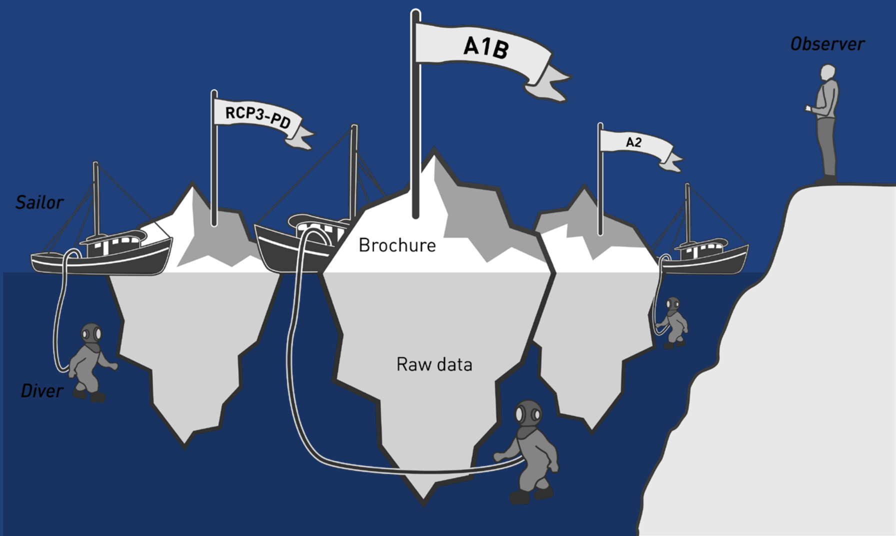
DISS. ETH NO. 26651

Adapting climate science.

Global customisations, national uses, and local appropriations.

Doctoral thesis by
Maurice Skelton



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Adapting climate science.

Global customisations, national uses, and local appropriations.

A thesis submitted to attain the degree of
DOCTOR OF SCIENCES of ETH ZURICH (Dr. sc. ETH Zurich)

presented by

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Abstract

Much scholarship has argued that information on future climate change ought to be the basis for climate adaptation decisions. But how has the impressive corpus of knowledge produced by climate scientists been processed and adapted to inform adaptation decisions in practice? This doctoral thesis compares and analyses how different actors have approached, grappled with, understood, generated relevance and acted upon climate science for adaptation. Drawing on surveys, semi-structured interviews, documentary materials, workshop observations, and the peer-reviewed literature, this thesis encompasses three empirical studies – on global customisations, national uses and local appropriations – as well as a reflective review ordering different social-scientific perspectives according to their underlying aims and concerns.

Starting with a historiographic perspective on the origin of the concept of 'climate', the introduction (chapter 1) illustrates what climate science at the turn of the 21st century is, before reviewing key social-scientific scholarship on climate adaptation and climate science. Chapter 2 then describes not only the particular data and methods employed in this thesis, but also reflects how methodological considerations influence the research project more generally.

Chapter 3 analyses how countries around the globe differ in their ability to customise climate models into climate projections supporting their national adaptation planning. While a surprising amount of nations have produced such information, the degree to which they are able to tailor the information to their needs and political cultures is strongly correlated with the countries' general competence to publish climate science. Thus, while climate information is widely available, customising it for own purposes remains restricted to a few countries.

Chapter 4 introduces the typology of *sailors*, *divers*, and *observers* to emphasise three particular ways climate projections have been used on a national level. It argues that the more qualitative or quantitative use of climate information is neither correlated to climate service users' affiliation to a sector, academia, or practice. Further, I find that many adaptation actors used information on climate futures in a qualitative way, but number-crunched current climate data. Communicating climate information, both qualitatively as well as quantitatively, is thus key to increase the national use of climate science.

Chapter 5 analyses how, and more importantly why, four sectors vulnerable to heatwaves appropriated scientific climate knowledge differently. By drawing on the work of Eviatar Zerubavel and his *cultural cognitive sociology*, I find that the *formative* and *performative* dimensions of knowledge play a major role in appropriating climate information. One, whether concepts are shared between a sector and climate science, allowing to similarly recognise the relevance of climate knowledge. Two, the more experts enjoy a large decision scope, the more they seem to be able to integrate heatwaves into their work. The decision scope is, however, influenced by the properties with which experts work: inert matter allows a different style of adaptation than people.

Chapter 6 is a reflective review paper that classifies the vast amount of research into five distinct ways social scientists study climate science and climate adaptation. The aim of this review is to draw out distinct underlying ontological and epistemological differences, which are in themselves influenced by partly competing priorities, concerns and aims. By introducing how social scientists committed to a *descriptivist* style are different to the *ameliorist*, *argumentivist*, *interpretivist* and *critical order of social science*, I aim to emphasise how social science on adapting climate science is a rich but also potentially tribal field.

Chapter 7 then discusses the three empirical papers and the review further, and details how the collected material on local appropriations could contribute to ongoing academic discussions. It also expands on how the Youth Strike for Climate influences discussions on climate adaptation (not mitigation), and how the entry of a new societal actor offers promising new research opportunities for the study of 'adapting climate science'.

Zusammenfassung

Wissenschaftliche Informationen zum Klimawandel sollten die primären Entscheidungsgrundlagen für die Klimaanpassung sein. Dies ist die gängige Lehrmeinung innerhalb der Forschung. Aber wie verarbeitet man den beeindruckenden Wissenskorpus, den die Klimaforschenden zusammengetragen haben, um Anpassungsentscheidungen zu treffen? Die vorliegende Dissertation vergleicht und analysiert, wie sich verschiedene Akteure im Bereich der Klimaanpassung mit Klimawissen auseinandersetzen. Es geht aber auch darum, wie Akteure die Relevanz für ihre Arbeit erkennen, um dieses Wissen zu integrieren. Auf der Grundlage von Umfragen, halbstrukturierten Interviews, Dokumenten, Beobachtungen in Workshops sowie der wissenschaftlichen Literatur umfasst diese Arbeit drei empirische Studien – von einem globalen Vergleich massgeschneiderter Anwendungen über nationale Nutzungen hin zu lokalen Aneignungen von Klimawissen – sowie eine Literaturrezension zu fünf Ausprägungen der Sozialwissenschaft im Klimakontext.

In der Einleitung (Kapitel 1) erfolgt zuerst eine historiographische Einordnung zur Begriffsherkunft des Konzepts 'Klima', bevor die Klimawissenschaft um die Wende zum 21. Jahrhundert beschrieben wird. Danach wird die zentrale sozialwissenschaftliche Forschung zur Klimaanpassung und dem Gebrauch von Klimawissen betrachtet. Kapitel 2 beschreibt dann sowohl wie methodische Überlegungen das Forschungsprojekt im Allgemeinen beeinflussen, als auch spezifisch welche Daten und Analysemethoden in dieser Arbeit verwendet wurden.

In Kapitel 3 wird analysiert, wie sich Länder rund um den Globus in ihren Fähigkeiten unterscheiden, aus Klimamodellen individuell massgefertigte Klimaszenarien für ihre nationale Anpassungsplanung zu erstellen. Während eine überraschende Anzahl von Nationen solche Klimaszenarien produziert haben, gibt es grosse Unterschiede in den Möglichkeiten, diese Klimainformationen individuell auf die jeweiligen Länderbedürfnisse und politischen Kulturen zuzuschneiden. Die Resultate zeigen zudem, dass die Fähigkeit zur massgeschneiderten Erstellung von Klimawissen für die nationale Klimaanpassung stark mit der Kompetenz in Klimawissenschaften des jeweiligen Landes korreliert. Somit ist der Zugang zu Klimamodellen zwar weltweit gewährleistet, aber nur wenige Länder haben die Fähigkeiten, diese auf die nationalen Gegebenheiten und Interessen masszuschneidern.

Kapitel 4 führt die Typologie der *Segler*, *Taucher* und *Beobachter* ein, um drei besondere Arten der Nutzung von Klimaszenarien auf nationaler Ebene hervorzuheben. Im Gegensatz zu früheren akademischen Beschreibungen von 'dem Nutzer' korreliert

die Art der Nutzung – qualitativ oder quantitativ – nicht mit der Zugehörigkeit der Nutzer zu einem Sektor, zur Forschung oder zur Praxis. Ferner zeigt sich, dass viele Anpassungsakteure qualitative Informationen über die Zukunft des Klimas verwenden, aber häufig quantitative Daten zu heutigem Klima benutzen. Die Bereitstellung von Klimainformationen sowohl qualitativer als auch quantitativer Art ist daher der Schlüssel für eine stärkere Nutzung von Klimainformationen für die Anpassung auf nationaler Ebene.

In Kapitel 5 wird analysiert, wie und vor allem warum sich vier für Hitzewellen anfällige Sektoren wissenschaftliches Klimawissen unterschiedlich aneignen. In Anlehnung an die Arbeiten von Eviatar Zerubavel und seiner *kognitiven Kultursoziologie* wird deutlich, dass die *formative* und *performative* Dimension von Wissen eine wichtige Rolle bei dessen Aneignung spielt. So erlauben einerseits mit der Klimawissenschaft gemeinsame Konzepte den jeweiligen Sektor-Experten, die Relevanz von Hitzewellen für die Expertenarbeit in ähnlicher Weise zu erkennen. Zum anderen zeigt sich auch, dass die Aneignung von Klimawissen deutlich erfolgreicher ist, falls Anpassungsoptionen im Entscheidungsspielraum von Experten liegen. Dieser Entscheidungsspielraum wird jedoch massgeblich davon beeinflusst, womit Experten arbeiten: Technische oder ökologische Anpassungsoptionen erlauben einen anderen Anpassungsstil als die Arbeit mit Menschen.

Die Literaturrezension in Kapitel 6 klassifiziert die heutigen Sozialwissenschaften mit Fokus Klimawissenschaften und Klimaanpassung in fünf verschiedene Typen. Die zugrundeliegenden ontologischen und epistemologischen Unterschiede dieser Typen zeigen sich auch in teilweise konkurrierenden Prioritäten, Anliegen und Zielen der Forschenden. Während beispielsweise gewisse Forschende hauptsächlich deskriptiv beschreiben wollen, sehen andere ihre Rolle in der Unterstützung von Klimaanpassung, der Argumentationsanalyse, der interpretativen Beschreibung oder dem kritischen Hinterfragen. Die Beschreibung dieser fünf sozialwissenschaftlichen Typen und ihre prominenten Forschungsthemen im Klimawandelkontext zeigt so auch deutlich die Diversität aber auch die Konfliktpotenziale innerhalb der Sozialwissenschaften auf.

In Kapitel 7 werden dann die drei empirischen Arbeiten und die Literaturrezension miteinander diskutiert. Weiter wird dargelegt, wie die gesammelten Forschungsdaten weitere akademische Diskussionen anstossen können. Zudem wird ein vielversprechendes neues Forschungsfeld charakterisiert: Während viel über den Einfluss des Klimaschulstreiks auf den Klimaschutz berichtet wird, ist die Wirkung auf das Thema Anpassung noch nicht näher erläutert worden. Wie diese politische Bewegung sich auf die Anpassungsarbeit von Experten auswirkt ist damit ein neues und vielversprechendes Forschungsfeld, um die Nutzung von Klimawissen besser zu verstehen.

Publications

This thesis includes two reprinted peer-reviewed articles and two manuscripts in review:

Chapter 3:	Skelton M, Porter JJ, Dessai S, Bresch DN, Knutti R (2019) Customising global climate science for national adaptation: A case study of climate projections in UNFCCC's National Communications. *Environmental Science and Policy* 101: 16–23. https://doi.org/10.1016/j.envsci.2019.07.015
Chapter 4:	Skelton M, Fischer AM, Liniger MA, Bresch DN (2019) Who is 'the user' of climate services? Unpacking the use of national climate scenarios in Switzerland beyond sectors, numeracy and the research–practice binary. *Climate Services*: 100113. https://doi.org/10.1016/j.cliser.2019.100113
Chapter 5:	Skelton M (in review,a) How sectoral experts recognise climatic relevance: the role of cognitive links and decision-making capacity.
Chapter 6:	Skelton M (in review,b) Orders of social science: Understanding social-scientific controversies and confluence on what 'high-quality' knowledge and 'good' adaptation is.

As lead or single author in all these papers I developed the research questions, refined the study aims; decided on adequate research designs; collected the data, except in chapter 4; analysed the data; as well as wrote and revised the manuscripts throughout the peer-review process. Both thesis supervisors and co-authors provided guidance, support, and feedback throughout this process.

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Recommended reading

I cherished the possibility – and necessity – of reading and accustoming myself with different thoughts and perspectives on research, social science and the social dimensions of climate change. I would like to take the opportunity of this thesis to mention which books, chapters and papers I not only found particularly interesting and helpful, but which have also shaped my thinking and work. While I not always endorse the perspectives taken, they nonetheless yielded interesting perspectives. Clustered into three themes, which are then ordered by significance, I highly recommend the following texts.

On the philosophy of research and social science

Freeman M (2016) *Modes of thinking for qualitative data analysis*. London: Routledge.

Hacking I (1999) *The social construction of what?* Cambridge, Mass., London: Harvard University Press.

Latour B (2013) *An inquiry into modes of existence: An anthropology of the moderns*. Cambridge, Massachusetts: Harvard University Press.

Dunleavy P (2003) *Authoring a PhD: How to plan, draft, write, and finish a doctoral thesis or dissertation*. Basingstoke, New York: Palgrave Macmillan.

Feyerabend P (1987[1978]) *Science in a free society*. London, UK, Brooklyn, NY: Verso.

Feyerabend P (1993 [1975]) *Against method*. London: Verso.

Critchley S (2001) *Continental philosophy: A very short introduction*. Oxford: Oxford University Press.

Michael M (2015) Ignorance and the epistemic choreography of method. In: Gross M and McGoey L (eds) *Routledge International Handbook of Ignorance Studies*: London: Routledge, pp. 84–91.

Livingstone DN (2003) *Putting science in its place: Geographies of scientific knowledge*. Chicago, London: University of Chicago Press.

Law J and Mol A (2001) Situating Technoscience: An Inquiry into Spatialities. *Environment and Planning D: Society and Space* 19(5): 609–621. https://doi.org/10.1068/d243t.

Key texts illuminating social interactions

Goffman E (1990 [1956]) *The presentation of self in everyday life*. London: Penguin.

Douglas M (1986) *How institutions think*. Syracuse, NY: Syracuse Univ. Press.

Zerubavel E (1999) *Social mindscapes: An invitation to cognitive sociology*. Cambridge, Mass.: Harvard Univ. Press.

Zerubavel E (2008) *The elephant in the room: Silence and denial in everyday life*. New York, Oxford: Oxford University Press.

Jasanoff S and Wynne B (1998) Science and decisionmaking. In: Rayner S and Malone EL (eds) *Human choice and climate change: The societal framework*. Columbus, Ohio: Battelle Press, pp. 1–87.

Rayner S (2012) Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses. *Economy and Society* 41(1): 107–125. https://doi.org/10.1080/03085147.2011.637335.

Sabetti F (1996) Path Dependency and Civic Culture: Some Lessons from Italy about Interpreting Social Experiments. *Politics & Society* 24(1): 19–44. https://doi.org/10.1177/0032329296024001004.

Jasanoff S (2005) *Designs on nature: Science and democracy in Europe and the United States*. Princeton, N.J.: Princeton University Press.

Zerubavel E (2015) *Hidden in plain sight: The social structure of irrelevance*. Oxford, NY: Oxford Univ. Press

Key texts around understanding society and climate change

Bankoff G (2001) Rendering the World Unsafe: 'Vulnerability' as Western Discourse. *Disasters* 25(1): 19–35. https://doi.org/10.1111/1467-7717.00159.

Agrawal A (2010) Why "indigenous" knowledge? *Journal of the Royal Society of New Zealand* 39(4): 157–158. https://doi.org/10.1080/03014220909510569.

Mauelshagen F (2016) Ein neues Klima im 18. Jahrhundert. *Zeitschrift für Kulturwissenschaften* 10(1): 39–57. https://doi.org/10.14361/zfk-2016-0104.

Latour B (2017) *Facing Gaia: Eight lectures on the new climate regime*. Cambridge, Medford MA: Polity.

Chakrabarty D (2009) The Climate of History: Four Theses. *Critical Inquiry* 35(2): 197–222. https://doi.org/10.1086/596640.

Skelton M, Porter JJ, Dessai S, et al. (2017) The social and scientific values that shape national climate scenarios: A comparison of the Netherlands, Switzerland and the UK. *Regional Environmental Change* 17(8): 2325–2338. https://doi.org/10.1007/s10113-017-1155-z

Lahsen M (2007) Trust Through Participation? Problems of Knowledge in Climate Decision Making. In: Pettenger ME (ed.) *The social construction of climate change: Power, knowledge, norms, discourses.* Aldershot: Ashgate, pp. 173–196.

Shackley S (2001) Epistemic Lifestyles in Climate Change Modeling. In: Miller CA and Edwards PN (eds) *Changing the atmosphere: Expert knowledge and environmental governance.* Cambridge, Mass.: MIT Press, pp. 107–133.

Gillard R, Gouldson A, Paavola J, et al. (2016) Transformational responses to climate change: beyond a systems perspective of social change in mitigation and adaptation. *Wiley Interdisciplinary Reviews: Climate Change* 7(2): 251–265. https://doi.org/10.1002/wcc.384.

Carrozza C (2014) Democratizing Expertise and Environmental Governance: Different Approaches to the Politics of Science and their Relevance for Policy Analysis. *Journal of Environmental Policy & Planning* 17(1): 108–126. https://doi.org/10.1080/1523908X.2014.914894.

Dobson J (2019) Reinterpreting urban institutions for sustainability: How epistemic networks shape knowledge and logics. *Environmental Science and Policy* 92: 133–140. https://doi.org/10.1016/j.envsci.2018.11.018.

Lahsen M (2005) Seductive Simulations? Uncertainty Distribution Around Climate Models. *Social Studies of Science* 35(6): 895–922. https://doi.org/10.1177/0306312705053049.

Keele S (2019) Consultants and the business of climate services: implications of shifting from public to private science. *Climatic Change* 12(Part 1): 465. https://doi.org/10.1007/s10584-019-02385-x.

Hulme M (2009) *Why we disagree about climate change: Understanding controversy, inaction and opportunity*. Cambridge, UK, New York: Cambridge University Press.

Mahony M and Hulme M (2016) Modelling and the Nation: Institutionalising Climate Prediction in the UK, 1988-92. *Minerva* 54(4): 445–470. https://doi.org/10.1007/s11024-016-9302-0.

Webber S (2015) Mobile Adaptation and Sticky Experiments: Circulating Best Practices and Lessons Learned in Climate Change Adaptation. *Geographical Research* 53(1): 26–38. https://doi.org/10.1111/1745-5871.12102.

Daipha P (2015) *Masters of uncertainty: Weather forecasters and the quest for ground truth*. Chicago: The University of Chicago Press.

