Communicating, tailoring and using climate projections in adaptation planning

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Submitted in accordance with the requirements for the degree of
Doctor of Philosophy

The University of Leeds
School of Earth and Environment

September 2015

The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

PhD Publications

Parts of this thesis have been published in the following:

International Journals

Lorenz, S., Dessai, S., Paavola, J. & Forster, P. M. 2015. The communication of physical science uncertainty in European National Adaptation Strategies. *Climatic Change*. **123** (1), pp. 143-155. (doi: 10.1007/s10584-013-0809-1)

Lorenz, S., Dessai, S., Paavola, J. & Forster, P. M. 2015. Tailoring the visual communication of climate projections for local adaptation practitioners in Germany and the UK. *Philosophical Transactions A*. **373** (2055), pp. 1-17. (doi: 10.1098/rsta.2014.0457)

Lorenz, S., Dessai, S., Paavola, J. & Forster, P. M. Adaptation planning and the use of climate change projections in local government in England and Germany. *Regional Environmental Change.* [UNDER REVIEW]

I am lead author on the above articles and designed the research questions, the methodology, and collected and analysed the data. The papers were co-authored with my supervisors whose roles were in the recommendations of revisions and edits to manuscripts.

Rationale for thesis by alternative format

This thesis looks at three distinct levels of analysis as part of the question as to how the communication, tailoring and use of climate projections can be improved for more effective adaptation planning decision support. The levels of analysis are national level, local level and individual level. Each part of this multi-level analysis has involved different research methods and different empirical data. Each set of methods, data collection and results has required rationalisation and grounding within the relevant literature, which has been achieved within the three papers more efficiently than within a traditional monograph.

The thesis consists of an introductory chapter setting out the context and rationale for the research, placing it within the wider literature, outlining the overarching research strategy and contributions to the fields of study, rationalising of the multi-methods approach, and detailing the data collection and case studies. The three empirical chapters are the three papers listed on the previous page. Paper 1 sets out the findings of the communication of physical science uncertainty within national adaptation plans, thus setting the overarching frame of communication at the national level. Paper 2 provides insights into the challenges of communicating and tailoring climate projections to individual adaptation practitioners. Lastly, paper 3 examines the use and usability of climate projections for local adaptation planning, specifically analysing local governments within England and Germany. These three results chapter are followed by a discussion and conclusion that brings together insights from the three papers and highlights lessons learned and the challenges found for communicating, tailoring and using climate projections for adaptation planning across the different levels highlighted in the papers (national, local and individual). This last chapter also reflects on the research approach, limitations to the research conducted and possible future research directions.

Acknowledgements

This research was supported and made possible by a whole range of different people, who all deserve my sincere gratitude. Firstly, I would like to thank NERC for providing the funding that allowed me to undertake this research in the first place. Furthermore, I would like to thank the School of Earth and Environment and the World Universities Network for providing additional support and funding. I am very grateful to my supervisors Suraje Dessai, Piers Forster and Jouni Paavola for their tireless support; this thesis would not be what it is without all of their advice, comments and recommendations over the past years. I also would like to particularly thank Suraje Dessai for his continued efforts in countering my concerns that I am a 'Jack of all trades and master of none'. The people in my research groups in both SRI and ICAS also deserve a big thank you; all of your feedback, thoughts and ideas throughout the research process were very much appreciated. In particular, I would like to say thank you to Lawrence Jackson and Andrea Taylor for imparting some of their seemingly infinite statistical wisdom to me along the way.

I would not have been able to conduct this research without the support and participation of the many adaptation practitioners in Germany and the UK that took part in my study. I am very grateful to all of them for their time, thoughts and insights, giving me such a rich set of data to base my study on. Particular thanks go to Jen Atkinson from Climate North East and Alex Hopkinson from Climate East Midlands, who provided so many helpful comments and thoughts especially in the earlier stages of this research.

I count myself very lucky to have an amazing bunch of family and friends around me, whose support, friendship and love has made all the difference along the way. Thank you to everyone in SRI who has kept me company on this journey. Sarah, Beth, Ellie, Kate, Rachel, Jami, Harriet and Ross, thank you for all the teas, coffees, insightful comments and glasses of wine, accompanied by a good dose of sarcasm.

It is thanks to my friends in Leeds, that I have felt at home here all this time. Particular thanks go to Sam and Sam, Stephen and Jo for being with me from the beginning of my time 'up North' and for making me want to come back to Leeds in the first place. Sam, thank you for tirelessly striving to provide me with original German jokes and your continued offers to feed me if needed.

I also do not know what I would have done without my wonderful teammates at the University of Leeds Handball Club. You are my favourite collection of Vikings (literally and metaphorically) – Astrid, Anna, Laura, Lena, Kamilla, Kath, Kristin, Magda, Mara, Mimi, Natalia and Thea – thank you for all the fun memories on and off the court! Thank you as well to Stella, for your pain inflicting hands and that yet always seem to be able to fix all aches and pains eventually to keep me fit enough to play.

Many people have made the UK home away from home and I want to say thank you to all of them for everything they have done. Andrew, Eli, Finlay, Christine, Peter, Sue, Jeff, Craig, Talie and Becca, thank you for being the wonderful people you are and for giving me a sense of home!

I am very lucky to have a wonderful set of friends and family in Germany as well that deserve a big thank you. To all my friends at home I'm so glad that the distance has not made any difference to our friendship. Wiebi, thanks particularly to you for not stopping to laugh at my German and for all the other laughs along the way! To my family - Dana, Dirk, Claudi, Karin, Julius, Lotte, Ulla, Olga and Uli – and to those of you that have been like family to me over the years, Steffi, Anne and Ralf – I want to say that I'm very fortunate to have you all around, thank you for being there for me! Above all thank you to my parents for having given me my roots and everything I needed to get here, I think this would have made you very happy.

Lastly, the biggest thank you goes to my wonderful better half. Dan, I don't know how you have put up with it and with me along this journey. You - with all of your love, support and confidence in me combined with all the laughs, Portsmouth updates, tasty salmon dishes, rabbit pictures, cheering by the side of the court and great proofreading skills - have made all of this possible. I could not have done it without you Lieblings!

Abstract

Planning for adaptation to climate change is often considered to be more effective if grounded on a solid evidence base and recognisant of relevant climate projections. How these climate projections are communicated, perceived and used is thus a key part of the adaptation process. The process of creating communications and communication tools that are considered usable by the intended users and therefore considered to be effective decision support is impacted by a range of complex factors that need to be considered in conjunction with each other.

The aim of this thesis is to examine the challenges for the communication, tailoring and use of climate projections for adaptation planning in Germany and the UK, both considered leaders on climate change adaptation, and suggest how cross-level insights from the individual, local and national scale can help to advance a more comprehensive understanding of the usability of communication tools for adaptation planning. This research adopts a multi-level perspective by exploring scientific uncertainty communication in national level adaptation strategies, usability of climate projections for local adaptation planning and comprehension and use of tailored information at the individual level. The thesis takes a mixed methods approach combining qualitative analysis from documentary and interview research with quantitative analysis using survey results.

Climate projections are inherently uncertain and their communication is thus always linked to the challenge of communicating physical science uncertainty. Based on the development of a new uncertainty assessment framework for comparing approaches to the inclusion and communication of physical science uncertainty, marked differences between the National Adaptation Strategies (NAS) of ten European countries are found. Through the examination of the English and German NAS in particular, this thesis theorises that similar stages of development in adaptation policy planning can nevertheless result in differences in the handling and communication of physical science uncertainty. In addition, the results show that the wider socio-political context within which the NAS are framed affects the extent to which physical science uncertainties are communicated comprehensively.

This socio-political and wider regulatory and legal context is also found to impact the demand for and use of climate projections for local adaptation planning in both England and Germany. Local planning in England has not only experienced a decline in use of climate projections, but the waning of the adaptation agenda more widely, amidst local government budget cuts and other adverse policy changes. In Germany, spatial planning makes substantial use of current climate information but the strictly regulated nature of planning prevents the use of climate projections, due to their inherent uncertainties. These findings highlight that the communication of climate projections is more effective at the local level when it is mindful of the wider context within which planning decisions are made, as this will impact the usability of provided tools and information.

As the adaptation agenda within the local government planning context is often the predominant responsibility of only very few people within a given local authority, this thesis also empirically tests a number of different graph formats for the provision of climate projection information. The findings show that respondents appear to use the graph formats for their own planning decisions or for communicating with other staff within the council that they think they understand the best, rather than the ones they actually understand the best. There is no consistent association between users' assessed comprehension and perceived comprehension, which highlights that effective information tailoring according to user needs, will require a more individualised approach and more systematic empirical testing.

These findings highlight that audience specific targeted communication to support well-informed adaptation planning may be more challenging than previously thought. If the aim is to increase usability of climate projections through tailored communication, it is important to jointly consider the particular constraints or requirements of the wider socio-political and institutional context within which adaptation planning takes place as well as recognise the varying needs, demands and preferences of the individual adaptation practitioner. This research helps to provide key considerations for the provision and design of more usable tools for communicating climate change projections within their intended adaptation planning context.

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List of Acronyms and Abbreviations

ASRP	Academy for Spatial Research and Planning
AC	Assessed Comprehension
ACS	Assessed Comprehension Score
ASC	Adaptation Sub-Committee
BEL	Belgium
BJV	Bundesministerium der Justiz und für Verbraucherschutz (Federal Ministry of Justice and Consumer Protection)
BVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry of Transport, Building and Urban Affairs)
CCRA	Climate Change Risk Assessment
CMIP	Climate Model Intercomparison Project
DCLG	Department for Communities and Local Government
DEFRA	Department for Environment Food and Rural Affairs
DEN	Denmark
EC	European Commission
ENESM	European Network for Earth System Modelling
ENG	England
ENSO	El Niño Southern Oscillation
EU	European Union
FIN	Finland
FRA	France
GCM	General Circulation Model
GER	Germany
GHG	Greenhouse Gas
HUN	Hungary
IDL	Interactive Data Language
IPCC	Intergovernmental Panel on Climate Change

JDM	Judgement and Decision-making
LA	Local Authority
MIKNRW	Ministerium für Inneres und Kommunales Nordrhein-Westfalen (Ministry of the Interior and Municipal Affairs North Rhine Westphalia)
NAP	National Adaptation Programme
NAPA	National Adaptation Programme of Action
NAS	National Adaptation Strategies
NEL	Netherlands
NI	National Indicator
NPPF	National Planning Framework
NRC	National Research Council of the National Academies
NRW	North Rhine Westphalia
NUSAP	Numerical Unit Spread Assessment Pedigree
PC	Perceived Comprehension Score
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PEAC	Pacific El Niño Southern Oscillation Application Centre
RCP	Representative Concentration Pathway
SADMC	Southern African Drought Monitoring Centre
SCO	Scotland
SGB	Städte- und Gemeindebund (Association of Towns and Municipalities)
TPI	The Planning Inspectorate
UAF	Uncertainty Assessment Framework
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
UKCIP	UK Climate Impacts Programme
UKCP09	UK Climate Projections 2009
US	United States of America
WAL	Wales

1. Chapter

Introduction

1.1 Introduction

This thesis offers an in-depth empirical analysis of the communication, tailoring and use of climate projections for climate change adaptation planning. It offers a combined assessment of how climate projections and their inherent uncertainties are currently communicated through National Adaptation Strategies (NAS); how climate change adaptation practitioners comprehend such climate projections and their visualisation preferences; and how their use of these projections is affected by the wider institutional context within which climate change adaptation planning takes place. A better understanding of the interplay between communication, tailoring and use of climate projections and information for climate change adaptation planning may help to ensure greater usability.

Section 1.2 will provide the context for the research by situating this thesis in the relevant wider academic debate and will set out the justification for this thesis. Section 1.3 will provide the aims and objectives of this thesis. In Section 1.4, the research strategy will be described providing an overview of the research philosophy and overarching methodological approach. The contribution of this thesis to the advancement in knowledge will be highlighted in Section 1.5 before Section 1.6 outlines the remaining structure and content of Chapters 2, 3, 4 and 5.

1.2 Context and rationale for the research

The research in this thesis draws from insights from three distinct fields of research: climate change adaptation, science for decision-making and communicating climate change. The following sections will focus on each of these fields in turn, drawing out specific justifications for this thesis arising from each research field, before finally providing a brief summary.

1.2.1 Climate change adaptation

1.2.1.1 Approaches to climate change adaptation

It is now recognised that even with significant efforts to reduce greenhouse gas emissions the world will experience a certain degree of climate change due to the inertia in the climate system (IPCC, 2013, Moss et al., 2013). Climate change adaptation[1] efforts are therefore increasing and a growing field of research has emerged (Bassett and Fogelman, 2013). Adaptation is understood as the 'process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities' (IPCC, 2014: 1758). Whilst a diversity of classifications of adaptation research and approaches to adaptation have been put forward within this field (Arnell, 2010, Bassett and Fogelman, 2013, Berrang-Ford et al., 2011, Dessai et al., 2005, Eakin and Patt, 2011, Ford et al., 2011, Hofmann et al., 2011), this thesis utilises the distinction of four broad approaches within adaptation research as defined by Eakin and Patt (2011). The four domains, all with different audiences, aims and utility for practice, are focused on: 1) *vulnerability and adaptive capacity*, 2) *building resilience*, 3) *risk assessment and impact response* and 4) *implementing practical policies* (Eakin and Patt, 2011). The focus for this thesis is particularly on the latter two.

The *risk assessment and impact response* approach, defined as the 'simulation of costs and benefits of distinct adaptation opinions (…) with the ultimate goal of reducing the probability or magnitude of a specific loss (…) posed by a specific climate hazard' (Eakin and Patt, 2011: 142), is the dominant approach in many industrialised countries (Eakin and Patt, 2011), and often recommended for the creation of adaptation plans and strategies across different levels of governance (Jones and Preston, 2011). The *implementing practical policies* approach on the other hand 'seeks to define concrete strategies for overcoming many of the identified barriers to adaptation' (Eakin and Patt, 2011: 143) by focusing on facilitating mainstreaming of adaptation, providing decision support and improving the communication of risk and uncertainty. Both, the *risk assessment and impact response* and the *implementing practical policies* approach to adaptation are relevant for the thesis. Whilst the two countries at the centre of this research predominantly follow a risk approach to adaptation planning, thus setting the overarching framing within which the research takes place, the thesis focuses on advancing knowledge on the communication, tailoring and use of climate projections (also referred to as climate change projections) for adaptation planning and therefore strives to offer practical insights and add to our understanding of providing better decision support for adaptation.

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[1] This thesis is focused on climate change adaptation, but in Chapters 1 and 5, which were not submitted for publication, the thesis will simply refer to 'adaptation' to capture this concept.

1.2.1.2 Planned climate change adaptation

Research has shown that developed countries are more likely to take a proactive or anticipatory approach to adaptation (Berrang-Ford et al., 2011). This proactive adaptation can also be described as planned adaptation, which is 'the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state' (Parry et al., 2007: 869). Planning for adaptation, is a concept born out of the desire to reduce the vulnerability and increase the adaptive capacity of a system and equally plan for the management of possible positive outcomes from climate impacts (Preston et al., 2011), thus requiring foresight and conscious intervention (Fankhauser et al., 1999). Füssel (2007) states that adaptation planning shows similarities to risk management, despite the complexity of the problem at hand, thus fitting well with the risk approach to adaptation adopted by many industrialised countries. To better understand how the insights from such risk approaches can be useful and beneficial for decision-making and adaptation planning in the face of climate change, the concept of climate-related decision support has been much researched over the last decade (Jones et al., 2014, Moser, 2009, NRC, 2007). Decision support is understood as 'organized efforts to produce, disseminate, and facilitate the use of data and information in order to improve the quality and efficacy of climate-related decisions' (NRC, 2007: 2) and will be explored in more detail in Section 1.2.2.2. This thesis focuses on planned adaptation as the focus rests on exploring the provision of usable climate information and effective decision support, so relevant to the deliberate planning decisions at the heart of this type of adaptation.

1.2.1.3 Governance of climate change adaptation

Berrang-Ford et al. (2011) highlight that such a planned and anticipatory approach to adaptation necessitates governmental participation due to the longer-term impacts to be dealt with and the resultant planning timescales. Different levels of government from the international and national to the local level participate in adaptation planning, thus making it a multi-level governance issue. In an international sense, it is Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) that sets out the requirement for its member states to develop national and, where appropriate, regional adaptation strategies (UNFCCC, 1992). Developed and developing countries have thus been creating NAS or national adaptation programmes of action (NAPAs). Whilst, it is recognised that the UNFCCC has a significant role to play in progressing the debate on climate change, Tompkins and Amundsen (2008) argue that it may nevertheless not inspire sufficiently effective national level action, due to a mismatch between the scale at which the UNFCCC acts, i.e. the governance scale at which the policies are being suggested, and the scale at which national policy agendas are shaped and implemented (Tompkins and Amundsen, 2008).

At European level, significant efforts have been made to progress the adaptation agenda following arguments to make adaptation an integral part of European Union (EU) climate policy alongside mitigation (Berkhout, 2005, Yamin, 2005). It has been highlighted that the EU not only has the right tools and skills to address adaptation, but under the legislation - relating to the cohesion policy, the environment protection policy and infrastructure policies - it also has a duty to take action (ASRP, 2007). A European adaptation framework and integrated approach were thus called for that would provide the support, guidance and coordination for adaptation within the different countries (ASRP, 2007, Isoard, 2011, Massey and Bergsma, 2008). This framework was set out by the EU through the Green (EC, 2007) and White Papers (EC, 2009) in 2007 and 2009 respectively, and more recently through the European Adaptation Strategy in 2013 (EC, 2013). One of the key aims formulated in this framework is to encourage the development and implementation of NAS in all member states of the EU by 2017 (EC, 2013), thus strongly advocating a planned approach to adaptation at national level. This thesis will examine a number of these European NAS in more detail.

At the national level it is proposed that the NAS set out a non-legally binding framework for action on adaptation (Bauer et al., 2012). Urwin and Jordan (2008) highlight that despite policy guidelines in themselves not being a sufficient solution, they nevertheless send a political signal that sets the priorities, which ultimately will have an impact on resource and budget allocations. It has been put forward that in some European countries, particularly in the UK, adaptation is actually emerging as a distinct policy field, which means that adaptation has a certain level of stability and is more likely to be dealt with in a systematic and structured manner (Massey and Huitema, 2015). Whilst national agenda setting for adaptation is clearly an important driver (Urwin and Jordan, 2008), it has been shown that focus often shifts towards lower levels of governance once an NAS has been developed (Bauer et al., 2011) and multi-level governance is thus needed (de Oliveira, 2009, Westerhoff et al., 2012). This is of particular relevance to the thesis as the research in Chapters 3 and 4 focuses on sub-national, state and local level entities and the adaptation practitioners within these.

Local government is considered the closest governance level to local action on adaptation (Measham et al., 2011) and the majority of adaptation actions actually implemented occur at the local level (Ford et al., 2011) and will in many cases be financed through local government budgets. Despite this, and the often voiced argument that adaptation is predominantly a local concern, a number of constraints have been identified that hinder adaptation at the local level. These constraints can be split into: 1) those determining the decision context, such as the need for stronger leadership and regulation from national level, staffing resources and expertise, financing and the institutional and legal context (Amundsen et al., 2010, Baker et al., 2012, Carter et al., 2015, Dannevig et al., 2012, Hjerpe et al., 2014, Lehmann et al., 2015, McDonald, 2011, Measham et al., 2011, Naess et al., 2005, Nalau et al., 2015, Porter et al., 2014); and 2) those that are specific to the issue of decision-making and adaptation planning decision support and include the lack of useful technical data, the unfamiliarity with this data and information and the associated demand for guidance on the use of climate projections for (adaptation) planning (Amundsen et al., 2010, Baker et al., 2012, Lehmann et al., 2015, Measham et al., 2011, Nalau et al., 2015).

1.2.1.4 Climate change adaptation planning and climate projections

Füssel (2007: 268) states that planned adaptation requires the 'use of information about present and future climate change to review the suitability of current and planned practices, policies, and infrastructure'. The climate projections that are said to be needed for effective adaptation planning, however, display a number of uncertainties (Foley, 2010, Füssel, 2007, Latif, 2011, Stainforth et al., 2007b). Of course, uncertainties associated with climate projections are not the only uncertainties affecting the adaptation planning process, but they are thought to form part of the cascade of uncertainties (Wilby and Dessai, 2010). Past research has thus already assessed and evaluated different existing decision analysis frameworks and analytical decision tools for decisions under uncertainty (Dessai and van der Sluijs, 2007). However, the inclusion of uncertainty into the decision-making process in local adaptation planning is still considered challenging (Measham et al., 2011).

At the same time, there are clear calls for and a consequential rise in climate services (Jones et al., 2014, NRC, 2007, Vaughan and Dessai, 2014), that strive to make climate projections widely accessible. Owing to the move from deterministic to probabilistic projections, due to the increased computing capacity of modelling centres and advancements in research, local adaptation planners are increasingly exposed to more explicitly communicated uncertainties with probabilistic projections. Despite the fact that tools and platforms, like for example the UK Climate Projections 2009 (UKCP09) and its associated interface, have been very costly to develop (UKCIP, 2011), their development has been justified as a relevant decision-making tool for a range of stakeholders, including local adaptation practitioners. However, it has been shown that the effective use of the generated information remains a challenge (Carter et al., 2015, Tang and Dessai, 2012). As stated in the previous section, there has thus been a clear call for more guidance on the use of such projections by local adaptation practitioners (Amundsen et al., 2010, Baker et al., 2012, Lehmann et al., 2015, Measham et al., 2011, Nalau et al., 2015).

Due to the combination of adaptation practitioners being increasingly exposed to complex climate projections and a growing demand for more usable information (to be explored in Section 1.2.2.3), more attention needs to be paid to how such projections can be made more accessible to adaptation decision-makers and planners (Hanger et al., 2012, Preston et al., 2011). In addition, with a view to facilitating a more consistent understanding and use of information on the scientific uncertainties relevant to adaptation planning, a more systematic approach to their communication has also been asked for in order to support effective adaptation in a European context (Biesbroek et al., 2010).

Some research has tried to make inroads into the question of providing climate projections for decision-making by for example testing how to translate climate change impacts on land-use more tangibly through the use of climate services by local planners (Goosen et al., 2014), or by suggesting a ‘one stop shop’ solution for the provision of climate model output data from a shared data platform to avoid misuse (Hallegatte, 2009). However, to date these efforts have been too focused on finding technical solutions and tools for the provision of useful information, whilst not sufficiently taking into account additional factors, such as the wider institutional setting within which these tools are being applied, which will influence the use of such information and tools. Therefore, it is the aim of this thesis to gain a better understanding of the role and impact of this wider institutional setting on the use of communication tools for decision support.

1.2.1.5 Justification for this thesis

The overview in Section 1.2.1 has provided two important insights. Firstly, it has been recognised that whilst adaptation action is predominantly implemented locally, the strategies, regulations and policies set at the national level determine the framework for adaptation and substantially influence local adaptation planning (Bauer et al., 2012, Keskitalo et al., 2012, Massey et al., 2014, Termeer et al., 2012, Westerhoff et al., 2011). Given the influence ascribed to national level policy for adaptation by previous research, this thesis aims to examine the communication of scientific uncertainties in NAS within Europe in order to explore whether a more systematic and structured approach to uncertainty communication can be found. Such an approach could then also be applied at other scales of the multi-level governance framework of adaptation planning.

Secondly, at the same time, there is a demand for the national level to provide more guidance on the use of climate projections as well as more systematic communication of scientific uncertainties. The local level is demanding more useful and accessible climate information to aid the adaptation planning process. This poses questions not only as to how such information can be designed and guidance and support provided, but beyond these more 'technical' aspects, there is also a need to better understand how the use of such information by local adaptation planners is situated within and influenced by the wider regulatory landscape that local adaptation planning faces. Therefore, this thesis aims to better understand how efforts to provide more structured uncertainty communication at national policy level as well as better tailored climate projections can be practically provided for the adaptation planning process. In addition, gaining a better understanding of the influences on the use of such information locally will help to contextualise and ground communication and tailoring efforts, which will be further explored in Section 1.2.3.

1.2.2 Science for decision-making

1.2.2.1 Shifting modes of science

It has been argued that the modern problems faced by society, particularly challenges posed by environmental problems and climate change, are complex and difficult (Lemos and Morehouse, 2005) and thus require a different way of conceptualising and practicing science. In light of this, academics have argued that we are witnessing a shift in the nature, role and conduct of science (Funtowicz and

Ravetz, 1993, Gibbons et al., 1994, Gibbons, 1999, Lubchenco, 1998, Nowotny, 1999).

The dominant model that science has followed since the end of World War II was set out by Vannevar Bush in his prominent essay 'Science: the endless frontier' (1945). In this, Bush describes what has come to be known as the linear model of science, in which 'the responsibility for the creation of new scientific knowledge rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research' (Bush, 1945: 246) and that it is scientific progress that will lead to progress in security, economy and health for society.

The last two decades, however, have seen the change from this 'conventional' science (van Kerkhoff, 2005), also described as Mode 1 science (Gibbons et al., 1994), that is conceptualised within disciplinary individualistic boundaries, towards a new kind of science that is more integrative, utility focused and that spans across disciplinary boundaries (van Kerkhoff, 2005). This new science is required because society is both facing increasing uncertainties about the climate system that is to be understood as well as increasing uncertainties in how to handle the ethical implications of some of the current complex challenges (Funtowicz and Ravetz, 1993). Furthermore, because of these ethical uncertainties, such as the responsibility to preserve the environment for future generations, the stakes are very high (Funtowicz and Ravetz, 1993). It is therefore necessary that the idea of the 'expert' is extended to all those that are impacted by these challenges and thus have a stake in the decision-making process (Funtowicz and Ravetz, 1993). It is argued that only through an extended and a more interactive dialogue, can decisions in the face of great uncertainty and great urgency still be appropriately scrutinised and quality assured (Funtowicz and Ravetz, 1993).

This new mode of science is therefore based on the idea that science needs to fulfil a new social contract with society in which it '(i) address[es] the most urgent needs of society, in proportion to their importance; (ii) communicate[s] their knowledge and understanding widely in order to inform decisions of individuals and institutions; and (iii) exercise[s] good judgment, wisdom, and humility' (Lubchenco, 1998: 496). The key tenet of this new mode of science is that there is a move away from the one-sided notion that 'science speaks to society' to enabling society to 'speak back to science' (Gibbons, 1999). This has been described as 'Mode 2 science' (Gibbons et al., 1994), which is 'socially robust' (Nowotny, 1999), 'context sensitive' (Gibbons, 2000) and 'post-normal' (Funtowicz and Ravetz, 1993). Mode 2 science results from negotiations between academics and non-academics, thus merging a number of different ways of conceptualising the world and society, it crosses disciplinary boundaries and it allows for multiple and diverse agents to play a role in the knowledge production process (Gibbons et al., 1994).

1.2.2.2 Decision support and knowledge systems for decision-making

It is proposed, that in the knowledge production process and the process of converting this knowledge into action, the knowledge systems between the different agents, often largely grouped into decision-makers (that is 'any individual or group with the capacity to commit to a particular course of action (McNie, 2007: 19) and scientists, differ' (McNie, 2007)). Therefore, past research points out that for this boundary between science and policy, or knowledge and action, to be better managed, effective knowledge systems need to have three key attributes: salience, legitimacy and credibility (Cash et al., 2002, Cash et al., 2003). These three attributes are defined as follows:

- ***Salience***: 'the relevance of information for an actor's decision choices, or for the choices that affect a given stakeholder' (Cash et al., 2002:4)
- ***Credibility***: the extent to which 'an actor perceives information as meeting standards of scientific plausibility and technical adequacy' (Cash et al., 2002: 4)
- ***Legitimacy***: the extent to which 'an actor perceives the process in a system as unbiased and meeting standards of political and procedural fairness' (Cash et al., 2002: 5)

It has been suggested that information that is salient, credible and legitimate forms an integral part of effective climate related decision support (Jones et al., 2014, NRC, 2007), already briefly touched upon in Section 1.2.1.2. Effective decision support has six characteristics: it '1) begin[s] with users' needs; 2) give[s] priority to process over products; 3) link[s] information producers with users; 4) build[s] connections across disciplines and organizations; 5) seek[s] institutional stability; and 6) design[s] processes for learning' (NRC, 2007: 3). Amongst a range of decision support services that can be provided at the science-policy boundary, communication services that focus on the dialogue, problem framing, translation, interpretation and visualisation of knowledge and information are key (NRC, 2007).

Cash et al. (2002, 2003, 2006), based on their work on the communication, translation and mediation of salient, credible and legitimate information, set out three guidance points that can help to inform effective communication services. Firstly, transparency needs to be ensured, all viewpoints need to be heard and certain rules and criteria for the decision-making process ought to be created through the process of mediation (Cash et al., 2003). Secondly, through effective communication all stakeholders should be included in the knowledge production process and the dialogue between all stakeholders should be interactive instead of one-way (Cash et al., 2003). Thirdly, the idea that all stakeholders, with their different experiences, worldviews, presumptions and at times even different languages ought to understand each other can be achieved through a process of translation (Cash et al., 2003). It needs to be borne in mind though, that following these guidance points effectively in most decision contexts will be challenging due to the extensive resources and time required for such a process.

Cash et al. (2006) applied these concepts to a study on the uptake of El Niño Southern Oscillation (ENSO) forecast information into decision-making in the Southern African Drought Monitoring Centre (SADMC) and the Pacific ENSO Application Centre (PEAC). They found that the translation function is particularly challenging as this in turn affects the legitimacy and saliency of information. They highlight that the different uptake of forecast information between the case studies can be explained by a lack of sufficient tailoring of such information to user needs in the case of the SADMC on the one hand, contrasted with the investment of extra resources into the translation and mediation functions by PEAC on the other hand. Cash et al. (2006) therefore stipulate that mediation and translation appear critical for greater uptake and usability of information.

Based on these insights, it is argued that effective decision support ought to make information available through ‘mediated and direct communication channels’ thereby ‘fostering its appropriate interpretation and use’ (NRC, 2007: 53). Whilst, Cash et al. (2003) focus on knowledge systems for sustainability more broadly, their concepts of saliency, credibility and legitimacy, can be applied in a variety of decision support scenarios and provide the guiding principles for the concept of usable science in the context of climate change to be explored in the next section. Furthermore, their ideas for user-tailored and mediated communication also connect well with communication services for effective decision support to be explored further in Section 1.2.3.

1.2.2.3 Usable climate science

The use of climate forecasts and climate information has been explored in a variety of different studies (e.g. Archer, 2003, Kiem and Austin, 2013, Kirchhoff et al., 2013b, Rayner et al., 2005, Tang and Dessai, 2012, Weaver et al., 2013). These identified a range of factors that impact the perceived usefulness and usability of climate information for decision-making, including governance and institutional frameworks (Kirchhoff et al., 2013b), economic concerns (Rayner et al., 2005), regulatory stipulations (Rayner et al., 2005), the risk perception and risk tolerance of decision-makers (Kirchhoff et al., 2013b), lack of resources, competing issues and faulty communication (Lemos and Rood, 2010) and in addition different perceptions of the usefulness of scientific knowledge between the producers and users of such knowledge. The variety of these constraints highlights the often complex realities within which decision support is needed and provided at the boundary between science and policy.

Research suggests though that the interaction at this boundary between knowledge and action can be more effective if an iterative approach is employed (Lemos and Morehouse, 2005). Such an approach is based on three key principles: interdisciplinarity, interaction with stakeholders, and the production of usable science (Lemos and Morehouse, 2005). Furthermore, the extent to which such an approach can be successfully achieved is determined by the availability of resources, disciplinary and personal flexibility, and the ‘level of fit’ between knowledge production and its application (Lemos and Morehouse, 2005).

Zooming in on the level of fit, the following three variables can help to examine it in more detail: relevance (the extent to which the information provided matches the problem under consideration), usefulness (the extent to which the information is provided at the relevant temporal and spatial scales) and usability (the extent to which stakeholders actually deem the information provided accessible and usable) (Lemos and Morehouse, 2005). Furthermore, Lemos et al. (2012) stipulate that fit is not static, but instead its perception can be affected by 1) changes in leadership and organisational arrangements, 2) collaboration and communication with producers, and 3) improved ways information from producers has been translated, communicated and formatted as a result of increased interaction between producers and users (Lemos et al., 2012).

McNie defines useful scientific information as that which ‘improves environmental decision-making by expanding alternatives, clarifying choices and enabling decision-makers to achieve desired outcomes’ (2007: 17), thereby not just focusing on what is being produced in the knowledge production process, but also on how effective this process is. It has been noted that whilst the terms ‘useful’ and ‘usable’ at times have been used interchangeably, usefulness ought to be considered as considering functionality and desirability, whereas usability describes application and fit (Lemos and Rood, 2010).

The focus of this thesis rests particularly on the issue of usable science/ usable knowledge, which Lemos and Moorhouse define as ‘that which can be incorporated into the decision-making processes of all stakeholders, and which enhances their ability to avoid, mitigate, or adapt to stressors in their environment’ (2005: 62). Furthermore, Dilling and Lemos propose that ‘usability exists within a range in which each use is defined by a perception of usefulness and the actual capacity (e.g. human and financial resources, institutional and organizational support, political opportunity) to use different kinds of information’ (2011: 681). In addition, building on earlier work from Sarewitz and Pielke (2007), which explores the interplay between supply (science) and demand (societal goals) of knowledge, Dilling and Lemos (2011) point out that any differences between what scientists might consider useful in theory and what decision-makers consider as usable in practice need to be carefully navigated or reconciled when striving for usable science.

1.2.2.4 Overcoming the usability gap

The research focusing specifically on climate information usability is not very extensive and whilst a number of studies have driven the research field forward through empirical work (e.g. Kiem and Austin, 2013, Tang and Dessai, 2012), it was Lemos et al. (2012) who provided a conceptual model on the ‘usability gap’. Their model clearly distinguishes between useful knowledge (as provided by producers of climate information) and usable knowledge (as required by users of climate information) and describes the factors and actions needed to transform the former into the latter.

They suggest that this transformation from useful to usable knowledge can take place by helping the better processing of information through an iterative process of tailoring (which includes translation and formatting) and have put forward a number of strategies which can help in the tailoring process, which include value-adding, customisation and retailing and wholesaling (Lemos et al., 2012). They have defined these three strategies as follows:

Value adding - formal processes through which producers through 'a process of selection and analysis, convert data to information that can inform and educate users' (Lemos et al., 2012: 792)

Retailing and wholesaling – 'supply of a subset of original model outputs to groups of users with similar information requirements in a manner that is easily taken up by the user (…) (R)etailing serves users with individualized decision-making process at a more localized scale (…) (W)holesaling serves users at a broader scale who themselves influence other potential information' (Lemos et al., 2012: 792)

Customisation – 'adjustments to meet an individual user's needs made at the end of the knowledge production process' (Lemos et al., 2012: 792)

The value of tailoring climate science to the needs of end-users has also been highlighted by Kiem and Austin (2013) in their research on the disconnect between science and end-users in Australian rural communities, where they highlighted that unsuitable formatting and a lack of understanding of the information presented were amongst the major causes for why more than 25% of participants in their study did not believe climate change information was useful.

However, the debate on tailoring is not clear cut. On the one hand, Kirchhoff et al. (2013a) suggest that tailoring should be upscaled in order to be more efficient. On the other hand, previous research based on analysing the use of climate forecast by small-scale farmers in the Limpopo Province, South Africa, argues that user groups should not be considered homogenous. Whilst this study focuses on a very different decision-making setting compared to this thesis, its suggestion that taking a very fine scale approach to characterising user preferences expressed for the design of climate forecasts would be more beneficial (Archer, 2003), is, nevertheless, very relevant to the research in this thesis.

1.2.2.5 Justification for this thesis

The above overview summarises the considerable advancements made in characterising the mechanisms, variables and strategies required for the creation of more usable knowledge to inform decision-making. Nevertheless, whilst Lemos et al. (2012) highlight that the tailoring and specifically the customisation of information plays a critical part in the transition from useful to usable knowledge (See Figure 1-1), the practicalities of tailoring and customisation have not sufficiently been explored to date. Despite calls for tailoring to be scaled-up, it needs to be questioned how upscaling can be facilitated effectively without compromising the usability of climate information if we do not have a rigorous base and understanding of these processes at a very fine and individual scale.

This thesis aims to address this current shortcoming in our understanding by exploring tailoring and customisation of climate information in an applied setting and at a more detailed scale with adaptation practitioners in local government. Systematic empirical testing with this particular user group has not previously been conducted. The empirical insights gained will not only contribute to a better understanding of the needs of this specific target audience, but will also help to build on Lemos et al.'s conceptual model (2012) by specifically focusing on the practicalities of customisation.

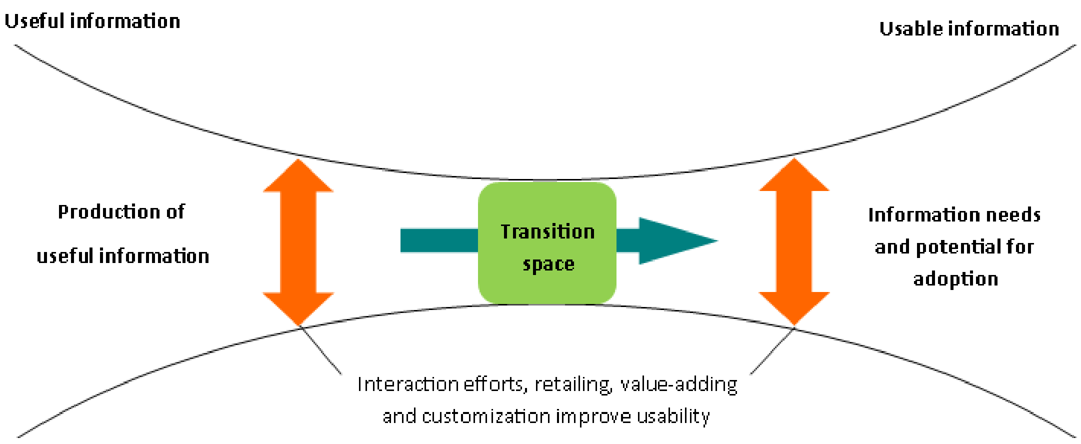

Figure 1-1 The transformation from useful to usable knowledge

This transformation takes places through the transition space between useful and usable knowledge, which is widened by customisation, interaction efforts, retailing and value-adding (adapted from Lemos et al. (2012))

1.2.3 Communicating climate change

1.2.3.1 Communicating risk, uncertainty and climate science

Despite starting to be recognised as a vibrant research field in its own right (Moser, 2010, Nerlich et al., 2010), climate change communication is arguably only in the early stages of its development (Fischhoff, 2011, Moser, 2010). Whilst developing its own theoretical framing and empirical grounding, it builds on insights from the fields of risk perception and communication, communication science, judgement and decision-making (JDM), behaviour research and uncertainty communication (Fischhoff, 2011, Moser, 2010).

Risk communication is an integral part of human life and 'can refer to any public or private communication that informs individuals about the existence, nature, form, severity, or acceptability of risks' (Plough and Krimsky, 1987: 6) and is considered as a process that happens between experts and lay people (Allen, 1987, Fischhoff, 1995, Leiss, 1996, Slovic, 1987). However, it has been put forward that the accumulation of knowledge about a certain risk in itself will not necessarily result in this being unanimously translated into action or agreement concerning this risk (Slovic, 1987). This realisation can be considered in the context of the shift away from Mode 1 science discussed in Section 1.2.2.1 Consequently, risk communication has gradually moved towards more of a two way communication process due to the realisation that both sides have valuable knowledge and insights to offer (Fischhoff, 1995, Fischhoff and Scheufele, 2013, Leiss, 1996, Plough and Krimsky, 1987, Slovic, 1987) and that science communication 'does not occur in a vacuum' (Fischhoff and Scheufele, 2013: 14031) but is placed within the social contexts and circumstances of the audience (Fischhoff, 1995, Leiss, 1996, Plough and Krimsky, 1987).

To aid this two-way process, clear guidance points for a science of communication are set out (Fischhoff, 2013, Fischhoff and Scheufele, 2013, Pidgeon and Fischhoff, 2011). These are largely based on the mental models approach, which acknowledges the diverse mental models between experts and different target audiences (Morgan, 2002). Consequently, such a science of communication ought to identify the most relevant science to the decisions at hand, understand people's prior knowledge, and design and evaluate communications so that they target the gaps between the first two (Fischhoff, 2013). Ultimately, Fischhoff argues, 'communication is adequate if it i) contains the information that recipients need, ii) in places that they can access, iii) in a form that they can comprehend' (Fischhoff, 2013: 14037). The parallels between this conceptualisation of effective science communication and the requirements for the provision of usable science set out in Section 1.2.2.3 are thus evident.

