate to calculate differences for intermediate years. Table HILL2-1 summarises changes by decade.

Between 2020 and 2040: $dT = 0.0375 * year - 75.75$
Between 2040 and 2100: $dT = -0.0125 * year + 26.25$

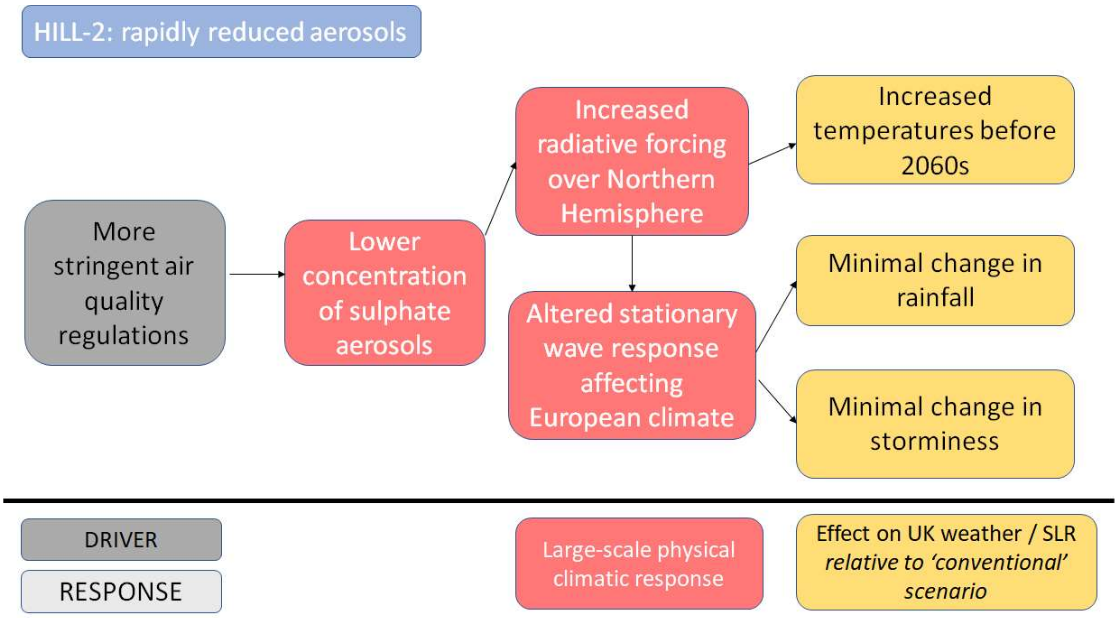


Figure HILL2-1: Causal loop diagram for the reduced aerosol scenario. The red boxes describe the large-scale climate processes affected by the storyline, and the yellow boxes describe the consequences for the UK.

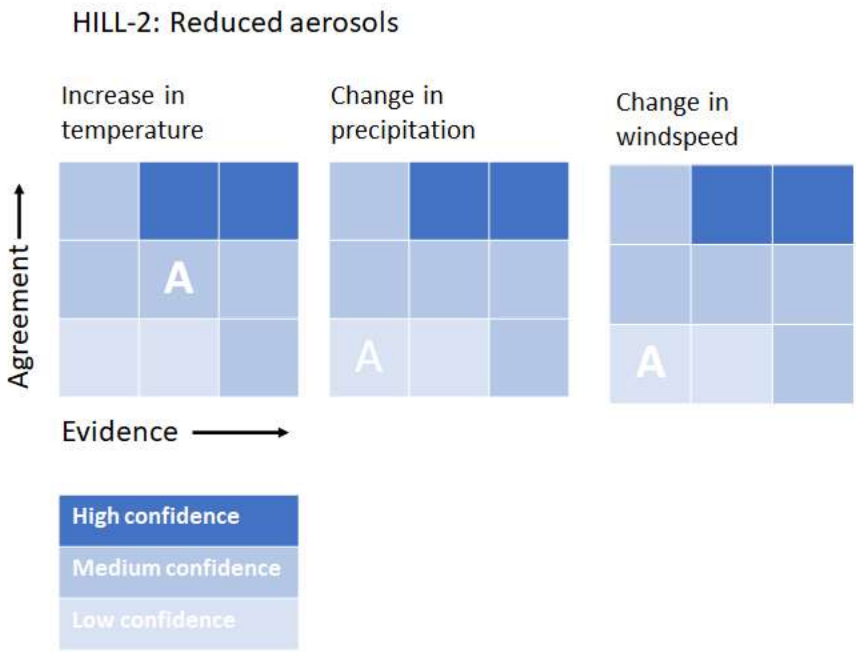


Figure HILL2-2: Confidence in the magnitude of projected changes in temperature, precipitation and windspeed. A denotes ‘annual’: confidence is the same for each season.

Table HILL2-1: Changes in monthly average temperature relative to conventional climate scenarios.

Decade	**Average temperature (°C)**
2020s	0.19
2030s	0.56
2040s	0.69
2050s	0.56
2060s	0.44
2070s	0.31
2080s	0.19

Apply the changes to all months

Add the changes in the table to the temperature changes in the UKCP18 climate scenarios.

HILL-3
Volcanic cooling

Storyline narrative

A major volcanic eruption ejects large quantities of aerosol into the stratosphere, cooling the earth for several years.

Description

Some volcanic eruptions emit large quantities of aerosol directly into the stratosphere, where they remain for several years. These aerosols reflect incoming solar radiation, leading to cooling at the surface of the earth, changes to the hydrological cycle and potentially changes to atmospheric circulation patterns.

Storyline type

The storyline describes a **forcing of climate change** outside the conventional range.

Variants

There are no variants to this storyline.

Links to other scenarios

There is a potential link to HILL-5.

Implications for UK and sea level

A reduction in average temperature for five years across the UK, with the greatest reduction of 2.5°C, relative to the long-term average, in the first year. Reduction in precipitation up to 20% in the first year. No direct effects on storminess or sea level in the UK.

Confidence

Decrease in temperature: High
Decrease in precipitation: Low
Change in windspeed: Low

Sources of evidence

The specific scenario is based on climate model simulations with hypothetical volcanic eruptions. Plausibility and confidence are based on a combination of historical experience, theory and climate model simulations.

HILL-3 Volcanic cooling

1. Description of the scenario

A major volcanic eruption emits aerosols into the stratosphere, which reflect incoming solar radiation leading to surface cooling globally and across the UK, stratospheric warming, changes to the hydrological cycle and potentially changes to atmospheric circulation patterns (Figure HILL3-1).

Volcanic eruptions have generated major shocks to the climate system in the historical and prehistorical past, and the broad consequences of an eruption for weather and climate across the globe are well understood. The primary uncertainty is in the location, timing and size of a volcanic eruption, as well as potential changes in atmospheric circulation affecting the UK.

2. Consequences for weather and sea level in the UK

The scenario defines a **reduction in monthly average temperature of up to 2.5ºC nine months** after the eruption, relative to the temperatures that would have pertained with no eruption. Temperatures return to the underlying trend after 60 months. Monthly **precipitation falls by 20%** by nine months after the eruption (Figure HILL3-2). It is assumed that there is **no change in windspeed** or storminess, because projected changes in atmospheric circulation affecting the UK are highly uncertain. The potential increases in winter precipitation and storminess in the first winter after an eruption outlined above are small relative to year-to-year variability.

3. Confidence in projected consequences for the UK

The plausibility of the driver of the storyline and confidence in the projected consequences for the UK are summarised in Figure HILL3-3.

A VEI7 eruption which would affect the UK is highly plausible – and has occurred in the past – although the timing and magnitude are both highly uncertain.

Confidence is based on the degree of evidence (from observations, theory and models) and the agreement amongst the sources of evidence. For this scenario, evidence comes from past observations, theory and model simulations.

It is well established that such an eruption could affect UK temperatures in the way described by the scenario. However, whilst there are plausible mechanisms for an eruption to alter UK precipitation and storminess, there is considerable uncertainty in whether these would actually be important in practice. This is partly because it depends on the characteristics of the eruption, partly because it is likely to be difficult to separate an effect from year-to-year variability, and partly because different climate models differ in the simulations of the effects of an eruption on atmospheric circulation.

A volcanic eruption would have no effect on sea level rise around the UK.

4. Applying the scenario

The scenario can be applied to any annual time series of monthly temperature and precipitation, assuming a specific month for the eruption. This is illustrated in Figure HILL3-4, which assumes an eruption in January 2025, applied to an example scenario describing change in temperature and rainfall. The precise effect of the scenario will depend on the sequencing of monthly temperature and rainfall.

The effect of multiple eruptions can be approximated by repeatedly applying the scenario.

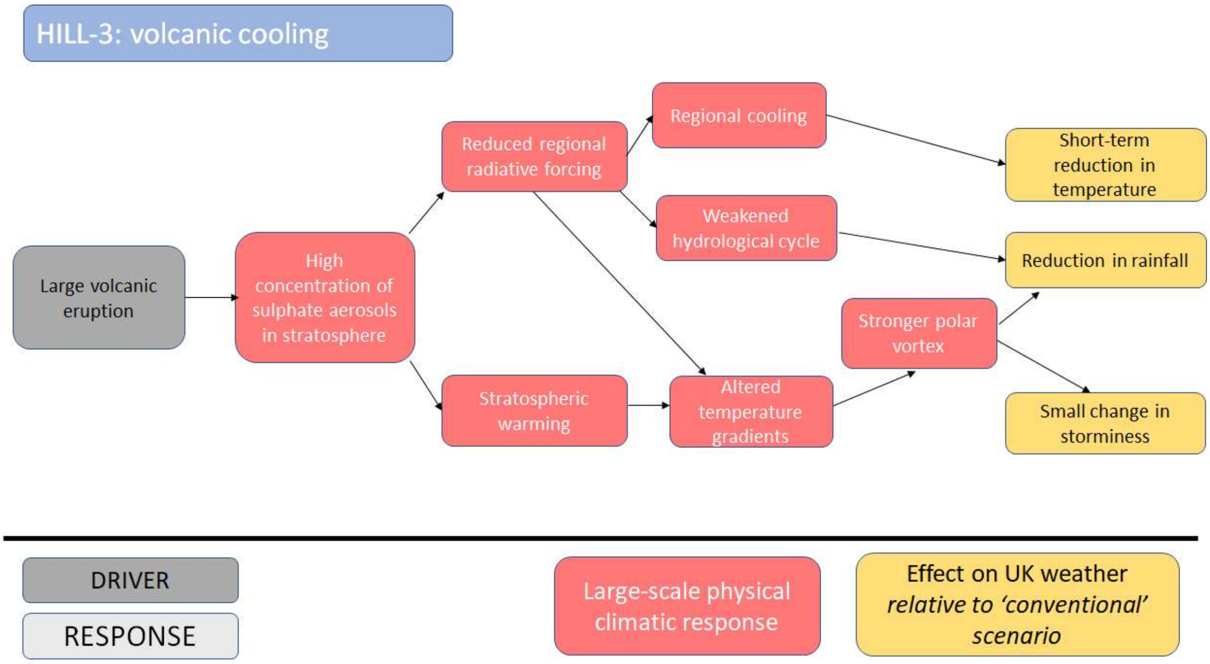


Figure HILL3-1: Causal loop diagram for the volcanic cooling scenario. The red boxes describe the large-scale climate processes affected by the storyline, and the yellow boxes describe the consequences for the UK.

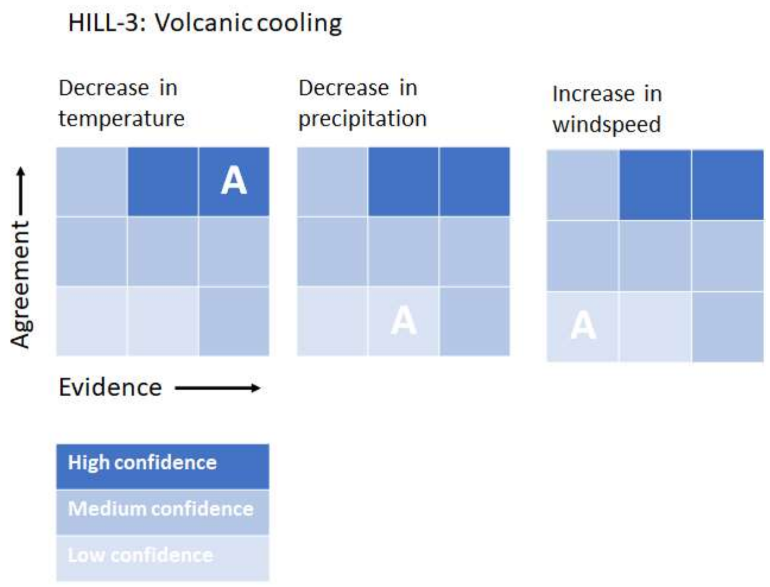


Figure HILL3-2: Confidence in the magnitude of changes in weather for the UK under the HILL-3 scenario. A: annual, W: winter, S: summer

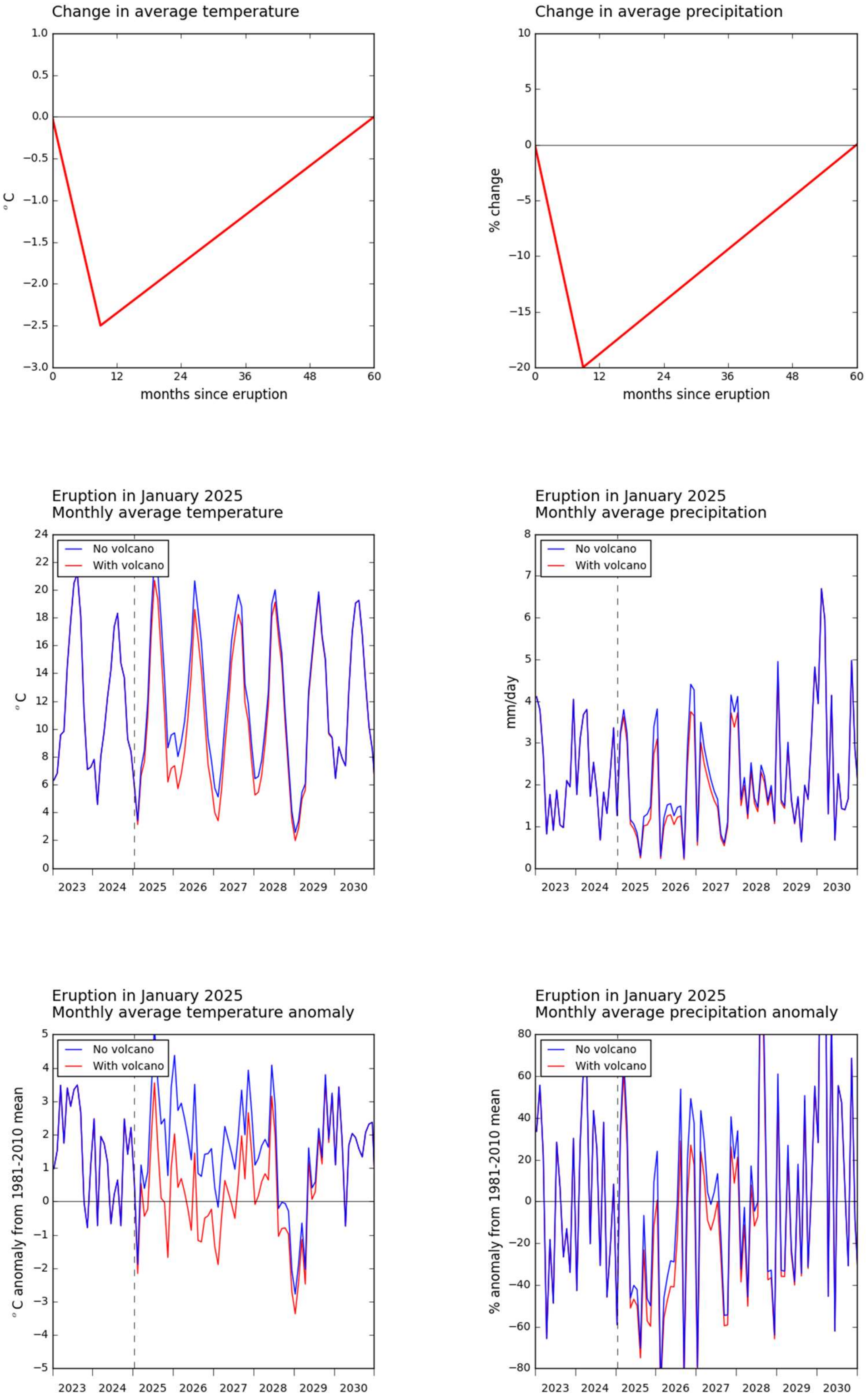


Figure HILL3-3: Scenario and illustration of its application. The top panels show the change in temperature and precipitation by month following the eruption. The middle and bottom panels show the scenario applied to a time series of monthly temperature and precipitation, assuming in this instance an eruption in January 2025. The middle panels show temperature and precipitation in °C and mm/day respectively, whilst the bottom panels show change relative to the 1981-2010 mean. The example temperature and precipitation data are for south east England from the UKCP18 global strand ensemble member 1.