1 Introduction: adapting climate science

Climate change is in many ways a cause for concern. Precisely because of these concerns however, the ways in which climate change is perceived, made sense of, taken up and responded to offer an intriguing perspective on human behaviour. How individuals and collectives shift their thinking in response to climate change, which action is prioritised through which narratives and beliefs, and how underlying cultural norms continue to influence discourse and practices. These all offer fascinating ways to study people's awareness of themselves, their surroundings and their consequent actions. In this doctoral thesis, I analyse and discuss one particular aspect of such societal responses to climate change: how different actors on global, national and local scales make climate science relevant for climate adaptation. Or, in short, adapting climate science.

With recent impacts of climate change not only being recorded by satellites and weather observations, but being synthesised in scientific journals and, increasingly, in major media outlets, climate adaptation has gained policy prominence. In particular since the Conference of Parties COP12 in Nairobi in 2006, climate adaptation has become similarly important as climate mitigation. As such, climate adaptation encompasses a wide range of proactive practices aiming to reduce the vulnerability – or to increase the resilience – of both human, natural and technical systems to cope with more intense and frequent heatwaves, droughts, torrential rainfalls, higher wind speeds, receding snowlines and rising sea levels (IPCC, 2014).

Intriguingly for social scientists, the climate adaptation approaches favoured by different stakeholders are quite diverse. Understanding not only how, but also why, actors are thinking similarly or differently about climate change in their work is of key interest. With climate adaptation often depicted as being an expert-led, knowledge-intensive process (e.g., Hedger et al., 2006), much academic scholarship prioritises the use of prospective climate science to anticipate how local weather events are likely to change (e.g., Lemos et al., 2012)[1]. Thus, analysing which factors shape the way climate science is customised, used and appropriated for climate adaptation not only gives insights into how concerns around climate change are understood and addressed, but also into the intriguing behaviour stakeholders exhibit in climate adaptation practices.

1 Throughout this doctoral thesis, I focus on climate knowledge derived from climate science. Indigenous, experiential or artistic sources of climate knowledge (cf. Engels 2019) receive little attention. However, as in particular chapter 5 highlights, stakeholders often make sense of climate science through prior experience and training.

This introduction is divided into four parts. In the first section, I expand how the idea of 'climate' came into being. The second section describes how social scientists have described climate science at the turn of the 21st century. The third section expands on how other scholars have studied climate adaptation and its relationship to climate science. In particular, it synthesises the literature for global customisations, national uses and local appropriations. In the fourth section, I state the overall aims and structure of this doctoral thesis.

1.1 A historiography of the idea of 'climate'

To better understand what 'climate change', 'climate science' and 'climate adaptation' has dominantly come to signify at the turn of the 21st century, I will shortly introduce the so-called historiography of climate, that is, how climate emerged as a stable, recognised way of describing particular environments. As this section argues, 'climate' has not always been understood as the statistical construction of so-called normal weather at a particular location dominant in today's conception and legitimized further by the Intergovernmental Panel on Climate Change IPCC (Hulme et al., 2009; Horn and Schnyder, 2016). Climate as both a term and concept has enjoyed different meanings, frightened some earlier contemporaries, unsettled religious explanations of the earth's creation, as well as being misused for justifying colonial expansion and terror (MacFarlane, 2003).

The historiographic study by Mauelshagen (2016) describes how, in the 18th century, 'climate' was newly coined as something physical, deviating from more ancient geographic understandings. Up to the 18th century, Mauelshagen argues, the widespread Enlightenment ideas still coupled the sun's inclination to human's inclinations and behaviour. This is, for instance, still today reflected in the etymological proximity of the words 'temperament', 'temperate' and 'temperature'. Such conceptions of climate as a synonym for geographic regions and people's sensual receptivity are still dominant even among the Baron de Montesquieu, often argued to be one of the founding father of the study of climate. However, also to Montesquieu, the dual notion of climate as being both geographical and physical is still prominent. While later academics, including Alexander von Humboldt and his isothermal maps, still developed conflicting physical definitions of climate, the second half of the 18th century sees widespread agreement that 'climate' is now seen as an umbrella term for all the factors influencing the regional temperature.

With this Newtonian, theory-based conception of climate, Mauelshagen (2016) argues against the more common Baconian assumption propagated for example by Edwards (2010) that, historiographically, climatology emerged from the scientific empiricism of 17th century England, where meteorological measurement techniques and the institutionalisation of observations allowed to produce a statistical product of weather events to something called climate. For Mauelshagen (2016), 'climatology' is in itself a novel research paradigm which focuses on causally and physically explaining heat conditions – beyond statistics. Interestingly, both the theoretical Newtonian perspective trying to understand heat fluxes through mathematical equations and the empirical Baconian approaches using observations seem to be present from the start of climatology, sometimes harmonising, sometimes conflicting.

Horn and Schnyder (2016) illustrate how researchers from other fields produced heterogeneous and interlinked understandings of climate in the 18th and early 19th century. 'Climate' was studied by geologists, biologists, medical doctors, meteorologists, physicists and anthropologists alike, their findings influenced each other's thinking. For instance, the geologic discovery of a distant, ancient past – largely without humans – not only challenged religious authorities, but also allowed to reconstruct local climates which must have been very different to the prevailing one (cf. MacFarlane, 2003). These discoveries of climates and time not being static but dynamic relatively quickly – within 30 years, according to Horn and Schnyder (2016) – led to portrayals of the future not only being different, but also without humans. Repercussions of this cognitive invention are still very lively today.

Additionally, anthropologists and philosophers alike were quick in using the different climates to justify colonial expansion due to different human cultural developments being causally linked to the local climate. This so-called climate determinism sought to legitimise oppression, land grab, and slavery, while also ordering societal hierarchies, policy-making and economic production in colonies (e.g., Jankovic, 2010).

The brutalities performed and legitimized by earlier anthropologists' work led to mainstream sociology distancing itself altogether from describing environmental influences on human culture for a long time (Welzer et al., 2010). This implies, in other words, that by actively ignoring cultural human–environment interactions since World War II, the social sciences and humanities left this topic out of their own accord to physical and natural-scientific descriptions. It is thus unsurprising that the point of reference and departure to social, political, and cultural climate change discussions at the turn of the 21st century is physical climate science. There is just scarce social-scientific work to build up an independent narrative.

1.2 Climate science at the turn of the 21st century

Climate science, as understood in this thesis and throughout much of the academic literature, refers to a conglomerate of intermingling practices, methods, theories, equations, data sources, concepts, institutions, as well as a large corpus of knowledge. The historian of science Paul Edwards (2010) has explored how weather phenomena have been collected, standardised, and institutionalised into distinct physical variables such as temperature, precipitation, humidity and air pressure. At the turn of the 21st century, climate science now uses meteorological data collected by weather stations, maritime buoys and regularly launched weather balloons. In addition, orbiting satellites take photos and spectral measurements enabling scientists to infer temperature, ozone concentration or snowfall through all layers of the atmosphere. Lastly, to understand the climate and its changes through the last hundreds of millennia better, ice cores have been taken from various glaciers, giving insights into the atmosphere's composition. Thus, with the help of meteorology and paleoclimatology, climate scientists have not only attained a truly global, regular and largely automated measurement system of weather variables at their disposal, but also datasets enabling them to compare current observations with pre-industrial ones.

This growth of data collection and processing was, however, only possible due to several actors' support (Edwards, 2010). Not only massive government funding was necessary to develop, install and maintain all these observation methods, but also computer scientists, data specialists, satellite engineers, transmission experts, and statisticians were needed to help shape climate science as it can be described today. In addition, supranational coordination ensuring the exchange of standardised weather measurements around the world in the form of the World Meteorological Organization WMO remains a necessary institution in producing climate science. In particular, the WMO continues to link up national weather services, as well as working towards the standardisation of meteorological observations across the globe. In response to the discovery of anthropogenic climate change, the WMO co-founded the Intergovernmental Panel on Climate Change IPCC .

The IPCC has had a profound impact not only on the conduct of climate science, but is also a key actor in evaluating, assessing and synthesising its findings (Edwards, 2010). With contributors ranging from physical climate scientists to climate impact modellers, economists, and social scientists, the IPCC's Assessment Reports are aimed to provide the scientific basis for climate mitigation and climate adaptation policies. However, since its inception in 1988, the IPCC has also attracted criticisms over geographically and disciplinary biased participation of contributing scientists, its neglect of indigenous sources of climate knowledge, and repeatedly had controversies over 'errors' in Assessment Reports (cf. Hulme and Mahony, 2010). Overall, the influence of 30 years of IPCC on how climate science is assessed and synthesised has also led to climate scientists prioritising their research differently, so as to be included in its Assessment and Special Reports, such as the studies on the impact of 1.5°C of global warming (IPCC, 2018).

One particular scientific development of continued interest for this doctoral thesis are climate models. Throughout the last decades, climate physicists have developed and refined numerous climate models which require supercomputers to simulate the global climate at high spatio-temporal resolution with both pre-industrial, current and a range of future carbon emissions scenarios (e.g., Shackley et al., 1998; Edwards, 2010; Parker, 2018). While simpler *energy balance models* exist to calculate average surface temperature in zero dimensions, this thesis examines so-called *complex climate models* (cf. Parker, 2018). Complex, or state-of-the-art, climate models include (a) *general circulation models* (GCMs) simulating earth's energy fluxes and atmosphere-ocean dynamics in three dimensions as well as between water (hydrosphere), ice (cryosphere), land (geosphere) and the sky (atmosphere) as well as (b) *regional climate models* (RCMs) which simulate the dynamics between these spheres only for smaller portions, i.e. regions, of the earth – but at even higher spatiotemporal resolution (Parker, 2018). With the cause of global warming now firmly established, climate models are complemented with various statistical models (e.g., Knüsel et al., 2019) to project plausible future climates in small regions up to the end of the 21st century to support climate mitigation and adaptation (e.g., Skelton et al., 2017).

1.3 Social scientific literature on adapting climate science

In the last few years, the knowledge on climate change assembled by climate scientists has grown exponentially, not only in volume, but also in diversity and methodology. With this proliferation, different ways to synthesise climate science for the purpose of informing adaptation and mitigation decisions are possible. In this doctoral thesis, adapting climate science refers to the ways scientific climate knowledge, produced by scientists with the aid of methods, theories, observations and models, is synthesised and prioritised by a range of stakeholders in order to, literally, make sense of climate change and inform climate adaptation decisions on different geographical scales.

For instance, in my master thesis, I analysed how British, Dutch and Swiss climate scientists produced considerably different climate projections intended to inform national adaptation decisions, influenced by underlying assumptions embedded in the respective political cultures about what is judged 'good' science for decision-making and 'good' stakeholder engagement (Skelton et al., 2017). This doctoral thesis takes that particular analysis a step further, and looks at how climate science has been customised on a global level (chapter 3), used on a national level (chapter 4), and appropriated by sectoral experts locally (chapter 5). Firstly, I want to briefly review the relevant strands of scholarship for each chapter.

1.3.1 Ways in which scientist have customised global climate science for national adaptation

Many have argued that having the scientific capacity to produce and translate global climate science into locally specific and nationally relevant climate knowledge is also a key capacity for the success of countries' adaptation efforts (e.g., Ho-Lem et al., 2011). However, a continuous strand of bibliometric research has shown that the origin of much climate science is limited to a few countries (e.g., Karlsson et al., 2007; Pasgaard and Strange, 2013; Haunschild et al., 2016). Similarly, authorship of the Intergovernmental Panel on Climate Change IPCC has been shown to be similarly unrepresentative of countries (e.g., Ho-Lem et al., 2011; Corbera et al., 2015).

This 'geographical imbalance' (Pasgaard et al., 2015) or 'North–South divide' (Karlsson et al., 2007; Blicharska et al., 2017) has been critiqued several times. The underlying issue is that the perceived necessity of having nationally legitimate, credible and relevant climate knowledge to inform climate adaptation is in tension not only with climate science being produced elsewhere, but also the global – rather than national – scope of climate models (e.g., Mahony and Hulme, 2018). As for instance the UK saw predicting climate change with climate models as a strategy to be more politically independent in climate negotiations (Mahony and Hulme, 2016), some scholars have argued that climate models are of also geopolitical concern for national sovereignty (Lahsen, 2007; Mahony and Hulme, 2012; Miguel, 2017).

Thus, while some scholars are critical of such model developments, seeing them as extensions of geopolitical dominance which are now also influencing climate adaptation, other scholars are more concerned about the difficulties in producing climate science in countries with less research funds and greater difficulty in accessing high-quality journals (e.g., Blicharska et al., 2017; Dike et al., 2018; Nasir et al., 2018). What remains understudied – and what chapter 3 contributes to these discussions – is an empirical picture, not of where climate science is produced, but how countries differ in customising global climate model output for national adaptation decision-making.

1.3.2 On the national use of climate science to inform climate adaptation

The conception that climate science ought to underlie and inform climate adaptation practices is also the starting point for climate services (cf., Vaughan and Dessai, 2014; Bruno Soares and Buontempo, 2019) and the doing co-production of knowledge paradigm (Bremer and Meisch, 2017) whereby scientists and stakeholders engage to produce more usable and actionable climate knowledge (Lemos et al., 2012; Kirchhoff et al., 2013). In this context, who the so-called 'users' are, what information needs they have, how they employ and adapt climate science into their work have all been the focus of research. As various countries around the globe have produced highly customised national climate projections to inform national adaptation (chapter 3; Skelton et al., 2017), how climate scenarios are taken up and how they could be improved has caught the interest of both climate scientists and environmental policy-makers.

A number of scientists have studied the climate knowledge requirements of so-called users. Two analytical perspectives are common. On the one hand, some have analysed the user needs of academics and practitioners (e.g., Benestad et al., 2014; Groot et al., 2014). On the other hand, others have distinguished users by their sectoral affiliation (e.g., Bruno Soares et al., 2018). However, one common challenge to such studies of needs is that any subsequent fulfilment of these requirements might still not lead to the information's use. Therefore, another strand of research has been to empirically analyse which climate information has actually been used. In particular the British context has been well researched, with studies by Tang and Dessai (2012) analysing the uptake of the British climate projections UKCP09; with a paper by Porter et al. (2015) comparing the use of climate information in local adaptation planning between 2003 and 2013; and with a country comparison between German and English local authorities by Lorenz et al. (2017). All these research papers highlight the fact that the availability of climate knowledge is no guarantee for its subsequent use. Often more contextual factors, such as institutional and legal frameworks or the larger economic situation allowing the financing of adaptation projects influence uptake of climate information.

Some scholars have however also been critical about who is included and who is excluded in such co-production projects. Archer (2003), for instance, highlighted that socio-economically marginalised users are often also those being underserved. Similarly, Klenk et al. (2015) critique the trend that stakeholders in joint research projects often play a minor role, calling for future engagement practices which are 'beyond lip service'. Meanwhile, with the notion of 'mini-me', Porter and Dessai (2017) have identified an underlying imagination of users, whereby climate scientists perceive users often as similarly numerate as themselves. All these studies point to a profound ambiguity of who 'the user' of climate services is, and which climate information is used similarly and which differently. A more specific and nuanced idea of 'users' of climate science in national adaptation planning might lead to more concrete findings to improve climate knowledge's usability, as well as them becoming more meaningful engaged.

1.3.3 On the local appropriation of climate science by a range of experts

At the local level the consideration of climatic changes in specific projects is often a responsibility of sectoral experts working in civil service and local administration – such as spatial planning, health, or building technology – rather than designated adaptation officials. In addition, climatic concerns are often in competition with many other legitimate priorities. Various scholars have described how particular sectors and groups of experts have appropriated climate knowledge into their work. For instance, Ryghaug and Solli (2012) have analysed how Norwegian road managers perceive climate change mainly through extreme weather events they observe, not through climate science. This leads to adaptation practices based on learning from past experiences without anticipatory science. Similarly, Rotter et al. (2016) describe how adaptation within the German railway system is simultaneously hampered by differing priorities and values, but that diligent single actors are able to integrate adaptation precisely because of such fractured interests.

With 'climate' being a statistical construction of weather (Hulme et al., 2009) and as such too elusive a concept for many non-climate audiences, various scholars have approached studying climate adaptation at the local level by focusing on specific climate impacts. One popular topic is adapting to urban heatwaves, likely to become more frequent and intense not only because of carbon emissions, but also increased urbanisation. Olazabal et al. (2018), for instance, have mapped not only the available knowledge on how to adapt to heatwaves in the city of Madrid (Spain), but have also pointed out that no single actor – dubbed 'super-stakeholder' – is able to be in possession of all of it. While some stakeholders know more than others, integrating new knowledge into adaptation strategies – such as that on urban heatwaves – requires sustained interactions between scientific and policy expertise. Heaphy (2018), meanwhile, describes how such sustained efforts between scientists and policy-makers worked out in the English cities of London and Manchester. Using the British climate projections UKCP09 as a basis to simulate future urban heat islands, Heaphy explores five projects linking the built environments and climate change, arguing that urban heat maps served as a 'heuristic role' in local spatial planning (ibid: 7).

Social scientists have described knowledge transfer as a collective and cultural process. In particular the work by American sociologist Eviatar Zerubavel offers an intriguing way of conceptualising the social functions of knowledge (e.g., Zerubavel, 1999). In chapter 5 I describe how such insights can help to explain why four sectors vulnerable to hot spells have appropriated knowledge on urban heatwaves so differently.

1.4 Aims of this doctoral thesis

To illustrate the diversity of the ways in which different actors use climate science for climate adaptation, this doctoral thesis encompasses three case studies – one global, one national, and one local – to empirically explore and analyse the different ways in which climate science has been tailored for, considered in and informed climate adaptation. Drawing on both qualitative and quantitative methods, face-to-face interviews as well as desk-based documentary analyses, these three studies highlight not only the similarities in which climate science has been tailored, received, used, judged, and resisted, but also why different countries, adaptation actors and sectoral experts have done this so differently from each other. While all thesis studies spotlight at a particular way of perceiving and responding to climate change, some empirical results also offer a contrast to the dominant academic framing, questioning how far certain assumptions are over-simplistic or glorifying.

In chapter 2, I expand on how I designed the research, selected and collected research material, how I assured my respondents' anonymity, what methods and 'styles of thinking' (Freeman, 2016) I employed in analysing and coding the material, and how I linked up my empirical results with the ongoing academic discussions and concepts. In addition, chapter 2 also includes some philosophical remarks on positionality, the value of methods, and how the chosen research framing also detects, amplifies and stabilises the ways in which phenomena are collectively perceived.

Chapter 3 describes the first empirical case study analysing how countries differ in their ability to customise global climate science through climate projections in order to inform their national adaptation efforts. I find that, while an unexpectedly high number of countries with limited financial and scientific resources have reported climate scenarios to the United Nations Framework Convention on Climate Change UNFCCC, the ability to customise the climate models and observation data according to the national political culture is clearly linked to a higher capacity of publishing outstanding climate science. Even though often appraised as capacity building trainings, freely available software producing one-size-fits-all climate scenarios may mask issues of scientific dependency, as users can only select from a restricted set of climate models and emissions scenarios . Software packages might therefore unwittingly restrict rather than foster countries' capacity to customise global climate science into nationally relevant and legitimate climate information.

