Technology Strategy Board
Driving Innovation

Design for future climate

Opportunities for adaptation in the built environment

Acknowledgements

We would like to thank all those who have contributed to this report, especially:

Roger Street, Gerry Metcalf and Stephanie Ferguson of the UK Climate Impacts Programme, which was set up in 1997 to help organisations in the public, private and voluntary sectors adapt to climate change. **www.ukcip.org.uk**

Chris Twinn of Arup, Anastasia Mylona of the Chartered Institution of Building Services Engineers, Chris Doran of Kier, Professor Bakr Bahaj of Southampton University, Ant Wilson of AECOM, Dave Farebrother of Land Securities, Emily Hay of the Department of Communities and Local Government, Will Lockhead of the Department for Environment, Food and Rural Affairs, and Alan Hall of the British Standards Institution.

The Natural Environment Research Council, whose researchers have created extensive knowledge on the impacts of changes in wind patterns, water table and extreme events on building design, structural stability of buildings and local scale flood risk.

Contents

Foreword by the author, Bill Gething

There is an overwhelming scientific consensus that the climate is changing and that the changes are linked to global greenhouse gas emissions that result from human activity, particularly from the use of fossil fuels.

Until recently policy and action has been directed towards mitigation – taking steps to reduce those emissions and thus to limit the extent of climate change. We have been slower to recognise that some change is inevitable, and that this will significantly affect our lifestyle and our environment.

The impact of climate change is particularly pertinent to the construction industry given the life expectancy of our buildings and the fact that we will need to adapt our existing built environment, to deal with a climate that may be significantly different from that in which it evolved.

The industry is in the early stages of developing practical responses to this agenda of adaptation, but we now need to make rapid progress. We need to agree on the climate parameters that we should use, fill in any gaps in the climate projections with other agreed risk-based techniques, and develop a set of validated tools and datasets tailored to our practical needs.

At the same time we need to explore the spatial scales at which particular adaptation measures are most effective, and the interactions between different solutions that address adaptation and mitigation.

This report aims to give an overview of the available climate information, highlight issues that are most relevant to the industry, signpost research and development work, and pose some questions to help practitioners develop their thinking and explore areas that are particularly relevant to their work.

It is inevitably a personal view written from the perspective of a practising architect but I hope it incorporates the perspectives of the many individuals from across the industry and academia with whom I discussed the issues and to whom I am indebted for their perceptive input.

Bill Gething is an independent sustainability and architectural consultant, having been a long-standing partner of the architectural and urban design practice of Feilden Clegg Bradley Studios, with whom he retains close ties. He was personally involved with many of the key projects that have contributed to the practice's international reputation for sustainable design and had overall responsibility for the practice's research work.

He is a visiting professor at the University of Bath, chair of BRE Global's Sustainability Board, a member of their Governing Body, and a member of the Commission for Architecture and the Built Environment's Ecotown review panel. He was the sustainability adviser to the president of the Royal Institute of British Architects from 2003 to 2009, and is a member of its Climate Change Board, responsible for developing the institute's suite of climate change guides.

Foreword by Iain Gray, Chief Executive, Technology Strategy Board

Over the last 18 months we have brought climate scientists and construction experts together to discuss how climate change is affecting, and will affect, the construction industry.

'We believe there are commercial opportunities for businesses that innovate around the changes in the climate.

This report will help innovative design teams get the information that they need to do this.'

It has become clear that the industry has not yet taken account of the scale and implications of the changes in climate that we can expect this century. To create a built environment that will cope with these changes, design teams will need to consider innovative solutions to ensure buildings are robust, comfortable for people to live and work in, and that can manage water in extreme conditions such as drought and flood.

We believe there are commercial opportunities for businesses that innovate around the changes in the climate; for example, by developing new materials and construction methods to retrofit existing buildings. We have been working with industry experts, research funders and the UK Climate Impact Programme to identify the information the construction industry needs to do this.

As part of this process we commissioned Bill Gething to produce this independent report on the issues facing the construction industry as it gets to grips with the effect of a changing climate on our built environment.

This report has been extremely valuable in helping to inform our work. Bill's views are very useful, in particular where he identifies areas where designers will need to rethink their rules of thumb, where existing design tools will no longer produce robust buildings, and where opportunities may be created by designing differently.

I commend the report and expect that it will prove to be equally valuable to the construction industry.

Introduction

The Earth's climate is changing – wetter winters and drier summers will affect existing buildings and alter the requirements of new ones. Whatever the cause of climate change, we will need to adapt our buildings so that they can cope with higher temperatures, more extreme weather and changes in rainfall.

That the world's climate is changing is irrefutable[1]. There is also an overwhelming scientific consensus that the changes are linked to global greenhouse gas emissions that result from human activity, particularly from the use of fossil fuels.

What is happening to the climate?

The headline impacts for the UK are that we can expect:

- warmer, wetter winters
- hotter, drier summers
- rising sea levels
- more extreme weather events.

Some change is inevitable. Because of the inertia in the climate system, even if global emissions were capped immediately the effect of past emissions would continue to be felt for decades.

As far as the UK is concerned, detailed information on the likely changes to our climate has been provided by the Met Office since the 1990s; the latest issue being the UK Climate Projections (UKCP09) published in June 2009[2]. This is the key source of climate data on which research organisations, regulation and standards setting bodies and the insurance industry are basing their responses to changes in our climate.

None of the projections show the climate stabilising this century. On this basis climate change must be regarded as an ongoing phenomenon, not a defined step change.

Weather events that are currently regarded as extreme are useful illustrations of what is projected to be normal in future.

Why do we need to adapt buildings?

The construction industry is already working to make buildings more energy efficient, reducing green house gas emissions to limit their effect on the future climate (known as mitigation).

However, the industry has been slower to recognise that some changes to our climate cannot be avoided; that these changes will have a significant impact on how our buildings will perform; and that, depending on the success of our global mitigation strategies, much more significant changes are likely in the second half of the century which will have a correspondingly greater effect.

Clearly, we will need to change the way we design, construct, upgrade and occupy buildings to accommodate the expected changes – the challenge of adaptation.

This represents a fundamental change in the way we think about design; changing from approaches that are based on past experience to those that are based on calculated projections of future climate.

How will climate change affect building design?

The impacts of the changing climate on the built environment can be grouped into three broad categories:

- those that affect comfort and energy performance – warmer winters may reduce the need for heating, but keeping cool in summer without increasing energy use and carbon emissions will present a challenge
- those that affect construction – resistance to extreme conditions, detailing, and the behaviour of materials
- managing water – both too much (flooding) and too little (shortages and soil movement).

These three areas are looked at in detail in the following sections of this report.

The difference between ‘climate’ and ‘weather’

‘Climate’ refers to average weather over a reasonably long period of time. Whilst weather is chaotic in nature, climate is more predictable.

A particularly cold winter cannot be taken as evidence that global warming is a myth. There are always extremes of hot and cold in weather patterns – however, when weather data is averaged out over space and time a trend emerges.

What about standards and regulations?

In April 2010 all government departments published Departmental Adaptation Plans, which set out in detail for the first time both their adaptation and mitigation agendas[3]. Included in the Department for Communities and Local Government’s plan[4] are work plans and time scales for incorporating adaptation aspects of building construction into Building Regulations and the Code for Sustainable Homes alongside the more familiar mitigation measures such as energy efficiency.

Similarly, standard-setting bodies such as the British Standards Institution are scoping the work needed to update standards in the light of projected climate change impacts.

In addition to the establishment of minimum standards, there may be a role for enhanced standards that individual organisations may choose to adopt to give an additional level of reassurance for aspects of climate change that are particularly relevant to them or to work to extend the time period.

The business case

There is significant potential for innovation in developing new materials, products and services to address aspects of climate change, but, as yet, specific briefing requirements for building design to address future climate impacts are rare. Because of the long timescales involved and the inherent uncertainties in the projections it is difficult for companies to build competitive advantage: the success of a particular strategy may not be apparent for many years, and few clients will spend more now for unquantified future benefits.

That said, companies that start to think now about ways to adapt new and existing buildings will have a first mover advantage over their competitors, developing and testing tools so that they are ready to provide adaptation services for a significant new market generated by the upcoming changes in regulations.

Public sector clients have the opportunity to lead the adaptation agenda and a number are starting to incorporate future climate criteria in their procurement of new facilities.

Opportunities and challenges

Balancing adaptation and mitigation

Adaptation and mitigation measures can be complementary; however, there can be direct conflicts. For example, a drive to reduce the use of artificial lighting energy by incorporating large areas of glazing to make better use of daylight can cause summer (and, with highly insulated buildings, mid-season) overheating unless glazing is very comprehensively shaded.

Adaptation in a low energy, low carbon world

Even if new low carbon sources of energy become the norm, energy is likely to be more expensive, and probably scarcer, in future. Adaptation strategies that rely on high levels of energy use should be avoided, both to avoid increasing emissions from fossil-based energy and to husband precious low carbon energy resources. Designers should use intelligent design based on a clear understanding of the projected changes to design out problems rather than, for example, relying on energy-intensive high-emission cooling technologies to condition poorly designed buildings.

Upgrading the existing stock and adapting buildings over time

As with the mitigation agenda, the existing stock is the real challenge, much of which performs poorly even in today's climate. We need to develop strategies for retrofitting adaptation measures but may also need to recognise critical thresholds where the practicalities and costs of adaptation mean that replacing a building becomes the only viable option.

Current projections show that the climate is likely to continue to change beyond the end of the century, so even new buildings are likely to need to incorporate strategies for further upgrading over time. An approach of sequential upgrading could be developed for aspects of both new and existing buildings.

Different elements of buildings have different life expectancies and replacement/maintenance cycles. Foundations and structure should be designed to a longer timescale than elements that might be replaced every 20 to 30 years such as glazing and cladding, or services that might be replaced every 15 to 25 years. These intervention opportunities can be exploited to adapt buildings at least cost.

Making the climate data more accessible

The UKCP09 projections are invaluable for illustrating the range of projected changes across a range of emissions scenarios, but the information is not in a form that can be used directly by designers. In particular, the projections are now presented as probabilistic ranges rather than single values. This reflects the uncertainties that stem from a combination of the natural variability of weather, the limitations of climate modelling and the variation between different but plausible models.

The information needs to be ‘translated’ into familiar forms that can be used by building designers to respond to a future climate – such as rules of thumb, contour maps and datasets that can be used with computer models.

A further level of complexity is added by the fundamental uncertainty about the pattern of future emissions on which the projections are based. These multiple uncertainties can only be realistically addressed by developing a common consensus on the parameters on which design decisions should be based. Regulation and standard-setting bodies have a vital role in collating that consensus; however, designers and clients will still need to understand how aspects of future climate outside the consensus view may need to be accommodated to mitigate climate risks that are particular to an individual project.

Variation between the regions

There are already significant differences in climate between the UK regions and these differences are projected to increase. Design responses must take into account local conditions – what might be important in one area might be much less so in another. For example, keeping cool in summer will be less of an issue in the northern regions than in the south. We may need to adapt materials and details for specific locations.

Regional Climate Change Partnerships have been set up to analyse the opportunities and challenges for each region. Their reports are available from the UK Climate Impacts Programme (UKCIP) website[5].

Scale

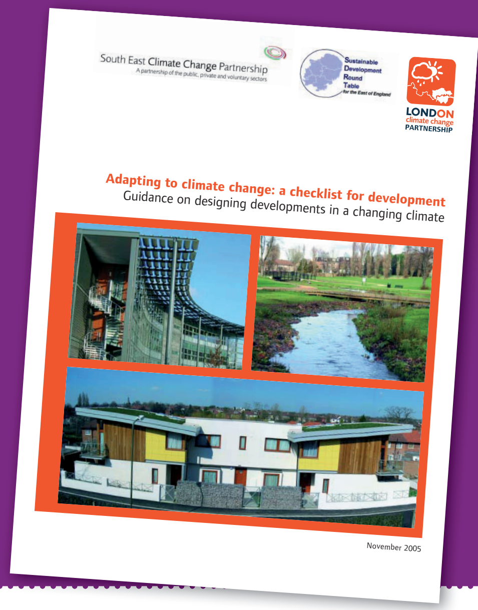
Adaptation strategies can be applied at different scales: from the individual building, to a region or catchment, to the whole country. The industry will need to understand which scales are the most practical and economic to address the different aspects of climate change. A report by the Town and Country Planning Association, *Climate Change Adaptation by Design*[6], provides useful guidance on adaptation strategies at three scales: the conurbation or catchment, neighbourhood, and building.

Design inspiration

Designing for adaptation is an opportunity to explore new design territory and to develop new materials and construction methods to address our changing climate.

A checklist for development

The 2005 report *Adapting to Climate Change: a Checklist for Development*, by the Three Regions Climate Change Group[7], provides a checklist summarising important climate issues that need to be considered when planning a development, as well as guidance. It covers location, site layout, building design, structure, envelope and materials, ventilation and cooling, drainage, water, outdoor spaces and connectivity.



The main sections of this report are colour coded to help you navigate through them easily (see below).

They are followed by appendices on UK climate change projections, further information and references.

Designing for comfort

Construction

Managing water

Designing for comfort

We need to adapt our buildings so that people can live and work in comfort as the temperatures rise. Innovations in design are essential to meet the challenges of hotter summers and warmer winters, while reducing the amount of energy we use.

In this section:

- Keeping cool – building design
- Keeping cool – external spaces
- Keeping warm

Keeping cool – building design

Warmer winters will have a generally positive effect on our buildings, with homes that are easier to heat and reduced energy costs. But warmer summers represent a significant challenge for keeping buildings comfortable.

Hotter summers will have the greatest impact on design

Of all the projected climate change impacts, hotter summers will affect the design of buildings the most. Recent hot spells have exposed the inadequacy of much of our building stock in dealing with higher outdoor temperatures. There are many recently built examples where a combination of better insulation and excessive, unprotected glazing lead to overheating.

What is a comfortable maximum indoor temperature?

Comfort is a personal matter and it seems likely that, in a warming climate, our tolerance for higher temperatures may well increase. Client requirements for summertime comfort are typically defined in terms of maximum absolute temperatures based on generally accepted current norms (e.g. 24°C ± 2°C); however, a definition relative to external temperature might be used to take account of our personal adaptive capacity.

In a study by the Chartered Institution of Building Services Engineers (CIBSE) and Arup (see p14), two thresholds were used to define discomfort – 'warm' (25°C) and 'hot' (28°C) – representing the band in which most people currently start to feel uncomfortable.

The 'warm' (25°C) temperature was used for bedrooms, because people tend to be less tolerant of higher temperatures when trying to sleep. Otherwise 28°C was used. A building was said to have overheated if temperatures exceeded the threshold for more than 1% of occupied hours.

Many naturally ventilated offices and schools are designed to similar thresholds. Excessive heat can cause ill health; however, there is no statutory maximum internal temperature in the current UK Building Regulations or health and safety guidance. It is recognised, however, that at higher temperatures – particularly in high relative humidity, which limits the body's ability to keep cool through perspiration – heat stress can occur and the body cannot maintain its core temperature of 37°C. The study by CIBSE and Arup used 35°C as a temperature above which there is a significant danger of heat stress.

CIBSE/Arup study on thermal comfort

This section discusses work by the Chartered Institution of Building Services Engineers (CIBSE) and Arup on the effect of a warming climate on summertime comfort in UK buildings, created using the 2002 UKCIP climate projections.

This study formed the basis of two of the most useful resources for building designers considering this topic: CIBSE's 2005 publication *Climate Change and the Indoor Environment: Impacts and Adaptation*[8]; and *Beating the Heat*[9], a joint 2005 publication by UKCIP, Arup and the Department for Trade and Industry.

Much emphasis has been put on the potential rise in deaths during summer as a result of climate change, using the summer of 2003 as an example. There was a direct link between high temperatures during the heat wave: 2,142 more people died – an increase of 16% – compared with the average for the previous five years during the same period, with old people being particularly vulnerable[10]. However, to put it in context the peak death rate of 1,692 (on 11 August 2003) was still lower than the typical mortality in the winter months[11].

Many existing buildings already perform badly in summer

The study by CIBSE and Arup investigated how typical existing buildings would cope with future rising summer temperatures. The study found that, with the exception of the advanced naturally ventilated office example, existing buildings are already failing to meet the comfort criteria set for the study (25°C and 28°C); and some, particularly 1960s office buildings, are failing spectacularly. The study showed that as the century progresses and external temperatures rise, summertime comfort will deteriorate further.

Passive design strategies offer real benefits

There is a huge opportunity to develop and demonstrate passive cooling design strategies. The *Beating the Heat* report[9] concluded that, for the UK, passive approaches to building design – that maximise comfort whilst minimising energy use – can produce buildings that can maintain comfortable conditions well into the century.

The report identified the following principle passive techniques:

- high levels of internal thermal mass (to make use of lower night-time temperatures)
- very careful exclusion of solar gain
- airtight construction and controlled secure ventilation (to exclude external air when hotter than comfortable internal temperatures)
- high levels of insulation to minimise heat gains through building fabric.

There are thus some building design 'habits' that will become increasingly unsustainable with increasing summer temperatures. For example, lightweight, under-ventilated, over-glazed structures will become intolerable even with active cooling, the most obvious example being the domestic conservatory.

Lessons can be learnt from passive design approaches used in vernacular building and urban design traditions of warmer climates. *Beating the Heat* drew parallels between the future summer climate of London and that of Marseilles today, noting potential lessons for passive building adaptation techniques but also how southern European lifestyles were similarly adapted to deal with high mid-day temperatures. Clearly, there is huge potential to use similar lifestyle adaptation techniques in a warming UK.

Standards and buildings practices have been developed around the world for a wide range of climate regimes, which can provide relevant pointers to future UK practice. However, lessons from warmer climates cannot necessarily be transferred wholesale to the UK. Whilst aspects of our future climate may be comparable to existing climates elsewhere, it is not as simple as transposing building techniques and shading from Marseilles, for example. Sun angles in London will not change, however much the climate warms.

Active cooling will be difficult to avoid by the end of the century

Unless carbon emissions are radically reduced to stabilise global warming, even buildings with good passive design are likely to require more active cooling toward the end of this century if temperatures continue to rise as indicated by the projections.

The CIBSE study concluded that the introduction of active cooling is likely to offset any reductions in emissions due to warmer winters – particularly as cooling typically uses carbon-intensive electricity rather than the relatively low-carbon-intensity gas used for heating. This illustrates the inter-relationship between the twin challenges of mitigation and adaptation.

There is clearly a huge opportunity to develop and demonstrate carbon-efficient cooling technologies and passive design skills (maximising comfort whilst minimising energy use).

Some buildings will not survive

It is generally recognised that the wintertime performance of some of the existing stock will prove so difficult and expensive to upgrade that it will make more sense to replace it with new highly insulated buildings.

The same logic applies to summertime performance. Whilst many buildings can be radically improved – for example, by adding shading and reducing excessive glazing – the fundamental form and structure of some buildings will not allow them to be economically upgraded to offer comfortable conditions in summer without using unacceptable amounts of energy. Likely candidates for demolition might be buildings with low thermal mass, limited ceiling heights or deep plans that rely on mechanical systems to keep them habitable in summer.

There are great opportunities for innovation

In meeting the challenge of designing for a different summer climate, we will need to extend our design skills and develop innovative technologies and products. For example:

- shading systems for both new build and the existing stock that could be progressively rolled out as circumstances change
- glazing and film technologies to improve the performance of glass in terms of solar exclusion
- the development of reflective solid materials to reflect heat off of building surfaces
- secure night-time ventilation systems to allow buildings to be purged of hot air whilst also excluding insects
- acoustically attenuated natural and mechanical ventilation systems to cope with conditions where external/internal noise is a problem
- more efficient cooling systems, exploiting building-based renewable technologies and/or improved groundwater and earth-coupled cooling systems
- improved cooling control systems to maintain comfortable conditions without using excessive energy
- affordable, safe, phase change materials to provide the performance of thermal mass without the weight associated with conventional materials – this is particularly relevant for prefabricated buildings, which tend to be lightweight.

Future climate design data

The changing climate requires a change in the way we think about design, from approaches that are based on past experience to those that are based on calculated projections of future climate.

The Projected Summer Data Year information from CIBSE presents some of the best data available for use with building environmental modelling tools, for 14 UK locations. Data of this type will be essential for developing adaptation strategies.

The current available data is based on the 2002 UKCIP climate projections, which follow the same key trends as the UKCP09 projections but without the same level of probabilistic detail. CIBSE is now working with industry and academic partners to update its information to reflect the UKCP09 probabilistic projections.

Keeping cool – external spaces

Shade will become essential

We will need to think differently about external spaces. Traditionally, the principle environmental design driver for external spaces in the UK has been to capture sun rather than protect us from it. In a warmer future, shade will become more important, as it is in southern Europe – not just for buildings but also for the spaces around them, including parking areas. There are obvious possibilities of combining shade with energy generation using photovoltaic panels.

Planting for drier summers

Deciduous trees and plants can provide beautiful, effective, low-cost shade that benefits from the process of transpiration to significantly enhance its cooling effect.

If summers become drier, however, landscape designers need to decide the best approach. Obvious, reactive options might be to avoid planting altogether or to use drought-tolerant trees and plants to reduce or eliminate the need for irrigation (xeriscaping). However, there are other, possibly counter-intuitive, options that might be used in some circumstances, such as using efficient irrigation as part of a holistic approach to support our indigenous trees and plants and to exploit the combined benefit of transpiration and shade.