Furthermore, challenges have been highlighted demonstrating that not only can effective communication processes fail when experts focus too much on their own preferences and interests when designing communication strategies (Bruine de Bruin and Bostrom, 2013), but that even with joint insights from the social, decision and communication sciences, human behaviour is very complex and difficult to predict (Fischhoff and Scheufele, 2013). Additionally in relation to the communication of climate change specifically, communicators have to face the added challenge of the numerous uncertainties associated with climate change arising from a number of different sources including human action and development pathways, climate sensitivity, natural variability, climate feedbacks, the complexity of the climate system, and uncertainties inherent in climate modelling (Collins, 2007, Curry and Webster, 2011, Foley, 2010, Latif, 2011, Patt and Dessai, 2005, Stainforth et al., 2007a).

A variety of research on the perception and communication of climate uncertainty has been conducted. Examples include studies on the role mental models (Sterman, 2011) and the audiences' view on the philosophy of science play (Rabinovich et al., 2012) in the process of understanding and accepting uncertainties and on the role of the communication of uncertainty in the policy making process (Patt and Weber, 2013, Wardekker et al., 2008). Patt and Weber (2013), in their review of the literature in this field, find that the overarching aim of effective uncertainty communication is to 'help decision-makers make informed judgements that allow them to achieve their long- as well as short-term objectives (Patt and Weber, 2013: 225). Specifically concerning the communication of uncertainty, a lot of emphasis has been placed on how the most common format of uncertainty communication, namely that used by the Intergovernmental Panel on Climate Change (IPCC), is interpreted and understood by the audience (Budescu et al., 2009, Budescu et al., 2012, Budescu et al., 2014, Patt and Schrag, 2003, Patt and Dessai, 2005). Based on the findings from these studies, a wide range of suggestions have been made to the IPCC when communicating uncertainties ranging from, for example, adjusting the likelihood range of specific events in accordance to the underlying level of consensus on them (Budescu et al., 2009) to giving more detailed advice on how to use the information communicated (Patt and Dessai, 2005).

However, despite the IPCC's work over the last two decades aiming to synthesise and communicate the status quo of the knowledge on climate change, research has found that improved scientific knowledge of the issue does not necessarily correlate with an increase in the public's understanding and willingness to take action or with an increased public knowledge of the growing scientific consensus (Ekwurzel et al., 2011, Morton et al., 2011, Whitmarsh, 2011). The inherent challenges with communicating climate change (Nerlich et al., 2010) have been demonstrated by a variety of studies. These have highlighted the influence of the media on the effectiveness of communication and public perception of climate change (Boykoff, 2007, Carvalho and Burgess, 2005, Doulton and Brown, 2009, Gavin et al., 2011, Nisbet, 2009, Weingart et al., 2000), the role of press freedom and trust in the government (Tjernstrom and Tietenberg, 2008) and the influence of perceived communicators motives on levels of trust in them (Rabinovich and Morton, 2012). In addition past studies have looked at the importance of message framing (Morton et al., 2011, Nisbet, 2009, Whitmarsh, 2011) and linguistic communication choices (Nerlich et al., 2010), as well as the reasons for doubt amongst the audience (Poortinga et al., 2011), the influence of cultural cognition (Kahan et al., 2011) and the importance of culturally sensitive communications (Nursey-Bray et al., 2012).

1.2.3.2 Visual communication of climate change

Whilst communication can take many different forms and utilise different channels, a substantive part of the communication of climate change happens visually, as not only are 'visualisations and graphics (…) the most universally engaging of outputs' (McInerny et al., 2014: 148), but, particularly in the case of climate change, they also help to 'make visible the invisible' (Schneider, 2012: 188).

A number of past studies have aimed to elicit the public's visual conceptualisations of climate change through qualitative interviews (Nicholson-Cole, 2005), or by using Q-methodology to understand people's engagement with images from newspapers (O'Neill et al., 2013). They have found that relying on the assumption of particular messages being conveyed uniformly to different viewers of the same image is erroneous (Nicholson-Cole, 2005) and that it is rare for one image to simultaneously elicit efficacy and saliency in the viewer (O'Neill et al., 2013). Furthermore, O'Neill and Smith (2014) provide an overview of the visual discourse within the communication cycle of climate visuals and of how the public understands and interprets climate change imagery, highlighting that the recurrent themes throughout this process are focused on time, truth and power. What is noticeable from this part of the research is the predominant focus on popular and often iconic images in the sense that the studies focus on newspaper images (O'Neill et al., 2013), commonly used global simulation images (Schneider, 2012), or iconic diagrams such as the 'burning embers' diagram, that has been subject to both academic (Mahony, 2014) and public news interest (McGrath, 2014). Whilst such imagery aims to increase understanding of and prompt action on climate change in general terms, it is unlikely that they are context-specific enough to form part of an explicit decision-making process or decision support.

There are also a number of studies that focus on the visualisation of climate change as an information and decision-aid for a given context or as part of an information tool. Wong-Parodi et al. (2014) state that '[a] decision aid should impart knowledge of decision-relevant facts, allow people to integrate those facts with their values well enough to form consistent preferences, and achieve active mastery needed to make sound inferences related to practical decision problems' (Wong-Parodi et al., 2014: 486). Some studies focus particularly on landscape visualisations as a decision-aid. Cohen et al. (2012), for example, took a participatory visioning approach with a local community to study how 3D visualisations of the changing mountain snow and landscape conditions in North Vancouver could inform dialogue about possible adaptation or mitigation response scenarios. A similar approach has also been used to utilise visualisations of possible climate futures to develop participatory flood management strategies in a flood-prone community in British Colombia (Burch, 2010). Moving away from such landscape visualisations, towards 2D communications of probabilistic information from climate model ensembles, Stephens et al. (2012) argue that effective visualisations of such information for decision-making need to be interpretable and useful to a particular user (saliency), and strike a sensitive and challenging balance between the communication on the level of confidence in the prediction (robustness) with the overall amount of detail communicated (richness).

1.2.3.3 Tailoring and evaluating visual communication

Although the field of visually communicating climate change is growing, there has to date been comparatively little empirical research on the communicative effectiveness of such visualisations (Lieske, 2012, Moser, 2010, Stephens et al., 2012). However, whilst climate visualisations might be a fairly recent phenomenon, the assessment of visuals and graphical representations more broadly has been widely researched in the fields of health and cognitive sciences (Ancker et al., 2006, Elting et al., 1999, Parrott et al., 2005), risk (Ibrekk and Morgan, 1987), design (Quispel and Maes, 2014) and computing (Kelleher and Wagener, 2011, Sanyal et al., 2009). More closely related to adaptation research, lessons can also be learned from research on environmental hazards and geosciences (Bostrom et al., 2008, Broad et al., 2007, Gahegan, 1999), and hydrology (Gimesi, 2009, Pappenberger et al., 2013). Insights from these past studies can help grow our understanding as to how to comprehensively assess and evaluate climate visualisations as well.

It is argued that graphical communication involves a process of encoding and decoding of information and that '[a] graphical method is successful only if the decoding is effective' (Cleveland and McGill, 1985: 828). Whilst there has been some discussion as to which variables should be utilised in the assessment of this effectiveness, it is recognised that a combined understanding of user comprehension, preferences and the ability to support user needs is required (Ancker et al., 2006, Bostrom et al., 2008, Hawley et al., 2008, Lipkus and Hollands, 1999, Spiegelhalter et al., 2011).

Numerous studies, particularly in the health sciences, have focused on the analysis of the perception and comprehension of different types of commonly used graphs such as pie charts, risk ladders, icon arrays, bar graphs, line graphs and less commonly used formats such as so-called 'spark plugs' or 'magnifying glasses' (Garcia-Retamero and Galesic, 2010, Garcia-Retamero and Dhami, 2011, Shah and Freedman, 2011, Spence and Lewandowsky, 1991, Stengel et al., 2008, Wong et al., 2012). These studies have found that a number of factors such as respondents' level of numeracy (Garcia-Retamero and Galesic, 2010) and graphical literacy (Garcia-Retamero and Galesic, 2010, Shah and Freedman, 2011), familiarity with the graph format used (Lipkus and Hollands, 1999, Roth, 2002, Shah and Freedman, 2011) and with the topic communicated (Shah and Freedman, 2011) all affect respondents' level of comprehension. User comprehension of visualisations has also been studied in relation to communicating natural hazards. Broad et al. (2007) in their study of the hurricane cone as communicated by the National Hurricane Center in the US, find that the public do not understand the uncertainty communicated through the cone and highlight common misconceptions, such as the presumed safety from the hazard for locations outside the outer boundaries of the cone or the overemphasis of focusing on the black line marking the assumed hurricane path. In another study examining the use of a coastal flooding risk tool in the US, Wong-Parodi et al. (2014) explored an evaluation procedure for the usability of climate change impact decision aids in terms of how they affect users' understanding of their situation defined in terms of their knowledge, consistency of preferences and active mastery of the material. They suggest that if designers of decision-aids were to apply these three measures consistently to the development of their visualisation tools, communications of intended aims would be more focused and explicit (Wong-Parodi et al., 2014).

The previously highlighted research has predominantly focused on understanding the comprehension and preferences of the public and only few studies have specifically focused on expert or practitioner audiences. A couple of studies with experts in both hazard mapping (Kunz et al., 2011) and flood forecasting (Pappenberger et al., 2013) highlight that there is no real consensus amongst specific target audiences as to visualisation preferences. Furthermore, specifically in relation to climate forecasts, a study by Davis et al. (2015) evaluated and compared a variety of different probabilistic forecasts from a range of forecasting centres and, through expert interviews, found that users perceived the forecast visualisations as difficult to interpret. The study however, does not specifically state how expert comprehension was assessed or evaluated, making it difficult to extract useful guidance for repeatable assessments for other visualisation tools. Daron et al. (2015), in their study with the African vulnerability and adaptation practitioner community, have taken a more quantitative approach to directly comparing user comprehension, likelihood assessment and preference for different visualisations of climate projections and found that users extract different messages from the same visualisation and that expressed preferences for visualisations are associated to user confidence and their comprehension of those visualisations.

Whilst it can be seen that previous research in this field is very varied, a number of overarching messages emerge from the different studies. Firstly, we cannot assume that one single image, graphical format or visualisation will be unanimously and uniformly interpreted and consequently it is not achievable to pick a single one that will be effective across target audiences or even within a specific target audience (Bostrom et al., 2008, Lipkus and Hollands, 1999, Nicholson-Cole, 2005). To increase effectiveness, visual communications should therefore be evaluated and tailored to specific individual or audience settings, perceptions, and needs (Broad et al., 2007, Hawley et al., 2008, Hess et al., 2011, McInerny et al., 2014, Stephens et al., 2012). Consequently, such tailoring refers to 'any number of methods for creating communications individualized for their receivers' (Hawkins et al., 2008: 1). Tailoring, however, cannot be conceptualised in a vacuum and requires systematic empirical testing and evaluation (Broad et al., 2007, Lipkus and Hollands, 1999, Wong-Parodi et al., 2014). The recognition by a number of key scholars in this field (Bostrom et al., 2008, Fischhoff, 2011, Lipkus, 2007, Pidgeon and Fischhoff, 2011, Spiegelhalter et al., 2011) that such testing and evaluation has only rarely been done to date provides the motivation for further empirical testing as suggested in this thesis.

1.2.3.4 Justification for this thesis

The review of the literature in this section has highlighted a number of key demands for further research. Firstly, it is evident that the emphasis in much of the research predominantly rests on examining the understanding and views of the public as the principal 'audience' of climate change communication. As outlined in Section 1.2.1, much of the implementation of adaptation planning will happen at the local scale and in a review on communicating adaptation specifically, local practitioners have been identified as a key target audience for communication (Moser, 2014). Moser (2014) suggests that a better translation and tailoring of climate information to such local practitioners would support an easier application of this information to the implementation of adaptation actions. However, detailed research on providing tailored visual communication to this target group is not available to date. This links to the second key finding from the review of the research, namely that there is a clear demand for more empirical research in this field to identify more systematic and structured processes for the assessment and evaluation of the effectiveness of climate visualisations. This thesis therefore aims to contribute to this field by gaining a better understanding of local adaptation practitioners as a target audience and by responding to the call for more empirical research in the field of tailoring of climate visualisations.

1.2.4 Summary

Ever more sophisticated and complex climate projections are available to inform adaptation planning. At the same time, increasing emphasis is being placed on creating and providing usable science for adaptation planning decision support. Communication plays a key role in this process and the argument is thus being voiced that more systematic and better tailored communications of climate projections and their uncertainties are needed. At the national level, the projections and their associated uncertainties are included and communicated in NAS to varying extents. At sub-national level local adaptation practitioners have been identified as a key target group of tailored communication due to their critical role in local adaptation planning. However, there is a distinct lack of relevant empirical research upon which to base effective tailoring efforts. In addition, based on the recognition that local adaptation practitioners, are based within a multi-level institutional setting, the actual use and usability of such tailored information needs to be explored accordingly in this context.

Given the influence ascribed to national level policy for adaptation by previous research, this thesis aims to examine the communication of scientific uncertainties in NAS within Europe in order to explore whether a more systematic and structured approach to uncertainty communication can be found. Such an approach could then also be applied at other scales of the multi-level governance framework of adaptation planning.

1.3 Aim and objectives

Reflecting on the gaps identified in previous research, the overarching aim of this thesis is to better understand the communication, tailoring and use of climate projections for adaptation planning. To achieve this aim, the thesis will assess the communication of climate projection uncertainty at national adaptation policy level in Objective 1, report on empirical findings from testing tailored climate visualisations with local adaptation practitioners in Objective 2; examine how the context of local planning influences the use of climate projections in Objective 3 and draw together overarching lessons for the creation of usable communication tools for effective decision support in adaptation planning in Objective 4.

Objective 1: Assess how European National Adaptation Strategies communicate physical climate uncertainties.

Objective 2: Test the association between comprehension and preferences for different tailored visualisations of climate projections by individual adaptation practitioners in local government in the UK and in Germany.

Objective 3: Examine the extent to which the wider (political, legal and regulatory) context within which local adaptation planning is placed influences the use of climate projections at the local level in North Rhine Westphalia in Germany and the South East and East Midlands regions of the UK.

Objective 4: Evaluate the communication, tailoring and use of climate projections for adaptation planning.

The following section will outline the overarching research strategy that was employed to meet these objectives.

1.4 Research strategy

1.4.1 Research Philosophy

Patwardhan et al. (2009) state that in order to meet the challenge of adaptation, a more integrated approach to research in this field is needed. This thesis takes such an integrated approach in order to effectively combine multi-level insights from the individual level (i.e. user comprehension and preferences of climate visualisations), local level (i.e. assessing the actual use of climate projections in adaptation planning in local government) and national level (i.e. the approaches taken to the communication of physical science uncertainty in NAS) for the communication, tailoring and use of climate projections for adaptation planning.

The literature argues that a number of different philosophical perspectives on a scale from positivism to subjectivism have been identified to play a role in integrative research (Evely et al., 2008). This thesis adopts a pragmatic approach, that is an approach that 'use[s] the combination of methods and ideas that helps one best frame, address, and provide tentative answers to one's research question[s]' (Johnson et al., 2007: 125). The reasons for adopting a pragmatic approach for this thesis are threefold. Firstly, pragmatism seeks to find and develop solutions that are fit-for-purpose (Hammond and Wellington, 2013). The underlying drive for this research is to contribute to the discussion on how usable climate knowledge and information can be created that is exactly that: 'fit for purpose' for adaptation planning. In that sense, the broader values and beliefs underlying both this philosophical approach and the drive for this research are well aligned. Secondly, pragmatism allows for the combination of the macro with the micro level (Onwuegbuzie and Leech, 2005), therefore supporting the multi-level approach of this thesis. Thirdly, pragmatism is pluralistic in nature (Creswell and Clark, 2011) and therefore allows the research to flexibly combine both subjective and objective knowledge as equally valuable (Creswell and Clark, 2011) and explore a variety of research questions (Onwuegbuzie and Leech, 2005) utilising different methods. It has therefore been argued that the philosophy underpinning pragmatism lends itself particularly well to a mixed methods approach (Hammond and Wellington, 2013, Johnson et al., 2007).

1.4.2 Methodological approach

1.4.2.1 Mixed methods approach

This study takes a mixed methods research approach. Different mixed methods scholars have come up with a variety of different definitions and they do not necessarily agree with each other on what, when, why, how much and with what orientation ‘mixing’ occurs in such an approach (Johnson et al., 2007). This study adopts Leech & Onwuegbuzie’s definition, which states that a mixed methods approach ‘involves collecting, analyzing, and interpreting quantitative and qualitative data in a single study (…) that investigate[s] the same underlying phenomenon’ (2009: 267).

1.4.2.2 Mixed methods design

The literature states that there are a number of different reasons for utilising a mixed methods approach (e.g. Creswell and Clark, 2011, Greene et al., 1989). This thesis utilises expansionist reasoning, which seeks to ‘extend the scope, breadth and range of inquiry by using different methods for different inquiry components’ (Greene et al., 1989: 269). As it was stated in the previous section, the underlying phenomenon to be investigated in this thesis is the communication, tailoring and use of climate projections for adaptation planning. The aim is therefore to look at the interplay between those three components and integrate qualitative and quantitative methods to create a more pragmatic understanding of the phenomenon (Greene et al., 1989).

Whilst a number of different typologies have been created for mixed methods research (Creswell and Clark, 2011, Greene et al., 1989, Leech and Onwuegbuzie, 2009, Tashakkori and Teddlie, 2010), the three dimensions defined by Leech & Onwuegbuzie (2009): time orientation, level of mixing and emphasis of approaches will be used to further describe the research approach taken in this thesis.

This research adopts a fixed mixed methods design (Creswell and Clark, 2011), which was planned at the outset of the research to follow three phases of data collection and analysis. Each phase links to one of the first three research objectives outlined in Section 1.3 and required different data collection and analysis methods. Figure 1-2 presents a schematic diagram highlighting the overall design of this thesis. The approach taken was thus largely sequential, as each phase followed on from the previous (Leech and Onwuegbuzie, 2009). However, due to the nature of some of the data preparation and collection methods, parts of the phases overlapped on two occasions. Firstly, the climate data preparation process was very time consuming and thus needed to be started early on in the research and secondly, the interviews in England commenced whilst the online survey in Germany was still open.

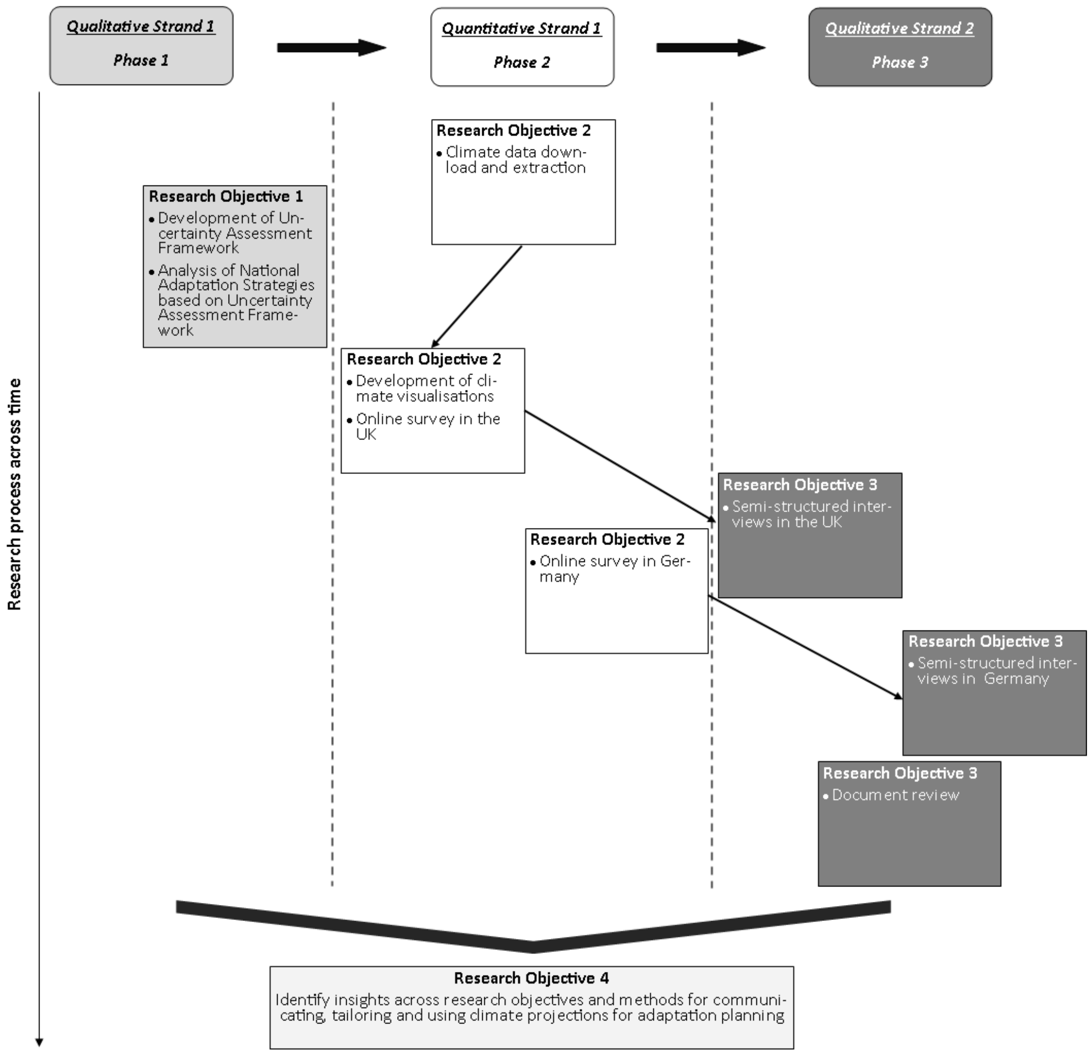

Figure 1-2 This schematic presents an overview of the research design for this thesis.

Figure 1-2 also shows that each stage only drew on either qualitative or quantitative methods. Whilst the convenience sampling (Onwuegbuzie and Collins,

2007) employed for the interviews in phase 3 was based on the surveys conducted in phase 2, both methods were not fully mixed within or across stages until the overarching interpretation stage for Objective 4 (Leech and Onwuegbuzie, 2009). This thesis is therefore a partially mixed study (Leech and Onwuegbuzie, 2009).

Lastly, two of the three research objectives used qualitative data and only one used quantitative data. Whilst this gives qualitative data a more dominant status, it shall, nevertheless, be stressed that both quantitative and qualitative data were equally as valuable in achieving the overarching research aim.

A detailed overview of the different research objectives, questions, data collection and analysis methods is provided in Table 1-1. Most of the detailed description for the data collection and data analysis methods for research objectives 1, 2 and 3 are outlined in the respective chapters. The following section will only expand on two issues relevant to this research in more detail (the case study approach and the process for preparing the climate projections data used in Chapter 3), as the word count restrictions placed on the accepted/ submitted papers upon which Chapters 2, 3 and 4 are based, did not allow for extensive details on these.

Table 1-1 Overview of the research objectives and the respective data collection and analysis methods

Main research objective	Research questions	Data required	Data collection method	Data analysis method
1) Assess how European National Adaptation Strategies communicate physical climate uncertainties.	a) How can the extent to which physical science uncertainties are communicated in NAS be compared more systematically?	Information from previous research on how the communication of uncertainty can be assessed	Literature search	Review of previous uncertainty assessment frameworks, reflection on gaps in prior studies Conceptualisation of novel Uncertainty Assessment Framework
	b) How much detail on the physical science of climate change and its associated uncertainties is included in the NAS?	Information on the types of physical science uncertainties covered in the NAS	Review of 10 European NAS (publicly available in English)	Content analysis through thematic coding according to the categories identified in the previously developed uncertainty assessment framework (UAF)

Main research objective	Research questions	Data required	Data collection method	Data analysis method
	c) What impact does the wider socio-political context within which NAS are conceptualised have on the communication of physical science uncertainties in them?	Information from previous research on development and context of climate change (adaptation) policy in Germany and the UK	Literature search	Reflection on previous studies and synthesis of impacts found on the communication of physical science uncertainty not previously highlighted

Main research objective	Research questions	Data required	Data collection method	Data analysis method
2) Test the association between comprehension and preferences for different tailored visualisations of climate projections by individual adaptation practitioners in local government in the UK and in Germany.	a) How can the effectiveness of visualisations of climate visualisations be tested empirically?	Climate model data for the development of example climate visualisations	CMIP5 download and file preparation through the programmes IDL and R in order to extract climate projections for a specific location	Climate data extraction to create 'alternative' and 'traditional' visualisations for the survey using the same underlying data
	b) How do different graph formats for visualising climate projections affect assessed comprehension?	Data on the assessed comprehension (AC) for different visualisations	Online survey presenting two pairs of visualisations	Statistical analysis to compare the AC within pairs of visualisations

Main research objective	Research questions	Data required	Data collection method	Data analysis method
	c) How are assessed and perceived comprehension associated?	Data on the AC and perceived comprehension (PC) for different visualisations	Online survey presenting two pairs of visualisations	Statistical analysis to assess associations between AC and PC
	d) How is (assessed and perceived) comprehension associated with the use of the visualisations?	Data on the AC, PC and respondents' subjective preferences for using the visualisations	Online survey presenting two pairs of visualisations	Statistical analysis to assess associations between AC and PC, and respondents' subjective preferences

Main research objective	Research questions	Data required	Data collection method	Data analysis method
3) Examine the extent to which the wider (political, legal and regulatory) context within which local adaptation planning is placed influences the use of climate projections at the local level in North Rhine Westphalia in Germany and the South East and East Midlands regions of the UK.	a) How are climate projections used in local adaptation planning?	Information on the extent to which adaptation practitioners use climate projections	Semi-structured interviews to explore views of adaptation practitioners on using climate projections Planning and climate change (adaptation) documents for interviewees' local governments to assess inclusion and detail on climate projections	Thematic coding of interviews to identify levels of use of climate projections Reflection on planning and climate change documents

Main research objective	Research questions	Data required	Data collection method	Data analysis method
	b) What characterises the wider institutional context within which local adaptation planning takes place?	Information on the status of adaptation at local level in Germany and the UK and the wider institutional framework (regulations, policies, legislation) within which it is implemented	Semi-structured interviews to understand the wider institutional influences on local adaptation Literature search	Thematic coding of interviews to identify the effect of the wider institutional setting Reflection on previous studies
	c) How do institutional context and the use and usability of climate projections for adaptation planning interact?	Information on institutional influences on climate information usability	Semi-structured interviews to understand the wider institutional influences on the use and usability of climate projections Literature search	Thematic coding of interviews to identify constraining and enabling factors in the external institutional framework for the use of climate projections Reflection on previous studies

Main research objective	Research questions	Data required	Data collection method	Data analysis method
4) Evaluate the communication, tailoring and use of climate projections for adaptation planning.		Information and findings gathered through objectives 1, 2 and 3.		Reflection on the combined findings and lessons to be learned for the communication, tailoring and use of climate projections for adaptation planning

1.4.2.3 Case study approach

To study the phenomenon of communicating, tailoring and using climate projections for adaptation planning in more detail in a specific context, this thesis takes a case study approach. As it is argued that case studies allow the researcher to explore an issue or a phenomenon through multiple lenses in order to understand the variety of different aspects it might entail (Baxter and Jack, 2008), it is well suited to the philosophical underpinnings and mixed methods approach outlined above.

Whilst the case study literature presents the researcher with a variety of definitions of this approach (Gerring, 2006, Seawright and Gerring, 2008, Yin, 2009), this thesis adopts Hay's definition, which stipulates that a case study 'involves the study of a single instance or small number of instances of a phenomenon in order to explore in-depth nuances of the phenomenon and the contextual influences on and explanations of that phenomenon' (Hay, 2010: 81). Utilising a purposive sampling approach (Hay, 2010, Onwuegbuzie and Leech, 2010), the overarching case studies chosen for this thesis are Germany and the UK, based on the fact that both of these are considered leaders on climate science and adaptation within Europe and more widely (Bauer et al., 2012, Massey and Bergsma, 2008, Swart et al., 2009) and on more pragmatic reasons such as being able to converse in both languages fluently, thus being able to conduct all required data collection without assistance. Although previous research highlights that there can be concerns in terms of the transferability or generalizability of findings from case study research (Ford et al., 2010, Hay, 2010, Onwuegbuzie and Leech, 2010), it has nevertheless been suggested that some of these concerns can be met through selecting multiple case studies (Baxter and Jack, 2008, Ford et al., 2010, Noor, 2008), as has been done in this thesis, as these enable the researcher to have a broader base of data and information in order to comprehensively understand the phenomenon at hand (Hay, 2010). When, considering the findings from this research, however, it ought to be borne in mind, that both of the chosen countries are considered to be leaders on adaptation (Bauer et al., 2012). Thus, countries with a less well developed adaptation agenda may face additional challenges and complexities that have not arisen from the case studies covered in this thesis and therefore, are not covered in this research.

Figure 1-3 shows a schematic of the iterative case study approach taken. The figure shows that the initial analysis of NAS for Germany, England, Wales and Scotland

(Northern Ireland had not published a NAS at the time of data collection) was followed by an exploratory analysis of the wider cultural and socio-political frameworks within which the NAS are framed for Germany and England. From this initial step follows the online survey conducted with local adaptation practitioners in both Germany and the UK.

Despite focusing only on local adaptation practitioners' responses for the analysis in Chapter 3, the online survey also captured regional and national adaptation practitioners. Using convenience sampling by asking survey respondents to state whether they would be interested in participating in a follow on research phase, the case study was further narrowed down by selecting the two regions from within the UK and one from within Germany that had the most respondents in the online survey in order to maximise the pool of potential interviewees. Through this process of convenience sampling, the two regions selected for the UK are both in England, the analysis in Chapter 4 focused specifically on England, rather than the UK as a whole.

Due to the geographical size of the focus areas varying between Germany and England, two were chosen for England to cover a spatially similar area to the one chosen in Germany (further detail on the focus areas is provided in Appendix C1). In addition to interviewees from the focus regions, a number of local, regional and national interviewees determined through both convenience sampling and snowballing were also interviewed to ground the findings from the focus areas in the wider context of Germany and England.

Further specific details on selecting the NAS, choosing England and Germany for the exploratory analysis in Phase 1, sampling the survey participants in Phase 2 and recruiting the interviewees in Phase 3 are described in the respective chapters.

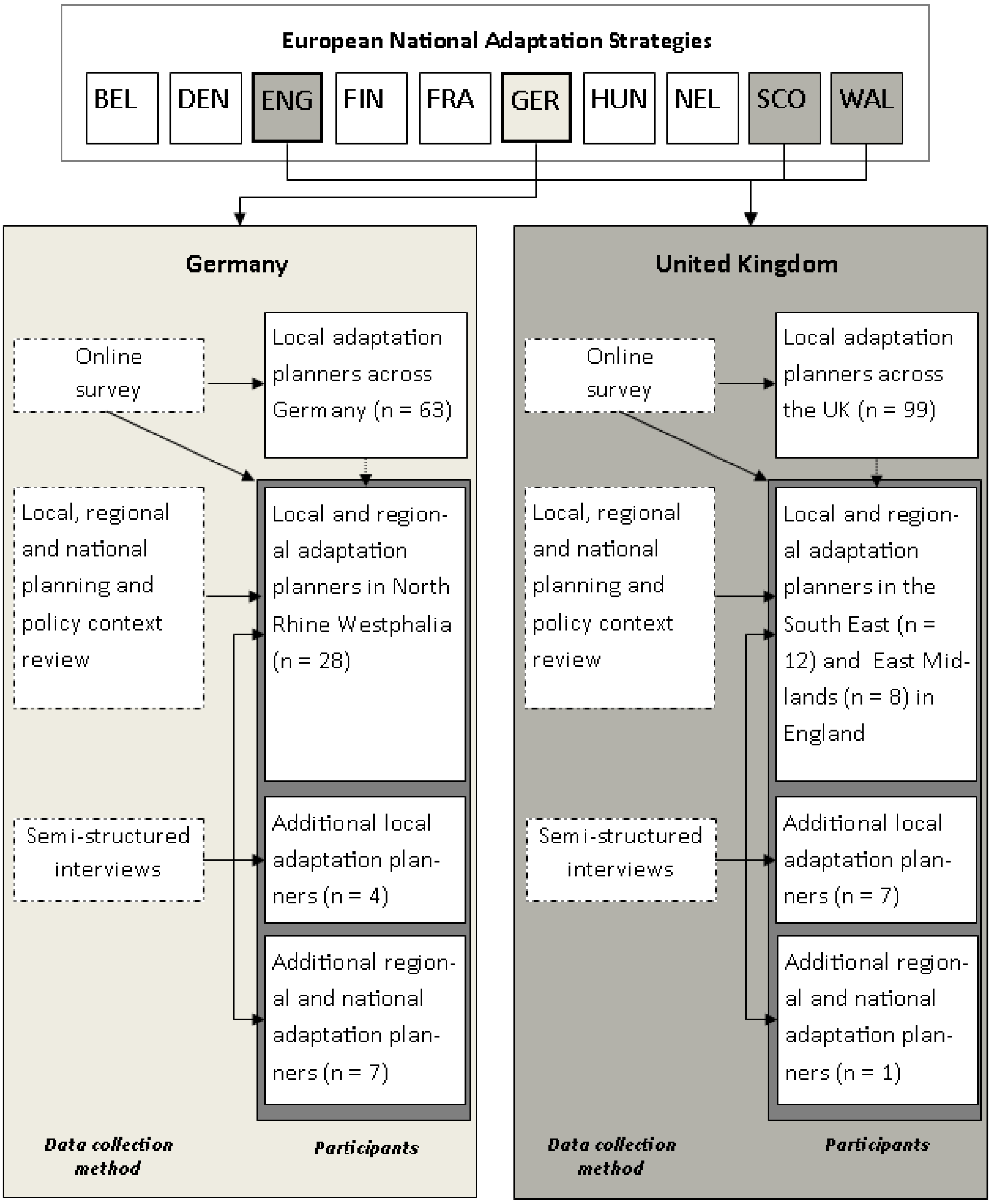

Figure 1-3 Overview of the case study sampling approach

1.4.2.4 Climate science

The data used for the creation of the climate visualisations for Chapter 3 was taken from the Climate Model Intercomparison Project (CMIP). At the time of the data extraction for this thesis, the project, which aims to facilitate and enable climate modelling experiments in a coordinated fashion, was in its fifth phase (CMIP5). CMIP5 provides state of the art climate model information and provides the foundation for a substantial part of the research underpinning the 5th Assessment Report of the IPCC.

The CMIP5 project designed a number of experiments that were run by climate modelling centres around the world (Taylor et al., 2012). The experiments aiming to explore long-term (up to 2100) climate projections are based on representative concentration pathways (RCPs), meaning that all models producing climate projections were forced by the same four radiative forcings (Moss et al., 2010), allowing for more direct comparison between the different General Circulation Models (GCMs). The four different RCPs have target radiative forcings for the year 2100 of 2.6 Wm^{-2} (RCP 2.6), 4.5 Wm^{-2} (RCP 4.5), 6.0 Wm^{-2} (RCP 6.0) and 8.5 Wm^{-2} (RCP 8.5) (Moss et al., 2010).

As not all models in the CMIP5 project had provided simulations for these experiments when the data for this thesis was needed, it was decided to limit the data extraction to the models in Table 1-2. The data extracted for the climate visualisations for Chapter 3 was monthly mean near-surface air temperature from the historical experiment (1975 – 2004; to create a baseline) and the RCP 6.0 experiment for the future time slice of 2040 - 2069. For the purpose of the experimental design in Phase 2 (Chapter 3), only one RCP could be chosen, as otherwise the survey would have become too extensive. The choice of the RCP is irrelevant for the experiment, however, as it only serves as one possible future pathway for which data could be extracted from the GCMs in order to design the visualisations. The mid-century time slice was chosen as the projected change in temperature will be clearly discernible by then. Additionally, this time slice will be within the planning horizons for a variety of local planning considerations due to the life span of certain structures (e.g. buildings, roads and tree planting).

As not all of the GCMs listed in Table 1-2 have the same grid resolution (ENESM, 2011, PCMDI, n.d.), all the output was regridded to a common 0.5 (longitude) x 0.5 (latitude) degree grid. Due to only limited data being needed for a given location to create the climate visualisations used in Chapter 3, it was decided to use the monthly means extracted (covering the summer months of June, July and August) to calculate seasonal means for the grid cell that covered Newcastle, UK. The projected change in mean summer temperature was then calculated by subtracting the baseline from the 2040-2069 time slice.

Based on this data, four visualisations, split into two pairs, were developed for the surveys reported in Chapter 3. These two pairs were intended to be based on the same underlying data but show different information content. Therefore, the two visualisations in pair 2 (the bubble plot and the histogram) represent frequency distributions of projected annual summer changes for each of the 30 years for each of the 14 GCMs. For the purpose of the creation of the visualisations, it was assumed that each of these GCMs was equally likely. The two visualisations in pair 1 (the scatter plot and the pictograph), use the same data but show the 30 year seasonal mean changes for each of the 14 GCMs; thus they are showing 14 mean values rather than the distribution of values.

Table 1-2 CMIP5 General Circulation Models used in the thesis

Model	Modelling Centre	Institution	Original grid resolution	
			Longitude (in degrees)	***Longitude (in degrees)***
bcc-esm1-1	BCC	Beijing Climate Centre, China Meteorological Administration (China)	2.7906	2.8125
CCSM4	NCAR	National Center for Atmospheric Research (USA)	0.9424	1.25
CSIRO-Mk3-6-0	CSIRO-QCCCE	Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence (Australia)	1.8653	1.875
FGOALS-s2	LASG-IAP	State Key Laboratory for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences (China)	1.6590	2.8125
GFDL-CM3	NOAA GFL	Geophysical Fluid Dynamics Laboratory,	2	2.5
GFDL-ESM2G			2.0225	2

GFDL-ESM2M		National Oceanic and Atmospheric Administration (USA)	2.0225	2.5
HadGEM2-ES	MOHC	Met Office Hadley Centre (UK)	1.25	1.875
IPSL-CM5A-LR	IPSL	Institut Pierre-Simon Laplace (France)	1.8947	3.75
MIROC5	MIROC	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	1.4008	1.40625
MIROC-ESM		Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	1.8653	1.875
MIROC-ESM-CHEM			1.8653	1.875
MRI-CGCM3	MRI	Meteorological Research Institute (Japan)	1.12148	1.125
NorESM1-M	NCC	Norwegian Climate Centre (Norway)	1.8947	2.5

Note: The grid resolutions in this table are based on information from the European Network for Earth System Modelling and the Program for Climate Model Diagnosis and Intercomparison (ENESM, 2011, PCMDI, n.d.).

1.4.3 Positionality

Positionality is considered to be the researcher’s perspective in the interaction with research participants which is shaped by the researcher’s ‘unique mix of race, class, gender, nationality, sexuality and other identifiers' (Mullings, 1999: 337). The nature of this unique mix can impact on the researcher's status as 'insider' or 'outsider' in a given research context. The debate on the insider/ outsider question (e.g. Herod, 1999, Mather, 1996, Mullings, 1999) and its impact on the knowledge produced during and through the research process highlights that the messiness of positionality results in 'a sliding scale of intimacy' (Herod, 1999) between the researcher and the research participants.

When making contact with research participants for both the surveys and the interviews, I introduced myself as a researcher from the University of Leeds. I also explained that my professional background prior to commencing postgraduate research had been in the field of adaptation and sustainability in local government in England, however, making clear that I no longer worked in that field.

As the majority of my interviewees worked in local government and had job descriptions that covered similar topics, I felt that the similar professional experience was a beneficial circumstance. This is not to say that the knowledge produced with the research participants was any more true than had I not had this professional background (Herod, 1999), but I did feel that participants particularly in the interview process were more at ease once they realised that I had a personal practical understanding of the nature of the environment they work in and the realities of that profession.