At the national level – chapter 4 – I discuss and problematize descriptions of 'the user' of climate information according to categories such as sectors, the research-practice binary or an assumed numeracy. Drawing on the metaphor of an iceberg to distinguish between *sailors* (qualitative users), *divers* (quantitative users), and *observers* (interested skimmers), I analyse the actual use of the Swiss climate scenarios CH2011 by the Swiss adaptation community. Aiming to clarify the often vague notion of 'the user' circulating in discussions on co-producing climate services, I highlight that there are no statistical correlations between the particular use of climate information and being in a particular sector, working in research or academia, or being able to crunch raw data. With the typology of *sailor*, *diver* and *observer*, this chapter serves to discuss who 'the user' is in a more nuanced and informed way.

In chapter 5, I compare the local appropriation of knowledge on urban heatwaves in four sectors: urban green space management, building technology, spatial planning, and health. This study aims to understand why two of these sectors were able homogenously and with many specific examples to describe how heatwaves impact their work, while two other sectors were, at most, unified in their critical deliberations and hesitance of recognising heatwaves as something with relevance for them. Drawing on insights derived from the cultural cognitive school of sociology (e.g., Zerubavel, 1999), I argue that a sector's uptake or hesitance of heatwaves is largely influenced by two factors. On the one hand, the more that climate scientists and these sectors share concepts and terms to describe their knowledge and responsibilities, the more likely we are to find specific examples of adaptation action being implemented. On the other hand, the appropriation of heatwaves into experts' thinking is also influenced by their degree of agency in implementing specific action. If experts are able to implement adaptation measures, then they are more likely to do so. If the agreement of numerous other actors to adaptation decisions is needed, then heatwaves are less likely to be recognised as an issue. As such, I argue that the way climate science is appropriated locally is a product of both conceptual proximity and performative ability.

This dissertation has benefitted from reading and making sense of the vast amount of scholarship produced by social scientists and the humanities on the subject of climate science and climate adaptation. Reflecting on this stimulating reading experience, chapter 6 groups this literature into five distinct research types. By introducing and contrasting the *descriptivist*, *ameliorist*, *argumentivist*, *interpretivist*, and *critical orders of social science*, I illustrate how each order is influenced by underlying yet stable differences in assumptions, aims, goals, and methodological priorities. While some scholars are comfortable in multiple orders – depending on research interest and collaboration – others are more factional and tribal.

In chapter 7 I discuss the parallels and differences of the three empirical case studies on global customisation, national use and local appropriation of climate science, and place them within the five orders of social science. In particular, I reflect on the agency of scientific climate knowledge for climate adaptation, and what factors influence how climate science is adapted. I also briefly discuss three more promising research articles using the data collected for this doctoral thesis. I close with a promising future research avenue: while the recent youth strikes for climate have boosted calls for ambitious mitigation efforts, less is known about how this movement impacts on adapting climate science. More social-scientific research could highlight how the youth strikes for climate influence the way climate science is perceived and made sense of, but also whether they have led to the lowering of the institutional and political barriers to adaptation projects.

2 Research design

Method textbooks emphasise how the research output is shaped by the overarching research aim, the specific research question, and the type of data particularly suitable and obtainable for such investigations. In this chapter, I describe and explain the choice of the research designs used in the following empirical chapters. In section 3.1, I reflect on the methodological, ontological and epistemological choices influencing both the research process and product, as well as how these choices have been described as being political. Section 3.2 describes my own positionality in this regard and how it has influenced the data collection and analysis. After specifying how and what type of data I collected (section 3.3), I detail which methods and what 'styles of thinking' (Freeman, 2016) I employed in analysing the data (section 3.4).

2.1 Metaphysics of methodology

Most researchers are likely to understand methods as the way data is obtained and analysed. For this purpose, various handbooks inform doctoral students and other research novices about the appropriate way of applying methods (e.g., Pallant, 2005; Flick, 2009; Kuckartz and McWhertor, 2014; Miles et al., 2014). However, while many Nobel prizes are awarded to inventers of new methods in the natural and life sciences, disagreements about the value and influence of methods have been at the heart of some nasty academic conflicts, even leading one author to being labelled 'the worst enemy of science' (cf. Preston et al., 2000).

In his book Against method the philosopher of science Paul Feyerabend sparked off a debate on research methodology (1993 [1975]). In the book he provocatively argued that methodological rigidity is a barrier to scientific progress – not its insurance. According to Feyerabend, only methodological innovation has the ability to produce research which questions the prominent assumptions of a scientific theory. Thinking along similar lines as the historian of science, Thomas S. Kuhn (1996 [1962]) and his paradigms, Feyerabend argued that only 'epistemological anarchism' would guarantee the continued progress of science. Accordingly he believes breakthroughs cannot be achieved by sticking rigorously to methodological rules, but instead science needs to 'be receptive to ideas from the most disparate and apparently far-flung domains' (Preston, 2016). Or, in short, 'anything goes' (Feyerabend, 1993 [1975]; cf. Hoyningen-Huene, 2000).

After method, the book by sociologist of science John Law (2004), enriches, updates and distorts Feyerabend's lifelong concern with the societal and scientific effects of 'science's conquest of abundance' through abstraction (cf. Hacking, 2000). In his book, Law has three aims. First, he problematises the aim of producing coherent results derived from a 'complex, diffuse and messy' world, stating that such research produces even more mess and confusion. Second, he wants to highlight the ways in which different methods 'produce not only different perspectives, but also different realities' (ibid: 13, emphases in original). Drawing on the laboratory studies performed by Latour and Woolgar (1979), Law highlights that this building of reality is a very delicate and often frustrating process. Third, he argues that social scientists ought to produce and know realities which are vague and indefinite so that they better reflect the 'fluxes' of the world. This is important, as methods both allow the detection of reality as well as its amplification. Law (2004) thus proposes that when choosing a method the reality which is being amplified should also be considered.

Mike Michael's (2015) essay on ignorance and the epistemic choreography implicitly and intriguingly weaves the concerns of both Feyerabend (1993 [1975]) and Law (2004) together, but at the level of the individual researcher. According to Michael, ignorance between the researcher and her respondents leads the researcher to perform a largely unnoticed yet scripted 'epistemic choreography'. On one hand, if both harmonise with each other, the similarities – such as values, assumptions, concerns and aims – are ignored in the analysis of data. This is comparable with Feyerabend's insistence that a particular theory produces only fitting observations (Hoyningen-Huene, 2000). On the other hand, frictions and misunderstandings between researcher and respondent are also often ignored during the analysis. This is often not deliberate. If certain responses do not fit the research framing they are 'othered', as Law (2004) puts it. In line with the Feyerabend's argument (1993 [1975]) that one should consider the exotic, mundane or silly to test scientific theories, Michael (2015) regards misbehaviours and idiotic remarks as reminders of the complex, messy world. Such deviations from that considered normal should not to be forsaken simply because they do not fit the research framing, but should be taken as a starting point of a trail potentially leading to insights which the initial research question did not consider.

2.2 Positionality

In the course of my research my personal interest in the particular and often intriguing ways in which climate adaptation and climate science influence each other has grown steadily, be it through fluid uptake, serious deliberation, resistance or disinterest. In particular, I have become interested in what underlying assumptions – cultural norms, scientific values, and social factors – drive and guide how climate science and climate adaptation are. And, amongst other things, this has led me to collect and analyse empirical data in such a way that it possibly emphasises other dynamics as those discussed in academic debates. Such redescriptions are of merit, as the way people describe their own actions might be quite different to an anthropologist's observations (Latour, 2013).

Overall, all three empirical case studies – global customisations, national uses and local appropriations of climate science for adaptation – aim to bring new perspectives to current academic discussions about adapting climate science. For instance, in all chapters I employ what Melissa Freeman (2016) labels 'categorical thinking': the use of pre-existing categories such as 'science', 'practitioners', 'sectors', 'quantitative' and 'qualitative' climate knowledge to describe and order key insights and differences. However, rather than only correlating or interlinking such categories to produce scientific findings, the research in this dissertation employ what Freeman (2016) dubs 'diagrammatical thinking'. Broadly emerging from thinkers such as Deleuze and Guattari (cf. Watson, 2009), diagrammatical thinking aims to show that other ways of describing and ordering the world are not only possible but also perhaps more desirable, cf. Hacking, 1999). As such, by employing diagrammatical thinking, I aim to demonstrate that a particular dominant framing might not always be able to account for similarities between categories (cf. chapter 4), and to illustrate what other important phenomena can also be identified by a shift of perspective (cf. chapters 3 and 4).

In this way, my doctoral thesis largely follows what I dub the *interpretivist* order of social science in chapter 6 (cf. Table 6.1). That is, my inquiry aims to better understand cultural interplays around adapting climate science, and wants to amplify certain underlying norms, motives or actors shifting and guiding this process. During interactions with interviewees, workshop participants as well as when studying desk-based documentary materials, I was often an intrigued participant. This has also been described as taking an emic perspective. Drawing to a large part on inductive reasoning two of my thesis chapters also use quantitative data – a rarer case among interpretivist scholarship (cf. Table 6.1). Overall, in my research I have taken a standpoint closely associated to that of constructivist ontology – whereby realities are locally and specifically co-constructed – and of subjectivist epistemology – where recognition of artefacts and legitimisation of findings are collectively mediated. Criticism and critiques of similar interpretivist research have included the use of speculative cause and effects as well as activist tendencies. Aware of such criticism, I have tried to address these through the use of empirical data and a particular method of analysing it.

2.3 Data

Data types used. Table 2.1 documents the four particular types of data used in this thesis: semi-structured interviews, documentary materials, survey, and peer-reviewed literature. One, semi-structured interviews were used to hear selected actors' experiences and personal judgements (e.g., Bogner, 2002; Fylan, 2005; Flick, 2009). Structured around a questionnaire informed by the research questions and aims, interviews are uniquely able to collect data on how interviewees live, work, understand, frame, navigate, prefer, or resist climate adaptation and climate science. As such, it can give valuable insights into procedural elements and the person's values.

Two, the documentary materials used are written sources issued by governments, associations, academics, and businesses about a certain issue. These sources can highlight legal orientation, institutional goals, and organisational procedures.

Three, surveys are a good way to collect structured data from a large range of actors. However, while it collects the respondents' personal knowledge and values, it is less able than interviews to take up their exact wording or lived experiences. The preparation of a survey and data collection was undertaken by an external environmental consultancy in chapter 4.

Four, my reflections on social-scientific research on adapting climate science in chapter 6 make prominent and widespread use of the peer-reviewed literature. In addition, parts of a published bibliometric study were used as a basis for the country classifications in chapter 3.

Research ethics. As data derived from interviewees and surveys are collected by – and thereby under the control of – the researcher, consideration of ethical concerns is required when carrying out research. As Swiss research law does not require formal ethical approval for non-clinical research with adults, I undertook the following steps to minimise ethical issues and any potentially negative outcomes for both participants and researcher. Consent to interviews and survey participation was always voluntary, and not tied to financial remuneration. Further, participants were informed about the aims of the study, the involved researchers, and that the collected material was only to be used for academic purposes. Lastly, direct quotes and paraphrases were anonymised to protect respondents' identity in the draft manuscripts and final publication. Publicly available material published by institutions or interviewees – such as documentary materials and peer-reviewed literature – is, as is customary in the social sciences, excluded from such anonymity.

Table 2.1 – Description of the employed units of comparison, data types, data sources, and methods in the different studies.

Study	Unit of comparison	Data type	Data source	Method
Global customisations (ch. 3)	Countries' climate projections	Quantitative	UNFCCC reports	Statistical analysis
National uses (ch. 4)	Swiss adaptation community	Quantitative & qualitative	Survey	Statistical analysis
			Group interviews	Qualitative text analysis
Local appropriations (ch. 5)	Experts in four sectors	Qualitative	Interviews; Reports; Workshops	Qualitative text analysis
Orders of social science (ch. 6)	Social research on climate science and adaptation	Qualitative	Peer-reviewed literature	Qualitative text analysis

2.4 Method

Emergent themes. Influenced by the interpretivist aim of describing known behavioural patterns (cf. chapter 6), all studies in this thesis aim to find stable arrangements around climate adaptation and climate science. Contrasting to the dominant way interpretivists conduct their studies, this thesis uses both qualitative and quantitative data. As these patterns often differ from one phenomenon to another, all studies try to find emergent themes using a largely inductive approach before being embedded into current academic debates. This research design has been influenced by grounded theory approaches (Glaser and Strauss, 1968).

Coding of text. In particular, the interview material was sorted and analysed using a qualitative coding approach (e.g., Kuckartz and McWhertor, 2014). As such, the transcribed interviews are loaded into a software program for qualitative text analysis, in my case MAXQDA. Based on the central research question, the questionnaire, and initial reflections after interviewing my recruited participants, I first sketched out recurrent themes, topics, emotions and experiences. During this first process of ordering my material, I also paid close attention to those situations which triggered significant emotional reactions within me. This included, on the positive side, surprising insights of aspects of which I was unaware before the interview, and, on the negative side, situations or comments which annoyed me during or after the interview. Considering the researcher's emotions more explicitly during the analysis has been argued not only to give valuable insights into one's own assumptions brought to the research influence the results, but can also avoid too quick conclusions by reflecting upon one's sympathy and antipathy with participants and interviewees

(Copp, 2008). Further, considering emotions can also create awareness of the 'epistemic choreography' at play during the evaluation phase of research (Michael, 2015).

On the basis of this rough ordering, I then designated various categories – so-called codes – which were of interest. In this first coding phase, I went through all the transcribed interviews and documents, assigning similar text passages with the same code. For instance, the interviewees' examples of adaptation action taken were labelled with the same code. After this first full reading and coding of material, I could sort interviewees' answers according to similar topics and themes. This facilitated the subsequent comparison within and between different categories. For instance, I was interested in both how similar (or different) experts discussed heatwaves within their sectors, as well as how different (or similar) the four sectors approached adaptation (s. chapter 5).

After prioritising those elements and research topics which I found most interesting and promising for publication, I then summarised each prioritised analytic unit – for instance, what adaptation action was proposed by building technicians, or what terms spatial planners used to describe the impact of heatwaves. As the size of my computer screen was unable to show all relevant results at any one time, I printed out all relevant codes and manually ordered them to find similarities and differences. In this process, I used scissors, different coloured markers, moderation cards, as well as both sides of a large, 1.2x1.5m pin board (see Figure 2.1). I had learnt this technique of visibly increasing the data density in my previous work as an environmental consultant. I found that pin boards are excellent aids in clustering and regrouping the wealth of text snippets, enabling me to get an overview quickly before getting back to details. Through this manual coding phase I was able to paraphrase key similarities and differences within and between sectors. Having earmarked particularly relevant quotes, I then double-checked all the relevant codes to see whether in my paraphrasing I had overlooked any contradictory statements, or whether my summary over-simplified key aspects of the sectors' work. If this was the case, I changed the summaries accordingly.

Overall, this manual approach of ordering the codes in a second step significantly slowed down the analysis, but had the benefit that I was better able to recall and conceptually link the multitude of text snippets into a somewhat coherent structure. Additionally, the cross-checking after the paraphrasing made me more confident that I had interpreted the results correctly. While I have not read about such an approach in a text book, the underlying principle of ordering is similar to those taught in handbooks (e.g., Kuckartz and McWhertor, 2014).

Statistical analysis. The quantitative data used in the chapters on global customisation (chapter 3) and national uses (chapter 4) were analysed statistically. Establishing the three typologies of users of climate projections – sailor, diver or observer – was

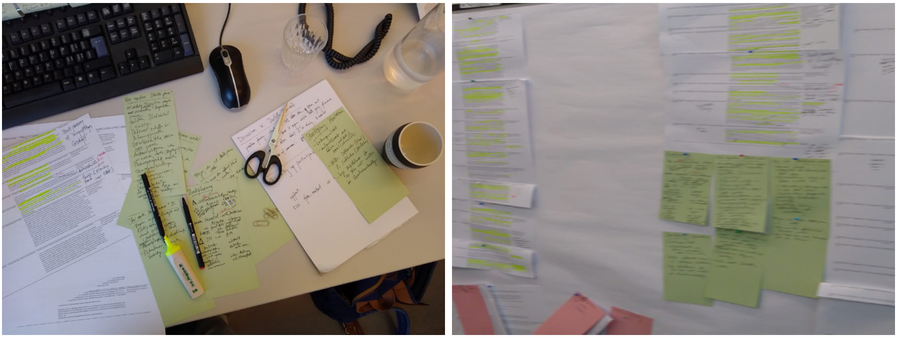

Figure 2.1 – Impressions of the second phase of analysis, highlighting how manual ordering and prepara-tion of paraphrases for key units of analysis took place in chapter 5. On the left, coded and sorted text is ready for colour-marking and handwritten summaries. On the right, the process of finding similarities and differences between sectors can be observed. Author photographs.

undertaken inductively from the material. Compared to the coding of text, however, the grouping of individual respondents to a user type required the creation of a meta-group by combining different answer options together. In this case, the clusters of final users emerged through a computer-based analysis, assigning individual respondents to a certain type through automatic checking for certain reply criteria (specifically, I used Boolean equations). Overall, the approach I used in establishing a typology from the data was very similar for both chapters 3 and 4. After being satisfied with the clustering – in chapter 4 by triangulating the quantitative data with the qualitative group interviews undertaken and in chapter 3 through discussions with climate scientists – I applied statistical tests to describe in which instances there are, or are not, correlations between key characteristic of countries and users. These analyses were carried out and visualised with the RStudio environment running the R language for statistical computing (R Core Team, 2018).

Quality and robustness. Scholars interested in what ensures quality and robustness of findings emphasise two dimensions. On the one hand, the so-called triangulation of different data types aims to stabilise findings when they are supported by multiple, independent data sources (e.g., Miles and Gilbert, 2005; Flick, 2011). On the other hand, Gutscher et al. (1996) argue that if data obtained by different methods align with each other, then any findings are assumed to be more robust. Thus, both dimensions stress the importance of singularity in multiple data or methods.

3 Customising global climate science for national adaptation: A case study of climate projections in UNFCCC's National Communications

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Abstract

Countries differ markedly in their production of climate science. While richer nations are often home to a variety of climate models, data infrastructures and climate experts, poorer sovereigns often lack these attributes. However, less is known about countries' capacity to use global climate science and customise it into products informing national adaptation. We use a unique global dataset, the UNFCCC National Communications, to perform a global documentary analysis of scientific submissions from individual countries (n=189). Comparing countries' climate projections with their competence in publishing climate science, our research examines the existence of geographical divides. Although countries proficient in publishing climate science use more complex climate modelling techniques, key characteristics of climate projections are highly similar around the globe, including multi-model ensembles of Global Circulation Models (GCMs). This surprising result is made possible because of the use of pre-configured climate modelling software packages. One concern is that these tools restrict customisation, such as country-specific observations, modelling information, and visualisation. Such tools may therefore hide a new geographical divide where countries with higher scientific capacities are able to inform what goes into these software packages, whereas lower scientific capacity countries are dependent upon these choices – whether beneficial for them or not. Our research suggests that free-to-use modelling and training efforts may unwittingly restrict, rather than foster, countries' capacity to customise global climate science into nationally relevant and legitimate climate information.