Green and blue spaces reduce the urban heat island effect

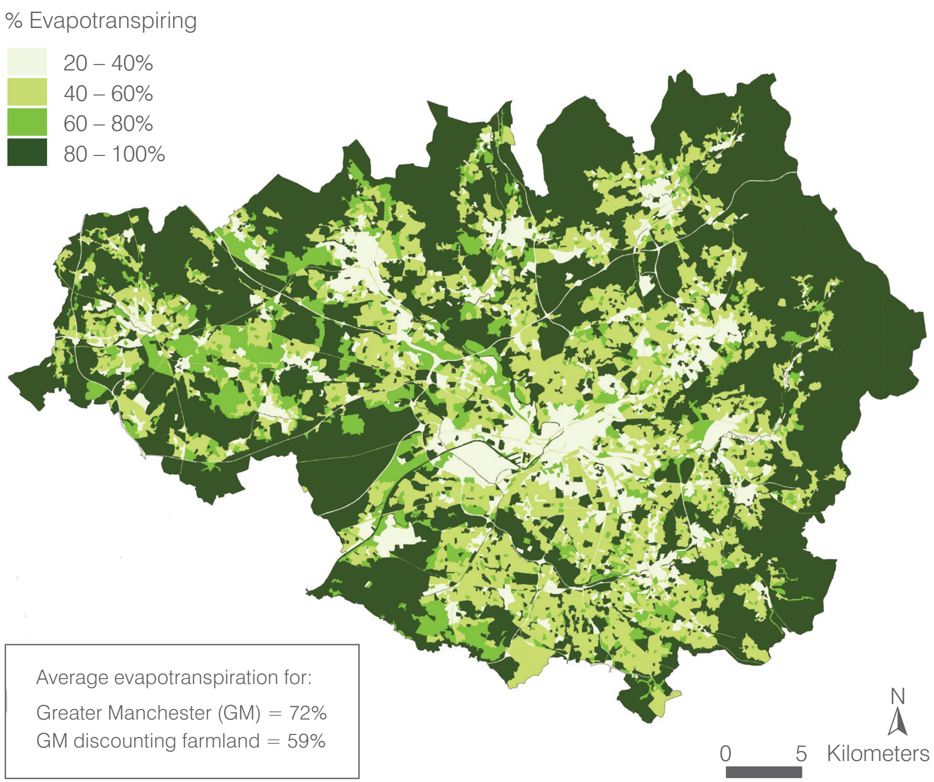
Green space (such as parks and woodland) and 'blue' space (water bodies such as rivers, canals and lakes) can significantly reduce the urban heat island effect, in which towns and cities are warmer than the surrounding rural area, particularly at night.

Researchers at Manchester University have modelled the effect of urban green space on surface temperatures in Greater Manchester, and have found that by adding 10% of green cover, maximum surface temperatures in high-density residential areas could be kept at or below the 1961-1990 baseline up to the 2080s[12]. Figures 1 and 2 show the relationship between green space and surface temperatures.

The project (ASCCUE – Adaptation Strategies for Climate Change in the Urban Environment), carried out between 2002 and 2007, identified a similar benefit by reducing surface water run-off and the ability to absorb rainfall within the city.

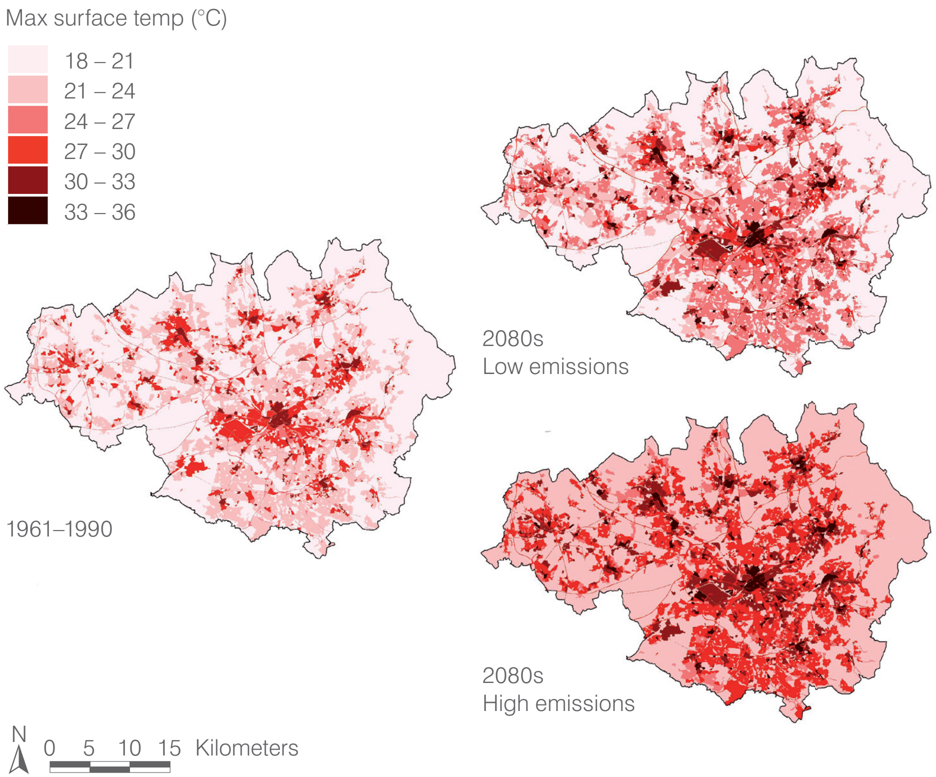
In the city of Berlin, planners have devised a way of defining how much green space is needed for each development site. This method, called the Biotope Area Factor[13], has been adopted by other local authorities, and in Sweden, Malmö city council has used it in the acclaimed Bo01 waterfront regeneration development.

Figure 1: green and blue surfaces in Greater Manchester, 2006[14]



The green and blue (evapotranspiring) surfaces in Greater Manchester are effective in controlling the urban heat island effect. The darker colours indicate higher rates of evapotranspiration from green space.

Figure 2: projected maximum surface temperatures in Greater Manchester for the 2080s[14]



Projected maximum surface temperatures in Greater Manchester (98th percentile summer day) for high and low carbon emissions scenarios in the 2080s, compared to 1961-1990, showing the beneficial impacts of green space in lowering temperature. The lighter colours indicate lower temperatures around green space.

Keeping warm

High levels of insulation will still be essential

New design approaches to heating buildings will be needed

Mechanical ventilation systems with heat recovery may be less beneficial

High levels of insulation will still be essential

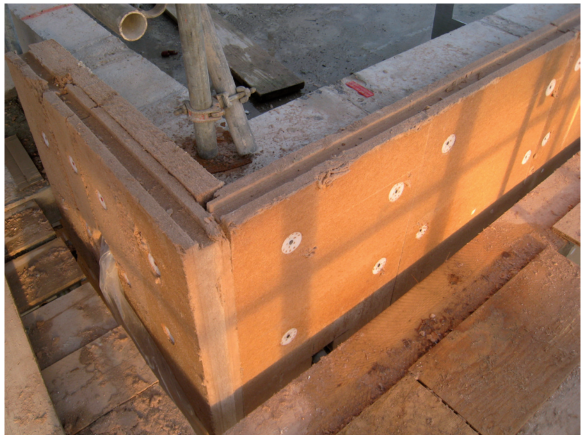
The trend towards warmer winters does not mean that insulation standards should be reduced – insulation will still be vital to reduce energy consumption and CO_2 emissions. The natural variability of weather means that there will always be relatively cold spells when high levels of insulation will be essential, particularly to limit uneconomic peak demands on utility grids.

New design approaches to heating buildings will be needed

For homes, the combination of better insulation and warmer winters will mean that the balance in the heat requirement between hot water and space heating will change, offering market opportunities to develop smaller heating systems and review controls.

Mechanical ventilation systems with heat recovery may be less beneficial

The current trend to install whole-house mechanical ventilation systems with heat recovery, as part of a drive to reduce ventilation heat loss, may need reviewing. For highly insulated air-tight homes, the heating season is already relatively short and, as winter temperatures rise, the period when heat reclaim is of significant benefit will reduce. There will also be market opportunities to develop optimised ventilation control systems or alternative strategies to make sure that the energy saved is not at the expense of energy used by mechanical systems.



Feilden Clegg Bradley Studios

Designing for comfort

This table summarises some interrelationships between anticipated changes in climate and opportunities for design, and indicates the timescales to consider when developing design strategies.†

Key

Climate trend		Climate information		Time˙	
☼	Hotter, drier summers	P	Primary issue	◔	Short – 10 years
☂	Warmer, wetter winters	S	Secondary issue	◑	Medium – 25 years
⚠	More extreme events			◕	Long – 50 years

Climate			Design opportunities	Temp – summer mean*	Temp – summer mean max*	Temp – duration of hot periods (Weather Generator)**	Temp – summer mean min (night)*	Temp – warmest night of the season*	Temp – winter mean*	Temp – winter extremes, min and max*	Wind – summer mean**	Wind – summer still periods**	Wind – direction**	Wind – summer extremes**	Wind – winter average**	Wind – winter extremes**	Sunshine – average (Weather Generator)**	Rainfall – summer average*	Rainfall – summer droughts (Weather Generator)**	Rainfall – summer extremes*	Rainfall – winter average*	Rainfall – winter wet periods (Weather Generator)**	Rainfall – winter extremes*	Time		
Climate			**Design opportunities: Keeping cool – building design**	**Climate information**																				**Time**		
☼			Shading – manufactured	P	P	S	S	S				P	S	S		S	P		S					◔	◑	
☼			Shading – building form	P	P	S	S	S				P	S	S		S	P		S							◕
☼			Glass technologies	P	P	S	S	S				P	S	S			P		S						◑	
☼			Film technologies	P	P	S	S	S				P	S	S			P		S					◔		
☼			Green roofs / transpiration cooling	P	P	S	S	S				P	S	S			P		S						◑	◕
☼			Shading – planting	P	P	S	S	S				P	S	S			P		S					◔	◑	◕
☼			Reflective materials	P	P	S	S	S				P	S	S			P		S					◔	◑	
☼			Conflict between maximising daylight and overheating (mitigation vs adaptation)	P	P	S	S	S				P	S	S			P		S					◔	◑	◕
☼			Secure and bug-free night ventilation	P	P	P	P	P				P	S	S			P		S					◔	◑	
☼			Interrelationship with noise and air pollution	P	P	P	P	P				P	S	S			P		S						◑	◕
☼			Interrelationship with ceiling height	P	P	P	P	P				P	S	S			P		S						◑	◕
☼			Role of thermal mass in significantly warmer climate	P	P	P	P	P				P	S	S			P		S							◕
☼			Enhancing thermal mass in lightweight construction	P	P	P	P	P				P	S	S			P		S						◑	◕
☼			Energy efficient / renewable powered cooling systems	P	P	P	P	P				P	S	S			P		S						◑	
☼			Groundwater cooling	P	P	S	S	S				P	S	S			P	S	S		P				◑	
☼			Enhanced control systems – peak lopping	P	P	S	S	S				P	S	S			P		S					◔	◑	
☼			Maximum temperature legislation	P	P	P	P	P				P	S	S			P		S						◑	◕
Climate			**Design opportunities: Keeping cool – external spaces**	**Climate information**																				**Time**		
☼			Built form – building to building shading	P	P	S	S	S				P	S	S			P		P							◕
☼			Access to external space – overheating relief	P	P	S	S	S				P	S	S			P		P							◕
☼			Shade from planting	P	P	S	S	S				P	S	S			P		P					◔	◑	◕
☼			Manufactured shading	P	P	S	S	S				P	S	S		S	P		P					◔	◑	
☼			Interrelationship with renewables	P	P	S	S	S				P	S	S			P		P						◑	
☼			Shading parking / transport infrastructure	P	P	S	S	S				P	S	S			P		P					◔	◑	
☼			Role of water – landscape / swimming pools	P	P	S	S	S				P	S	S			P		P				S		◑	◕
Climate			**Design issue and opportunities: Keeping warm**	**Climate information**																				**Time**		
	☂		Building fabric insulation standards						P	P					S	S	P								◑	◕
	☂		Relevance of heat reclaim systems						P	P					S	S	P								◑	
	☂		Heating appliance design for minimal heating – hot water load as design driver						P	P					S	S	P							◔	◑	

†Designers should also consider the following issues: low carbon, low energy world; behaviours will adapt to the climate; existing stock; design for robustness, maintenance and reparability; regulation vs competitive advantage; delight; regional variation. ˙10 years until replacement or upgrade *Full probabilistic information is available from UKCPO9 **Information is not available or only by using the UKCPO9 Weather Generator (see appendix 1).

Construction

Although the effect of climate change on wind speeds and soil stability is not yet clear, we need to review our techniques, materials and fixings to ensure that new buildings are weatherproof and robust.

In this section:

- Structural stability – below ground
- Structural stability – above ground
- Weatherproofing, detailing and materials

Structural stability – below ground

Changing rainfall patterns may increase shrinkage of clay soils

Foundations must be designed for the lifetime of a building

There are opportunities for innovation in foundations

Underground pipework may be affected

Slopes and retaining structures may become less stable

It is a fundamental requirement of building design that buildings should be weather tight and robust enough to withstand anticipated extremes of weather.

Materials, standards and detailing approaches have developed incrementally based on past experience of failures over time or in extreme events.

Given the projected changes, past experience needs to be tempered by future projections to modify the rules of thumb, standards, regulations and codes on which the construction industry relies to inform design work and product standards.

Regulatory authorities and the British Standards Institution are in the process of scoping the impact of climate change on the entire range of standards and regulations; however, it will take some time for the process of analysis and updating to work through. In the mean time, the industry will need to make intelligent decisions based on current available information.

Changing rainfall patterns may increase shrinkage of clay soils

Damage to buildings founded on shrinkable clay is a familiar issue in the UK as changes in the water content of these soils cause them to shrink or expand, which can affect foundations when conditions fall outside the norm.

Although the majority of the country is not susceptible to clay shrinkage, it is a significant problem in the densely occupied south east, where the majority of clays with high and very high volume change potential are located. Damage occurs to shallow foundations (and hence the domestic sector in particular) where there are a series of consecutive dry summers and dry winters. The effect is more marked where buildings are close to trees, which can remove moisture from the ground as far as 6m below the surface.

Total annual rainfall is not projected to change significantly; however, there will be changes in the pattern of seasonal rainfall. Unfortunately, whereas changes in soil moisture were included in the 2002 UKCIP climate projections, they have been dropped for UKCP09 as there is insufficient correlation between models to provide statistically robust projections. It is therefore difficult to predict how this will affect shrinkable clay soils.

An indication of the relationship between changing rainfall patterns across the country and subsidence risk can be seen by overlaying a shrinkable clay map with UKCP09 projection maps (figures 3 and 4).

Reduced summer rainfall may also affect some species of tree, particularly beech, which may suffer dieback or wilt, reducing their water uptake. This can also have an impact on foundations.

In the last 40 years there has been a strong correlation between insurance claims to deal with subsidence and dry years (1976, 1989, 1990, 1995 and 1996). Interestingly, claims peaked in 1989–90 and have decreased since then even though similar conditions have been experienced[16]. This may be because insurance claims are being handled differently and/or because the more susceptible properties have been underpinned in previous years. This, combined with the requirement (driven to a great extent by insurers of new construction) for new properties in susceptible areas to be built with deeper foundations may have had the effect that the stock has gradually become more tolerant to soil moisture change.

Peat soils can be permanently damaged by drought. Peat layers can decompose if they dry out and are not able to recover at the end of the dry period.

Foundations must be designed for the lifetime of a building

A relatively small increase in initial cost for founding at a deeper level may be a worthwhile insurance against very expensive and disruptive remedial work in the future. Similarly, if remedial works have to be undertaken to an existing building, these need to be designed as a once and for all intervention, it makes sense to err on the side of caution.

There are opportunities for innovation in foundations

There may be situations where modifying existing practice becomes impractical or uneconomic. For example, the deeper traditional strip foundations have to be constructed, the more attractive alternative strategies such as mini piles become, offering considerable potential for innovation.

Underground pipework may be affected

Underground pipework tends to be laid relatively close to the surface in the zone that is currently, or may in future be, affected by soil shrinkage and swelling. Modern flexibly jointed pipework (for drainage, gas or water) should be resistant to cracking but older rigid pipework may be vulnerable.

Slopes and retaining structures may become less stable

The stability of earth 'structures' – such as flood defence berms, ground works that form part of sustainable urban drainage systems, or landscaped mounds formed to reduce landfill waste generated on site – needs to be considered in terms of flood loadings and slope stability in very dry or saturated conditions.

Current design standards for retaining structures will need to be reviewed to include climate-related research findings. Initial observations from the long-term BIONICS research project into the stability of embankments[17] indicate that drainage under them reduces the risk of deep-seated failures (which are difficult to remediate) and that the effect of construction traffic on embankments constructed of certain soils increases their strength more than had previously been thought.

The effect of excessively dry or wet conditions on trees and planting on embankments will also need to be considered. Drought may result in reduced plant cover and an increased vulnerability to erosion under wet conditions.

Figure 3: UK soils subject to clay shrinkage[15]

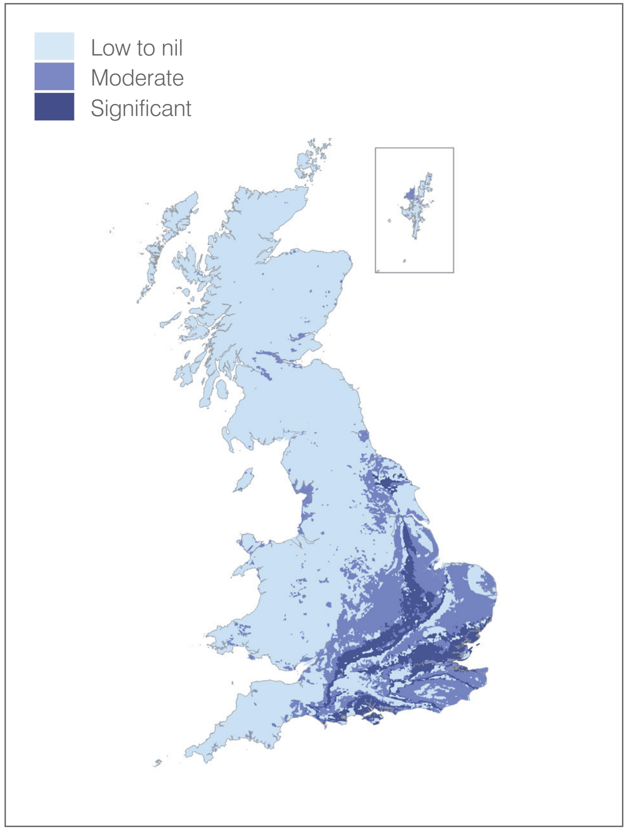
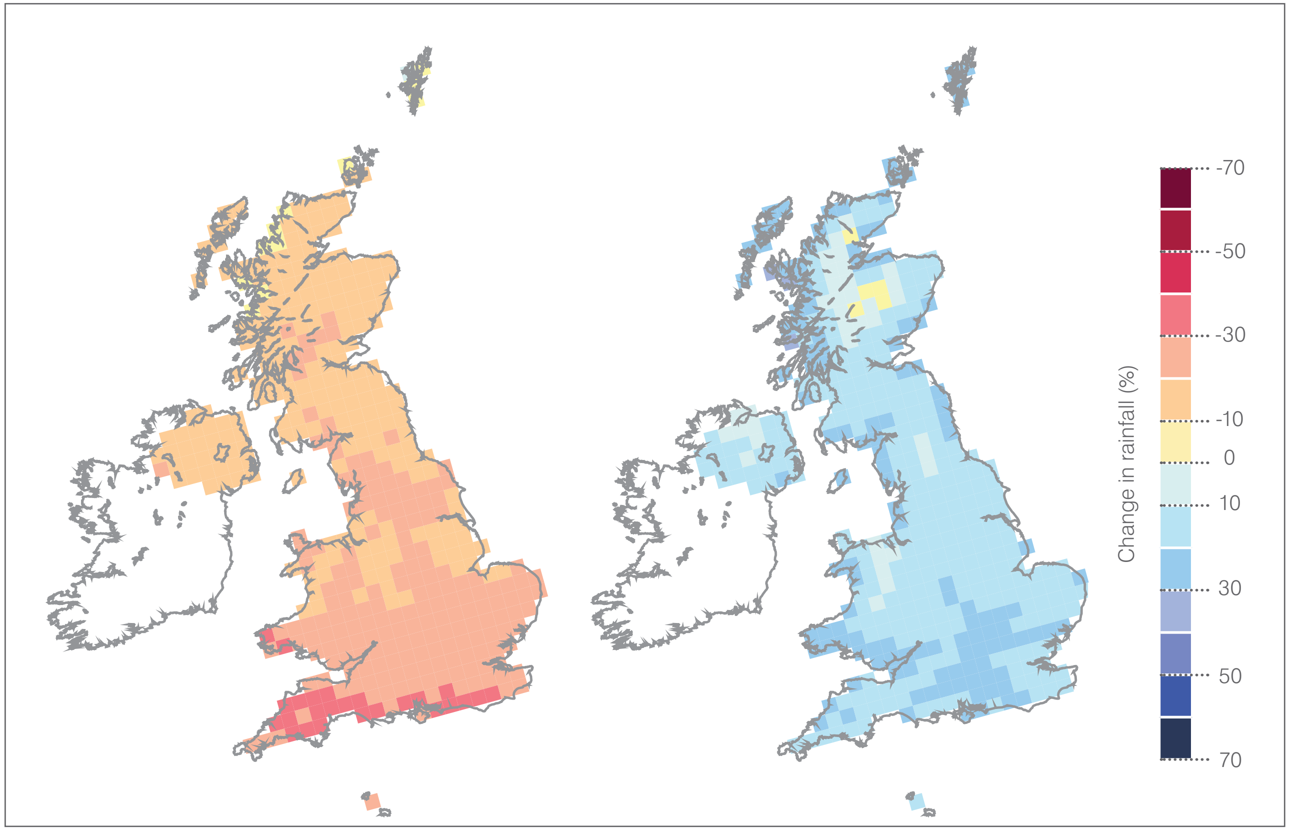


Figure 4: UKCP09 projections for change in rainfall for the 2080s[2]



The risk of subsidence due to soil shrinkage is highest in the south east, where there are significant areas of shrinkable clay (figure 3) and where the greatest changes in rainfall patterns are projected (figure 4). Figure 4 shows projections for change in rainfall for the 2080s (50% probability, medium emissions scenario) relative to a baseline of 1961-1990.