HILL-4
Stronger Arctic Amplification

Storyline narrative

More extreme Arctic Amplification and/or a more extreme response to it, leading to changes in the position of the jet stream and therefore UK weather and climate.

Description

It is well established that high latitudes warm more rapidly than lower latitudes, partly due to amplified feedbacks due to loss of snow and sea ice cover (“Arctic Amplification”). This alters temperature and pressure gradients and leads to a shift in the winter jet stream to the south. This reduces the frequency of westerly weather patterns and increases the exposure of the UK to cold weather events in winter.

Storyline type

The storyline describes a **climate system response** outside the conventional range.

Variants

There are no variants to this storyline.

Links to other scenarios

The plausibility of this scenario is influenced by HILL-1.

Implications for UK climate and sea level

Fewer westerly weather patterns, leading to average temperatures in winter up to 1.5°C cooler by the end of the century than in conventional projections, and lower rainfall and lower windspeeds than in conventional projections. More frequent cold extremes in winter.

Confidence

Decrease in winter temperature:	Low
Decrease in winter rainfall:	Low
Decrease winter windspeed:	Low

Sources of evidence

The specific scenario is based on the UKCP18 RCP8.5 projections. Plausibility and confidence are based on a combination of historical experience, theory and climate model simulations.

HILL-4 Stronger Arctic Amplification

1. Description of the scenario

Rapid increases in temperature in high latitudes and loss of Arctic Sea ice lead to a shift in the jet stream to the south in winter, which alters circulation patterns affecting the UK reducing the frequency and strength of westerly winds (Figure HILL4-1). Increased warming at the surface in high latitudes leads to an increased frequency of sudden stratospheric warmings and a weakening of polar circulation. This increases the frequency of persistently cold weather patterns, and therefore the chance of cold, dry and low wind winters.

2. Consequences for weather and sea level in the UK

By the 2080s, enhanced Arctic Amplification under the scenario here would result in a reduction in temperatures in winter months, relative to what would have occurred without enhanced Arctic Amplification, of 1.5°C (Table HILL4-1). This would lead to an increase in the frequency of exceedance of cold weather extremes where extremes are defined as percentiles (for example the 10th percentile from the conventional distribution). The frequency of extremes below fixed thresholds would reduce as temperatures rise, but more slowly than they would reduce under conventional scenarios.

Precipitation and windspeed in winter months would be reduced by up to 20 and 15 percentage points respectively, relative to conventional scenarios. This has the effect of *reducing* projected increases in precipitation and changing projections of little change in mean windspeed to *reductions* in mean windspeed.

The scenario assumes no change in spring, summer and autumn temperature or windspeed relative to conventional scenarios.

There are no projected effects on sea level.

3. Confidence in projected changes in UK weather

The confidence in the projected consequences for the UK are summarised in Figure HILL4-2.

There is strong evidence that Arctic Amplification is occurring and will continue, but there is limited robust evidence that Arctic sea ice will decline much more rapidly than represented in current climate models.

There is limited evidence that enhanced Arctic Amplification would lead to changes in UK weather and climate outside the range defined by conventional scenarios. The most recent comprehensive assessment of climate model responses concludes that whilst there is a robust weakening of winter circulation in response to increased Arctic sea ice loss, the effect is weak although may be underestimated by models and there is little evidence of a clear effect on temperatures across northern Europe.

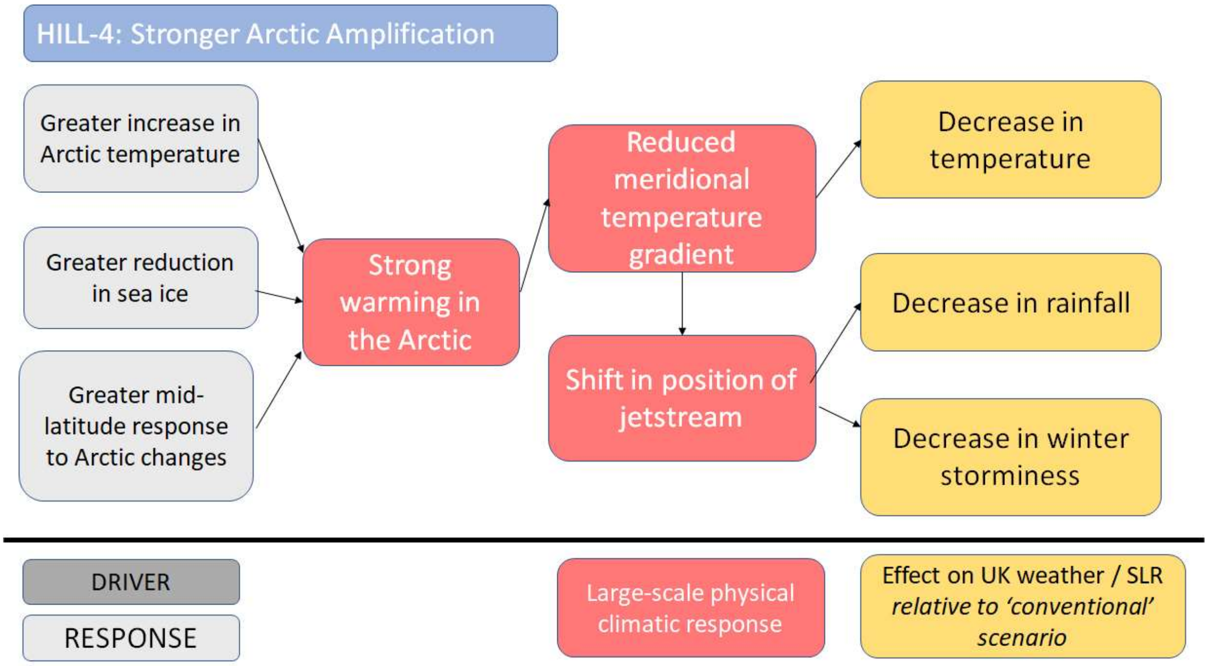


Figure HILL4-1: Causal loop diagram for the Arctic Amplification scenario. The red boxes describe the large-scale climate processes affected by the storyline, and the yellow boxes describe the consequences for the UK.

4. Applying the scenario

The scenario (Table HILL4-1) is defined as an absolute difference to be applied to changes (relative to the 1981-2010 mean) in months between November and April with conventional UKCP18 projections with any emissions scenario. Interpolate between the values in the table to get differences for individual years. The temperature changes can simply be added to any climate projection. To apply the precipitation and windspeed changes, first calculate the difference from the 1981-2010 mean, rescale the difference, and apply back to the 1981-2010 mean. Apply the same changes to each day in the month

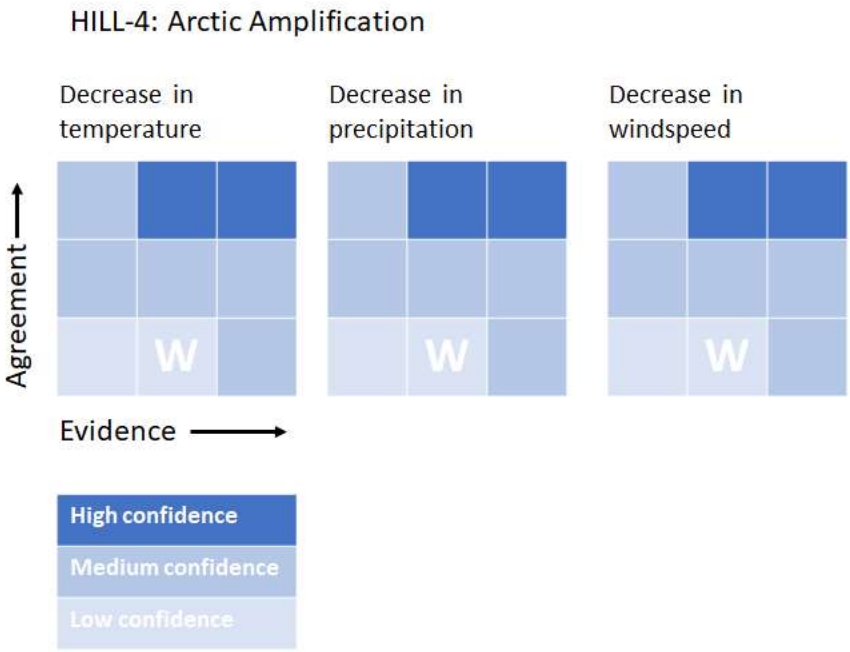


Figure HILL4-2: Confidence in the magnitude of projected changes in winter weather

Table HILL4-1: Changes in winter month average temperature, precipitation and windspeed, relative to conventional climate scenarios.

	Average temperature (°C)	**Average precipitation (% points)**	**Average windspeed (% points)**
2020s	-0.50	-7	-5
2030s	-0.7	-9	-7
2040s	-0.8	-11	-8
2050s	-1.0	-13	-10
2060s	-1.2	-16	-12
2070s	-1.3	-18	-13
2080s	-1.5	-20	-15

Apply the changes to months between November and April.

Add the changes in the table to the absolute (temperature) and percentage (rainfall and windspeed) changes relative to 1981-2010 in the UKCP18 climate projections.

HILL-5
Change in ocean circulation

Storyline narrative

A step change in ocean circulation in the North Atlantic leads to cooling across western Europe.

Description

The temperature of the Atlantic Ocean influences temperatures in the UK and the position of storm tracks. Changes in ocean circulation in the North Atlantic lead to lower sea surface temperatures, and therefore lower temperatures, lower rainfall and stronger storms. Ocean circulation change can be triggered by collapse of the Atlantic Meridional Overturning Current (AMOC) or a collapse of the sub-Polar Gyre (SPG).

Storyline type

The storyline describes a **climate system response** outside the conventional range.

Variants

There are two variants to this storyline:

HILL5a: AMOC collapse
HILL5b: SPG collapse

Links to other scenarios

The plausibility of this scenario is influenced by HILL-1.

Implications for UK climate and sea level

AMOC collapse leads to a reduction in temperature of 5°C below what would otherwise have occurred, a reduction in summer rainfall of up to 40%, an increase in frequency of winter storms, and a higher sea level.

Weakening of the sub-Polar Gyre leads to a reduction in temperature of around 1°C below what would have otherwise occurred, a reduction in summer rainfall of up to 20%, and a small increase in the frequency of winter storms.

Confidence in UK effects

Reduction in temperature:	High
Reduction in winter precipitation:	Low
Increase in winter precipitation:	Med
Reduction in summer precipitation:	Med
Increase in summer precipitation:	Low
Increase in winter windspeed:	Med
Increase in sea level:	Low

Sources of evidence

The specific scenarios are based on the climate model projections. Plausibility and confidence are based on a combination of historical experience, theory and climate model simulations.

HILL-5 Abrupt change in ocean circulation

1. Description of the scenario

An abrupt change in ocean circulation in the North Atlantic leads to lower temperatures across the UK, reduced precipitation (except in the north and west), and stronger windspeeds and more storms in the north and west (Figure HILL5-1). Two variants to the scenario are based on different abrupt changes: a collapse in the Atlantic Meridional Overturning Circulation (HILL-5a) and a collapse in the Sub-Polar Gyre (HILL-5b). HILL-5a describes more extreme changes than HILL-5b.

2. Consequences for weather and sea level in the UK

If the Atlantic Meridional Overturning Circulation (AMOC) were to collapse, then temperatures across the UK would decrease, mean winter precipitation would increase in the north and west and decrease in the south and east, and summer rainfall would decrease across the whole of the UK, relative to the changes that would be expected if the AMOC did not collapse. Winter windspeeds would increase and the number of winter windstorms would increase.

Table HILL5-1 summarises the HILL-5a AMOC collapse scenario: it assumes that collapse begins in 2030, and its maximum effect is seen in 2050. The scenario is based on the hosing experiment reported by Jackson et al. (2015) and Mecking et al. (2016) using HadGEM3 GC2: this was also used by Ritchie et al. (2020). Like Ritchie et al. (2020), it is assumed here that (i) the difference between the stable climates without and with AMOC collapse can be applied to conventional climate scenarios assuming an increase in greenhouse gas concentrations (here UKCP18 projections), (ii) AMOC collapse starts in 2030 and is complete by 2050, and (iii) the full difference is applied after 2050, and between 2030 and 2050 an interpolated difference is applied.

Changes in ocean circulation linked to AMOC collapse lead to changes in sea level, and following collapse sea level around the UK coast could be up to 40cm (after 20 years) higher than without collapse.

If the Sub-Polar Gyre (SPG) were to collapse, the effects would be similar in principle to those of an AMOC collapse, although smaller. Table HILL5-1 summarises the HILL-5b SPG collapse scenario: it assumes that collapse begins in 2030, and its maximum effect is seen in 2050. It is assumed that SPG collapse has no effect on UK sea level rise.

3. Confidence in estimated consequences for the UK

The confidence in the magnitude of the projected changes in temperature, precipitation, windspeed and sea level for the UK is summarised in Figure HILL5-2. Confidence is based on the degree of evidence (from observations, theory and models) and the agreement amongst the sources of evidence. For this scenario, there is evidence from observations (mostly paleoclimatic), theory and models enabling the assessment of changes in climate following AMOC or SPG collapse. However, there is strong disagreement amongst models on the potential magnitude of change in precipitation and windspeed in particular. This disagreement is partly dependent on differences between models in the characteristics of abrupt change in ocean circulation, and partly dependent on differences in simulated response across western Europe to abrupt change.