3.1 Introduction

If countries are to adapt to the impacts of climate change, it's critical they possess the scientific capacity needed to produce knowledge on a relevant scale and to translate it into policies to inform local decision-making (Ho-Lem et al., 2011). Such thinking sits at the heart of the Intergovernmental Panel on Climate Change (IPCC) efforts to synthesise climate science to inform policies under the United Nations Framework Convention on Climate Change (UNFCCC). Yet not all countries are able to produce scientific climate information, or to the same extent. Studies have shown that rich, high emissions countries publish the bulk of climate research (e.g. Haunschild et al., 2016; Pasgaard and Strange, 2013). This 'geographical imbalance' (Pasgaard et al., 2015) makes it challenging to inform policies equally if peer-reviewed publications are favoured. As a result, 'who' produces climate science, and even 'where' climate science is produced, can have far reaching effects for the commitment to UNFCCC agreements (Corbera et al., 2015; Hulme and Mahony, 2010) as well as the commitment to local adaptation efforts too (Blicharska et al., 2017; Miguel, 2017; Lahsen, 2007).

To understand these geographies of climate science, it's crucial to examine why differences in the publication of climate science have emerged and what differences exist over countries' capacity to customise global climate science. A major challenge here is how to compare countries with different characteristics (e.g. size, wealth, education, stability). Measuring scientific outputs by peer-reviewed publications has proved a reliable method for highlighting the volume and geographic distribution of climate research (Haunschild et al., 2016; Pasgaard et al., 2015; Karlsson et al., 2007). But interpreting such metrics as capacity to customise climate science entails the assumptions that all countries have similar interests in publishing climate science, as well as similar capacities to contribute research (cf. Dike et al., 2018). An alternative approach is to compare the ability of countries when using and producing (adaptation-relevant) climate science where the objective is the same for all involved. Any deviation from common reporting requirements – either going above and beyond or failing to meet set standards – would provide an indication of different scientific capacities between countries, including those with few peer-reviewed publications.

To do this, our paper presents a global comparison of climate projections' characteristics reported in UNFCCC National Communications, as a proxy of a country's capacity to produce nationally relevant, adaptation-focused scientific climate information. Section 3.2 summarises the literature on the geographies of climate science. Section 3.3 explains how we collected the data and how we classify countries according to their competence in publishing climate science. Section 3.4 explores differences in reporting climate projections and countries' compliance with UNFCCC requirements. Section 3.5 identifies similarities and variances in the modelling characteristics, and contrasts these with countries' publication competence. Section 3.6 details how the reported climate futures[2] are similar, regardless of countries' quantity and quality of publications. Section 3.7 and 3.8 offer a discussion about the emergence of a new, and mostly hidden, geographical imbalance in the way countries are supported to customise climate science for national decision-making.

3.2 On the geographies of climate science

Bibliometric studies have repeatedly revealed a geographical imbalance over the distribution of peer-reviewed climate publications (Haunschild et al., 2016; Pasgaard and Strange, 2013; Karlsson et al., 2007); and the authorship of IPCC reports (Corbera et al., 2015; Ho-Lem et al., 2011). Nearly half of all non-Annex 1 countries (45%) had no authors contributing to IPCC's first Assessment Reports between 1990 and 2007 (FAR, SAR, TAR, AR4) (Ho-Lem et al., 2011). Furthermore, a positive correlation exists between the wealth, education attainment, number of climate publications and the number of IPCC authors of a country (Ho-Lem et al., 2011; Karlsson et al., 2007) as well as the stability of institutional arrangements within it (Pasgaard et al., 2015; Pasgaard and Strange, 2013). In turn, historically the largest carbon emitters, and arguably the less vulnerable to climate change, have focused their research towards mitigation, not adaptation which most interests highly vulnerable countries (Pasgaard et al., 2015).

Moreover, critical scholars argue that the ambitions of countries to produce world-leading scientific climate knowledge[3], and climate models specifically, are shaped by varying histories and politics, and can (unwittingly) create geopolitical entanglements (Mahony and Hulme, 2018). For instance, Mahony and Hulme (2016) describe the motivations behind the establishment of the UK Met Office Hadley Centre to produce 'sound science' for politicians in order 'to develop a trust[worth]y model of one's own' (Mahony and Hulme, 2016: 465). UK politicians thought it necessary to balance and influence the IPCC with a specialist British entity. 'The capacity to predict was seen as allied to the capacity to adopt a political stance inde-

2 In this article, we use the term 'climate futures' to spotlight ways of envisioning futures in order to discuss climate change today. As such, 'climate futures' emphasise multiple socio-economic and temporal frames used to describe climate change in the future. We introduce 'climate futures' to make clear we aren't comparing plausible future states of the climate in a particular region ('future climates').

3 Throughout this study, we only analyse the use of knowledge derived from climate science. This has, in part, to do with other types of climate knowledge, for instance indigenous, experiential or artistic (cf. Engels 2019), not included in our UNFCCC dataset. However, as the word's origin highlights, *custom*isation of climate science for national adaptation could well include weaving in other nationally prevalent forms of complementary climate knowledges into climate projections.

pendent of both Europe and the US' (ibid). To this day, the Met Office Hadley Centre continues to have a national as well as international agenda; the latter illustrated by the release of a free-to-use regional climate modelling software package known as PRECIS, designed for countries with lower scientific capacities to make climate risk assessments (Mahony and Hulme, 2012).

With such socio-political ideologies guiding climate model development, the central role of climate models in climate science and policymaking (cf. Shackley et al., 1998; Skelton et al., 2019a), and the hegemony of only a few countries producing climate models, resistance to the application of climate research built elsewhere and for different purposes can be anticipated. Indeed, Myanna Lahsen (2007) has revealed how Brazilian policymakers distrusted joint climate science projects – between the global north and global south – believing them to be another way in which unequal power relations are entrenched by furthering the interests of the richer countries, not those of Brazilian scientists or politicians. Without a global climate model, emerging economies such as Brazil, can find it difficult to 'act sovereignly' in international climate negotiations (Miguel, 2017: 7). With 'climate modeling appearing as a strategic science' for emerging economies the 'national production of this type of technoscience [climate models] is an important pragmatic geopolitical approach for countries of the South wishing to occupy positions within the international climate change framework' (Miguel, 2017: 8).

While Brazil and China have their own climate modelling centres, other nations may lack the same level of technical infrastructure and investment. Such observations have led Blicharska et al. (2017) to urgently call for this so-called 'north-south divide' to be tackled. Fostering 'Post-Paris long term climate [science] capacity' requires moving away from the 'fly in fly out' climate science consultancy paradigm to a mode of training younger climate scientists also within countries' universities (Nasir et al., 2018: 130f; Dike et al., 2018).

Such studies, and calls-for-action, all problematize the idea of a value-free science which is legitimate around the world and can be imported and exported without encountering local or political friction. Yet science is always infused with national interests, histories, and politics that makes it more or less problematic to apply in different contexts. Both the UK and Brazil case studies above reveal similar political perceptions about climate models, regardless of their competence in climate science. However, the comparison by Skelton et al. (2017) of how climate science leaders produced their national climate projections shows that leading countries also rely heavily on climate models produced outside their countries (partly to account for their structural uncertainty, cf. Parker, 2010). Swiss, Dutch and British climate scientists focused far more on customising these global homogenous datasets into nationally legitimate climate science, even to the degree of (subconsciously) tailoring it to the countries' social and epistemic values. This tailoring included climate scientists interacting with certain users of climate scenarios in a nationally particular way (through user representation, broad participation, or elicitation), as well as scientists favouring research that reflected nationally particular assumptions of science for 'good' decision-making (such as, peer-reviewed, novel and innovative, or user friendly) (Skelton et al., 2017). While climate science has been a supra-national, global endeavour since its inception a hundred years ago (cf. Edwards, 2010), its global knowledge products tend to homogenise local differences and meaning instead of enriching the global datasets with local socio-political values (Hulme, 2010). As such, studies that focus only on the origin of climate science miss the political and scientific importance of customising that global climate science into something that is nationally legitimate, salient and credible (Cash et al., 2003).

3.3 Data and methods

To meaningfully compare countries' capacity to produce nationally relevant climate science for decision support, we conducted a documentary analysis of countries' most recent National Communication (n=189). National Communications are a unique global dataset, which report on the progress of a UNFCCC member's mitigation and adaptation commitments. Analysis of this dataset has been undertaken for a number of comparative studies, from the formulation and implementation of climate policies across different countries (Albrecht and Arts 2005) to tracking progress made on global adaptation by differentiating global leaders from the laggards (Lesnikowski et al., 2015). UNFCCC provides clear guidance (UNFCCC, 2008) and training sessions (UNFCCC, 2012, 2016) on what National Communications should include. These submissions are authored and officially signed-off by the countries in question. Analysing deviations from these reporting requirements – by either going beyond or below expected standards – are indicators for national differences in using and customising climate science, potentially revealing a geographical imbalance.

We downloaded the most recent National Communication submissions from the UNFCCC website, submitted to the UNFCCC between 30.10.1999 and 31.12.2016. Each one of the n=189 submissions was weighted equally, irrespective of when it was written (see Suppl. Figure 1). We then coded all the submissions manually. This involved reading each document and recording answers to a range of questions concerning climate projections in an Excel database. These questions included (i) were Global Circulation Models (GCMs) or Regional Climate Models (RCMs) used; (ii) what downscaling techniques were used (e.g. statistical/dynamical); (iii) how many emissions pathways were used; and (iv) which timeframes were used (e.g. >2080s) (see Annex to chapter 3 for a full list).

Various countries reported multiple sets of climate projections, for example one covering the entire national territory and a second one only for a particular administrative region. To distinguish these, we define a 'set of climate projections' as one product, potentially encompassing multiple climate models, outputs, and emissions pathways to describe multiple yet coherent climate futures. This includes, for instance, aggregating climate information from multiple climate models and/or climate model runs for one emissions pathway. When a country reported more than one set of climate projections, we applied two criteria to narrow the selection down to one set. First, we prioritised the set of climate projections that focused on the entire country, rather than a single geographical region. Second, we selected the climate projection that contained higher concentrations of information (measured as the relative space used by text descriptions, graphs and tables).

In order to contrast countries' capacity to produce climate projections with their general competence in publishing climate science, we classify countries according to the quantity and quality of their publications. For this, we draw on Haunschild et al. (2016) comparing more than 200,000 peer-reviewed publications and their citations between 1980 and 2015, using keywords similar to 'climat* change'. By selecting the proportion of papers belonging to the 10% most frequently cited – the indicator $PP_{top10\%}$ – Haunschild et al. (2016) ranked countries' competence in publishing climate change research. We use this indicator to create three levels of publication competence: proficient, advanced, and preliminary. We define proficient as a $PP_{top10\%}$>20 and >1000 published papers between 1980 and 2015. N=17 countries fit this category, including many European countries as well as Australia, New Zealand, and the US (see Annex to chapter 3 for a full list). All proficient countries have dedicated climate modelling centres developing GCMs and/or RCMs. Countries classified as advanced have >1000 published papers but a $PP_{top10\%}$<20. N=14 nations meet these criteria, including Brazil, China, Greece, India, Israel, and Japan. In advanced nations, climate science is funded and publications are numerous, but they are not often excellent. The remaining n=158 countries have a preliminary competence with <1000 published papers (which may or may not be excellent). This includes, for example, all African countries except South Africa, Chile, Croatia, Liechtenstein, Tajikistan, and Viet Nam. In preliminary countries, publishing large amounts of climate science is a challenge, either due to being a poorer, highly populated country or a smaller, richer nation.

Lastly, our research highlights, and is subject to, some limitations with the UNFCCC National Communications dataset. Amongst the countries that failed to submit any climate projections in their National Communications, further research revealed that Australia (CSIRO and Bureau of Meteorology, 2007b), Canada (Barrow et al., 2004) and Spain (Gutiérrez et al., 2012), have in fact all produced national climate projections. Why these climate projections were not included in the submissions is unclear. Such observations are, however, helpful in revealing the challenges of working with global datasets where reporting requirements are either inconsistently met or simply ignored. Further, the voluntary nature of reporting National Communications for non-Annex 1 countries results in climate projections produced at irregular intervals (see Suppl. Figure 1). Thus, n=10 countries reported climate projections within their National Communications submitted between 1999 and 2008, complicating comparison as more recent submissions have more climate models available. However, the majority (n=120/189, 63%) of National Communications have been submitted in the short time span between 2013 and 2016.

3.4 Did all countries include climate projections in their National Communications?

Of the 196 UNFCCC member states, 189 countries submitted National Communications[4]. In 90% (n=170/189) of cases, countries' submissions included climate projections as part of their vulnerability and adaptation assessment (Figure 3.1). While the UNFCCC reporting guidelines don't prescribe how many climate projections should be reported, a broad consensus emerged. The majority of countries (n=126/189, 67%) provided a single, national, set of climate projections, while a minority of countries (n=43/189, 33%) chose to report multiple sets of climate projections. Multiple climate projections often focused on several different spatial or administrative scales (e.g. regions, cities and airports), and could be used to inform local government policies and decision-making.

Crucially, Figure 3.1 highlights that the global distribution of climate projections, based on UNFCCC National Communications, plays out differently to what might be expected from the literature (cf. Blicharska et al., 2017; Haunschild et al., 2016; Pasgaard and Strange, 2013). Climate projections are produced and available across the globe – but more often (and in higher numbers) in countries classified as preliminary and advanced (n=145/158, 92%) rather than proficient in publishing climate science (n=13/17, 76%). A Kruskal-Wallis H test confirms that the number of reported climate projections is indeed (inversely) correlated to a country's publication competence ($X^2(2, n=189)=8.0, p<.05$). This is even more surprising given that the vulnerability section reporting guidelines for non-Annex I countries of the UNFCCC are voluntary. Aware of various countries' capacity and resource constraints, the UNFCCC ran several 'hands-on training workshops' before the submission of National Communications, introducing free-to-use and well-established software tools such as PRECIS and MAGICC/SCENGEN (UNFCCC, 2016).

Among the few preliminary countries failing to report climate projections are n=5 oil-rich countries (Angola, Bahrain, Egypt, Qatar, and the United Arab Emirates)

4 Iraq's submitted National Communication was unavailable for download. Iraq was thus not considered in the 189 submissions.

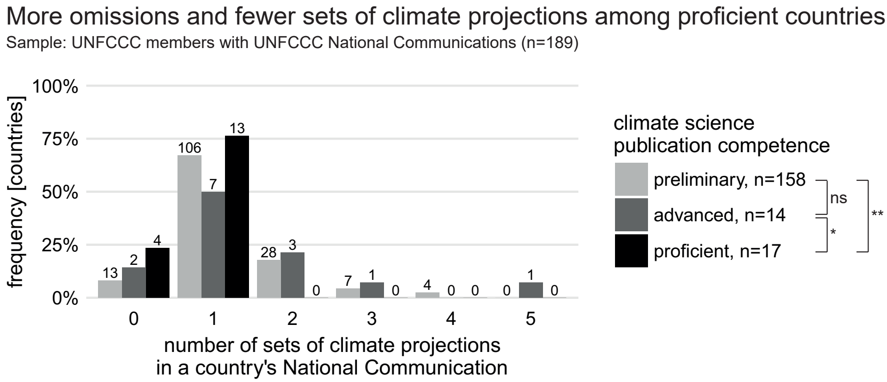

*Figure 3.1 – Number of sets of climate projections reported in UNFCCC National Communications, grouped by countries' climate science publication competence. Most countries submitted a single set of climate projections. Distributions are compared with Mann-Whitney U tests comparing two country groups; ns denotes 'not significant', *p<.05, **p<.01.*

and n=3 Small Island Developing States (SIDS). This finding echoes that of Pasgaard et al. (2015) where SIDS are correlated with lower numbers of climate change publications. Among the proficient countries omitting climate projections in their National Communications are interestingly some which had them readily available, such as Australia (CSIRO and Bureau of Meteorology, 2007b), Austria (Loibl et al., 2009) and Canada (Barrow et al., 2004)[5].

3.5 What climate model characteristics do National Communications submissions share?

Of the n=170 (out of 189) National Communications that provided climate projections, our research found that while the complexity of the methods used correlates significantly with a country's climate science publication competence, the number of climate models (e.g. Global Circulation Models (GCMs) or Regional Climate Models (RCMs)) is independent of a country's publication record.

3.5.1 *Climate modelling complexity*

As shown in Figure 3.2, we created a rank order from the least to the most complex climate projections approaches. For instance, while some techniques don't require

5 The Australian omission is likely associated with new climate projections being developed at the time, and not tied to political reasons. Australia's Sixth National Communication was prepared under the outgoing Labour administration favouring climate action.

specialist knowledge to produce climate projections, others allow a high level of customisation with different sets of observations, models or statistical methods. Modelling efforts were classified according to one of seven ranks:

1. *Other.* No details provided about the methods or data sources used. N=1 advanced and n=10 preliminary nations fitted this category.

2. *Lookup.* Existing datasets, such as the United Nations' Climate Change Country Profiles (McSweeney et al. 2010), are used to insert tables or figures into the National Communications. No data customisation is possible.

3. *Plug-and-play*. Software packages including MAGICC-SCENGEN (Wigley, 2008) and SimCLIM (Warrick et al., 2005) are used to calculate climate futures using a simple energy-balance model with pattern-scaling. Some data customisation is possible.

4. *GCM only.* Raw data is downloaded from portals such as 'Climate Explorer' (Trouet and van Oldenborgh, 2013) and projections produced using one or multiple GCMs. However, the spatial resolution of GCMs (100km and more) cannot account for topographical features such as mountain ranges or islands.

5. *Statistical downscaling.* GCM outputs are downscaled using statistical techniques to achieve a higher spatial resolution. A high level of technical skill is required to perform downscaling competently (Wilby et al., 2002).

6. *PRECIS.* Tailored to researchers in countries with lower coverage of observational datasets, the RCM PRECIS requires solid expertise while running on a Linux-based PC with a simple user interface.

7. *Dynamical downscaling.* A highly demanding technical approach for producing high-spatial resolution outputs (e.g. <25km) using RCMs. Freedom for customisation is high. However, RCMs have issues with nonlinear feedbacks and miss long-distance climate linkages (teleconnections).