Structural stability – above ground

The effect of climate change on future wind loading is unclear

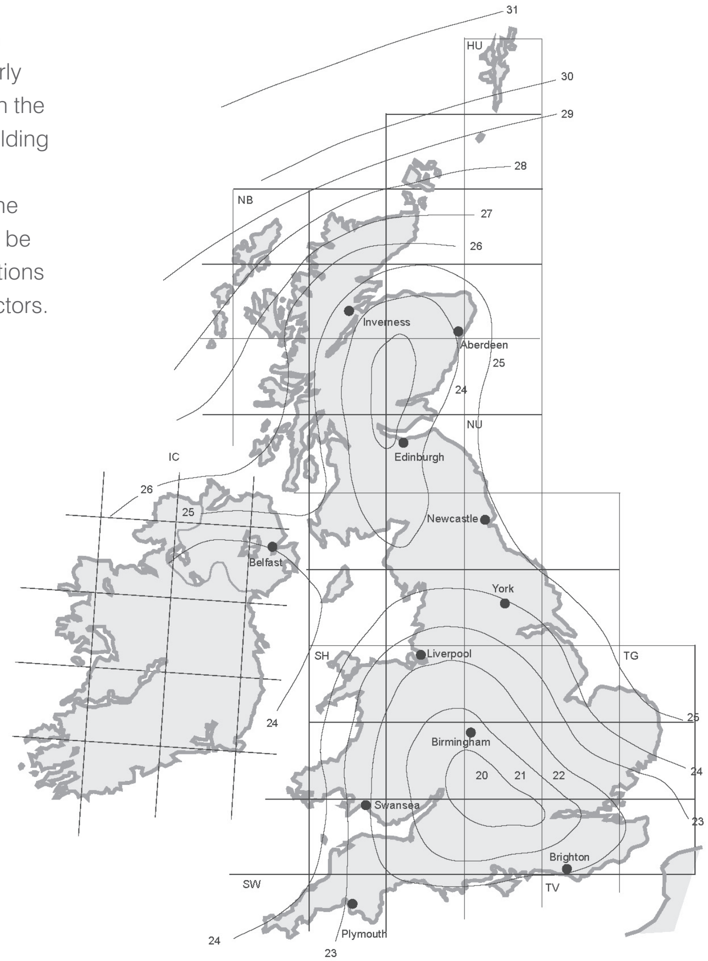
Older buildings are at greater risk of wind damage

Frame and foundation design should take a long-term view

The effect of climate change on future wind loading is unclear

Design wind loads on buildings are dependent on geographical location – whether a site is particularly sheltered (for example, in a city) or exposed (as on the coast) – and also on the shape and size of the building itself. There are well established design tools and standards based on current conditions, such as the BRE's basic wind speed map (figure 5) which can be used as a basis for structural design, with conventions for adjustment to take account of specific local factors.

Figure 5: basic wind speed map 1997[18]



Historically, windstorm damage is the primary cause of building insurance claims due to natural events in Europe, and assessing future risk is thus of critical interest to insurers. In 2003 the Association of British Insurers recommended that design codes for buildings in the south east of the UK should be increased by 10%[19]. This was based on the 2002 climate projections, which indicated, albeit with a low level of confidence, that there would be a general increase in wind speed, with associated changes in wind direction. The south coast was predicted to see the largest increase, whereas storms in the north would be likely to remain within current natural variability.

However, wind data has been excluded from the UKCP09 probabilistic projections for climate change. This is because there is too little statistical agreement between different climate models to produce robust projections for changes in wind patterns and, more importantly, for changes in the position of the North Atlantic storm track, which drives the pattern and strength of winter storms (and hence the majority of wind damage) as compared with the natural variability evident in historical measurements.

Some information is available from the Met Office regional climate model. This is inconclusive but indicates that future average winter wind speeds may reduce slightly across the country.

There have been proposals to refine design codes for wind loading to try to fine tune a design based on climate change wind projection data. However, given the lack of correlation between different models, there is a danger that this refinement may imply a degree of accuracy that does not match with the uncertainties of the underlying data.

Wind speed is thus one environmental parameter where, at present, the historical record provides stronger evidence for changes to design standards than projections from climate models.

Older buildings are at greater risk of wind damage

Since the first British Standard wind loading code of practice was published in 1944, design wind loads used in codes and standards have more than doubled for some types of building. In some parts of the UK (notably London, the south east, the east of England and Northern Ireland) they have increased by a factor of more than three to reflect wind speeds observed during extreme events that were significantly above design speeds.

Buildings constructed before the introduction of codes or built to older versions of codes are more at risk, particularly as they age or if they are poorly maintained.

Frame and foundation design should take a long-term view

With the uncertainty about future wind speeds, the construction industry needs to develop a cost-effective strategy with the flexibility to accommodate new data as it becomes available. However, for the fundamental components of a building, such as the structural frame and foundations, it may make sense to design a higher, long-term standard based on the anticipated life of the building.

The extra cost will be relatively modest compared with the cost (or practicality) of retrofitting strengthening measures later. Other building elements have lower life expectancies and might be designed to lower standards in the anticipation that they could be upgraded when replaced or maintained.

Weatherproofing, detailing & materials

Winter driving rain may increase

Detailing of weatherproofing and fixings may need to change

Materials may behave differently

We need new retrofit solutions to watertightness

Higher temperatures and UV radiation may affect materials

Changing ways of working on site

Winter driving rain may increase

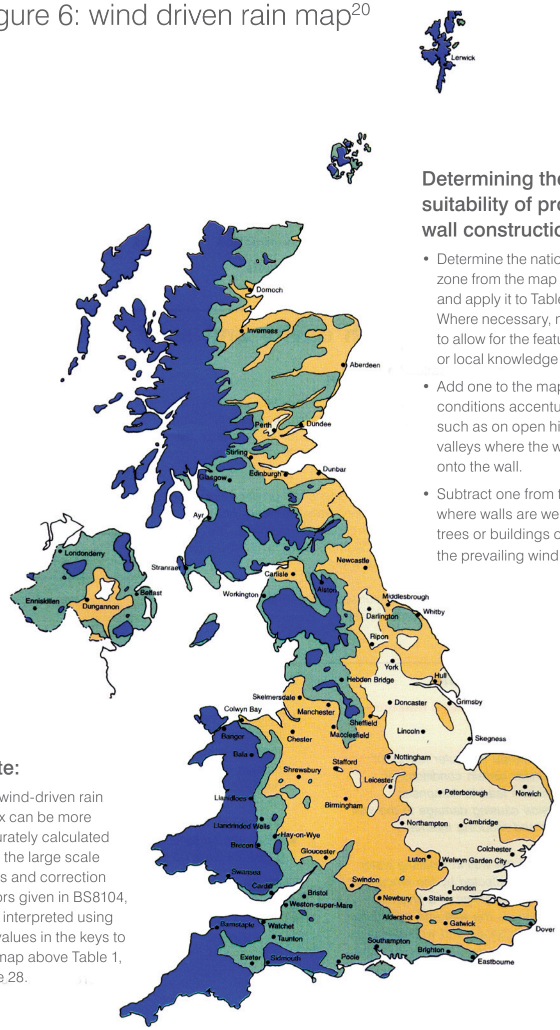
The level of exposure that the building will have to deal with is a key factor in the selection of the materials and construction technique to be used.

The wind driven rain map from which the degree of exposure of a site can be estimated is an excellent example of the use of simple but effective design rules that have developed from long experience to inform design decisions in an understandable and practical way (figure 6). The map simply divides the country into four zones and is used as a general basis for exposure standards which can then be refined to reflect local conditions.

Exposure zones	Approximate wind-driven rain* (litres/m² per spell)
1. Sheltered	less than 33
2. Moderate	33 to less than 56.5
3. Severe	56.5 to less than 100
4. Very severe	100 or more

*Maximum wall spell index derived from BS8104

Figure 6: wind driven rain map[20]



Determining the suitability of proposed wall constructions

- Determine the national exposure zone from the map on this page and apply it to Table 1 on page 28. Where necessary, modify the zone to allow for the features given below, or local knowledge and practice.
- Add one to the map zone where conditions accentuate wind effects such as on open hillsides or in valleys where the wind is funnelled onto the wall.
- Subtract one from the map zone where walls are well protected by trees or buildings or do not face the prevailing wind.

Note:

The wind-driven rain index can be more accurately calculated from the large scale maps and correction factors given in BS8104, then interpreted using the values in the keys to the map above Table 1, page 28.

Previous guidance[21] has pointed towards an increase in winter driving rain, although, as noted previously, the direct relationship between this and climate change is less definitive in the 2009 projections. The consensus is that exposure ratings may need to be revisited in parallel with design wind speeds and using a similar methodology based on direct historical observation rather than driven by climate modelling per se.

In practice, there is a relatively small difference in cost between designing for one exposure rating as compared with another. This, coupled with the lack of definitive evidence of a major step change in wind behaviour, suggests that a degree of safety can be added by designers simply electing to use a higher rating than the minimum current recommendation until standards are revised to provide a commonly agreed factor of safety without overdesigning across the board.

Detailing of weatherproofing and fixings may need to change

Traditionally construction has developed across the country to reflect the level of exposure, generally increasing from east to west and south to north, and details have been devised to provide extra protection such as:

- recessed window and door reveals
- projecting cills with drips
- render finishes
- extended eaves
- greater laps and fixings to roof and cladding fixings
- avoidance of fully filled cavities.

With a potential increase in winter driving rain, construction and fixing details may need to be revised as described above, learning lessons from design practice in more exposed locations in the UK and in harsher climates abroad.

Materials may behave differently

It is a mistake to assume that familiar materials will continue to behave in exactly the same ways in a changing climate. Designers will need to have a thorough understanding of the fundamental principles of materials behaviour and building physics so as to predict behaviour under different climate conditions.

Publications such as BRE's *Thermal Insulation, Avoiding Risks*[22], provides useful guidance on the appropriateness of different materials and construction build-ups for different levels of exposure, in particular the suitability of fully filled cavities in cavity walls. Similarly, guidance that analyses building failures under current conditions, such as *Understanding Dampness*[23], provides insight into the mechanisms of failure that can inform design thinking in the face of an unfamiliar future climate.

For example, brickwork, whether used in traditional solid walls or cavity construction, is not an impervious barrier. Its weather resistance relies on a dynamic process of wetting and drying. In today's climate it may not become sufficiently saturated to allow significant quantities of water into the cavity or through to wet built-in joist ends in traditional solid walled buildings; however, this may not be the case if winter rainfall and wind speeds increase.

Routine maintenance/replacement is an obvious opportunity to upgrade to higher standards, and there may also be opportunities to improve weather tightness as part of works to upgrade a building's thermal performance (in response to the mitigation agenda). For example, adding external wall insulation protected by a rain screen could provide a higher standard of weather resistance than the original wall.

Even recent cavity walls might need thermal upgrading to meet the envisaged carbon emissions reductions, and this may also be an opportunity to deal with fully filled cavity walls that may start to give problems in more exposed conditions.

Conversely, the use of internal wall insulation in solid wall properties will need to take account of the likely increase in driving rain when developing detail solutions. Designers will need to consider, for example, the vulnerability of joist ends in a solid wall that might become more saturated than is currently the case, particularly as the masonry will be colder by virtue of the insulation and this will reduce its tendency to dry out.

It is essential that we get the detailing right on these solutions, including the relevance of regional or exposure variations before we roll these out across the country.

Higher temperatures and UV radiation may affect materials

Higher temperatures and increased UV radiation will put a strain on synthetic materials and may also affect colour-fastness. Materials with high coefficients of thermal expansion will need increased allowances for movement, and more care will be needed with construction details at interfaces between materials with different coefficients of expansion.

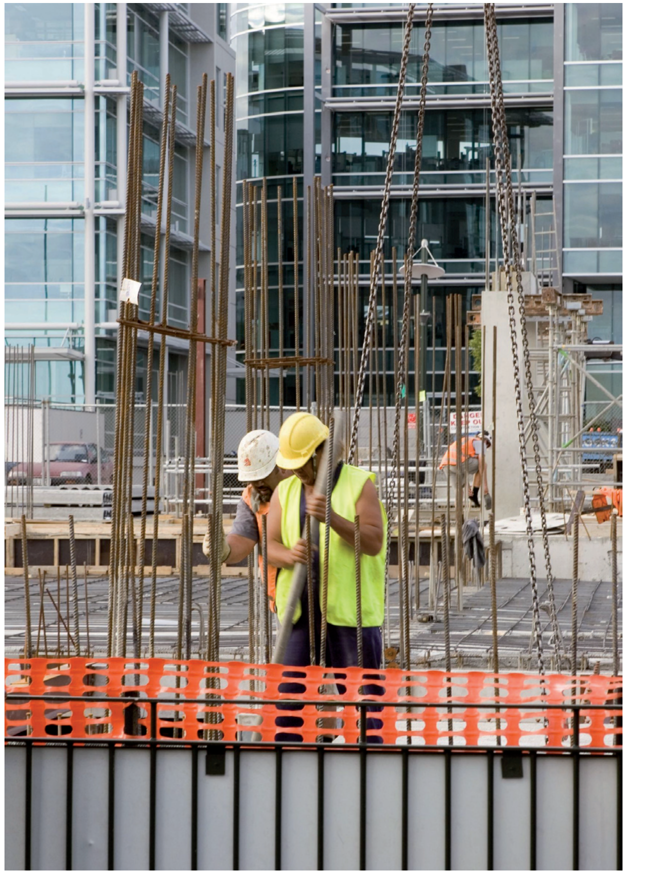
Changing ways of working on site

The same environmental issues that apply to finished buildings will also apply to buildings under construction and to associated temporary site buildings. For example, site huts typically used today are likely to be intolerable in future summers, and simply adding mechanical cooling to low-grade structures will not be an option.

Similarly, when constructing sealed skin fully mechanically serviced buildings, strategies will need to be developed either by the building designer or contractor to provide acceptable conditions for the work force until services are commissioned.

In addition, the summertime limits of any construction processes that depend on particular environmental conditions, such as laying concrete, will need to be defined and managed in the same way as is currently the case with winter conditions.

Similar attention may be necessary to deal with intense rainfall during the construction phase if full drainage systems have not been completed. For example, bunds to protect site water courses from pollution may need to be extended so as not to be overtopped in such events.



Designing for construction

This table summarises some interrelationships between anticipated changes in climate and opportunities for design, and indicates the timescales to consider when developing design strategies.†

Key

Climate trend	
☼	Hotter, drier summers
☂	Warmer, wetter winters
⚠	More extreme events

Climate information	
P	Primary issue
S	Secondary issue

Time'	
◔	Short – 10 years
◑	Medium – 25 years
◕	Long – 50 years

Climate		Temp – summer mean*	Temp – summer mean max*	Temp – duration of hot periods (Weather Generator)**	Temp – summer mean min (night)*	Temp – warmest night of the season*	Temp – winter mean*	Temp – winter extremes, min and max*	Wind – summer mean**	Wind – summer still periods**	Wind – direction**	Wind – summer extremes**	Wind – winter average**	Wind – winter extremes**	Sunshine – average (Weather Generator)**	Rainfall – summer average*	Rainfall – summer droughts (Weather Generator)**	Rainfall – summer extremes*	Rainfall – winter average*	Rainfall – winter wet periods (Weather Generator)**	Rainfall – winter extremes*	Time
Climate	**Structural stability – below ground**	**Climate information**																				**Time**
☼ ☂ ⚠	Foundation design – subsidence / heave / soils / regions													S		P	P	S	S	S	S	◕
☼ ☂ ⚠	Underpinning													S		P	P	S	S	S	S	◕
☼ ☂ ⚠	Retaining wall and slope stability															P	P	S	P	P	P	◕
Climate	**Structural stability – above ground**	**Climate information**																				**Time**
⚠	Lateral stability – wind loading standards													P								◕
☂ ⚠	Loading from ponding													S					S	P	P	◕
Climate	**Fixings and weatherproofing**	**Climate information**																				**Time**
⚠	Fixing standards – walls, roofs													P							P	◑ ◕
⚠	Detail design for extremes – wind – 3-step approach													P							P	◑ ◕
⚠	Lightning strikes (storm intensity)											P		P				P			P	◑ ◕
⚠	Tanking / underground tanks in relation to water table – contamination, buoyancy, pressure																		P	P	P	◑ ◕
⚠	Detail design for extremes – rain – thresholds / joints													P						S	P	◑ ◕
Climate	**Materials behaviour**	**Climate information**																				**Time**
☂ ⚠	Effect of extended wetting – permeability, rotting, weight														S				P	P	P	◔ ◑
☼	Effect of extended heat / UV – drying out, shrinkage, expansion, de-lamination, softening, reflection, admittance, colour fastness	S	P	P	S										P							◔ ◑
⚠	Performance in extremes – wind – air tightness, strength, suction / pressure																	S	S	S	P	◔ ◑
☂ ⚠	Performance in extremes – rain																		S	P	P	◔ ◑
Climate	**Work on site**	**Climate information**																				**Time**
☼	Temperature limitations for building processes		P	P	S	S									P							◔
☼ ☂ ⚠	Stability during construction													P							S	◔
☼ ☂ ⚠	Inclement winter weather – rain (reduced freezing?)																		P	P	P	◔
☼	Working conditions – site accommodation	S	P	P	S	S				S				S	P						S	◔
☼	Working conditions – internal conditions in incomplete / unserviced buildings (overlap with robustness in use)	S	P	P	S	S				S					P							◔

†Designers should also consider the following issues: low carbon, low energy world; behaviours will adapt to the climate; existing stock; design for robustness, maintenance and reparability; regulation vs competitive advantage; delight; regional variation. '10 years until replacement or upgrade *Full probabilistic information is available from UKCPO9 **Information is not available or only by using the UKCPO9 Weather Generator (see appendix 1).

Managing water

With the prospect of summer droughts, more frequent extreme rainfall and increased flooding, water management is becoming a serious challenge for the building industry.

In this section:

- Water conservation
- Drainage
- Flooding

Water conservation

Drinking water will be in increasingly short supply

Rainwater or grey water systems may become the norm

Blue amenity space will play an increasingly important role

The total annual rainfall for all parts of the UK is not projected to change significantly, but its distribution between winter and summer is likely to be different.

This shift in seasonal rainfall patterns together with increasing intensity and frequency of extreme events is likely to result in flooding on the one hand and scarcity of water on the other.

Existing reservoirs are not designed to deal with summer droughts, and this is exacerbating pressure from concentrating development in some parts of the country and increasing competition from agriculture, power generation and industry.

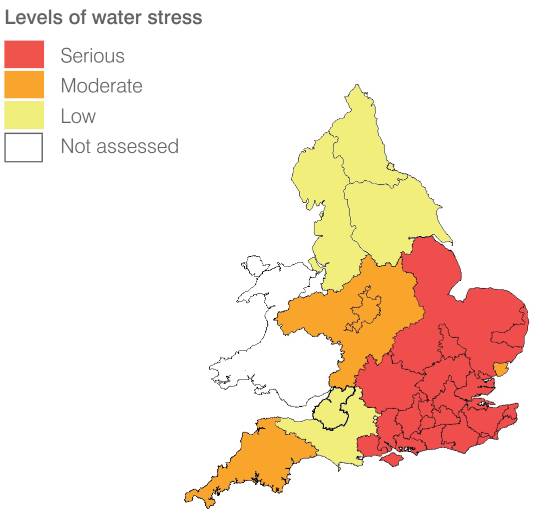
Water management is an area of the adaptation agenda that is well tied into our planning and regulatory system already; however, the effects of future change need to be factored in.

Drinking water will be in increasingly short supply

The statistic that there is already less water available per person in England and Wales than there is in many Mediterranean countries is often quoted to illustrate the shortage of a resource that we have habitually assumed was abundant.

Droughts in recent years illustrate the conditions that are projected to become the norm in future and indicate the stresses that the water authorities in some parts of the country will face, particularly in the south east (where there is also the most pressure to develop). Figure 7 shows areas of water stress in England in 2007.

Figure 7: areas of water stress in England[24]



Large civil engineering projects are already being considered to increase the supply of water to stressed areas, such as desalination or large-scale connections between water resources in different parts of the country. But large projects of this type consume significant quantities of energy and should not be undertaken without full consideration of alternative conservation approaches. One wonders when water scarcity might become a defining factor in deciding whether development is desirable or, indeed, viable.

The construction industry itself is a significant user of water, and in response to the need to reduce consumption has set a target to use 20% less water in the production of materials and during construction by 2012, compared with 2008[25].