4. Applying the scenario

The scenarios (Table HILL5-1) are defined as a difference to be applied to conventional UKCP18 projections with any emissions scenario. In both cases, it is assumed that collapse starts in 2030 and has its maximum effect in 2050. Interpolate to estimate differences between 2030 and 2050, and after 2050 apply the differences in Table HILL5-1 in each year. The differences are to be added to the changes defined by conventional UKCP18 projections. For example, if a UKCP18 projection has a change in summer rainfall of -23% in 2050 (relative, for example, to a 1981-2010 baseline), then add the change from Table HILL5-1 (e.g. -25 percentage points for southern England for 2050) to produce a change of -48% which should be applied to the 1981-2010 mean. An example is shown in Figure HILL-5-3. Apply the same monthly change to all days in the month.

The HILL-5a sea level rise scenario is applied by assuming sea level increases above UKCP18 marine projection values by an additional 1.3cm each year every year from the date of collapse, reaching a maximum additional increase of 40cm after 30 years. With a collapse in 2030, after 2060 the sea level rise will therefore be 40cm higher than specified in the UKCP18 marine projections.

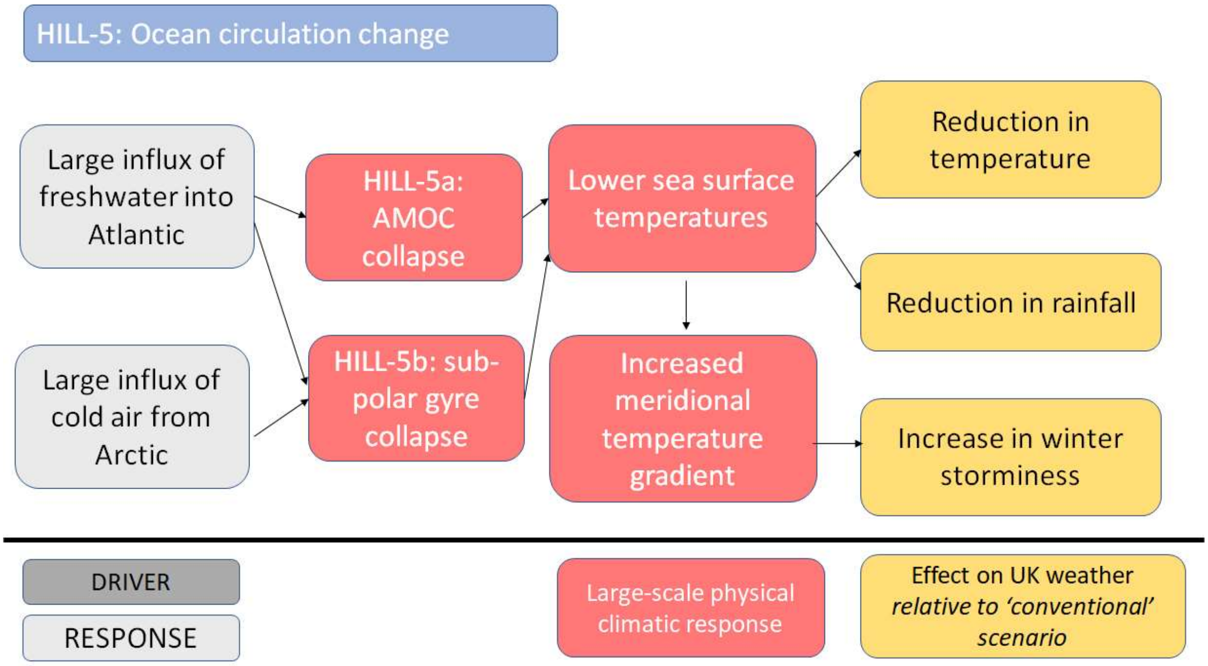


Figure HILL5-1: Causal loop diagram for an abrupt change in ocean circulation. The red boxes describe the large-scale climate processes affected by the storyline, and the yellow boxes describe the consequences for the UK.

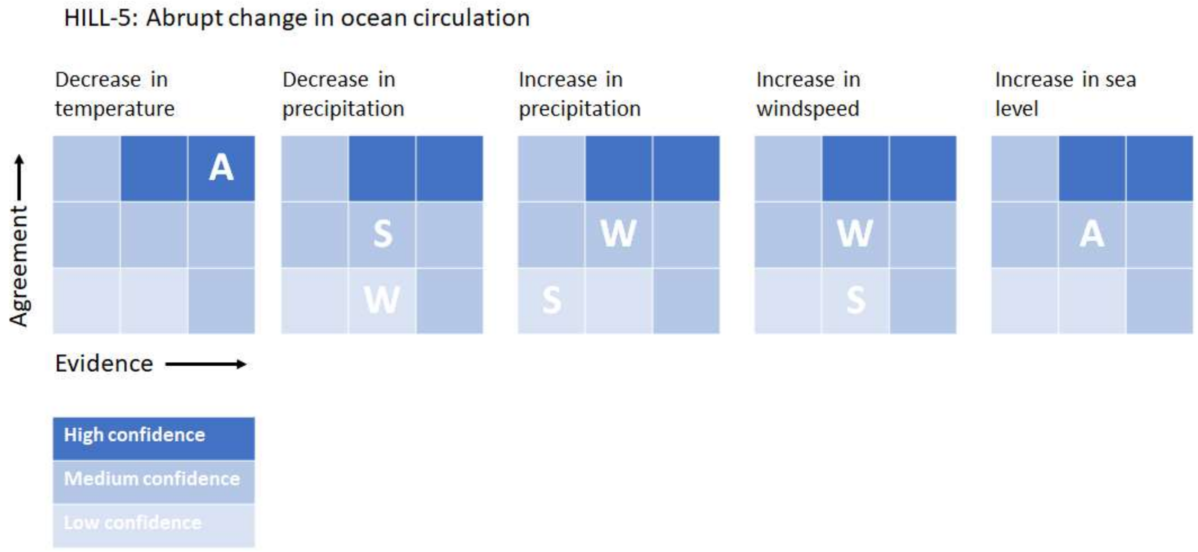


Figure HILL5-2: Confidence in the magnitude of changes in weather and sea level for the UK under the HILL5a and HILL5b scenarios: A: annual, W: winter, S: summer

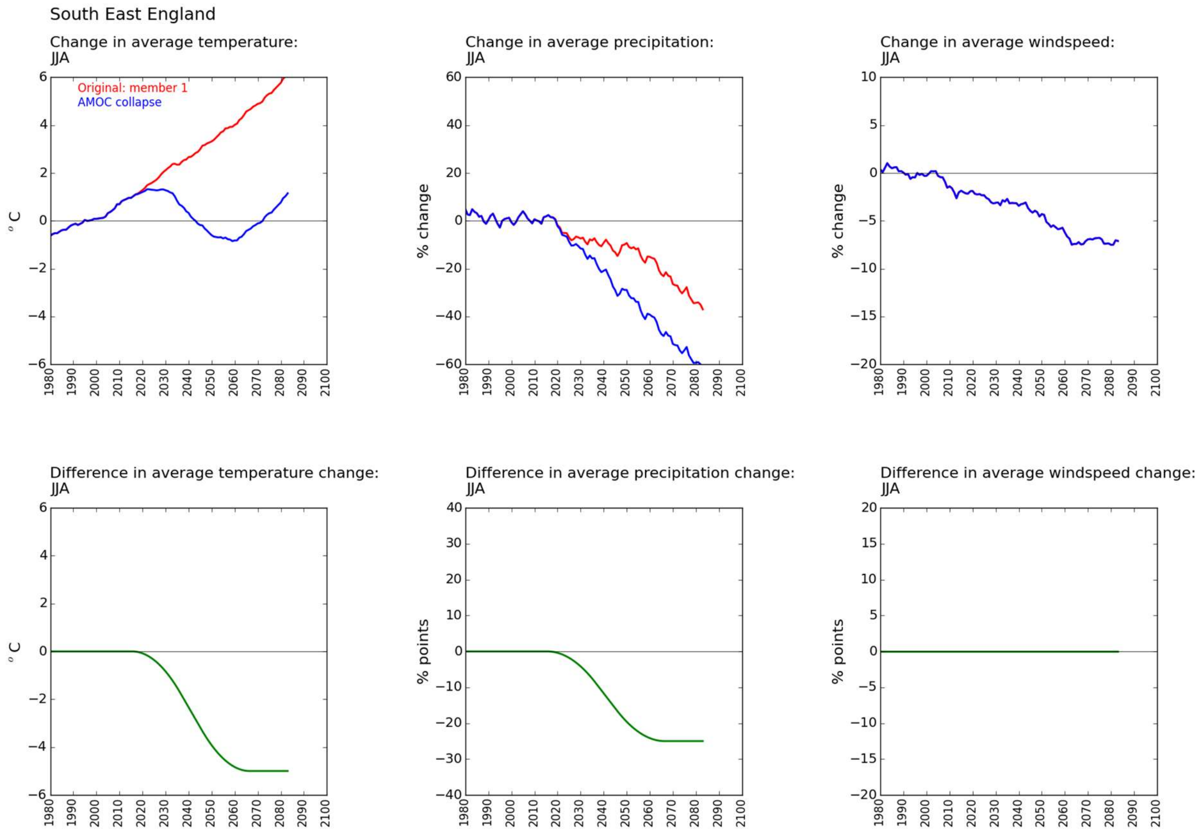


Figure HILL5-3: Example application of HILL-5a AMOC collapse scenario: southern England. The bottom row shows the change applied (from Table HILL5-1) and the top row shows the original and altered projection for change in summer temperature, rainfall and windspeed in southern England. In this example, the changes are applied to the UKCP18 global strand PPE15 member 1.

Table HILL5-1: HILL-5 AMOC collapse and SPG collapse scenarios

The scenarios define change relative to the change from 1981-2010 in conventional climate projections and should be added to conventional projections. Between 2030 and 2050 interpolate to calculate changes and apply the changes in the table from 2050 onwards.

HILL-5a AMOC collapse: Northern UK

	J	F	M	A	M	J	J	A	S	O	N	D
Temperature (°C)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
2040	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
2040s	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5	-4.5
2050	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
Precipitation (% points)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	5	5	0	-5	-5	-8.8	-8.8	-8.8	-5	-2.5	0	5
2040	10	10	0	-10	-10	-17.5	-17.5	-17.5	-10	-5	0	10
2040s	15	15	0	-15	-15	-26.3	-26.3	-26.3	-15	-7.5	0	15
2050	20	20	0	-20	-20	-35	-35	-35	-20	-10	0	20
Windspeed (% points)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	2.5	2.5	1.25	1.25	1.25	0	0	0	1.25	1.25	1.25	2.5
2040	5	5	2.5	2.5	2.5	0	0	0	2.5	2.5	2.5	5
2040s	7.5	7.5	3.75	3.75	3.75	0	0	0	3.75	3.75	3.75	7.5
2050	10	10	5	5	5	0	0	0	5	5	5	10

HILL-5a AMOC collapse: Southern UK

	J	F	M	A	M	J	J	A	S	O	N	D
Temperature (°C)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	-1.25	-1.25	-1.25	-1.25	-1.25	-1.25	-1.25	-1.25	-1.25	-1.25	-1.25	-1.25
2040	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
2040s	-3.75	-3.75	-3.75	-3.75	-3.75	-3.75	-3.75	-3.75	-3.75	-3.75	-3.75	-3.75
2050	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
Precipitation (% points)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	-2.5	-2.5	-3.75	-5	-6.25	-6.3	-6.3	-6.3	-5	-3.75	-3.75	-2.5
2040	-5	-5	-7.5	-10	-12.5	-12.5	-12.5	-12.5	-10	-7.5	-7.5	-5
2040s	-7.5	-7.5	-11.3	-15	-18.8	-18.8	-18.8	-18.8	-15	-11.3	-11.3	-7.5
2050	-10	-10	-15	-20	-25	-25	-25	-25	-20	-15	-15	-10
Windspeed (% points)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	2.5	2.5	1.25	1.25	1.25	0	0	0	1.25	1.25	1.25	2.5
2040	5	5	2.5	2.5	2.5	0	0	0	2.5	2.5	2.5	5
2040s	7.5	7.5	3.75	3.75	3.75	0	0	0	3.75	3.75	3.75	7.5
2050	10	10	5	5	5	0	0	0	5	5	5	10

HILL-5b SPG collapse

	J	F	M	A	M	J	J	A	S	O	N	D
Temperature (°C)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
2040	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
2040s	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9
2050	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
Precipitation (% points)												
2030	0	0	0	0	0	0	0	0	0	0	0	0
2030s	2.5	2.5	0	0	0	-2.5	-2.5	-2.5	0	0	0	2.5
2040	5	5	0	0	0	-5.0	-5.0	-5.0	0	0	0	5
2040s	7.5	7.5	0	0	0	-7.5	-7.5	-7.5	0	0	0	7.5
2050	10	10	0	0	0	-10	-10	-10	0	0	0	10

Mean monthly windspeed is assumed unchanged in HILL-5b

Southern UK includes Wales plus England up to and including the east and west Midlands. Northern UK includes north west England, north east England, Yorkshire and Humberside, Scotland and Northern Ireland.

HILL-6
Enhanced sea-level rise

Storyline narrative

Accelerated ice loss from Antarctica and Greenland will substantially enhance sea-level rise.

Description

Enhanced sea-level rise is driven by changes in the surface mass balance in Greenland, which changes outlet glaciers and dynamics of the main ice sheet, and disintegration of marine ice shelves in Antarctica and the onset of marine ice sheet instability and marine ice cliff instability.

Storyline type

The storyline describes a **climate system response** outside the conventional range.

Variants

There are no variants to this scenario

Links to other scenarios

Enhanced sea-level rise will be influenced by HILL-1.

Implications for UK sea level

Average sea level increases around the UK coastline by between 1.8 and 2.2m by 2100, relative to the 1981-2000 average, with very high emissions. The increase is greatest in southern and eastern England. In a 2°C world the increase is between 0.8 and 1.1m by 2100. Under both emissions scenarios sea level continues to increase after 2100.

Confidence

Plausibility of driver:	Low
Confidence in UK effects:	High

Sources of evidence

The specific scenario is based on climate and ice-sheet model simulations and structured expert evaluation of multiple lines of physical evidence and is taken directly from the IPCC AR6 report. Plausibility and confidence are based on a combination of historical experience, theory and climate and ice-sheet model simulations.

HILL-6 Enhanced sea-level rise

1. Description of the scenario

Accelerated ice loss from Greenland and Antarctica enhance rates of global sea-level rise. With very high emissions (SSP5-8.5) global average sea level rises by 2.3m by 2100 relative to current levels. Even in a 2^{o}C world (SSP1-2.6) Greenland and Antarctica could both experience accelerated ice loss, leading to a global average sea level increase of 1.1m by 2100. The scenarios are based directly on the IPCC AR6 high-end storyline of 21st century sea level rise.

The high-end sea level scenarios are driven by changes in the surface mass balance in Greenland, which changes outlet glaciers and dynamics of the main ice sheet, and disintegration of marine ice shelves in Antarctica and the onset of marine ice sheet instability (MISI) and marine ice cliff instability (MICI) (Figures HILL6-1 and HILL6-2). A range of processes contribute to regional relative sea level variations around the UK coast, including gravitational fingerprint effects, ocean dynamics and vertical land movement.