Figure 3.2 reveals a clear-cut geographical imbalance in which countries' capacity to use complex modelling techniques and to customise climate model output into national climate projections is highly correlated with their competence of publishing climate science (Kruskal-Wallis H test: $X^2(2, n=170)=19.6$, $p<.0001$). Further Mann-Whitney U comparisons between only two competence levels (Figure 3.2, legend) reveals that distributions differ most for proficient countries, which almost all mapped onto a single, the most complex, category (i.e. dynamical downscaling,

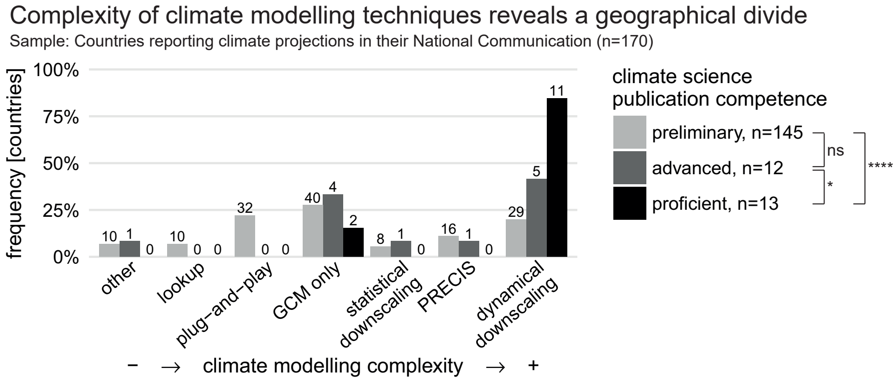

*Figure 3.2 – Distributions of climate modelling complexity, ranked from less complex (left) to more complex methods (right), grouped by countries' publication competence. More complex modelling efforts allow more customisation, but require a higher level of understanding and technoscientific modelling infrastructures. Distributions are compared with Mann-Whitney U tests comparing two levels of publica-tion competence; ns denotes 'not significant', *p<.05, ****p<.0001.*

n=11/13, 85%). This contrasts with most preliminary countries (n=82/145, 57%) choosing a less complex modelling method (i.e. lookup, plug-and-play, GCM only). The lack of scientific infrastructures and data availability may help explain the preference for less demanding climate modelling approaches. For instance, one of the advantages of plug-and-play methods, such as MAGICC-SCENGEN, is that they can be stored on USB devices and run offline, getting away from internet bandwidth problems. Furthermore, empirical studies have shown that simple energy balance models can perform surprisingly well compared to more complex climate models (e.g. GCMs) but require a fraction of the skill, time, and technoscientific infrastructure (Shackley et al., 1998).

That said, nearly a third of countries with preliminary numbers of climate science publications (n=45/145, 31%) made use of the two most complex modelling approaches: PRECIS and dynamical downscaling, both using RCMs. In n=16 cases, output from the UK Met Office's freely available PRECIS model (Jones et al., 2004) was used. Another n=16 countries with preliminary publication competence are smaller European nations benefitting from pan-European RCM modelling projects such as ENSEMBLES (van der Linden and Mitchell, 2009). These two factors help explain why preliminary and advanced nations differ *almost* significantly in their distributions (Mann-Whitney U test: $X^2(1, n=157)=3.6$, p=.06).

A geographical imbalance also emerged when analysing where the underlying climate projections methods originated. Many of the modelling tools were developed by Anglophone scientists for explicit use outside their own countries, with focus on global applicability and user orientation. MAGICC-SCENGEN (Wigley, 2008) and the UN Climate Change Country Profiles (McSweeney et al., 2010) are from the United States; SDSM (Wilby et al., 2002) and PRECIS (Jones et al., 2004) are from the United Kingdom; and SimCLIM (Warrick et al., 2005) is a commercial product from New Zealand. The two continental European projects are different in this regard: the Dutch ClimateExplorer (Trouet and van Oldenborgh, 2013) is a database of GCM simulations (without direct means to produce climate projections), while Germany funded a science partnership with South Africa producing nationally-specific climate projections (DEA, 2013).

3.5.2 Number of climate models used

Figure 3.3a is a boxplot showing the number of Global Circulation Models (GCMs) used to produce climate projections in countries' National Communications, grouped by their publication competence. Excluding the outliers, where Argentina used 42 GCMs and Finland 28 GCMs, the data shows little difference in the distributions of GCMs. While the median number of GCMs is higher for proficient countries, a Kruskal-Wallis H test shows that the distributions are independent of countries' publication competence ($X^2(2, n=122)=2.14, p=.34$). The wide use of multiple GCMs is thus encouraging, given that multi-model ensembles inform about certain aspects of structural uncertainties in climate modelling practices (Kreienkamp et al., 2012; Knutti et al., 2010; Parker, 2010). The availability of multiple GCMs in less complex climate projections may well have to do with up to 20 GCMs included in MAGICC-SCENGEN (Wigley, 2008). In addition, more recent submissions benefitted from projects such as the Coupled Model Intercomparison Project (CMIP, e.g. Meehl et al., 2014) facilitating the download of multi-model output.

Figure 3.3b shows the distribution in the number of Regional Climate Models (RCMs) used by those countries employing PRECIS or dynamical downscaling (see Figure 3.2). A Kruskal-Wallis H test corroborates the visual impression that the distributions of RCMs don't differ significantly with publication competence ($X^2(2, n=54)=5.17, p=.08$). However, Figure 3.3b indicates that the recommended use of multi-model ensembles (Knutti et al., 2010) hasn't as yet been transferred to the use of multiple RCMs as well. Only European countries, thanks to the European ENSEMBLES project (van der Linden and Mitchell, 2009), have had multiple RCM simulations available for their national territory. This may change as the global availability of RCMs increases through initiatives such as CORDEX (Giorgi et al., 2009). However, it remains to be seen how much countries with less publication experience and less technoscientific infrastructure can harness these additional sources, as computational complexities, dataset size, time required, and resources needed all increase.

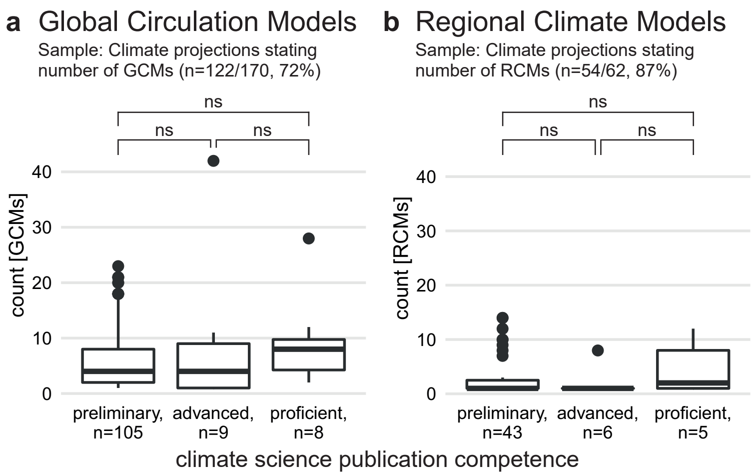

Figure 3.3a and b – Distributions of the number of Global Circulation Models (GCMs, a) and Regional Climate Models (RCMs, b) used in climate projections, grouped by countries' publication compe-tence. While Figure 3.3a shows that multi-model GCM ensembles are common independently of the country classification, most climate projections with RCMs have used only a single one (Figure 3.3b). Mann—Whitney U tests performed for comparing two country groups supports their independence; ns denotes 'not significant'. NB: Bold line denotes the median; box the 25th and 75th percentile; whiskers the 5th and 95th percentile; points are outliers.

3.6 What type of climate futures do countries report?

To be able to inform adaptation decisions, it's key to not only have the ability to use multiple models, but also to incorporate different socio-economic conditions and timeframes to understand how different climate futures can develop. Too many timeframes and/or emissions pathways can result in an inability to work through different variations, creating a decision-making paralysis. Too few, by contrast, locks decision-makers into a deterministic view that discounts the importance of uncertainty (Hulme and Dessai, 2008; Parker, 2010). To that end, this section highlights: (i) how many timeframes were considered (e.g. up to 2050s or 2090s); and (ii) how many emissions pathways were used (e.g. single vs. multiple).

First, the vast majority of countries – independently of their publication competence in climate science – used multiple timeframes (n=129/170, 76%) up to the end of the century (Figure 3.4a). IPCC guidance notes that '[t]he length of time period considered in the assessment studies can significantly affect results' (Knutti et al., 2010: 11). In response, the UNFCCC recommended that countries 'consider time frames ranging from 2030 to 2100' in order to adequately incorporate climatic changes arising from socio-economic factors in longer-term (e.g. after the 2060s) (UNFCCC, 2008: 12; see also Hawkins and Sutton, 2009). While comparing all three country

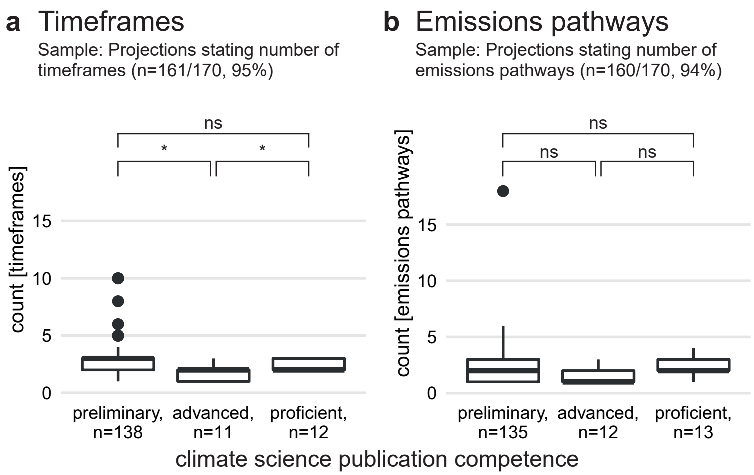

*Figure 3.4 – Distributions of the number of timeframes (a) and emissions pathways (b), grouped by countries' publication competence. Significances of Mann-Whitney U tests between two levels highlight that only advanced countries used significantly fewer timeframes; ns denotes 'not significant', *p<.05. NB: Bold line denotes the median; box the 25th and 75th percentile; whiskers the 5th and 95th percentile; points are outliers.*

classifications simultaneously shows no significantly different distributions in the number of timeframes reported (Kruskal-Wallis H test: X^2(2, n=161)=4.9, p=.08), comparing only two publication competence levels reveals that advanced countries reported significantly fewer timeframes than both proficient and preliminary countries (Figure 3.4a). This has mainly to do with the third of advanced countries reporting only a single timeframe (n=4/12, 33%).

Second, the number of emissions pathways (Figure 3.4b) is independent of a country's publication competence (Kruskal-Wallis H test: X^2(2, n=160)=3.4, p=.18). Whilst UNFCCC guidance (UNFCCC, 2008: 12) acknowledges that 'developing baseline scenarios can be complex and time-consuming', it is recommended that at least two emissions pathways be selected – one high and one low temperature response – to capture the uncertainty around future greenhouse gas emissions (Kreienkamp et al., 2012).

Overall, n=13 preliminary and n=3 advanced nations reported only a single emissions pathway and a single timeframe, depicting thus a deterministic view on only a single, mostly pessimistic, climate future. These countries most often reported a mid- to long-term future with a high (e.g., A1B) (n=8) or very high (e.g., RCP8.5) (n=5) emissions pathway. No country classified as proficient did so.

3.7 Discussion: What is the geography of climate science for adaptation?

Our examination of climate projections reported by countries (n=170 of 189) in their UNFCCC National Communications, between 1999 to 2016, raises fresh questions about the debates on 'geographical imbalances' (Pasgaard et al., 2015) and the so-called 'north-south divide' (Blicharska et al., 2017). In particular, our analysis characterises countries' capacity to use and customise climate science. Our results paint a complex picture:

(a). Comparing the complexity of modelling approaches, our study supports that countries proficient in publishing climate science are also significantly more often able to use the most sophisticated method available. Dynamical downscaling requires most expertise and infrastructure, but also allows most customisation (e.g., choice of models, observation datasets, visualisation). In a study contrasting the climate projections of three leaders in climate science, Skelton et al. (2017) found that this customisation included making modelling choices influenced by the respective country's civic epistemology and political culture in order to increase the climate projections' national legitimacy. Furthermore, comparing preliminary and advanced nations' climate projections reveals that the complexity of modelling approaches is only just statistically insignificant (p=.06), even though the publication competence is quite different. This is partly due to preliminary countries able to profit from pan-European modelling projects such as ENSEMBLES (van der Linden and Mitchell, 2009), and partly due to free-to-use climate model tools such as SDSM or PRECIS allowing countries with few publications to outperform nations with many publications. For instance, Bhutan and Paraguay are able to produce high-resolution climate projections with PRECIS, while Brazil and China have developed their own climate models, but reported projections using GCMs without downscaling.

(b). Our results question the so-called 'north' and 'south' binary (cf. Blicharska et al., 2017; Karlsson et al., 2007) as too simplistic to characterise countries' capacity to customise global climate science. We found that some 'southern' countries have their own climate models and used a more complex modelling technique in their climate projections (e.g., Brazil, China, India, or Russia) while other 'northern' countries (e.g., Bahrain, Barbados, and the United Arab Emirates) failed to report climate projections altogether. The 'north-south divide' calls for a geographically fairer distribution in the production of climate science, but is unable to explain differences within the 'north' and 'south'. Our research questions the capacity of countries to use and translate global climate science for their local context. For example, 'lookup' methods require no climate science expertise, while plug-and-play methods such as MAGICC-SCENGEN already allow users to select (preconfigured) climate models, timeframes and emissions pathways. Further up the line, the use of 'GCMs only' requires already some expertise in working with 'raw' climate model output as well as significant computer storage and internet bandwidth. ‘PRECIS’ meanwhile is so sophisticated that the developers (UK Met Office) run particular workshops in order to guarantee competent use as well as to ensure feedback of how reliable PRECIS output is for countries on different continents (Mahony and Hulme, 2012). With this breadth of ‘lookup’ to highly complex modelling approaches, requiring no skill to much expertise and technoscientific infrastructure, allowing no to high customisation, countries’ climate projections allow an empirically rich comparison of countries’ capacity to customise global climate science and produce nationally relevant information regardless of their peer-reviewed publication output. Such insights call for debates on ‘geographical divides’ to be extended to the uptake of climate science and its translation into national decision-support products, rather than only the origin of peer-reviewed climate science.

(c). Our results indicate – surprising given the geographical imbalance – a strong commitment by nations around the world to identify and assess climate risks with climate models, even to the point that countries with preliminary publication competence reported climate projections more often (and in higher numbers) than proficient nations (Figure 3.1). Factors that have influenced such countries’ capacity to perform the scientifically more demanding parts of the National Communications include: science and technology transfer in the form of free-to-use climate modelling software such as PRECIS; free training sessions provided by UNFCCC to give expert guidance on how to prepare climate projections for the National Communications (UNFCCC, 2012, 2016); financial support to help fund the National Communication process; and countries’ requirements to ‘develop high quality [Green Climate Fund] proposals that demonstrate need [vulnerabilities]’ to increase access to financial aid tied to adaptation and mitigation (Fonta et al., 2018: 1215).

(d). The preference of the UNFCCC for climate projections to be included in National Communications (UNFCCC, 2008) may, unwittingly, introduce new geographical imbalances. Modelling initiatives such as PRECIS have been undertaken to assess climate risks in regions where little data, or scientific infrastructures, exist (Mahony and Hulme, 2012). However, making available climate science doesn’t address longer-term capacity concerns such as who becomes an IPCC author (Corbera et al., 2015; Ho-Lem et al., 2011) or who publishes in high-impact journals (Haunschild et al., 2016; Pasgaard et al., 2015). Using the example of early-career climate scientists in Africa, Dike et al. (2018) emphasise the need to improve and support internal structures for producing climate science within individual countries, for example in universities (Nasir et al., 2018). Otherwise aims such as informing adaptation policies through climate science while simultaneously basing those decisions on fairer and more locally produced scientific knowledge base remains problematic, with geopolitical implications. Although our research shows that most countries – independent of their climate science competence – seem unconcerned about using multiple climate models originating from other countries (cf. Miguel, 2017; Mahony and Hulme, 2016), they might be concerned with a lack of local customisation of such globally uniform datasets, including taking over the tool producers' social and scientific values of 'good' science for decision-making (cf. Skelton et al., 2017).

Our research questions the extent to which efforts to minimise gaps in climate science *availability* may mask, or even worsen, a country's *dependency* on climate science produced only elsewhere. For instance, the recent push towards co-produced climate services *customised* to a stakeholder's need (cf. Vaughan and Dessai, 2014; Porter and Dessai, 2017; Bruno Soares and Buontempo, 2019; Skelton et al., 2019a) is very difficult to achieve when countries rely on pre-configured climate modelling software. While in the near future the means of accessing climate science might well change, as modelling software such as MAGICC-SCENGEN is discontinued and climate information websites are evolving (Hewitson et al., 2017), customisation restrictions will likely continue.

Future research should critically examine what interrelated factors maintain, shift and potentially worsen the geographical imbalance in countries' capacity to customise global climate science. Based on our research, five factors play an important role: (i) UNFCCC's reporting requirements mirroring IPCC's epistemic focus on climate models for risk assessments; (ii) 'goodwill' efforts by leading climate scientists in rich, high emissions countries (predominantly Anglophone); (iii) capacity-building commitments from climate science leaders within UNFCCC; (iv) UNFCCC assistance provided to non-Annex 1 countries with fewer climate science publications when preparing National Communications; and (v) countries' improved access to financial aid (e.g. GCF) following vulnerability assessments.

3.8 Conclusion

Analysing individual countries' capacity to use existing global climate science for informing national decision-making, our research supports a geographical imbalance. Most countries – irrespective of their climate science publication competence – are able to produce climate projections with similar modelling principles. While countries with less publication experience are now gaining valuable experience in using scientific climate knowledge, especially free-to-use modelling software, they haven't as yet developed the capacity to customise globally uniform datasets. These countries, as a result, remain dependent on the climate models, expertise and tools to assess climate risks from scientifically leading countries, and have to tacitly accept what constitutes 'good' science for decision-making. Although climate modelling tools improve the availability of global climate science they may also contribute to a growing divide in the *capacity of countries to* customise science to their national contexts.

4 Who is ‘the user’ of climate services? Unpacking the use of national climate scenarios in Switzerland beyond sectors, numeracy and the research–practice binary

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Abstract

By whom are national climate scenarios taken up, and which products are used? Despite numerous (national) climate scenarios being published by countries across the globe, studies of their actual uptake and application remain low. Analysing a survey and group interviews on the ways the Swiss climate scenarios CH2011 have been actually used by the Swiss adaptation community, we encoded the emerging differences in a new typology of *observers*, *sailors*, and *divers*. Taking an iceberg as a metaphor for climate scenarios, most respondents were *sailors*, accessing only key findings above the waterline (i.e., summary brochures). However, the vast majority of climate scenario data remains below the surface (i.e., downscaled climate model data), accessible only to the quarter of respondents labelled *divers*. Lastly, another quarter are *observers*, interested in the iceberg from afar, but without applying the climate information directly to their work. By describing three ways of using climate scenarios, we aim to clarify the often vague notion of ‘user’ circulating prominently in discussions around climate services and knowledge co-production. In addition, our results question the adequacy of simplifying climate scenario use by a user’s easily observable characteristics – such as being a researcher or practitioner, by sector or by numeracy. Our typology thus highlights the diversity of use(r)s within sectors or academia, but is also able to characterise various similarities of use(r)s between sectors, researchers and practitioners. Our findings assist in more nuanced and informed discussions of how ‘users’ are imagined and characterised in future developments of usable climate services.

Practical Implications

Climate services and climate information products are increasingly produced across the world. While national climate scenarios are frequently evaluated by academics in order to have them critically peer-reviewed for their climate-scientific adequacy, the *actual* use of such climate scenarios (rather than needs) has been largely neglected in the peer-reviewed literature. However, such evaluations are necessary for two reasons. One, to understand in what ways the often expensive climate scenarios have been used. Two, to discern how future sets of climate scenarios and other climate services can be improved for users. Our study characterising the actual use of the Swiss national climate scenarios achieves both these two goals.