Changes to Part G of the Building Regulations introduced a new minimum water efficiency standard of 125 litres per person per day for all new homes from April 2010[26]. The drive towards lower water consumption is supported by a wide variety of available low water use fittings that can be used as like-for-like replacements. However, this market is somewhat schizophrenic, particularly at the luxury end that aspires more towards 'tropical downpour' showers, over-sized baths and external hot tubs that are diametrically opposed to a conservation agenda.

Behaviour and pricing can have a profound impact on water use. Households that are metered[27] use on average 10-15% less water than unmetered households[28]. The Environment Agency has called for most homes in seriously water stressed areas to be metered by 2015[29], allowing the introduction of tariff structures that reduce demand.

Rainwater or grey water systems may become the norm

Efficient fittings and careful use alone may not be able to deliver the necessary reduction in consumption.

Households will increasingly need to supplement high-quality potable mains water with either rainwater or grey water for non-potable uses, and there is a growing market for suitable systems.

Rainwater systems will need to take potential summer droughts into account in the sizing of tanks. This may mean that grey water systems, which use water more than once – storing a relatively small amount over a short period rather than a large quantity over a long period – become a more attractive proposition (providing of course that main supplies are not significantly interrupted).

Given the cost and complexity of adapting existing water supply infrastructure to provide separate potable and non-potable supplies, as is the case in some Mediterranean countries, the simplest point of intervention for the existing stock is at the scale of the individual home or block, and this is where there has been most product development. At the larger scale of new neighbourhoods or even whole communities there are opportunities to exploit potential economies of scale and to provide other benefits in the process.

Blue amenity space will play an increasingly important role

A holistic approach to water management across a larger site offers opportunities to work with gravity to exploit water both practically and aesthetically, both for supply and dispersal, by incorporating water bodies to store or treat surface water and landscaped swales and flood mitigation areas as part of a wider flood management strategy.

Integration with landscape has the twin benefits of balancing the need for irrigation with a complementary planting strategy, whilst providing much needed green and ‘blue’ amenity space to help reduce the urban heat island effect in denser areas.

Mandy Reynolds, Fotoforum

Drainage

Larger capacity building gutters, downpipes and drainage may be needed

Foul sewers may fail to function properly as we use less water

Drains may be overwhelmed by extreme rainfall

Extensive work may be required to existing sewers

Larger capacity building gutters, downpipes and drainage may be needed

Building gutters, downpipes and surface water drainage will need to be sized to deal with any projected increases in extreme rainfall. British standards committees are reviewing the impact of climate change projections on standards.

Given the level of uncertainty, the need for building rainwater drainage always to include a fail-safe strategy for water to overflow harmlessly outside rather than inside a building in an extreme event will become increasingly important.

Opportunities to store rainwater at high level in buildings should also be explored to provide a simple means of providing water for non-potable uses, such as WC flushing, using gravity to drive the system rather than pumping from underground tanks.

Foul sewers may fail to function properly as we use less water

Water shortage provides an impetus to reduce the amount of water used, potentially to the extent that traditional design standards may not have sufficient water to keep operating properly. It may be that radical alternatives such as vacuum-based drainage become more attractive or necessary, which may increase energy consumption as compared with a gravity-driven water-based system.

Drains may be overwhelmed by extreme rainfall

Extreme rainfall, combined with widespread replacement of landscaped or garden space with hard surfacing for parking etc, means that existing combined and surface water systems can be overwhelmed, leading to sewer flooding.

Since 2008, the installation of significant areas of impermeable hard surfacing in domestic front gardens can no longer be carried out as 'permitted development', and similar measures for non-domestic premises were introduced in April 2010. The 2010 Flood and Water Management Act made the right to connect to sewers conditional on meeting requirements for sustainable drainage, and introduced the requirement that new surface water drainage should, wherever possible, be dealt with on site using a Sustainable Urban Drainage System (SUDS). The date that this aspect of the Act comes into force is yet to be announced.

Extensive work may be required to existing sewers

Even with measures to avoid negative impacts from new development on existing infrastructure, existing sewer systems may be inadequate to cope with the increased load from extreme events, and significant civil engineering work may be needed to improve sewer capacity and avoid serious flooding. The use of SUDS in existing built areas (retrofit SUDS) has also been discussed and studies have been planned by United Utilities and the Environment Agency to test their effectiveness.

Flooding

SUDS design parameters may need review

SUDS are well established, and are now a requirement for all new developments through the planning system to reduce the impact of rainfall events[30]. However, changes in the ability of soils to absorb and disperse surface water in future will need to be factored in to SUDS design.

In any event, SUDS designs should always include robust, failsafe strategies to allow the system to overflow without flooding buildings both within a site and downstream of it.

Design teams need to consider urban flash flooding

Some areas will be subject to significant recurring coastal or river flood risks. These risks are relatively well understood and are tied in well to our standard planning practices. The Environment Agency is currently analysing the implications of the UKCP09 projections for its guidance.

However, all sites will need to consider risks of urban and flash flooding, as flash flooding can be a highly localised phenomenon depending on projected high levels of rainfall. Here again, the Environment Agency is developing its analysis of many vulnerable urban areas, and designers and developers will need to be aware that they may also need to deal with upstream risks resulting from projected increases in rainfall.

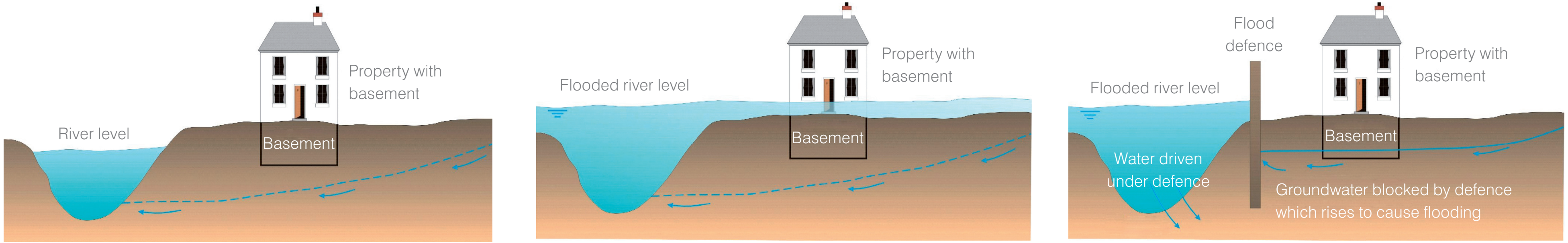
Ground water levels may change

Ground water levels may change significantly for a variety of reasons – both natural, such as high rainfall, or man-made, such as the introduction of an underground barrier. An example of the latter might be the introduction of a new flood defence in an area prone to river flooding (figure 8).

The defence must be taken down to a depth that will stop it being bypassed by river water flowing out underground; however, this might also interrupt natural sub-surface water movement in the other direction under normal conditions. The natural ground water movement is in effect dammed by the underground flood defence, and the water table rises as a result.

The causes and effects are not necessarily obvious and each case needs to be assessed individually, involving specialist advice if in doubt.

Figure 8: flood defences may increase ground water level[31]



Before: ground water drains under a basement of a riverside property.

Before: river in flood.

After: flood defence defends house but dams ground water, which then floods basement.

Recurring flooding will require investment to improve defences

Recurring river flooding results from extreme rainfall, overtopping or breaching of flood defences, often in combination with high rainfall over a period of time that has saturated the catchment area. Warning procedures are well established to minimise danger to life; however, there is an increasing need to prevent costly damage to property.

Coastal flooding places our towns and cities (both financial and cultural assets) at risk. It may be possible to add or improve defences to resist rising sea levels and storm surges but this will require very significant investment. Where there is space, it may be more appropriate to adopt a strategy of retreat, allowing space for surges to reduce the pressure on hard defences.

Three strategies for dealing with flood risk areas

Avoidance – the simplest and most pragmatic approach to avoiding flood risk is not to build in flood risk areas. An additional factor of safety can be incorporated by design responses such as raising the floor level of a building to prevent water ingress under extreme circumstances. This is the fundamental strategy that underpins current official guidance for new development.

Resistance – in areas where flood water is likely to reach a building – for example, areas that have low flood risk today but might become more susceptible to flood risk in the future – it may be possible to 'dry-proof' buildings to prevent water entering. This can be achieved by incorporating permanent or temporary barriers such as door dams and non-return drainage valves and is only effective for floods of short duration and heights up to around 1m. Above this level, water pressure is likely to cause structural damage and the majority of apparently solid wall constructions will leak. Success here also depends on completeness in the defence; a missing air brick cover will render the entire defensive system useless.

Resilience – there may be situations where there is an unavoidable risk of flooding that cannot be dealt with by site or wider area controls. Under these circumstances there is much that can be done to minimise the damage and simplify reinstatement once the floods have subsided. This is a technique sometimes referred to as 'wet proofing'.

Designing to manage water

This table summarises some interrelationships between anticipated changes in climate and opportunities for design, and indicates the timescales to consider when developing design strategies.†

Key

Climate trend	
☀	Hotter, drier summers
🌧	Warmer, wetter winters
⚠	More extreme events

Climate information	
P	Primary issue
S	Secondary issue

Time`	
◔	Short – 10 years
◑	Medium – 25 years
◕	Long – 50 years

Climate: Hotter, drier summers	Climate: Warmer, wetter winters	Climate: More extreme events	Topic	Time: Short – 10 years	Time: Medium – 25 years	Time: Long – 50 years
			Water conservation			
☀			Low water use fittings	◔	◑	◕
☀			Grey water storage	◔	◑	
☀			Rain water storage	◔	◑	◕
☀			Alternatives to water-based drainage			◕
☀			Pools as irrigation water storage		◑	◕
☀			Limits to development			◕
☀	🌧		Water-intensive construction processes	◔		
			Drainage – external / building related			
	🌧	⚠	Drain design			◕
	🌧	⚠	SUDS and soakaway design		◑	◕
		⚠	Gutter / roof / upstand design		◑	◕
			Flooding – avoidance / resistance / resilience			
		⚠	Environment Agency guidance – location, infrastructure			◕
		⚠	Combination effects – wind + rain + sea level rise			◕
		⚠	Flood defence – permanent			◕
		⚠	Flood defence – temporary – products etc	◔	◑	
		⚠	Evacuation / self sufficiency			◕
		⚠	Flood tolerant construction			◕
		⚠	Flood tolerant products and materials		◑	◕
		⚠	Post-flood recovery measures			◕
			Landscape			
☀	🌧		Plant selection – drought resistance vs cooling effect of transpiration		◑	◕
☀	🌧		Materials behaviour in high temperatures		◑	◕
☀	🌧		Changes to ecology		◑	◕
☀			Irrigation techniques	◔		
☀			Limitations on use of water features – mosquitoes etc		◑	◕
☀			Role of planting and paving in modifying micro climate and heat island effect		◑	◕
			Failsafe design for extremes – water			◕
☀			Firebreaks			◕

Topic	Temp – summer mean*	Temp – summer mean max*	Temp – duration of hot periods (Weather Generator)**	Temp – summer mean min (night)*	Temp – warmest night of the season*	Temp – winter mean*	Temp – winter extremes, min and max*	Wind – summer mean**	Wind – summer still periods**	Wind – direction**	Wind – summer extremes**	Wind – winter average**	Wind – winter extremes**	Sunshine – average (Weather Generator)**	Rainfall – summer average*	Rainfall – summer droughts (Weather Generator)**	Rainfall – summer extremes*	Rainfall – winter average*	Rainfall – winter wet periods (Weather Generator)**	Rainfall – winter extremes*
Water conservation																				
Low water use fittings															P	P		S		
Grey water storage															S	S		S		
Rain water storage															P	P		S		
Alternatives to water-based drainage															P	P		S		
Pools as irrigation water storage	S	S	S											S	P	P				
Limits to development															P	P		S		
Water-intensive construction processes															P	P				
Drainage – external / building related																				
Drain design																	S	S	P	P
SUDS and soakaway design																	S	S	P	P
Gutter / roof / upstand design																				P
Flooding – avoidance / resistance / resilience																				
Environment Agency guidance – location, infrastructure																	P	S	P	P
Combination effects – wind + rain + sea level rise											P		P				P	S	P	P
Flood defence – permanent																S	S	S	P	P
Flood defence – temporary – products etc																	S	S	P	P
Evacuation / self sufficiency																	S		P	P
Flood tolerant construction																	S	S	P	P
Flood tolerant products and materials																	S	S	P	P
Post-flood recovery measures																	S		P	P
Landscape																				
Plant selection – drought resistance vs cooling effect of transpiration	P	P	P										S	P	P	P	S		P	S
Materials behaviour in high temperatures	S	P	S																	
Changes to ecology	P	P	P										S	P	P	P	S		P	S
Irrigation techniques	P	P	P										S	P	P	P	S		P	S
Limitations on use of water features – mosquitoes etc	P	P	P										S	P	P	P	S		P	S
Role of planting and paving in modifying micro climate and heat island effect	P	P	P										S	P	P	P	S		P	S
Failsafe design for extremes – water																				P
Firebreaks	P		P					S	S	S	S			P	P	P		S		

†Designers should also consider the following issues: low carbon, low energy world; behaviours will adapt to the climate; existing stock; design for robustness, maintenance and reparability; regulation vs competitive advantage; delight; regional variation. `10 years until replacement or upgrade *Full probabilistic information is available from UKCPO9 **Information is not available or only by using the UKCPO9 Weather Generator (see appendix 1).

Conclusion

Our existing built environment has evolved in response to our climate, the materials available and a similarly evolving lifestyle; at least until the advent of cheap energy and powerful systems to make up for the shortcomings in recent building design. Thus our climate, the buildings we inhabit and our lifestyle are thoroughly enmeshed.

We have no alternative but to develop adaptation strategies to deal with inevitable change that stems from past emissions. Further, more challenging changes are likely depending on our success or otherwise in reducing future emissions. The mitigation and adaptation agendas are thus entirely interlinked: the more successful we are at the former, the less the change we will need to address by the latter. The challenge is how to adapt an evolved and familiar built environment so that it is fit for an unfamiliar future without at the same time increasing our carbon emissions to feed a vicious circle of further change.

Despite the availability of climate change projections for some years, the construction industry is still very much at the early stages of developing practical responses to the adaptation agenda. There is a wealth of information available through the UKCP09 projections; however, whilst it is of immense value in illustrating a range of projected changes across a range of emissions scenarios, it is not directly usable by those making day-to-day decisions about the design or procurement of buildings. The projections used do not indicate that the climate will stabilise during this century and change must therefore be regarded as an on-going phenomenon.

Particular areas of concern include thermal comfort. The trend for hotter summers will have perhaps the greatest impact on design. Many existing buildings already perform badly in summer, and while passive design strategies will offer real benefits, active cooling will be difficult to avoid by the end of the century. It will also be necessary to manage overheating of external spaces by providing shading, green space (such as parks and woodland) and 'blue' space (water bodies such as rivers, canals and lakes). Fortunately winters are expected to be less cold and there will be less need for winter heating.

The urgency of the adaptation challenge is succinctly set out in the ministerial foreword to *Climate Change: Taking Action*, the overview document accompanying individual Departmental Climate Change Adaptation Plans published in March 2010 as a requirement of the Climate Change Act 2008:

High levels of insulation will still be vital, the balance of the heat requirement between hot water and space heating will change, offering market opportunities to develop smaller heating systems and review controls. Mechanical ventilation systems with heat recovery may become less cost effective as the heating season shortens.

The weather tightness and structural stability of buildings is another area of concern with the changing climate. Shrinkage of clay soils may become a growing concern as existing foundations are affected and need to be underpinned. Foundations in new buildings will need to be designed for the lifetime of the building, particularly in the south east where the majority of clay soils with high volume changes are located. Underground pipework, slopes and retaining structures may also be affected, potentially resulting in expensive remediation.

In terms of wind loading, the climate projections do not include reliable models of changes in wind patterns. However, older buildings built to lower Association of British Insurers design codes are at more structural risk. For new buildings, it makes sense to design the frame and foundations to a higher standard to minimise expensive remediation later. Other building elements have lower life expectancies and might be designed to lower standards in the anticipation that they could be upgraded when replaced or maintained.

> ‘The UK Climate Projections 2009 show that past emissions are likely to make summers over 2°C warmer in southern England by the 2040s – more than enough to affect the way we live and work. And unless global emissions are successfully reduced, we could be faced by much more damaging impacts by the 2040s.’[32]

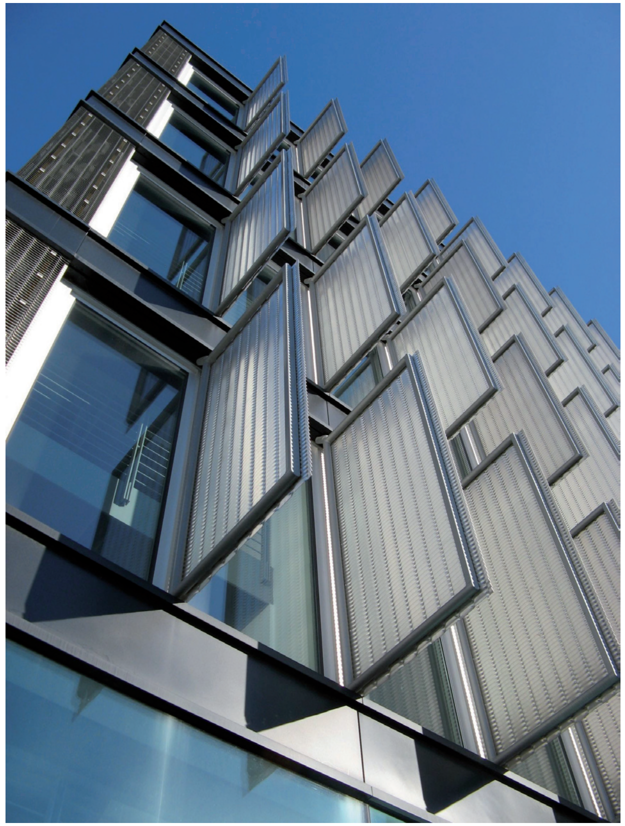
As the projections indicate higher levels of winter driving rain, weatherproofing and the performance of traditional construction materials may change. There is evidence to show that brick cavity walls can fail to be watertight and detailing of fixings will need to be upgraded.

The climate projections indicate that although the total annual rainfall will not change much in the UK, the balance between winter and summer will change. Drier summers mean that water conservation will become more important as potable water will be in increasingly short supply and rainwater or grey water use will become the norm.

Management of flooding is already a major issue, and with more extreme precipitation events expected in winter, larger capacity building gutters, downpipes and drainage will be needed. There is a significant risk of drains and foul sewers flooding and failing to function. Thus, new developments may require extensive work to improve sewer capacity. Recurring flooding and changes in ground water levels will require investment in flood resistance and resilience, while urban flash flooding must also be considered during extreme rainfall events.

Different adaptation approaches may need to be developed that relate to the life spans of different building elements. Fundamental elements may require a step change in design approach to take account of their extended life expectancy, whereas some elements can be regularly upgraded as part of normal maintenance and replacement cycles in a more incremental or reactive approach.

The industry now needs to make rapid progress within a coherent framework, provided by Government, that will enable design teams to develop and test out holistic adaptation strategies using data and tools that we are confident can accurately represent the interactions between our buildings and future climate.



Appendix 1: UK climate projections

In this section:

- UK Climate Projections 2009
- Climate overview

The UK Climate Projections 2009 provide the most up-to-date estimates of how the climate may change over the next 100 years. They are an invaluable source of information if you wish to find out more about the future climate at a national or regional level.

UK Climate Projections 2009

Probabilistic data

Three scenarios for greenhouse gas emissions

Absolute values as well as projected changes

Published tables, maps and graphs

Creating bespoke maps and graphs

The key source of information on recent and future UK climate change is the UK Climate Projections 2009 (UKCP09)[2], based on projections provided by the Met Office.

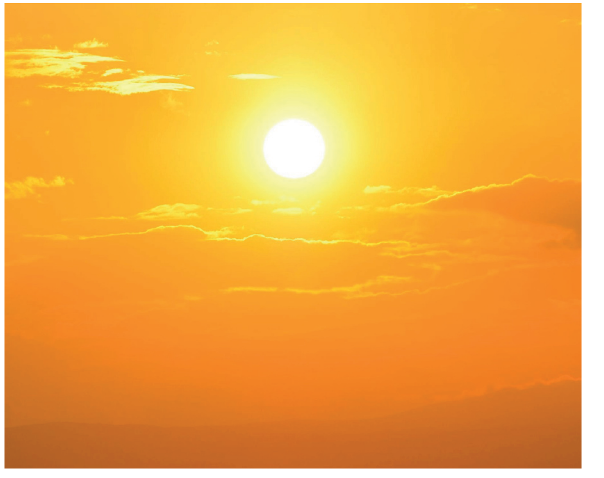
This is the fifth generation of UK projections and is the most comprehensive, updating and augmenting the previous set published in 2002 (UKCIP02).

This is the information on which research organisations, regulation and standards-setting bodies and the insurance industry are basing their responses to climate change. The older UKCIP02 scenarios are still available to refer to in connection with existing guidance until that is updated.

Information is available from the UKCP09 website, and a full description can be found in *UK Climate Projections: Briefing Report* sections 3 and 4[33].

A range of tools, methods and guidance are also available from the website of the UK Climate Impacts Programme (UKCIP)[34], which was set up in 1997 to work in partnership with the public, private, research and voluntary sectors to help them develop strategies to adapt to climate change.