The effects of thermal expansion and mass loss from glaciers and ice sheets continue long after emissions have slowed or stopped, because it takes many hundreds of years for the cryosphere and the deepest parts of the ocean to adjust to increased air temperatures, and the rise in sea level over the very long term may be several tens of meters.

2. Consequences for weather and sea level in the UK

The rise in sea level around the UK is slightly lower than the global average and varies around the coastline. This variation is partly because the rise in sea level is lower in the north than the south due to the reduced gravitational effect of the reduction in the Greenland Ice Sheet, and partly because the north of the UK is rising due to rebound after the last Ice Age. The greatest increase is along the south and east coasts, and the lowest in the north and west. With high emissions, the maximum increase is 2.2m by 2100 relative to 1981-2000 and the lowest 1.9m; in a 2^{o}C world, the range is 0.8 to 1.0m.

Sea level continues to rise after 2100 under both scenarios. By 2150, the increase with very high emissions would be between 5.5 and 5.8m (an increase of around 3.4m in the 50 years after 2100). In a 2^{o}C world, sea level would rise by 1.3 to 1.6m by 2150 (an increase of around 0.5m in the 50 years after 2100).

3. Confidence in estimated consequences for the UK

The IPCC AR6 (Fox-Kemper et al., 2021) assigned low confidence to the high-end sea level rise storyline. It concluded that whilst theoretical studies provided ‘medium evidence’ of the processes involved in accelerated sea level rise, there was low agreement across studies in quantifying their effects. This is due to limited process understanding, limited availability of evaluation data, missing or crude representation in current models, the high sensitivity of models to uncertain boundary conditions and parameters, and uncertain atmospheric and ocean forcing.

4. Applying the scenario

Projections for sea level rise around the UK with low and very high emissions scenarios based in the IPCC AR6 storyline are available from the NASA sea level projection tool (https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool). The tool includes projections for 44 sites around the UK (plus two on the Isle of Man).

Option 1

Select a location and download the data spreadsheet. The HILL-6 scenarios are the 95th percentile rows for the low confidence SSP1-2.6 (2°C world) and SSP5-85 (very high emissions world) scenarios in the ‘Total’ worksheet. Note that the 95th percentile should not be interpreted as a likelihood: it is best interpreted as a characterisation of an extreme. The spreadsheets also contain projections for the components of sea level rise. Note that the sum of components for a given percentile does not correspond to the total sea level rise for that percentile (this is because of the way the statistical emulator used to construct the scenarios worked). The AR6 scenarios extend to 2150.

The AR6 scenarios present sea level rise relative to the 1995-2014 mean. For consistency with the UKCP18 Marine Projections which use a 1981-2000 reference level, add 0.041m to the AR6 scenarios.

Option 2

Use the regional average sea level projections shown in Table HILL-6-1.

Fox-Kemper, B. et al. (2021). Ocean, cryosphere and sea level change. In V. Masson-Delmotte et al. (Eds.), *Climate change 2021: The physical science basis*. Contribution of Working Group 1 to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

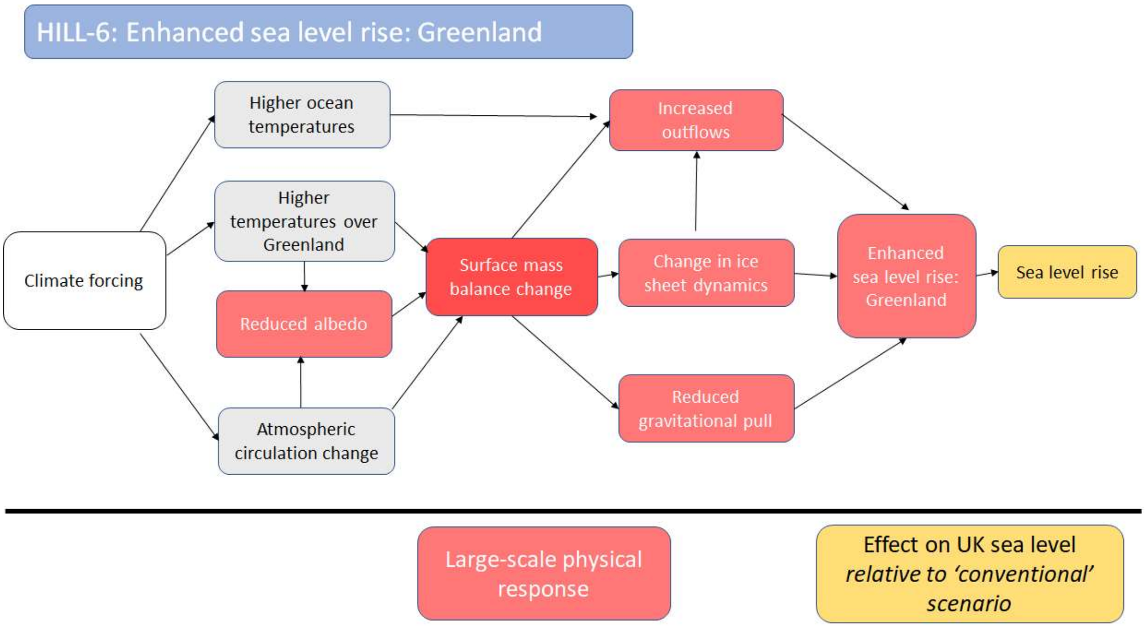


Figure HILL6-1: Causal relation between processes leading to a high-end contribution of Greenland to sea level rise.

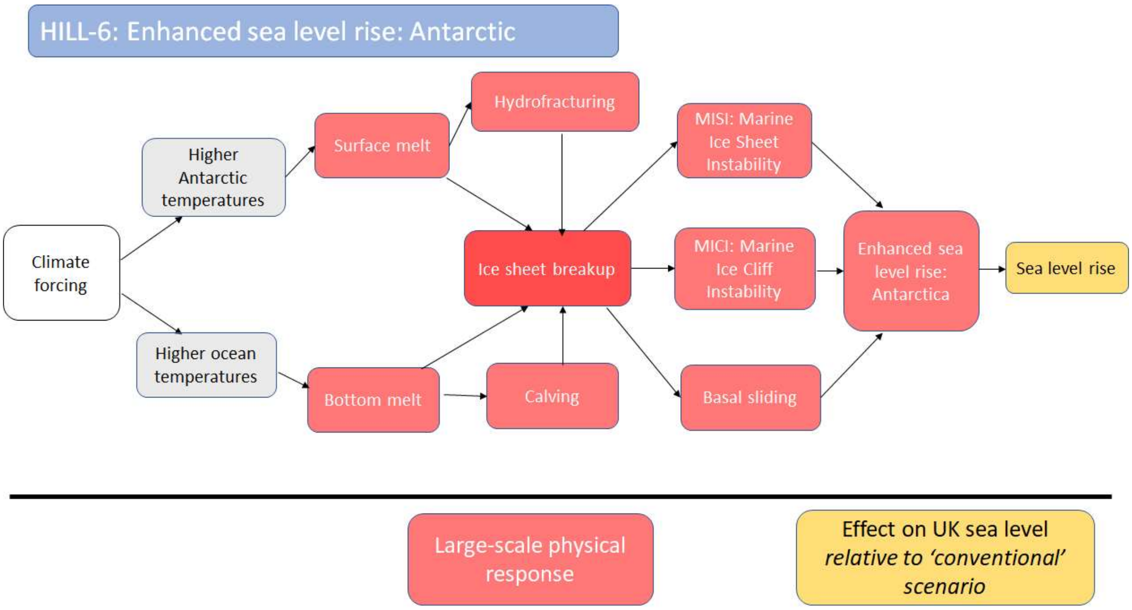


Figure HILL6-2: Causal relation between processes leading to a high-end contribution of Antarctica to sea level rise.

Table HILL6-1: Regional average sea level rise scenarios, in meters relative to 1981-2000

Emissions		2020	2030	2040	2050	2060	2070	2080	2090	2100
Low	South and East	0.18	0.26	0.35	0.46	0.56	0.65	0.74	0.85	0.96
High	South and East	0.17	0.26	0.40	0.56	0.74	0.98	1.28	1.67	2.11
Low	North and West	0.17	0.23	0.31	0.41	0.49	0.57	0.65	0.74	0.83
High	North and West	0.16	0.24	0.36	0.50	0.66	0.88	1.17	1.53	1.95

South and east: south west England, south east England, east England, Yorkshire and Humberside, north east England, eastern Scotland, south Wales
North and west: northern Scotland, western Scotland, north west England, north Wales, Northern Ireland

Part B: HILL Extreme Anomalies

Introduction

The scenarios describe plausible extreme ‘worst-case’ months and seasons (winter, spring, summer and autumn), defined in terms of temperature, rainfall and windspeed. They are expressed as differences from a long-term mean (“anomalies”) and are intended to characterise maximum departures from ‘average’ conditions in a year as an aid to planning for extreme conditions. They do not describe extreme short-duration events (such as heatwaves, cold spells, windstorms and heavy rainfall) and are not intended as replacements for sector-specific extreme scenarios.

Principal assumptions

The scenarios are presented as departures from a long-term mean, which can be applied to a long-term mean calculated over any period of at least 30 years – for example 1981-2010, 2021-2050 or 2041-2070. The anomalies are based on historical experience and physical plausibility, and it is assumed that the magnitude of the potential extreme anomalies does not change over time: there is however some evidence that extreme rainfall anomalies may become more extreme in summer. It is assumed that the anomalies apply across the whole of the UK at the same time. Likelihoods are not assigned to the scenarios, but they are all assumed to be physically plausible.

Plausible maximum anomalies vary with spatial scale: the finer the scale, the larger the maximum potential anomaly. The headline quantifications presented here are for the regional scale (UK administrative regions). Table HILL-E1 gives suggested factors to convert to anomalies at different spatial scales: interpolate for other scales.

The scenarios describe temperature, rainfall and windspeed anomalies. Corresponding extreme anomalies for other climate variables can if necessary be defined from the narrative storylines.

Three sets of scenarios

Three sets of scenarios are defined. The first set characterises individual extreme months or seasons. The five basic scenarios in this set describe hot, cold, wet, dry or windy months or seasons. Each has compound variants describing plausible combinations of temperature, rainfall and windspeed (for example hot, wet and windy), and each has a ‘backstory’ describing the meteorological conditions and climate drivers associated with the extreme. A sequence of extreme months or seasons can be constructed by assuming that each month or season is independent of the one before.

The second set of scenarios explicitly assumes that persistent anomalous weather continues for successive months. They are based on four storylines describing the climatic conditions generating anomalous weather (strongly cyclonic or strongly anticyclonic) in two seasons (extended winter, from November to April, and extended summer, from May to October). Each scenario describes compound anomalies – relative to a long-term mean - in monthly temperature, rainfall and windspeed for sequences of months.

The third set of scenarios is based on observed historical extreme monthly events (analogue scenarios). These scenarios are less extreme than the first two sets but incorporate realistic spatial variability and compound anomalies in temperature, rainfall and windspeed.

Sources of evidence

The scenarios are collectively based on four lines of evidence: historical observations of temperature, rainfall and windspeed, statistical analysis of relationships with drivers of climatic variability, interpretation of the output from climate model simulations, and physical reasoning.

Table HILL-E1: Adjustments to apply to the regional scenarios for extreme anomalies at different spatial scales

Variable	**Scale**	**Month**	**Month**	**Season**	**Season**
		Hot	**Cold**	**Hot**	**Cold**
Temperature	5x5km = 25km^2	+1°C	-1	+1°C	-1
	12x12 = 144km^2	+1	-1	+1	-1
	25x25 = 625km^2	+1	-1	+1	-0.75
	60x60 = 3600km^2	+0.5	-0.5	+0.75	-0.5
		Wet	**Dry**	**Wet**	**Dry**
Rainfall	5x5km = 25km^2	x1.5	0	x1.5	0
	12x12 = 144km^2	x1.3	0	x1.3	0.3
	25x25 = 625km^2	x1.2	0	x1.2	0.5
	60x60 = 3600km^2	x1.1	0	x1.1	0.7
		Windy	**Calm**	**Windy**	**Calm**
Windspeed	5x5km = 25km^2	x1.25	x0.4	x1.2	x0.7
	12x12 = 144km^2	x1.25	x0.6	x1.2	x0.7
	25x25 = 625km^2	x1.1	x0.8	x1.1	x0.9
	60x60 = 3600km^2	x1	x1	x1	1x

Apply the temperature adjustments as absolute changes to the regional extreme anomalies, and the rainfall and windspeeds adjustments as ratio changes.

Set 1 anomaly scenarios

These scenarios describe extreme hot, cold, wet, dry or windy anomalies. They are summarised below.

A plausible sequence of months and seasons can be constructed by joining extreme anomaly scenarios in any combination (for example hot, wet, hot, dry, wet).

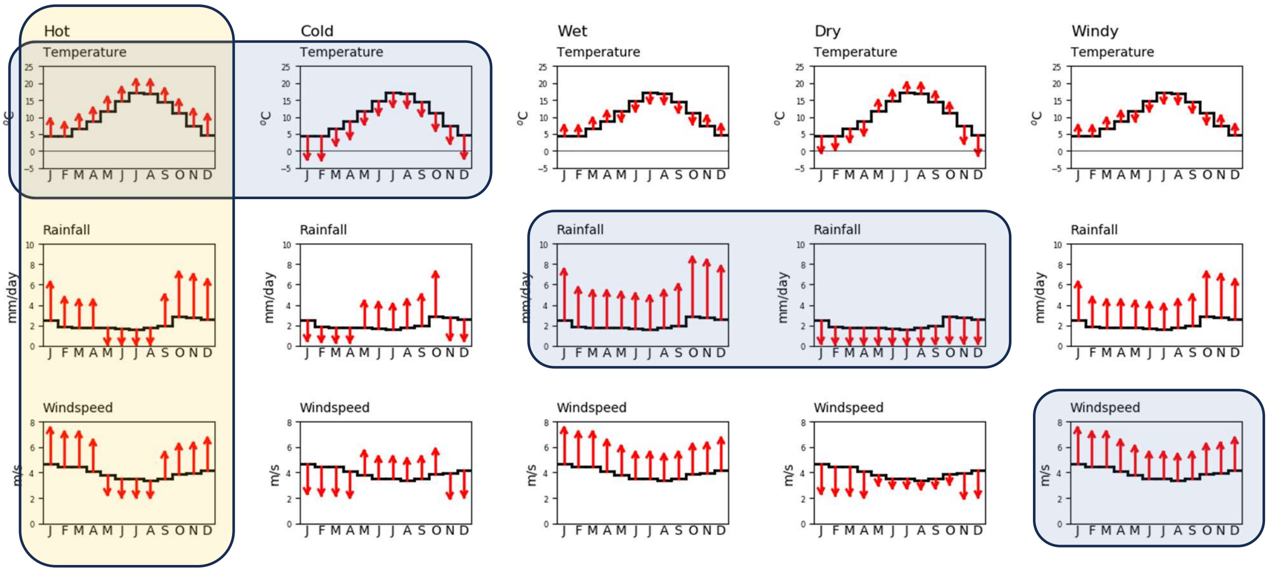


Illustration of the Set 1 extreme monthly anomalies for an example location in England. The arrows illustrate an extreme anomaly from the long-term mean. Anomalies in each month can be assumed to be independent. The blue shaded boxes show the core hot, cold, wet, dry and windy scenarios. The orange shaded box illustrates the compound hot extreme anomaly scenarios.