Whilst this position towards the 'insider' end of the 'sliding scale of intimacy' was more apparent in the interview process in England, the question of my personal positionality with the German interviewees was somewhat more 'messy'. Having grown up in Germany, I did not encounter any issues concerning transcultural communication (Herod, 1999). In addition, there was also a lot of interest as to how things were done in England on the question of adaptation in local government. Whilst, seemingly being more towards the 'outsider' end of the scale due to my affiliation with a university from outside Germany and my work experience within a different local government system, these facts, in actual fact sparked interest and led to constructive exchanges, confirming findings by Herod (1999).

1.4.4 Research Ethics

As the research conducted for Chapters 3 and 4 required the involvement of human participants, relevant risk assessments were completed and Ethical Approval from the University of Leeds Ethics Review Committee was sought (AREA 12-062) before the data collection commenced. The key concerns covered in the ethical review for this research were focused on obtaining participant consent and ensuring confidentiality (Berg, 2007).

When trying to recruit participants for the survey, an introductory email was sent to potential participants giving a brief overview of the aim of the survey, containing the link to it, and informing them that if anyone had further questions before taking part in this research, they could contact me (see Appendix D.1). The detailed information about the project, confidentiality and informed consent were provided at the start of the survey in both countries (see Appendix B.1 and B.2).

As the aim of the interviews was to focus more specifically on two regions in England and one region (Land) in Germany, the three regions were chosen based on the number of participants from that region that had participated in the survey. For the interviews those survey participants who had provided their contact details at the end of the survey for further research involvement were then contacted again via email (see Appendix D.2) to recruit them for follow up interviews. A number of interviewees in Germany were also recruited based on recommendations from other interviewees (snowballing). Informed consent for the interviews was sought before the interviews commenced.

1.5 Novelty and contribution of the thesis

This thesis offers a number of empirical and methodological contributions to advance the field of communicating, tailoring and using climate projections for adaptation planning, which will be outlined below and articulated in detail in the respective empirical chapters.

Firstly, in developing the uncertainty assessment framework (UAF) (described in Chapter 2), this thesis provides a new diagnostic tool to systematically assess and compare the communication of physical science uncertainty in plans and strategies aiming to communicate the climate science basis for adaptation planning. Such an assessment will help to point out which uncertainties are being reported and which may need more coverage in order to achieve a more comprehensive picture upon which to base adaptation planning decisions. The methodological approach suggested is not only valuable for the assessment of the NAS of relevance to this thesis, but could also be applied to plans and strategies across different levels and in different contexts of decision-making for adaptation.

Secondly, this thesis adopts an experimental approach to test user comprehension and preferences for different types of climate visualisations/ graph formats. Such testing will enable a better understanding of how consistent and strong the associations between preference and comprehension are and how they are affected by changing graph formats. Whilst similar approaches are commonly used in the health and decision sciences, it is a novel methodological approach in the tailoring of climate information. The experimental design tested in this thesis could be applied more widely by climate service providers and boundary organisations to enable the tailoring of climate information to a variety of different users.

In addition to these methodological contributions, the thesis also offers new empirical data. Although NAS have been analysed comparatively before, previous research has not specifically focused on the communication of climate science and its inherent uncertainties communicated within them. Furthermore, this thesis provides empirical evidence from the UK and Germany of local adaptation practitioners' comprehension and preferences for different ways of visualising climate projections. Similar empirical testing of this kind has not previously been conducted with these users.

Moreover, the thesis offers an in depth empirical analysis of the actual usability of climate projections for local planning in England and Germany. Despite local government being considered a key player for the design and implementation of local adaptation solutions, the communication, tailoring, use of climate projections at that level has to date remained under-researched. The analysis of the two case studies will help to show how differing institutional contexts, and legal and planning frameworks affect the use and usability of climate projections for local adaptation planning. Thus, this thesis provides new empirical data to further the understanding of the complexity of climate information usability and adaptation decision support.

1.6 Outline and thesis structure

This thesis is divided into 5 chapters. Having outlined the overarching research context, justifications for this thesis and research strategy as well as the contribution this thesis makes to the advancement of knowledge in this first chapter, Chapters 2, 3 and 4 will present the literature reviews, detailed methodologies and research findings specific to the research objectives 1, 2 and 3 respectively. Chapter 5 will present the discussion and concluding remarks.

Chapter 2 addresses research objective 1. This chapter develops a new uncertainty assessment framework (UAF) which is subsequently applied to review how openly and transparently physical science uncertainties are communicated in European NAS. The results highlight that there are marked differences in the communication approach. In addition, the exploratory analysis of the German and English NAS show that this can be explained by the wider socio-political context within which the NAS are conceptualised and implemented.

Chapter 3 concerns research objective 2 and explores the complexities of tailoring climate projections by testing the effectiveness of climate visualisations with local adaptation practitioners in Germany and the UK. The findings show that respondents' actual comprehension is not consistently linked with their perceived comprehension or their preferences. Yet, there is a strong association between perceived comprehension and respondents' preferences for using different graph formats.

Chapter 4 corresponds to research objective 3. This chapter assesses the use and usability of climate data and projections for adaptation planning in local government in England and Germany. The results show that external institutional context - setting out the legal, regulatory and wider policy and planning framework - within which local adaptation planning takes places strongly influences the usability of climate data and projections in the local adaptation planning process.

Chapter 5 demonstrates how the respective research objectives have been met and draws together the research findings from the three results chapters to highlight the overarching implications for the question of communicating, tailoring and using climate projections for adaptation planning (Objective 4). The chapter also reflects on the research approach taken, its potential limitations as well as future research directions before setting out the contributions to the research field and providing concluding remarks.

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2. Chapter

The communication of physical science uncertainty in European National Adaptation Strategies

This chapter has been published as:

Lorenz, S., Dessai, S., Paavola, J. & Forster, P. M. 2015. The communication of physical science uncertainty in European National Adaptation Strategies. *Climatic Change*. **123** (1), pp. 143-155. (doi: 10.1007/s10584-013-0809-1) *(An extra paragraph was added to the thesis on p. 64 that is not contained in the published version of this paper.)*

Abstract

Many European countries have developed National Adaptation Strategies (NAS) to guide adaptation to the expected impacts of climate change. There is a need for more structured communication of the uncertainties related to future climate and its impacts so that adaptation actions can be planned and implemented effectively and efficiently.

We develop a novel uncertainty assessment framework for comparing approaches to the inclusion and communication of physical science uncertainty, and use it to analyse ten European NAS. The framework is based on but modifies and integrates the notion of the "cascade of uncertainties" and the NUSAP (Numeral Unit Spread Assessment Pedigree) methodology to include the overarching assessment categories of Numerical Value, Spread, Depth and Substantiation.

Our assessment indicates that there are marked differences between the NAS in terms of inclusion and communication of physical science uncertainty. We find that there is a bias towards the communication of quantitative uncertainties as opposed to qualitative uncertainties. Through the examination of the English and German NAS, we find that similar stages of development in adaptation policy planning can nevertheless result in differences in handling physical science uncertainty. We propose that the degree of transparency and openness on physical science uncertainty is linked to the wider socio-political context within which the NAS are framed. Our methodology can help raise awareness among NAS users about the explicit and embedded information on physical science uncertainty within the existing NAS and would help to design more structured uncertainty communication in new or revised NAS.

Keywords: climate change adaptation, National Adaptation Strategies, Europe, uncertainty, communication

2.1 Introduction

During the past decade, climate change adaptation has gained importance on the climate change policy agenda and since 2005 a number of European countries have published their National Adaptation Strategies (NAS). It has been recognised that due to the inertia in the climate system, Europe and the rest of the world will experience substantial climate change and related impacts even if stringent mitigation targets are set and achieved. Therefore, understanding the risks of climate change (and adaptation) and uncertainties associated with them is important.

In Europe adaptation efforts are guided by the adaptation framework (EC, 2009) developed by the European Union (EU), which aims to establish a European adaptation strategy and to encourage greater coordination and integration of adaptation across its member states. The framework encourages, but does not mandate, member states to prepare and implement their own NAS. Several studies have examined aspects of climate change adaptation in Europe (Hanger et al., 2012, Juhola and Westerhoff, 2011, Termeer et al., 2012). Studies of NAS have typically focused on their content, context of their development, their dissemination, policy integration, and monitoring and evaluation (Biesbroek et al., 2010, Swart et al., 2009). The question of how different countries deal with uncertainty within adaptation planning (Hanger et al., 2012) and the role and inclusion of scientific information and uncertainty in NAS has sometimes been addressed (Biesbroek et al., 2010), though no detailed analysis has been conducted on the inclusion and communication of physical science uncertainty and potential variations between them across countries.

Traditionally, risk communication was considered to improve understanding of the world people live in and the risks they face (Fischhoff, 1987). In the area of climate change, the risks people face, however, can be geographically and temporally removed and somewhat mismatched with necessary actions. Therefore, there is a need for scientists to provide usable information on the risks associated with climate change and its impacts to inform the decision-making process (Pidgeon, 2012). Ad-hoc communication cannot be relied on to address this high-stake problem: a more structured and organized approach is needed (Fischhoff, 2011).

There are many uncertainties related to climate change and many studies have tried to classify them (e.g. Curry and Webster, 2011, Dessai and Hulme, 2004, Stainforth et al., 2007). The communication of uncertainty is thus becoming an increasingly debated subject (e.g. Budescu et al., 2009, Fischhoff, 2007, Moser and Dilling, 2011, Rabinovich and Morton, 2012). A key finding of this research is that a 'one-size-fits-all' approach to communication does not yield a desired response. Audience-specific communication (Moser and Dilling, 2011) and an awareness of the fact that the production and processing of knowledge are deeply rooted within the practices and traditions of individual countries (Jasanoff, 2011) are needed.

A number of studies have examined the link between adaptation planning and decision-making on the one hand and uncertainty on the other hand (e.g. Dessai and van der Sluijs, 2007). This research has focused on mapping and matching theoretical methods, tools and decision frameworks on adaptation and uncertainty in the policy making sphere. That is, they have focused on the link between the two in the theoretical process of decision-making. We propose to examine empirically to what extent scientific uncertainty is considered and communicated in the outcomes of these processes, such as in the National Adaptation Strategies, by using a novel uncertainty assessment framework.

There is an increasing demand for coordinated uncertainty communication in the adaptation field (Lourenço et al., 2009). For this demand to be met, we need to gain a better understanding as to how uncertainty is currently communicated within the relevant policy contexts. However, it has to date not been studied to what extent the different European NAS consider and communicate scientific uncertainty, even though they are the most important currently existing policy documents in Europe, aiming to provide decision-relevant information for national adaptation planning. By analysing them, we can consider a central question that arises from existing research in an empirical way: Considering that substantial uncertainties do exist regarding climate change and adaptation, to what extent are they communicated transparently in the NAS? This paper presents an uncertainty assessment framework which provides a tool to compare the different levels of information disclosed on scientific uncertainty in the NAS. The insights gained from this research will be useful in both the development of NAS and will also add an extra dimension to the knowledge base for the European Adaptation strategy.

In what follows, we will first analyse how NAS communicate their scientific underpinnings. We then introduce an uncertainty assessment framework based on the integration of the notion of the "cascade of uncertainty" (e.g. Schneider, 1983, Wilby and Dessai, 2010) and a modification of the NUSAP (Numeral Unit Spread Assessment Pedigree) methodology (Funtowicz and Ravetz, 1990, van der Sluijs et al., 2005a, van der Sluijs et al., 2005b). This framework enables us to assess and compare the NAS in terms of how they include and communicate physical science uncertainty. Secondly, seen that the communication approaches are clearly distinct in the different NAS, we use the British (focusing on England) and German cases to take a first step towards exploring some of the broader policy contexts and socio-political factors that form the context and influence the development process of the NAS. This excursus is suggestive of how differences in uncertainty communication practices across countries cannot be explained by the state of the knowledge base, the stage of adaptation planning or the institutional context alone, they also relate to country-specific socio-political frameworks; a finding which opens an interesting avenue for further research.

2.2 Methodology

We employed qualitative content analysis in a systematic review of the coverage of physical science uncertainty in the NAS. Most countries plan to publish both NAS (overarching guidance document) and National Adaptation Plans (outline of specific adaptive measures and delivery responsibility). By June 2012, 14 NAS had been adopted in Europe. Of these, we have considered only those available in English. These are the NAS for: Belgium, Denmark, England, Finland, France, Germany, Hungary, Netherlands, Scotland and Wales (see Table A-1 in Appendix A.1 for more details on these NAS. The NAS of Scotland, Wales and England are considered separately because of the UK's devolved legal system). The progress and implementation of the adaptation strategy and delivery frameworks vary across countries and their strategies vary substantially in terms of their level of detail. Yet they can be considered sufficiently comparable in all important respects.

We developed a novel uncertainty assessment framework for comparing the different countries' approaches to the inclusion and communication of physical science uncertainty. The framework is based on the integration and modification of the concept of the "cascade of uncertainties" and the NUSAP methodology (see Figure 2-1 for the conceptualisation of the framework). The NUSAP method

(Funtowicz and Ravetz, 1990, van der Sluijs et al., 2005b) was originally designed to combine quantitative assessments of uncertainty (the Numeral, its Unit and the Spread) with qualitative judgements (Assessment and Pedigree). It thus allows for a systematic consideration of the different dimensions of uncertainty (van der Sluijs et al., 2005b).

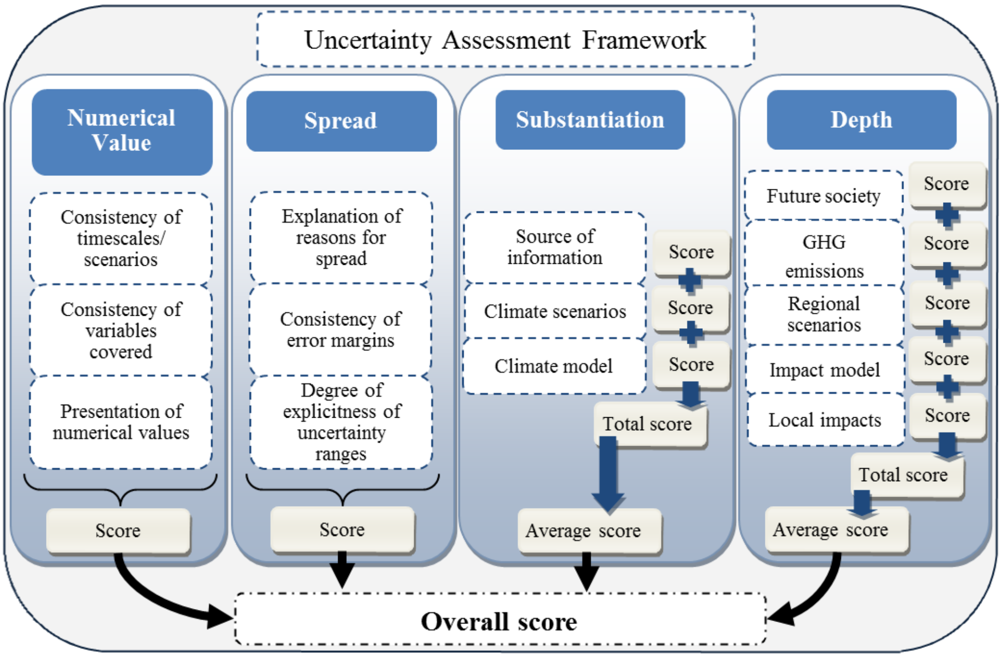

Figure 2-1 The uncertainty assessment framework

The figure conceptualises the uncertainty assessment framework, which is based on the integration and modification of the NUSAP methodology and the idea of the cascade of uncertainty.

Our uncertainty assessment framework considers Numerical values (Do strategies assign numbers to the climate projections and uncertainties they mention?), Spread (Do strategies use ranges to convey the climate information rather than one deterministic number?), Substantiation (To what extent are NAS transparent about the foundation of the science communicated within them?) and Depth (To what extent do NAS take account of the various sources of uncertainty using the outcomes from the cascade of uncertainties?). Substantiation was assessed in terms of source of information (extent of references to other information sources within NAS), climate scenario (extent and clarity of specific information on climate scenario used) and model projections (level of explicitness about which climate model was used to create projections in NAS).

In order to conduct the content analysis, all NAS were imported into the qualitative data analysis software NVivo. An a priori coding schema (Bazeley and Jackson, 2013) was developed based on the uncertainty assessment framework in Figure 2-1, with the four main categories being: Numerical Value, Spread, Substantiation and Depth. The sub-categories under these four main categories are based on the respective points of investigation shown in Figure 2-1 (e.g. the sub-categories for Spread are: source of information, climate scenario and climate model). Before this coding schema was applied to the NAS, it was discussed and validated by two experts, who were also members of the research group. When reading and analysing the NAS, a selective coding approach (Miles et al., 2014) was adopted to assign relevant parts of the NAS to the different categories in the coding schema. Once all NAS had been coded, the range of statements assigned to the different categories from across the NAS could then be compared against each other.[1]

Each category was scored to facilitate comparison as follows: 2 Points - information has been included in detail in the strategy, 1 Point - required information for a given category has been mentioned, but without further detail or explanations possibly also containing inconsistencies or lack of clarity. 0 Points - no information at all has been provided. The scores were then averaged firstly for the three criteria under Substantiation and then for all of the four main categories of the framework to generate an overall score for each NAS. Depth incorporates the concept of the cascade of uncertainty as described by Wilby and Dessai (2010) which helps to assess identified sources of uncertainties in the NAS. The uncertainties multiply as they pervade different levels of the cascade from future society, greenhouse gas (GHG) emissions, climate model, regional scenario, impact model, local impacts to adaptation responses (Wilby and Dessai, 2010). We omitted the final level in the cascade, adaptation responses, as they will be more central to the National Adaptation Plans than to the NAS.

The cascade of uncertainty draws attention to the multitude of uncertainties that affect the climate adaptation planning and delivery process. It is thus a useful tool to assess to what extent the NAS are explicit about the different uncertainties present. We used a scoring system (explained below) to facilitate the comparison

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1 This paragraph was added in the thesis, but is not included in the published version of this paper.

of NAS. Scores were given for each source of uncertainty and an average score calculated for each NAS.

2.3 Results - The inclusion or exclusion of science and uncertainty

Before analysing in detail the communication of scientific uncertainty, a number of more general observations on the communication of science in the NAS can be made. Firstly, there is a tendency to communicate physical science in the text of the NAS, rather than by using visual means such as graphs, tables or figures. Different countries communicate projections differently in text, some using numbers with or without decimal points, others using ranges rather than absolute numbers, and still others using proxy statements (e.g. number of frost days) (Finnish NAS) or not quantifying statements at all ("more mild winters and hot summers" (Dutch NAS).

Visual communication of science also varies substantially in the NAS. For instance, the NAS of Scotland explicitly explains how to understand the used probabilistic projections whereas the NAS of Germany uses graphs in a similar way as the Intergovernmental Panel on Climate Change (IPCC) does in its Assessment Reports without detailed explanation. These different choices regarding visual communication may be indicative of different expectations placed on the audience, and different contextual frameworks within which these strategies have been developed.

There are also marked differences in the coverage of uncertainty between countries. Germany and the Netherlands mention uncertainty more than the other NAS. However, the acknowledgement of uncertainty itself often does not result in the provision of further details and explanation. There seems to be a gap between the amount of information included on the science and the amount of information given on uncertainty in most NAS. This suggests that although a lot of emphasis is placed on communicating science, communication of uncertainty is considered less important. We now move to more detailed analysis of the NAS.

2.3.1 Uncertainty assessment framework

We present our qualitative comparison of the ten NAS in Table 2-1. The quantitative categories (Numerical Values and Spread) in the uncertainty assessment framework show higher scores compared to the qualitative categories (Substantiation and Depth). Furthermore, the majority of the countries have the same score across the two quantitative categories showing a predominantly consistent approach in the different countries in the quantitative representation of scientific uncertainty. The Finnish and Scottish NAS achieve the highest scores in both quantitative categories as their numerical projections are very clearly presented and the potential spread/ range in the numbers is well explained. Due to their preference for qualitative descriptors (e.g. mild winters and hot summers), the English and Dutch NAS score lowest in these categories.

Table 2-1 Qualitative assessment framework for the comparison of the coverage of science and uncertainty across the different NAS

	BEL	DEN	ENG	FIN	FRA	GER	HUN	NEL	SCO	WAL
Numerical values (NV)	NV used in main body of the text	NV used in main body of the text, detailed table on projections is included	NV only given for selective variables	NV used in main body of the text, detailed table on projections is included	NV used in main body of the text	NV used in main body of the text	NV used in main body of the text, detailed table on projections is included but assumed average global warming by 1°C is not justified	NV only given for selective variables	NV included in tables	NV used in main body of the text but are given for different timescales for temperature and precipitation
NV Score	**1**	**2**	**0**	**2**	**1**	**1**	**1**	**0**	**2**	**1**
Spread	Values with very specific uncertaint y ranges	Error margins and ranges for variables are inconsistent	No ranges are given for any values	Range of variation between the minimum and	Model outputs for two regional models	Model outputs for four regional models are visualised ->	Mean, median and standard deviation are stated but not explained	No ranges are given for any values	Central estimates and probability ranges are explicitly stated	Central estimates and probability ranges explicitly

	are used but not explained			maximum value of the different scenarios included and explained	used are visualised -> spread is visualised, confidence intervals explicit	spread is visualised for one scenario			and explained	stated for some variables but not explained where ranges come from
Spread Score	**1**	**1**	**0**	**2**	**2**	**2**	**1**	**0**	**2**	**1**
Substantiation										
Source of information (SOI)	References included in the main body of the text and reference list included at	No references included	Includes references both within the main body of the text and the footnotes	References included in relevant sections within main body of the text, sector specific reference	Very few references included in the document	References included in the main body of the text and reference list included at the end	Very few references included in the document	No references included	References included within footnotes	Very few references included in the document

	the end			list is included at the end						
SOI Score	*2*	*0*	*1*	*2*	*1*	*2*	*1*	*0*	*1*	*1*
Climate scenario (CS)	High, low and middle scenario	IPCC SRES[a] A2, SRES B2, EUC2 (European target of maximum global temperature of 2C)	No specific details on scenarios	SRES A1FI, A2, B2 and B1	SRES A2, SRES B2	IPCC SRES A2, A1B, A1 for mean temperature, A1B for more detailed projections and Germany maps	No specific details on scenarios	Four scenarios but no specifications on details	Three scenarios but only medium and high emission scenario are mentioned (based on IPCC scenarios)	Medium emission scenario (based on IPCC scenarios)
CS Score	*1*	*2*	*0*	*2*	*2*	*2*	*0*	*1*	*2*	*2*
Climate model (CM)	Global and regional, but no further	No specifications	No specifications	Multitude as different studies are used to	French regional climate models:	Global model: ECHAM5, and German	PRUDENCE	No specifications	No specifications	No specifications

	specifications			summarise projections for Finland, PRUDENCE[b]	ARPEGE-Climat and LMDZ	regional climate models: REMO, WETTREG, STAR, CRM				
CM Score	*0*	*0*	*0*	*1*	*2*	*2*	*1*	*0*	*0*	*0*
Average Substantiation Score	**1**	**1**	**0**	**2**	**2**	**2**	**1**	**0**	**1**	**1**
Depth	See Table 2 for details on the scores									
Depth Score	**1**	**0**	**1**	**2**	**1**	**2**	**0**	**0**	**0**	**0**
TOTAL SCORE	**1**	**1**	**0.25**	**2**	**1.5**	**1.75**	**0.75**	**0**	**1.25**	**0.75**

[a] SRES - Special Report on Emissions Scenarios

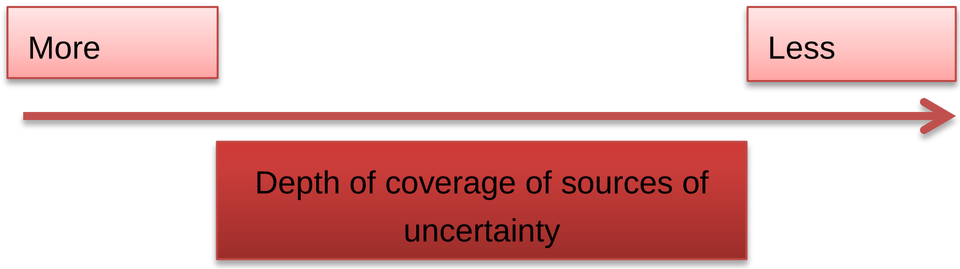
[b] PRUDENCE - Prediction of regional scenarios and uncertainties for defining European climate change risks and effects

Within the qualitative categories we notice a stark difference between the Substantiation and Depth category. The average scores for Substantiation are only marginally lower compared to the scores in the quantitative categories. Within this category, we notice that scores for Source of information and Climate scenario are highest, whereas the scores for Climate model are substantially lower. Only the German NAS achieves top scores for all three categories. All other NAS show inconsistent scores across the Substantiation categories. For the second qualitative category, Depth, we used the concept of the cascade of uncertainties to examine which sources of uncertainty are explicitly included in the NAS. Table 2-2 indicates how the six sources of uncertainty are covered in the NAS and the resultant average score is then included in Table 2-1. The NAS of Germany and Finland cover most of the sources of uncertainty but they do not do so extensively. The other eight NAS include a few sources of uncertainty at most and half of the strategies barely acknowledge uncertainty in their communication.

The most frequently mentioned sources of uncertainty are GHG emissions and climate models. This may reflect a perception that research is closer to being able to quantify uncertainty originating from these sources (e.g. Majda and Branicki, 2012, Smith et al., 2009) than it is able to do so with uncertainty originating from other sources. Many NAS do not even acknowledge regional climate projections as a potential source even though there is wide agreement that they are marked by a number of uncertainties (e.g. Foley, 2010, Stainforth et al., 2007). Furthermore, the uncertainties within the category ‘Future society’ encompass socio-economic uncertainties, demographic developments and technological advances, which are very difficult to predict (hence the use of scenarios) and yet are the main initial impetus into the cascade as they determine the level of GHG emissions upon which climate and resultant impact projections are based.

Table 2-2 The cascade of uncertainties in the NAS[a]

	GER	FIN	FRA	BEL	ENG	DEN	NEL	SCO	WAL	HUN
Future society	✓	✓✓			✓					
GHG emissions	✓✓	✓✓	✓	✓	✓		✓	✓	✓	
Climate model	✓✓	✓✓	✓	✓	✓	✓	✓			✓
Regional scenarios	✓✓	✓								
Impact model	✓		✓							
Local impacts	✓✓	✓✓		✓		✓				
Total score	10	9	3	3	3	2	2	1	1	1
Average score	**2**	**2**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**



[a] The table shows the different levels of the cascade of uncertainty and gives a qualitative assessment of the inclusion/ exclusion of each one in the different NAS. ✓✓ type of uncertainty mentioned and some more detail/explanation given (2 points), ✓ type of uncertainty mentioned (1 point), blank cells signify that the type of uncertainty was not mentioned (0 points).

The results show that most NAS have shortcomings regarding the qualitative categories of assessment and perform better in quantitative terms. That is, they include quantitative values when talking about climate projections but are not explicit about where those numbers come from. There is a lack of explicitness about the underlying future socio-economic uncertainties that will resonate throughout the cascade.

There are also marked differences between the NAS in terms of their score patterns across categories of assessment. There can be many reasons for this such as different policy frameworks and drivers, target audiences, scientific and cultural traditions, levels of knowledge and public acceptance of climate change, as well as the aim of the NAS, the stage of adaptation planning and the institutional context. We will take a first step towards exploring some of these potential influences on the communication of uncertainty within the NAS in the next section.

2.4 Discussion – Biases, inconsistencies and contrasting discourses

2.4.1 Biases and inconsistencies in the communication of uncertainty

We examined the inclusion and communication of scientific uncertainty across ten European NAS and analysed the patterns between different categories in the uncertainty assessment framework and between countries. Our framework has also revealed salient differences in the communication of uncertainty in the different countries' NAS, reinforcing the call for a much needed more systematic communication of uncertainty (Biesbroek et al., 2010, Lourenço et al., 2009). Across all countries a bias emerges towards communicating uncertainties that are perceived to be more quantifiable at the cost of communicating more qualitative uncertainties such as future socio-economic conditions. This bias however, leads to the question of how countries can justify quantifying and communicating uncertainty further down the cascade, when those at the top are barely mentioned. Not only does this mean that an incomplete picture of uncertainties is portrayed but it also skews the attention towards those uncertainties that the strategies are explicit about. This could create a false sense of certainty where this in actual fact does not exist and direct attention to those uncertainties that are potentially not the key ones to be concerned about.

A number of factors are generally considered to influence the design of NAS such as the stage of adaptation planning (Hanger et al., 2012), the institutional setting with its dominant problem framing and the aim of the NAS (Termeer et al., 2012). As the decision about the level of communication of uncertainty is part of the design of the NAS, it could be assumed that these factors can also be used to explain the differences in the communication of uncertainty in the NAS. However, when these different factors are applied to explain the differences in our findings, our empirical data does not seem to tell the expected story.

Firstly, past research explains that according to the stage of adaptation planning there are different ways of dealing with uncertainty in different countries such as hiding, or embracing uncertainties and including uncertainties in decision-making (Hanger et al., 2012). Our framework reveals that some of these different ways of dealing with uncertainty can also be seen in the different categories in the framework with the quantitative uncertainties being more 'embraced' and the 'qualitative' uncertainties being generally more 'hidden'. Hanger et al.'s (2012) research, for example, showed that British policymakers recommend that uncertainty should be embraced in the adaptation planning process. It is surprising, therefore, that the textual communication of uncertainty in the English NAS is rather limited and seems to be in contrast with a) the statements made by the policymakers in past research and b) with the adaptation planning development stage that England is at; the UK has often been framed as being amongst those countries furthest advanced in the adaptation planning process in Europe (Juhola and Westerhoff, 2011, Massey and Bergsma, 2008).

A second explanation for the lack of uncertainty communication in the NAS could be that the problem framing for climate change adaptation prevalent in the institutional setting is aimed at reducing complexity (Termeer et al., 2012). Therefore, lengthy discussions of uncertainties that cannot easily be quantified could be considered as counteracting such an intention. However, even though past research found that the institutional settings in Finland, the UK and the Netherlands are all marked by a one-dimensional problem framing attitude (Termeer et al., 2012), the Finnish on the one hand and the Dutch and English NAS on the other hand are at opposite ends of the scores from our uncertainty assessment framework.

Thirdly, we could look to the differing aims of the NAS as an explanation for the difference in uncertainty communication. These aims can vary between different countries from agenda-setting to being more of a coordinating umbrella type document (Termeer et al., 2012). The German NAS for example has been described to be one of the milestones of the agenda-setting process and as a strategy for mobilisation within the country (Stecker et al., 2012). It is thus surprising to note the open treatment of uncertainty in the German NAS. The finding that openly discussing uncertainties in policy documents results in a lack of political support and financial assistance (Termeer et al., 2012) seems to stand in contrast with the aim of mobilisation. These examples, seeming contrasts and somewhat 'surprising' results show that the differences in uncertainty communication cannot be explained in a simple, straightforward way but instead it is necessary to take a broader view at the cultural and socio-political frameworks within which the NAS are conceptualised in order to achieve a richer understanding and insight.

2.4.2 Contrasting discourses – an excursus

To gain a profound understanding of the influence of the policy frameworks and drivers, socio-political contexts, and scientific and cultural traditions on the specific characteristics of the communication of uncertainties in NAS, a systematic analysis and comparison of all countries with an NAS would be needed. We will, however, only take an exploratory look at England and Germany, as a first step towards more systematic research in this direction. We chose those two countries as though neither of them is at the extreme ends of the assessment scale, they provide us with an interesting comparison and an opening for further investigation. We chose the English NAS from the UK for further analysis and comparison with the German one.

The two countries share a number of commonalities: they have often been considered leaders in climate change adaptation in Europe (Juhola and Westerhoff, 2011), they are at the cutting edge of climate science, they show similarities in the agenda setting process of climate adaptation (Keskitalo et al., 2012, Stecker et al., 2012) and following the research set out by Hanger et al. (2012) they should be dealing with uncertainty in a similar fashion as their journeys along the adaptation planning path are at a similar point. Yet their NAS differ in terms of the style of communication and transparency of scientific uncertainty.

2.4.2.1 The German context

Germany has a strong tradition of environmental politics and a societal environmental consciousness that goes back to the 1980s (Beck, 2012, Krueck et al., 1999). Climate change started gaining political attention in 1986 when several influential scientists framed climate change as a ‘climate catastrophe’ (Beck, 2004, Krueck et al., 1999, Weingart et al., 2000). The German parliament established the Enquete Commission (a politico-scientific parliamentary enquiry) on ‘Preventative Measures to Protect the Earth’s Atmosphere’ the following year quickly succeeded by a second (Beck, 2004, Krueck et al., 1999, Weingart et al., 2000). These commissions involved a cross-section of stakeholders from industry, NGOs, the scientific community and politics (Beck, 2004).

The Enquete Commissions first embarked on fact-finding and assimilation of the scientific evidence in order to establish a consensus on the knowledge, resonating with the German consensus-oriented political culture (Beck, 2012, Krueck et al., 1999). This consensus not only legitimised the centrality of scientific expertise in the policy making process (Beck, 2012), but also stabilised and institutionalised climate change as an issue (Beck, 2012, Krueck et al., 1999). The commissions managed to avoid the politicization of climate science and achieved closure on its legitimacy early on (Beck, 2004, Krueck et al., 1999, Weingart et al., 2000). The Commissions also defined climate change as a research problem, which stresses scientific uncertainty inherent in the issue and influences the public discourse on the subject (Krueck et al., 1999). The Commissions ensured that scientific uncertainty was regarded as a dynamo for instant action rather than an excuse for inaction and controversy (Beck, 2004). This acceptance of climate science and uncertainty related to it was mirrored in the public which hardly challenged climate science (Jasanoff, 2011). The transparency and detailed treatment of uncertainty in the German NAS can thus be seen to reflect the politico-scientific tradition of accepting and understanding the inevitability of uncertainty in climate science.

2.4.2.2 The English context

Similarly to the German case, climate change came onto the agenda in the UK in the late 1980s with a speech by the then Prime Minister Margaret Thatcher to the Royal Society (Hulme and Turnpenny, 2004). By the mid-1990s the Hadley Centre had been created and two reports outlining the impacts of climate change and possible government responses had been published (Hulme and Turnpenny, 2004). The UK Climate Impacts Programme (UKCIP) was set up in 1997 and has played a leading role in adaptation nationally and internationally, inspiring others, including Germany, to follow suit (Stecker et al., 2012). Developments on the climate impacts side were followed by a report on energy and the environment in 2000 by the Royal Commission on Environmental Pollution and the National Climate Change Programme in the same year (Hulme and Turnpenny, 2004) which were followed by a Government Energy White Paper in 2003 (Owens, 2010). In 2008, the Climate Change Act came into force.

Though expert advice through the Royal Commission on Environmental Pollution, UKCIP, the Hadley Centre and as of 2008 the Committee on Climate Change has clearly influenced the policy making process, it remains unclear whether expert advice alone inspired the UK government action on climate change. Geopolitical factors and a desire to distance the UK from the US in climate policy have also been said to have played an important role (Owens, 2010). Furthermore, although the UK was the first country to make action on climate change legally binding, political consensus on what to do about climate change in the UK remains elusive (Carter, 2008). Austerity measures taken during the economic crisis have also had a significant effect on the environmental and climate change agenda in which party politics bind for public support (Carter, 2008).

In many respects, the UK is leading the way with the probabilistic UKCP09 climate scenarios and the boundary work that is taking place at the science-policy interface through the UKCIP led stakeholder engagement (Tompkins et al., 2010). It thus seems surprising that the NAS does not seem to sufficiently reflect the richness of the available knowledge. While the UK is at the forefront of ground breaking climate research, cultural preferences continue to reside with trusting empirical observations opposed to conceptual models (Jasanoff, 2011). Scientists – with some exceptions (e.g. Pall et al., 2011) – and the UK media are often reluctant to link specific weather events to climate change (Gavin et al., 2011). Thus the majority of people do not think that there is empirical evidence of climate change and its impacts (Clements, 2012). In contrast, the German parliament and the German media have been explicit in making a link between extreme events and climate change (Stecker et al., 2012, Weingart et al., 2000). Although the scientific knowledge base on climate change has been importantly formed by UK scientists, model projections and associated uncertainties may not sit comfortably with a tradition of evidence-based policy making, and thus do not find a place in the English NAS but instead are left behind in the boundary space, where they can be further explored but are not in the limelight of the policy context.

2.4.3 What do these two cases tell us?

The two case studies are suggestive of the broader socio-political context within which the NAS have developed and are nested. They seem to propose that the traditions of environmental policy, the level of societal and political consensus on the credibility and salience of scientific knowledge on climate change and its associated uncertainties and the actions required, and the extent of politicization of climate change affect the openness and transparency of NAS regarding scientific uncertainties. Dominant framings of climate change (de Boer et al., 2010), different governance regimes (Rothstein et al., 2012), different civic epistemologies

(Jasanoff, 2011), and different risk management cultures also underpin differences in NAS.

What is, and importantly what is not, included with regard to information on uncertainties in the adaptation planning process is interesting and reflective of wider cultural traditions. Other factors such as the susceptibility to change, or the perceived role of the state in risk management, are also arguably important and point to the need for further research.

Both case studies point to the different styles for communicating uncertainty in England and Germany. While exploratory in nature, they do highlight:

a) similar adaptation development stages between countries do not necessarily result in similar communication approaches,

b) even if policymakers support the 'embracing' of uncertainties this does not mean that these are communicated comprehensively in the NAS and

c) the NAS may serve different functions and different audiences which will affect the level of communication of scientific uncertainty within them.

2.5 Conclusion

Our analysis has shown that there are marked differences between and within European NAS regarding the level of detail they provide on climate science and uncertainty related to it. This shows that even though these documents are defined as the same type of policy-document, different countries have very different takes on what should and should not be communicated within their NAS. This selective communication of uncertainty however, does not paint a complete picture of the actual knowledge base and could potentially create a false sense of certainty.

It can be argued that the NAS fulfil different aims and may thus differ in the level of detail and the transparency on scientific uncertainty. However, seen that the process through which the NAS are developed often happens 'behind closed doors' (Termeer et al., 2012: 9), it may be difficult to reconstruct which assumptions have been made and which uncertainties taken into account if these are not openly communicated.

European countries have called for 'structured communication about […] uncertainties […] to correctly develop adaptation actions' (Lourenço et al., 2009: 15). We suggest that a starting point for achieving this may be to encourage a more systematic acknowledgment and communication of uncertainties for which the uncertainty assessment framework can be used. It proved clearly useful for the classification of the different types and aspects of uncertainties communicated and provided a valuable structure against which the different NAS could be compared. The framework could help raise awareness among research users about explicit and embedded information on scientific uncertainty within documents.

By its very nature this methodology does not take into account the foundations on and the contexts within which these NAS have been developed, the available knowledge or the perception or status quo of uncertainty within adaptation decision-making in these countries; nuances which could be achieved through more in-depth research. However, what this methodology enables is to use it as a diagnostic tool to highlight that the communication of scientific uncertainty is not just contingent on the stage of adaptation planning, the aim of the NAS or the institutional context within the different countries. Instead, there are most likely broader socio-political factors that were touched upon briefly in the two exploratory case studies that also affect how countries communicate scientific uncertainty differently.

To achieve more structured uncertainty communication it is thus not only necessary to encourage greater consistency in the acknowledgement of uncertainties for which the uncertainty assessment framework may be useful, but to compliment this with more systematic research into the impact of the broader national socio-political frameworks on this communication. This complimentary approach may help to overcome the dichotomy between the demand for more structured uncertainty communication across Europe and the realisation that different politico-scientific cultures and traditions may make it difficult to design a single European one-size-fits-all approach for communication (Beck, 2012).

Acknowledgments This research has been conducted with funding from the UK Natural Environment Research Council (NERC). Suraje Dessai is supported by the UK Natural Environment Research Council (NE/H003509/1) and the European Research Council under the European Union's Seventh Framework Programme (FP7/2007 2013)/ERC Grant agreement no. 284369. Jouni Paavola acknowledges the support of the UK Economic and Social Research Council (ESRC) for the Centre for Climate Change Economics and Policy (CCCEP).We would also like to thank James Porter and the two anonymous reviewers for their helpful comments and suggestions.

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3. Chapter

Tailoring the visual communication of climate projections for local adaptation practitioners in Germany and the UK

This chapter has been accepted for publication as:

Lorenz, S., Dessai, S., Paavola, J. & Forster, P. M. 2015. Tailoring the visual communication of climate projections for local adaptation practitioners in Germany and the UK. *Philosophical Transactions A*. **373** (2055), pp. 1-17. (doi: 10.1098/rsta.2014.0457) *(An extra paragraph was added to the thesis on pp. 94-95 that is not contained in the published version of this paper.)*

Abstract

Visualisations are widely used in the communication of climate projections. However their effectiveness has rarely been assessed amongst their target audience. Given recent calls to increase the usability of climate information through the tailoring of climate projections, it is imperative to assess the effectiveness of different visualisations.