In order to make appropriate changes in the way we design new buildings and develop strategies for adapting the existing stock we need to understand the likely pattern, timescale and magnitude of the projected changes in some detail.



Probabilistic data

The UKCP09 projections differ fundamentally from their predecessors in that information is presented as probabilistic ranges of values indicating percentage likelihood rather than single values for each climate variable considered. This is because they are now based on the outputs from a range of climate models rather than the UK Met Office's Hadley Centre model alone. This makes them more robust in that they take into account a wider range of variants and different but plausible climate modelling methodologies.

Explaining probability

Having a probabilistic range of values makes interpretation of the climate projections more complicated.

In addition to the three equally likely climate scenarios based on different levels of greenhouse gas emissions, within each scenario there is a range of values that may occur.

These ranges are presented as percentages that relate to how likely a climate change impact is to occur.

These ranges are useful when managing risk – for example:

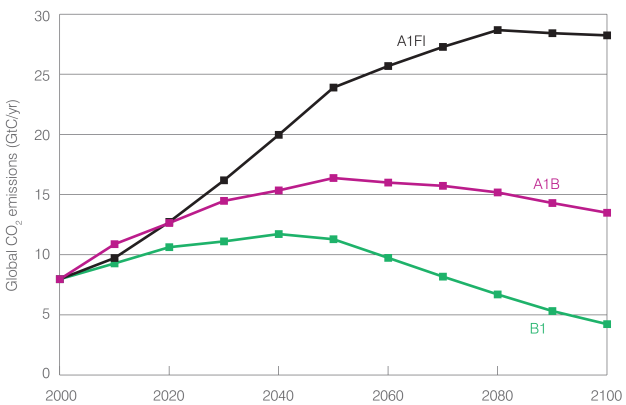
- some events that are extremely unlikely to occur may have potentially catastrophic consequences and so should be designed for
- other climate impacts, although very likely to occur will have lesser impacts in certain regions and so can be disregarded.

The graphs in this section show the impacts that are likely to occur, where 'likely' refers to probabilities between 90% (very likely) to 10% (very unlikely).

Three scenarios for greenhouse gas emissions

The projections are based on a representative range of three of the greenhouse gas emissions scenarios used for the latest Intergovernmental Panel on Climate Change (IPCC) Assessment Report[35], as shown in figure 9.

Figure 9: emissions scenarios used for UKCP09[33]



A1FI = High CO_2 emissions
A1B = Medium emissions
B1 = Low emissions

As with the IPCC Assessment Report, none of these scenarios should be regarded as being statistically more likely to occur than any other. They are simply based on different assumptions about greenhouse gas emissions, land use, technological and economic development.

In addition, an H ++ (extreme) scenario[33] has been developed specifically to investigate sea level rise and storm surges. This aims to reflect the effect of melting ice that is not well represented at present in global climate models but which represents a major source of uncertainty in projecting sea level rise.

Absolute values as well as projected changes

Absolute figures for climate variables (e.g. 19°C) are provided in addition to relative data on climate change (e.g. 2°C rise). Projections of change are useful for understanding the relative difference between what we are familiar with and future conditions, but absolute figures are more useful in understanding the actual effect of a change on, say, designing the size of a drain or maintaining a particular internal temperature.

Full probabilistic data is provided for:

Over land:

- mean temperature
- mean daily maximum temperature
- mean daily minimum temperature
- warmest day of the season (99th percentile of daily maximum temperature in a season)
- coolest day of the season (1st percentile of daily maximum temperature in a season)
- warmest night of the season (99th percentile of the daily minimum temperature in a season)
- coldest day of the season (1st percentile of daily minimum temperature in a season)
- precipitation rate (rain/snowfall combined)
- wettest day of the season (99th percentile of daily precipitation rate in the season)
- specific humidity
- relative humidity
- total cloud
- net surface long wave flux
- net surface short wave flux
- total downward short wave flux
- mean sea level pressure.

Over sea:

- mean air temperature
- precipitation rate
- total cloud
- mean sea level pressure.

Probabilistic data is not provided for:

- wind speed
- snow
- soil moisture
- surface latent heat flux[36].

Projections for these were included in UKCIP02, albeit with relatively low levels of confidence attached. The change is due either to technical incompatibility between the results of the different models now used for the UK projections or because results vary significantly between different models which, in turn, do not match observed data particularly well.

Non-probabilistic data for specialist users on wind speed are available (outside UKCP09) based on outputs from the Met Office regional climate model for the medium scenario only from the Climate Impacts LINK website[37]. A technical note is available on the interpretation of this information[38]; however, in simple terms, it projects a slight decrease in winter mean wind speed over the UK.

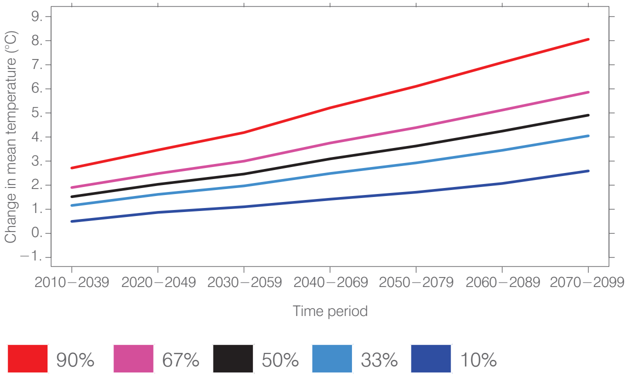
Published tables, maps and graphs

A wide range of data tables, maps and graphs is available for climate variables for probabilities, ranging from 10% (very likely to be exceeded) to 90% (very unlikely to be exceeded) in a number of different forms, the most useful of which are:

Plume plots

These show a plume of probability under a given emissions scenario, giving the likely (10% to 90%) range of change of a particular climate variable over time for a particular location; in the case of figure 10, change in mean summer temperature.

Figure 10: typical plume plot[33]



Pre-prepared maps

These are available for each of the three emissions scenarios for three time periods (2020s, 2050s and 2080s) for the majority of climate variables for:

- the UK as a whole
- administrative regions
- river basins
- marine areas.

Creating bespoke maps and graphs

A new user interface is available on the UKCP09 website to provide custom graphics and data tables tailored to individual user needs.

This includes analytical tools, for example:

A new Weather Generator is available for expert users only, which generates 'synthetic' hourly data. The outputs do not represent actual weather and can only be used by considering together the results of many runs of the tool (at least 100). This provides statistically credible probabilistic representations of what might occur given a particular future climate and is useful in investigating the potential occurrence of events like heatwaves, frost and dry spells.

A Threshold tool has also been developed that can be used in combination with the Weather Generator to produce statistics for the number of occasions when a variable (such as temperature) might be above or below a chosen value. This is useful for investigating heatwaves, heating or cooling degree days. Again, this is only suitable for expert use.

Overview of the projected climate

Graphs

Maps

Tables

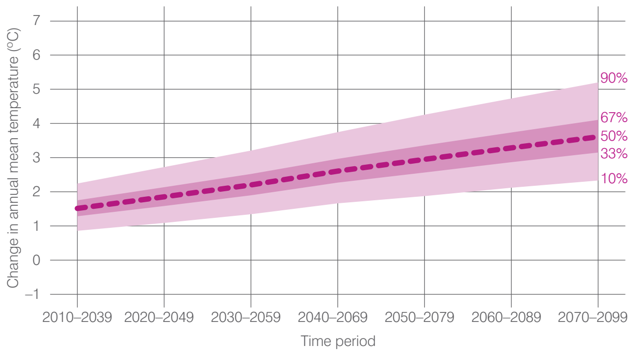
There is a wealth of information available on the UKCP09 website which is summarised in the *UK Climate Projections: Briefing Report*.[33]

For those who principally need a broad understanding of the range of issues we might need to deal with, the following graphs and maps, developed by UKCIP for this report, give a simple overview. The tables on pages 60 and 61 summarise some of the projected changes for the 2080s.

Graphs

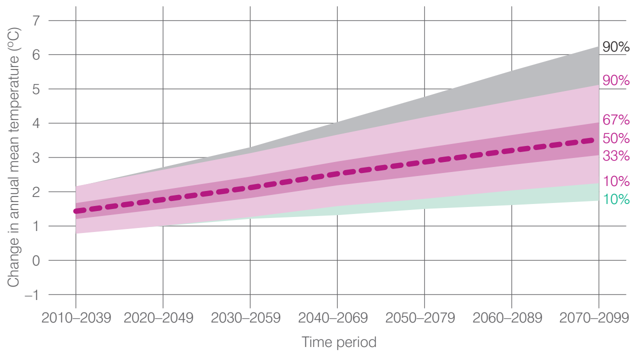
Taking annual mean temperature as an example, figure 11 shows the projected range of likely change (relative to the baseline period of 1961-1990) for the south east of England under the medium emissions scenario based on a UKCP09 plume plot. The central estimate is shown as a heavy dotted line, with the 10-90% probability range as a lightly shaded area and the 33-67% probability range more darkly shaded.

Figure 11: annual mean temperature change in south east England (medium scenario)[2]



In figure 12, given that none of the emissions scenarios can be regarded as being statistically more likely than any other, in order to take account of the full range of likely projections for the full range of emissions scenarios, the projections for the low (10% – shaded green) and high (90% – shaded grey) scenarios have been added to the graph.

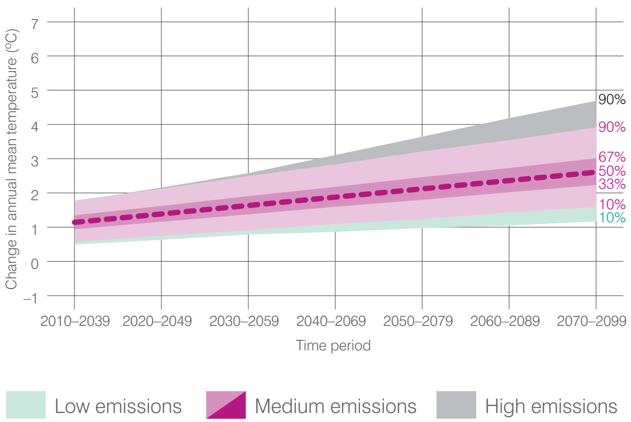
Figure 12: annual mean temperature change in south east England (all scenarios)[2]



Low emissions   Medium emissions   High emissions

A similar exercise can be carried out for other UK regions: north Scotland is shown in figure 13 as a comparative example.

Figure 13: annual mean temperature change in north Scotland (all scenarios)[2]



The projected changes for north Scotland are slightly less than that for the south east of England, both in terms of magnitude and spread for different scenarios, illustrating the point that climate impacts are a regional issue, with different projected levels of change for different regions.

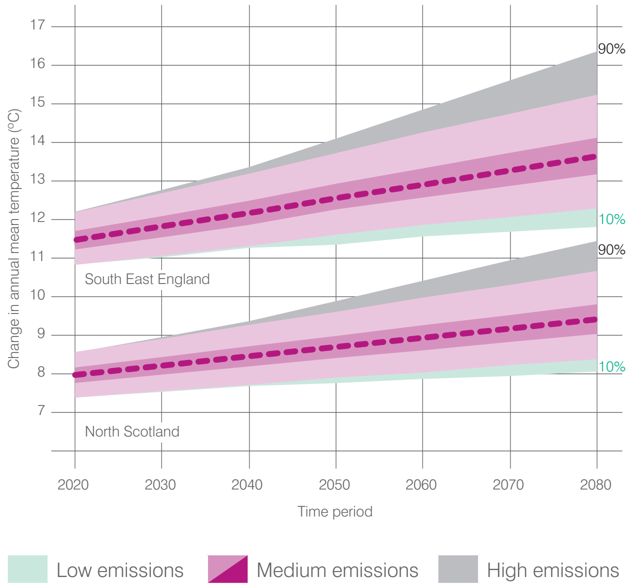
Plume plots demonstrate very effectively that, for all climate variables and scenarios modelled, the climate is still extremely likely to be changing at the end of the twenty-first century rather than stabilising or showing signs of returning to the climate we are currently familiar with. This has two consequences:

- firstly, that adaptation is likely to be an ongoing issue for the foreseeable future rather than accommodating a single step change; and
- secondly, that adaptation measures designed to accommodate a higher emissions scenario or a higher probability than in fact turns out to be the case will simply have a longer life. To put it another way, many changes that might be at the upper end of probability under a high scenario in the 2020s are projected to become the norm in, say, the 2050s.

Obviously, if global agreements are put in place that manage to limit global temperature change to under 2°C, a more optimistic picture might emerge. However, in the absence of this we have little alternative but to prepare for higher and ongoing levels of change.

In figure 14, the same plume plots plotted against absolute temperature rather than temperature change (these are approximate extrapolations of UKCP09 data for illustrative purposes rather than data supplied directly from UKCP09) illustrate that, whereas there is a significant difference in temperature across the UK currently, under a changing climate the climate will become more divergent, and more so at the upper levels of emissions scenarios and probabilities. Under these circumstances it will become increasingly important to take account of climate differences in different locations across the country.

Figure 14: change in absolute annual mean temperature for south east England (top) and north Scotland (bottom) (all scenarios)[39]

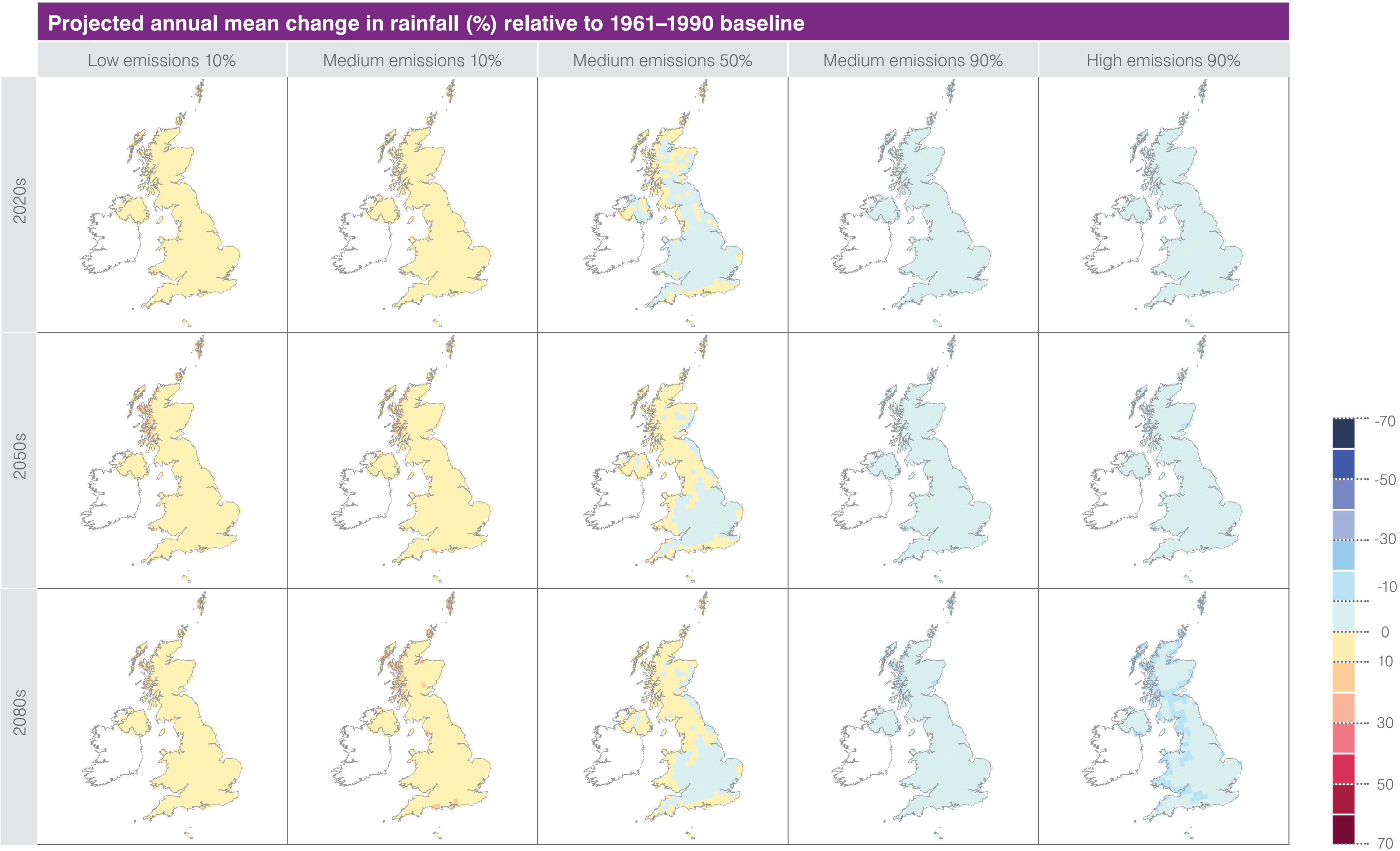


Maps

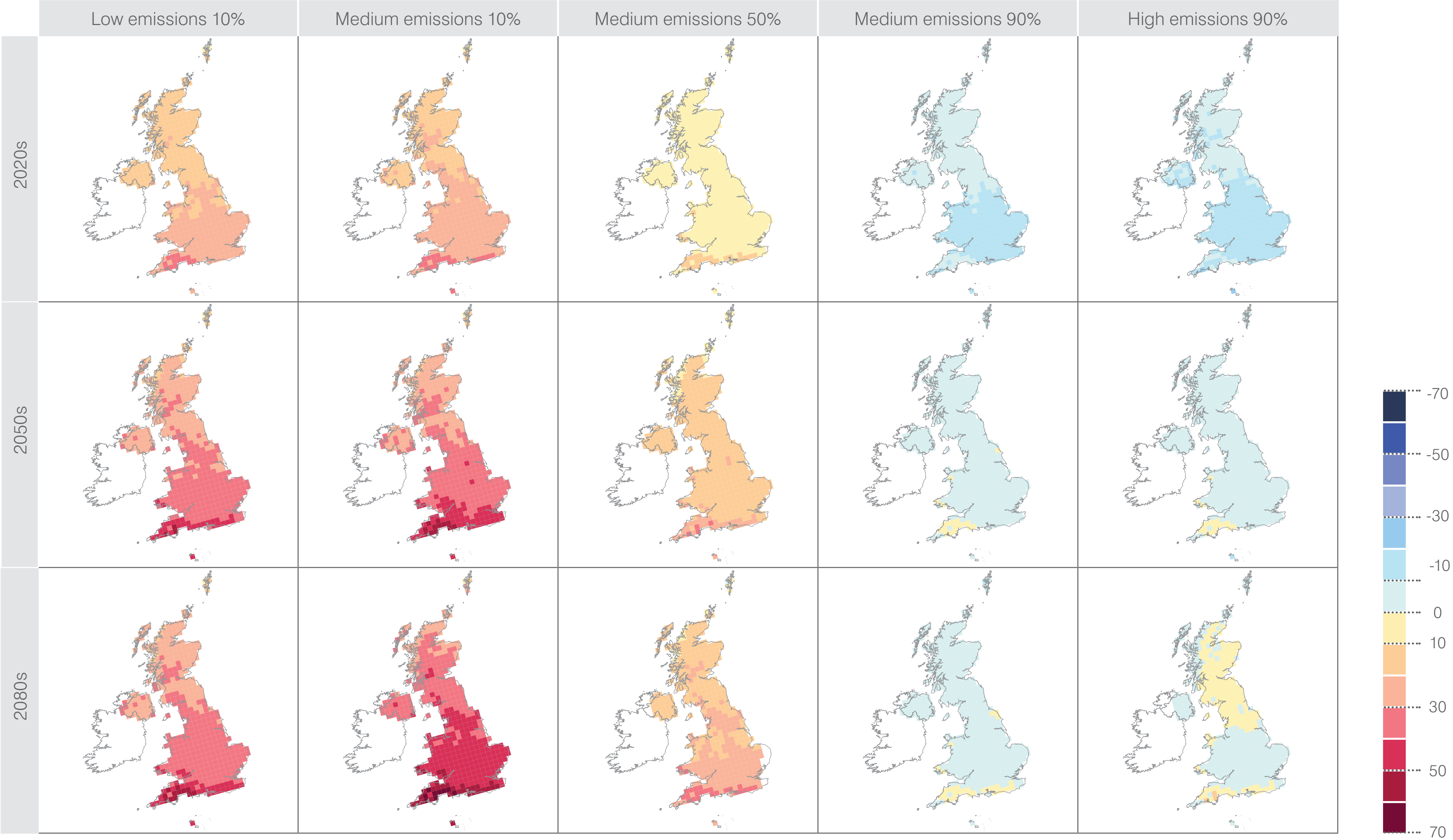
The maps produced in UKCP09 are perhaps the most useful visualisation of the effects of climate change for different aspects of climate.