HILL Extreme Anomaly:
Hot

Characteristics

Regional average monthly temperatures **4°C** above the long-term mean between February and October, and **5°C** above the mean in November and January. December average temperatures **6°C** above the long-term mean in England from the Midlands southwards, and **5°C** above the long-term mean elsewhere.

Average seasonal temperatures **3°C** above the long-term mean across the UK.

Compound months and seasons

November to April

Wet (rainfall **2.5** times the long-term mean) and **windy** (mean windspeed **1.6** times the long-term mean)

Winter season **wet** (rainfall **2** times the long-term mean) and **windy** (mean windspeed **1.4** times the long-term mean)

May to October

Dry (rainfall **10%** of mean) and **calm** (mean windspeed **60%** of mean)

Summer season **dry** (rainfall **25%** of mean) and **calm** (mean windspeed **80%** of mean)

Spring season

Wet (**2** times the mean) and **windy** (**1.4** times the mean) or **dry** (**25%** of mean) and **calm** (**80%** of mean).

Autumn season

Wet (**2** times the mean) and **windy** (**1.4** times the mean) or **dry** (**25%** of mean) and **calm** (**80%** of mean).

Note: extreme anomalies at finer spatial scales are larger

Narrative storyline

November to April

Mild months and winter seasons are generated by a strong jet stream bringing frequent weather systems across the Atlantic. Airflows are predominantly from the west or south west, and cyclonic conditions dominate. The NAO index is positive. Weather patterns 4, 15 and 21 are common.

May to October

Hot months and summer seasons occur when a weak, highly meandering jet stream enables the development of persistent atmospheric blocks associated with quasi-stationary planetary waves and anticyclones affecting UK weather patterns. Airflows are predominantly from the south, south east or south west. The (summer) NAO index is positive, and pressure is high over Scandinavia. Sea surface temperatures around the UK are higher than average. Dry soils across Europe amplify the high temperatures due to enhanced positive feedbacks. Increased chance of intense convection and heavy localised rainfall. Weather patterns 17 and 27 are common.

Spring

Hot springs can be generated either by a strong jet stream (extended mild winter) or by blocking anticyclones (early hot summer)

Autumn

Hot autumns can be generated either by blocking anticyclones (extended hot summer) or a strong jet stream (early mild winter)

HILL Extreme Anomaly: Cold

Characteristics

Regional average monthly temperatures **7°C** below the long-term mean between December and February, **5°C** below the mean in March, April, October and November, and **4°C** below the mean between May and September.

Average winter seasonal temperatures **5°C** below the long-term mean across the UK, and **3°C** below the long-term mean in spring, summer and autumn.

Compound months and seasons

November to April

Dry (rainfall down to **20%** of the long-term mean) and **calm** (mean windspeed down to **50%** of the long-term mean) and can be foggy

Winter season **dry** (rainfall down to **40%** of the long-term mean) and **calm** (mean windspeed down to **75%** of the long-term mean)

May to October

Wet (rainfall **2.5** times the mean) and **windy** (mean windspeed **1.6** times the long-term mean)

Summer season **wet** (rainfall **2** times the mean) and **windy** (mean windspeed **1.2** times the long-term mean)

Spring season

Wet (**2** times the mean) and **windy** (up to **1.4** times the mean) or **dry** (**25%** of mean) and **calm** (**80%** of mean).

Autumn season

Wet (**2** times the mean) and **windy** (**1.4** times the mean) or **dry** (**25%** of mean) and **calm** (**80%** of mean).

Narrative storyline

October to April

Cold months and winter seasons are generated by persistent anticyclonic conditions centred over Eurasia and Scandinavia, occurring when a weak, meandering jet stream leads to blocking. Airflows are predominantly from the north east, east and south east. The NAO and Arctic Oscillation are negative, and the stratospheric polar vortex is weak. Sudden Stratospheric Warmings lead to cold spells. Persistent snow cover amplifies cold extremes. Weather patterns 27 and 28 are common.

May to September

Cool months and summer seasons occur when a strong jet stream to the south of its average position brings a succession of weather systems across the UK from the west. Airflows are predominantly from the north and north west. Weather patterns 19, 26 and 30 are common.

Spring

Cold springs can be generated either by prolonged anticyclonic conditions (extended cold winter) or by a strong southerly jet stream (early cool summer).

Autumn

Cold autumns can be generated either by early anticyclonic conditions (early cold winter) or by a continuation of a strong southerly jet stream (late cool summer).

Note: extreme anomalies at finer spatial scales are larger

HILL Extreme Anomaly:
Wet

Characteristics

Regional average monthly rainfall **3** times the long-term mean in England, Wales and Northern Ireland, and **2.5 times** the long-term mean in Scotland

Average seasonal rainfall **2** times the long-term mean in England, Wales, Scotland and Northern Ireland

Compound months and seasons

November to April

Mild (temperature **3°C** above the long-term mean) and **windy** (mean windspeed **1.6** times the long-term mean)

Winter season **mild** (temperature **2°C** above the long-term mean) and **windy** (mean windspeed **1.25** times the long-term mean)

May to October

Cool (temperature **3°C** below the mean) and **windy** (mean windspeed **1.6** times the long-term mean)

Summer season **cool** (temperature **2°C** below the mean) and **windy** (mean windspeed 1.2 times the long-term mean)

Spring season

Warm (**2°C** above the long-term mean) and **windy** (**1.3** times the mean) or **cool** (**2°C** below the long-term mean) and **windy** (**1.3** times the mean).

Autumn season

Warm (**2°C** above the long-term mean) and **windy** (1.3 times the mean) or **cool** (**2°C** below the long-term mean) and **windy** (1.3 times the mean).

Narrative storyline

Wet months and seasons in England and Wales are generated by a strong jet stream to the south of its average position bringing frequent weather systems and storms across the Atlantic. Airflows are predominantly from the south or south west, and cyclonic conditions dominate. The NAO and East Atlantic pattern indices are both positive.

Wet months and seasons in Scotland and Northern Ireland are generated by a strong jet stream, with airflows predominantly from the west and south west. Westerly conditions dominate.

Weather patterns 29 and 30 are common throughout the year. In summer, weather patterns 11 and 24 are common in England and Wales, and 29 is common further north.

Note: extreme anomalies at finer spatial scales are larger

HILL Extreme Anomaly: Dry

Characteristics

Regional average monthly rainfall **10% (x0.1)** of the long-term mean

Average seasonal rainfall **30% (x0.3)** of the long-term mean

Compound months and seasons

November to April

Cool (temperature **4°C** below the long-term mean, and **6°C** below in December-January) and **still** (mean windspeed **50% less** than the long-term mean)

Winter season **cool** (temperature **3°C** below the long-term mean) and **calm** (mean windspeed **20% less** than the long-term mean in England and Wales and **40% less** in Scotland and Northern Ireland)

May to October

Hot (temperature **3°C** above the mean) and **calm** (mean windspeed **20% less than** the long-term mean)

Dry summers can be **hot** (temperature **2°C** above the mean) and **calm** (mean windspeed 10% less than the long-term mean)

Spring season

Cool (**2°C** below the long-term mean) and **calm** (**20% less** than the mean) or **hot** (**2°C** above the long-term mean) and **calm** (**20% less** than the long-term mean)

Autumn season

Warm (**2°C** above the long-term mean) and **calm** (**20% less** than the mean) or **cool** (**2°C** below the long-term mean) and **calm** (**20% less** than the mean)

Narrative storyline

Dry months and seasons in England and Wales are generated by a jet stream to the north of its average position, resulting in weather systems passing further north than usual. Anticyclonic conditions dominate with high pressure over Scandinavia, and airflows typically come from the east and south east. In summer the NAO is strongly positive and in winter strongly negative. Persistent dry conditions across Europe lead to further reductions in rainfall due to reductions in precipitation recycling, exaggerating the dynamic effect.

Dry months and seasons in Scotland and Northern Ireland are typically generated by a weak jet stream. Anticyclonic conditions dominate with frequent airflows from the east, south east and south.

Weather patterns 17, 25, 27 and 18 are common.

Note: extreme anomalies at finer spatial scales are larger

HILL Extreme Anomaly: Windy

Characteristics

Regional average monthly windspeed **1.6 times** the long-term mean in England and Northern Ireland, and **1.8 times** the long-term mean in Scotland and Wales

Average seasonal windspeed **1.5 times** the long-term mean

Compound months and seasons

November to April

Mild (temperature **3°C** above the long-term mean) and **wet** (**2.5 times** the long-term mean)

Winter season **mild** (temperature **2°C** above the long-term mean) and **wet** (**2** times the long-term mean)

May to October

Cool (temperature **3°C** below the mean) and **wet** (**2.5** times the long-term mean)

Windy summers can be **cool** (temperature **2°C** below the mean) and **wet** (**2** times the long-term mean)

Spring season

Hot (**2°C** above the long-term mean) and **wet** (**2** times the mean) or **cool** (**2°C** below the long-term mean) and **wet** (**2** times the mean).

Autumn season

Hot (**2°C** above the long-term mean) and **wet** (**2** times the mean) or **cool** (**2°C** below the long-term mean) and **wet** (**2** times the mean).

Narrative storyline

Windy months and seasons are generated by a strong jet stream bringing frequent weather systems and clusters of storms across the Atlantic. Airflows are predominantly from the west and south west, and cyclonic conditions dominate.

Weather patterns 20, 26 and 30 are common throughout the year.

Note: extreme anomalies at finer spatial scales are larger

Set 2: Persistently extreme anomalies

These scenarios describe plausible sequences of extreme anomalies driven by persistent climatic drivers. They are summarised below.

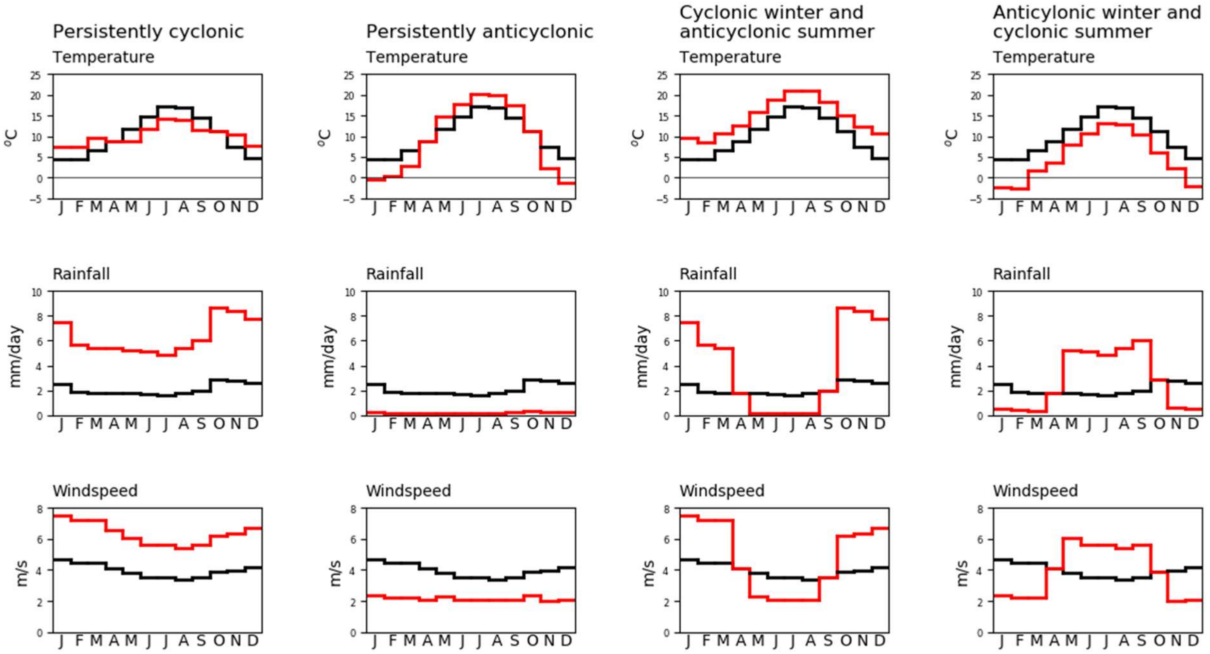


Illustration of the Set 2 extreme persistent monthly anomalies for an example location in England. The red line shows the maximum anomaly from the long-term mean.

HILL Extreme Anomaly: Persistently cyclonic

Characteristics

Rainfall **3** times the mean and windspeeds **1.6** times the mean, with temperatures **3ºC above** the mean between November and March and **3ºC below** the mean between May and September: April and October temperatures are close to the mean.

Storyline

This storyline describes persistently wet and windy conditions. Temperatures are below the long-term average in summer and above the average in winter.

Persistent cyclonic conditions bring mild, wet air from the west with high windspeeds and frequent and clustered storms. Strong cyclonic conditions are associated with a strong jet stream and in winter are characteristic of a strong North Atlantic Oscillation, positive East Atlantic Pattern and positive Arctic Oscillation. In summer, the jet stream is to the south of its average position. The summer NAO and the Arctic Oscillation are negative.

Weather patterns in cyclonic conditions come from across the Atlantic Ocean. In winter, temperatures are therefore milder than average, and in summer they are cooler than average. This effect is exaggerated during winter because sea surface temperatures around the UK are higher than average during persistent cyclonic conditions.

At some point in spring and autumn temperatures will be close to average. Met Office Weather Patterns 20, 23 and 26 are examples of strongly cyclonic conditions.

Similar conditions can persist across the whole of the UK.

Note: extreme anomalies at finer spatial scales are larger

HILL Extreme Anomaly: Persistently anticyclonic

Characteristics

Rainfall **10%** of the mean and windspeeds **50%** of the mean, with temperatures **3ºC below** the mean between November and March and **3ºC above** the mean between May and September: April and October temperatures are close to the mean.

Storyline

This storyline describes persistently dry and calm conditions. Temperatures are above the long-term average in summer and below the average in winter.

Persistent anticyclonic conditions bring dry air from the east and south. In winter this air is colder than average, and in summer is warmer than average. Persistent anticyclonic conditions are associated with a weak jet stream that has generated large meanders and persistent blocking, and a strong Scandinavian High Pressure anomaly. During winter cold spells are preceded by Sudden Stratospheric Warming and southerly extension of the Polar Vortex. During summer, persistent hot anticyclonic conditions increase the chance of intense convective storms and heavy localised rainfall.

At some point in spring anticyclonic conditions shift from bringing cold air to the UK to bringing warm air: this transition can be sudden. Similarly, in autumn the shift from warm to cold conditions can be abrupt.

‘Persistent’ anticyclonic conditions do not imply that a single anticyclone persists for many months, but rather that anticyclonic conditions lasting many days occur frequently with short interludes. Met Office Weather Patterns 17 and 27 are examples of strongly anticyclonic conditions.

Persistently anticyclonic conditions are associated with stronger feedbacks between the surface and the atmosphere, leading to higher hot extremes in summer, colder cold extremes in winter, and drier dry extremes.