National climate scenarios form the basis for many climate change risk assessments and national adaptation strategies, characterising plausible future meteorological changes in temperature, precipitation, as well as other climatic indices such as rising snowlines or numbers of tropical nights. Climate scenarios are produced with physics-based calculations with different amounts of greenhouse gas (GHG) emissions, the main driver of anthropogenic climate change. The different GHG emissions pathways are used to highlight the implications of different global carbon mitigation policies. As such, national climate scenarios are produced for decision-makers working in civil administration, associations, industry, consultancies and non-governmental organizations (NGOs) of a particular country, as well as politicians, journalists and the interested 'general public'. In addition, climate scenarios serve researchers as a basis for climate impact studies which highlight the effects of atmospheric changes on land surfaces, such as rockslides or floods.

Taking the example of the Swiss national climate scenarios CH2011 (2011), we present three distinct ways CH2011 has actually been used by the Swiss adaptation community. These three ways are not categorisations drawn from the existing literature, but emerge from our in-depth analysis of our empirical data (a survey and group interviews). To easily differentiate between the three types of users, we introduce a metaphor taken from Braunreiter and Blumer (2018) on energy scenario use: Climate scenarios are like an iceberg, where different perspectives give access to different parts of the iceberg. Divers are able to access the vast climate model raw data lying beneath the water's surface. Divers thus prefer thematic depth to breadth. Sailors see only the tip of the iceberg, containing key results of the climate scenario summary brochures. Sailors are however able to navigate between icebergs and other landscapes quickly. Sailors thus prefer thematic breadth to depth. Observers have seen the iceberg, albeit from a distance. Observers have skimmed the tip of the iceberg, that is, the summary brochures. Characteristically, observers have not directly applied the climate scenarios. Compared to the active appliers of sailors and divers, observers did not introduce findings of the climate scenarios into their work.

Previous studies on 'the users' of climate information have often characterised these based on easily observable (i.e. independent) traits. This includes distinguishing between researchers and practitioners; by comparing or focusing on sectors; or explaining the use of raw data with a user's assumed numeracy (i.e. the ability to work with large quantitative datasets). We then compare our own typology of observers, sailors, and divers with these three groups proposed in the literature. Interestingly, these groups do not match our own typology: We find a mix of observers, sailors, and divers within sectors, research and practice. Further still, our research warns against explaining low use of climate scenario raw data by saying that these users are incapable of processing vast amounts of climate model output. Most users made use of large datasets for today's climate (i.e., observations and reanalyses), but not of the large datasets provided through climate scenarios. While this indicates that many 'numerate' users opted to use climate scenario brochures qualitatively, producing raw climate scenarios datasets tailored to users' spatio-temporal needs might well change this result.

How can our study help in producing future climate services? We conclude with four points. One, producers of climate services should be aware that there is a diversity of use(r)s within sectors as well as among researchers and practitioners. However, our typology of observers, sailors and divers also highlights that there are similarities in what products – brochures and datasets – are used within such user categories. Two, while our study supports efforts to tailor climate services to sectors or practitioners, our study recommends producing both brochures for sailors, and datasets for divers. Three, there is a considerable share of people working in the adaptation community which flick through brochures, but do not apply them directly. Increased efforts to incorporate these users' voices in future climate scenario projects could significantly increase their uptake. Four, more intensive exchanges – and studies thereof – could highlight why so many users make quantitative use of data on today's climate, but only qualitative use of brochures (if at all). Overall, our analysis paints a heterogeneous picture of climate scenario use within sectors and among researchers and practitioners – but also three surprisingly similar ways between such classifications.

4.1 Introduction: who uses what climate information?

> «I hate the term 'user'».
> «I don't have a problem with the term 'user'».[6]

These two quotes illustrate that the term 'user' is contested yet convenient to discuss the application of climate information. The two conflicting opinions are symbolic of a larger discomfort with the concept of 'the user': While the term 'user' is clear in terms of definition (people who use information are 'information users'), the term is both ambiguous and vague. 'Users' can refer to climate impact modellers, risk managers, administrative officials, or interested publics equally. Further, 'users' may have different ways of using climate information. The vagueness thus complicates efforts of producing 'usable' climate information, as important nuances often remain implicit. In this study, the term 'user' refers to all people, regardless of their sectoral, academic, or professional affiliation, who have interacted with climate scenarios, by minimally having skimmed one of the various brochures, often also applying data into their work.

To support climate adaptation and carbon mitigation initiatives, various countries have published a set of climate scenarios tailored specifically to their country (cf. Skelton et al., 2017). This includes the Netherlands (KNMI, 2015), the US (Melillo et al., 2014), South Africa (DEA, 2013), Ireland (Gleeson et al., 2013), Germany (DWD, 2012), Switzerland (CH2011, 2011), and Australia (CSIRO and Bureau of Meteorology, 2007a). In addition, there is guidance to include climate scenarios in the reporting of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (Skelton et al., 2019b). Despite these numerous national efforts, the actual use of (national) climate scenarios remains blurred. One notable exception is the UK Climate Projections 2009 (UKCP09, Jenkins et al., 2009; cf. Heaphy, 2015 and Hulme and Dessai, 2008). For instance, Tang and Dessai (2012) analysed how a diverse set of British actors, obliged to report on adaptation, perceived and made use of UKCP09. A longitudinal study by Porter et al. (2015) found that the availability of climate information has risen in British Local Authorities between 2003 and 2013, but that budget cuts and lack of political support restricted adaptation action. Further, comparing local government's use of national climate scenarios in Germany and the UK, Lorenz et al. (2017) found that only few people considered climate information in adaptation. With national climate scenarios recently updated (CH2018, 2018; Lowe et al., 2018) and a European roadmap for climate projections proposed (Hewitt and Lowe, 2018; Met Office and CNRS, 2018), it becomes increasingly important to also understand the utility of different products climate scenarios provide, such as summary brochures or large climate model datasets.

6 The statements were made at a session on 'Inclusion of climate-sensitive sector needs' at a workshop within the Copernicus Roadmap for European Climate Projections project (Met Office and CNRS (2018).

Knowing better how climate scenarios are actually used (or resisted) can also help climate research projects to incorporate the requirement of 'user-orientation' better. As such, climate scientists are urged to collaborate with stakeholders on equal terms, a concept also known under the term co-production (cf. Bremer and Meisch, 2017). This change of producing knowledge is most evident in the rise of climate services (Lourenço et al., 2016; Vaughan and Dessai, 2014; Hewitt et al., 2012). However, as the importance of co-produced climate knowledge increases, vague and ambiguous notions of 'the user' become problematic. Scientists can too easily pick their preferred characterisation of 'the user', failing thus to include users with other needs. For instance, Archer (2003) showed that certain user groups (often socio-economically worse off) were underserved. Calls for engagement 'beyond lip service' (Klenk et al., 2015) have been made. This is important, because when public money is spent on the development of usable climate information (Lemos et al., 2012), then the questions of 'who is included in the knowledge production process', 'to whom is the climate information tailored to' and 'who uses climate information' become of considerable importance (Klenk et al., 2015).

Who uses national climate scenarios in what ways? This paper provides an empirically grounded characterization of national climate scenario uses. Section 4.2 details our case study, the Swiss climate change scenarios CH2011, before introducing how the data was collected and analysed (section 4.3). Section 4.4 introduces our typology of climate scenario users: observers, sailors, and divers. In section 4.5 we discuss the implications of our findings, comparing our typology with common characterisations of users from the literature. We close with a brief conclusion in section 4.6.

4.2 Case study: the Swiss national climate scenarios CH2011

In this study, we analyse the actual use of the Swiss national climate scenarios CH2011 (2011) by the Swiss adaptation community[7]. These scenarios were jointly produced by climate scientists working in several academic and public institutions over three years, in order to speak with 'one voice' (Skelton et al., 2017: 2332; see also Brönnimann et al., 2014). Climate scenarios[8] are a distinct form of climate knowledge, 'potentially encompassing multiple climate models, outputs, and emissions pathways to describe multiple yet coherent climate futures. This includes, for instance, aggregating climate information from multiple climate models and/or climate model runs for one emissions pathway' (Skelton et al., 2019b).

7 We define 'Swiss adaptation community' as the participants of Switzerland's Symposia on Climate Adaptation and the project managers who received funding through the Swiss Pilot Programmes on Climate Adaptation.

8 We use the term 'climate scenarios' to encompass 'climate projections', 'climate change scenarios', and 'national climate assessments'. Assessments of climate impacts are excluded, as they are qualitatively different.

The CH2011 climate scenarios contain meteorological changes of temperature and precipitation. These were provided with three uncertainty estimates (upper, mean, lower) based on a probabilistic approach (Fischer et al., 2011) characterizing model uncertainty and internal variability. Climatic changes conditional on three emissions pathways (reflecting different levels of global mitigation strategies) were explored for three future time periods covering the 21st century. Likely future temperatures and precipitation are communicated against the baseline climate of 1980-2009 for three regions of Switzerland, and as localized daily temperature series for several Swiss weather stations. CH2011 contained various products: a summary brochure (available in English, German, French, and Italian); a technical report (in English only); as well as raw data downscaled to stations or as a gridded dataset for precipitation and temperature.

The Swiss climate scenarios CH2011 (2011) inform the Swiss national adaptation strategy. Praised as a pre-requisite for climate-sensitive planning, climate scenarios are seen as the basis for explicit, often quantitative risk assessments (Willows and Connell, 2003b; e.g. CH2014-Impacts, 2014) and have found qualitative application in national adaptation strategies (Widmer, 2018; Lorenz et al., 2015; Biesbroek et al., 2010). In addition, they informed a large number of adaptation projects from different sectors (Rössler et al., 2019; BAFU, 2017). In autumn 2018, the successor Swiss climate scenarios CH2018 (2018) were published (www.climate-scenarios.ch).

4.3 Material and Methods

To analyse the uptake of, as well as resistances towards, climate information within the Swiss adaptation community, we make use of data gathered in 2015 as part of an assessment of the Swiss climate scenarios CH2011 (MeteoSwiss, 2016). This assessment was mandated by the Swiss Federal Office of Meteorology and Climatology MeteoSwiss to an environmental consultancy. Its aim was to better understand the ways both present and future weather and climate data were used, and how CH2011's usability could be improved further. A description of this multi-stage assessment process can be found in the Annex to chapter (page 2f).

For this paper, we analysed two data sources from the original CH2011 assessment (MeteoSwiss, 2016): (i) a written survey, and (ii) group interviews. First, the written survey elicited a good overall response rate of 45% (n=115/256 approached participants), having been sent to three groups: participants of the 7th Swiss Symposium on Climate Adaptation (n=70/187, 37%), project managers who received funding through the Swiss Pilot Programme on Climate Adaptation (BAFU, 2017) (n=10/29, 34%), as well as the sectoral group interviewees (n=35/40, 88%). Survey questions include how data of today's climate was used; which CH2011 climate scenario products were used in what way; and what the requirements for the next generation of national climate scenarios were. The survey (in English) is provided in the Annex to chapter (page 2f). Second, n=9 group interviews, arranged by those sectors identified as relevant in Switzerland's national adaptation strategy (FOEN, 2012a), were made with n=33 well-known experts with significant academic and/or professional experience on adaptation working in administration, academia, or in industry. Structured around the survey – which the interviewees answered in writing as a preparation – the discussion explored and clarified past uses and future requirements of the sector representatives. Minutes of the group interviews were taken manually during the interviews. The transcripts thus reflect the interview in condensed form.

We established a user classification emerging from the survey data, rather than categorise users according to previous characterisations in the literature. To cross-validate the emerging classification, and to deepen the understanding how climate scenarios have been used, we manually coded the group interview transcripts with MAXQDA, a qualitative text analysis software.

4.4 How do observers, sailors, and divers make use of climate scenarios?

4.4.1 Who uses climate scenarios? Introducing a typology emerging from the data

We grouped survey participants based on what information from the climate scenarios CH2011 they used. (a) respondents using at least one of the four raw datasets provided (e.g., change in mean seasonal cycle per station); (b) respondents making use of key findings presented in at least one of the three summary brochures, including graphs and tables (e.g., climate scenarios report for regions); (c) respondents who skimmed – but did not directly apply– at least one of the three summary brochures, including graphs and tables; and (d) a group labelled 'other' who did not fit one of the three previous groups, comprising mostly respondents not answering these particular survey questions. To label the three different types of users (a), (b), and (c), we draw on a typology of energy scenarios users. With the metaphor of scenarios as an iceberg, Braunreiter and Blumer (2018) distinguish two products: the iceberg's visible tip above the water's surface consists of key results provided as summary brochures, while the vast amount of the iceberg (raw data) lies beneath the sea surface accessible only to those with the skills and interests to do so. Braunreiter and Blumer (2018) label the users (a) interested in bulk of ice divers, and those respondents (b) keen to explore the iceberg's visible tip sailors (Figure 4.1).

However, compared to the binary typology by Braunreiter and Blumer (2018), a third way (c) of using climate scenarios emerged in our analysis. Partly due to our more diverse sample going beyond academics, various people in the Swiss adaptation community replied that they did not *directly apply* any information from the climate scenarios to their work, but skimmed the brochures out of interest. We thus extend the sailor–diver binary to characterise this third group (c) as *observers*. Sticking to the metaphor of the iceberg, observers are users who have seen the iceberg (climate scenarios) from afar (Figure 4.1). Observers are thus potential sailors or divers. Divers and sailors can support observers to apply climate scenarios, thus becoming sailors or divers themselves.

4.4.2 *How do observers, sailors and divers use climate scenarios?*

Sailors made up the largest share of users in the Swiss adaptation community (n=45/115, 39%) (Figure 4.2). Interestingly, observers (n=29/115, 25%) and divers (n=29/115, 25%) were equally common. The following paragraphs paint a more detailed picture of these three user types.

Observers are interested in future changes of Switzerland's climate, skimmed the CH2011 brochures – but characteristically did not apply any climate information to their work. The following quote illustrates this interest-without-use:

> 'So far, [we have made] no direct use of the [climate] information. Uncertainties are important for communication [purposes], but they are hardly usable in practice because, in the end, dimensioning [of transport infrastructure against particular natural hazards] must be based on specific values, regardless of the uncertainties. We cannot dimension it [infrastructure projects] to maximum values everywhere [to increase resilience], simply because of the [high] costs. However, we differentiate dimensioning regionally. For operationally important routes or infrastructure we dimension more cautiously, that is with a greater safety margin, than for less important ones. For example, we dimension more cautiously for Zurich with the flood risk posed by the river Sihl than for a [nationally] less significant location. [...] I am interested in the development of individual natural hazard processes [under climate change]: floods, surface runoff, mudflows, torrents, but also in drinking water supply of small train stations (#11, observer, group interview, emphasis added).

Working with uncertainties 'in practice' as well as a lack of required information on climate impacts are thus reasons for the interest-without-use characteristic for observers. The quote echoes a Norwegian study of the transportation sector, where 'climate science is often focused on uncertainties, while climate adaptation strives to hold on to the little certainties that exist' (Ryghaug and Solli, 2012: 434). That the category of 'observer' is a meaningful characterisation of climate scenario use is further supported by 86% (n=25/29) unable to recall which emissions pathway(s)

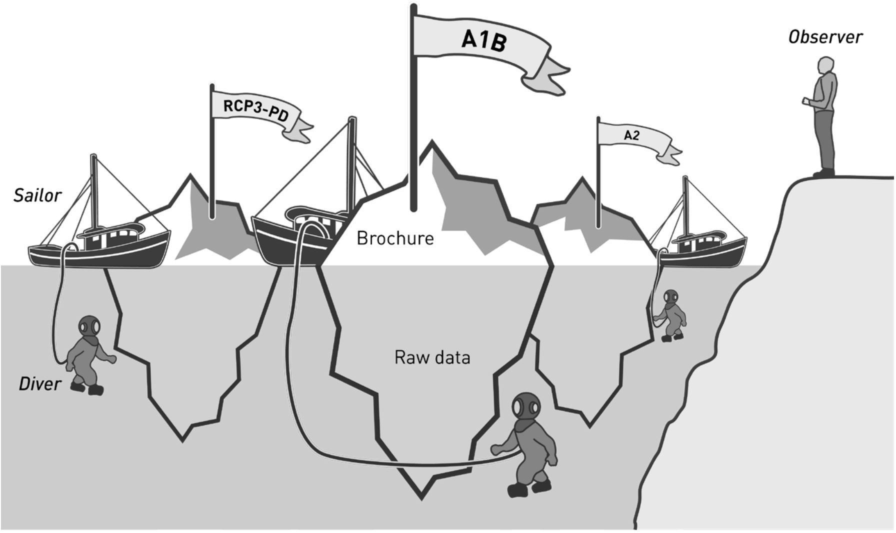


Figure 4.1 – Conceptual illustration of our typology of climate scenario use, drawing on the metaphor of the iceberg. Divers are interested in the bulk of data accessible only to those with the skills, while sailors make use of key results visible from the surface (and are supported by the raw data). Observers are inter-ested in climate scenarios (i.e., the iceberg), but did not apply them. Illustration: S. Bösch, ETH Zurich

they considered (Figure 4.2a). Similarly, the share of observers (n=18/29, 62%) not answering the survey question on the use of future time periods is highest, compared with that of divers and sailors (Figure 4.2b). As such, observers have seen the iceberg (i.e. climate scenarios), but either had a different approach to managing uncertainties, lacked quantitative or qualitative information in CH2011 required to achieve the project's goals, or had no specific project they could apply CH2011 data to.

Sailors worked with at least one of the three written summary brochures of CH2011, qualitatively using the information written in the text or portrayed in the graphs, maps and tables. Figure 4.2 highlights that sailors are often interested in the direction of climatic changes, with almost half of sailors (n=20/45, 44%) unable to recall which emissions pathways they used. Similarly, a quarter of sailors (n=12/45, 27%) could not answer which of the three future time periods they worked with (Figure 4.2). This indicates a certain (passive) disinterest or (active) disregard in how climate scientists communicate climate change, as the following quote by a senior adaptation officer shows:

> 'In climate risk analyses and climate strategies [undertaken by local government] there is presently hardly any need for specific [quantitative climate scenario] data, rather [a need] for the direction of change. Cantonal [provincial] experts cannot differentiate between the effects of 2°C or 4°C [warming]' (#31, sailor, group interview).

While the survey data highlights a majority of sailors using more than one future time period (n= 26/45, 58%), the group interviews revealed a tendency for planning horizons being more near-term than the provided 2035s. '[Organisation Y] uses a planning horizon of 15 years. Forecasts extending beyond this period are presently of no importance for practitioners' (#71, sailor, group interview). Similarly, 'the time horizon considered [in my sector] is rather short-term, for government agencies it is five to ten years, for research slightly longer' (#62, sailor group interview). These two quotes illustrate that climate scenarios lack relevance when planning in near-term only (cf. Vincent et al., 2017). To sum up, sailors are interested in the key findings found in the summary brochures, such as the trends of climatic changes. However, the bulk of the iceberg below the sea surface (the raw data of climate scenarios) remains hidden to sailors.

Divers distinguish themselves according to their use of at least one of the four gridded or station-data raw datasets provided by CH2011. These divers often run climate impact models (#27, #64, #68, #76, #94, divers, group interviews).