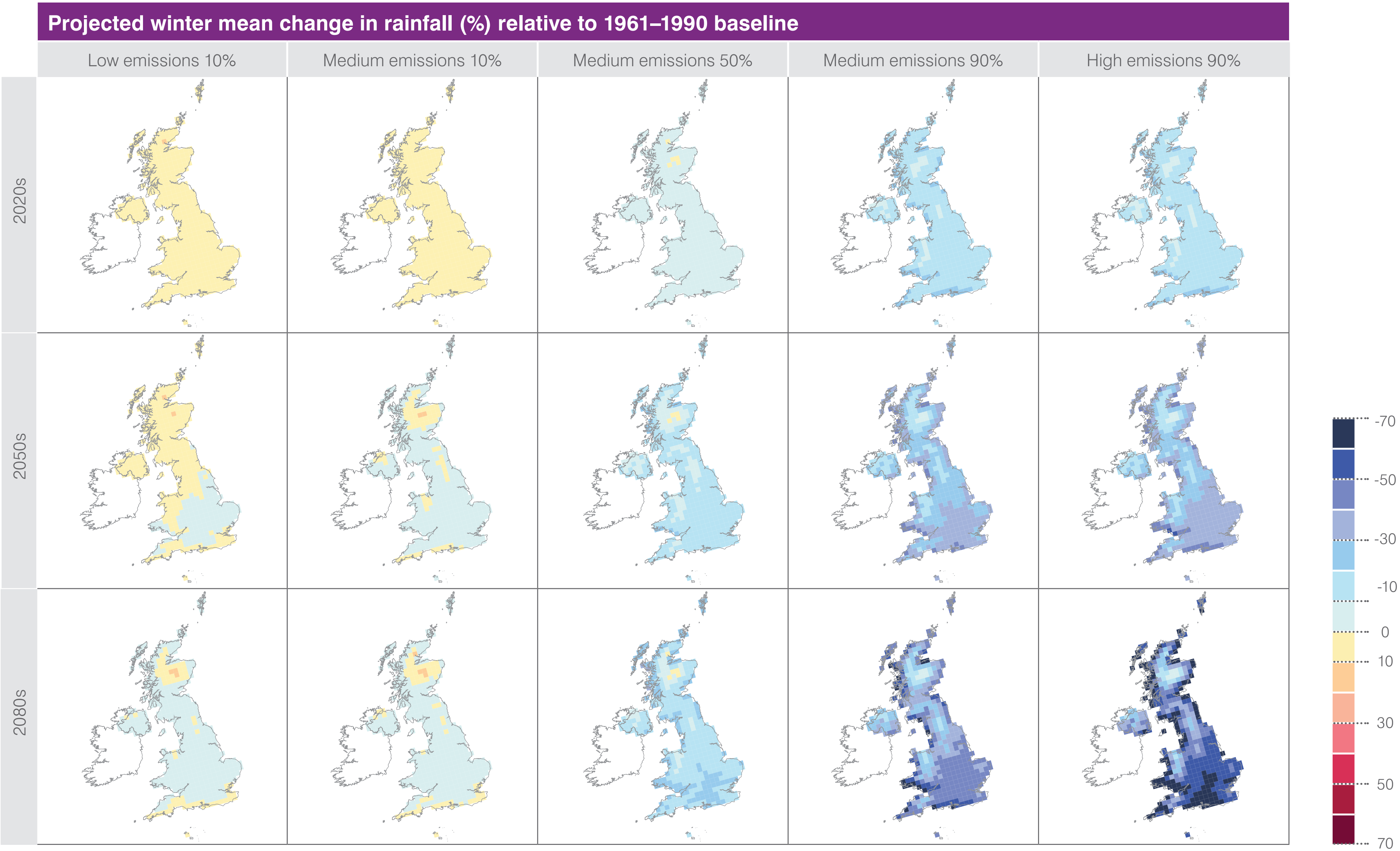
The maps on the following pages[2] have been assembled from UKCP09 data to give overviews of the likely range of change across the country and across all three emissions scenarios for a number of the most relevant climate variables.

These maps show the likely range of change from the 10th percentile projection for the low emissions scenario, through the likely range for the medium scenario, to the 90th percentile projection for the high scenario. Change less than that shown for the 10th percentile projection for the low emissions scenario is very unlikely, as is change greater than that shown for the 90th percentile projection for the high scenario (assuming of course that the range of emissions scenarios modelled are themselves reasonable projections).

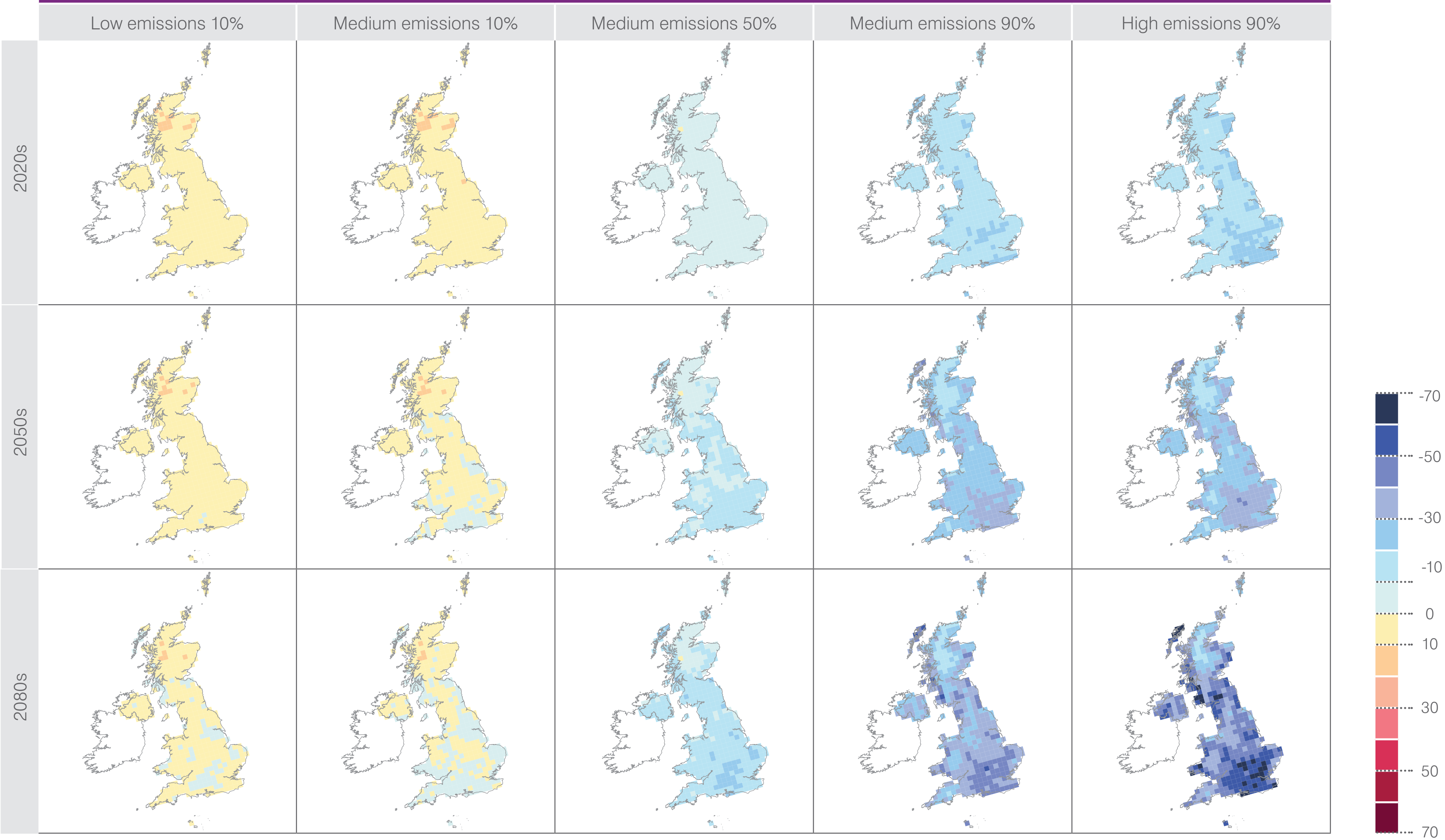

Projected annual mean change in rainfall (%) relative to 1961–1990 baseline
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
-70
-50
-30
-10
0
10
30
50
70

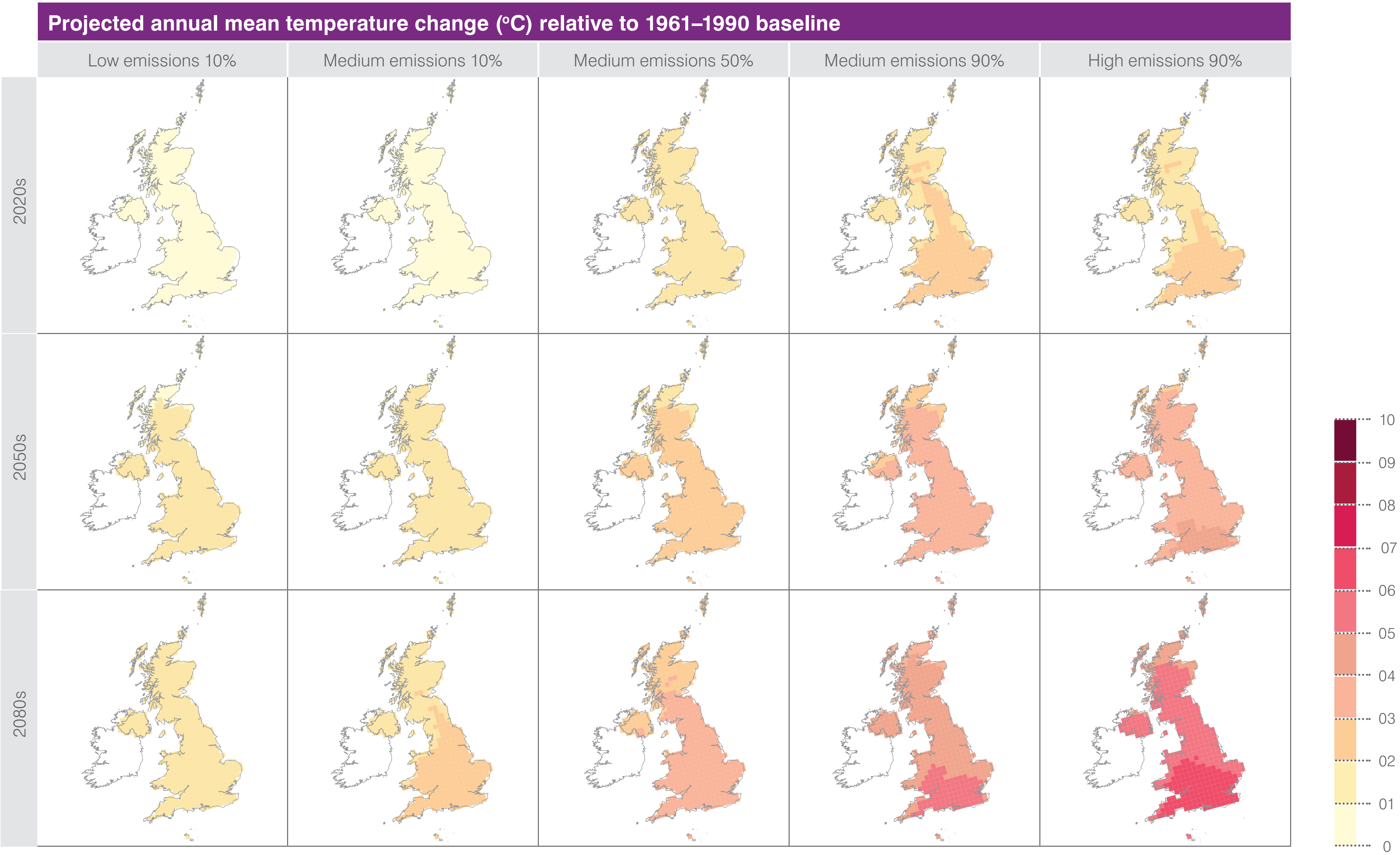
Projected summer mean change in rainfall (%) relative to 1961–1990 baseline



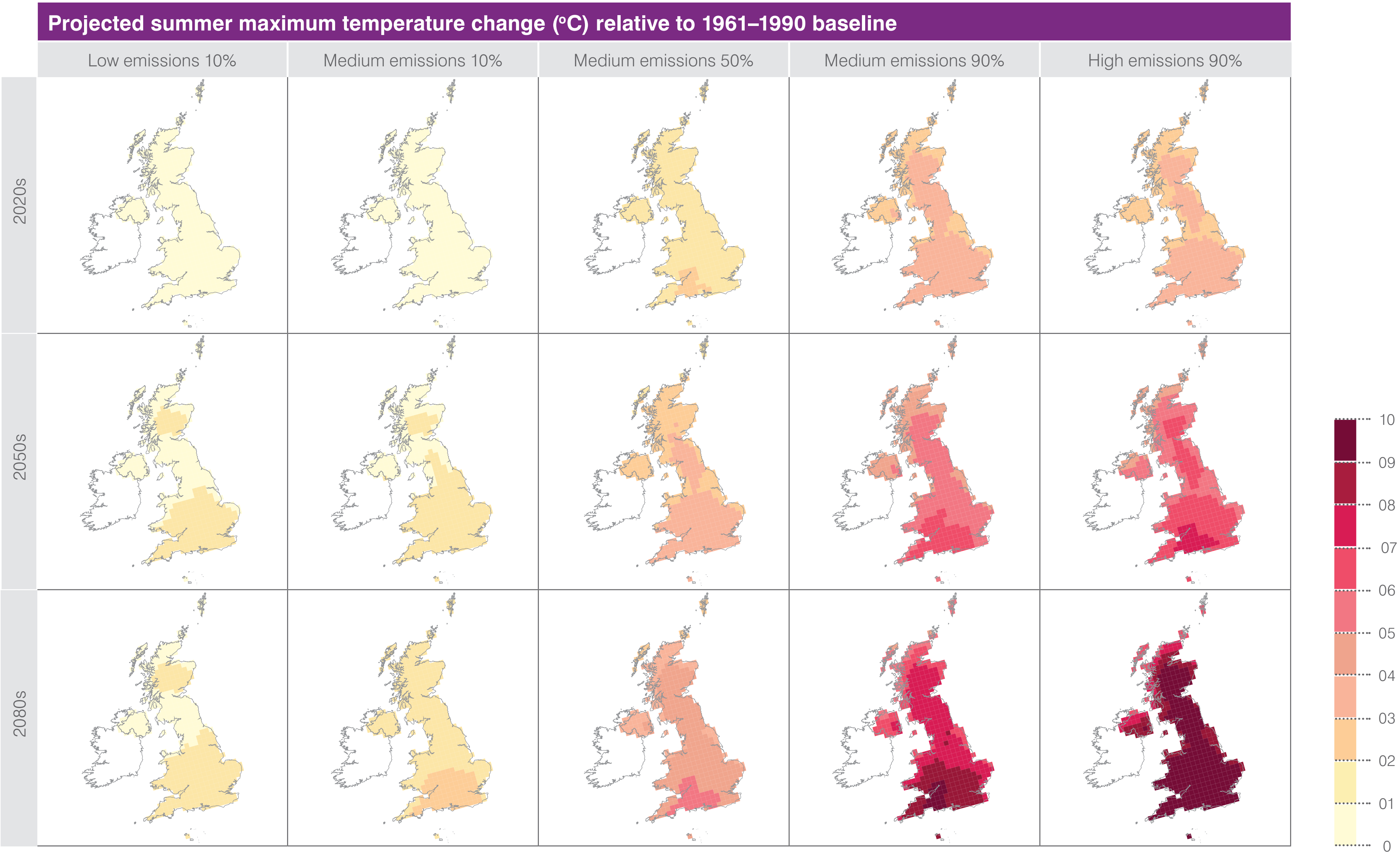

Projected winter mean change in rainfall (%) relative to 1961–1990 baseline
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
-70
-50
-30
-10
0
10
30
50
70