Similar conditions can persist across the whole of the UK.

Note: extreme anomalies at finer spatial scales are larger

HILL Extreme Anomaly: Cyclonic in winter and anticyclonic in summer

Characteristics

Temperatures **3ºC** above the mean, with high rainfall (**3 times** the mean) and windspeeds (**1.6 times** the mean) between October and March and low rainfall (**10%** of the mean) and windspeeds (**50%** of the mean) between May and August: April and September rainfall and windspeed are close to the mean.

Storyline

This storyline is hot all year round but wet in winter and dry in summer.

Persistent cyclonic conditions bring mild, wet air from the west in winter with high windspeeds and frequent and clustered storms. Strong cyclonic conditions are associated with a strong jet stream and are characteristic of a strong North Atlantic Oscillation and Arctic Oscillation. Sea surface temperatures around the UK are above average. Weather patterns in cyclonic conditions come from across the Atlantic Ocean and are therefore milder than average. Met Office Weather Patterns 20, 23 and 26 are examples of strongly cyclonic conditions.

Persistent anticyclonic conditions in summer bring dry air from the east and south, which is warmer than average. They are associated with a weak jet stream that has generated large meanders and persistent blocking, and a strong Scandinavian High Pressure anomaly. 'Persistent' anticyclonic conditions do not imply that a single anticyclone persists for many months, but rather that anticyclonic conditions lasting many days occur frequently with short interludes. Met Office Weather Patterns 17 and 27 are examples of strongly anticyclonic conditions. Persistently anticyclonic conditions are associated with stronger feedbacks between the surface and the atmosphere, leading to higher hot extremes and drier dry extremes. Persistent hot anticyclonic conditions increase the chance of intense convective storms and heavy localised rainfall

A shift from persistently cyclonic conditions to persistently anticyclonic conditions (and vice versa) can be very abrupt and occur over a few days.

Similar conditions can persist across the whole of the UK.

Note: extreme anomalies at finer spatial scales are larger

HILL Extreme Anomaly: Anticyclonic in winter and cyclonic in summer

Characteristics

Temperatures **3ºC** below the mean, with low rainfall (**10% of** the mean) and windspeeds (**50% of** the mean) between October and March and high rainfall (**3 times** the mean) and windspeeds (**1.6 times** the mean) between May and August: April and September rainfall and windspeed are close to the mean.

Storyline

This storyline is cool all year round but dry in winter and wet in summer.

Persistent anticyclonic conditions in winter bring dry air from the east and south, which is warmer than average. Persistent anticyclonic conditions are associated with a weak jet stream that has generated large meanders and persistent blocking, and a strong Scandinavian High Pressure anomaly. Cold spells are preceded by Sudden Stratospheric Warmings and extension of the Polar Vortex to the south.

‘Persistent’ anticyclonic conditions do not imply that a single anticyclone persists for many months, but rather that anticyclonic conditions lasting many days occur frequently with short interludes. Met Office Weather Patterns 17 and 27 are examples of strongly anticyclonic conditions. Persistently anticyclonic conditions are associated with stronger feedbacks between the surface and the atmosphere, leading to colder cold extremes. Cold and still conditions produce a greater frequency of fog.

Persistent cyclonic conditions in summer bring mild, wet air from the west with high windspeeds and frequent storms. Strong cyclonic conditions are associated with a strong jet stream and are characteristic of a strong North Atlantic Oscillation. Weather patterns in cyclonic conditions come from across the Atlantic Ocean and are therefore milder than average. Met Office Weather Patterns 20, 23 and 26 are examples of strongly cyclonic conditions.

A shift from persistently cyclonic conditions to persistently anticyclonic conditions (and vice versa) can be very abrupt and occur over a few days.

Similar conditions can persist across the whole of the UK.

Note: extreme anomalies at finer spatial scales are larger

Set 3: Historical analogues

Historical extreme months and seasons can provide analogues for future extreme monthly and seasonal anomalies. If the month or season is expressed as an anomaly from a long-term mean (for example 1981-2010), then that anomaly can be applied to a projected future long-term mean (for example 2051-2080) to describe a plausible extreme month or season in a warmer world.

The most extreme historical months and seasons vary across the UK: whilst some are extreme across a large region, the most extreme in a region is typically more geographically-defined. The most appropriate analogue for a particular location may therefore be different to one for another.

Tables 3.1 to 3.6 show the most extreme monthly and seasonal temperature, rainfall and windspeed anomalies by region, over the period of historical record. The hot and cold extremes are calculated over 1884-2022 and are expressed as anomalies in °C from the 1981-2010 mean. The wet and dry extremes are calculated over 1836-2022, and the windy and calm extremes calculated over 1969-2022: both are expressed as ratios of the 1981-2010 mean. These tabulated extreme anomalies should be interpreted as a guide to plausible extremes, and anomalies from one month can be applied to other months in the same season. All are expressed to one decimal place. Apply the adjustment factors in Table HILL-E1 to define scenarios at finer spatial scales.

Table 3.7 shows historical extreme compound months and seasons (cold+dry, cold+wet, hot+dry and hot+wet) by region. They are defined as months or seasons with both temperature and rainfall extremes in the most extreme five over the period 1884-2022. The cold+dry and the hot+wet compound extremes occur (with a couple of exceptions) between autumn and spring, and the cold+wet and hot+dry occur between spring and autumn. Not all months have an historical compound extreme, and for such months it is reasonable to apply an extreme from another month in the same season. Similarly, some regions do not have some types of historical compound extreme, and here it is reasonable to apply an extreme from a nearby region.

Table 3.1: Hot extremes: maximum °C difference from 1981-2010 mean, over the period 1884-2022

		South West England	South East England	London	East of England	East Midlands	West Midlands	Yorkshire and Humb.	North West England	North East England	Wales	West Scotland	East Scotland	North Scotland	Northern Ireland
Jan	year	1916	2007	2007	2007	1916	1916	1916	1916	1916	1916	1989	1989	1989	1898
	anom	2.7	2.6	2.6	2.8	2.8	3.1	3.0	2.9	2.7	2.8	2.8	3.2	3.1	2.5
Feb	year	1990	1990	1990	1990	1998	1998	1998	1998	1998	1998	1998	1998	1998	1998
	anom	2.8	3.4	3.4	3.3	3.2	3.1	3.5	3.3	3.5	2.8	3.4	4.0	3.6	3.3
Mar	year	1957	2017	2017	1938	1938	1957	1938	1957	1938	1957	2012	1938	2012	1938
	anom	2.6	2.5	2.6	2.6	2.7	2.6	3.0	2.5	3.3	2.8	2.7	3.2	2.9	2.7
Apr	year	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011
	anom	3.3	3.7	3.9	3.5	3.5	3.4	3.3	3.1	3.2	3.2	2.9	3.0	3.0	3.0
May	year	2008	2008	1992	1947	2022	1992	2018	2008	2017	2008	2008	2018	1889	2008
	anom	2.0	2.0	2.0	1.9	1.9	1.9	2.0	1.9	1.9	2.1	2.1	1.9	2.0	2.1
Jun	year	1976	1976	1976	1976	1976	1976	1976	1940	1940	2018	1940	1940	1970	1887
	anom	2.2	2.6	3.0	2.8	2.5	2.2	2.1	2.0	2.4	2.2	2.1	2.1	2.1	2.9
Jul	year	1983	2006	2006	2006	2006	2006	2006	2006	2006	1983	2006	2006	2006	2013
	anom	3.1	3.1	3.4	3.2	3.2	3.2	2.9	2.8	2.7	2.6	2.1	2.4	2.2	2.4
Aug	year	1995	1995	1997	1997	1997	1995	1975	1995	1975	1995	1947	1995	1947	1995
	anom	3.0	2.6	2.8	2.8	2.6	2.7	2.2	2.5	2.1	3.0	2.4	2.0	2.4	2.7
Sep	year	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2021
	anom	2.5	2.9	3.1	3.1	3.0	2.7	2.8	2.6	2.7	2.3	2.1	2.3	2.4	1.8
Oct	year	2001	2001	2001	2001	2001	2001	2001	2001	2001	1995	2001	2001	1908	1969
	anom	2.5	2.7	2.7	2.9	2.8	2.8	2.8	2.8	2.9	2.5	2.6	2.9	2.8	2.5
Nov	year	1994	1994	1994	1994	1994	1994	2011	1994	2011	1994	1994	2011	2011	1994
	anom	2.9	3.0	3.0	2.7	2.6	3.0	2.4	2.6	2.5	2.9	2.6	2.7	2.6	2.3
Dec	year	2015	2015	2015	2015	2015	2015	2015	2015	2015	2015	1988	1988	1988	1934
	anom	5.1	5.6	5.6	5.4	5.1	5.3	4.4	4.3	3.9	4.7	3.1	3.3	2.9	2.8
DJF	year	2016	2016	2016	2016	2016	2016	1989	1989	1989	2016	1989	1989	1989	1989
	anom	2.3	2.5	2.5	2.4	2.3	2.3	2.0	2.2	2.3	2.1	2.3	2.5	2.2	1.8
MAM	year	1893	2017	2017	2017	2011	2017	2011	2017	2017	1893	2017	2014	2003	1893
	anom	1.7	1.6	1.7	1.6	1.7	1.5	1.6	1.4	1.6	1.7	1.2	1.3	1.4	1.5
JJA	year	2018	2022	2022	2022	2022	2018	2022	1995	2022	1995	1995	2003	2003	1995
	anom	1.7	1.7	1.9	1.9	1.8	1.7	1.8	1.4	1.5	1.6	1.3	1.4	1.6	1.5
SON	year	2006	2006	2006	2006	2006	2011	2006	2006	2006	2011	2006	2006	2006	2021
	anom	1.9	2.2	2.3	2.3	2.2	1.9	2.1	2.0	2.1	1.7	1.7	1.8	1.7	1.5

The extremes are calculated from regional HadUK-Grid observed data

Table 3.2: Cold extremes: maximum °C difference from 1981-2010 mean, over the period 1884-2022

		South West England	South East England	London	East of England	East Midlands	West Midlands	Yorkshire and Humb.	North West England	North East England	Wales	West Scotland	East Scotland	North Scotland	Northern Ireland
Jan	year	1963	1963	1963	1963	1963	1963	1940	1940	1940	1963	1895	1895	1895	1963
	anom	-7.5	-7.2	-7.0	-6.7	-6.3	-7.1	-5.6	-5.6	-5.0	-6.8	-4.5	-4.6	-4.2	-4.5
Feb	year	1895	1895	1895	1947	1947	1895	1947	1895	1895	1895	1895	1895	1895	1895
	anom	-6.4	-6.6	-6.9	-6.5	-6.4	-6.8	-5.8	-6.3	-5.5	-6.8	-5.7	-5.8	-5.0	-5.0
Mar	year	1962	1892	1892	1892	1962	1962	1892	1892	1947	1962	1947	1947	1947	1892
	anom	-3.7	-4.1	-4.5	-4.3	-4.1	-4.1	-4.0	-3.9	-4.3	-3.7	-3.9	-4.7	-3.7	-3.4
Apr	year	1986	1917	1917	1917	1917	1922	1917	1917	1917	1986	1917	1922	1917	1922
	anom	-2.9	-3.4	-3.7	-3.7	-3.5	-3.1	-3.5	-3.4	-3.3	-3.0	-3.0	-3.0	-3.1	-3.5
May	year	1941	1902	1902	1902	1902	1885	1902	1885	1902	1885	1902	1902	1923	1885
	anom	-2.7	-3.	-3.3	-3.2	-3.0	-3.0	-3.1	-3.2	-2.8	-3.1	-2.9	-2.9	-2.8	-2.5
Jun	year	1972	1916	1916	1916	1916	1972	1916	1972	1916	1972	1927	1927	1927	1927
	anom	-3.2	-3.1	-3.4	-3.0	-2.9	-3.0	-2.7	-2.6	-2.4	-3.2	-2.5	-2.6	-2.3	-2.9
Jul	year	1922	1888	1919	1919	1888	1922	1888	1922	1888	1922	1922	1965	1888	1922
	anom	-2.8	-3.2	-3.6	-3.6	-3.4	-3.3	-3.7	-3.1	-3.2	-2.9	-2.6	-3.1	-2.5	-2.9
Aug	year	1912	1912	1912	1912	1912	1912	1912	1912	1912	1912	1956	1912	1912	1912
	anom	-3.5	-3.7	-3.9	-3.4	-3.6	-3.7	-3.3	-3.3	-3.2	-3.2	-2.8	-3.1	-2.8	-3.5
Sep	year	1986	1912	1912	1952	1952	1952	1952	1952	1952	1952	1918	1918	1918	1918
	anom	-2.9	-3.2	-3.4	-3.2	-3.1	-3.3	-3.0	-2.9	-2.9	-2.7	-2.6	-3.0	-3.1	-3.0
Oct	year	1892	1905	1887	1905	1905	1892	1896	1896	1896	1896	1896	1896	1885	1896
	anom	-3.6	-4.1	-4.4	-4.1	-3.9	-3.7	-3.8	-3.9	-3.7	-3.8	-3.5	-3.6	-3.7	-3.4
Nov	year	1919	1923	1923	1923	1910	1915	1910	1915	1910	1915	1910	1919	1919	1919
	anom	-3.9	-4.2	-4.3	-3.9	-4.0	-4.2	-3.9	-4.6	-4.0	-4.1	-4.1	-4.2	-3.8	-3.7
Dec	year	1890	1890	1890	1890	1890	1890	2010	2010	2010	1890	2010	2010	2010	2010
	anom	-5.4	-6.5	-6.9	-6.2	-5.5	-5.8	-4.9	-5.0	-4.7	-5.2	-4.6	-4.7	-4.2	-5.2
DJF	year	1963	1963	1963	1963	1963	1963	1963	1963	1963	1963	1963	1895	1895	1963
	anom	-5.0	-5.3	-5.3	-5.2	-5.0	-5.3	-4.4	-4.2	-3.9	-4.7	-3.2	-3.4	-2.9	-2.9
MAM	year	1887	1888	1887	1887	1891	1887	1891	1891	1891	1887	1891	1891	1891	1979
	anom	-2.2	-2.6	-2.9	-2.6	-2.4	-2.5	-2.8	-2.6	-2.6	-2.5	-2.2	-2.4	-2.4	-2.1
JJA	year	1922	1888	1888	1907	1922	1922	1888	1888	1888	1922	1922	1888	1922	1912
	anom	-2.0	-2.4	-2.6	-2.3	-2.4	-2.6	-2.8	-2.3	-2.6	-2.2	-2.0	-2.3	-2.0	-2.2
SON	year	1887	1887	1887	1887	1919	1919	1887	1887	1887	1887	1885	1952	1885	1919
	anom	-2.8	-3.1	-3.4	-3.0	-2.9	-2.8	-3.0	-2.7	-2.4	-2.8	-2.3	-2.2	-2.2	-2.1

The extremes are calculated from regional HadUK-Grid observed data

Table 3.3: Wet extremes: maximum ratio to 1981-2010 mean, over the period 1836-2022