This paper explores the complexities of tailoring through an online survey conducted with 162 local adaptation practitioners in Germany and the UK. The survey examined respondents' assessed and perceived comprehension of visual representations of climate projections as well as preferences for using different visualisations in communicating and planning for a changing climate. Comprehension and use are tested using four different graph formats, which are split into two pairs. Within each pair the information content is the same but is visualised differently.

We show that even within a fairly homogenous user group, such as local adaptation practitioners, there are clear differences in respondents' comprehension of and preference for visualisations. We do not find a consistent association between assessed comprehension and perceived comprehension or use within the two pairs of visualisations that we analysed. There is, however, a clear link between perceived comprehension and use of graph format. This suggests that respondents use what they think they understand the best, rather than what they actually understand the best. These findings highlight that audience-specific targeted communication may be more complex and challenging than previously recognised.

Keywords: Climate change adaptation, climate projections, visualisation, communication, decision-making, local government

3.1 Introduction

Adaptation to climate change is inevitable (Moss et al., 2013). Climate projections - 'simulated response[s] of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols' (Planton, 2013: 1256) - are often used in scientific analysis and risk assessments to help decision-makers understand the risks posed by climate change and plan accordingly. This preparation for climate risks can also be described as planned adaptation to climate change, which is considered to be 'the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change' (Füssel, 2007). If maladaptation is to be avoided and decision-making made effective, then climate projections and information need to be usable by those people in the private and public sphere who have to practically prepare and plan for the impacts of a changing climate, namely adaptation practitioners. Borrowing from Lehmann et al. (2015: 80) we define adaptation practitioners as 'decision-makers in the field of planned climate adaptation'. Specifically, in our research, we study adaptation practitioners within local government in Germany and the UK.

Climate projections are often communicated visually; the change of temperature over time for example is most often displayed in the form of a line graph, whereas bar charts are usually used to show precipitation amounts. With graphic representation of climate data being a key means of communicating these data, it is important to examine the usability of visualisations closely. Some research has already been conducted on the role of climate visualisations in the fields of climate change (van der Linden et al., 2014), impacts (MacLeod and Morse, 2014), modelling and projections (Kaye et al., 2012), and adaptation and decision-making (Sheppard et al., 2011, Wong-Parodi et al., 2014). Moreover, lessons can also be learnt from research on visualisation of risk and other information in the health and cognitive sciences (Ancker et al., 2006, Elting et al., 1999, Parrott et al., 2005), environmental hazards and geosciences (Bostrom et al., 2008, Broad et al., 2007, Gahegan, 1999), risk (Hess et al., 2011, Ibrekk and Morgan, 1987), design (Quispel and Maes, 2014), computing (Kelleher and Wagener, 2011, Sanyal et al., 2009), and hydrology (Gimesi, 2009, Pappenberger et al., 2013). Nevertheless, the lack of empirical work on visual communication is acknowledged and more research on visualisation of uncertainty has been called for (Bostrom et al., 2008, Broad et al., 2007, Spiegelhalter et al., 2011).

The existing literature suggests that visualisations and communication ought to support user needs (Bostrom et al., 2008) and be tailored to the target audience (Nicholson-Cole, 2005, Spiegelhalter et al., 2011). Tailoring has been suggested as one way to bridge the usability gap, that is the gap between the information produced by users and the information considered as usable by users (Lemos et al., 2012). Usability is understood as the combined 'perception of usefulness and the actual capacity (…) to use different kinds of information' (Dilling and Lemos, 2011: 681). The concept of tailoring of visualisations thus speaks to the understanding that different audiences have different perceptions, capacities and characteristics, which will impact their interpretation of a visualisation (Nicholson-Cole, 2005). Tailoring therefore aims to better understand these audience specific aspects and customise or individualise visualisations accordingly to increase their effectiveness (Hawkins et al., 2008). As to climate information, aspects that might be tailored specifically to audience needs could include, but are not limited to, the content of the visualisation (e.g. showing mean temperature rise or showing maximum temperature rise), hue and saturation of colour (Kaye et al., 2012), the inclusion of relevant past experiences for comparison (such as the mean temperature of the 2003 summer when talking about temperature projections) (Schar et al., 2004) or the type of graph format (such as using a thermometer to show temperature rise, rather than a line graph) (Karl, 2009).

For the effectiveness of visualisations to be increased, Stephens et al. (2012) in their review of the communication of climate model ensembles, found that it is important to consider the balance between richness (the amount of data represented), robustness (the representation of scientific confidence and consensus) and saliency (the relevance of the information to user needs) in a visualisation. It has been put forward that the more detailed assessment of such user needs, also termed as 'strategic listening', can be achieved with help from the decision sciences (Pidgeon and Fischhoff, 2011).

Ultimately, a more scientific approach to the communication of science is called for (Pidgeon and Fischhoff, 2011), which necessitates more and better evaluated case study research, particularly focusing on both the preferences and the understanding of visualisations (Spiegelhalter et al., 2011). At the same time, it has been highlighted that, while understanding user preference is important, there is a need to ensure that choice of visualisation based on preference alone does not lead to misunderstanding (Pappenberger et al., 2013), but enables the user to make 'better informed' decisions. Consequently, Pappenberger et al. (2013) call for more research on how varying both the information content and different graph formats impacts on user comprehension. Assessing user comprehension and preferences is a complex undertaking due to discrepancies between subjective and objective knowledge of an issue (Stoutenborough and Vedlitz, 2014), both being influenced by a variety of different cognitive and attitudinal measures (Stoutenborough and Vedlitz, 2014, van der Linden, 2015). Being aware of the distinction between the different types of knowledge or comprehension may thus help to get a better understanding of the potential inconsistencies between preferences and comprehension, found in previous studies (Ancker et al., 2006, Elting et al., 1999, Parrott et al., 2005). Consequently, an increased understanding of both user preferences and comprehension will support better tailoring of climate information, which ultimately will make this information more usable (Lemos et al., 2012, Moser, 2014).

Considering these complexities, is it really feasible to produce tailored visual climate information in practice? This paper examines this question by conducting an empirical experiment with local adaptation practitioners in Germany and the UK on the usability of visualisations of climate projections. Local adaptation practitioners are an under-researched group of users of climate information (Demeritt and Langdon, 2004, Porter et al., 2014), despite being recognised as playing an important role in addressing the challenges posed by climate change (de Oliveira, 2009, Pearce and Cooper, 2011). We explored local adaptation practitioners' understanding of and preferences for different visualisations of climate projections. Our aim is not to find one 'ideal' visualisation, but rather to highlight the complexities involved in tailoring and improving the usability of climate information.

3.2 Methodology

An online survey was developed to explore how local adaptation practitioners in Germany and the UK interpret visual representations (hereafter referred to as graph formats) of climate projections. The survey design, despite asking hypothetical questions, allowed us to collect empirical data that will nevertheless be reflective of decision and communication scenarios for adaptation practitioners. Both countries are considered to be amongst the leaders of climate change adaptation in Europe (Bauer et al., 2012, Juhola and Westerhoff, 2011), but exhibit differences in terms of the extent to which adaptation has become a discrete policy field (Massey et al., 2014) and in terms of how scientific uncertainty is communicated in national adaptation strategies (Lorenz et al., 2015). Owing to the context-specific nature of climate information for decision-making, tailoring and usability will have to be examined at a more local scale. Keeping in mind the national differences between the two countries, we explore differences and similarities in the comprehension of and preference for information provision at the local level that can help to inform the tailoring of climate information and its visualisations.

The aim of the survey was to better understand both participants' comprehension of and their preferences for different graph formats in planning, decision-making and communicating adaptation in their organisations. We purposefully sampled employees in local government who work on environmental policy, climate change, sustainability or adaptation. Participants were recruited through direct email, advertisements in newsletters and web portals, and through networks of relevant organisations such as the UK Climate Impacts Programme, the local government Association Climate Local Online Forum and the Klimaplattform. All participants completed the same questions and were not randomised. The survey was administered in German and English, and was translated by the lead researcher, to ensure consistency of the questions. Responses were collected between March – July 2013 in the UK (n = 99) and between October 2013 – February 2014 in Germany (n = 63). Individuals entering the survey were not offered any incentives or monetary rewards in return for their participation.

3.2.1 Development of different visualisations (graph formats)

Four graph formats were developed to visualise the output of 14 General Circulation Models (GCMs) from the fifth phase of the Climate Model Intercomparison Project (CMIP5). The graph formats used in the two countries were based on output values for the grid cell around Newcastle, UK, in order to expose the participants from both countries to the same climate information. The choice of the grid cell is irrelevant for the experiment, as the purpose was only to extract data from the climate models for a given location. Of the four graph formats used (Figure 3-1), two can be considered 'traditional' (linear scatter plot and histogram) and the other two 'alternative' (pictograph and bubble plot). We split these graph formats into two pairs, each containing one traditional and one alternative graph format showing the same information content within each pair, but with information content between pairs being different. Both pairs, however, utilised the same underlying data.

- **Pair 1:** The scatter plot and the pictograph show the change in mean summer temperature for the 2050s (2040 - 2069) under the Representative Concentration Pathway 6.0 (Moss et al., 2010), a medium greenhouse gas concentration trajectory, relative to a historical baseline period (1975 – 2004). The plots thus show 30 year seasonal mean changes for each of the 14 GCMs.

- **Pair 2:** The histogram and the bubble plot show the frequency for ranges of change in summer temperature for the 2050s (2040 - 2069) under the Representative Concentration Pathway 6.0 (Moss et al., 2010), a medium greenhouse gas concentration trajectory, relative to a historical baseline period (1975 – 2004). The plots are based on annual summer changes for each of the 30 years for each of the 14 GCMs.

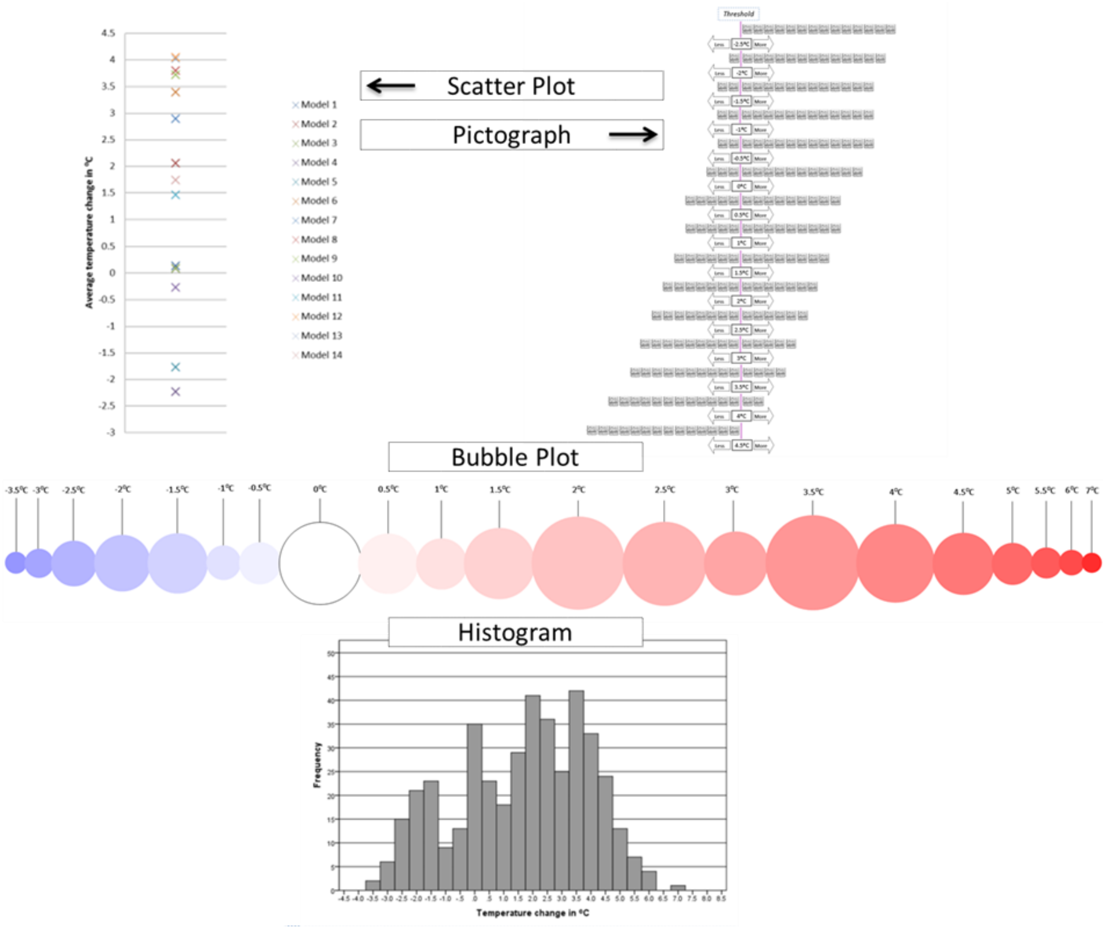

Figure 3-1 Overview of the four graph formats

The four graph formats that were used in the survey. Each one of them also contained a figure caption explaining the data and the concept of the figure. (Full-sized figures can be found in Appendix B.1.)

3.2.2 Experimental procedure

To begin with, the survey participants were given a brief introduction to the survey and the aims of the research project, including information on confidentiality and informed consent. The climate data visualised in the survey were briefly explained and, although exactly the same data and graph formats were shown in both surveys, the English survey stated that the values were for a location in northeast England, whereas the German participants were informed that it was for a location in northeast Germany. This was done to ensure that the participants from both countries felt that the data shown would be relevant to their national contexts.

3.2.3 Criterion assessment

The aim of this analysis was to assess four key criteria within the two pairs: assessed and perceived comprehension (PC); use by self and use for showing to others, further explained below.

3.2.3.1 Assessed and perceived comprehension

Respondents were shown the four graphs in the following order: 1) scatter plot, 2) histogram, 3) pictograph, and 4) bubble plot. Respondents were not informed that the information content shown within pairs was the same and we deliberately showed the figures in this order so that respondents would alternate between pairs and the different information content and questions, so that practice effects could be kept to a minimum. Respondents were asked to answer the following multiple choice questions about the graph formats.

Pair 1: scatter plot and pictograph

- How many models project a decrease in summer temperature?
- How many models project an increase in summer temperature by more than 3.0°C?
- None of the models project a temperature change above which temperature value (to the nearest half of a degree)?

Pair 2: histogram and bubble plot

- Which is the most likely temperature change projected by the models?
- What is the range of projected temperature change in the figure?
- Which value is more likely, -2.5°C or 5.0°C?
- Are you more likely to get a temperature change below -2.5°C or above 5.0°C?

Every response was coded '0' for incorrect and '1' for correct answers. An assessed comprehension score (ACS) was created by calculating the mean of the coded answers for each respondent for each figure. To assess perceived comprehension (PC), respondents were asked 'Which figure did you find the easiest to understand?', with the option of choosing any one of the four formats.

3.2.3.2 Use by self and use for showing to others

Local adaptation practitioners not only consume climate information for their own use and planning, but also communicate it further to colleagues, managers or elected representatives. Therefore, we assessed the preferences for the use of graph formats that is both inward-facing (use by self) and outward-facing (use for showing to others). Use by self relates to individual decision-making. Preferences and perceived usability of graph formats for use by self were assessed by asking 'If you had to make a planning decision, which of these figures would you find most helpful for your decision-making process?' Respondents could choose one of the four graph formats or 'Depends on the decision' or 'None of the above'. Preferences for use for showing to others were assessed by the question 'If you had to persuade someone in your organisation (e.g. your colleagues or your boss) of the necessity to start planning for changes in future summer temperatures, which one of these figures would you choose?' Respondents could choose one of the four graph formats or 'I wouldn't use a figure at all'. Perceived comprehension, use by self and use for showing to others were recoded into a binary variable (1 = selected, 0 = not selected) for each of the four graph types. These binary variables were subsequently used in the Spearman's rank order correlation tests described in Section 3 (b). The survey also collected qualitative data, as respondents had the opportunity to leave further explanations of their choices in comments boxes for the questions on perceived comprehension, use by self and use for showing to others.

3.2.4 Other sample characteristics and sample description

Table 3-1 gives an overview of the other sample characteristics for the two samples. The UK sample is somewhat younger than the German sample and thus has a higher percentage of respondents with fewer years of relevant work experience, but in the main the two samples are comparable.

Table 3-1 Sample description

		UK sample (n = 99)	German sample (n = 63)
gender	female	40.4%	42.9%
	male	59.6%	57.1%
age groups	20-29 years	13.1%	3.2%,
	30-39 years	36.4%	22.2%,
	40-49 years	30.3%	27.0%
	50-59 years	16.2%	39.7%
	60 and over	4.0%	7.9%
education	degree or higher academic qualification	92.9%	100%
	no degree or higher academic qualification	7.1%	
work experience in a related job	0-5 years	17.2%	15.9%
	6 – 10 years	32.3%	17.5%
	11 – 15 years	20.2%	14.3%
	16 – 20 years	9.1%	3.2%
	21 – 25 years	7.1%	25.4%
	26 – 30 years	5.1%	15.9%
	31 – 35 years	4.0%	4.8%
	36-40 years	5.1%	3.2%
colour blind		2%	0%

Three measures around self-assessed knowledge and experience were included: 1) level of engagement with climate projections (‘How much do you engage with climate projections in your day-to-day job?), 2) involvement in adaptation in work within the organisation (‘Have you been actively involved in the climate change adaptation process in your organisation?’), and 3) climate change knowledge (‘How good is your knowledge of the topic of climate change?’). These three measures were assessed on a 6 point Likert scale with 1 being the least favourable and 6 being the most favourable option. As the survey also collected data using the subjective numeracy scale developed by Fagerlin et al. (2007), which measures individual scale items on a 6 point Likert scale, it was decided to use the same scale for all of the measures in the survey to ensure consistency.

We did not find any systematic effects of socio-demographics, self-assessed knowledge and experience or subjective numeracy on comprehension or use that were consistent across both country samples. Further details on these results can be found in Appendix B.3.

3.3 Results

Following the production of descriptive statistics for the four key criteria and the other sample characteristics, it was decided to use non-parametric statistical analysis as the assessed comprehension scores (ACSs) for the graph formats were not normally distributed (Pallant, 2010).

3.3.1 Outcome description

We hypothesised at the outset that the four key criteria would be associated with each other.

The specific hypotheses (H_1 – H_6) we stipulated at the outset were:

- **H_1**: Within each visualisation pair, the figure respondents choose as easiest to understand (*perceived comprehension*) will be the one they achieve the highest *assessed comprehension* score on.
- **H_2**: Within each visualisation pair, the figure respondents choose as most helpful for making a planning decision (*use by self*) will be the one they achieve the highest *assessed comprehension* score on.
- **H_3**: Within each visualisation pair, the figure respondents choose to persuade another person in their organisation to plan to adapt (*use for*

showing to others) will be the one they achieve the highest *assessed comprehension* score on.

- **H_4**: The figure respondents deem to be the easiest to understand (*perceived comprehension*) will be the one they choose as most helpful for making a planning decision (*use by self*).
- **H_5**: The figure respondents deem to be the easiest to understand (*perceived comprehension*) will be the one they choose to persuade another person in their organisation to plan to adapt (*use for showing to others*).
- **H_6**: The figure respondents choose as most helpful for making a planning decision (*use by self*) will be the same as the one they choose to persuade another person in their organisation to plan to adapt (*use for showing to others*).[1]

Figure 3-2 illustrates these hypothesised associations between assessed (A) and perceived comprehension (B) and use by self (C) and use for showing to others (D). Below we assess each criterion separately, followed by the relationships between them.

[1] This paragraph was added in the thesis, but is not included in the published version of this paper.

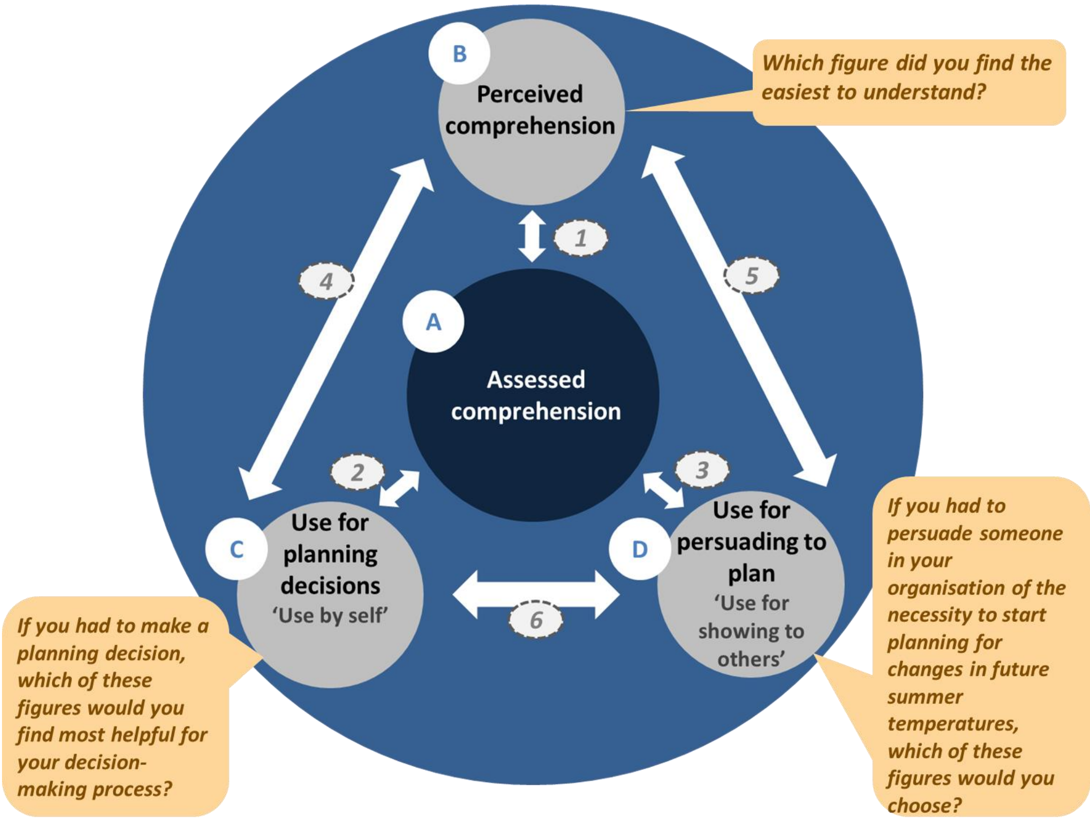

Figure 3-2 Overview of the four key criteria

The four key criteria are denoted by capital letters: assessed comprehension (A); perceived comprehension (B); use for planning decisions – use by self (C); and use for persuading to plan – use for showing to others (D). The associations are represented with the numbered arrows (1-6).

3.3.1.1 Assessed comprehension (A)

Table 3-2 summarises the mean ACS and standard deviation for each graph format in the two countries, as well as comparisons of the two samples. Whilst the UK respondents achieved statistically significantly higher ACSs on the scatter plot, histogram and bubble plot than German respondents, they achieve a significantly lower ACS on the pictograph. Such a marked difference between assessed comprehension of the two samples for each of the four graph formats is interesting to note, especially given the similarity of the two country samples highlighted in Table 3-1.

Examining the ACSs within each pair of visualisations in more detail using the Wilcoxon signed rank test, we notice a statistically significant drop of the ACS in pair 1 by .39 from the scatter plot to the pictograph in the UK sample ($z = -7.36$, $p < .0001$, $r = .52$). This is .31 more than in the German sample, where the ACSs on both the scatter plot and the pictograph do not differ significantly. In the second pair, the ACSs on both the histogram and the bubble plot do not differ significantly in either sample. We thus note that, within both pairs in the German sample, graph format did not affect assessed comprehension. Interestingly for the UK sample, this only holds true for pair 2 but not for pair 1, where the pictograph's low ACS is noteworthy. This could be explained by 'bad design' affecting respondents' ACS. In a study by Daron et al. it was found that a similar graph format to the pictograph utilising the exceedance of thresholds, was also the least preferred by respondents (2015). However, this may only be a partial explanation, as we do not observe the same significant difference across both country samples. It may thus be that respondents in the UK might have been less willing to engage with something new or different, and therefore may have spent less time on trying to understand the graph format resulting in a lower ACS. The findings suggest that showing respondents different graph formats might not make much of a difference, unless the graph formats widely differ from what respondents are used to. In that case, assessed comprehension seems to be lower.

Table 3-2 ACSs for all graph formats

		UK			Germany			ACS compared across both countries		
		mean	s.d.	median	mean	s.d.	median	U	z	r
pair 1	**scatter plot**	0.88	0.17	1	0.70	0.23	0.67	***1761	-5.23	0.41
	pictograph	0.49	0.29	0.33	0.62	0.32	0.67	**2391	-2.63	0.21
pair 2	**histogram**	0.90	0.16	1	0.79	0.24	0.75	**2298	-3.21	0.25
	bubble plot	0.88	0.15	1	0.80	0.22	0.75	*2494.5	-2.39	0.19

Note: For the mean ACS higher values reflect better comprehension of the graph format; ACS was compared between countries with the Mann Whitney U test, with entries in the three columns headed U, z and r providing the detailed test statistics; * $p < .05$; ** $p < .01$; *** $p < .001$

3.3.1.2 Perceived comprehension (B), use by self (C) and use for showing to others (D)

When examining the relationship between the original uncoded variables with the Chi Square test for independence, we do not find any statistically significant difference between the UK and German respondents in PC ($\chi2$ (3, n = 162) = 4.08, p = .25, Cramer's V = .16), use by self ($\chi2$ (5, n = 162) = 8.59, p = .13, Cramer's V = .23), or use for showing to others ($\chi2$ (4, n = 162) = 2.51, p = .64, Cramer's V = .13). Respondents' dichotomized choices of graph formats (selected or not selected) for all three variables have been summarised in the first data column in Table 3-3. The qualitative explanations given by the respondents suggest that the three key reasons for the popularity of the histogram, in order of popularity, are: familiarity with the graph format, perceived clarity of display (also found to be important in Daron et al. (2015) and perceived ease of readability of frequencies. Some of this preference for the histogram may also be explained by the 'frequency format hypothesis', which stipulates that humans have evolved to find frequency distributions naturally easier to interpret (Gigerenzer, 1998). However, not only has the explanatory power of this hypothesis been recently questioned (Sirota et al., 2014), but we would also like to highlight that it may be that respondents simply perceived the other graph formats as less effective than the histogram due to their design. For use for showing to others the bubble plot is the second most popular format. Its higher ranking for use for showing to others compared to use by self could be explained by the view of local adaptation practitioners that they have to do some persuading and convincing to increase buy-in for adaptation actions. Qualitative survey responses suggest that the bubble plot is considered to be more visually persuasive and a good 'initial hook' for discussions.

3.4 Differences in assessed comprehension across perceived comprehension and use (1, 2 & 3)

Having provided a brief overview of the four criteria, the following analysis will focus on the extent of association between these criteria. We conducted Spearman's rank order correlation tests to examine the strength of the association between the ACS on each of the graph formats and respondents' preferences to select or not select the respective graph format for perceived comprehension (1), use by self (2) or use for showing to others (3). The results of the tests are summarised in Table 3-3.

Table 3-3 Correlations of ACS for each graph type across PC, use by self and use for showing to others

				UK					Germany				
				choice	pair 1		pair 2		choice	pair 1		pair 2	
					S	P	H	B		S	P	H	B
				PC - ACS									
PC (1)	pair 1	S	yes	21.2	.11				34.9	-.07			
			no	78.8					65.1				
		P	yes	6.1		.17			3.2		-.03		
			no	93.9					96.8				
	pair 2	H	yes	**54.5^**			.09		**47.6^**			-.07	
			no	45.5					52.4				
		B	yes	18.2				.02	14.3				.11
			no	81.8					85.7				
				use by self - ACS									
use by self (2)	pair 1	S	yes	13.1	-.10				17.5	.05			
			no	86.9					82.5				

Note: The percentage of respondents choosing the respective graph type for each of the criteria (PC, use by self and use for showing to others) is given in the first data column. The strength of the relationship between whether the respondents selected (‘Yes’) or didn’t select (‘No’) the respective figure is then expressed through the Spearman correlation coefficient rho; * $p < .05$ ** $p < .01$ *** $p < .001$; ^ most preferred graph format; S= Scatter Plot; P = Pictograph; H = Histogram; B = Bubble Plot; N/A = cannot be computed as the Pictograph was not chosen by any respondent for use by self

	pair 2	P	yes	5.1	.19	0	N/A
			no	94.9		100	
		H	yes	**52.5^**	.10	**42.9^**	**-.26***
			no	47.5		57.1	
		B	yes	3	-.08	11.1	.02
			no	97		88.9	
				use for showing to others - use by self			
use for showing to others (3)	pair 1	S	yes	9.1	-.07	11.1	-.13
			no	90.9		88.9	
	pair 2	P	yes	2	.11	3.2	-.09
			no	98		96.8	
		H	yes	**48.5^**	.16	**52.4^**	-.02
			no	51.5		47.6	
		B	yes	24.2	.15	25.4	.10
			no	75.8		74.6	

We note that there is no consistent association between ACS and the other criteria for the graph formats within either pair. Only one of the associations of the 23 tested is statistically significant ($p = .04$), but, as this association has been observed in isolation, it should be treated with caution due to the potential risk of a Type I error in this case. The fact that we did not find consistent associations is interesting, given our initial hypothesis that the ACS would be associated with the other criteria. If respondents were better judges of their actual understanding of a graph format, we would have expected this to be at least reflected in higher correlation coefficients and more significant associations for the relationship between assessed and perceived comprehension. It is possible that other factors influence the association between assessed comprehension and use, such as the type of planning decision at hand or the prior knowledge and experience of the respective colleague(s) in question for use for showing to others. These factors may guide choice more than just assessed comprehension, but are more difficult to capture due to varying decision and communication contexts. We will return to this question in more detail in the discussion.

3.4.1 Relationship between perceived comprehension, use by self and use for showing to others (4, 5 & 6)

Our investigation into the relationship between PC, use by self and use for showing to others found a consistently strong link between each of them in both the UK and the German samples; see Table 3-4 for details.

Table 3-4 Relationship between PC, use by self and use for showing to others

		$\chi 2$
PC – use by self	UK	94.31***
	Germany	46.74***
PC – use for showing to others	UK	51.73***
	Germany	37.37***
use by self – use for showing to others	UK	68.89***
	Germany	39.65**

Note: Entries are the Pearson's Chi Square values; ** $p < .01$; *** $p < .001$

Furthermore, we note that, in the German sample, for the scatter plot, the histogram and the bubble plot the majority of the respective respondents picked the same figures both as easiest to understand (PC) and as appropriate for use by self. In the UK sample, we observed the same for the histogram and the pictograph; however, the majority of those who picked the scatter plot as easiest to understand (PC) would still pick the histogram for planning (use by self). In both samples, we found that the majority of respondents who picked the histogram or the bubble plot as the easiest to understand (PC) also picked it as the most persuasive when showing it to someone else. On the other hand, many of those who chose the scatter plot as the easiest to understand (PC) still picked the histogram for persuasion (use for showing to others). Lastly, we found that respondents' choice of graph formats for use by self and use for showing to others was consistent. For this we see the strongest link for the histogram and the bubble plot in both samples.

What these results point towards is that, while perceived comprehension and use are strongly associated and respondents' preferences are thus consistent, the lack of association of the three preference measures with assessed comprehension across both pairs appears to separate respondents' subjective preferences from actual comprehension. This seems to indicate that respondents tend to use what they think they understand best, rather than what they actually understand best.

3.5 Discussion

The aim of this paper was to explore empirically the differences and similarities in the comprehension of and preference for different forms of visualisation amongst adaptation practitioners in the UK and Germany. Our findings within both pairs of graph formats suggest that in both countries there is a disconnect between users' assessed comprehension and subjective preference. However, there is a strong link between people's perceived comprehension and their preferences for graph formats they use themselves and for communicating with colleagues and superiors about the necessity to take action on adaptation (see Fig 3-3). As we have observed the same associations and lack thereof across both pairs of graph formats, showing different information content, these observations seem to suggest that this is likely to be an issue encountered with visual communication of climate information more widely.

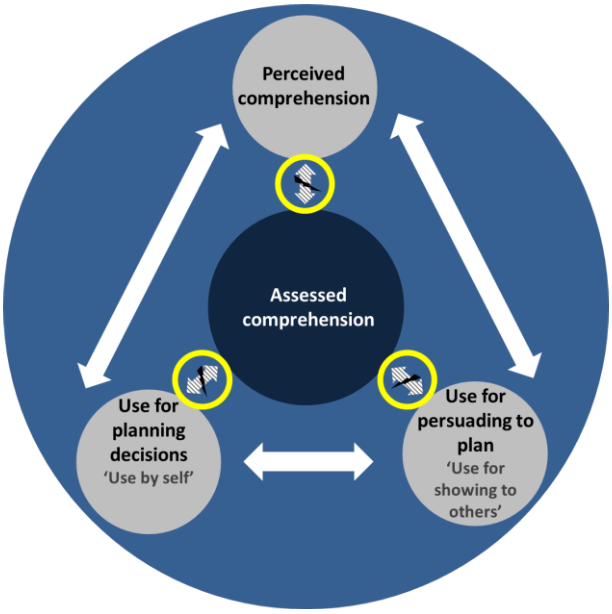

Figure 3-3 Associations between the four key criteria

This figure shows on the one hand, the disconnect between users' assessed comprehension and the other three key criteria, and, on the other hand, the strong relationship between perceived comprehension and use by self and use for showing to others.

Our findings regarding the gap between comprehension and preference resonate with the results reported in the health sciences literature. Parrott et al. (2005) found that people's reading of familiar graph formats is affected by learned heuristics: respondents' familiarity plays a bigger role in the process of reading and sense-making of graphs than the actual comprehension of the information shown. They argue that this could lead to a disconnect not only between the encoded and decoded meaning of the graph but also in respondents stating preferences for graphs that they do not understand as well as other graphs (Parrott et al., 2005). Our results also resonate with findings of a study of physicians' assessment of visually displayed information, in which respondents' preferences for graph formats and displays appeared to be based on familiarity with the graph formats rather than on their comprehension (Elting et al., 1999). Qualitative explanations in our surveys suggested this as well. The disconnect supports Ancker et al.'s (2006) argument that, although it is important to focus on the preferences of information recipients, this may result in poor quantitative judgements. There is a complex interplay between respondents' comprehension and preferences for use of visualisations in practice, and cognitive biases are involved in it. We need to be aware of them and consider how they could be dealt with or overcome if we are to make visual communication of climate projections more effective.

We note that the biases in information provision and use are consistent across the two samples. This is interesting considering the differences in relation to adaptation at the national level between the two countries (Lorenz et al., 2015, Massey et al., 2014). This is not to say that local adaptation practitioners are a homogenous group and that advice for tailoring is generalizable. On the contrary, the findings highlight that comprehension and preferences, and thus usability, are specific to the individual and in many cases likely to be connected to the stage of adaptation planning in a given local authority or municipality. Respondents highlighted that certain graph formats are better for initial persuasion needed to ensure buy-in into adaptation, whereas other formats communicate better the exact figures needed for more specific adaptive measures. The consistent cognitive biases and the within group differences demonstrate that the demands for more 'audience specific communication' may be more complex and challenging than has been recognised to date. To address these challenges, we make a number of suggestions based on the insights from our research.

Firstly, our results ought to be situated within the wider judgement and decision-making literature. Insights from this research have shown that, although often there are differences between self-reported and actual knowledge of climate change (Stoutenborough and Vedlitz, 2014), they affect both people's concern and risk perception of the topic (Malka et al., 2009, Milfont, 2012, Sundblad et al., 2007). Despite 'knowledge of climate change' being a broader construct than comprehension and preference for graph formats, which has been assessed in this study, we would nevertheless suggest that these systematic deviations of human judgement affecting the decision-making process pose similar challenges for climate visualisations. A better understanding of the cognitive factors influencing subjective and objective knowledge/comprehension may thus help to tailor visualisations more effectively. Moreover, whilst the literature has already called for a greater integration of the decision-sciences into the development of technical information (Knopman, 2006) and into the wider question on communicating climate change (Rodríguez Estrada and Davis, 2015), we suggest this integration needs to be made explicit for the issue of visualisations as well. Just as much as visual material should not be considered as a simple add-on to the science communication process (Pidgeon and Fischhoff, 2011), use and comprehension of visualisations and their impact on communication and decision-making deserve more attention from the judgement and decision-making literature other than just as a sub-section of the 'climate change knowledge' issue.

Secondly, some audiences are more likely to be susceptible to the change of graph format than others and thus innovative designs may not work equally well in different contexts. In the UK, we noticed a significant drop in ACS from the scatter plot to the pictograph, which was not seen in the German sample. Additionally, we even noticed a slight (although insignificant) increase in ACS from the histogram to the bubble plot in the latter sample. The role of familiarity, the willingness to engage with and the impact of new designs may thus be dependent on the audience. A better understanding of this may help to decide where best to target innovative visualisations and where it is better to use ‘tried and tested’ designs.

Lastly, based on the finding that some graph formats are considered to be more persuasive than others and thus may lend themselves more to certain communication aims, we suggest that more research should be done on understanding how to match visualisations with communication aims. Climate visualisation, like science communication more widely, would benefit here from a much more interdisciplinary approach (Fischhoff, 2011, Pidgeon and Fischhoff, 2011). If designs were created collaboratively, based on more detailed knowledge of the cognitive comprehension and biases of the target audience, more persuasive and engaging, yet scientifically robust, visualisations could be created. Some of the concerns of climate scientists arise out of the worry that making something ‘easier to understand’ comes at the cost of scientific rigour (Fischhoff, 2011), and we suggest that this concern can be overcome through joint design of visualisations.

In all of these suggestions, we see that what the field of information tailoring needs first and foremost is greater collaboration between different fields of expertise and between producers and users of information and we should thus consider co-design (McInerny et al., 2014) alongside co-production. Lemos and Rood’s (2010) argument that producers and users of knowledge have different assumptions as to what is useful and what is actually usable information should be applied also to the visual aspects of information provision. Whilst research strives to find new and more effective ways of communication and visualisation of information and impacts, we acknowledge that what is effective cannot necessarily be judged a priori by the information producers (MacLeod and Morse, 2014) without empirical testing. Even if individual mismatches between comprehension and preferences could be overcome or addressed, past research highlights that there are further cognitive challenges, such as confirmation bias, anchoring or belief persistence (Nicholls, 1999), and institutional complexities, such as different approaches to risk governance (Rothstein et al., 2012), that need to be considered in tailoring efforts.

What is designed as the best fit for comprehension and preferences may not fit with the local institutional contexts and guidelines.

Throughout all of this, we cannot lose sight of the ulterior motive of climate science communication to foster action on adaptation and improve adaptive capacity. Strengthening adaptive capacity will often occur through social and organisational learning (Pelling et al., 2008, Vulturius and Swartling, 2015). Vulturius & Swartling (2015) found that learning and engagement with adaptation improved when information users could relate communicated scientific knowledge better to their contexts and needs, highlighting a need for more tailored information. If co-production and co-design of information were thus to take place alongside each other, it can be anticipated that learning is further increased with an ultimate positive impact on adaptive capacity as well.

We acknowledge that there are potential limitations to our findings, such as self-selection bias: our sample may have more respondents with an inherent interest in visualisation and under-represent the less interested. Due to different computer display sizes and resolutions, some respondents reported not being able to see the entire visualisation without scrolling, which may have affected their responses. However, self-selection bias is an issue that social science surveys will always have to be mindful of and seeing the visualisations did not appear to have been systematically problematic. Therefore we do not think that these issues significantly impact our findings. Furthermore, it could also be that those who are less motivated to utilise climate projections may be less motivated to utilise formats that they perceive to be less easy to use (even if they are better at using them), which could impact on the relationship between assessed and perceived comprehension. Lastly, our statistical tests may have lower statistical power than ideally desirable due to the small sample size. Nevertheless, we have uncovered interesting patterns that are consistent across both samples, increasing our confidence in our findings. Further experimental data collection with larger samples and in more countries would allow for more rigorous statistical testing.