Projected change in wettest day of winter (%) relative to 1961–1990 baseline

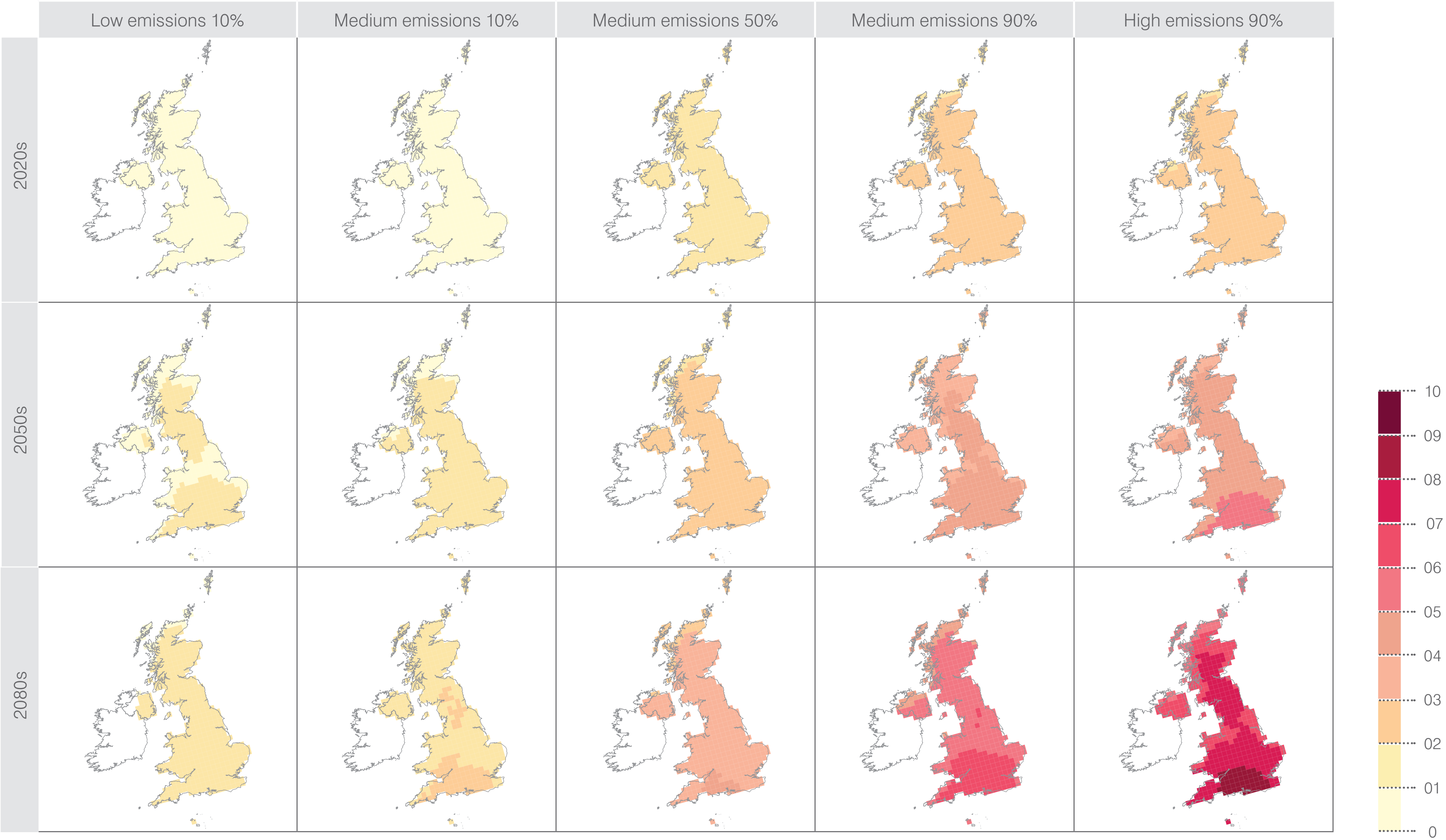


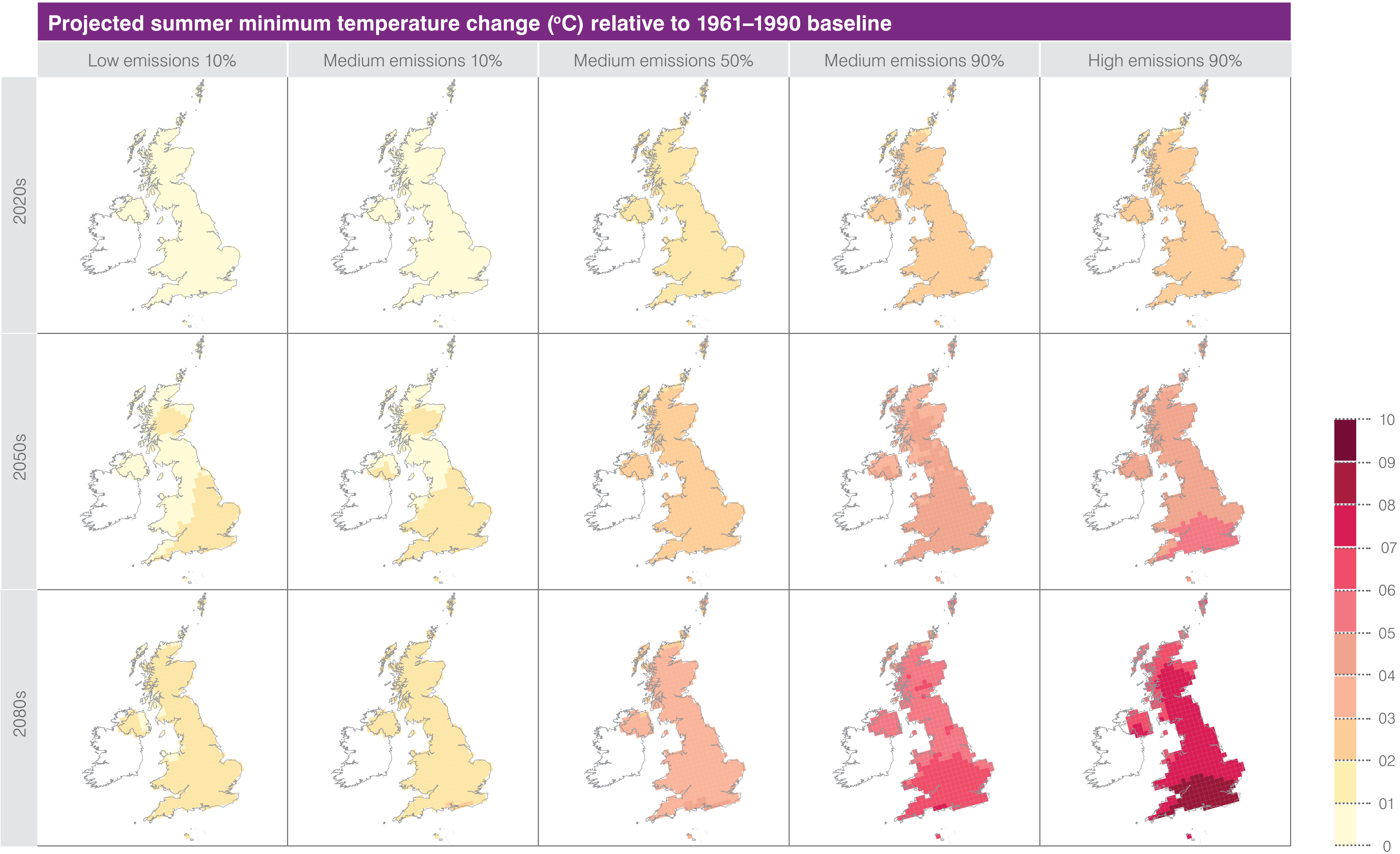


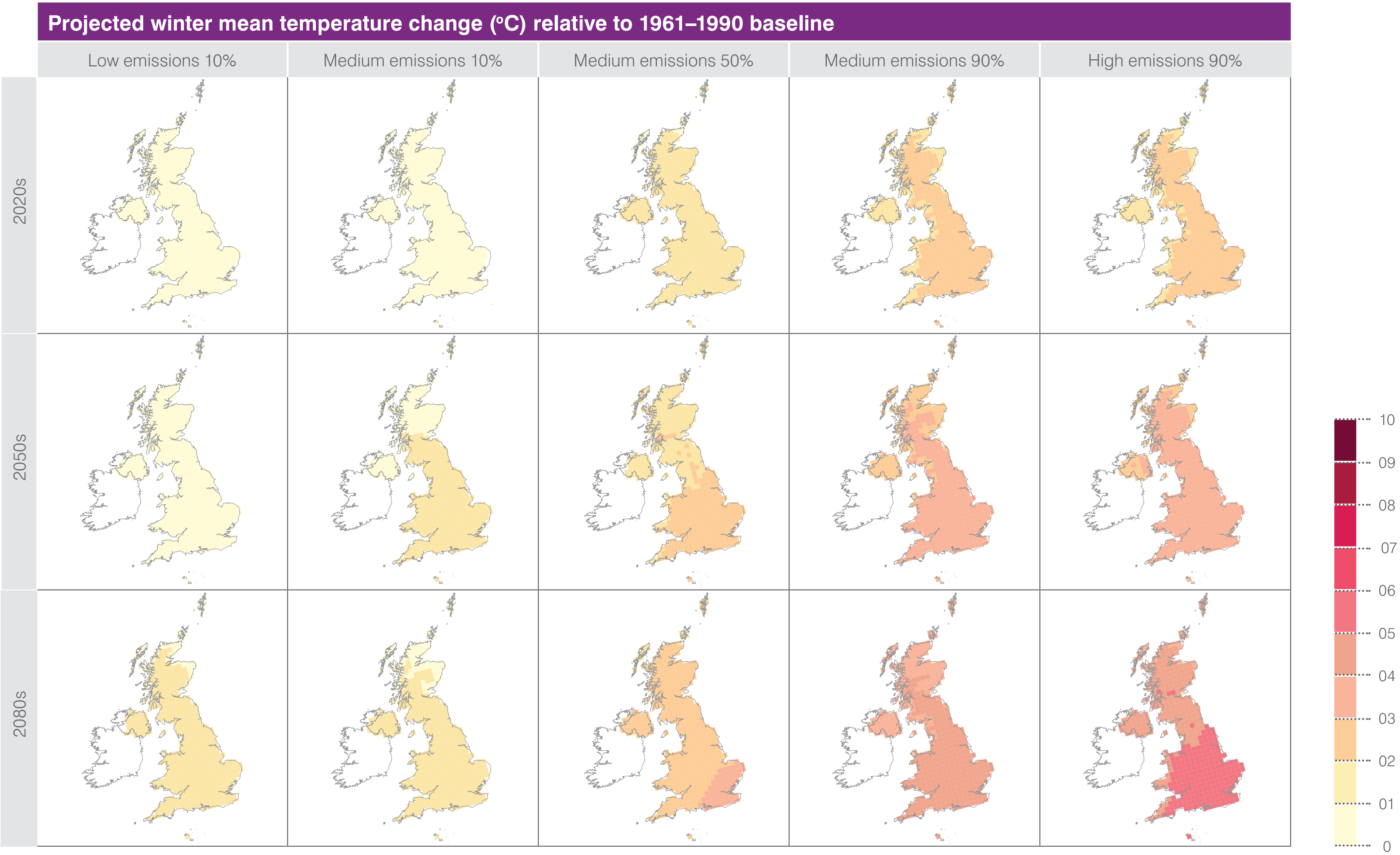
Projected annual mean temperature change (°C) relative to 1961–1990 baseline
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
10
09
08
07
06
05
04
03
02
01
0


Projected summer maximum temperature change (°C) relative to 1961–1990 baseline
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
10
09
08
07
06
05
04
03
02
01
0

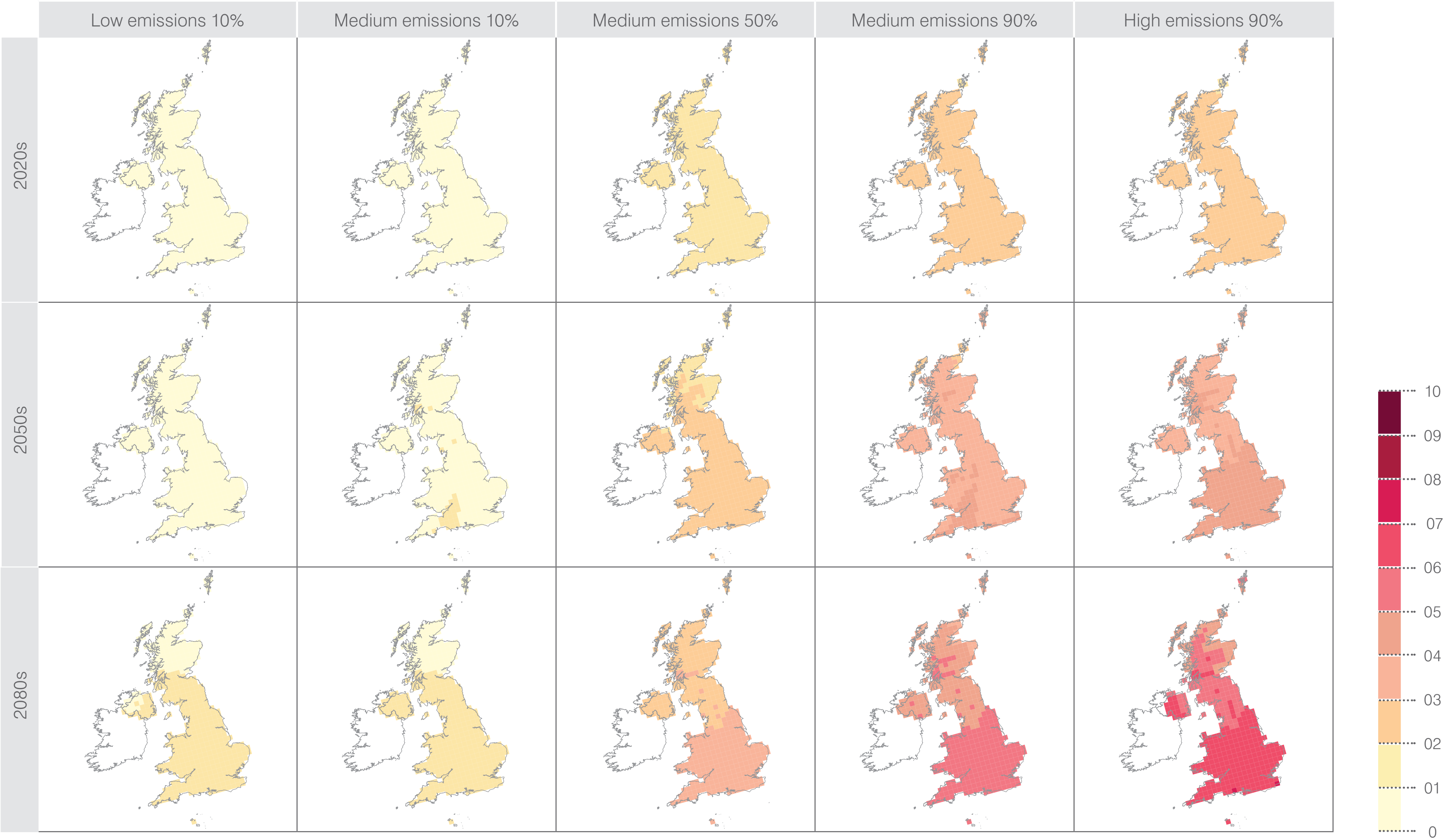
Projected summer mean temperature change (°C) relative to 1961–1990 baseline

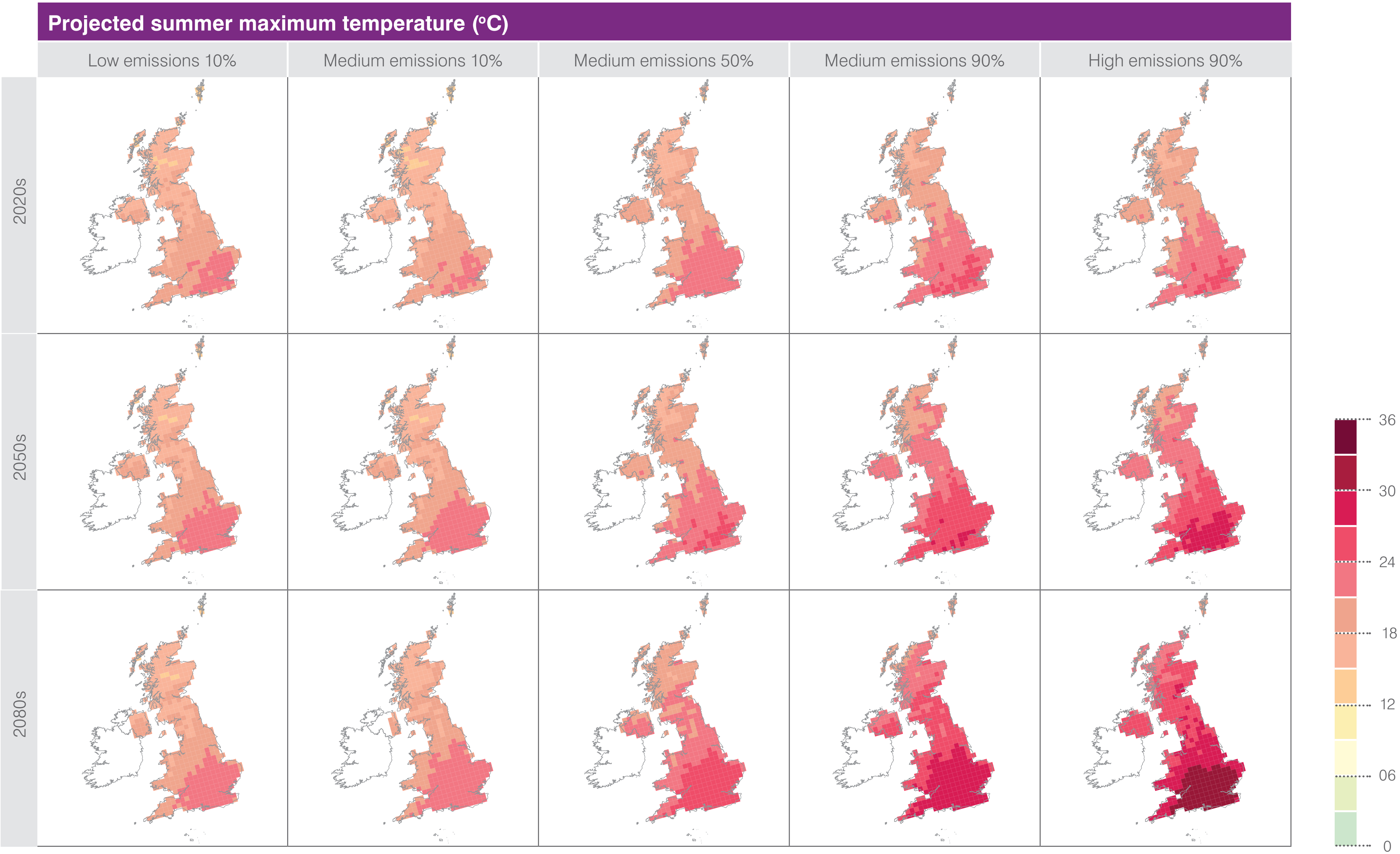


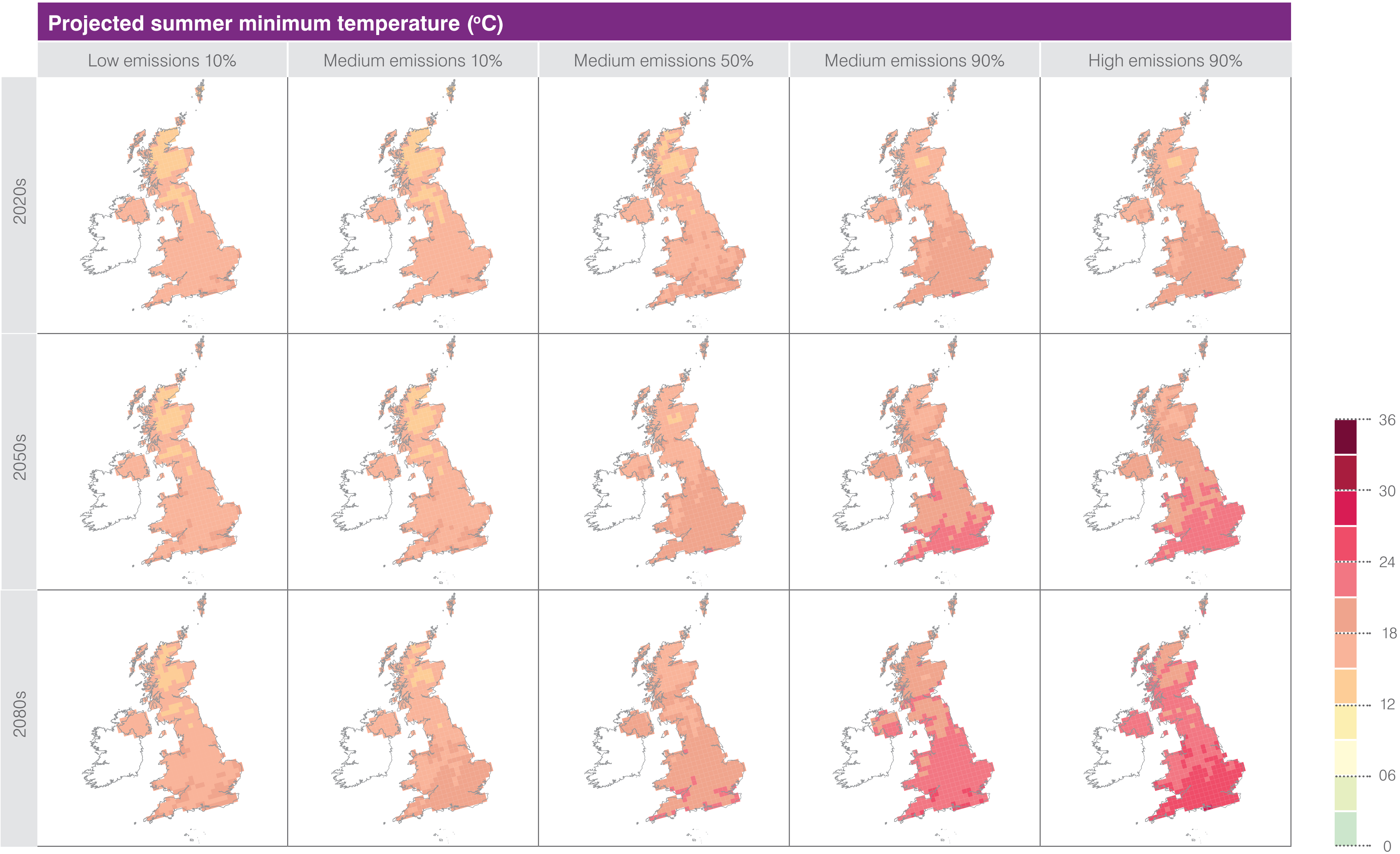

Projected summer minimum temperature change (°C) relative to 1961–1990 baseline
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
10
09
08
07
06
05
04
03
02
01
0


Projected winter mean temperature change (°C) relative to 1961–1990 baseline
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
10
09
08
07
06
05
04
03
02
01
0

Projected winter minimum temperature change (°C) relative to 1961–1990 baseline




Projected summer maximum temperature (°C)
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
36
30
24
18
12
06
0



Projected summer minimum temperature (ºC)
Low emissions 10%
Medium emissions 10%
Medium emissions 50%
Medium emissions 90%
High emissions 90%
2020s
2050s
2080s
36
30
24
18
12
06
0

Tables

Projected changes by 2080

Here are some examples of projected changes by 2080 for the medium emissions scenario (relative to the baseline period of 1961-1990)[2].

A range of values is given. Values are very unlikely to be less than the 10% value and very unlikely to be greater than the 90% value, the 50% value is the central estimate.

Climate aspect	Likely range		
All areas of the UK will become warmer, more so in summer than winter	10%	**50%**	90%
Change in summer mean temperatures:			
Greatest in southern England	2.2°C	**4.2°C**	6.8°C
Least in the Scottish islands	1.2°C	**2.5°C**	4.1°C

Climate aspect	Likely range		
Mean daily maximum temperatures will increase everywhere	10%	**50%**	90%
Winter maximum:			
Southern England	0.7°C	**1.5°C**	2.7°C
Northern Britain	1.3°C	**2.5°C**	4.4°C
Summer maximum:			
Southern England	1.0°C	**5.4°C**	9.5°C
Northern Britain	1.0°C	**2.8°C**	5.0°C
Warmest day in summer (no simple geographical pattern):			
Lowest change	–2.4°C	**2.4°C**	6.8°C
Highest change	0.2°C	**4.8°C**	12.3°C

Climate aspect	Likely range		
Mean daily minimum temperatures will increase everywhere	10%	**50%**	90%
Winter daily minimum:			
Least change	0.6°C	**2.1°C**	3.7°C
Greatest change	1.5°C	**3.5°C**	5.9°C
Summer daily minimum:			
Least change (northern Scotland)	1.3°C	**2.7°C**	4.5°C
Greatest change (southern Britain)	2.0°C	**4.1°C**	7.1°C

Climate aspect	Likely range		
Little change in total annual rainfall (central estimate) but a change in the balance between winter and summer	10%	**50%**	90%
Total range (no simple geographical pattern)	–16%		14%
Winter:			
Greatest increase (western side of the UK)	9%	**33%**	70%
Greatest decrease (Scottish Highlands)	–11%	**Little change**	7%
Summer:			
Greatest decrease (far south of England)	–65%	**–40 %**	–6%
Smallest decrease (Scottish Highlands)	–8%	**Little change**	10%
Wettest day in winter:			
Lowest estimate (northern Scotland)	–12%	**Little change**	13%
Highest estimate (parts of England)	7%	**25%**	56%
Wettest day in summer:			
Lowest estimate	–38%	**–12%**	9%
Highest estimate	–12%	**–1%**	51%

Climate aspect	Likely range		
Relative humidity will decrease in summer in parts of southern England, by less elsewhere. Winter changes are a few per cent less everywhere	10%	**50%**	90%
Lowest estimate (southern England)	–20%	**–9%**	0%
Summer cloud cover decreases in parts of southern England but increases in parts of northern Scotland	10%	**50%**	90%
Summer mean cloud cover:			
Maximum decrease (southern England)	–33%	**–18%**	–2%
Maximum increase (northern Scotland)	0%	**0%**	11%
Winter mean cloud cover:			
Little change	–10%		10%

Gulf Stream (Atlantic Ocean circulation): very unlikely that there will be an abrupt change during the century

Snowfall: not included in probabilistic data; however, the Met Office regional climate model projects reductions in winter mean snowfall.