		South West England	South East England	London	East of England	East Midlands	West Midlands	Yorkshire and Humb.	North West England	North East England	Wales	West Scotland	East Scotland	North Scotland	Northern Ireland
Jan	year	2014	2014	2014	1939	2014	2014	2008	1928	1948	1948	1928	2016	1993	1877
	anom	2.1	2.6	2.6	2.3	2.0	2.2	2.1	2.0	2.6	1.9	1.7	2.1	1.7	1.7
Feb	year	1923	1951	1951	1916	1977	2020	2020	2020	1848	2020	1990	1848	1990	2020
	anom	2.6	2.8	3.4	2.3	3.2	2.9	3.0	3.1	2.5	2.6	2.3	2.4	2.1	2.7
Mar	year	1947	1947	1947	1947	1947	1947	1981	1981	1979	1981	1994	1903	1990	2019
	anom	2.5	2.7	3.0	2.6	2.5	2.7	2.4	2.1	2.2	2.5	1.7	1.7	2.2	1.7
Apr	year	2000	2000	2012	1998	2012	2000	2012	1843	1998	1920	1947	1947	1947	1961
	anom	2.5	2.7	2.6	2.7	2.8	2.4	2.4	2.3	2.3	2.2	2.1	2.1	2.2	1.9
May	year	2021	1843	1843	2007	1932	1886	1967	1967	1924	2021	2011	1906	2011	1916
	anom	2.3	2.3	2.4	2.4	2.5	2.8	2.7	2.2	2.6	2.5	2.4	2.2	2.6	2.1
Jun	year	1860	1860	1903	1997	2007	2007	2007	2012	2012	2012	1872	1838	1872	2012
	anom	3.0	2.8	3.2	2.4	2.8	2.8	3.1	2.5	2.4	2.6	2.2	2.2	2.0	2.4
Jul	year	1936	1888	1855	1875	1880	2007	1920	1988	1940	1939	1988	1940	1940	1936
	anom	2.6	2.6	3.3	2.8	2.7	2.7	2.4	2.2	2.6	2.7	2.0	2.2	2	2.3
Aug	year	1912	1912	1878	1912	1912	1912	1956	1956	1956	1917	2009	1948	1992	2008
	anom	3.0	2.8	2.8	3.2	2.5	2.8	2.5	2.6	2.8	2.6	2.2	2.3	1.9	2.1
Sep	year	1866	1896	1968	1918	1883	1976	1918	1918	1976	1918	1950	1950	1950	1950
	anom	2.8	2.7	3.0	2.3	2.3	2.7	2.5	2.5	2.5	2.4	2.1	2.0	1.9	2.2
Oct	year	1960	1865	1880	1865	1903	1903	1903	1967	1903	1903	1995	1903	1983	1870
	anom	2.0	2.2	2.3	2.4	2.3	2.1	2.5	2.0	2.7	1.9	1.5	1.6	1.6	2.1
Nov	year	1929	1940	1940	1940	1852	1852	2009	2009	2009	1929	2009	1984	1981	1852
	anom	2.4	2.3	2.6	2.5	2.3	2.5	2.1	2.3	2.1	2.1	1.9	2.1	1.7	2.1
Dec	year	1934	1914	1914	1914	1868	1914	1868	2015	1876	2015	2015	2015	2015	1876
	anom	2.2	2.5	2.8	2.7	2.5	2.2	2.3	2.5	2.6	2.0	2.0	2.4	1.8	2.0
DJF	year	2014	2014	2014	1915	1877	1990	1915	2016	2016	2014	2014	2016	1989	1877
	anom	2.0	2.4	2.2	1.9	1.7	1.9	1.6	1.9	1.9	1.7	1.7	1.9	1.4	1.7
MAM	year	1947	1979	1979	1981	1979	1932	1979	1920	1947	1920	1986	1947	1990	1986
	anom	1.6	1.7	2.0	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.5	1.6	1.5	1.5
JJA	year	1879	1879	1903	1879	1912	1912	1912	2012	2012	1879	1985	1877	2019	1912
	anom	2.2	2.2	2.6	2.0	2.0	2.1	1.9	1.8	1.8	2.0	1.7	1.8	1.5	1.7
SON	year	1960	2000	2000	1852	2019	1960	2000	1954	1872	2000	1954	1984	1981	2000
	anom	1.7	2.0	2.1	1.8	1.9	1.8	1.9	1.7	1.8	1.7	1.5	1.5	1.6	1.5

The extremes are calculated from regional HadUK-Grid observed data

Table 3.4: Dry extremes: minimum ratio to 1981-2010 mean, over the period 1836-2022

		South West England	South East England	London	East of England	East Midlands	West Midlands	Yorkshire and Humb.	North West England	North East England	Wales	West Scotland	East Scotland	North Scotland	Northern Ireland
Jan	year	1855	1880	1880	1880	1880	1855	1880	1997	1880	1997	1963	1997	1881	1855
	anom	0.1	0.16	0.16	0.1	0.15	0.12	0.12	0.1	0.21	0.08	0.11	0.25	0.18	0.15
Feb	year	1932	1891	1891	1891	1891	1891	1891	1932	1891	1932	1932	1932	1963	1932
	anom	0.02	0.02	0.02	0.04	0.08	0.07	0.07	0.05	0.05	0.03	0.02	0.09	0.1	0.06
Mar	year	1840	1929	1929	1929	1929	1929	1929	1840	1929	1840	1840	1856	1856	1837
	anom	0.06	0.04	0.02	0.05	0.11	0.11	0.13	0.11	0.1	0.07	0.09	0.07	0.04	0.13
Apr	year	1938	1893	1912	2007	1938	1938	1938	1980	2020	1938	1842	1842	1842	1842
	anom	0.05	0.03	0.04	0.02	0.07	0.06	0.12	0.09	0.08	0.11	0.06	0.07	0.08	0.07
May	year	1896	2020	2020	2020	2020	2020	1844	1836	1859	1844	1836	1859	1859	1844
	anom	0.06	0.09	0.05	0.06	0.12	0.1	0.17	0.06	0.11	0.05	0.07	0.08	0.12	0.11
Jun	year	1925	2018	2018	1962	1925	1925	1925	1925	1925	1925	1921	1865	1889	1921
	anom	0.02	0.05	0.01	0.1	0.04	0.04	0.05	0.09	0.08	0.03	0.29	0.23	0.28	0.14
Jul	year	1911	2022	2022	2022	1911	1911	1868	1868	1868	1911	1863	1863	1955	1898
	anom	0.17	0.1	0.08	0.1	0.11	0.17	0.27	0.18	0.26	0.24	0.15	0.21	0.26	0.21
Aug	year	1940	1940	1995	1947	1947	1940	1995	1947	1947	1995	1947	1947	1947	1947
	anom	0.07	0.04	0.04	0.09	0.08	0.13	0.13	0.06	0.09	0.14	0.02	0.04	0.05	0.13
Sep	year	1865	1959	1959	1959	1959	1959	1959	1910	1865	1959	1894	1972	1894	1894
	anom	0.05	0.06	0.04	0.03	0.05	0.06	0.11	0.15	0.18	0.11	0.05	0.15	0.13	0.07
Oct	year	1978	1969	1978	1978	1947	1969	1978	1946	1969	1947	1946	1946	1946	1838
	anom	0.09	0.06	0.06	0.1	0.13	0.14	0.25	0.16	0.22	0.19	0.1	0.12	0.11	0.24
Nov	year	1879	1945	1945	1867	1945	1945	1945	1945	1867	1945	1945	1867	1945	1855
	anom	0.14	0.13	0.09	0.29	0.21	0.15	0.23	0.09	0.18	0.14	0.12	0.21	0.2	0.25
Dec	year	1926	1840	1926	1843	1843	1840	1843	1844	1844	1844	1853	1843	1927	1844
	anom	0.16	0.16	0.18	0.15	0.14	0.14	0.12	0.09	0.2	0.16	0.14	0.28	0.14	0.2
DJF	year	1964	1992	1992	1858	1858	1858	1858	1891	1858	1964	1964	1964	1838	1891
	anom	0.35	0.34	0.28	0.35	0.2	0.3	0.27	0.29	0.35	0.28	0.34	0.39	0.33	0.38
MAM	year	1893	1893	1893	2011	1852	1938	1852	1984	2020	1893	1840	1852	1852	1837
	anom	0.27	0.22	0.22	0.2	0.32	0.37	0.34	0.43	0.41	0.38	0.39	0.38	0.29	0.41
JJA	year	1995	1995	1921	1921	1995	1995	1976	1976	1995	1976	1869	1955	1955	1983
	anom	0.32	0.34	0.31	0.35	0.23	0.32	0.27	0.38	0.33	0.3	0.51	0.41	0.43	0.43
SON	year	1978	1978	1978	1978	1964	1978	1964	1915	1867	1922	1915	1972	1894	1837
	anom	0.3	0.21	0.22	0.35	0.43	0.46	0.46	0.35	0.48	0.52	0.41	0.42	0.47	0.46

The extremes are calculated from regional HadUK-Grid observed data

Table 3.5: Windy extremes: maximum ratio to 1981-2010 mean, over the period 1969-2022

		South West England	South East England	London	East of England	East Midlands	West Midlands	Yorkshire and Humb.	North West England	North East England	Wales	West Scotland	East Scotland	North Scotland	Northern Ireland
Jan	year	1974	1974	1983	1983	1983	1983	1993	1983	1983	1974	1974	1983	1974	1993
	anom	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.9	1.5
Feb	year	1990	1990	1990	1990	1990	1990	1990	1990	1990	1990	1990	1990	1997	1990
	anom	1.6	1.7	1.6	1.6	1.6	1.6	1.7	1.6	1.5	1.6	1.5	1.5	1.4	1.5
Mar	year	1994	1979	1979	1994	1994	1994	1994	1994	1994	1994	1994	1990	1979	1990
	anom	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Apr	year	1972	1972	1972	1972	1977	1972	1977	1977	1977	1972	1977	1977	1991	1973
	anom	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.3	1.3	1.3	1.3	1.4
May	year	1972	1977	1977	1972	1986	1986	1986	1986	1986	1986	1986	1986	1970	2011
	anom	1.3	1.4	1.5	1.4	1.3	1.3	1.4	1.6	1.4	1.6	1.4	1.4	1.4	1.5
Jun	year	2012	2012	1977	1981	1981	1994	1981	1981	1981	1981	1981	1994	1994	1981
	anom	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.3	1.3	1.3	1.3	1.3
Jul	year	1974	1974	1974	1974	1974	1970	1970	1970	1974	1988	1970	1969	1970	1970
	anom	1.3	1.4	1.4	1.3	1.3	1.4	1.3	1.4	1.2	1.4	1.4	1.3	1.3	1.3
Aug	year	1985	1985	1992	1985	1985	1985	1985	1985	1985	1985	1985	1985	1982	1985
	anom	1.4	14	1.3	1.3	1.4	1.5	1.4	1.6	1.3	1.6	1.4	1.3	1.2	1.3
Sep	year	1974	1974	1974	1978	1978	1978	1978	1978	1978	1978	1978	1978	1978	1980
	anom	1.4	1.4	1.45	1.3	1.4	1.2	1.4	1.4	1.5	1.4	1.3	1.3	1.3	1.3
Oct	year	1998	1998	1998	1998	1998	1998	1983	1983	1983	1998	1983	1983	1977	1983
	anom	1.3	1.3	1.3	1.4	1.3	1.5	1.3	1.4	1.5	1.3	1.4	1.4	1.4	1.2
Nov	year	2009	1980	1977	1977	1977	1977	1977	1986	1977	1977	1986	1978	1971	1986
	anom	1.5	1.5	1.8	1.5	1.5	1.5	1.4	1.5	1.5	1.4	1.3	1.3	1.4	1.4
Dec	year	1974	1974	1974	1974	1974	1974	1974	1974	1974	2015	1974	1974	1974	1974
	anom	1.5	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.7	1.5	1.6	1.6	1.6	1.6
DJF	year	1990	1990	1975	1995	1990	1990	1990	1995	1976	1990	1974	1989	1974	1981
	anom	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.2	1.3	1.3	1.4	1.2
MAM	year	1972	1972	1977	1977	1977	1994	1994	1986	1994	1986	1994	1994	1970	1986
	anom	1.3	1.3	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.28	1.3	1.2	1.2	1.2
JJA	year	1985	1974	1974	1977	1977	1985	1985	1985	1981	1985	1974	1974	1974	1986
	anom	1.2	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.2	1.1	1.1	1.2
SON	year	1980	1974	1980	1980	1977	1980	1977	1977	1977	1980	1977	1977	1977	1980
	anom	1.2	1.3	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.3	1.3

The extremes are calculated from regional HadUK-Grid observed data

Table 3.6: Calm extremes: minimum ratio to 1981-2010 mean, over the period 1969-2022

		South West England	South East England	London	East of England	East Midlands	West Midlands	Yorkshire and Humb.	North West England	North East England	Wales	West Scotland	East Scotland	North Scotland	Northern Ireland
Jan	year	2022	2017	2017	1997	1997	1997	1997	1997	1997	1997	1997	1997	2001	1997
	anom	0.68	0.65	0.63	0.66	0.59	0.64	0.57	0.55	0.5	0.66	0.6	0.58	0.65	0.61
Feb	year	1993	1993	1993	1975	1975	1985	1975	2010	2010	2010	2010	2010	2010	2010
	anom	0.72	0.68	0.7	0.73	0.71	0.71	0.59	0.58	0.6	0.65	0.56	0.6	0.6	0.54
Mar	year	2012	2012	2011	2012	2012	2011	2011	2011	2011	2011	2011	1991	1991	2011
	anom	0.72	0.72	0.76	0.7	0.72	0.65	0.7	0.67	0.71	0.69	0.71	0.69	0.69	0.65
Apr	year	2007	1996	2009	1996	1984	2021	2021	2021	1974	2021	1974	1974	1974	1974
	anom	0.79	0.76	0.8	0.83	0.84	0.76	0.79	0.74	0.62	0.77	0.71	0.65	0.6	0.76
May	year	1989	2004	2004	2004	2004	2004	2004	1990	1990	2004	1990	1990	1990	1990
	anom	0.78	0.75	0.76	0.75	0.74	0.72	0.76	0.7	0.68	0.71	0.7	0.71	0.73	0.7
Jun	year	2006	1993	1993	1993	1993	1993	2014	2014	2014	2014	2014	2014	1991	2016
	anom	0.79	0.78	0.75	0.81	0.81	0.75	0.75	0.75	0.7	0.76	0.78	0.76	0.76	0.81
Jul	year	1983	1983	1994	1983	1983	1983	1994	2021	2021	1983	2021	2021	2021	2021
	anom	0.8	0.77	0.79	0.79	0.78	0.73	0.76	0.68	0.67	0.67	0.7	0.72	0.79	0.7
Aug	year	1981	1981	2002	2002	2002	1984	1983	2002	1997	1976	1976	2000	2000	1983
	anom	0.82	0.78	0.77	0.76	0.79	0.81	0.75	0.78	0.76	0.76	0.77	0.79	0.8	0.72
Sep	year	2014	2003	2003	2014	1971	2014	2014	2014	2014	2014	1972	1972	2002	2014
	anom	0.76	0.74	0.76	0.71	0.74	0.68	0.66	0.65	0.65	0.64	0.65	0.66	0.75	0.66
Oct	year	2007	2007	2007	2007	2007	2007	2007	1993	1993	2007	1993	1993	2012	1993
	anom	0.66	0.66	0.64	0.67	0.65	0.6	0.66	0.62	0.67	0.64	0.65	0.73	0.68	0.63
Nov	year	1988	1988	1988	1988	1988	1988	1983	2016	1993	1988	2019	1993	2019	2016
	anom	0.7	0.69	0.64	0.73	0.71	0.69	0.74	0.74	0.7	0.71	0.73	0.73	0.72	0.74
Dec	year	2016	2016	1984	2016	2010	2010	2010	2010	2010	2010	2010	2010	2010	1976
	anom	0.73	0.7	0.67	0.77	0.73	0.66	0.7	0.58	0.71	0.58	0.61	0.67	0.62	0.74
DJF	year	2010	2017	2017	2017	2010	1985	2010	2010	2010	2010	2010	2010	2010	2010
	anom	0.83	0.77	0.76	0.81	0.81	0.73	0.75	0.69	0.72	0.72	0.66	0.7	0.71	0.7
MAM	year	1971	2004	2022	2004	1984	2010	1984	1984	2021	1971	1984	1984	2010	2010
	anom	0.88	0.87	0.88	0.86	0.86	0.84	0.81	0.81	0.79	0.79	0.81	0.85	0.86	0.81
JJA	year	1999	1996	1987	2002	1999	2021	1983	2021	2021	1983	2021	2021	1991	1983
	anom	0.89	0.89	0.85	0.9	0.9	0.82	0.85	0.81	0.79	0.84	0.83	0.85	0.89	0.81
SON	year	2007	2007	2007	2014	1993	1993	1993	1993	1993	1993	1993	1993	1993	1993
	anom	0.79	0.84	0.85	0.86	0.84	0.79	0.84	0.79	0.78	0.78	0.81	0.78	0.81	0.83

The extremes are calculated from regional HadUK-Grid observed data

Table 3.7: Historical compound extreme monthly and seasonal anomalies, as a difference from the 1981-2010 mean (temperature) and a ratio to the 1981-2010 mean (rainfall).