3.6 Conclusion

In the introduction we highlighted that visualisation of information faces the demands for more audience-specific tailoring, greater evaluation of its effectiveness and more empirical evidence. Yet, requests for the communication and visualisation of climate change adaptation information to be more effective and understandable (Moser, 2014) and suggestions for the tailoring of climate information (Lemos et al., 2012) have remained mostly within the theoretical realm. We report empirical evidence about the complexities involved in the visualisation of information and tailoring of communication in practice. Our results highlight that ideal solutions for tailored communication of climate data for decision-making on adaptation may not be found and that their search may be problematic and futile because of a lack of within-group homogeneity and the disconnect between assessed and perceived comprehension and preferences for the use of graph formats. This does not mean that further advances in this field are not needed - our results just highlight that claims regarding effective visualisations need to be tested and verified with more veracity, as much within groups as between them.

We recognise that visual information provision to decision-makers is only a small part of the much more extensive process of co-production of knowledge and the facilitation of user-producer interaction. Yet visual information is a crucial issue if we are to consider the information provision and knowledge production process holistically. Our paper responded to the request for more empirical evidence, researching both adaptation practitioners' comprehension and their preference for different visual formats for the communication of climate projections. We did not set out to find an 'ideal' visualisation, but instead our results demonstrate that we need to invest more thought into how tailoring can be facilitated at the same time as realising that, even though there may be no such thing as a universal solution to the tailoring question, co-design and increased empirical testing may take us some way towards more rather than most effective visualisations.

Acknowledgements We would like to thank Andrea Taylor, Yasmina Okan and Stephan Lewandowsky, as well as the two anonymous reviewers for their helpful insights, feedback and comments on an earlier version of this manuscript.

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4. Chapter

Adaptation planning and the use of climate change projections in local government in England and Germany

This chapter has been submitted for publication as:

Lorenz, S., Dessai, S., Paavola, J. & Forster, P. M. Adaptation planning and the use of climate change projections in local government in England and Germany. *Regional Environmental Change.* [UNDER REVIEW] *(Two extra paragraphs were added to the thesis on p. 123 that are not contained in the submitted version of this paper.)*

Abstract

Planning for adaptation to climate change is often regarded to be a local imperative and considered to be more effective if grounded on a solid evidence base and recognisant of relevant climate projections. Research has already documented some of the challenges of making climate information usable in decision-making but has not yet sufficiently reflected on the role of the wider institutional and regulatory context.

This paper examines the impact of the external institutional context on the use and usability of climate projections in local government through an analysis of 44 planning and climate change (adaptation) documents and 54 semi-structured interviews with planners in England and Germany conducted between July 2013 and May 2014.

We show that there is little demand for climate projections in local adaptation planning in either country due to existing policy, legal and regulatory frameworks. Local government in England has not only experienced a decline in use of climate projections, but also the waning of the climate change adaptation agenda more widely, amidst changes in the planning and regulatory framework and severe budget cuts. In Germany, spatial planning makes substantial use of past and present climate data but the strictly regulated nature of planning prevents the use of climate projections, due to their inherent uncertainties. Findings from the two countries highlight that if we are to better understand the usability of climate projections, we need to be more aware of the external institutional context within which planning decisions are made. Otherwise we run the risk of continuing to provide tools and information that are of little use within their intended context.

Keywords: Local government, climate change adaptation, planning, climate change projections, institutions, regulation

4.1 Introduction

Climate change adaptation is considered a global challenge. At the same time it is widely recognised that it happens across multiple scales, that is local, regional, national and international scales (Adger et al., 2005). It is often argued that specific actions and adaptation planning will need to be undertaken locally. Local government is thus often considered a key deliverer of anticipatory and planned adaptation (e.g. de Oliveira, 2009, Hurlimann and March, 2012, Measham et al., 2011) in the form of provided public services and goods such as spatial planning, green infrastructure, flood risk management, housing and emergency planning (ASC, 2012).

'Planned adaptation to climate change means the use of information about present and future climate change to review suitability of current and planned practices, policies, and infrastructure' (Füssel, 2007a, emphasis added). Effective and efficient adaptation planning is considered dependent not only on climate projections at appropriate scales but also on the joint working of scientists, practitioners, decision-makers and stakeholders (Füssel, 2007a). An increasing body of research has explored how both this joint working and the creation of usable science for adaptation planning can be facilitated and better understood (Dilling and Lemos, 2011, Kiem and Austin, 2013, Kirchhoff, 2013, Lemos et al., 2012). Usability is considered to exist 'within a range in which each use is defined by a perception of usefulness and the actual capacity (e.g. human and financial resources, institutional and organizational support, political opportunity) to use different kinds of information' (Dilling and Lemos, 2011: 681). The perception and capacity referred to above are influenced by both contextual factors (formal and informal institutions, competing factors in the decision-making process, organisational culture, wider cultural context of information use, availability of alternative action pathways) and intrinsic factors (understanding of the decision-context, spatial and temporal scales of information, perceived legitimacy and trust in scientific information, accessibility of information) (Dilling and Lemos, 2011). Within the immediate institutional settings, for example within municipalities, rural communities, or water management companies to name but a few examples, the contextual factors are often considered too narrowly (Kiem and Austin, 2013, Kirchhoff, 2013, van Stigt et al., 2015) and when wider policy and legal frameworks have been considered, such as in Dilling and Berggren's (2015) analysis of user needs in US mountain states, these authors only briefly touch upon on it.

To explore the usability of climate projections in local adaptation planning we need to investigate the institutional context of adaptation in local government. Past research has found that reasons for slow progress in local adaptation include those that are internal to Local Authorities (LAs) (internal institutional context) and those that are external, filtering down from higher levels of government (external institutional context) (Measham et al., 2011). The former include lack of and unfamiliarity with technical data, human resources, lack of political will, unclear or ill-defined responsibilities, competing priorities and lack of expertise (ASC, 2012, Amundsen et al., 2010, Baker et al., 2012, Measham et al., 2011). The latter include lack of leadership, guidance and consistency from higher level governments; restrictive policies and lack of regulation and/or funding (Amundsen et al., 2010, Baker et al., 2012, Lehmann et al., 2015, Naess et al., 2005, Nalau et al., 2015, Porter et al., 2014).

Planning (for adaptation) is considered to be a key tool for progressing action on reducing vulnerability to climate impacts (Hurlimann and March, 2012), and LAs have substantial power over local planning in terms of both strategic decision-making and land-use management (Measham et al., 2011). However, local planning is also considered to face several challenges (Hurlimann and March, 2012) to do with the external institutional context it is impacted by (Measham et al., 2011). A key challenge is that of developing conviction, highlighting that planning is subject to political changes and ideologies (Hurlimann and March, 2012) and thus continuously in flux (Carter et al., 2015). Therefore, to obtain a comprehensive understanding of these challenges it is necessary to acknowledge the key role of the broader external institutional context within which adaptation planning functions (Amundsen et al., 2010, Lehmann et al., 2015, Naess et al., 2005).

To increase our understanding of whether or not planning (for adaptation) can effectively use climate projections we need to consider the insights from both the debates on the usability of climate information and of the broader challenges local planning faces. Therefore, this paper examines the impact of the external institutional context within which planning takes place on the use and usability of climate projections in local adaptation planning. In Section 2 we outline our case studies and methodology. The differences in the use and usability of climate projections in adaptation planning in England and Germany will be described in Section 3. How these are impacted by the external institutional context will be discussed in Section 4, before we present our conclusions in Section 5.

4.2 Case studies and methods

4.2.1 Case study description and adaptation policy context

The United Kingdom (UK) and Germany are both considered leaders in climate change adaptation (Massey et al., 2015, Swart et al., 2009), even though it has been argued that the UK has shown greater advances in making adaptation a distinctive policy field than Germany (Massey and Huitema, 2015). The approaches to adaptation in both countries are thus somewhat different. In the UK, the national government plays a key role in agenda setting and coordination (Massey et al., 2015). As some key national adaptation policy documents such as the National Adaptation Plan are specific to the devolved administrations, our analysis focuses on England. In Germany, the states (*Länder*) play key roles in setting priorities and developing regulatory frameworks while national government is the provider of scientific information and financial support (Massey et al., 2015). These differences highlight that we need to be mindful of the different scales at which the institutional context for adaptation planning can be determined (national level in England and state level in Germany). Figure 4-1 provides an overview of the multi-level legal and policy context of local adaptation planning in the two countries. This external context will be explained and explored in more detail in the reminder of the paper.

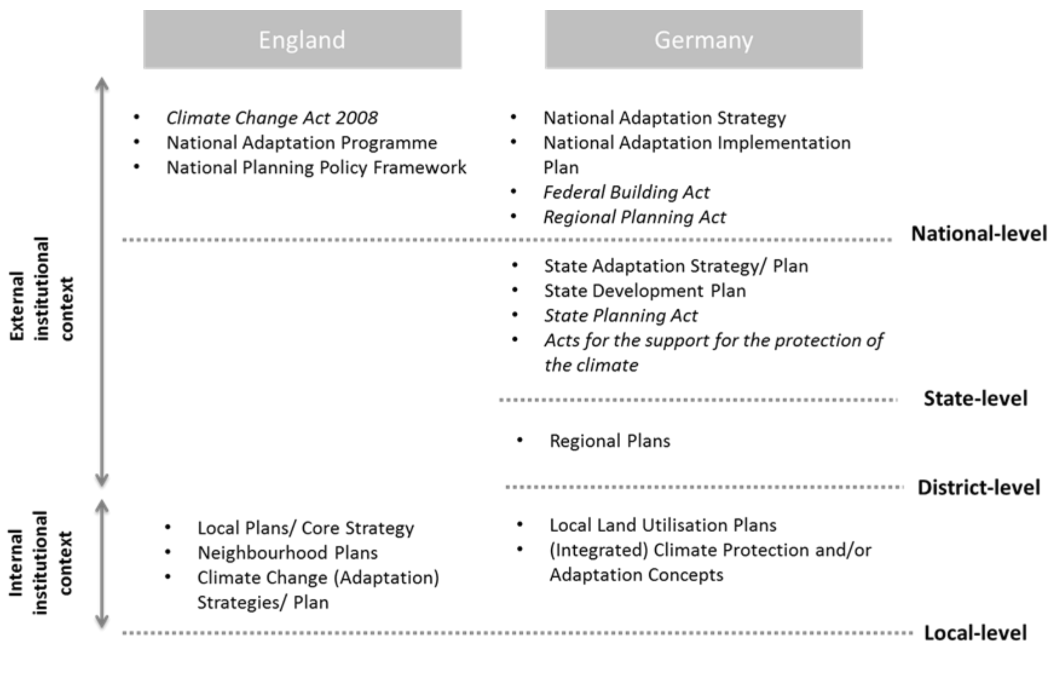

Figure 4-1 Overview of the legal and policy context of local adaptation planning in England and Germany

Note: Acts are marked in italics.

In both countries, local government is a key implementer of adaptation (Massey et al., 2015) and despite some national differences in governance structures, they are largely similar in how climate protection is addressed (Bulkeley and Kern, 2006). In Germany, we collected data from one of the 16 federal states, North-Rhine Westphalia, whilst our data from England comes from the South East and the East Midlands regions. (For a description of the three regions see Appendix C.1).

4.2.1.1 England

In England, the Climate Change Act 2008 contains the key provisions on action on both climate change mitigation and adaptation (UK Parliament, 2008). The national government has responsibility to undertake a comprehensive climate change risk assessment (CCRA) every five years, with the first one published in 2012. The CCRA makes use of the UK Climate Projections 2009 (UKCP09), which are the nationally funded central source and go to place of climate information (both climate projections and observed past climate data) for the country. In 2013, a National Adaptation Programme (NAP) requiring a progress report every two years was created for England. The NAP considers local government to 'play(s) a central role in leading and supporting local places to become more resilient to a range of future risks and to be prepared for the opportunities from a changing climate' (DEFRA, 2013: 96). Prior to the change of government in 2010, local authority performance was measured and compared by the Audit Commission by using a set of 198 National Indicators (NIs) (DCLG, 2007a). LAs could prioritise 35 of these indicators in their Local Area Agreement according to specific local needs and visions. The process-based indicator NI188 – Planning to adapt to climate change provided guidance on how to progress on adaptation and helped measure progress on the ground.

The regulatory and planning framework has undergone substantial changes between 2010-2015 because of the decentralisation and localism agenda of the conservative-liberal coalition government. Local Authorities are no longer required to report to the central government on their performance and the indicator set has been scrapped. The new National Planning Policy Framework (NPPF), which sets out planning guidance for England, still requires Local Planning Authorities to 'adopt proactive strategies to mitigate and adapt to climate change' in their Local Plans (DCLG, 2012: 22), but the earlier more detailed Planning Policy Statements, including specific guidance on climate change (DCLG, 2007b), have been withdrawn. Local government has also experienced a 28% budget cut (Hastings et al., 2015) and has been amongst the hardest hit by the centrally imposed austerity measures (Hastings et al., 2015, Lowndes and Pratchett, 2011).

4.2.1.2 Germany

The German political system and administrative structure is decentralised and polycentric (Beck et al., 2009). The Federal Ministry for the Environment, the most important national level player (Beck et al., 2009, Hustedt, 2013), has together with the federal states (*Länder*) developed a national adaptation strategy (NAS) published in 2008. It sets the overarching framework and guidance for adaptation at the national level (Beck et al., 2009). The implementation plan of the NAS was published in 2011 and is to be evaluated by the Federal Environment Agency (Hustedt, 2013).

The details of delivery and implementation of adaptation are determined by the policies and goals of the individual Länder. Baden-Wurttemberg and North-Rhine Westphalia (NRW) have even enshrined action on adaptation within their 'Act for the support for the protection of the climate'. The NRW Act states that 'the negative impacts of climate change are to be limited through the development and implementation of sector specific adaptation measures that are attuned to the respective regions' (MIKNRW, 2013). Furthermore, states such as Bavaria, Hesse and NRW have published or are developing state adaptation strategies and plans.

At the national level, climate adaptation is specifically mentioned in the Federal Building Act (BJV, 2014, Art 1.5) and the Regional Planning Act: the latter stipulates that 'the spatial requirements of climate protection are to be taken into account, through measures that mitigate climate change as well as through those that serve adaptation' (BJV, 2008, Art 2.6). The latter provision is also reflected in the NRW State Planning Act (MIKNRW, 2005). As planning is very hierarchically regulated in Germany, local planning is supposed to fit in and be compatible with higher-level plans. Therefore, a broad overarching framework for local adaptation planning does exist.

4.2.2 Methods

4.2.2.1 Interviews

We conducted 54 semi-structured interviews with 67 adaptation practitioners at the local, regional and national level in Germany and England between July 2013 and May 2014. As we focus on planned adaptation, we follow Lehmann et al. (2015) by defining adaptation practitioners as 'decision-makers in the field of planned climate adaptation'. The majority of the interviewees (n = 52) came from the three focus regions mentioned above (England: South East and East Midlands, Germany: NRW). The remaining ones (n = 15) were based outside of the three regions to ensure that our findings resonate with the German and English experience outside of our focus regions. Our interviewees included a) local government officials mostly from environment departments (n= 51), officials from regional organisations (n=5), district governments (n=1), regional ministries (n=3), regional authorities (n=3), federal authorities (n=2) and the national weather service (n=2). For a more detailed characterisation of interviewees, see Appendix C.2.

Interviewees were selected from a pool of respondents to a survey on the visual communication of climate projections conducted in the two countries who had indicated willingness to participate in further research. Details of the surveys are reported in a previous study (Lorenz et al., 2015). Additional interviewees were approached upon recommendation of initial interview participants (snowball sampling). The 45-90 minute interviews took place with 1-3 participants and were conducted by the lead author in the interviewees' native language (German or English).

The core themes the interview protocol covered included progress on adaptation within the organisation; regulatory and statutory framework for action on adaptation; communication and inclusion of climate projections in strategic documents, and participants' use of climate projections and communication preferences of projections (the interview protocols for LAs can be viewed in Appendix C.4 and C.5). The interviews were semi-structured to allow for conversations to progress flexibly to the issues and concerns raised by the interviewee. They were conducted either face-to-face or over the phone, were audio recorded and later transcribed.

Transcribed interviews were imported for analysis into the qualitative software analysis tool NVivo (Bazeley and Jackson, 2013). Based on existing literature on the nature of adaptation planning and the concept of climate information usability, an initial a priori coding schema was developed (Miles et al., 2014). Through open and axial coding during the repeated reading of the interviews (Miles et al., 2014), this initial schema was allowed to evolve throughout the data analysis process (Harding, 2013). Coding categories that emerged only in one of the two case study countries were also applied through specific selective coding (Miles et al., 2014) to the interviews from the other country to establish potential similarities and differences between the two countries.

It ought to be noted, that the qualitative analysis approach taken in this paper is markedly different to the approach taken in the first paper (Chapter 2). Whereas the aim in Chapter 2, namely to conduct a structured assessment of the communication of physical science uncertainty in NAS, necessitated a top-down application of the coding schema (based on the uncertainty assessment framework), this paper's aim is to let the insights into the realities of local adaptation planning emerge from the interview data. The coding and analysis approach employed for this paper are therefore more bottom-up in nature.[1]

4.2.2.2 Document analysis

We searched and gathered publicly available strategic planning and climate change documents for the LAs we conducted interviews with in the regions we focused on to triangulate our findings from the interview material. In particular, we analysed whether the documents referred to or used climate projections. We reviewed 14 documents for England and 30 documents for Germany. For an overview of the material reviewed for each of the LAs in the three focus regions see Appendix C.3.

We analysed climate change (n = 6) and climate change adaptation strategies and plans (n = 4) for 8 out of 14 LAs we conducted interviews in, in the two regions we focused on in England. Only two LAs had both types of strategies, and six LAs did not have either publicly available. As 10 of the 14 LAs are local planning authorities, we also reviewed their core strategies, which determine the overarching guidance

[1] This and the previous paragraph were added in the thesis, but are not included in the submitted version of this paper.

for local planning. But as only three of these 10 LAs have adopted strategies and one more has a draft plan available online, we could only review four core strategies. In light of the Planning Inspectorate's latest progress review (2015), this is symptomatic for all English Local Planning Authorities – 38% of them do not have an adopted Local Plan.

In Germany, we reviewed the NRW state development plan (*Landesentwicklungsplan*), the regional plans for the districts in NRW (*Regionalplan*) (n = 14) and the publicly available local land utilisation plans (*Flächennutzungsplan*) (n = 6) for those LAs in NRW we conducted interviews in. In addition, we examined the climate protection (and adaptation) concepts and plans, which were publicly available for 10 out of the 15 LAs in NRW we interviewed in (n = 9, as two of the LAs commissioned a joint concept). The concepts mainly focused on mitigation and were funded either nationally or by the state environment ministry. However, 'special concepts' that focus on adaptation and integrated concepts looking at both mitigation and adaptation are also supported.

4.3 Results

4.3.1 England

The headline result from our analysis is that local progress on adaptation has largely been driven by government regulation. Without the 'Planning to adapt to climate change' indicator NI188, many LAs would not have taken action on adaptation. Despite some of its recognised shortcomings, it gave LAs much-needed direction of travel and five stages to pass through on the way to a regularly reviewed risk-based action plan (Local and Regional Partnership Board, 2010). The risk-based approach to adaptation in England is particularly evident in the indicator level 2, which asks for services to be comprehensively assessed against climate (change) impacts. This led the Department for Environment, Food and Rural Affairs (DEFRA) and the UK Climate Impacts Programme (UKCIP) to advocate and stress the use of climate projections in LAs. Training on the use of the UK Climate Projections 2009 (UKCP09) was provided to some LA officers, to enable assessors to consider possible future states, likelihoods and consequences of potential impacts. However, many LAs failed to generate sufficient information on current and past vulnerabilities and exposure to impacts to be able to effectively use climate projections to deduce potential future vulnerabilities.

> *'I think what you ended up with was a lot of councils who really thought that it was very important that they used this thing [UKCP09] but had no idea why…Unless you have already done a bit of understanding about what your vulnerabilities have already been, your current risks and the ways you have already been impacted, then you don't know how to interrogate that properly necessarily. So many of our councils hadn't done any of that work yet and… I think were not helped by the fact that DEFRA and the government office were coming over and going, "You need to know about this, you are going to use this, it's going to solve your problems around adaptation".' (REG03)*

Due to the novelty of the adaptation agenda and lack of awareness of vulnerabilities and exposures, it is thus questionable whether the LAs would have used climate projections to the same extent as they did had it not been for the top-down push.

The use of climate projections also remained confined to awareness raising in the early stages of adaptation planning, rather than becoming integrated into the overall planning process. Often the projections were not consulted again after local impacts had been identified, '*largely because they don't change very much, the implications for us as a district, there's no new information for us*' (SE06). Although the projections could have been of use in planning e.g. as an additional layer on the Geographical Information System, this has rarely been done. When and where it has been done, climate projections have been used predominantly by the climate change team or the flood risk management team.

The limited capacity of LAs for adaptation planning is also reflected in how comprehensive risk assessments required under NI188 were conducted. The comprehensive risk assessment was intended to cut across all council services to build capacity. However in most instances risk assessments were led and conducted by climate change officers. Climate change adaptation thus remained firmly rooted in the environment / climate change teams rather than being integrated more broadly into local planning and service management processes across the council. Even in environment and climate change teams the uptake of UKCP09 varied: some teams made regular use of them whilst others hardly used them at all. The use of climate projections thus appears not only to have been confined to certain (initial) stages of the adaptation planning progress but also mostly to the respective officer or team tasked with the climate change agenda.

'In terms of having something that is quite detailed and information heavy, I don't think we've got an outlet for it…I would love to see it and look at the analysis of it and play around with it and see what happens, but in terms of usefulness outside of our team I just can't see it because we have to be so simplified to people.' (EM03)

When the capacity to use climate projections is confined to very few people, competing pressures on said staff create a real risk of side-lining engagement with the projections. Local council budget cuts after the 2010 general election and the dismantling of NI188, have led LAs to redefine their priorities away from adaptation. At the same time, expertise with the use of climate projections has often been lost when staff have been made redundant, or rendered useless when staff are transferred to other roles.

'And so we were progressing quite well, 'til 2011, when all the indicators…went out the window with the new government, really. So it was all change again, and adaptation, at that point in particular, really dropped completely off the radar.' (SE01)

The abolition of the indicator NI188 and the extreme cuts to LA budgets happened at the same time, thus making it difficult to distinguish the exact cause for staffing losses. However, the interviewees considered that by making tasks related to adaptation voluntary, the abolition of the indicator NI188 put people focusing on those tasks at risk. Many, despite the varied criticisms of NI188, were thus sad to see it go.

The lack of integration of climate projections into strategic and spatial planning in LAs is also supported by documentary analysis. UKCP09 is not mentioned in any of the core strategies, and the two that refer to climate projections at all not only focus on headlines such as 'summers are likely to be drier and hotter' but in fact refer to climate predictions instead of climate projections. UKCP09 provides an array of possible future climate outcomes and their associated probabilities: mistaking them as certain predictions highlights lack of understanding of the nature and intended use of UKCP09. Although climate (adaptation) plans and strategies refer to UKCP09 and climate projections more frequently, they again remain focused on headlines or highlight the temperature and precipitation changes without reflecting on how they might impact strategic and spatial planning.

In summary, our results highlight that the demand for and use of climate projections in LAs emerged to respond to the requirements of NI188 and the push for UKCP09 by national departments and programmes. With the start of austerity and shift in priorities after 2010, the policy-created demand for the use of climate projections was dismantled. This quickly led to loss of capacity and expertise in local authorities on climate adaptation generally and the use of climate projections more specifically.

4.3.2 Germany

In Germany adaptation is considered a local matter and local authorities have planning sovereignty, despite having to conform to higher level plans. Adaptation has been a voluntary task at local government level and doubts have been voiced whether any local action will be taken before adaptation becomes a mandatory task, especially in financially strained municipalities.

> *'It is naturally always the case with voluntary tasks, that they always get put to the back of the queue. That is naturally the case with municipalities, and that is the majority in NRW, for example have financial problems, and then people like to or it is not otherwise possible, concentrate on things, that are legally mandated and as long as there is no legal mandate, to deal with the topic, many just simply ignore it.' (NRW19)*

Although the climate protection act in NRW sets out a roadmap for action on climate change, it only sets clear targets for mitigation. The article on adaptation is vague and leaves the extent of expected action on adaptation unclear. Thus there is not the kind of top-down guidance for progression stages in local adaptation planning as there was in England under NI188.

Despite progress on adaptation at national level, at the local level adaptation still seems to be in the early stages and climate projections are thus unlikely to play an important role in local decision-making processes in Germany. Our document review corroborates this: climate projections are referred to in the climate change (adaptation) plans of three LAs and in the state adaptation plan. However, they are not mentioned at all in any of the local, regional or state-level planning documents in NRW. These findings indicate that like in England, climate projections have not been integrated into local strategic and spatial planning in Germany.

On the other hand, we find that climate data in the form of climate function maps and planning recommendation maps has been widely used in the planning process for several decades in larger LAs. These maps are based on measured data of a variety of climate variables. Some LAs have even conducted consecutive analyses to establish the change in these climate variables. Planning maps indicate the present state of local climate, subdivided into geographical areas with different microclimatic conditions and land-use characteristics (Heaphy, 2014). This practice is guided by technical rules established by the Society of German Engineers (Matzarakis et al., 2008). The rules describe how the urban climate is to be represented and evaluated in maps that underpin urban and regional planning recommendations (Heaphy, 2014). These maps often highlight potential heat islands and cold air paths and guide where additional development can or cannot take place.

Thus, whilst climate projections are not used in local planning, past and present climate data is. The use of these climate function and recommendation maps is strictly regulated and an integral part of planning across LAs. '*In that sense, as an evaluation tool, it is a very important instrument here in the municipality. It is taken seriously*' (NRW12). Small-scale simulations are sometimes created with tools such as Envimet, a micro-climate simulation tool, to establish how planning options would affect local micro-climate and influence future climate locally. That is, these tools are used to assess planning options and help with decision-making and resource allocation. These findings highlight that there is capacity, tools and a regulatory framework enabling the use of past and present climate data – but not projections of future climate — in local planning.

The current state of climate is by many LAs considered sufficient for planning purposes: it helps to identify and highlight existing vulnerabilities and exposure to impacts, as well as to discuss alternative adaptation measures. '*Yes well, I mean, in the present state of the climate, I can obviously already see a lot of mistakes, which* *will probably be the same with climate change*' (DEU07). Climate change (adaptation) documents of a few of the LAs consider analyses of current local climate a sufficient foundation for the development of an adaptation strategy.

Some LAs have used climate projections to complement current climate maps to explore the future state of local climate, effectively linking climate projections to a tool that has been used in planning for a while. This demonstrates that climate projections can be used with established planning tools and highlights the potential capacity of the local planning system to extend its use of past and present climate data to include future climate projections. However, maps based on projections have often been used only internally, not for communication with elected council members or the public. This is because they are not considered to be certain enough to be able to inform planning processes and because they are difficult to communicate. That is, lack of use of climate projections is less of an issue of insufficient technical capacity or lack of tools but more an issue of lack of fit with regulatory and institutional requirements and perceived communication and engagement challenges.

Finally, climate projections are not used simply because it is not required by the rules of federal and regional funding (mentioned in Section 4.2.2.2) available to LAs. As many LAs have very constrained budgets, activities that are not mandatory are extremely unlikely to be undertaken.

> *'The funding programme stipulates certain things, that one has to do and tick off the list, as otherwise one doesn't get all of the funding. These climate projections were not specifically asked for…Only during the creation [of the climate protection concept] one becomes wiser, but then there simply wasn't any time or budget left.' (NRW18)*

Our findings demonstrate that in Germany top-down drivers have created a planning system that could potentially accommodate the use of climate projections, as the use of past and present climate data is already well integrated into current planning. However, the planning system makes it difficult to expand the current system to climate projections due to their inherent uncertainty (BVBS, 2013). Additionally, the lack of top-down regulation and guidance on adaptation leaves adaptation voluntary which makes it difficult to justify the allocation of resources for increased use of climate projections.

4.4 Discussion

Our findings highlight that to better understand the usability of climate projections at the local scale, it is important to ground the use of climate projections within a wider context determined by differing planning frameworks, statutory duties, regulations and approaches to adaptation.

In England, there was initially a very ambitious approach to adaptation both nationally and locally on the basis of the regulatory framework around NI188 put in place by the Labour Government. NI188 was prioritised in about 30% of LAs (Cooper and Pearce, 2011) and it has been considered a strong steering mechanism and driver of action (ASC, 2012, Boyd et al., 2011). Its risk-based approach to adaptation planning and the push for the use of UKCP09 created a momentary demand for climate projections in LAs.

From 2010, the Conservative-Liberal Coalition Government introduced substantial changes to the regulatory and planning framework within which LAs are situated. Not only was the indicator set dismantled, but the Localism Act 2011 promoted a voluntary approach to climate change adaptation, causing an 'erosion of resolve' in LAs to progress on adaptation (Dixon and Wilson, 2013). The Act also abolished the regional tier of government and planning, leaving responsibilities for housing developments and planning to Local Governments (Lowndes and Pratchett, 2011).

The Localism Act stipulates that local planning is to occur within the frame of a Local Plan, which reflects the 'local area's vision' (UK Parliament, 2011), arguably not sufficiently taking into account impacts happening at higher scales (Wende et al., 2012). At even finer resolution, the government encourages the creation of community-led neighbourhood plans, which are not required to specifically consider sustainability or environmental issues as long as they align with the planning framework set out in the respective Local Plans. However, as 38% of Local Authorities do not have a Local Plan (TPI, 2015), neighbourhood plans would be directly guided by the NPPF (Scott, 2011), which has no specific stipulations for adaptation. Due to the changes imposed by the central government, adaptation is thus not sufficiently considered in local development planning (ASC, 2012).

The LAs have made over 50% efficiency savings (Hastings et al., 2015) and made staff redundancies of over 30% (Hastings et al., 2015). Spending on planning has more than halved in some places (Fitzgerald and Lupton, 2015). These cut backs increase focus on mandatory frontline services and tasks: largest cuts will hit those services that LAs are not legally tasked to provide (Fitzgerald and Lupton, 2015). This new emphasis on frontline services does not bode well for precautionary 'discretionary' concerns such as climate change adaptation. Competing priorities (Cooper and Pearce, 2011), the lack of mandatory targets and the loss of capacity have marginalised adaption planning (Porter et al., 2014).

Whilst the English story is one of rise and demise of the use of climate projections for local adaptation planning, Germany is much more at the beginning of this journey. The use of climate function and planning recommendation maps discussed in Section 4.3.2. highlights that the use of past and present climate data for the assessment of current vulnerabilities and exposure is well embedded in the German planning system, predating more recent concerns related to climate adaptation. This planning style resonates with a vulnerability driven approach to adaptation (Adger, 2006, Füssel, 2007b), which prioritises current exposure and may thus see less need to use future climate projections. Too narrow a focus on past and current exposure and vulnerability, however, may not prepare German LAs sufficiently to cope with future climate change (Dilling et al., 2015).

The use of climate data in the German planning system is firmly regulated by law, regulations and directives (Matzarakis et al., 2008). They make the use of climate projections difficult, because they do not fulfil the formal expectations about the nature of the information they provide (BVBS, 2013). Spatial planning recommendations have to be based on data that is spatially sufficiently concrete and accurate so that valid planning recommendations can be made (BVBS, 2013). This is something climate projections struggle to help with due to their inherent uncertainty. That is, climate projections do not "fit in" to the planning system rather than there not being demand for them as such.

Although NRW has passed a climate protection act, it is considered a political declaration of 'advisory character' due to the lack of clear targets, responsibilities and sanctions in the law. But making adaptation and its planning mandatory is also problematic in a situation where strapped council budgets would not easily cope with additional expenses (Nalau et al., 2015) as statutory duties would not be fundable from national schemes (SGB, 2013).

Our findings highlight that an exploration of contextual factors, impacting the perception of usefulness and capacity to use different kinds of information, clearly needs to extend beyond the immediate institutional context to a much closer consideration of the external institutional context as well. In England, the momentary drive for adaptation and demand for climate projections before 2010 was largely created by the top-down regulatory and planning framework and the push for the use of UKCP09 by national departments and organisations. When local government was hit by austerity and the policy and planning framework changed, the usefulness of climate projections for local adaptation planning evaporated. In Germany there may be greater capacity to use climate projections in local planning due to planners' familiarity with the use of past and present climate data. This capacity is again an outcome of the wider planning system and its requirements. Yet the rules and requirements of the planning system also render climate projections un-usable for local planning, because of their lack of fit with the requirements of planning regulations. Therefore, it is unlikely that there will be a substantial increase in the demand for climate projections in Germany in the near future (BVBS, 2013), as planning law is unlikely to change quickly (McDonald, 2011).

Whilst climate projections are not considered usable in local adaptation planning for different reasons in the two countries, their experiences highlight the impact and importance of the external institutional context on the usability of climate projections. Our findings are largely based on interviews within our three focus regions and thus spatially limited and only provide a snapshot in time. Our additional interviews from outside the focus regions, whilst limited in number, nevertheless support our findings and thus show that these are not due to regional particularities but instead highlight that LAs in both countries are equally subject to the external influence of the national planning frameworks, laws and regulations.

The English experience raises the question to what extent the discussion on the usability of climate projections at a local level is sensible at all at the moment. It rather looks as if the discussion should be about the creation of a new external institutional setting which would be conducive to fostering local adaptation planning, with or without the use of climate projections. A shift in attention is also necessary in Germany, where the lack of fit is more likely to be addressed effectively if planning regulations become more amenable to using climate projections as data for evidence based decision-making. The framework for the use of such information is already in existence, as past and present climate data is already integral to planning.

Addressing the question of usability is not just about better understanding the interplay between what science can provide and what users need or want, but also about what users can actually do within the political and economic constraints within which they act. This question of 'what can be done' is not determined by the immediate internal institutional setting only: the wider external context clearly matters too. There may be challenges outside of the user-producer interaction that even co-production or co-creation cannot overcome, and we do need to be aware of them to obtain a pragmatic understanding of the usability of climate projections in adaptation planning. Adaptation has long been considered highly contextual (Füssel, 2007a) and so is usability of climate data and projections. We may run the risk that our current focus on too narrowly defined improved usability tries to come up with smarter and smarter solutions through tailoring and customisation of information, whilst being ignorant of the wider context by which its usability is impacted.

This is not to say that we do not need to continue to gain a better understanding of the user-producer interface in order to make information more usable (Lemos et al., 2012). Rather, it is to say that we also need a better understanding as to how to nest the usability debate into the bigger institutional and contextual debate of adaptation planning.

4.5 Conclusion

In this paper we explored the usability of climate projections within local adaptation planning in England and Germany. We find that although it is well recognised that the external institutional context strongly impacts local adaptation planning, this recognition needs to be more clearly integrated into the discussion on the usability of climate projections at the same scale. Whilst initially there was a very ambitious drive in English LAs to use climate projections, this was very much a top-down policy-driven demand, which no longer exists after the policy framework was dismantled. In Germany the progress in using climate projections is much slower and less ambitious but on the other hand past and present climate data is widely used in local planning. This is partly explained by the strict regulation of planning in Germany which does not facilitate the use of climate projections as part of the planning process (BVBS, 2013).

The usability of climate projections is influenced by a myriad of factors, but the external institutional context clearly plays a crucial role in both countries. This means that just as the progress on adaptation at the local scale can be helped or hindered by the wider rules, policies and regulations, so can the usability of climate projections.

The debate on tailoring and customisation of climate information is about making climate information as usable as possible in a given setting. To achieve this it needs to look beyond the immediate institutional context within which users and producers interact and look outwards to the wider setting and legal and regulatory system within which they are placed. The developments and changes in the wider setting, may in turn be better understood through insights from policy studies on such questions as policy innovation and adaptation (Massey et al., 2014, Massey and Huitema, 2015), but also the impact of policy dismantling (Bauer and Knill, 2012, Jordan et al., 2013).

If this wider setting, however, proves not to be conducive to the use of climate projections for adaptation planning, we need to ask ourselves whether our endeavours to increase usability are futile. Whilst striving to ensure greater usability at local level, we cannot let our attention slip away from the question as to how we create a wider setting that encourages both local adaptation planning and the use of climate projections at the same time.

Acknowledgements The authors would like to thank Ross Gillard for his helpful insights and feedback on an earlier version of this manuscript.

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5. Discussion and Conclusion

5.1 Introduction – overview of the research

It has been recognised that adaptation to a changing climate is inevitable (IPCC, 2014, Moss et al., 2013). Consequently, there has been an increasing call in recent years to advance the science of communicating climate change (Fischhoff, 2011, Pidgeon and Fischhoff, 2011), to enhance the tailoring of climate information for adaptation planners (Daron et al., 2015, Stephens et al., 2012) and to improve the provision of usable information for adaptation decision-making (Dilling, 2011, Kiem, 2013, Lemos, 2012). This thesis has investigated the communication, tailoring and use of climate projections and their inherent uncertainties for adaptation planning. In its undertaking, it has set out to not only progress knowledge in these areas, but has also contributed methodological communication tools to facilitate both a more structured approach to the communication of climate science, and more effective adaptation decision support.

This thesis has examined the interaction between these matters by using a multi-level mixed method approach. Firstly, the research compares the extent to which physical science uncertainty is included and communicated in NAS across Europe (Chapter 2). This comparison helps to understand the overarching national setting and to provide a diagnostic tool to assist with more structured uncertainty communication in policy documents for adaptation planning. Chapter 3 highlighted the practical challenges encountered in the tailoring of climate projections (for local adaptation practitioners) through empirical testing of climate visualisations. Lastly, Chapter 4 investigated the impacts that the wider institutional context has on the use and usability of climate projections for adaptation planning (at the local level).

This research has focused on the individual, local and national level of two countries that are considered leaders in the field of adaptation (Bauer et al., 2012, Swart et al., 2009). Whilst the data collected and analysed here is specific to these case studies, wider insights can nevertheless be gleaned that contribute to the debate on how communication tools can be designed for effective adaptation planning decision support.

This thesis has responded to the demand that a science of communication (Fischhoff, 2013) needs to be more seriously applied to the communication of (climate) science for adaptation planning. As a more interdisciplinary approach has been called for to achieve this, this thesis has endeavoured to go beyond the theoretical consideration of what a science of communication for adaptation might benefit from, and has provided empirical insights into the practicalities of realising both more structured communication approaches and more effective communication tools. By showing how the communication, tailoring and use of climate projections and their uncertainties are interlinked, as well as positioned within a wider institutional setting, this thesis presents a more pragmatic understanding of the realities of creating effective communication tools.

Sections 5.2.1 to 5.2.3 revisit each of the three research objectives in turn to draw out the key findings from each of the empirical chapters, and discuss the extent to which this thesis has helped to advance our understanding of the communication, tailoring and use of climate projections and uncertainties. In Section 5.2.4, the insights from the three research objectives will be viewed together, highlighting the key considerations that need to be borne in mind if communication tools for more effective adaptation planning decision support are to be realised. This will inform Section 5.3, which will highlight the implications of these research findings for policy and practice. Section 5.4 reflects on the opportunities and challenges posed by the mixed-method multi-level research approach before highlighting some of the limitations of this research in Section 5.5. Section 5.6 will outline priorities and opportunities for further research and lastly Section 5.7 will provide a summary of the contributions to this field of study.

5.2 Revisiting the research objectives

The previous results Chapters 2-4 have focused on examining research objectives 1-3. The main findings of these chapters and the respective advancements in knowledge will be summarised below. The insights gained from each individual research objective and the examination as to how these are interdependent and interlinked will provide a more comprehensive understanding upon which to base insights for research objective 4, which will be considered in detail in Section 5.2.4.

5.2.1 Understanding the communication of climate projections and physical science uncertainty

Objective 1: *Assess how European National Adaptation Strategies communicate physical climate uncertainties.*

Past research has highlighted that there is a call for a more structured approach to the communication of physical science uncertainty to inform effective adaptation planning (Lourenço et al., 2014). At the same time a more structured approach to adaptation planning itself at the national level is being asked for by the European Union through its adaptation framework and subsequent European Adaptation Strategy (EC, 2009, EC, 2013). Past comparisons of NAS have focused on aspects such as content, context, policy integration and monitoring and evaluation of adaptation planning (Hanger et al., 2012, Juhola and Westerhoff, 2011, Termeer et al., 2012). Some have also focused on the role of uncertainty in adaptation planning and the communication of scientific information in NAS (Biesbroek et al., 2010, Hanger et al., 2012). However, there has been no attempt to date to provide a systematic comparative insight into how European NAS communicate physical science uncertainties inherent to the scientific information used to inform adaptation planning.