> '[To simulate climate impacts] most variables require [temperature and precipitation] data at least [in a] daily [resolution]. Also, it [the data] needs to be consistent between variables [temperature and precipitation], for instance [to allow] weather simulations over 20 years. In addition, we need [the variables] global radiation and moisture. [Lastly,] we need [the data] transiently[, i.e. data not truncated into distinct time periods]' (#68, diver, group interview).

Despite the CH2011 being truncated into three future time periods, and the co-variation of temperature and precipitation being unavailable, divers were still able to work with these datasets. This is indicative of the skill and knowledge divers have in working with potentially suboptimal climate model output. This skill translated into divers generally working with multiple timeframes as well as numerous emissions pathways (Figure 4.2). For instance, the share of divers (48%, n=14/29) working with the full range of plausible global mitigation scenarios (i.e., using all three emissions pathways provided) was more than double that of sailors (20%, n=9/45). In addition, divers (69%, n=20/29) were more likely to explore the near-term, the mid-term as well as the long-term changes than sailors (58%, n=26/45). As such, divers are numerate and climate-literate users, able to navigate the complexities of post-processed and downscaled climate model outputs.

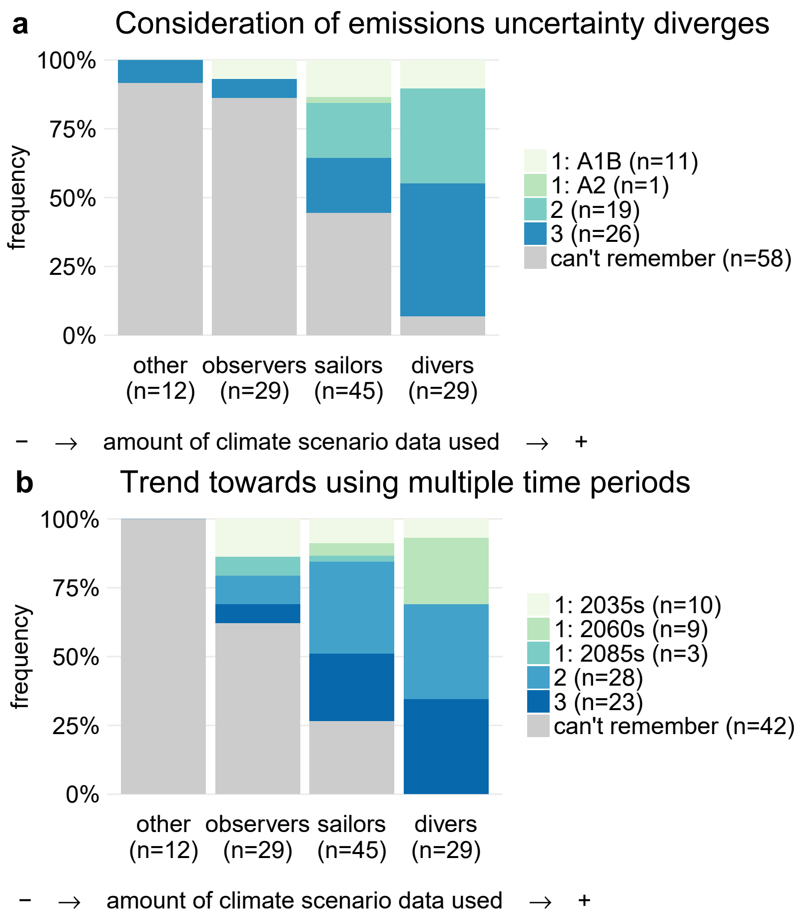


Figure 4.2 – Use of key characteristics of climate scenarios among divers, sailors, and observers. a) number of emissions pathways used by observers, sailors, and divers. The emissions pathway A1B is shorthand for moderate global mitigation efforts, while A2 denotes unstopped carbon emissions. b) num-ber of future time periods considered by our three types. If only a single time period was used, respondents preferred a short-term (2035s) or medium-term (2060s) for their planning. Note that the data shows actual use, not users' needs or interests.

Overall, the data-based classification of the survey participants into observers, sailors and divers reveals three distinct ways of putting climate scenarios to use. The chi square tests of independence in Table 4.1 confirms that there is a statistically significant difference how observers, sailors and divers used the emissions pathways ($X^2(6, n=103) = 41.49$, $p<.0001$) and time periods ($X^2(6, n=103) = 30.65$, $p<.0001$) provided in CH2011. Both the group interviews as well as the survey results thus indicate that our typology has empirical merit.

4.4.3 *In which sectors do observers, sailors and divers work – and as what: researchers or practitioners?*

Survey participants indicated being either researchers, practitioners or members of the 'public'. We find a relatively well-balanced distribution of observers, sailors and divers in research and practice (Figure 4.3). Between 45% and 60% of observers, sailors and divers are practitioners. Researchers are most common among data-hungry divers (52%, n=15/29). Interestingly, there are more researchers grouped as observers (45%, n=13/29) than sailors (31%, n=14/45). Members of the 'public' were mostly working *for* the 'public', such as consultants or journalists, and were more often observers than divers. Figure 4.3 thus clearly indicates that there are multiple ways climate scenarios are used within research and practice.

Sector size varies greatly in the survey sample – and within the Swiss adaptation community. The two largest sectors trans-sectoral (n=20 respondents) and natural hazards sector (n=19) make up one third of the sample (Figure 4.4). Further, the sectors water (n=12), agriculture (n=10), and energy (n=9) have average shares in the survey sample. Lastly, the six sectors with the fewest respondents – mitigation, biodiversity, tourism, forestry, health, and spatial planning – make up less than a quarter (Figure 4.4). More generally, these sectors are less well represented within the adaptation survey sample. Due to the low sample size, we refrain from extrapolating and describing these six sectors in general terms.

Divers are most common in the sectors water (42%, n=5/12), trans-sectoral (30%, n=6/20) and agriculture (30%, n=3/10). Thus, working with models – one of the few available techniques to process the considerable amount of data generated by climate models – seem to contribute to high shares of divers. For example, hydrologists use weather and climate raw data as an input in their flood risk models (e.g., Rössler et al., 2019). Similarly, the survey sample consisted of various impact modellers, studying a plant's suitability, agricultural yield and pest epidemiology in a changing climate. Lower-than-average use of raw data is linked to few survey participants, such as mitigation, biodiversity, health, and spatial planning.

Sailors are more numerous than average in the sectors trans-sectoral (50%, n=10/20) and natural hazards (47%, n=9/19), thus making noteworthy use of climate scenario brochures. The high share of sailors in the cluster 'trans-sectoral' is unsurprising, given that the crosscutting nature of adaptation favours generalists. Further, the survey was targeted at pilot adaptation projects receiving governmental funding, often interlinking sectors (BAFU, 2017). Observers made up more than half of the survey respondents in the energy sector (56%, n=5/9). More exchanges with the energy sector could clarify why the CH2011 brochures were not further integrated into their line of work.

Table 4.1 – Chi square tests of independence between being an observer, sailor or diver and key charac-teristics visualised in Figure 4.2–Figure 4.5. As such, there is a highly significant relationship between the number of emissions pathways as well as time periods with our typology of observers, sailors, and divers. However, there is no significant relationship between our typology of climate scenario use to participants' type of work, their sectoral affiliation, or their use of today's climate data.

Characteristic	Overall sample[a]	Observer	Sailor	Diver	Chi square tests of independence
Number of emissions pathways used					
1	12	2	7	3	X2 (6) = 41.49
2	19	0	9	10	p < .0001
3	25	2	9	14	n = 103
Can't remember	47	35	20	2	
Number of time periods considered					
1	22	6	7	9	X2 (6) = 30.65
2	28	3	15	10	p < .0001
3	23	2	11	10	n = 103
Can't remember	30	18	12	0	
Type of work					
Public	9	4	4	1	X2 (4) = 5.25
Researcher	42	13	14	15	p = 0.26
Practitioner	52	12	27	13	n = 103
Sectors[b]					
Trans-sectoral	19	3	10	6	X2 (10) = 8.54
Energy	9	5	2	2	p = 0.58
Agriculture	9	3	3	3	n = 82
Natural hazards	18	4	9	5	
Water	10	2	3	5	
Other	17	4	9	4	
Use of data of today's climate[c]					X2 (2) = 1.67
$Sailor_{present}$	21	3	11	7	p = 0.43
$Diver_{present}$	61	17	25	19	n = 82

[a] For the purpose of these statistical analyses, we disregard the category 'other' (n=12) for being an inconclusive category.

[b] Various sectors had low overall numbers of participants. We consider only those sectors with n≥9 participants.

[c] We disregard the category 'otherpresent' (n=29) for being an inconclusive category in this statistical analysis.

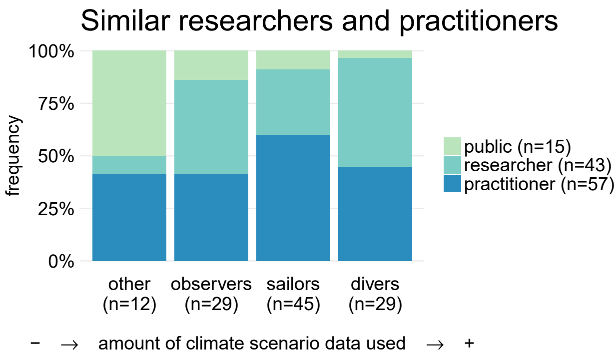


Figure 4.3 – Column graph indicating the respective shares of observers, sailors and divers working as researchers, practitioner or as a member of public. The shares of researchers and practitioners using the climate scenarios CH2011 as observers, sailors and divers are also statistically similar. Note that the data shows actual use, not users' needs or interests.

Statistically, Table 4.1 confirms the described trends visible in Figure 4.3 and Figure 4.4. The chi square tests of independence reveal no significant relationship between our three distinct ways of using climate scenarios with respondents' type of work as researcher, practitioner of member of the public ($X^2(4, n=103) = 5.25, p=.26$) or respondents' sector ($X^2(10, n=82) = 8.54, p=.58$). As such, researchers and practitioners are similar in their mixed ways of using climate scenarios. Similarly, within sectors there is a heterogeneous blend of using climate scenarios as observers, sailors, and divers. Differences between sectors are discernible only for those sectors with few members in the Swiss adaptation community.

4.4.4 *Are observers and sailors only able to use qualitative data?*

Survey respondents also specified which kind of data of today's climate they were using. This allows us to analyse if the type of using future climate scenarios corresponds to which present climate data was accessed. For instance, we can check whether sailors also use data for today's climate qualitatively, or if they change their type and become e.g. more numerate. This section contains three steps. One, to create a typology on the use of present climate data very similar to the typology of future climate scenarios. While we stick to the terminology of sailors and divers for both, we denote in the index whether it is about the use of climate scenarios ('future') or today's climate ('present'). Two, we contrast how different the same respondents make use of future climate scenarios and of present day climate data. Three, we explore why so many users switch from more quantitative uses of present climate to more qualitative uses of future climates.

We extend our sailor-diver typology of future climate scenarios to the use of present climate data through the following criteria: We define $\text{divers}_{\text{present}}$ as those partici-

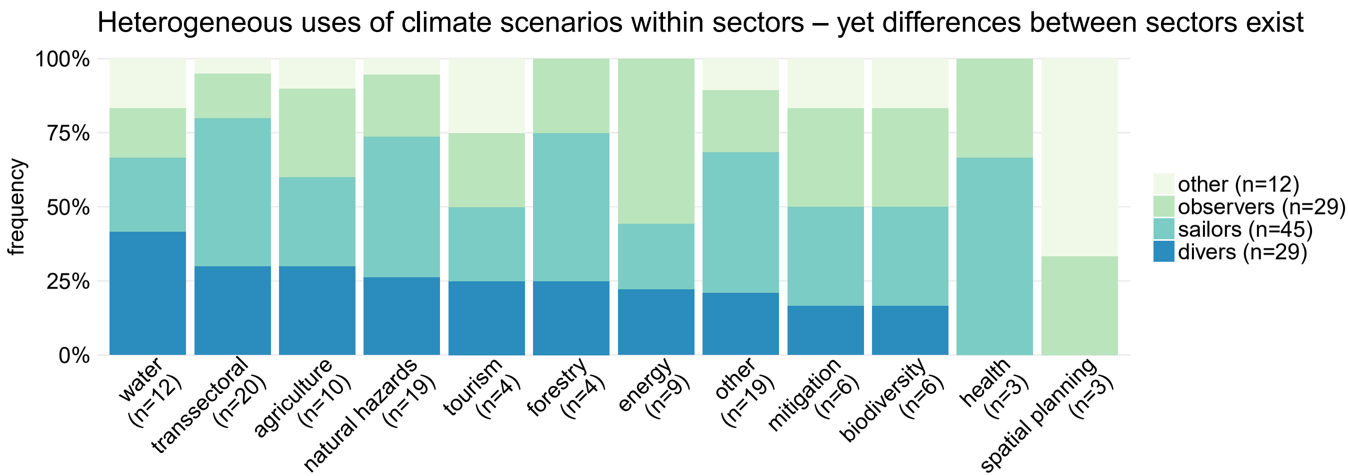


Figure 4.4 – Shares of divers, sailors and observers within and between individual sectors. Sectors are ordered by their share of divers. For instance, even for the water sector with data-intensive hydrologists the share of divers remains below 50%. Note too, that the number of respondents varies across sectors, reflecting partly which sectors dominate the Swiss adaptation community. Natural hazards, for instance, is better represented than tourism or forestry. Note that the data shows actual use, not users' needs or interests.

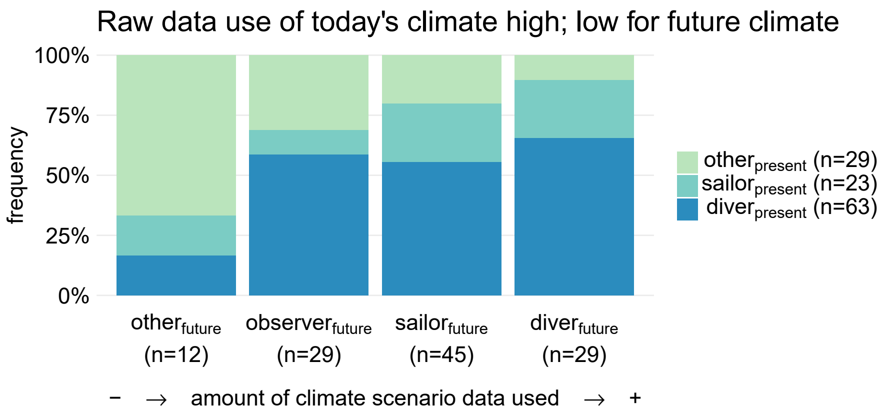


Figure 4.5 – Plot contrasting whether survey participants used past and present climatological data simi-larly as future climate scenarios. The graph highlights that this is, for a majority, not the case. For in-stance, many diverspresent of today's climatology are not climate scenario diversfuture. Note that the data shows actual use, not users' needs or interests.

pants using data on today's climate in a quantitative way, i.e. with a high temporal resolution ('10 minutes', 'hourly' or 'daily') as well as using either station observation data or the 2x2km gridded dataset. Surprisingly, a majority of survey respondents (55%, n=63/115) are divers$_{present}$ (Figure 4.5). Sailors$_{present}$ are those users giving preference to more qualitative summaries, i.e. using temporal averages for current climatological variables ('monthly', 'seasonal' or 'annual'). 20% (n=23/115) of survey respondents classified as sailors$_{present}$. Because the survey questions for today's climate differed in their answer options to those of the climate scenarios CH2011, we are unable to create the 'observer$_{present}$' type. This leads to a larger share of survey respondents being categorised as 'other$_{present}$' (n=29/115, 25%) compared to 'other$_{future}$' (n=12/115, 10%). The omission of one option might also have led to slightly increased numbers of 'sailors$_{present}$' and 'divers$_{present}$'.

Overall, the shares of sailors and divers are very different between present and future climate (Figure 4.5). There are twice as many divers$_{present}$ (55%, n=63/115) than divers$_{future}$ (25%, n=29/115). Correspondingly, the share of sailors$_{present}$ (20%, n=23/115) is almost half of sailors$_{future}$ (39%, n=45/115). Figure 4.5 illustrates that, overall, users often switch their particular way of using climate data. The statistical tests in Table 4.1 confirms that the participants' way of using today's climate data is independent of the way climate scenarios have been employed ($X^2(2, n=82) = 1.67$, $p=.43$). Overall, an impressive two thirds (!) of survey participants (n=77/115, 67%) changed their respective type of use. Thus, the particular user type of present climate data is no predictor of using future climate scenarios similarly. But what has caused these n=25 divers$_{present}$ to become sailors$_{future}$, and n=17 divers$_{present}$ to re-group as observers$_{\text{future}}$ (Figure 4.5)? In-depth analysis of the group interviews revealed three explanations: (a) qualitative work with future climate trends is sufficient for the respondents' work; (b) the climate scenarios CH2011 lacked the climate data needed; and (c) missed windows of opportunity.

a. Some divers$_{\text{present}}$ indicated that sailing climate scenarios brochures is sufficient for their work. 'Showing different [emissions] scenarios ... is important, quantitative details [about future climatological variables] are less important' (#113, diver$_{\text{present}}$ & sailor$_{\text{future}}$, group interview). Another user echoes: '[organisation K] needs graphics to answer letters to citizens who are sceptic about climate change, or for questions of pupils for their final school project' (#97, diver$_{\text{present}}$ & sailor$_{\text{future}}$, group interview).

b. Some divers$_{\text{present}}$ were eager for climate scenario raw data, but CH2011 lacked the required information:

> '[I] desire climate data primarily on extreme precipitation [for my assessments of] changes in flood risks, landslides, and slope stability as well as changes in temperature [for my assessments of] permafrost, glacier retreat. Differences in their [precipitation and temperature] distribution over seasons, months and regions are important' (#51, diver$_{\text{present}}$ & sailor$_{\text{future}}$, group interview).

Users required quantitative data on extremes (#3, #51, #62, all divers$_{\text{present}}$ & sailors$_{\text{future}}$, group interviews) and information on the co-variation of temperature and precipitation (#21, #48, #110, all divers$_{\text{present}}$ & sailors$_{\text{future}}$, group interviews). However, the CH2011 producers felt that the scientific understanding at the time was not mature enough to provide data on extremes (cf. Skelton et al., 2017). And due to the chosen multi-model combination technique (Bayesian methodology), it was not possible to provide information on the co-variation of temperature and precipitation changes (Fischer et al., 2011). However, the new Swiss climate change scenarios CH2018 (2018) contain these required datasets. We thus expect that the user base of CH2018 will be made up by a larger number of divers, while attracting overall more application due to its increased relevance to other sectors such as biodiversity and energy specialists.

c. A third group of divers$_{\text{present}}$ would have applied the raw data of CH2011, but it was not available at the time. 'CH2011 was [published] too late for the research program Forest + Climate Change, which started in 2009' (#21, #48, #110; all divers$_{\text{present}}$ & sailors$_{\text{future}}$, group interview). Such missed windows of opportunity can thus partially explain why some users switched from being divers$_{\text{present}}$ to sailors$_{\text{future}}$ of climate scenarios.