Region	Compound	Month	Year	Temp	Rain	Year	Temp	Rain	Year	Temp	Rain
South West England	cold+dry	Feb	1895	-6.4	0.05						
	cold+dry	Nov	1896	-3.4	0.27						
	cold+dry	DJF	1891	-3.1	0.48						
	cold+wet	May	1979	-2.3	1.9						
	cold+wet	Jul	1888	-2.4	2.4						
	cold+wet	Aug	1912	-3.5	3.0						
	cold+wet	Sep	1974	-2.2	2.5						
	hot+dry	Mar	1938	1.7	0.12						
	hot+dry	Apr	1893	2.6	0.09						
	hot+dry	Jun	2018	2.2	0.14						
	hot+dry	Aug	1995	3.0	0.17	2003	2.0	0.27			
	hot+dry	Sep	1929	2.0	0.2						
	hot+dry	MAM	1893	1.7	0.27	2011	1.4	0.35			
	hot+dry	JJA	1976	1.7	0.36	1983	1.4	0.46	1995	1.5	0.32
	hot+wet	Feb	1990	2.8	2.4						
	hot+wet	Aug	1997	2.0	2.1						
	hot+wet	Nov	2002	1.8	1.9						
	hot+wet	Dec	1934	3.1	2.2						
	hot+wet	DJF	1990	1.7	1.7						
South East England	cold+dry	Feb	1895	-6.6	0.12						
	cold+dry	Dec	1933	-4.1	0.19						
	cold+dry	DJF	1891	-3.9	0.39						
	cold+wet	Jun	1991	-2.4	2.2						
	cold+wet	Jul	1888	-3.2	2.6						
	cold+wet	Aug	1912	-3.7	2.7						
	hot+dry	Apr	2007	3.1	0.04	2011	3.7	0.07			
	hot+dry	Jun	2018	1.7	0.05						
	hot+dry	Jul	2022	1.9	0.1						
	hot+dry	Aug	1947	2.1	0.19	1995	2.6	0.08	2003	2.2	0.31
	hot+dry	MAM	2011	1.5	0.28						
	hot+dry	JJA	1976	1.6	0.4	2022	1.7	0.46			
	hot+dry	SON	2011	1.9	0.49						
	hot+wet	Feb	1990	3.4	2.4						
	hot+wet	Nov	2009	1.9	2.2	2022	2.4	2.2			
	hot+wet	Dec	1934	3.2	2.4						
	hot+wet	DJF	1990	2.1	1.8						
London	cold+dry	Feb	1895	-6.8	0.12						
	cold+dry	Dec	1933	-4.0	0.18						
	cold+dry	DJF	1891	-4.3	0.39						
	cold+wet	Jul	1888	-3.6	3.0						
	cold+wet	Aug	1912	-3.9	2.3						
	cold+wet	JJA	1888	-2.6	2.0	1903	-2.2	2.6			
	hot+dry	Apr	2007	3.0	0.06	2011	3.9	0.08			
	hot+dry	May	1989	1.8	0.09						
	hot+dry	Jun	2018	1.8	0.01						
	hot+dry	Jul	2022	2.2	0.08						
	hot+dry	Aug	1995	2.5	0.04	2003	2.4	0.21			
	hot+dry	Sep	1929	2.5	0.12						
	hot+dry	Dec	1988	2.2	0.22						

	hot+dry	MAM	2011	1.6	0.26						
	hot+dry	JJA	1976	1.7	0.34						
	hot+dry	SON	2011	1.9	0.44						
	hot+wet	Feb	1990	3.4	2.3						
	hot+wet	Dec	1934	3.1	2.1						
	hot+wet	DJF	1990	2.1	1.8	2020	1.9	1.6			
East of England	cold+dry	Dec	1890	-6.2	0.28	1933	-3.4	0.25			
	cold+dry	DJF	1891	-3.8	0.42						
	cold+wet	Jul	1888	-3.2	2.2						
	cold+wet	Aug	1912	-3.4	3.2						
	cold+wet	Oct	1892	-3.7	2.1						
	hot+dry	Feb	1998	2.7	0.17						
	hot+dry	Apr	2007	2.7	0.02	2011	3.5	0.1			
	hot+dry	Jun	1976	2.8	0.22						
	hot+dry	Jul	2022	2.1	0.1						
	hot+dry	Aug	1995	1.9	0.14						
	hot+dry	MAM	2011	1.6	0.2						
	hot+dry	JJA	2022	1.9	0.46						
	hot+dry	SON	2011	2.0	0.45						
	hot+wet	DJF	1990	2.0	1.6						
East Midlands	cold+dry	Feb	1895	-6.4	0.19						
	cold+dry	Dec	1890	-5.5	0.28						
	cold+wet	Jul	1888	-3.4	2.3						
	cold+wet	Aug	1912	-3.6	2.5	1956	-3.2	2.1			
	cold+wet	JJA	1956	-2.0	1.6						
	hot+dry	Mar	1938	2.7	0.17						
	hot+dry	Apr	2007	2.8	0.11	2011	3.5	0.11			
	hot+dry	Jun	1976	2.5	0.2	2006	1.8	0.22			
	hot+dry	Aug	1995	2.0	0.12						
	hot+dry	MAM	2011	1.7	0.35						
	hot+dry	JJA	1976	1.4	0.33						
	hot+dry	SON	2011	2.0	0.53						
West Midlands	cold+dry	Feb	1895	-6.8	0.12						
	cold+dry	Sep	1986	-2.9	0.2						
	cold+dry	Dec	1890	-5.8	0.31	1933	-3.3	0.17			
	cold+wet	Jul	1888	-3.1	2.4						
	cold+wet	Aug	1912	-3.7	2.8						
	hot+dry	Mar	1938	2.4	0.18						
	hot+dry	Apr	2011	3.4	0.1						
	hot+dry	Aug	1995	2.7	0.15						
	hot+dry	MAM	1893	1.4	0.47	2011	1.5	0.43			
	hot+dry	JJA	1976	1.5	0.41	1995	1.5	0.32	2018	1.7	0.53
Yorkshire and Humb.	cold+dry	Dec	1890	-4.2	0.32						
	cold+wet	Mar	1947	-4.0	2.1						
	cold+wet	Apr	1986	-2.7	1.8						
	cold+wet	Jul	1888	-3.7	2.3						
	cold+wet	Aug	1956	-3.2	2.5						
	cold+wet	Oct	1892	-3.8	2.1						
	hot+dry	Mar	1938	3.0	0.22						
	hot+dry	Apr	2007	2.7	0.16	2011	3.3	0.16			
	hot+dry	Jun	1976	2.1	0.17						
	hot+dry	Aug	1947	1.6	0.13	1995	1.8	0.13			
	hot+dry	MAM	2011	1.6	0.44						
	hot+dry	JJA	1976	1.2	0.27						
	hot+wet	Jan	2008	2.1	2.1						
	hot+wet	Nov	2015	2.1	1.8						
	hot+wet	Dec	2015	4.4	2.0						
	hot+wet	DJF	2016	1.9	1.6						

North West England	cold+dry	Jan	1941	-4.2	0.34	1963	-5.2	0.18			
	cold+dry	Feb	1986	-4.7	0.08						
	cold+dry	Mar	1892	-3.9	0.31						
	cold+dry	Sep	1894	-2.4	0.16	1986	-2.4	0.21			
	cold+dry	Dec	1890	-4.3	0.13	2010	-5.0	0.29			
	cold+dry	DJF	1963	-4.2	0.41						
	cold+wet	Jul	1888	-3.1	.0						
	cold+wet	Aug	1956	-3.0	2.6						
	hot+dry	Aug	1947	2.2	0.06	1995	2.5	0.18			
	hot+dry	JJA	1976	1.4	0.38	1995	1.4	0.45			
	hot+wet	Feb	1990	2.5	2.2						
	hot+wet	Nov	2015	2.1	2.0						
	hot+wet	Dec	2015	4.3	2.5						
	hot+wet	DJF	2016	1.9	1.9						
North East England	cold+wet	Mar	1888	-3.7	1.7	1947	-4.3	2.0			
	cold+wet	Aug	1956	-3.2	2.8	1986	-3.0	2.1			
	cold+wet	Sep	1918	-2.7	2.2						
	hot+dry	Mar	2012	2.7	0.22						
	hot+dry	Jul	2006	2.7	0.29						
	hot+dry	Aug	1995	1.9	0.15						
	hot+dry	Oct	1969	2.3	0.22						
	hot+dry	Dec	1971	2.7	0.34						
	hot+dry	JJA	2022	1.5	0.56						
	hot+wet	Feb	1990	2.2	2.0						
	hot+wet	Dec	2015	3.9	2.5						
	hot+wet	DJF	2016	1.5	1.9						
Wales	cold+dry	Jan	1963	-6.8	0.18						
	cold+dry	Feb	1895	-6.8	0.09	1986	-5.5	0.07			
	cold+dry	Sep	1986	-2.6	0.16						
	cold+dry	Nov	1896	-3.1	0.28						
	cold+dry	Dec	1890	-5.2	0.25	1933	-3.4	0.29			
	cold+dry	DJF	1917	-3.1	0.47	1963	-4.7	0.43			
	cold+wet	Jul	1888	-2.5	2.1	1920	-2.2	2.2			
	cold+wet	Aug	1912	-3.2	2.3						
	hot+dry	Apr	1893	2.3	0.15						
	hot+dry	Jun	2018	2.2	0.24						
	hot+dry	Jul	1983	2.6	0.34						
	hot+dry	Aug	1947	2.3	0.18	1995	3.0	0.14			
	hot+dry	Oct	1969	2.3	0.26						
	hot+dry	MAM	1893	1.7	0.38						
	hot+dry	JJA	1976	1.4	0.3	1995	1.6	0.42			
	hot+wet	Jan	1990	2.0	1.6						
	hot+wet	Feb	1990	2.8	2.1						
	hot+wet	Dec	1934	3.0	1.7	2015	4.7	2.0			
	hot+wet	DJF	2016	2.1	1.7						
West Scotland	cold+dry	Jan	1895	-4.5	0.3	1941	-4.1	0.16	1963	-4.1	0.11
	cold+dry	Feb	1895	-5.7	0.19	1947	-5.3	0.13	1986	-3.8	0.05
	cold+dry	Mar	1892	-3.2	0.21						
	cold+dry	Dec	2010	-4.6	0.32						
	cold+dry	DJF	1895	-3.1	0.45	1963	-3.2	0.43			
	hot+dry	Jul	2021	1.9	0.34						
	hot+dry	Aug	1947	2.5	0.02	1995	2.3	0.26			
	hot+dry	Oct	1908	2.4	0.28						
	hot+dry	JJA	1976	1.1	0.52	1995	1.3	0.56	2021	1.2	0.55
	hot+wet	Oct	1995	2.1	1.5						
	hot+wet	Dec	2015	2.9	2.0						
	hot+wet	DJF	2014	1.4	1.7						
	hot+wet	SON	2011	1.6	1.4						

East Scotland	cold+dry	Dec	1892	-2.7	0.4						
	hot+dry	Feb	1993	2.1	0.26						
	hot+dry	Mar	2012	3.1	0.29						
	hot+dry	May	1896	1.5	0.35						
	hot+dry	Jun	1887	1.7	0.3	1940	2.1	0.3			
	hot+dry	Aug	1947	1.9	0.04	1995	2.0	0.24			
	hot+wet	Nov	2022	1.9	1.6						
	hot+wet	Dec	2015	2.9	2.4						
	hot+wet	SON	2022	1.5	1.4						
North Scotland	cold+dry	Jan	1963	-3.7	0.2						
	cold+dry	Feb	1947	-4.9	0.16	1986	-3.5	0.11			
	cold+dry	DJF	1963	-2.4	0.47						
	hot+dry	May	2008	1.9	0.25						
	hot+dry	Aug	1947	2.4	0.05	1955	1.5	0.3	1995	2.0	0.36
	hot+dry	Oct	1908	2.8	0.27						
	hot+dry	JJA	1976	1.1	0.62	2021	1.1	0.64			
	hot+wet	Feb	1998	3.6	1.9						
	hot+wet	Oct	2001	2.6	1.5						
	hot+wet	DJF	1989	2.3	1.4						
Northern Ireland	cold+dry	Jan	1963	-4.5	0.34						
	cold+dry	Feb	1986	-3.7	0.07						
	cold+dry	Mar	1892	-3.4	0.26						
	cold+wet	Aug	1956	-2.3	1.8						
	cold+wet	JJA	1912	-2.2	1.7						
	hot+dry	Mar	2012	2.3	0.27						
	hot+dry	May	2008	2.1	0.26						
	hot+dry	Jun	1887	2.9	0.26						
	hot+dry	Jul	1983	1.8	0.28						
	hot+dry	Aug	1947	2.2	0.13	1995	2.7	0.14			
	hot+dry	Sep	1895	1.6	0.21						
	hot+dry	MAM	1893	1.5	0.48						
	hot+dry	JJA	1995	1.5	0.49						
	hot+wet	Dec	2015	2.4	1.9						
	hot+wet	SON	2011	1.4	1.4						

The extremes are calculated from regional HadUK-Grid observed data over the period 1884-2022. A compound extreme has both a temperature and a rainfall anomaly in the largest five over 1884-2022.