Chapter 2 presents a new uncertainty assessment framework (UAF) and applied this to ten European NAS using a qualitative content analysis. This analysis has helped to advance our understanding of the communication of physical science uncertainties in two ways. Firstly, the UAF provides a methodological contribution in presenting a new diagnostic tool that combines a variety of issues considered important for the comprehensive assessment and communication of scientific uncertainty. Three of the categories in the UAF – Numerical Value (*do strategies assign numbers to the climate projections and uncertainties they mention?*), Spread (*do strategies use ranges to convey the climate information rather than one deterministic number?*) and Substantiation (*To what extent are NAS transparent about the foundation of the science communicated within them?*) – focus specifically on the communication of climate projections and their associated uncertainties. The fourth category – Depth (*To what extent do NAS take account of the various sources of uncertainty using the outcomes from the cascade of uncertainties?*) – takes a broader look and assesses how comprehensively NAS communicate the variety of uncertainties relevant to the adaptation planning process. Taken together, these four assessment criteria can help guide more structured uncertainty communication in NAS and other policy documents relevant to adaptation planning. Whilst this analysis sits alongside other research that has compared NAS against a number of criteria and against each other (Bauer and Steurer, 2015, Biesbroek et al., 2010, Greiving and Fleischhauer, 2012, Hanger et al., 2012, Swart et al., 2009, Termeer et al., 2012), it adds to this research empirically by providing a systematic assessment of how scientific uncertainty is currently considered and communicated in NAS.

The results from Chapter 2 show that out of the six levels in the cascade of uncertainties considered in the UAF (future society, GHG emissions, climate model, regional scenarios, impact model, local impacts), uncertainties in climate models (and thus climate projections) together with uncertainties in GHG emissions are the joint most frequently communicated ones. However, the top level of the cascade of uncertainties (the state of future society), with its varied potential pathways and associated uncertainties, is rarely mentioned. Consequently, there appears to be a bias towards communicating those uncertainties, perceived as easier to quantify, compared to those potentially harder to quantify, e.g. technological advancements, population growth, land-use changes etc.. Given the emphasis placed on climate models and climate projections in the NAS and consequently the adaptation planning process, a transparent and systematic approach for their communication ought to be expected. However, the assessment of the NAS highlights that even at the levels of the cascade prominent in the NAS, communication of relevant uncertainties has not been systematised. Adaptation practitioners have been demanding more guidance on the use of climate projections and more systematic communication on uncertainties from higher levels of government. The application of the UAF to ten European NAS showed that, to date, such guidance in national level adaptation plans and strategies appears to be rather unstructured and partial. This finding highlights that the variety of uncertainties relevant to the adaptation planning and decision-making process are not presently evenly communicated, thus providing incomplete reflection of the full range of uncertainties relevant to adaptation planning. Furthermore, even those that receive more attention through this uneven reporting lack systematic and transparent communication.

Whilst this tendency towards communicating only selective levels of the cascade is noticeable for the majority of the NAS, there are, nevertheless, marked differences between the different NAS. Chapter 2 shows that similar stages of development in adaptation policy planning can nevertheless result in differences in handling physical science uncertainty in strategic policy documents, which contrasts earlier findings by Hanger (2012). Chapter 2, in fact, highlights that external factors previously used to explain different approaches to communicating climate information and uncertainties, such as the stage of adaptation planning (Hanger et al., 2012), the aim of the NAS, the institutional setting and the dominant problem-framing of adaptation (Termeer et al., 2012), often do not sufficiently explain the choices made for the communication of its scientific underpinnings. Instead, this thesis suggests through the exploratory analysis of the German and English NAS, that a broader view encompassing the socio-political and cultural context is required for a more comprehensive assessment of communication approaches. Such a broader view will help to better understand how the traditions of environmental policy, the level of societal and political consensus on the credibility and salience of climate science knowledge, and the degree to which climate change has been politicised can impact how comprehensively different NAS communicate scientific uncertainties.

The aim of Chapter 2 was firstly to show that if recommendations for a more structured approach to the communication of uncertainties are to be made, a baseline needs to be established examining the current status quo and existing communication approaches first. The UAF helps not only to examine similarities and differences in existing documents but can also aid in highlighting aspects of the communication of uncertainties that may need to be focused on more so as not to portray an incomplete picture of the knowledge base or potentially even create a false sense of certainty. This is not exclusively applicable to national level policies such as NAS, but is equally applicable across different scales and different types of plans, policies or strategies concerning adaptation planning.

Chapter 2 has highlighted that whilst recommendations can be made on how to take a more structured and balanced approach to the communication of physical science uncertainty using the UAF (e.g. in adaptation planning documents such as the NAS, but also across other scales of adaptation planning) adaptation strategies and plans will inevitably be embedded within and influenced by the wider socio-political, economic and cultural context within which they are designed and implemented. Ultimately, the UAF can be used as a diagnostic or guiding tool.

These findings help to show, that there is certainly scope to develop tools and frameworks that allow for a more systematic communication of climate science uncertainties for adaptation decision support. However, the findings also highlight that whilst such tools and frameworks can be applied and recommendations for required changes can be made upon them, their utility should not be considered in a vacuum. Communications (such as NAS) are developed within certain institutional settings, policy frameworks, socio-political contexts and scientific and cultural traditions and any recommendations for communication changes made will need to be cognisant of these. If such wider settings are ignored, it is unlikely that specific communication recommendations are applicable and effective.

5.2.2 Trialling tailoring of climate projections

Objective 2: *Test the association between comprehension and preferences for different tailored visualisations of climate projections by individual adaptation practitioners in local government in the UK and in Germany.*

In the field of visual communication of climate change there has been an increasing call for more usable climate information to be provided through the increased tailoring of climate information (Lemos et al., 2012) in line with audience needs (Nicholson-Cole, 2005, Spiegelhalter et al., 2011). Thus, exploring how climate visualisations can be tailored more effectively for adaptation planning requires further investigation. However, despite tailoring being a possible solution to overcoming the climate information usability gap (Lemos et al., 2012), to date, there has been a lack of empirical evidence (Bostrom et al., 2008, Broad et al., 2007) that provides insight into both how this might elicit the most effective outcomes and be feasible in practice.

Past research has highlighted that a better understanding of both user preferences and user comprehension of visualisations are needed (Spiegelhalter et al., 2011). Whilst there have been calls to test different types of information content and graph types for visualising climate information (Pappenberger et al., 2013), it is equally important to get a better understanding of the interplay between comprehension and preference for a range of visualisations that could be tailored for different audiences.

Chapter 3 collected empirical data, testing the challenges encountered by tailoring even when just one specific ‘audience’, in this case local adaptation practitioners, is considered. Two reasons warranted the closer examination of local adaptation practitioners in this thesis. Firstly, it has been recognised that the implementation of practical adaptation measures is often a local matter (de Oliveira, 2009, Hurlimann and March, 2012, Measham et al., 2011), and secondly, adaptation planners have demanded more guidance and structured communication of climate projections to support the adaptation efforts in their municipalities. If such communications in the form of climate visualisations (as e.g. provided by climate services or boundary organisations) are to be effective, more testing and empirical data from specific target audiences are required.

Chapter 3 is therefore based on the quantitative analysis of two online surveys undertaken with local government adaptation practitioners in Germany and in the UK, which assessed both practitioners' comprehension and preferences for climate visualisations. The surveys explored two pairs of graph formats, contrasting 'traditional' and 'alternative' ways of visualising the same underlying data. Chapter 3 tested respondents' assessed and perceived comprehension, and their preferences for using these graph formats for informing their own decision-making (use by self) as well as for communicating effectively with colleagues and superiors (use for showing to others). In doing so, the chapter found that there were no systematic significant associations between assessed comprehension across perceived comprehension and use within either of the two pairs. These results replicate similar experimental findings from the health sciences (Ancker et al., 2006, Elting et al., 1999, Parrott et al., 2005) in the field of climate visualisations. The results, however, did find a systematic association between the three subjective preference measures: perceived comprehension, use by self and use for showing to others.

The contributions to the literature that this chapter makes are twofold. Firstly, Chapter 3 responded to the call for more experimental research in the field of visualising and communicating climate projections (Bostrom et al., 2008, Broad et al., 2007, Spiegelhalter et al., 2011) by applying a methodological approach that is more commonly found in the health sciences or JDM literature. Secondly, the results empirically contribute to better understanding the practical challenges of tailoring climate information to adaptation practitioners in local government, an under-researched target audience (Demeritt and Langdon, 2004, Porter et al., 2014) despite their being at the forefront of delivering adaptation.

The results in Chapter 3 highlight that 'audiences' are not homogenous, but that within group differences need to be acknowledged. In practice, when tailoring climate information, this means that even ‘audience specific’ tailoring, that is often called for (Nicholson-Cole, 2005, Spiegelhalter et al., 2011) may not be as effective as expected. Instead, tailoring of climate information should be considered more as a process of ‘individualisation’ (Hawkins et al., 2008), which responds to individual user needs and preferences.

In addition, the findings from Chapter 3 highlight that the systematic deviations of human judgement mean that this individualisation cannot solely be conducted based on preference or comprehension alone; therefore empirically substantiating previously raised concerns (Pappenberger et al., 2013). The thesis therefore highlights a dual challenge for the producers of visual climate information, such as boundary organisations or climate service providers. Firstly, visual products, even if targeted at a specific ‘audience’, may not be met with the same level of comprehension and preference by the individual decision-makers within that audience. Secondly, even if a finer scale approach were to be taken, individualised tailoring to user preferences and comprehension would also be difficult to achieve due to the lack of consistency between users’ preferences and comprehension. If tailoring were to happen according to user preferences alone, there might be a risk that user selected graph formats are not as well understood as the non-selected formats. Equally, if tailoring was to be based solely on user comprehension, it is possible that user engagement might be lower due to those producer-selected graph formats not being those preferred by the users.

Whilst individualised visualisations may have the potential to be more responsive to specific decision-makers’ needs (tailored to comprehension) and demands (tailored to preferences), it is not clear yet how to reconcile user needs and demands in this context. The joint consideration of preference and comprehension is more likely to provide a more complete insight into the usability of graph formats, but how to negotiate the discrepancies between those two constructs will need further investigation.

In addition, Chapter 3 highlighted that to aid effective tailoring of information to user needs, it is also important to understand what the graph formats are meant to be used for. Different stages of adaptation planning, such as raising awareness and persuading colleagues and superiors of the need for action likely call for different visualisations compared to those used for specific planning decisions. The findings thus suggest that whilst tailoring ought to be more individualised, individual adaptation practitioners nevertheless access and use the tailored information at different stages of the adaptation planning process. Therefore, the external adaptation planning context within which tailoring for adaptation practitioners takes places needs to be kept in mind for tailoring to be more effective.

Chapter 3 has thus not only managed to empirically prove the previously stipulated value of and the need for greater integration of insights and methodological approaches from the psychological and decision sciences into the field of climate information visualisations (Pidgeon and Fischhoff 2011), but has also highlighted the need for more experiments of this kind to refine the recommendations made for the tailoring of climate information.

The results from this chapter help to improve how we understand the two building blocks of usability: the perception of usefulness and the capacity to use information, when applied to the concept of tailoring climate information. Lemos et al. (2012) stated that tailoring through customisation can help to transform useful into usable knowledge, thus providing more decision relevant information. The findings from this research have shown that this process of customisation or individualisation is complicated. It will certainly require more empirical groundwork to understand how to reconcile user preferences and comprehension before any recommendations for tailoring can be upscaled as suggested by Kirchhoff et al. (2013).

5.2.3 Understanding the use and usability of climate projections

Objective 3: *Examine the extent to which the wider (political, legal and regulatory) context within which local adaptation planning is placed influences the use and consequently the communication and tailoring of climate projections at the local level.*

Chapter 4 was conceived by merging insights from research on both influences affecting the use and usability of climate information (Dilling and Lemos, 2011, Lemos et al., 2012) as well as influences affecting the progress of local adaptation planning (Amundsen et al., 2010, Baker et al., 2012, Measham et al., 2011). Both areas of research highlight that factors internal to the decision-making process, as well as those that are external to it determine the context within which decision-making takes place and can affect the usability of information and local adaptation planning (Baker et al., 2012, Kiem and Austin, 2013, Kirchhoff, 2013).

However, how these notions of ‘internal’ and ‘external’ are conceptualised differs between the two research fields. Whereas research on local adaptation planning has highlighted that external factors filtering down from higher (that is regional or national) scales can impact the progress of local adaptation planning (Baker et al., 2012, Lehmann et al., 2015, Naess et al., 2005), research on the usability of climate information has to date largely stopped short of comprehensively considering external factors beyond those at the organisational scale (Dilling and Berggren, 2015, Kiem and Austin, 2013, van Stigt et al., 2015).

To comprehensively examine the usability of climate projections in local adaptation planning, it is necessary to understand the institutional context, as this will not only impact the progress of adaptation planning, but consequently also the use and usability of climate projections. Chapter 4 therefore examines local planning and climate change documents, as well as empirical data collected in interviews with local adaptation practitioners in England and Germany, to explore the role of the wider institutional and regulatory context on the use and usability of climate information for local adaptation planning.

The contributions this chapter makes to the literature are both of an empirical and a theoretical nature. Firstly, the empirical data collection targeted local adaptation practitioners, considered an under-researched climate information user group (Demeritt and Langdon, 2004, Porter et al., 2014) that nonetheless works at a scale considered to be key for adaptation implementation (de Oliveira, 2009, Hurlimann and March, 2012, Measham et al., 2011). Furthermore, the interviews, particularly in England, captured a unique temporal insight from those local adaptation practitioners that had largely experienced the change in the status of local adaptation planning from ‘before’ the start of the government’s austerity measures in 2010 and ‘after’. Thus they could provide their critical reflections on this, corroborating findings from recent research (Porter et al., 2014) that adaptation has been deprioritised in English local government. Secondly, the findings highlight that to better understand the use and usability of climate information in the context within which local adaptation planning decisions are made, their discussion needs to be more firmly grounded in and cognisant of research on the role and effect of the external institutional context, previously highlighted to be so relevant to adaptation planning (Amundsen et al., 2010, Baker et al., 2012, Measham et al., 2011).

Case study England: The results in Chapter 4 show that local adaptation to climate change in England has largely been driven by government regulation, in the form of the National Indicator NI188 – "Planning to adapt to climate change". Whilst climate projections have been used in progressing against this indicator, this has been attributed largely to the risk-based nature of the indicator, which asks for the systematic assessing of and planning for the risks posed by future climate change, alongside the top-down push for the use of climate projections by DEFRA and UKCIP starting with the release of UKCP09 in 2009. With the dismantling of the indicator, the change in the national planning framework and the severe budget cuts experienced by local governments, adaptation and the use of climate projections to inform it has waned substantially since 2010 (Porter et al., 2014). Chapter 4 provides the empirical evidence for concerns expressed by previous research that a rolling back of the statutory regulations and changes to the planning framework would negatively impact the drive for adaptation (Cooper and Pearce, 2011, Scott, 2011). With the spending on planning being drastically cut (Fitzgerald and Lupton 2015) and efficiency savings having to be made in the order of 50% (Hastings et. al 2015), adaptation is considered a discretionary service, thus resulting in an 'erosion of resolve' (Dixon and Wilson 2013) to push progress against it. As climate projections have not been systematically integrated into strategic and spatial planning at the local scale and because climate related expertise is largely confined to specific officers that is often lost due to staffing changes and capacity loss following budget cuts, it is clear that climate projections have become much less usable and used since the regulation-driven demand has subsided.

Case study Germany: Furthermore, Chapter 4 found that Germany lacks top-down regulation concerning adaptation, as the state-level policy setup does not make adaptation a statutory requirement for local government. Nevertheless, local planning in Germany has a strongly regulated and structured approach to using measured climate data (Matzarakis et al., 2008) as part of the decision-making process for spatial planning. Thus, whilst there is not only a capacity to use, but also a systematic application of climate data to spatial planning, this capacity and experience with using similar types of data have to date only rarely been translated into using climate projections for the same purpose. Often adaptation practitioners consider climate data to sufficiently assist them in identifying past and present vulnerabilities and levels of exposure, even if it is argued in the literature that such an approach is likely to fall short of identifying the full range of vulnerabilities resulting from a changing climate (Dilling et al., 2015).

The findings in Chapter 4 support previous research that has highlighted that the use of climate projections for spatial and strategic planning is considered problematic due to the inherent uncertainties associated with them (BVBS, 2013) and due to the projections not being spatially sufficiently concrete or accurate. This highlights that the lack of demand for climate projections in local adaptation planning in Germany is partly due to the lack of fit with the regulatory and planning requirements determined by the external institutional context. A more enabling regulatory and planning framework would allow for the expertise and proficiency already developed in local planning in Germany to extend from using climate data to using climate projections for adaptation planning.

Comparing both countries: The findings in Chapter 4 from two countries that are considered leaders on adaptation (Bauer et al., 2012, Swart et al., 2009) and major climate service providers, whilst particular to those countries, highlight that even amongst the frontrunners in the field of adaptation planning and climate information, the wider institutional context may not be sufficiently conducive to supporting the use and usability of climate projections for local adaptation planning. This highlights that even more systematic communication or more empirically grounded tailoring endeavours may nevertheless remain futile even in countries further along the progress axis of adaptation planning. Whilst questions remain regarding what a wider setting that is more conducive to local adaptation planning might look like, with or without climate projections, this thesis nevertheless helps to highlight that usability discussions on the user-producer interaction and interface need to be considered in the wider institutional context.

5.2.4 Assessing and testing communication, tailoring and use

Objective 4: Evaluate the communication, tailoring and use of climate projections for adaptation planning.

Calling for a more systematic approach to the communication of climate science in general and climate projections more specifically, as well as improving the research community's and the climate information producers' and users' understanding of the usability of such information for adaptation planning can only be answered by an interdisciplinary approach. This response needs to encompass considerations: firstly, of how communication can be more systematically analysed and consequently addressed in a more structured way; secondly, of how the demand for more tailored communication of climate projections can be realised in practice; and thirdly, of how the use of this information on climate projections for adaptation planning is embedded within and determined by a wider institutional setting. Taken together the insights gleaned from Objectives 1-3 can help advance the understanding of the realities and practicalities of designing and providing effective communication tools for adaptation planning decision support. Drawing from the findings from the previous three research objectives, this last research objective will draw out three key considerations that are needed to achieve this and acknowledge how they all need to be considered in conjunction with each other.

5.2.4.1 Assessment procedures, techniques and frameworks

Communication tools for decision support need appropriate procedures, techniques and frameworks that help to assess and guide present and future communication approaches. Testing techniques and procedures could be employed to trial communications with different users before being launched. Both the UAF and the experimental design utilised for testing the visualisations can be employed prior to or during the conceptualisation of diverse forms of climate projections communications, as well as their associated uncertainties (visually or textually), to help inform a more structured process within which communication is developed and tested. This would help to move communication guidelines away from assumption based theoretical recommendations and towards establishing an empirically-grounded evidence base for communication designs.

Whilst the UAF is based on concepts developed to communicate uncertainties in the environmental and climate sciences, the experimental design for testing the visualisations was informed by insights gained predominantly from the health sciences and JDM literature (e.g. Galesic and Garcia-Retamero, 2011, Hawley et al., 2008, Hess et al., 2011, Shah and Freedman, 2011). This highlights that in order to develop the tools and techniques needed to achieve a more effective, systematic and empirically grounded approach to creating usable communication, it will be beneficial to utilise and build on those already developed in disciplines such as psychology, health science, communication science, design and JDM. The framework and techniques presented in this thesis have added to building a bigger repertoire of available methodologies that can be used for systematising climate science communication, but further interdisciplinary learning and methodological development is needed (see Section 5.6).

5.2.4.2 Audience awareness

For communication tools to be usable and effective decision support tools for adaptation, they need to be cognisant of their audiences. Building on the realisation in previous research that communication needs to be audience specific and that climate communication faces a number of different target audiences; this thesis puts forward the notion that it is necessary to take an even more fine-scale approach. Indeed, it seems essential to go beyond considering the ‘target audience’ as a single homogenous collective, but instead consider the individual decision-makers within the target audience, with their preferences, needs and demands, in much more detail.

Experimental testing of climate visualisations can help to explore the practicalities of information tailoring through a process of ‘individualising’ information. Furthermore, it can help to create a more comprehensive and empirically grounded baseline understanding of associations (and the lack thereof) between different constructs and biases relevant to information use and understanding. Whilst it will not be possible to facilitate individualised tailoring for every decision-maker planning for adaptation, advances in knowledge of the interplay between these biases, preferences and perceptions may facilitate the design of ‘more tailored’ rather than ‘most tailored’ climate visualisations.

5.2.4.3 Appreciation of the wider context

The third key consideration is that the use and application of communication tools for decision support will always be situated within a wider institutional context. Whilst important insights on the design of effective assessment tools and experimental techniques can be gleaned from other research fields, those studies have often focused only on the individual and not on decision-makers (and adaptation practitioners) that act within wider institutional settings. In addition, whilst there is an awareness of different risk governance and decision-making cultures (Jasanoff, 2011, Rothstein et al., 2012), the impact of those wider socioscientific contexts on the applicability of more structured scientific uncertainty communication is often not sufficiently considered.

Although more guiding standards and empirically grounded communication may be designed through systematic frameworks and more individualised tailoring that is mindful of the cognitive biases and the association between individuals' comprehension and preferences, these endeavours will ultimately be futile if they are not cognisant of the 'Realpolitik' of the wider context. The political will and the economic climate strongly influence the importance assigned to adaptation and consequently the use of climate projections for such planning decisions. This thesis has highlighted that whether the aim is to assess the communication of physical science uncertainties in NAS or the usability of climate projections for local adaptation planning; both issues need to be understood as nested within such a wider institutional context. Therefore insights from techniques, tools and frameworks considered in isolation will only reveal partial insights and solutions and thus risk remaining ineffective.

5.2.4.4 The interplay between communication, tailoring and use

Each one of the three considerations explored in the preceding paragraphs (the provision of procedures, techniques and frameworks; the awareness of the target audience; and the appreciation of the wider context) contributes to the creation of more effective communication tools and need to be studied and understood in their own right. However, addressing them in isolation of each other will not yield effective solutions. Even the most individualised and tailored climate projections will not be very usable if the external context does not create an enabling environment for their application to adaptation planning. Conversely, the institutional context may be very favourable to progressing adaptation planning, but if climate projections are not presented in a usable and individualised format they are unlikely to be integrated into the adaptation planning process. It is the recognition of this interplay and the consequential realisation that addressing only one or two of the three considerations will not suffice, that can help research and practice to move towards a more comprehensive approach at creating systematic and usable communication tools.

5.3 From theory into practice - implications of this research

The research presented in this thesis is specific to the NAS analysed for the ten countries in Chapter 2 and to the adaptation practitioners surveyed and interviewed from Germany and the UK in Chapter 3 and 4. Whilst caution should be applied in drawing general conclusions from the case studies, a number of key insights can nevertheless be outlined for the communication, tailoring and use of climate projections for adaptation planning. These insights, whilst providing valuable theoretical and empirical contributions to the academic debate on decision support can also be used to outline a number of practical recommendations and guidance points as well as highlighting where further research is needed.

1) **Provide diagnostic communication tools and frameworks:** Demands for more structured communication of climate projections and the related physical science uncertainties can be met with the help of diagnostic tools such as the UAF presented in Chapter 2. Tools such as the UAF can also be applied to other policy documents across a range of scales relevant to adaptation planning that want to clearly and transparently communicate the scientific underpinnings upon which the adaptation actions and measures they propose are based. This thesis demonstrated that the ten NAS analysed showed a bias towards communicating those uncertainties that were perceived as easier to quantify. In practice, this can help to highlight that not all the uncertainties that may be of concern to the adaptation planning process have been comprehensively communicated to the reader. Bringing attention to these gaps in communication can help raise awareness that further information may need to be sought and/ or that the communication in future documents ought to be adjusted to bring in these details on those uncertainties that are harder to quantify.

2) **Move towards reconciling user comprehension and preference:** To test the effectiveness of visualisations of climate projections (and their uncertainties) and consequentially their value as effective decision support tools, more attention needs to be paid to the associations between assessed comprehension and the more subjective measures of perceived comprehension and use for a variety of different visualisations. A clearer understanding of the specific design factors that

influence both comprehension and use will not only help to assess the effectiveness of those visualisations already in use, but may also help to guide future design and tailoring efforts for boundary organisations and climate services to provide more effective and individually tailored products. Climate service providers and boundary organisations may want to consider providing a choice of different visualisations to the user if information is communicated interactively. Once the user has stated his or her preferences (e.g. by clicking on the respective graph types) this could be followed up with one or two simple assessed comprehension questions for the specific graph type. This would allow the user to decide whether the chosen graph format is suited to their comprehension and preferences or whether they may want to consider a different graph type. Of course, this would require further testing to explore user perception and engagement with such an interactive approach. Furthermore, a clearer understanding needs to be achieved between reconciling the need to individualise tailoring of climate information, as demonstrated in this thesis, with the demand previously expressed to upscale tailoring efforts (Kirchhoff et al., 2013).

3) **Tailor to adaptation planning stages and scenarios:** In many cases, the users of climate visualisations use these not only to formulate planning decisions and help them in their own decision-making but also to further communicate with peers and superiors in their respective organisations who are part of the adaptation planning process. Chapter 3, for example, highlighted that users found the bubble plot to be more persuasive than the other graph formats. To better understand what kind of visualisations are usable during the adaptation planning process, and hence should be provided by climate services and boundary organisations, preferences for the type of visualisation (and the information content portrayed in a visualisation) for different decision and communication scenarios and different stages of adaptation planning need to be further explored. This could be used to not only tailor visualisations better to both user comprehension and user preferences, but also to the specific adaptation planning stages and processes that adaptation practitioners are undertaking.

4) **Reach out to the 'non-traditional' climate projections user**: This thesis has highlighted that adaptation planning is strongly influenced by the

wider political and economic setting, and is especially easily deprioritised locally, when budgets and staff are cut or reassigned to services considered to be more at the 'front line'. For the expertise on climate adaptation, on the one hand, and the use of climate projections, on the other hand, to not dwindle completely in such circumstances, it may be necessary to target users in departments or services that are traditionally less likely to be involved in adaptation as such. Thus, the tailoring of climate visualisations and communication tools ought to consider how they can also respond to a wider diversity of background expertise, knowledge and potential application of information to decision scenarios.

5.4 Reflections on the research approach

To respond to the call for more interdisciplinary research on the communication of climate science (Fischhoff, 2011, Pidgeon and Fischhoff, 2011) for adaptation decision-making, the research in this thesis was designed using a mixed method, multi-level approach. This approach provided the opportunity to not only examine the challenges to communicating, tailoring and using climate projections across different levels relevant to adaptation planning (Adger et al., 2005), but to highlight the interdependencies between and the resultant challenges for the communication at each of these levels.

Interdisciplinarity has been called a 'risky activity (…) often daunting and exhausting (…) but also exhilarating' (Robinson, 2008: 84). Reflecting on the research approach and research process for this thesis, this seems like a very poignant description. The multi-level mixed method approach combined a variety of quantitative and qualitative methods including content analysis, experimental survey design and interviews. Consequently, the data utilised in this thesis included: documentary data from NAS as well as planning and adaptation strategies, a wealth of quantitative data from GCM outputs used for the creation of the visualisations for the surveys, as well as the survey results and qualitative interview data from adaptation practitioners. The use of the different methods in conjunction with each other helped to provide a more comprehensive scrutiny of the practicalities of examining communication tools for adaptation planning decision support. It is only through the combination of the diverse methods and insights from the different disciplines across the different levels that a more realistic and pragmatic picture emerges.

However, the endeavour to empirically ground the request for more structured communication and increased usability of climate information using an interdisciplinary approach generates particular challenges in itself. By aiming to bring together the expertise and methods from a range of different disciplines in one research project, it is difficult to attain due and full appreciation for each individual discipline. This type of research therefore may be challenged for not sufficiently meeting the expectations posed by specialists in the fields of climate science, communication, psychology, judgement and decision-making, planning or policy making. Nevertheless, this thesis has helped to highlight, that only by bringing insights from all of these fields together, can the communication of climate science for adaptation planning be more comprehensively understood. The breadth of such an approach results in inadvertently having to fall short of engaging in as much depth with each individual field, as studies that are more specifically grounded in one particular discipline would be able to do. Yet, it nevertheless allows for a wider and more effective array of tools and methods for more systematic communication approaches to be suggested.

Knopman called for such a research approach to aid the integration of JDM ‘with the development of technical information and decision support tools for complex, long-term environmental problems’ (Knopman, 2006: 2). This thesis has put forward such an integrative approach specifically focused on the creation of effective communication tools for supporting adaptation decision-making. Whilst the findings suggest that this was useful in gaining a more pragmatic understanding of both the practicalities of specific decision support tools as well as embedding their usability within a wider institutional context, a number of limitations, nevertheless, ought to be highlighted.

5.5 Limitations

Although the methodological approach taken for this thesis has facilitated the collection and analysis of a rich set of empirical data and the emergence of a number of interesting and novel insights, a few limitations need to, nevertheless, be pointed out.

Whilst, the importance of the external institutional context has become clearer, questions remain as to what kind of interventions at the external institutional level are achievable to address the challenges identified by this research. The two case studies have highlighted that although the external context is influential on local adaptation practitioners in both countries, particular interventions to shape the external context would be context-specific and would require further research. It is likely that such interventions would be challenging to implement in practice as short-termism still largely dominates institutional settings that often struggle to consider the long-term planning needed for adaptation decision-making.

In relation to this, it also needs to be noted that the target group of this thesis were adaptation practitioners in local government. As described in the thesis, local government planning is very much driven by and embedded in specific institutional conditions. Target audiences in other sectors, both private and public, will be influenced by a different set of institutional factors which is likely to affect how they use climate projections and thus their perceptions of usability. The role of the wider institutional context on the usability of climate information emphasised in this thesis is thus likely to be sector dependent.

A further limitation of this thesis is that to investigate the associations between the comprehension and use, a hypothetical scenario and only a small number of 'test' visualisations were used. Thus, whilst it has been possible to highlight the associations or lack thereof between user comprehension and subjective preference measures for the four graph formats tested, it was not possible to investigate whether changing the graph formats in different ways or using alternative graph formats would render different results. Further empirical testing thus ought to be conducted with a bigger variety of visualisations and more specific decision-scenarios to corroborate the findings.

5.6 Future research directions

Future research can build further on the data collected as part of the research for this thesis. The surveys conducted in both countries also included questions assessing respondents' perceptions as to the 'aesthetics' and the perceived 'scientificness' of the different graph formats shown. Whilst these have not been explored further in this thesis, analysis of this data may yield interesting insights into the extent to which these constructs are associated with comprehension and use of information and may help guide further recommendations as to the tailoring of climate projections to user perceptions.

Furthermore, data on respondents' estimation of the likelihood of a change in temperature and the direction of that change, as well as information on respondents' confidence in their assessment has also already been collected through the German survey. Daron et al. (2015) in their study of testing climate data visualisations with practitioners in the vulnerability and adaptation community in Africa found that a higher estimation of likelihood of change is associated with a higher confidence in this estimation. It would thus be interesting to further explore the data from the German survey to examine to what extent confidence and comprehension are associated. This could help to further our understanding as to how individual assessments of likelihood and confidence may affect the use of visualisations and thus contribute to tailoring visualisations effectively so they are more cognisant of such potential cognitive biases.

The surveys conducted for this thesis focused specifically on local adaptation practitioners from two countries. However, the range of user groups of climate projections and climate information are very varied within and between countries. Further empirical testing of visualisations with other user groups from different sectors and different countries may therefore yield a more nuanced understanding of potential differences in comprehension and preferences. This would allow better insights as to which biases and (lack of) associations between constructs are more common across users and which are specific to certain sub-groups.

For the empirical testing of alternative graph formats, this thesis created graph formats based on GCM data for mid-century, but used these in a hypothetical adaptation planning scenario. Further research, ought to consider more systematic testing of visualisations and visual tools that are already being provided and used by adaptation practitioners for a variety of decision and planning contexts. This would provide more specific insights as to their usability and could help to improve the communication of decision-relevant information.

Lastly, Chapter 4 provided only a snapshot at a particular time with its analysis of the use of climate projections for local adaptation planning. As one of the key findings from this thesis is that the external institutional context substantially impacts the use of climate information at the local scale, it would be interesting to conduct a longitudinal study in both countries to capture changes in this wider context, such as legislation changes, economic recovery, political changes and analyse to what extent these filter down to the local level and affect the use and usability of climate projections for adaptation planning.

5.7 Conclusion

This thesis set out to analyse the complex interplay between communication, tailoring and use of climate projections (and their inherent uncertainties) in the context of adaptation planning. The mixed methods multi-level research approach enabled this thesis to make empirical and methodological in addition to theoretical contributions to advancing our knowledge of both understanding the communication of climate projections as well as their usability for adaptation planning.

Designing the UAF helped to not only provide a new diagnostic tool to enable a more structured approach to communicating physical science uncertainty in adaptation policy documents, but its practical application to the ten European NAS also provided an empirical insight on how this issue is dealt with in already existing documents. In addition, the exploratory analysis of the German and English NAS highlighted that any application of the UAF and similar frameworks that aim to systematise uncertainty communication will have to be cognisant of the respective wider institutional, cultural and political settings within which they are applied.

The experimental methodology applied to testing the different visualisations of climate projections provided rich empirical data on the interplay between user comprehension and preferences, which had not previously been examined within the field of climate visualisations for local adaptation planning. In addition, it contributed to the advancement of our understanding of how climate information more effectively tailored to user needs may be achieved by applying methodologies more commonly used in other research fields.

The semi-structured interviews conducted with some of the survey participants facilitated a more in-depth understanding of the actual usability of climate projections for local adaptation planning. By looking at the users potentially targeted by tailoring efforts and their practical adaptation planning contexts, this thesis has also highlighted that the usability and therefore ultimately the practical effectiveness of more tailored climate information can only be comprehensively assessed if the role of the external institutional context is taken into considerations. The wider economic and political setting strongly determines the status quo of local adaptation planning and thus will also provide an enabling or hindering context for the use and usability of climate projections for adaptation decision support.

Collecting data through a variety of methods and across a number of different scales, has allowed this thesis to take a detailed and holistic view on the communication and usability of climate information for adaptation planning. The thesis has advanced the state of the knowledge by highlighting that there is an intricate interplay between communicating, tailoring and using information for adaptation planning, that if ignored will render attempts to create a more structured approach to the communication of climate science to science users futile and ineffective.

Through the development of the UAF and the trialling of the tailoring of visualisations, this thesis has highlighted that creating structured and effective communication tools for adaptation planning decision support can be facilitated, but will require further research and empirical data to be more effectively designed. However, even with more effective communication tools at hand for decision support, the institutional context within which they are employed by adaptation practitioners may ultimately play the deciding role as to whether or not they are actually used. It has been highlighted how the tools, experimental designs and techniques utilised in the thesis could be useful for those organisations or knowledge producers that aim to improve the information provision for more effective adaptation planning. Yet, the research focus should also not stray too far from aiming to find solutions and pathways towards more enabling and conducive environments that are supportive of adaptation planning and consequently allow for the insights gained at the finer scales to be applicable and fruitful in practice.

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Appendix A
Online Resources for Chapter 2

A.1 Key features of European NAS

Table A-1 Key features of European NAS analysed in this study

	Country	Title	Year	Coordinating Body	Number of pages of strategy document	Action plans
BEL	Belgium	National climate change adaptation strategy	2010	Flemish Nature, Environment and Energy Department	51	National adaptation plan expected end of 2012
DEN	Denmark	Strategy for adaptation to a changing climate	2008	Danish Energy Agency	47	National action plan expected during 2012
ENG	England	Framework for action for adapting to climate change in England	2008	Department for Environment, Food and Rural Affairs	51	National adaptation plan for the UK expected in 2013
FIN	Finland	National strategy for	2005	Ministry of Agriculture and	280	*Action plan*

		adaptation to climate change		Forestry of Finland		*published in 2008*
FRA	France	National climate change impact adaptation plan	2006	Ministry of Ecology, Sustainable Development, Transport and Housing	72	*Strategy already contains very detailed actions and delivery partners*
GER	Germany	Strategy for adaptation to climate change	2008	Federal Ministry for the Environment, Nature Conservation and Nuclear safety	73	*Adaptation action plan published in 2011*
HUN	Hungary	National climate change strategy (NCCS) (extensive chapter on adaptation)	2008	Ministry for Environment and Water Department of Environmental Development	114 (20pp on adaptation specifically)	National adaptation strategic framework is planned as part of the first revision of the NCCS in 2013
NEL	Netherlands	National adaptation strategy	2007	Ministry of Housing, Spatial Planning and the Environment	Inter-administrative policy paper (16), Policy memorandum	Action plans are currently being undertaken

					(42)	
SCO	Scotland	Climate change adaptation framework	2009	The Scottish Government	34	National adaptation plan for the UK expected in 2013
WAL	Wales	Climate change strategy (extensive chapter on adaptation)	2010	Welsh Assembly Government	110 (22pp on adaptation specifically)	*Welsh adaptation delivery plan*
						National adaptation plan for the UK expected in 2013

Appendix B
Online Resources for Chapter 3

B.1 Questionnaire - UK

Welcome

The past year has shown us how much we can be affected by extreme weather events and how much damage such events can cause. Scientists and government produce climate projections of the future to help organisations minimise such damages under a changing future climate.

Are climate projections being communicated in a format that you can understand? Are there easier, more intuitive, ways of visualising and communicating the same information? This survey explores to what extent you understand and interpret visualisations of climate projections: are your needs being met? It is very important to understand your views and feed that back to the scientists. This research aims to improve scientific communication to help you and others better understand and interpret climate projections to enable you to create more resilient and future-proof organisations.

Who should get involved?

I am looking for people from the business community and the local government sector. Beyond that it doesn't matter if you are actively involved in the adaptation process within your organisation or are only just starting to think about it, are very experienced with using climate data or have always steered clear of graphs and figures, I would like to hear your opinion. It is extremely important that scientists take into account the views and perceptions of everyone who is expected to adapt to climate change when they design their communication, so all of your opinions are valued.

Project information

This survey is being conducted as part of a PhD project entitled 'Uncertainties in European climate projections and their consequences for National Adaptation Strategies' at the University of Leeds and is funded by the Natural Environment Research Council. This research project runs between Oct 2011 and September 2015.

Confidentiality and consent

Taking part in the survey is voluntary. If you do complete the survey you are consenting to your responses being collected and analysed. As the findings are going into a PhD thesis responses may be published, however, all data will be anonymised. I would like to reassure you that all the original data collected here will be kept in strictest confidence and will be used for research purposes only.

You have the right to withdraw at any point before submitting the survey. After that I can only withdraw your responses, up to the point when the data has been written up, if you provide a name and e-mail address at the end of the survey.

Findings and research outcomes

If you would like to know the findings from this survey and the outcomes of the further research, I would be happy to share these with you once all the data has been anonymised and written up. If you are interested please just get in touch!

Contact

If you have any questions about the survey or the research project please contact, Susanne Lorenz ee08sl@leeds.ac.uk

http://www.see.leeds.ac.uk/people/s.lorenz

Keep in touch

If you find this topic interesting and would be happy to be contacted again during further stages of the research please include your contact details at the end of the survey and/or get in touch with me directly.

How long will it take?

The survey should not take more than 20 minutes to complete.

Thank you very much for your time and your input!

About you

Participant

1. Are you a participant from the
   - Public Sector (please answer questions in section 1 and enter 'N/A' for the questions in section 2)
   - Business Community (please answer questions in section 2 and enter 'N/A' for the questions section 1)

Section 1

2. Name of Public Sector employer (Optional)

3. Department
4. Job title
5. Name of county

Section 2

6. Name of business sector employer (Optional)
7. Business sector
8. Business size
   - Less than 10
   - Between 10 and 50
   - Between 50 - 250
   - More than 250
9. Job title
10. Name of county business is located in

More about you

11. Your age
    - Under 20
    - 20 -29
    - 30-39
    - 40-49
    - 50-59
    - 60 and over
12. Your gender
    - Male
    - Female
13. Are you colour-blind?
    - Yes
    - No
14. Which qualifications do you have? Tick every box that applies if you have any of the qualifications listed.

If your UK qualification is not listed, tick the box that contains its nearest equivalent.