- Mountain areas: between –65% and –80%
- Elsewhere: between –80% and –95%

Wind speed: also not included in probabilistic data; however, the Met Office regional climate model projects reductions in winter mean wind speed of a few per cent over the UK

No assessment is included of how the urban heat island effect may change

Appendix 2: Further information

Climate

UK Climate Projections 2009 (UKCP09). http://ukclimateprojections.defra.gov.uk

UK Climate Impacts Programme. www.ukcip.org.uk

Climate Change 2007: Synthesis Report: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, 2007. www.ipcc.ch under Publications and Data / Reports

Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, 2007. www.ipcc.ch under Publications and Data / Reports

Climate Change Controversies: a Simple Guide, The Royal Society, 2008. http://royalsociety.org/Climate-change-controversies-a-simple-guide

Warming: Climate Change – the Facts, Met Office, 2009. www.metoffice.gov.uk/climatechange/guide/quick

Policy/strategic

Climate Change: Taking Action: Delivering the Low Carbon Transition Plan and Preparing for a Changing Climate, Defra, HM Government, 2010. www.defra.gov.uk/environment/climate under Adaptation across Government

Government Departmental Adaptation Plans, 2010, are available at www.defra.gov.uk/environment/climate under Adaptation across Government

Warming to the Idea: Meeting the Challenge of Climate Change in the South West, South West Climate Impacts Partnership, 2003. www.ukcip.org.uk under Work in the UK / South West

Regional Climate Change Impacts Studies are available at www.ukcip.org.uk under Work in the UK

Stern Review: The Economics of Climate Change. Executive Summary, HM Treasury, 2006. www.hm-treasury.gov.uk under Independent Reviews

Stern Review: The Economics of Climate Change. Part V: Policy Responses for Adaptation, HM Treasury, 2006. www.hm-treasury.gov.uk under Independent Reviews

Adapting to Climate Change: the Role of Public Procurement, Greater London Authority, 2009. www.london.gov.uk/lccp under Publications

Heatwave Plan for England: Protecting Health and Reducing Harm from Extreme Heat and Heatwaves, NHS, 2009. www.dh.gov.uk/prod_consum_dh/groups/dhdigitalassets/documents/digitalasset/dh_099583.pdf

General/community

UKCIP Adaptation Wizard V2.0, UKCIP. www.ukcip.org.uk/wizard

Climate Change Adaptation by Design: a Guide for Sustainable Communities, R Shaw, M Colley and R Connell, Town and Country Planning Association, 2007. www.tcpa.org.uk under Publications

Adapting to Climate Change: a Checklist for Development: Guidance on Designing Developments in a Changing Climate, Greater London Authority, 2005. www.ukcip.org.uk under Publications

Adapting to Climate Change Impacts – a Good Practice Guide for *Sustainable Communities,* Land Use Consultants in association with Oxford Brookes University, CAG Consultants and Gardiner Theobald, Defra, 2006. www.london.gov.uk/lccp under Publications

The Draft Climate Change Adaptation Strategy for London: Public Consultation Draft, Greater London Authority, 2010. www.london.gov.uk/climatechange/sites/climatechange/staticdocs/Climiate_change_adaptation.pdf

Wild Weather Warning: a London Climate Impacts Profile, London Climate Change Partnership, Greater London Authority, 2009. www.london.gov.uk/lccp under Publications

London's Commercial Building Stock and Climate Change Adaptation: Design, Finance and Legal Implications, London Climate Change Partnership – Finance Group, 2009. www.london.gov.uk/lccp under Publications

Adapting to Climate Change: Creating Natural Resilience, London Climate Change Partnership, Greater London Authority, 2009. www.london.gov.uk/lccp under Publications

London's Urban Heat Island: a Summary for Decision Makers, Greater London Authority, 2006. www.london.gov.uk/sites/default/files/uploads/UHI_summary_report.pdf

Homes

Your Home in a Changing Climate: Retrofitting Existing Homes for Climate Change Impacts, Arup for Three Regions Climate Change Group, Greater London Authority, 2008. www.london.gov.uk/trccg under Publications

Economic Incentive Schemes for Retrofitting London's Existing Homes for Climate Change Impacts, London Climate Change Partnership, Greater London Authority, 2009. www.london.gov.uk/lccp under Publications

Developing Homes for a Changing Climate: Benchmarking how UK Home Builders are Responding to Climate Change Risks and Opportunities, Next Generation, 2008. www.nextgeneration-initiative.co.uk/ckfinder/userfiles/files/NextGeneration_Report_full_2008.pdf

Climate Change and Innovation in House Building: Designing out Risk, NHBC Foundation, 2007. www.nhbcfoundation.org under Research and Publications

Homes for a Changing Climate: Adapting our Homes and Communities to Cope with the Climate of the 21st Century, W Anderson, Green Books, 2009

Construction

Potential Implications of Climate Change in the Built Environment, H M Graves and M C Phillipson, BRE Bookshop, 2000

Climate Change: Impact on Building Design and Construction, M Phillipson and C Stirling, BRE Bookshop, 2004

Climate Adaptation – Guidance on Insurance Issues for New Developments, Association of British Insurers, 2009. www.climatewise.org.uk under Resources

The Vulnerability of UK Property to Windstorm Damage, Association of British Insurers, 2003

Designing Roofs for Climate Change: Modifications to Good Practice Guidance, G Saunders, BRE Press, 2006

Understanding Dampness, P Trotman, C Sanders, H Harrison, BRE Bookshop, 2004

Comfort

Climate Change and the Indoor Environment: Impacts and Adaptation, CIBSE, 2005

Beating the Heat: Keeping UK Buildings Cool in a Warming Climate, J N Hacker, S E Belcher and R K Connell, UKCIP Briefing Report, UKCIP, 2005. www.ukcip.org.uk under Publications

Use of Climate Change Scenarios for Building Simulation: the CIBSE Future Weather Years, CIBSE, 2009

Modelling the Impact of Climate Change in Schools: the Issue of Overheating, D Coley and T Kershaw, Exeter University Centre for Energy and the Environment, 2009. www.exeter.ac.uk/research/excellence/keythemes/climate/conference/documents/schools.pdf

Reducing Overheating – a Designer's Guide, Energy Saving Trust, 2005. www.energysavingtrust.org.uk/Publication-Download/?p=1&pid=260

Water

Flood and Water Management Act 2010, Crown Copyright, 2010. www.opsi.gov.uk/acts

Water for People and the Environment: Water Resources Strategy for England and Wales, Environment Agency, 2009. http://publications.environment-agency.gov.uk

Sustainable Water: State of the Water Sector Report, Water, UK, 2008. www.water.org.uk under Reports and Publications

Flooding in England: a National Assessment of Flood Risk, Environment Agency, 2009. http://publications.environment-agency.gov.uk

Climate Change, Adapting for Tomorrow, Environment Agency, 2009. http://publications.environment-agency.gov.uk

Improving the Flood Performance of New Buildings: Flood Resilient Construction, joint CLG and Defra research publication, managed by CIRIA, authors: P Bowker, M Escarameia and A Tagg, RIBA Publishing, Crown Copyright, 2007. www.planningportal.gov.uk/uploads/br/flood_performance.pdf

Planning Policy Statement 25: Development and Flood Risk, Department of Communities and Local Government, 2006.

Facing up to Rising Sea Levels: Retreat? Defend? Attack? Building Futures, RIBA and Institution of Civil Engineers, 2010. www.buildingfutures.org.uk under Outputs

Designing for Flood Risk, RIBA, 2009. www.architecture.com/FindOutAbout/Sustainabilityandclimatechange/ClimateChange/Toolkits.aspx

Thames Estuary 2100 Study, Environment Agency, 2010. http://environment-agency.gov.uk/static/documents/Research/_16__2_page_TE2100_study.pdf

Foresight Future Flooding, Foresight programme Flood and Coastal Defence project, 2004. www.foresight.gov.uk/Flood%20and%20Coastal%20Defence/Executive_Summary.pdf

Making Space for Water: First Government Response to the Autumn 2004 Making Space for Water *Consultation Exercise,* Defra, 2005. www.defra.gov.uk/environment/flooding/documents/policy/strategy/strategy-response1.pdf

EPSRC funded research

2002: Building Knowledge for a Changing Climate (BKCC)

Building Knowledge for a Changing Climate: collaborative research to understand and adapt to the impacts of climate change on infrastructure, the built environment and utilities, Newcastle University, 2007. (Summary report of the BKCC research programme and the following projects.) www.ukcip.org.uk/images/stories/Pub_pdfs/BKCC-Results.pdf

ASCCUE: Adaptation Strategies for Climate Change in the Urban Environment. *Prof. J Handley, School of Environment and Development, University of Manchester*

AUDACIOUS: Urban Drainage – Addressing Change and Intensity, Occurrence and Uncertainty of Stormwater. *J Blanksby, Department of Civil and Structural Engineering, University of Sheffield*

BESEECH: Building Economic and Social information for Examining the Effects of Climate cHange. *Prof. P Ekins, Policy Studies Institute*

BETWIXT: High resolution weather scenarios. *Dr C Goodess, Climatic Research Unit, School of Environmental Sciences, University of East Anglia*

BIONICS: Slope stability. *Dr S Glendinning, School of Civil Engineering and Geosciences, Newcastle University*

CRANIUM: Risk management. *Prof. J Hall, School of Civil Engineering and Geosciences, Newcastle University*

EHF: Engineering Historic Futures. *Prof. M Cassar, Centre for Sustainable Heritage, University College London*

GENESIS: A Generic Process for Assessing Climate Change Impacts on the Electricity Supply Industry and Utilities. *Dr S Watson, Centre for Renewable Energy Systems Technology, Loughborough University*

Impact of climate change on UK air transport
Dr R Noland, Centre for Transport Studies, Imperial College London

2007: Adaptation and Resilience in a Changing Climate (ARCC)

Further information about the following ARCC research projects is available from www.ukcip-arcc.org.uk

ARCADIA: Adaptation and Resilience in Cities: Analysis and Decision making using Integrated Assessment. *Prof. J Hall, Newcastle University*

- **Aim:** To provide system-scale understanding of the inter-relationships between climate impacts, the urban economy, land use, transport and the built environment, and to use this understanding to design cities that are more resilient and adaptable.

ARCC-Water: Water System Resilience

Dr M New, University of Oxford; Dr S Dessai, Exeter University; Dr J Harou, UCL; Dr W Medd, Lancaster University; Dr S Wade, HR Wallingford; Prof. R Wilby, Loughborough University

- **Aim:** An integrated 'whole system' approach to water resource planning in SE England under multiple uncertainties, in which portfolios of infrastructure and demand management options maintain secure supplies (increased reliability and reduced vulnerability to failure) and enhance the environment.

BIOPICCC: Built Infrastructure for Older People in Conditions of Climate Change. *Prof. S Curtis, Durham University; Dr D Val, Heriot-Watt University*

- **Aim:** To develop a methodology for selecting locally sensitive, efficient adaptation strategies during the period up to 2050 to ensure that the infrastructures and health and social care systems supporting well-being of older people (i.e. those aged 65 and over) will be sufficiently resilient to withstand harmful impacts of climate change.

COPSE: Coincident Probabilistic climate change weather data for a Sustainable built Environment. *Prof. G Levermore, University of Manchester*

- **Aim:** To develop a methodology for deriving weather data for building designers etc that is based on future data rather than observational records from the last 20 years or so.

CREW: Community Resilience to Extreme Weather. *Dr G Wood, Cranfield University*

- **Aim:** To develop a set of tools for improving the capacity for resilience of local communities to the impacts of extreme weather events.

De²RHECC: Design & Delivery of Robust Hospital Environments in a Changing Climate. *C A Short, University of Cambridge; K J Lomas, Loughborough University; P J Clarkson, University of Cambridge; C M Eckert, Open University; C J Noakes, University of Leeds*

- **Aim:** The project aims to investigate the design and delivery of economical and practical strategies for the adaptation of the NHS Retained Estate to increase its resilience to climate change whilst meeting the challenging carbon reduction goals and performance requirements of the NHS.

DOWNPIPE: The use of probabilistic climate scenarios in decision making for adaptation of building and property drainage (Design Of Water Networks using ProbabilistIc PrEdiction). *Dr L Jack, Prof J Swaffield, Prof A Prior, Dr G Wright, Heriot-Watt University*

- **Aim:** To realise potential benefits to property drainage design and adaption by using probabilistic data from UKCP09. The location and extent of any under-capacity will be identified and adaptation solutions proposed, thus impacting positively on the mitigation of flood risk.

FUTURENET: Future Resilient Transport Networks. *Prof. C J Baker, University of Birmingham; Prof. N Dixon, University of Loughborough; Prof. R Dingwall, University of Nottingham; Dr D Gunn, BGS; Dr S Wade, HR Wallingford; Dr N Paulley, TRL*

Aim: To determine:

- What will be the nature of the UK transport system in 2050 (taken as the mid-point of the UKCIP scenarios), both in terms of its physical characteristics and its usage?
- What will be the shape of the transport network in 2050 that will be most resilient to climate change?

LUCID: The Development of a Local Urban Climate Model and its Application to the Intelligent Development of Cities. *Prof. M Davies, University College London*

- **Aim:** To understand the impact of local climate on energy use, comfort and health.

Low Carbon future: Decision support for building adaptation in a low carbon climate change future. *Prof. P Banfill, Prof. G Gibson, Dr. G Menzies, Heriot-Watt University*

- **Aim:** To produce a general, deterministic and computationally efficient methodology for adequately sizing HVAC (heating, ventilating and air-conditioning) plant and equipment in buildings.

PROCLIMATION: The use of probabilistic climate scenarios in building environmental performance simulation. *Prof. V I Hanby, De Montfort University*

- **Aim:** To develop and implement methodologies for using probabilistic climate projections (UKCP09) in building simulation and other related analytical procedures.

PROMETHEUS: The use of probabilistic climate data to future-proof design decisions in the buildings sector. *Dr D Coley, University of Exeter*

- **Aim:** To develop a new set of probabilistic reference years that can be understood and used by building designers.

SCORCHIO: Sustainable Cities: Options for Responding to Climate Change Impacts and Outcomes. *Prof. G Levermore, University of Manchester*

- **Aim:** To develop tools that use the latest forecasts from the UK Climate Impacts Programme (UKCIP) to help planners, designers, engineers and users to adapt urban areas, with a particular emphasis on heat and human comfort.

SNACC: Suburban neighbourhood adaptation for a changing climate: identifying effective, practical and acceptable means of suburban re-design. *Prof. K Williams, University of the West of England (UWE)*

- **Aim:** The proposed research answers the question: how can existing suburban neighbourhoods be best adapted to reduce further impacts of climate change and withstand ongoing changes?

Appendix 3: References and notes

1 Prof R Watson, Chief Scientific Advisor, Defra. Foreword in: *UK Climate Projections: Briefing Report,* G J Jenkins, J M Murphy, D M H Sexton, J A Lowe, P Jones and C G Kilsby, Met Office Hadley Centre, Exeter, UK, 2009. http://ukclimateprojections.defra.gov.uk under Published Material

2 UK Climate Projections 2009 (UKCP09). http://ukclimateprojections.defra.gov.uk

3 For all government Departmental Adaptation Plans, see www.defra.gov.uk/environment/climate/programme under Adaptation across Government

4 *Communities and Local Government Departmental Adaptation Plan,* Department for Communities and Local Government, 2010

5 For reports by Regional Climate Change Partnerships, see www.ukcip.org.uk under Work in the UK

6 *Climate Change Adaptation by Design: a Guide for Sustainable Communities,* R Shaw, M Colley and R Connell, Town and Country Planning Association, 2007. www.tcpa.org.uk under Publications

7 *Adapting to Climate Change: a Checklist for Development: Guidance on Designing Developments in a Changing Climate,* Greater London Authority, 2005. www.ukcip.org.uk under Publications

8 *Climate Change and the Indoor Environment: Impacts and Adaptation,* CIBSE, 2005

9 *Beating the Heat: Keeping UK Buildings Cool in a Warming Climate,* J N Hacker, S E Belcher and R K Connell, UKCIP Briefing Report, UKCIP, 2005. www.ukcip.org.uk under Publications

10 'Summer Mortality: Deaths up in August Heatwave', Office of National Statistics, February 2005. www.statistics.gov.uk/cci/nugget.asp?id=480

11 *Mortality Statistics: General: Review of the Registrar General on Deaths in England and Wales, 2005,* Office of National Statistics, 2007. www.statistics.gov.uk/downloads/theme_health/Dh1_38_2005/DH1_No_38.pdf

12 *Adaptation Strategies for Climate Change in the Urban Environment,* draft final report to the National Steering Group, J Handley and J Carter, University of Manchester, 2006. www.sed.manchester.ac.uk/research/cure/research/asccue/publications.htm

13 See www.stadtentwicklung.berlin.de/umweltlandschaftsplanung/index_en.shtml

14 'Adapting cities for climate change: the role of the green infrastructure', S E Gill, J F Handley, A R Ennos and S Pauleit, *Built Environment*, 33(1), pp115-133, 2007

15 UK shrink swell map, reproduced with the permission of the British Geological Survey, copyright NERC. All rights reserved

16 *Indicators of Climate Change in the UK* (2003) Insurance, Energy, Tourism and Fire: JP Palutikof: Domestic Property Insurance Claims Related to Damaging Weather Events. www.ecn.ac.uk/iccuk/indicators/12.htm

17 Joint EPSRC and UKCIP research project: BIOlogical and eNgineering Impacts of Climate change on Slopes, led by the University of Newcastle. www.k4cc.org/bkcc/bionics

18 Basic windspeed map, copyright BRE, reproduced with permission

19 *The Vulnerability of UK Property to Windstorm Damage,* Association of British Insurers, 2003

20 Wind driven rain map, copyright BRE, reproduced with permission

21 *Potential Implications of Climate Change in the Built Environment,* H M Graves and M C Phillipson, BRE Bookshop, 2000, p11; and *Climate Change: Impact on Building Design and Construction,* M Phillipson and C Stirling, BRE Bookshop, 2004, p5

22 *Thermal Insulation, Avoiding Risks,* C Stirling, BRE, 2002

23 *Understanding Dampness,* P Trotman, C Sanders, H Harrison, BRE Bookshop, 2004

24 *Identifying Areas of Water Stress: Consultation Document,* Environment Agency, 2007, p9. http://publications.environment-agency.gov.uk/pdf/GEHO0107BLUT-e-e.pdf

25 *Strategic Forum Targets to 2012,* Strategic Forum for Construction, no date. www.strategicforum.org.uk under Targets

26 *Approved Document G: Sanitation, Hot Water Safety and Water Efficiency,* Crown Copyright, 2010. www.planningportal.gov.uk/england/government/buildingregs/technicalguidance

27 In February 2009 the number of metered customers was around 35%, expected to rise to 37% by March 2010. www.ofwat.gov.uk

28 *Critical Review of Relevant Research Concerning the Effects of Charging and Collection Methods on Water Demand Different Customer Groups and Debt*, UKWIR Report 05/CU/02/1

29 *Household Water Metering: Position Statement,* Environment Agency. www.environment-agency.gov.uk/research/library/position

30 *Flood and Water Management Act 2010,* Crown Copyright, 2010. www.opsi.gov.uk/acts

31 *Making Space for Water: Groundwater Flooding Records Collation, Monitoring and Risk Assessment (ref HA5) Consolidated Report,* JacobsGIBB Ltd for the Environment Agency, 2007

32 *Climate Change: Taking Action: Delivering the Low Carbon Transition Plan and Preparing for a Changing Climate,* Defra, HM Government, 2010. www.defra.gov.uk/environment/climate under Adaptation across Government

33 *UK Climate Projections: Briefing Report,* G J Jenkins, J M Murphy, D M H Sexton, J A Lowe, P Jones and C G Kilsby, Met Office Hadley Centre, Exeter, UK, 2009 (citing the IPCC). http://ukclimateprojections.defra.gov.uk under Published Material

34 See www.ukcip.org.uk

35 *IPCC Fourth Assessment Report: Climate Change 2007.* www.ipcc.ch under Publications and Data / Reports

36 The amount of energy moving from the surface to the air due to evaporation (positive values) or from the air to the land due to condensation (negative values).

37 http://badc.nerc.ac.uk/data/link

38 *Interpretation for use of Surface Wind Speed Projections from the 11-Member Met Office Regional Climate Model Ensemble,* S Brown, P Boorman, R McDonald and J Murphy, 2009. http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_wind_technote.pdf

39 Figure extrapolated from UKCP09 information.

About the Technology Strategy Board

The Technology Strategy Board was established by the Government in 2007. As the UK's primary technological innovation agency, we promote and invest in research, development and exploitation of technology and innovation for the benefit of UK business, to increase economic growth and improve the quality of life. Investing around £1bn in innovation between 2008 and 2011, we are sponsored by the UK's Department for Business, Innovation and Skills.

www.innovateuk.org

Low impact buildings

We launched the Low Impact Buildings Innovation Platform in May 2008 to help the UK construction industry deliver buildings with a much lower environmental impact. Our vision is to enable UK industry to supply the emerging market in low-impact buildings and solutions driven by Government targets and policy. We are investing jointly with industry and other funders in projects to bring innovative solutions to this growing market, and to overcome barriers to the wider use of existing solutions.

Modern Built Environment KTN

The Modern Built Environment Knowledge Transfer Network (KTN) is a key route for engagement with other bodies, particularly industrial and academic. The Modern Built Environment KTN is our partner in running briefing workshops for all our competitions for funding, and actively works to build consortia that can bid for funding to Technology Strategy Board programmes. With more than 10,000 individual members, more than 2000 organisations involved, and more than 100 events and workshops, the KTN supports us by providing an industry perspective.

www.mbektn.co.uk

Technology Strategy Board

North Star House
North Star Avenue
Swindon SN2 1UE

T 01793 442700
E enquiries@tsb.gov.uk
www.innovateuk.org

Bill Gething

Sustainability + Architecture
E bill@billgething.co.uk

This brochure has been printed by the BAPC (British Association for Print and Communication) 'Environmental Printer of the Year' 2008 using waterless printing, a lithographic process that eliminates water consumption and the release of VOCs (volatile organic compounds) into the atmosphere. Printed on an FSC certified paper made with 100% post consumer waste and bleached using a Totally Chlorine Free process.