If you have qualifications outside the UK, tick the 'Foreign qualifications' box and the nearest UK equivalent (if known).

(select all that apply)

- 1-4 O Levels/ CSEs/ GCSEs (any grades), Entry Level, Foundation Diploma
- NVQ Level 1, Foundation GNVQ, Basic Skills
- 5+ O Levels (passes), CSEs (grade 1)/ GCSEs (Grades A*-C), School Certificate, 1 A Level/ 2-3 AS Levels/ VCEs, Higher Diploma
- NVQ Level 2, Intermediate GNVQ, City and Guilds Craft, BTEC First/ General Diploma, RSA Diploma
- Apprenticeship
- 2+ A Levels/ VCEs, 4+ AS Levels, Higher School Certificate, Progression/ Advanced Diploma
- NVQ Level 3, Advanced GNVQ, City and Guilds Advanced Craft, ONC, OND, BTEC National, RSA Advanced Diploma
- Degree (e.g. BSc, BA)
- Higher Degree (e.g. MA, MSc, PhD, PGCE)
- NVQ Level 4-5, HNC, HND, RSA Higher Diploma, BTEC Higher Level
- Professional qualifications (e.g. teaching, accountancy)
- Other vocational, work-related qualifications
- Foreign qualifications
- No qualifications

15. How many years of work experience have you got in your profession/ job? This can include different employers, but would exclude radical career shifts (e.g. from being a chef to being a maths teacher).

- 0-5 years
- 6-10 years
- 11-15 years
- 16-20 years
- 21-25 years
- 26-30 years
- 31-35 years

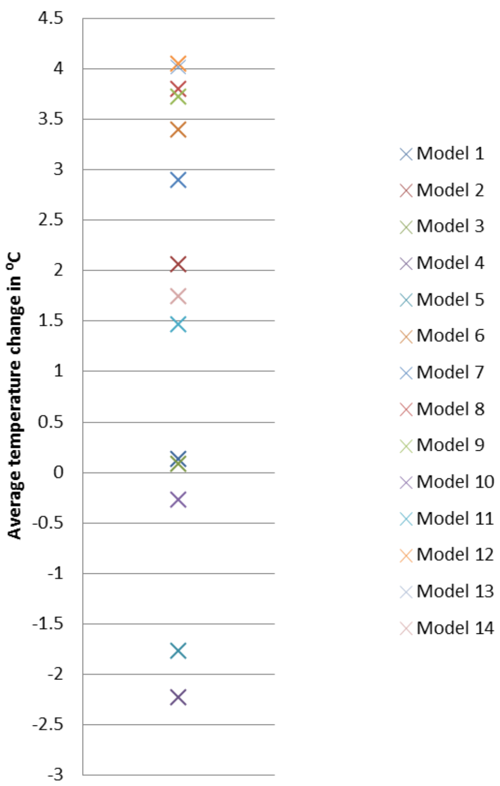
- 36-40 years
- 41-45 years

Visualisations of climate projections

In this section we want to see how easy to interpret and how intuitive you find different types of visualising climate change projections.

The data

The visualisations in this survey are based on monthly data from 14 global climate models created by climate modelling centres around the world, for the 2050s (2040 - 2069), under a medium emissions scenario. The data is for a 50 km x 50 km area in North East England.



The figure illustrates the change in average summer temperatures for the 2050s (2040 - 2069) as projected by each one of the 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004.

16. How many models project a decrease in summer temperature?

- 1
- 2
- 3

- 4

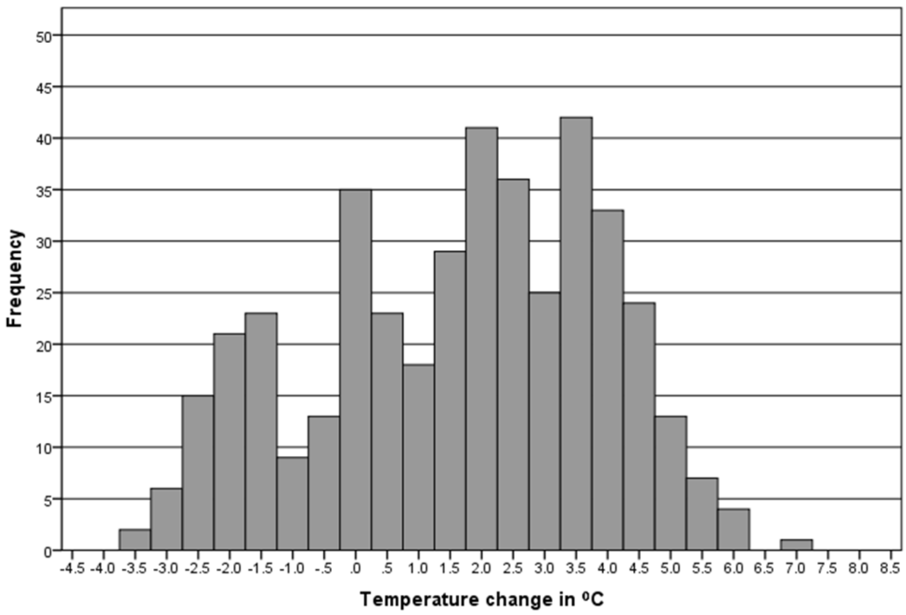
17. How many models project an increase in summer temperature by more than 3.0°C?

- 3
- 4
- 5
- 6

18. None of the models project a temperature change above which temperature value (to the nearest half of a degree)?

- -2.5°C
- 2°C
- 4.0°C
- 4.5°C

19. Science cannot tell us which of these models is the 'correct one'. Knowing this, which temperature value do you think your organisation should plan for?



The figure illustrates the change in summer temperature for the 2050s (2040 - 2069) as projected by 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004. Each bar represents a temperature range of 0.5°C (e.g. the bar marked '0°C' includes all projected temperature values between –0.25°C and 0.25°C). The focus in the figure rests on the midpoints in these ranges and the bars have been marked accordingly. The height of the bar depends on how frequently the values within its range have been projected by the models, and is thus linked to the likelihood of those values having been projected. In this plot we assume that each model is equally likely.

20. Which is the most likely temperature change projected by the models?

- -3.5°C
- 2.0°C
- 3.5°C
- 7.0°C

21. Which is the least likely temperature change projected by the models?

- -3.5°C
- 3.5°C
- 6.5°C
- 7.0°C

22. What is the range of projected temperature change in the figure?

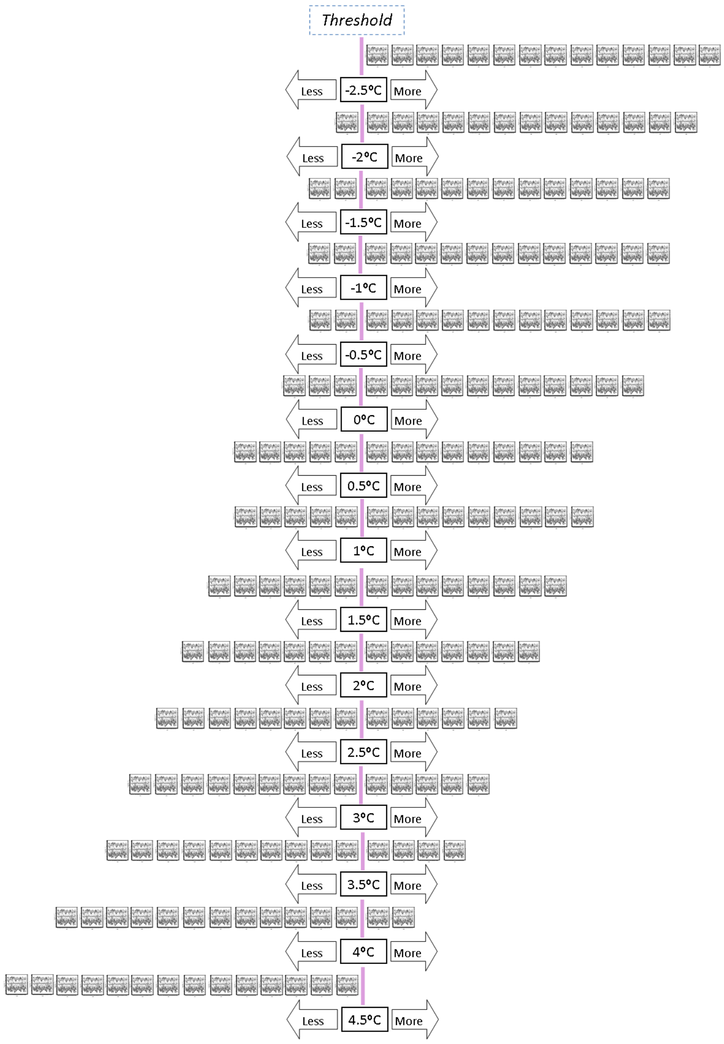
- Between -3.5°C and 7.0°C
- Between 0°C and 4.5°C
- Between -3.5°C and 6.0°C
- Between 2.0°C and 4.0°C

23. Which value is more likely -2.5°C or 5.0°C?

- -2.5°C
- 5.0°C

24. Are you more likely to get a temperature change below -2.5°C or above 5.0°C?

- below -2.5°C
- above 5.0°C



The figure illustrates the change in average summer temperatures for the 2050s (2040 - 2069) as projected by each one of the 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004. The figure shows how many models project a mean change above or below a number of thresholds. Each square represents a model. The purple line in the centre of each line of squares is the threshold and the respective temperature thresholds are given in the boxes beneath the purple line.

25. How many models project a decrease in summer temperature?

- 1
- 2
- 3
- 4

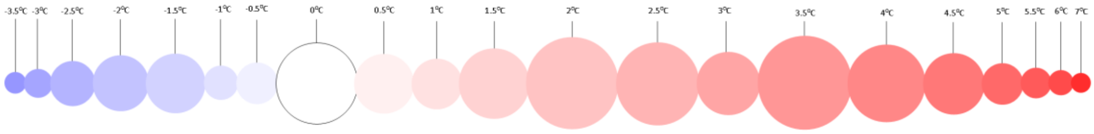
26. How many models project an increase in summer temperature by more than 3.0°C?

- 3
- 4
- 5
- 6

27. None of the models project a temperature change above which temperature threshold (to the nearest half of a degree)?

- -2.5°C
- 2°C
- 4.0°C
- 4.5°C

28. Science cannot tell us which of these models is the 'correct one'. Knowing this, which temperature threshold do you think your organisation should plan for?



The figure illustrates the change in summer temperature for the 2050s (2040 - 2069) as projected by 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004. Each bubble represents a temperature range of 0.5°C (e.g. the bubble marked '0°C' includes all projected temperature values between –0.25°C and 0.25°C). The focus in the figure rests on the midpoints in these ranges and the bubbles have been marked accordingly. The size of the bubble depends on how frequently the values within its range have been projected by the models, and is thus linked to the likelihood of those values having been projected. In this plot we assume that each model is equally likely.

29. Which is the most likely temperature change projected by the models?

- -3.5°C
- 2.0°C
- 3.5°C
- 7.0°C

30. Which is the least likely temperature change projected by the models?

- -3.5°C
- 3.5°C
- 6.5°C
- 7.0°C

31. What is the range of projected temperature change in the figure?

- Between -3.5°C and 7.0°C
- Between 0°C and 4.5°C
- Between -3.5°C and 6.0°C
- Between 2.0°C and 4.0°C

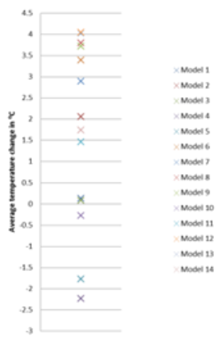
32. Which value is more likely -2.5°C or 5.0°C?

- -2.5°C
- 5.0°C

33. Are you more likely to get a temperature change below -2.5°C or above 5.0°C?

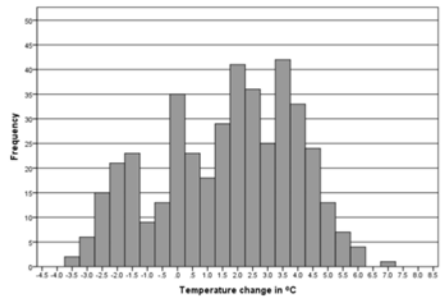
- below -2.5°C
- above 5.0°C

Figure 1



The figure illustrates the change in average summer temperatures for the 2050s (2040 - 2069) as projected by each one of the 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004.

Figure 2



The figure illustrates the change in summer temperature for the 2050s (2040 - 2069) as projected by 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004. Each bar represents a temperature range of 0.5°C (e.g. the bar marked '0°C' includes all projected temperature values between –0.25°C and 0.25°C). The focus in the figure rests on the midpoints in these ranges and the bars have been marked accordingly. The height of the bar depends on how frequently the values within its range have been projected by the models, and is thus linked to the likelihood of those values having been projected. In this plot we assume that each model is equally likely.

Figure 3

The figure illustrates the change in average summer temperatures for the 2050s (2040 - 2069) as projected by each one of the 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004. The figure shows how many models project a mean change above or below a number of thresholds. Each square represents a model. The purple line in the centre of each line of squares is the threshold and the respective temperature thresholds are given in the boxes beneath the purple line.

Figure 4

The figure illustrates the change in summer temperature for the 2050s (2040 - 2069) as projected by 14 global climate models under a medium emissions scenario relative to the temperatures of 1975 - 2004. Each bubble represents a temperature range of 0.5°C (e.g. the bubble marked '0°C' includes all projected temperature values between –0.25°C and 0.25°C). The focus in the figure rests on the midpoints in these ranges and the bubbles have been marked accordingly. The size of the bubble depends on how frequently the values within its range have been projected by the models, and is thus linked to the likelihood of those values having been projected. In this plot we assume that each model is equally likely.

34. Which figure did you find the easiest to understand?

- Figure 1
- Figure 2
- Figure 3
- Figure 4

35. Please briefly explain your choice in the space below (e.g. colour, type of graph used etc.). (Optional)

36. Which figure do you feel is presenting the information in the most scientific way?

- Figure 1

- Figure 2
- Figure 3
- Figure 4
- All of them equally

37. Please briefly explain your choice in the space below. (Optional)
38. Which figure do you find the most aesthetically pleasing to the eye?
    - Figure 1
    - Figure 2
    - Figure 3
    - Figure 4
39. Please briefly explain your choice in the space below. (Optional)
40. If you had to make a planning decision, which of these figures would you find most helpful for your decision-making process?
    - Figure 1
    - Figure 2
    - Figure 3
    - Figure 4
    - Depends on the decision
    - None of the above
41. Please briefly explain your choice in the space below. (Optional)
42. If you had to persuade someone in your organisation (e.g. your colleagues or your boss) of the necessity to start planning for changes in future summer temperatures, which one of these figures would you choose?
    - Figure 1
    - Figure 2
    - Figure 3
    - Figure 4
    - I wouldn't use a figure at all
43. Please briefly explain your choice in the space below. (Optional)

Knowledge, understanding and preference

The last section is about your knowledge, understanding and preferences. For each of the following questions, please check the box that best reflects your answer.

Knowledge and experience

44. How much do you engage with climate projections in your day-to-day job (e.g. UK Climate Projections)?

1 = Not at all

6 = A lot

1 2 3 4 5 6

45. How good is your knowledge of the topic of climate change?

1 = Not at all good

6 = Extremely good

1 2 3 4 5 6

46. Have you been actively involved in the climate change adaptation process in your organisation?

1 = Not at all

6 = A lot

1 2 3 4 5 6

Preference

47. When you hear a weather forecast, do you prefer predictions using percentages (e.g., "there will be a 20% chance of rain today") or predictions using only words (e.g., "there is a small chance of rain today")?

1 = Always prefer percentages

6 = Always prefer words

1 2 3 4 5 6

48. When people tell you the chance of something happening, do you prefer that they use words ("it rarely happens") or numbers ("there's a 1% chance")?

1 = Always prefer words

6 = Always prefer numbers

1 2 3 4 5 6

49. When reading the newspaper, how helpful do you find tables and graphs that are part of a story?

1 = Not at all helpful

6 = Extremely helpful

1 2 3 4 5 6

50. How often do you find numerical information to be useful in your line of work?

1 = Never

6 = Very often

1 2 3 4 5 6

51. How often do you use graphs and figures in your own work?

1 = Never

6 = Very often

1 2 3 4 5 6

Understanding

52. How good are you at working with fractions?

1 = Not at all good

6 = Extremely good

1 2 3 4 5 6

53. How good are you at working with percentages?

1 = Not at all good

6 = Extremely good

1 2 3 4 5 6

54. How good are you at figuring out how much a shirt will cost if it is 25% off?

1 = Not at all good

6 = Extremely good

1 2 3 4 5 6

55. How good are you at calculating a 15% tip?

1 = Not at all good

6 = Extremely good

1 2 3 4 5 6

Your comments and feedback

56. If you have any additional thoughts or suggestions, whether that is on the survey, other examples of visualising information that you really like or comments on the research, I would love to hear them. Please use the space below or get in touch with me directly (ee08sl@leeds.ac.uk) (Optional)

The University of Leeds will be conducting further research in this area during the next 24 months, if you would be happy to be contacted in the near future as part of a follow-up to this questionnaire to discuss some of the issues raised about climate change communication, please provide contact details below.

Your details

57. Name (Optional)

58. Email address (Optional)

59. Phone (Optional)

End of the survey

Thank you for your time and for taking part in this survey. Your participation is much appreciated!

If you would like to discuss this topic with me further please do not hesitate to get in touch:

Susanne Lorenz ee08sl@leeds.ac.uk

If you would like to find out more about my research please go to:

http://www.see.leeds.ac.uk/people/s.lorenz

B.2 Questionnaire - Germany

Herzlich Willkommen!

Das letzte Jahr hat uns gezeigt, wie sehr uns Extremwetterereignisse beeinflussen können und wie viel Schaden solche Ereignisse verursachen können. Wissenschaftler und die Regierung erstellen Klimaprojektionen für die Zukunft, um Organisationen dabei zu helfen, solche Schäden unter einem zukünftigem Klimawandel zu vermeiden.

Werden diese Klimaprojektionen in einer Art und Weise kommuniziert, die Sie verstehen? Gibt es einfachere, intuitivere Wege dieselben Informationen zu visualisieren und zu kommunizieren? Dieses Forschungsprojekt zielt darauf ab, wissenschaftliche Kommunikation zu verbessern and Ihnen die Informationen aus der Wissenschaft zum Thema Klimawandel in einer verständlichen Art und Weise näher zu bringen, sodass Sie die Risiken der möglichen Folgen für Ihre Organisationen abschätzen können.

Wer sollte sich beteiligen?

Dieses Forschungsprojekt richtet sich insbesondere an Personen, die im Amts- oder Verwaltungswesen arbeiten, sei es bei der Stadt, der Gemeinde, dem Landkreis, oder beim Land. Ob Sie aktiv bei Ihrer Organisation im Klimaanpassungsprozess involviert sind oder gerade erst anfangen sich mit dem Thema zu beschäftigen, ist nicht von Bedeutung. Kern der Sache ist es, Ihre Meinung zu hören, denn Wissenschaftler müssen diese kennen, wenn sie mit Ihnen kommunizieren wollen.

Information zum Forschungsprojekt

Diese Befragung wird als Teil einer Doktorarbeit mit dem Titel "Unsicherheiten in europäischen Klimaprojektionen und deren Auswirkungen auf nationale Anpassungsstrategien" an der University of Leeds, Großbritannien, durchgeführt und wird durch den Forschungsrat für die natürliche Umwelt (Natural Environment Research Council) in Großbritannien finanziert. Das Forschungsprojekt läuft von Oktober 2011 bis September 2015.

Einverständnis und Vertraulichkeit

Die Teilnahme an dieser Befragung ist freiwillig. Wenn Sie diese Befragung ausfüllen, stimmen Sie der Erfassung und Analyse Ihrer Antworten zu. Da die Ergebnisse in eine Doktorarbeit eingebunden werden, werden Antworten eventuell veröffentlicht. Natürlich werden alle Daten vorher anonymisiert. Ich versichere Ihnen, dass alle hier gesammelten Originaldaten vertraulich behandelt und nur zu **Forschungszwecken verwendet werden.**

Es steht Ihnen frei, die Befragung jederzeit im Laufe der Bearbeitung abzubrechen, wenn Sie es wünschen. In diesem Fall, kann das Forschungsprojekt nur dann auf die bereits eingegebenen Daten zugreifen, wenn Sie einen Namen und eine Emailadresse am Ende der Befragung hinterlassen.

Forschungsergebnisse

Falls Sie Interesse an den Resultaten der Befragung bzw. dem gesamten Forschungsprojekt haben, teile ich Ihnen diese sehr gern mit, sobald alle Daten anonymisiert und ausgewertet sind. In diesem Fall, können Sie mich, Susanne Lorenz, gerne der unten genannten Emailadresse kontaktieren.

Kontakt

Wenn Sie Fragen zur Erhebung oder zum Forschungsprojekt haben, kontaktieren Sie bitte Susanne Lorenz unter ee08sl@leeds.ac.uk

http://www.see.leeds.ac.uk/people/s.lorenz

Bleiben Sie in Verbindung

Falls Sie dieses Thema interessant finden und es Ihnen nichts ausmachen würde, nochmals für die nächsten Forschungsphasen kontaktiert zu werden, dann hinterlassen Sie bitte Ihre Kontaktdaten am Ende der Befragung oder setzen Sie sich direkt mit mir in Verbindung.

Navigation

Um zur nächsten Frage zu gelangen, drücken Sie bitte die Weiter-Taste. Bitte verwenden Sie ab diesem Zeitpunkt die Vor- und Zurücktasten in Ihrem Browserfenster nicht mehr, denn das wird die Befragung abbrechen. Erst wenn die Befragung beendet ist und die letzte Seite erreicht wurde, werden alle Antworten automatisch gespeichert. Falls Sie vorher abbrechen, wird keine Ihrer Antworten gespeichert sein.

Herunterladen der grafischen Darstellungen

Es kann vorkommen, dass Ihr Internetbrowser Abbildungen als „unsichere Elemente" erkennt und Sie fragt, ob Sie diese herunterladen wollen. Nur wenn Sie dies akzeptieren, werden Sie die grafischen Darstellungen auch sehen können. Hervorgerufen wird diese Meldung durch bestimmte IT-Einstellungen in Ihrer Organisation.

Wie lange dauert die Befragung?

Die Befragung wird Sie nicht mehr als 25 Minuten Ihrer wertvollen Zeit berauben.

Vielen Dank, dass Sie sich die Zeit nehmen, dieses Forschungsprojekt zu unterstützen.

Über Sie

1. Arbeiten Sie
   - Im öffentlichen Dienst (Gemeindeebene)
   - Im öffentlichen Dienst (Landesebene)
   - Im öffentlichen Dienst (Bundesebene)
   - In der Forschung
   - Für ein Privatunternehmen
   - Sonstige(s) (Bitte machen Sie nähere Angaben):
2. Für welche(s) Organisation/ Amt/ Einrichtung arbeiten Sie? (Beantwortung freigestellt)
3. In welcher Abteilung arbeiten Sie? (Beantwortung freigestellt)
4. Als was sind Sie tätig?
5. In welchem Bundesland arbeiten Sie?
6. Wie viele Angestellte hat die Organisation/ das Amt/ die Einrichtung für welche(s) Sie arbeiten? (Beantwortung freigestellt)
   - Weniger als 10
   - Zwischen 10 und 50
   - Zwischen 50 und 250
   - Mehr als 250
7. Wie alt sind Sie?
   - Unter 20
   - 20 -29
   - 30-39
   - 40-49
   - 50-59
   - 60 und älter
8. Welches Geschlecht haben Sie?
   - Männlich
   - Weiblich
9. Sind Sie farbenblind?

- Ja
- Nein
- Ich bin mir nicht sicher

10. Welche Abschlüsse haben Sie erzielt? Kreuzen Sie bitte alle Antworten an, die auf Sie zutreffen.

Ordnen Sie bitte im Ausland erworbene Abschlüsse einem gleichwertigen deutschen Abschluss zu.

(Wählen Sie alle zutreffenden)

- Abschluss nach höchstens 7 Jahren Schulbesuch (insbesondere Abschluss im Ausland)
- Haupt-/Volksschulabschluss
- Realschulabschluss (Mittlere Reife), Abschluss an der Polytechnischen Oberschule oder gleichwertiger Abschluss
- Fachhochschulreife
- Allgemeine oder fachgebundene Hochschulreife
- Anlernausbildung oder berufliches Praktikum von mindestens 12 Monaten
- Berufsvorbereitungsjahr
- Lehre, Berufsausbildung im dualen System
- Vorbereitungsdienst für den mittleren Dienst in der öffentlichen Verwaltung
- Berufsqualifizierender Abschluss an einer Berufsfachschule/Kollegschule, Abschluss einer 1-jährigen Schule des Gesundheitswesens
- 2- oder 3-jährige Schule des Gesundheitswesens (z. B. Krankenpflege, PTA, MTA)
- Fachschulabschluss (Meister/-in, Techniker/-in oder gleichwertiger Abschluss)
- Berufsakademie, Fachakademie
- Abschluss an einer Verwaltungsfachhochschule
- Fachhochschulabschluss, auch Ingenieurschulabschluss
- Abschluss einer Universität/ wissenschaftlichen Hochschule/ Kunsthochschule
- Promotion

- Kein Abschluss

11. Wie viele Jahre an Arbeitserfahrung haben Sie in Ihrem Beruf? Das schließt unterschiedliche Arbeitgeber mit ein. Drastische Berufswechel sind davon ausgeschlossen (z.B. ein Berufswechsel vom Koch zum Mathelehrer).

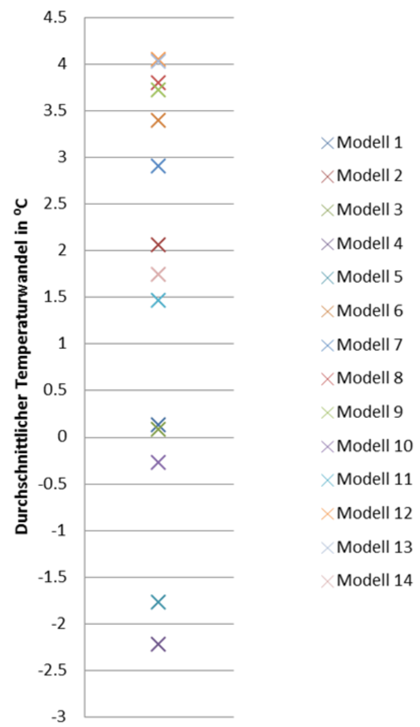
- 0-5 Jahre
- 6-10 Jahre
- 11-15 Jahre
- 16-20 Jahre
- 21-25 Jahre
- 31-35 Jahre
- 36-40 Jahre
- 41-45 Jahre

Grafische Darstellung von Klimaprojektionen

In diesem Teil der Befragung möchten wir sehen, wie einfach es für Sie ist verschiedene grafische Darstellungen von Klimaprojektionen zu interpretieren und wie erfassbar Sie diese finden.

Die Klimadaten

Die grafischen Darstellungen in dieser Erhebung basieren auf monatlichen Projektionen von 14 globalen Klimamodellen für die Mitte dieses Jahrhunderts (2040 - 2069) unter der Annahme einer gemäßigten zukünftigen Entwicklung von Treibhauskonzentrationen in der Atmosphere. Diese wurden von Klimamodellierzentren rund um den Globus erstellt. Die Daten beziehen sich auf ein 50 km mal 50 km großes Gebiet im Nordosten von Deutschland.



Die Abbildung zeigt den Wandel der Sommermitteltemperatur für die Mitte dieses Jahrhunderts (2040 – 2069) im Vergleich zu den Temperaturen von 1975 – 2004, wie er von jedem der 14 globalen Klimamodelle unter der Annahme einer gemäßigten zukünftigen Entwicklung von Treibhausgaskonzentrationen in der Atmosphere simuliert wird.

12. Wie viele Modelle zeigen eine Abnahme der Sommermitteltemperaturen?

- 1
- 2
- 3
- 4

13. Wie viele Modelle zeigen einen Anstieg der Sommermitteltemperaturen von mehr als 3.0°C?

- 3
- 4
- 5
- 6

14. Keines der Klimamodelle zeigt einen Temperaturwandel über welcher Temperatur (zum nächstgelegenen halben Grad gerundet)?

- -2.5°C

- 2°C
- 4.0°C
- 4.5°C

15. Die Wissenschaft kann uns nicht sagen, welches dieser Modelle richtig liegt. Mit diesem Wissen im Hinterkopf, für welchen Temperaturwert sollte Ihre Organisation, Ihrer Meinung nach, planen?
16. Was erwarten Sie, wie sich die Sommermitteltemperatur entsprechend dieser Abbildung in der Zukunft ändern wird?

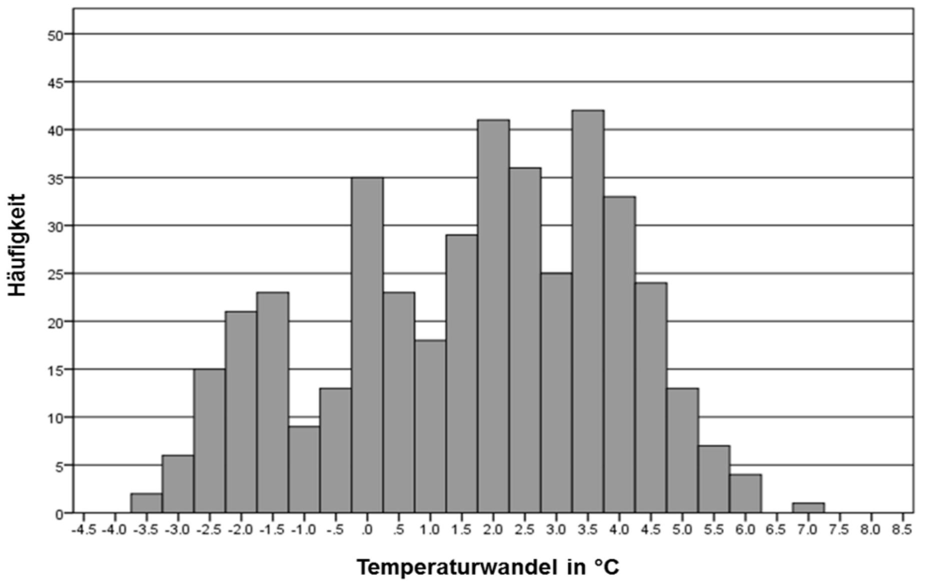
- Hohe Wahrscheinlichkeit einer Abnahme
- Mittlere Wahrscheinlichkeit einer Abnahme
- Niedrige Wahrscheinlichkeit einer Abnahme
- Keine Veränderung in der Zukunft
- Hohe Wahrscheinlichkeit eines Anstiegs
- Mittlere Wahrscheinlichkeit eines Anstiegs
- Niedrige Wahrscheinlichkeit eines Anstiegs

17. Wie überzeugt sind Sie von Ihrer Antwort zur vorherigen Frage?

1 = Gar nicht überzeugt

6 = Äußerst überzeugt

1 2 3 4 5 6



Die Abbildung zeigt den Wandel der Sommermitteltemperatur für die Mitte dieses Jahrhunderts (2040 – 2069) im Vergleich zu den Temperaturen von 1975 – 2004, wie er von jedem der 14 globalen Klimamodelle unter der Annahme einer gemäßigten zukünftigen Entwicklung von Treibhausgaskonzentrationen in der Atmosphere simuliert wird. Jeder Balken stellt eine Temperaturspanne von 0.5°C dar (z.B. der Balken der als '0°C' gekennzeichnet ist, beinhaltet alle simulierten Temperaturwerte zwischen –0.25°C und 0.25°C). Der Fokus in dieser Abbildung ist auf den Mittelpunkten in diesen Spannen und die Balken wurden dementsprechend gekennzeichnet. Die Höhe der Balken hängt davon ab, wie häufig die Werte in ihrer Spanne von den Modellen simuliert wurden, und ist somit mit der Wahrscheinlichkeit der Projektion dieser Werte verbunden. In dieser Abbildung nehmen wir an, dass jedes Modell die gleiche Wahrscheinlichkeit hat.

18. Basierend auf den Projektionen der Modelle, welchen Temperaturwandel halten Sie für den Wahrscheinlichsten?

- -3.5°C
- 2.0°C
- 3.5°C
- 7.0°C

19. Basierend auf den Projektionen der Modelle, welchen Temperaturwandel halten Sie für den Unwahrscheinlichsten?

- -3.5°C
- 3.5°C
- 6.5°C
- 7.0°C

20. Welche Wertespanne zeigen die Klimamodelle in der Abbildung?

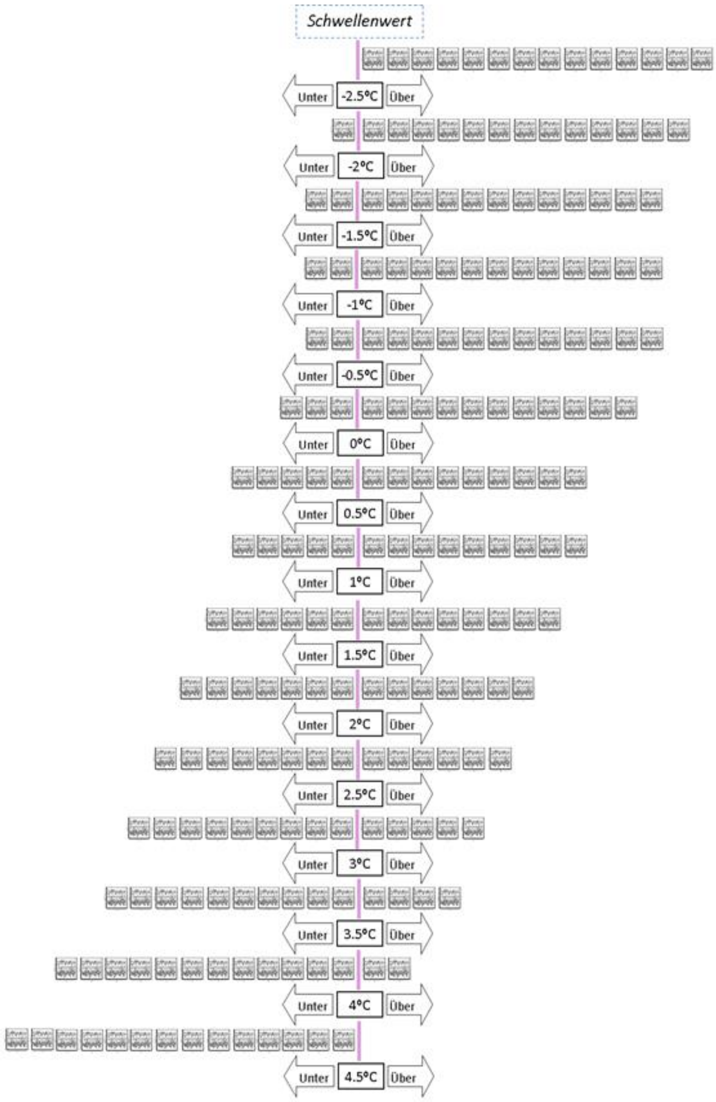
- Zwischen -3.5°C und 7.0°C
- Zwischen 0°C und 4.5°C
- Zwischen -3.5°C und 6.0°C
- Zwischen 2.0°C und 4.0°C

21. Welcher Wert ist wahrscheinlicher: -2.5°C oder 5.0°C?
    - -2.5°C
    - 5.0°C
22. Ist ein Temperaturwandel unter -2.5°C oder über 5.0°C wahrscheinlicher?
    - unter -2.5°C
    - über 5.0°C
23. Was erwarten Sie, wie sich die Sommermitteltemperatur entsprechend dieser Abbildung in der Zukunft ändern wird?
    - Hohe Wahrscheinlichkeit einer Abnahme
    - Mittlere Wahrscheinlichkeit einer Abnahme
    - Niedrige Wahrscheinlichkeit einer Abnahme
    - Keine Veränderung in der Zukunft
    - Hohe Wahrscheinlichkeit eines Anstiegs
    - Mittlere Wahrscheinlichkeit eines Anstiegs
    - Niedrige Wahrscheinlichkeit eines Anstiegs
24. Wie überzeugt sind Sie von Ihrer Antwort zur vorherigen Frage?

1 = Gar nicht überzeugt

6 = Äußerst überzeugt

1 2 3 4 5 6



Die Abbildung zeigt den Wandel der Sommermitteltemperatur für die Mitte dieses Jahrhunderts (2040 – 2069) im Vergleich zu den Temperaturen von 1975 – 2004, wie er von jedem der 14 globalen Klimamodelle unter der Annahme einer gemäßigten zukünftigen Entwicklung von Treibhausgaskonzentrationen in der Atmosphere simuliert wird. Die Abbildung zeigt wie viele Modelle einen durchschnittlichen Wandel unter oder über einer Anzahl von Schwellenwerten simulieren. Jedes Quadrat repräsentiert ein Modell. Die lila Linie in der Mitte jeder Quadratreihe ist der Schwellenwert und der jeweilige Temperaturwert ist in dem Kasten unter der lila Linie angegeben.

25. Wie viele Modelle zeigen eine Abnahme der Sommermitteltemperaturen?

- 1
- 2
- 3
- 4

26. Wie viele Modelle zeigen einen Anstieg der Sommermitteltemperaturen von mehr als 3.0°C?

- 3
- 4
- 5

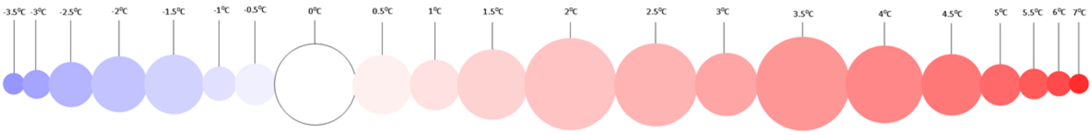
- 6

27. Keines der Klimamodelle zeigt einen Temperaturwandel über welcher Temperatur (zum nächstgelegenen halben Grad gerundet)?
    - -2.5°C
    - 2°C
    - 4.0°C
    - 4.5°C
28. Die Wissenschaft kann uns nicht sagen, welches dieser Modelle richtig liegt. Mit diesem Wissen im Hinterkopf, für welchen Temperaturwert sollte Ihre Organisation, Ihrer Meinung nach planen?
29. Was erwarten Sie, wie sich die Sommermitteltemperatur entsprechend dieser Abbildung in der Zukunft ändern wird?
    - Hohe Wahrscheinlichkeit einer Abnahme
    - Mittlere Wahrscheinlichkeit einer Abnahme
    - Niedrige Wahrscheinlichkeit einer Abnahme
    - Keine Veränderung in der Zukunft
    - Hohe Wahrscheinlichkeit eines Anstiegs
    - Mittlere Wahrscheinlichkeit eines Anstiegs
    - Niedrige Wahrscheinlichkeit eines Anstiegs
30. Wie überzeugt sind Sie von Ihrer Antwort zur vorherigen Frage?

1 = Gar nicht überzeugt

6 = Äußerst überzeugt

1 2 3 4 5 6



Die Abbildung zeigt den Wandel der Sommermitteltemperatur für die Mitte dieses Jahrhunderts (2040 – 2069) im Vergleich zu den Temperaturen von 1975 – 2004, wie er von jedem der 14 globalen Klimamodelle unter der Annahme einer gemäßigten zukünftigen Entwicklung von Treibhausgaskonzentrationen in der Atmosphere simuliert wird. Jede Blase stellt eine Temperaturspanne von 0.5°C dar (z.B. die Blase die als '0°C' gekennzeichnet ist, beinhaltet alle simulierten Temperaturwerte zwischen –0.25°C und 0.25°C). Der Fokus in dieser Abbildung ist auf den Mittelpunkten in diesen Spannen und die Blasen wurden dementsprechend gekennzeichnet. Die Größe der Blase hängt davon ab, wie häufig die Werte in ihrer Spanne von den Modellen simuliert wurden, und ist somit mit der Wahrscheinlichkeit der Projektion dieser Werte verbunden. In dieser Abbildung nehmen wir an, dass jedes Modell die gleiche Wahrscheinlichkeit hat.

31. Basierend auf den Projektionen der Modelle, welchen Temperaturwandel halten Sie für den Wahrscheinlichsten?

- -3.5°C
- 2.0°C
- 3.5°C
- 7.0°C

32. Basierend auf den Projektionen der Modelle, welchen Temperaturwandel halten Sie für den Unwahrscheinlichsten?

- -3.5°C
- 3.5°C
- 6.5°C
- 7.0°C

33. Welche Wertespanne zeigen die Klimamodelle in der Abbildung?

- Zwischen -3.5°C und 7.0°C
- Zwischen 0°C und 4.5°C
- Zwischen -3.5°C und 6.0°C
- Zwischen 2.0°C und 4.0°C

34. Welcher Wert ist wahrscheinlicher: -2.5°C oder 5.0°C?

- -2.5°C
- 5.0°C

35. Ist ein Temperaturwandel unter -2.5°C oder über 5.0°C wahrscheinlicher?

- unter -2.5°C
- über 5.0°C

36. Was erwarten Sie, wie sich die Sommermitteltemperatur entsprechend dieser Abbildung in der Zukunft ändern wird?

- Hohe Wahrscheinlichkeit einer Abnahme

- Mittlere Wahrscheinlichkeit einer Abnahme
- Niedrige Wahrscheinlichkeit einer Abnahme
- Keine Veränderung in der Zukunft
- Hohe Wahrscheinlichkeit eines Anstiegs
- Mittlere Wahrscheinlichkeit eines Anstiegs
- Niedrige Wahrscheinlichkeit eines Anstiegs

37. Wie überzeugt sind Sie von Ihrer Antwort zur vorherigen Frage?

1 = Gar nicht überzeugt

6 = Äußerst überzeugt

1 2 3 4 5 6

Abbildung 1

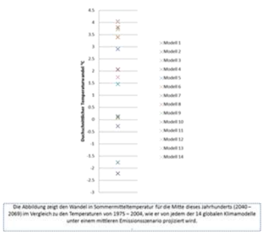


Abbildung 2

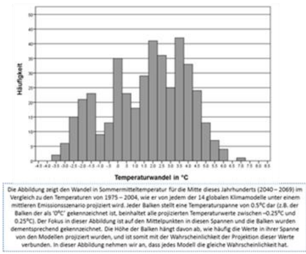


Abbildung 3

Abbildung 4

38. Welche der Abbildungen fanden Sie am einfachsten zu verstehen?
    - Abbildung 1
    - Abbildung 2
    - Abbildung 3
    - Abbildung 4

39. Bitte erläutern Sie hier kurz Ihre Wahl (z.B. Farbe, Art der benutzten Abbildung etc.) (Beantwortung freigestellt)

40. Welche Abbildung repräsentiert, Ihrer Meinung nach, die Information in der wissenschaflichsten Art und Weise?
    - Abbildung 1

- Abbildung 2
- Abbildung 3
- Abbildung 4
- Alle vier gleichwertig

41. Bitte erläutern Sie hier kurz Ihre Wahl. (Beantwortung freigestellt)
42. Welche Abbildung finden Sie am ästhetischsten?

- Abbildung 1
- Abbildung 2
- Abbildung 3
- Abbildung 4

43. Bitte erläutern Sie hier kurz Ihre Wahl. (Beantwortung freigestellt)
44. Welche dieser Abbildung würden Sie für Ihren Entscheidungsprozess am hilfreichsten finden, wenn Sie eine Planungsentscheidung treffen müssten?

- Abbildung 1
- Abbildung 2
- Abbildung 3
- Abbildung 4
- Das hängt von der Entscheidung ab
- Keine der hier gezeigten Abbildungen

45. Bitte erläutern Sie hier kurz Ihre Wahl. (Beantwortung freigestellt)
46. Welche dieser Abbildungen würden Sie auswählen, wenn Sie jemanden (z.B. einen Kollegen oder Vorgesetzten) in Ihrer Organisation davon überzeugen müssten, dass es nötig ist, anzufangen für einen Wandel in zukünftigen Sommertemperaturen zu planen?

- Abbildung 1
- Abbildung 2
- Abbildung 3
- Abbildung 4
- Ich würde überhaupt keine Abbildung benutzen

47. Bitte erläutern Sie hier kurz Ihre Wahl. (Beantwortung freigestellt)

48. Falls diese grafischen Darstellungen zur Kommunikation von Klimaprojektionen benutzt werden würden, wie sehr würden Sie der Zuverlässigkeit der zugrunde liegenden Informationen vertrauen?

1 = Gar nicht

6 = Äußerst viel

1 2 3 4 5 6

- Abbildung 1
- Abbildung 2
- Abbildung 3
- Abbildung 4

Wissen, Verständnis und Präferenz

Der letzte Teil dreht sich um Ihr Wissen, Ihr Verständnis und Ihre Präferenzen. Kreuzen Sie bitte für jede der folgenden Fragen das an, was am besten auf Sie zutrifft.

Wissen und Erfahrung

49. Wie viel beschäftigen Sie sich mit Klimaprojektionen in Ihrem täglichen Beruf?

1 = Nie

6 = Sehr viel

1 2 3 4 5 6

50. Wie gut ist Ihr Wissen zum Thema Klimawandel?

1 = Gar nicht gut

6 = Äußerst gut

1 2 3 4 5 6

51. Sind Sie aktiv im Klimaanpassungsprozess in Ihrer Organisation eingebunden?

1 = Gar nicht

6 = Sehr viel

1 2 3 4 5 6

Präferenzen

52. Wenn Sie den Wetterbericht hören, bevorzugen Sie dann Vorhersagen mit Prozenten (z.B. ‚es gibt eine 20% Chance, dass es heute regnet') oder Vorhersagen die nur Wörter benutzen (z.B. ‚es gibt eine geringe Chance, dass es heute regnet')?

1 = Bevorzuge immer Prozente

6 = Bevorzuge immer Wörter

1 2 3 4 5 6

53. Wenn Ihnen die Chance, dass etwas passiert, gesagt wird, bevorzugen Sie dann Wörter (‚es passiert selten') oder Nummern (‚es gibt eine 1% Chance')?

1 = Bevorzuge immer Wörter

6 = Bevorzuge immer Nummern

1 2 3 4 5 6

54. Wenn Sie die Zeitung lesen, wie hilfreich finden Sie Tabellen und Graphen, die Teil einer Geschichte sind?

1 = Gar nicht hilfreich

6 = Äußerst hilfreich

1 2 3 4 5 6

55. Wie oft finden Sie numerische Informationen in Ihrer Arbeit nützlich?

1 = Nie

6 = Sehr oft

1 2 3 4 5 6

56. Wie oft benutzen Sie Graphen und Abbildungen in Ihrer eigenen Arbeit?

1 = Nie

6 = Sehr oft

1 2 3 4 5 6

57. Es gibt unterschiedliche Wege die Unsicherheiten in Klimaprojektionen zu kommunizieren.

   a) Wie nützlich finden Sie verbale Beschreibungen (z.B. Wahrscheinlichkeitsaussagen)?

b) Wie nützlich finden Sie numerische Beschreibungen (z.B. Prozente, Wertebereiche)?

c) Wie nützlich finden Sie grafische Darstellungen (z.B. Abbildungen und Graphen)?

1 = Gar nicht nützlich

6 = Äußerst nützlich

1 2 3 4 5 6

Verständnis

58. Als wie gut würden Sie sich beim Arbeiten mit Brüchen einschätzen?

1 = Gar nicht gut

6 = Äußerst gut

1 2 3 4 5 6

59. Als wie gut würden Sie sich beim Arbeiten mit Prozenten einschätzen?

1 = Gar nicht gut

6 = Äußerst gut

1 2 3 4 5 6

60. Als wie gut würden Sie sich dabei einschätzen, auszurechnen wie viel ein Hemd mit 25% Rabatt kostet?

1 = Gar nicht gut

6 = Äußerst gut

1 2 3 4 5 6

61. Als wie gut würden Sie sich dabei einschätzen, ein Trinkgeld von 15% auszurechnen?

1 = Gar nicht gut

6 = Äußerst gut

1 2 3 4 5 6

Ihre Kommentare und Feedback

62. Falls Sie noch weitere Gedanken oder Vorschläge haben, sei es zur Befragung, Beispiele zur grafischen Darstellungen von Informationen, die Ihnen

besonders gefallen oder Kommentare zu dieser Forschung, teilen Sie mir diese gerne mit. Bitte nutzen Sie dieses Feld oder kontaktieren Sie mich direkt (ee08sl@leeds.ac.uk) (Beantwortung freigestellt)

Die University of Leeds wird in den kommenden 24 Monate noch weitere Forschungsaktivitäten in diesem Bereich betreiben. Ich würde mich freuen, wenn ich Sie auch zukünftig zur Weiterverfolgung dieser Befragung, kontaktieren darf, um manche dieser Themenpunkte im Bereich Klimakommunikation zu diskutieren. Sollten Sie einverstanden sein, dann bitte ich Sie hier Ihre Kontaktdaten zu hinterlassen. Ihre Antworten in der Befragung bleiben natürlich trotzdem anonym and die Angabe der Kontaktdaten ist davon unabhängig.

Ihre Angaben

63. Name (Beantwortung freigestellt)
64. Emailadresse (Beantwortung freigestellt)
65. Telefonnummer (Beantwortung freigestellt)

Ende der Befragung

Vielen Dank, dass Sie sich die Zeit genommen haben, an dieser Befragung teilzunehmen.

Falls Sie dieses Thema weiter diskutieren möchten, setzen Sie sich einfach mit mir in Verbindung:

Susanne Lorenz ee08sl@leeds.ac.uk

Falls Sie mehr über dieses Forschungsprojekt herausfinden möchten, finden Sie mehr Informationen auf dieser Seite (auf Englisch):

http://www.see.leeds.ac.uk/people/s.lorenz

Sie können mir auch auf Twitter folgen:

https://twitter.com/Susanne_Lorenz

B.3 Effects of other sample characteristics on comprehension and use

Table B-1 Effects of other sample characteristics on assessed comprehension.

				Mann-Whitney U test results		Kruskal-Wallis test results					
				Gender	**Education**		**Age**	**Work experience**	**Projections engagement**	**CC knowledge**	**Adapta-tion involve-ment**
	Pair 1										
A	**ACS - scatter plot**	**UK**	**U**	1150.5	292.0	**χ²**	2.81	7.08	3.16	6.94	6.75
			z	-.26	-.50						
		Germany	**U**	4.65	N/A	**χ²**	4.01	4.04	6.52	7.62	1.76
			z	-.36	N/A						
	ACS - pictograph	**UK**	**U**	***889.5**	308.5	**χ²**	0.23	5.05	3.69	1.81	6.238
			z	-2.20	-.20						
		Germany	**U**	4.28	N/A	**χ²**	3.24	3.76	2.92	2.77	2.57
			z	-.85	N/A						
	Pair 2										
	ACS -	**UK**	**U**	1060.5	308.5	**χ²**	6.19	5.74	2.48	3.53	10.99

histogram		**z**	-1.03	-.22						
	Germany	**U**	.46	N/A	χ^2	6.33	6.10	8.87	2.66	2.50
		z	-.34	N/A						
ACS – bubble plot	**UK**	**U**	1149.5	209.5	χ^2	2.70	13.47	7.86	4.53	4.52
		z	-.25	-1.78						
	Germany	**U**	.46	N/A	χ^2	2.97	9.48	5.77	6.01	8.40
		z	-.36	N/A						

* p < .05; ** p < .01; *** p < .001

Table B-2 Effects of other sample characteristics on perceived comprehension, use for self and use for showing to others.

Chi-square test for independence test results

				Age	Gender	Education	Work experience	Projections engagement	CC knowledge	Adaptation involvement
B	PC	**UK**	χ^2	14.64	1.88	1.29	13.77	16.45	13.94	18.36
		Germany	χ^2	19.67	2.39	N/A	19.21	11.57	8.71	13.94
C	Use by self	**UK**	χ^2	16.82	3.86	1.80	39.50	17.43	15.39	14.93
		Germany	χ^2	17.00	4.24	N/A	31.17	16.25	11.36	19.67
D	Use for showing to others	**UK**	χ^2	19.09	2.70	1.98	36.71	15.72	15.69	17.39
		Germany	χ^2	25.93	4.23	N/A	33.31	25.43	16.49	10.97

Table B-2 and B-3 summarise the associations between the other sample characteristics and the four criteria (A, B, C and D), the ACSs are broken down for each graph type. With education being a constant in the German sample due to all participants having at least a Bachelor degree, no statistical tests could be undertaken for this variable. The only significant finding can be seen in the UK sample; males (Md = .67, n = 59) have a higher ACS on the pictograph than females (Md = .33, n = 40), U = 889.50, z = -2.20, p = .03, r = .16. There are no further significant effects on assessed or perceived comprehension, use for self and use for showing to others.

Table B-4. Effect of Subjective Numeracy Score (SNS) on ACS, PC, use by self and use for showing to others as measured by Spearman's Rho

			SNS
ACS	pair 1		
	scatter plot	**UK**	-.04
		Germany	.15
	pictograph	**UK**	**.24***
		Germany	.24
	pair 2		
	histogram	**UK**	.18
		Germany	.09
	bubble plot	**UK**	-.03
		Germany	**.27***
PC	pair 1		
	scatter plot	**UK**	-.12
		Germany	.17
	pictograph	**UK**	.17
		Germany	-.03
	pair 2		
	histogram	**UK**	.12
		Germany	-.10
	bubble plot	**UK**	-.09
		Germany	-.09
Use by self	pair 1		
	scatter plot	**UK**	-.13
		Germany	-.04
	pictograph	**UK**	.19

		Germany	N/A[1]
	pair 2		
	histogram	**UK**	.07
		Germany	.15
	bubble plot	**UK**	-.01
		Germany	.14
	pair 1		
Use for showing to others	scatter plot	**UK**	-.16
		Germany	.04
	pictograph	**UK**	.11
		Germany	-.09
	pair 2		
	histogram	**UK**	-.03
		Germany	.00
	bubble plot	**UK**	.15
		Germany	-.02

* p < .05; ** p < .01; *** p < .001

We find no systematic influence of subjective numeracy (SNS) on comprehension or use that is consistent across both samples. We see only two significant correlations between SNS and assessed comprehension (ACS) on the Bubble Plot (r = .27, n = 63, p = .03) for the German sample, and between SNS and ACS on the pictograph (r = .24, n = 99, p = .02) for the UK sample. In both instances, higher SNS scores are associated with higher ACS on the respective graph format, but the effect size is small in both cases.

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[1] This test cannot be performed as no respondent picked the pictograph for use by self.

Appendix C
Online Resources for Chapter 4

C.1 Focus area description

Our empirical data collection focused on the South East Region and the East Midlands Region of England, as they encompass a range of climate change impacts demanding adaptation whilst showcasing socio-economic and demographic diversity. The South East is the country's most populous region with ~8.7 million inhabitants (ONS 2014a), 75% of which live in urban areas (Causer and Park 2011). It is second only to London, in terms of economic performance, contributing almost 15% to the UK's gross value added (GVA) (ONS 2014b). The South East is impacted by flooding with 25% of properties at risk, but after London, the region is also likely to suffer the most from extreme heat events (Climate UK 2012a), especially because of its higher proportion of older people (Causer and Park 2011).

The East Midlands Region currently has 4.6 million residents (ONS 2014a), but it is expected to see the highest population growth amongst the English regions over the next two decades (Beaumont 2009). The region contributes almost 6% of UK GVA (ONS 2014b). The regional economy was originally based on the textile and coal industry and manufacturing together with agriculture are still drivers of the economy (Beaumont 2009). Flooding especially at the coast but also water shortages for agricultural production are key projected impacts from climate change (Climate UK 2012b).

In Germany, our study focuses on the state of North Rhine Westphalia (NRW). It is the industrial heartland of the country as well as a state in which adaptation policy is being increasingly legislated. NRW is Germany's most populous state with ~17.6 million inhabitants (SB 2013). The state contributes almost 22% to German GVA (SB 2014), with the financial, insurance and business sectors dominating. The industrialised zone in the Rhine Valley is considered as one of Germany's most sensitive regions to a number of climate change impacts (Rannow et al. 2010), with flooding and heat stress projected to be causing the largest impacts (Rannow et al. 2010, Schröter et al. 2005).

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C.2 Overview of interviewees

Table C-1 Overview of interviewees

Case study region	Interviewee	Index	Interview	Date
East Midlands – England	Employee of a LG	EM01	Face-to-Face	15 Oct 2013
	Employee of a LG	EM02	Face-to-Face	17 Oct 2013
	Employee of a LG	EM03	Face-to-Face	22 Oct 2013
	Employee of a LG	EM04	Face-to-Face	4 Nov 2013
	Employee of a LG	EM05 & EM06	Face-to-Face	5 Nov 2013
	Employee of a LG	EM07	Face-to-Face	20 Nov 2013
	Employee of a Regional Organisation	REG02	Face-to-Face	7 Nov 2013
South East – England	Employee of a LG	SE01	Face-to-Face	24 Oct 2013
	Employee of a LG	SE02	Face-to-Face	25 Oct 2013
	Employee of a LG	SE03	Face-to-Face	29 Oct 2013
	Employee of a LG	SE04 & SE05	Face-to-Face	30 Oct 2013
	Employee of a LG	SE06	Face-to-Face	8 Nov 2013
	Employee of a LG	SE07 & SE08	Face-to-Face	9 Dec 2013
	Employee of a LG	SE09	Phone	18 Dec 2013

	Employee of a LG	SE10 & SE11	Face-to-Face	23 Oct 2013
	Employee of a Regional Organisation	REG03	Face-to-Face	13 Nov 2013
Non-case study England	Employee of a LG	ENG01	Phone	22 Jul 2013
	Employee of a LG	ENG02	Phone	18 Sept 2013
	Employee of a LG	ENG03	Phone	26 Sept 2013
	Employee of a LG	ENG04	Phone	27 Sept 2013
	Employee of a LG	ENG05	Phone	27 Sept 2013
	Employee of a LG	ENG06	Phone	30 Sept 2013
	Employee of a LG	ENG07	Phone	21 Oct 2013
	Employee of a Regional Organisation	REG01	Face-to-Face	12 Nov 2013
North Rhine Westphalia - Germany	Employee of a LG	NRW01	Face-to-Face	23 Jan 2014
	Employee of a LG	NRW02	Face-to-Face	27 Jan 2014
	Employee of a LG	NRW03, NRW04 & NRW05	Face-to-Face	28 Jan 2014
	Employee of a LG	NRW06	Face-to-Face	31 Jan 2014
	Employee of a	NRW07	Face-to-	3 Feb 2014

	LG		Face	
	Employee of a LG	NRW08 & NRW09	Face-to-Face	4 Feb 2014
	Employee of a LG	NRW10	Face-to-Face	5 Feb 2014
	Employee of a LG	NRW11 & NRW12	Face-to-Face	6 Feb 2014
	Employee of a LG	NRW13 & NRW14	Face-to-Face	7 Feb 2014
	Employee of a LG	NRW15 & NRW16	Face-to-Face	18 Feb 2014
	Employee of a LG	NRW17	Face-to-Face	19 Feb 2014
	Employee of a LG	NRW18	Face-to-Face	26 Feb 2014
	Employee of a LG	NRW19	Face-to-Face	27 Feb 2014
	Employee of a LG	NRW20	Phone	7 Mar 2014
	Employee of a LG	NRW21	Phone	7 Mar 2014
	Employee of a LG	NRW22	Phone	10 Mar 2014
	Employee of a Regional Ministry	NRW23 & NRW 24	Face-to-Face	29 Jan 2014
	Employee of a Regional Authority	NRW25	Face-to-Face	30 Jan 2014
	Employee of a District Government	NRW26	Face-to-Face	4 Feb 2014
	Employee of a	NRW27	Face-to-	30 Jan 2014

	Regional Organisation		Face	
	Employee of a Regional Organisation	NRW28	Face-to-Face	5 Feb 2014
	Employee of a Federal Authority	DEU01 & DEU02	Face-to-Face	28 Feb 2014
	Employee of a Federal Weather Service	DEU03	Phone	17 Mar 2014
	Employee of a Federal Weather Service	DEU04	Phone	25 Apr 2014
Non-case study Germany	Employee of a Regional Authority	DEU05 & DEU06	Face-to-Face	15 Apr 2014
	Employee of a Regional Ministry	DEU07	Phone	5 May 2014
	Employee of a LG	DEU08	Phone	7 Apr 2014
	Employee of a LG	DEU09	Phone	29 Apr 2014
	Employee of a LG	DEU10	Phone	5 May 2014
	Employee of a LG	DEU11	Phone	9 May 2014

C.3 Planning and climate change (adaptation) documents

Table C-2 Overview of planning and climate change (adaptation) documents reviewed

Case study region	Local government	Index	Core strategies	Climate change strategies	Climate change adaptation strategies or concepts
East Midlands – England	LG_E_1	EM01			
	LG_E_2	EM02			
	LG_E_3	EM03		✓	✓
	LG_E_4	EM04			
	LG_E_5	EM05		✓	
	LG_E_6	EM06	Not a PA*	✓	
	LG_E_7	EM07	✓	✓	✓
South East – England	LG_E_8	SE01	Not a PA		✓
	LG_E_9	SE02	✓ (draft)	✓	
	LG_E_10	SE03	✓	✓	
	LG_E_11	SE04 & SE05	Not a PA		

	LG_E_12	SE06			
	LG_E_13	SE07 & SE08	Not a PA		✓
		SE09			
	LG_E_14	SE10 & SE11	✓		
Case Study Region	**Local government**	**Index**	**Climate protection concepts**	**Integrated climate protection and adaptation concept**	**Land utilisation plans**
North-Rhine Westphalia - Germany	LG_D_1	NRW01			
	LG_D_2	NRW02			✓
	LG_D_3	NRW03, NRW04 & NRW05	✓		
	LG_D_4	NRW06			
	LG_D_5	NRW07	✓		
		NRW10			
	LG_D_6	NRW08 & NRW09	✓		✓
	LG_D_7	NRW11 & NRW12			
	LG_D_8	NRW13 & NRW14			✓

	LG_D_9	NRW15 & NRW16	✓#		
	LG_D_11	NRW18			✓
	LG_D_10	NRW17		✓	✓
	LG_D_12	NRW19		✓	✓
	LG_D_13	NRW20		✓	
	LG_D_14	NRW21		✓	
	LG_D_15	NRW22		✓	

*PA = Planning Authority; # LG_D_9 and LG_D_11 commissioned a joint climate protection concept

C.4 Interview questions – German local government

Allgemeiner Sachverhalt

- Könnten Sie mir kurz etwas zur Regierungs-/Verwaltungsstruktur sagen, in der wir uns hier befinden – d.h. sind wir hier in einer kreisangehörigen Stadt, einer kreisfreien Stadt, einem Kreis etc. und in welcher Bezirksregierung befinden wir uns hier?
- Wieviele Angstellte arbeiten hier in der Stadt/ Kreis (ungefähr)? Wieviele dieser Angestellten beschäftigen sich mit Klimaschutz/ Klimaanpassung?
- Könnten Sie mir kurz erklären, wie man hier in der Stadt/im Kreis auf der politischen/ verwaltungstechnischen Ebene mit dem Thema Klimawandel umgeht? Wer hat welche Verantwortungen/ welche Themenbereiche. Wer sind die Hauptakteure?
- Wie ist das Verhältnis im Bereich Klimaschutz/-anpassung zur Bezirksregierung, zum Land, zu den anderen Kommunen/ Städten? Wie ist die Zusammenarbeit und wie ist der Klimawandel auf den verschiedenen Regierungs-/Verwaltungsebenen organsiert/ aufgeteilt?

Welche Partei leitet die Bezirksregierung und von welcher Partei wir die Stadt/ der Kreis geleitet? Wie hat sich das in den letzten 10 Jahren geändert?

- Ein bisschen über Sie selbst – was ist ihr fachlicher Hintergrund? Was haben Sie studiert? Seit wann haben Sie ihre jetztige Stelle und was haben Sie vorher beruflich gemacht?
- Was umfasst Ihr momentaner beruflicher Aufgabenbereich? Und würden Sie den Hauptteil dieser Aufgaben als eher strategisch oder eher operativ bezeichnen?
- Könnten Sie mir ein bisschen über die Planungshorizonte für die verschiedenen Entscheidungen/ Handlungsfelder in Ihrem Aufgabenbereich erzählen? Wie werden diese festgelegt?
- Welche gesetzlichen Verpflichtungen hat Ihre Organisation in Bezug auf die Klimaanpassung? Wie hat sich der gesetzliche Rahmen fur Klimaanpassung entwickelt?

- Wie sind Sie in die Klimaanpassung in Ihrer Organisation eingebunden? Welche Aufgaben/ Verantwortungen haben Sie? An welchen Handlungs- und Entscheidungsprozessen wirken Sie mit?
- Wie würden Sie den Fortschritt im Bereich Klimaanpassung in Ihrer Organisation beschreiben?
- Ihrer Meinung nach, wie steht dieser Fortschritt im Vergleich zu anderen Städten/ Kommunen in NRW, aber auch außerhalb von NRW?
- Denken Sie, dass Klimaanpassung in xxx auf der Tagesordnung steht? Würden Sie sagen xxx hat sich erfolgreich an die Klimafolgen angepasst?

Entscheidungsprozesse und Informtationsnutzung

- Welche Studien und strategischen Dokumente sind in xxx zum Thema Klimaschutz und Klimaanpassung vorhanden?
- Was sind die Planungszeiträume in diese n Dokumenten (1 Jahr, 5, 10 etc...).
- Wissen Sie, ob in diesen Studien/ Dokumenten Klimaprojektionen mit einbezogen wurden, und wenn ja, wie diese kommuniziert werden (z.B. Abbildungen, Diagramme, Wahrscheinlichkeitsaussagen, rohe Daten etc.)?
- Wissen Sie wie und warum diese Art der Kommunikation für diese Dokumente gewählt wurde?
- In welchem Maß nutzen Sie Klimaprojektionen für Ihren Aufgabenbereich? Wenn nicht, wieso nicht?
- Falls Sie diese nicht benutzen, wissen Sie ob jemand anderes in Ihrer Organisation sie benutz? Wer und warum?
- Falls Sie Klimaprojektionen benutzen, woher nehmen Sie diese (normalerweise) [e.g. DWD, PIK, andere Forschungsinstitute, IPCC... etc.]? Und in welchem Format bevorzugen Sie diese Informationen? (rohe Daten, Zusammenfassungen, stichpunktartige Fakten...)
- Warum benutzen Sie die von Ihnen genannten Ressourcen/ Informationsquellen?
- Würden Sie sagen, dass sich Ihre Nutzung von Klimaprojektionen in den letzten 5 Jahren geändert haben (mehr oder weniger, andere Ressourcen, etc)?
- Falls Sie Klimaprojektionen benutzen, was möchten Sie von ihnen erfahren (jährliche Mittelwerte, Trends, regionale Mittelwerte, Extremwerte...)

- Wie möchten Sie diese Informationen erhalten? (Diagramme, Abbildungen, Tabellen etc.)
- Verwenden Sie persönlich grafische Darstellungen von Klimaprojektionen in Ihren täglichen Aufgaben? Finden Sie grafische Darstellungen in diesem Bereich nützlich für die Erfüllung Ihrer Aufgaben?
- Wenn ja welche und warum diese? Was möchten Sie von einer Grafik von Klimaprojektionen wissen (z. B. Unsicherheitsspannen, Vergleiche zwischen verschiedenen Klimamodellen, die Spanne der Projektionen, nur Mittelwerte/ Durchschnitte, Trendlinien...)?
- Warum benötigen Sie diese Informationen/ Details?
- Benutzen Sie grafische Darstellungen für andere Sachverhalte? Wenn ja welche?
- Stellen Sie Ihre eigenen grafischen Darstellungen her? Wenn ja, welche Kriterien sind für Sie besonders wichtig, wenn Sie diese herstellen?
- Wenn ich Sie fragen würde, z. B. einen Temperaturwandel grafisch zu kommunizieren/ darzustellen, wie würden sie das machen?
- Klimaprojektionen beinhalten viele Unsicherheiten, die in grafischen Darstellungen z. B. durch Fehlerindikatoren (die kleinen Antennen) oder Dichtefunktionen dargestellt werden können. Denken Sie, dass Sie dieses Level an Details für die Erfüllung Ihrer Arbeitsaufgaben benötigen? Warum ja/ nein?
- Denken Sie, dass diese Art und Weise der Darstellung für andere Kollegen in Ihrer Organisation nützliche ist/ dass Klimaprojektionen auch von anderen Mitarbeiter als benutzerfreundlich betrachtet werden – ist das wichtig?
- Können Sie sich an ein Beispiel erinnern in dem Klimaunsicherheiten gut grafisch dargestellt wurden? Und/ oder an ein Bespiel einer grafischen Darstellung zum Thema Klimawandel, dass Sie sehr hilfreich/ informativ fanden – oder Sie es also komplett nutzlos empfunden haben?
- Können Sie erklären warum Sie das Bespiel entweder besonders gut/ schlecht fanden?
- Denken Sie, dass man grafische Darstellungen zum Thema Klimaprojektionen verbessern könnte? Wenn ja wie? Oder denken Sie, dass man

diese Art von Informationen besser in einer anderen Art und Weise kommunizieren sollte? Was würden Sie personlich als am nützlichsten empfinden?

- Wie sehen Sie die Rolle von Infografiken im Bereich der Kommunikation von Klimaprojektionen?

Kommunikationsanpassung

- Mit wem kommunizieren Sie in Ihrer Organisation zum Thema Klimaanpassung?
- Welche Informationen/ Kommunikationswege/ Grafiken benutzen Sie dafür und wie entscheiden Sie sich für diese?
- Wie passen Sie die Informationen zum Thema Klimaanpassung an die Leute/ Kollegen an, mit denen Sie reden?
- Können Sie sich an ein Beispiel erinnern, bei dem Sie denken, dass Sie entweder Klimaanpassung besonders gut/ oder schlecht kommuniziert haben (e.g. Vortrag, Studie etc.). Was würden Sie fur den Auslöser des (Miss)Erfolgs einschätzen?
- Haben Sie noch Fragen an mich und/ oder möchten Sie noch etwas anderes hinzufügen?

C.5 Interview questions – English local government

Context

- What is the size of your LA in terms of number of employees? How big is your team?
- Which party is currently leading it? Have there been any changes in the last 10 years in the political leadership?
- A little bit about you - What is your background? What did you study at University? And how did you get to the job that you are doing today?
- What are the broad themes/ responsibilities in your current position? Do you have both strategic and operational responsibilities/ tasks?
- What are the standard planning horizons for decisions you have to make within your role?
- Which statutory obligations does your LA have in terms of reporting or acting on climate change adaptation? Are you involved in this process and if so which tasks or activities are you involved with? Which decisions/ actions do you feed into?
- Where in the process of adaptation do you think your organisation is currently at? If it helps to think of it in terms of the Levels of NI 188 – which Level do you think you are at?
- Has the change in statutory reporting had an impact on the progress on adaptation within your local authority? Have you seen any direct impacts of the change in statutory reporting (e.g. staff or budget cuts)?
- Do you think adaptation is still on the agenda for your LA? Why / why not? Would you say your LA has successfully adapted to CC?

Decision-making and information use

- What kind of documents does your LA have in terms of climate change and also adaptation (e.g. climate change strategy etc.)? What are the planning horizons within the strategies?
- Is information on climate projections included in these and if so how are they communicated (e.g. maps, figures, graphs, likelihood statements, numbers etc.)? Do you know how and why these ways of communication are/ were chosen?

- In your role…do you use information on projected climate change? If not – why not?
- If yes where do you go to get this information from and what do you tend to use? (e.g. raw data, UKCP09 interface or summary reports, headline statements etc.)? Why do you use these sources?
- Have you changed how and how much you use climate change projection information over the past 5 years?
- If you do use climate projection information -what do you want from it/ what are you looking for? (headline figures, means, yearly figures or trends, a regional average, extremes etc.)
- How do you want this information? (i.e. graphs, charts, maps) Do you make use of different types of graphics? Why in this format – what do you want the graphic to tell you? (e.g. uncertainties, comparisons of other models, range of projections, singular answers, trends, figures or headlines)? Why do you need this?
- Climate projections involve a lot of uncertainty, which can be portrayed in visualisations through error bars, probability density functions etc. Is this level of detail on uncertainty something you consider necessary for your work?
- Can you think of an example of a good visualisation that has incorporated uncertainty well?
- How would you feel more comfortable with the communication of uncertainty? Do you think visualisations could be improved, or would you prefer other means of communicating this information – e.g. text or numbers…?
- In general, do you find graphics helpful when informing the decision within your role? How (for which decisions)?
- Have you come across any particular visualisation or graphic in your work you have found particularly useful/ useless? Can you explain what makes them useful/ useless?
- Do you feel that currently available visualisations on climate change projections are accessible to others in your organisation? Is that important?
- **Characteristics of climate information**
- Do you make your own graphics as part of your work? If so what are the key criteria you have for designing a graphic?

- If you had to communicate a change in temperature or a change in rainfall graphically, how would you do it?
- If you remember, the survey had a number of different types of graphics, some were more ‘traditional’ like the histogram and some were more ‘alternative’ like the bubble plot. Do you think it is useful to explore these different options? Are they valuable?

Tailoring of climate information

- Who do you talk to in your organisations about climate change adaptation? What kind of information do you use when talking to them about climate change? How do you decide which one to use?
- Can you think of an example where you have communicated climate change to either councillors, other members of staff, the public etc. and it has gone particularly well/ or not well at all? Why do you think that was?
- Do you change the information you use when talking to different people internally/ externally? If so how?
- Do you have any questions for me?

Appendix D
Participant recruitment

D.1 Survey participants recruitment email

Dear …,

I am currently conducting a research project at the University of Leeds, looking into how climate science could be better communicated so that it is more useful and accessible to local government staff and businesses when trying to make their organisations more resilient and future-proof to severe weather and a changing climate.

The past year has shown us how much we can be affected by extreme weather events and how much damage such events can cause. Scientists and government produce climate projections of the future to help organisations minimise such damages under a changing future climate. Are climate projections being communicated in a format that people can understand? Are there easier, more intuitive, ways of visualising and communicating the same information?

I used to work in local government on climate change, sustainability and adaptation myself but am now based at the University of Leeds. With my research I am trying to explore what works and what doesn't work in terms of climate communication for people that need to make decisions to make their organisations and businesses future-proof**. It is very important to understand your views and feed that back to the scientists. This research aims to improve scientific communication to help local governments and businesses better understand and interpret climate projections in order to support their journey towards creating more resilient organisations.**

To this end a survey trialling a number of different climate visualisations to explore your views has been created. If you could spare 20 minutes then please click on the link below and take a look. If you wish to complete the survey, please do so by the end of June 2013.

https://www.survey.leeds.ac.uk/climatevis

If you are not the right person to talk about this topic within your council, I would be very grateful if you could forward this information on the relevant person.

If on the other hand you have been working on climate change and/ or resilience within your council, it would be extremely helpful if you also could forward this on to those colleagues who you may have worked with on this topic to capture their views as well.

If you have any questions about the survey or the research project please contact Susanne Lorenz ee08sl@leeds.ac.uk

Your input would be very much appreciated!

Many thanks in advance!

Kind regards,

Susanne

D.2 Interview participants recruitment email

Dear …,

You may remember filling in a survey conducted for a PhD project at the University of Leeds on communicating climate change projections a few months ago. I would like to thank you very much for your participation and your input – it is much appreciated.

As part of the next phase of my research I would like to interview people that have completed my survey to talk a bit more about what people think about, like and don't like in terms of communicating and visualising climate change projections. The survey was a good first step to get a feel for the variety of perceptions and likes and dislikes amongst users of such information and I would now like to explore this a bit more by talking to people directly. I was thus wondering whether you would be happy for me to interview in person - I would need about 1 hour if possible. The interview would have a number of key questions to guide our conversation, but I am very much interested in your views and experiences, so I would like us to be able to go wherever the conversation takes us.

Could you let me know whether you would be happy with this and if so when might be a good time in the first half of October for us to have a chat? If you agree to be interviewed you will not be required to travel. We will arrange a time and place convenient for you and I will meet you there.

Thank you very much for your interest in this research.

Kind regards,

Susanne

D.3 Obtaining consent for the interviews

Consent to take part in the interviews for the PhD project

'Uncertainties in European climate projections and their consequences for National Adaptation Strategies'

	Add your initials next to the statements you agree with
I confirm that I have read and understand the information sheet dated [insert date] explaining the above research project and I have had the opportunity to ask questions about the project.	
I understand that my participation is voluntary and that I am free to withdraw at any time until the data collected has been written up and anonymised without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. I understand that I can get in touch with the lead researcher Susanne Lorenz to discuss this further ee08sl@leeds.ac.uk	
I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. I understand that my responses will be kept strictly confidential.	
I agree for the interview to be recorded and I understand that the interview will be transcribed and anonymised afterwards, and that the original record will be deleted.	
I agree for the data collected from me to be used in relevant future research.	
I agree to take part in the above research project and will inform the lead researcher should my contact details change.	

Name of participant	
Participant's signature	

Date	
Name of lead researcher	Susanne Lorenz
Signature	
Date*	

*To be signed and dated in the presence of the participant.

D.4 Project information sheet

Uncertainties in European climate projections and their consequences for national adaptation strategies

Thank you for completing the online survey and for wanting to remain involved with this research.
Before you agree to participate in the next steps of the research, I would kindly ask you to take a look at the project information below so that you can make an informed choice as to whether or not you would like to remain involved. Your participation in this project is completely voluntary. If anything is unclear or you have any further questions please do not hesitate to get in touch with me.

The Project:

This research is about exploring how the communication of climate projections (i.e. how the climate will change in the future) could be improved so that this data is easier to understand/ use for people that work in local/regional government and the business community. This will help to make adaptation to climate change more robust and effective. The project seeks to incorporate the needs, views and ideas from those people that are either already actively using climate data to help them plan for climate change within their professional lives or that may currently not use this kind of data, but would benefit from using it. This research is thus aiming to explore how different forms of visualisation (e.g. graphs, bar charts, maps etc.) are perceived and understood. The aim is to see whether there are alternative forms of visualising this often complex data that can be used and developed based on user views that might be easier to understand and more intuitive. That is why I would like you to be involved! Your views, opinions and suggestions as professionals using or wanting to use climate projections could help to improve the communication process.

Basic Facts:

Who: Susanne Lorenz is the lead researcher on this project. If you would like to get in touch please email ee08sl@leeds.ac.uk or for further information please take a look on http://www.see.leeds.ac.uk/people/s.lorenz

What: The research I am conducting is part of my PhD project which is funded by the Natural Environment Research Council

Where: I am based at the Institute for Climate and Atmospheric Science and the Sustainability Research Institute at the School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK

When: The research is taking place between 2011 – 2015.

What do you have to do/ what will happen to you if you take part?

There are three parts to this research:

1) The online survey
2) The interviews
3) The focus groups

If you are receiving this additional information on the project it is most likely because you have completed the online questionnaire.

The next steps are thus the interviews and then the focus groups. You are free to choose whether you would like to be involved in either, or both or if you would rather not be involved at all.
Interviews – I would like to talk to you to find out more about what you think about how to visualise climate projections. These interviews can be either conducted on the phone or face-to-face. If we decide to have a face-to-face interview, you will not be required to travel. We will arrange a time and place convenient for you and I will meet you there. I estimate that the interviews will last between 30 minutes to 1 hour.

Focus groups – The final step in the research are focus groups which are aimed at bringing together different participants to encourage mutual discussion on how to improve the visualisation and communication of climate projections. The focus groups will be held within your region and are likely to last between 2 and 3 hours.

What are the possible risks and benefits from taking part?

Although there are no direct risks or benefits to you as a participant, the findings from the research will hopefully help to make the communication of climate projections more user friendly which should be beneficial for the climate adaptation process.

What about confidentiality and what will happen with the results of the research?

I would like to reassure you that all the information collected through this research will be kept in strictest confidence and will be used for research purposes only. As the findings are going into a PhD thesis they may be published. You have the right to withdraw from the research at any point before the data is written up and anonymised.

What would I like to know from you and why is this important?

I am interested in your views on what works and doesn't work when we try to communicate climate projections. Climate models are becoming increasingly sophisticated and yet we don't often ask whether how this data is communicated is actually understandable and effective. Making climate projections more easily usable to professionals working to adapt to climate change could make this process more robust and effective.

Will you be recorded?

I would like to audio-record the interviews and (potentially) the focus groups so that we can have an interesting and stimulating conversation without me having to focus on taking notes. All interviews and focus groups will be transcribed and anonymised afterwards and the original recording will be deleted. If you do not wish for the interview or the focus group you are participating in to be recorded then please let me know and I will just take notes while we talk.

Any other questions

If you have any questions at all, please just get in touch with me!!

You will have a copy of this information sheet and the relevant consent forms for your records.