In summary, the distinct way of using climate scenarios as observers$_{\text{future}}$, sailors$_{\text{future}}$ or divers$_{\text{future}}$ is in two-thirds of the cases not related to the same use of present climatological data (Figure 4.5). The chi square tests of independence in Table 4.1 confirm that there is no statistically significant relationship between the ways climate scenarios and data on today's climate have been used. Thus, use of raw station data and gridded datasets of present climatology is more common than the focus on climate scenarios would suggest. This result indicates that a large share of the adaptation community is 'numerate' and able to work with large sets of quantitative data.

4.5 Discussion: Who is using climate scenarios in what ways?

We have analysed the use of the Swiss climate scenarios CH2011 within the Swiss adaptation community four years after its publication. Three distinct ways of using climate scenarios emerged from the dataset: observers, sailors, and divers. Using the metaphor of the iceberg as climate scenarios (Braunreiter and Blumer, 2018), sailors access key findings above the surface. The vast majority of data supporting these findings lies below water, accessible only to divers. Observers were interested in the iceberg from a distance – but did not apply the climate scenarios to projects. Sailors made up the majority of users, with tied shares of divers and observers.

So how does our typology compare with other user characterisations offered in the scientific literature, such as (a) the research–practice binary; (b) by sectors; and (c) by users' numeracy and ability to work with climate model data?

a. Studies on the user needs of climate information have often differentiated between requirements within academia and outside (Rössler et al., 2017; Benestad et al., 2014; Groot et al., 2014). However, as Figure 4.3 highlights, the picture of more data-hungry scientists and qualitative practitioners is too simplistic. The particular way climate scenarios are used is not linked to being a researcher or practitioner (Table 4.1). Our findings show that it is not only impossible to reliably predict how climate scenarios are used with the research–practice binary, it is also an inadequate way to generalise 'users'. The research–practice binary might make sense to describe different aims – understanding for scientists, relevance for practitioners (Pohl et al., 2017) – but fails to adequately describe users of climate scenarios.

b. Various authors have characterised users and their requirements by sectors (e.g. Bruno Soares et al., 2018). However, Figure 4.4 illustrates that the way climate scenarios are used cannot be reliably predicted by a user's sector. We find a mix of observers, sailors and divers among all (but two) sectors, echoing the conclusion by the original typology developers: '[s]ailors and divers are not principally split along the disciplinary backgrounds of interviewees' (Braunreiter and Blumer, 2018: 123). While these results do not disqualify sector-specific climate services, the focus on sectors clouds the diversity of use(r)s within sectors and the similarity of user(r)s across sectors. As such, sectoral characterisations of climate scenario use are likely influenced by the sectoral organisation of academic and governmental units, as the sectoral focus of climate risk analyses (e.g. Funk, 2015; CH2014-Impacts, 2014) and national adaptation plans (e.g. Defra, 2018; FOEN, 2012a) highlights.

c. The use of different climate scenario products has been explained by users' numeracy, that is, their ability to work quantitatively with climate raw data. For instance, a Copernicus Climate Change Service survey labelled numerate users as 'Donna Data', and those using aggregated packages 'Pete Product' (C3S, 2017). In the 'mini-me' characterisation, Porter and Dessai (2017) criticise climate scientists imagining users to be similarly numerate and modelling-proficient as themselves. We show that a significantly larger proportion of users is able to process and work with large climate datasets when they concern today's climate (Figure 4.5). A perceived lack of numeracy is in many cases more imagined than justified. Further studies should illuminate why there is no statistically significant relationship between $\text{divers}_{\text{present}}$ and $\text{divers}_{\text{future}}$ (Table 4.1). As such, even when users are similarly numerate as climate scientists, there seem to be underlying reasons why many users prefer to work qualitatively with climate scenarios.

To sum up, our results caution against using 'external' (i.e., independent) traits of users – such as the research–practice binary or sectoral affiliation – as explanations and predictors of how climate scenarios are used. We further highlight that a user's numeracy is in many cases higher than the focus on climate scenarios would suggest. Overall, the different aims of researchers and practitioners (Pohl et al., 2017), the similarity of problems faced within sectors, and the mere possession of particular numerate skills are thus not indicative of how climate information is used.

Inherent to studies assessing users are limitations. For instance, our sample was deliberately targeted towards the Swiss adaptation community. The survey was sent out to selected members, leading to data collected only on 'the usual climate-primed suspects'. In addition, the number of responses for some sectors was very low (e.g., health, spatial planning); often the sectors currently underrepresented in the Swiss adaptation community. While the survey results are likely to be representative of the Swiss adaptation community, the findings are certainly not representative outside this community or the general public. As such, exploring the use (or neglect) of climate scenarios in regional and local adaptation planning, or by sectoral experts not part of the adaptation community, could complement this study. Two further geographical limitations are a bias towards the German-speaking part of Switzerland, and the socio-political differences among countries. Climate scenario use in Germany and the UK, for instance, is influenced by their different institutional-political settings (Lorenz et al., 2017). While we would be surprised if our typology of observers, sailors, divers could not be transferred to these countries (after all, the products within climate scenarios are similar across countries, cf. Skelton et al., 2017), the respective shares of observers, sailors, and divers may well be different.

The successor Swiss climate scenarios CH2018 (2018) profited from the feedback from the original assessment (MeteoSwiss, 2016). While the original report contained content and communication recommendations, this study adds significant explanatory power by reclassifying the data upon an emerging pattern and describing the similarities with the typology of sailors, divers and observers. This allows, for instance, to highlight how the original recommendations help the different types of user. As such, improved brochures with personified key messages (for reaching a larger audience and increasing the number of sailors); quantitative information on extremes (which will likely make some observers and sailors of CH2011 to become divers); and transient raw datasets (satisfying needs of observers and sailors of CH2011 to become divers) were some of many changes in CH2018 (2018) to provide more user-oriented climate scenarios. Switzerland has not only improved their product climate scenarios, but could institutionalise user dialogues under the roof of the Swiss National Centre for Climate Services (NCCS). This allows to exchange with users beyond the duration of individual projects; a constraint present in e.g. Sweden (Ernst et al., 2019). As such, this assessment and its typology can serve as a baseline for comparing future studies on climate scenario use in other countries too.

How can our findings help to develop 'usable' climate scenarios and other climate services (Lemos et al., 2012)? We conclude with four points: One, our typology of sailors, divers and observers offers climate services producers a concept to understand *what* information products are used how and *by whom*. It serves as a reminder that the distinct ways of using climate information – quantitatively or qualitatively – are neither predicted by a user's numeracy nor by a user's sectoral, academic or professional affiliation. However, our typology also shows that there are cross-cutting similarities in using climate services, helping to produce usable climate services. Two, while our study supports efforts to tailor climate services to sectors or practitioners, producers of climate services should bear in mind that within sectors and among practitioners there are both sailors and divers. Thus, our study strongly recommends that climate information should be distributed both as key findings in brochures as well as through datasets. For example, our findings suggest that sectoral products of Copernicus Climate Change Service (e.g., Thépaut, 2016) benefit from climate information for both sailors and divers. Three, to make observers (skimming brochures without applying them) into either sailors or divers, efforts to incorporate observers' voices through exchanges 'beyond lip service' (Klenk et al., 2015) in climate services projects is encouraged. Four, more intensive exchange – or further studies – could highlight why so many users make quantitative use of data on today's climate, but only qualitative use of brochures (if at all).

Overall, our analysis paints a heterogeneous picture of the different ways climate scenarios are used. Our typology of observers, sailors, and divers captures essential differences, and extends the potentially misleading user characterisations by sector, the research–practice binary, or users' numeracy. As such, it helps to see the diversity of use(r)s within and among sectors, researchers and practitioners, but also the similarity of use(r)s between these groups. Using our typology to discuss which climate information is used how, it can help to tailor climate services by clarifying vague discussions about 'users' and by addressing the underlying concerns of the introductory quote 'I hate the term 'user''.

4.6 Conclusion

Our work introduces a typology to better characterise *actual* use(r)s of climate information. The concept of observers, sailors, and divers encapsulates three ways of using climate scenarios. Using the metaphor of the iceberg, most respondents were *sailors*, accessing only the key findings above the waterline (i.e., summary brochures). The vast majority of data remains below the surface (i.e., raw data), accessible only to the quarter of respondents labelled *divers*. Lastly, another quarter are *observers*, interested in the iceberg (i.e., climate scenarios), but did not (yet) use it directly for any particular project. We find observers, sailors and divers in both research and practice; in all (but two) sectors; and demonstrate that numeracy among users is generally much higher than perceived, as many sailors and observers of future climate scenarios are skilled in using quantitative data of today's climate. As such, our results question the adequacy of describing the ways of actual using climate scenarios primarily by a user's easily observable characteristics. Our typology offers a first step in better understanding in what distinct ways climate information is used, can extend vague notions and discussions of 'the user', and helps to tailor future climate scenarios and other climate services by highlighting the similarities of distinct use(r)s not within sectors, but between the three user categories proposed in the literature: sectors, researchers and practitioners. This analysis thus calls for more nuanced discussions of how use(r)s are imagined, portrayed and characterised.

5 How sectoral experts recognise climatic relevance: the role of cognitive links and decision-making capacity

In review as Skelton M (in review, a) How sectoral experts recognise climatic relevance: the role of cognitive links and decision-making capacity.

Abstract

Scientific climate knowledge is often argued to be a key ingredient in climate adaptation. Focusing on individual sectors and institutions, researchers have given insights as to how climate knowledge is reframed according to institutional cultures and priorities. This study extends such scholarship by comparing how four sectors – greenspace management, building technology, spatial planning, and health – perceive, judge, transfer, and appropriate knowledge on urban heatwaves, and what adaptation options are proposed. Based on semi-structured interviews, documentary materials and observations of two workshops collected in two Swiss cities, I draw on Eviatar Zerubavel and his 'cultural cognitive sociology' whose work emphasises how collectively shared patterns of recognition and thinking guide and facilitate human judgement. I find two factors to influence knowledge appropriation. On the one hand, the *formative* dimension of knowledge underscores that experts understand climate knowledge similarly when a sector shares key concepts with climate science. If such 'cognitive links' are missing, the answers on how heatwaves impact experts' work are more varied. On the other hand, the *performative* dimension of knowledge highlights that experts' eagerness to adapt is influenced by diverging technical, legal, and social possibilities. When experts' decision scope is large, then uptake of climate knowledge is more fluid. With a more explicit understanding of why sectors differ in their appropriation and integration of climate knowledge into their work, this study is a reminder that only fitting knowledge is of value to sectoral experts.

5.1 Introduction

Climate adaptation is often portrayed as a knowledge-intensive endeavour (e.g., Willows and Connell, 2003a; Adaptation Sub-Committee, 2016). Knowledge has also been fascinating American sociologist Eviatar Zerubavel (1999, 2015). For over three decades, he has studied how recognition and thinking are exhibited similarly within comparable 'thought styles' (Fleck, 1979[1935]), and how cognition structures human interactions and guides collective behaviour. The insights and conceptualisations of the Zerubavelian 'school' of cultural cognitive sociology (Brekhus, 2007) have, however, not yet been applied to the question of how scientific climate knowledge gets transformed and potentially appropriated by professional experts working in sectors vulnerable to climatic changes. While some studies have elaborated how prior expertise and institutional cultures influence the way climate change has, literally, been made sense of and appropriated within one sector (e.g., Ryghaug and Solli, 2012; Klenk et al., 2017), multi-sectoral comparisons of how such prior thought styles shift the perception of climate change are rare.

In this study, I compare empirically how, and more importantly why, four sectors often described as being vulnerable to urban heatwaves – building technology, greenspace management, spatial planning, and health – have appropriated scientific climate knowledge on heatwaves differently or similarly. In particular, by drawing on the work of Zerubavel, I explain the underlying dynamics of how prior expertise and collectively shared patterns of recognition influence the uptake of, or resistance to, climate knowledge in these sectors. The comparison of four sectors rather than one also allows a more nuanced conceptualisation of the underlying dynamics influencing how sectoral experts perceive and judge the relevance of climate science, and how they link up climate change with other sectoral concerns and aims.

In section 2, I review three distinct areas of scholarship relevant to this study: how actors appropriate climate change and climate knowledge, the Zerubavelian cultural cognitive sociological perspective, and urban adaptation to heatwaves. Section 3 describes the sector selection, the case study cities, as well as the methodology and type of analysis undertaken. In section 4, I compare how the four sectors differ in recognising and linking up heatwaves with their work. Section 5 then contrasts the adaptation options proposed by the four sectors. I then discuss how and why some sectors were able to appropriate heatwaves similarly and also give them priority, while others struggled to recognise the impact and importance of heatwaves for their work (section 6).

5.2 Literature review

5.2.1 *Uptake of scientific climate knowledge informing climate adaptation*

Two distinct strands of research studying the uptake of scientific climate knowledge can be distinguished. On the one hand, the dominant discussion around 'climate services' (e.g., Vaughan and Dessai, 2014) places a premium on 'co-produced', 'tailored' and 'usable' climate information (Lemos et al., 2012). Aimed at overcoming the mismatch of 'supply and demand' (Sarewitz and Pielke JR., 2007) or the 'usability gap' (Lemos et al., 2012), the underlying conception emphasises that in many instances improved – more usable, more actionable – climate knowledge would lead to an increase in its use for climate adaptation. While various studies have been published on the information needs of so-called users (e.g., Bruno Soares et al., 2018), more recently there have also been empirical studies on the actual use of such co-produced climate information (e.g., Lorenz et al., 2017; Skelton et al., 2019a).

A second strand of research has elaborated how prior expertise and institutional cultures influence how climate change is, literally, made sense of and appropriated. For instance, drawing on the Public Understanding of Science literature, Ryghaug and Solli (2012) emphasise how Norwegian road managers perceive and frame climate change predominantly through their experience of past extreme weather events rather than through the statistical conception of climate (cf. Hulme et al., 2009). In contrast to the climate services conception of knowledge uptake, several studies have shown that climate adaptation within organisations is often hampered because climatic changes are not perceived to be salient to an organisation's work (Berkhout, 2012). Such attitudes may also be exhibited because 'standardization organizations and public authorities do not take climate change and adaptation needs into account' (Rotter et al., 2016: 618). Weber (2006: 115) has argued that stakeholders' 'finite pool of worry' might lead to exclude climatic concerns. This research thus emphasises that climate knowledge is not inherently of value, and might even be 'uncomfortable' (Rayner, 2012). Further, Preston et al. (2015) have identified eight 'adaptation heuristics', including 'no regrets adaptation' where win-win situations are sought, and 'predict and respond' framings where scientific assessments guide adaptation deliberations. Lastly, while academic debates around the role of 'local' knowledge in adaptation have intensified, the review by Klenk et al. (2017) reveals that many of these studies still focus on 'extractive' practices, comparing local and scientific knowledge, rather than the interplay between the two.

5.2.2 *Zerubavel's cultural cognitive school of sociology*

The academic interest of sociologist Eviatar Zerubavel has focused on the surprising similarities in which people recognise patterns around them, how they focus their attention, what knowledge gets appropriated and remembered, how perceptions are classified, and how knowledge remains unspoken (Zerubavel 1991; 1999; 2015). He argues that recognition and thinking are much influenced by people's social and professional surroundings. A shared way of attending to and judging things thus allows an exchange of shared interests and commitments. As such, there are certain 'socio-attentional patterns' which are exhibited by more than a single individual, but not by all. This is similar to the concept of 'thought styles' (Fleck, 1979[1935]).

From the perspective of the 'Zerubavelian culturalist cognitive school of sociology' (Brekhus, 2007), experts in the field of greenspace management or building technology are likely to exhibit different sets of knowledge which is 'collectively memorised'. Central to Zerubavel's study are both a *formative* and *performative* dimension of knowledge, explaining how and why knowledge gets appropriated successfully.

Formative. Knowledge and its distinct way of being thought about and reasoned with creates groups of people which collectively share similar perceptions of the world and create similar relevance. As such, knowledge can structure human interactions and guide collective behaviour. However, for Zerubavel it is clear that these culturally and socially mediated forms of recognition and thinking are not universal, and that the continued existence of such a 'thought style' requires new members who learn to perceive, judge, classify, think and know similarly. This can be seen, for example, in university education which not only ensures the continued existence of thought styles, but enables knowledge to be shared and memorised. What is known, and how it is thought about, thus enables individuals to connect up with other people sharing the particular way of thinking and form distinct thought collectives.

Performative. Knowledge and thinking also allow fulfilment of a designated role. Experts, for instance, can perform their advisory or constructive functions legitimately because they exhibit more specialist knowledge and a deeper understanding of a particular subject area. The socio-attentional pattern embedded within a thought style allows them not only to notice, but also to deliberate on and judge certain information more competently. This facilitates carrying out a particular task or responsibility well. However, not all knowledge is necessarily performative, and might thus not be considered relevant.

Overall, Zerubavel's work can help explain why knowledge and groups of experts are similarly organised. Not only can shared knowledge and socio-attentional patterns form a common group identity, they also allow people to perform a designated role. Both attributes thus emphasise the social underpinnings of knowledge, and play an important role which knowledge is transferred between two thought styles. In a similar vein Mary Douglas (1986: 71) finds that '[anthropologists] are less inclined to ask why people forget. For them, remembering is the peculiar thing that needs to be explained.' Her own work has illustrated that the solutions proposed by thought styles often mirror their activities. Successful appropriation of scientific climate knowledge into sectors' thinking is thus not a random process, but one that is influenced by the *formative* and *performative* dimension of knowledge. Still, as the concept of 'hypocognition' illustrates, various (sub)cultures may fail to recognise and describe something adequately and similarly (Wu and Dunning, 2018).

5.2.3 *Urban adaptation to heatwaves*

Studies on climate adaptation taking place within cities have proliferated, in particular those relating to spatial planning. While German cities as an exception have a legacy of accounting for urban climate (Hebbert and Webb, 2012), elsewhere climate-aware planning is rarely prioritised (Eliasson, 2000). Scholars have also called for more explicit discussions of justice issues around how urban climate adaptation impacts marginalised groups (Shi et al., 2016). Klinenberg (2002) has unearthed how mortality rates during the 1995 Chicago heatwave were accentuated by socio-political factors. This concern is shared by Leitner et al. (2018) analysing how the concept of 'urban resilience' has brought together powerful international actors to influence cities' adaptation action, but excludes more vulnerable actors. Other researchers have been interested in the prominence of ecosystem-based adaptation options – such as the promotion of 'green' walls and roofs – within European cities' adaptation plans (Geneletti and Zardo, 2016). Lastly, some studies have focused on the knowledge requirements of local governments, finding that enough science is available for the assessment of vulnerabilities, yet not for the implementation of adaptation options (Nordgren et al., 2016). While the proliferation of studies indicates closer academic attention to urban adaptation, many studies have often focused on multiple climate impacts.

A limited range of studies have specifically been published on adaptation to urban heatwaves. For instance, Heaphy (2018) has analysed five transdisciplinary research projects producing knowledge on urban climate change. Taking climate models as a starting point for changing urban policies (cf. Heaphy, 2015), cities learned about the climatic changes which then fed into 'evidence-based approaches underwriting policies on green infrastructure and urban design' (Heaphy, 2018: 622). Further, Reischl et al. (2018) evaluated the adaptation efforts of Graz (Austria), and found that risk perception of heatwaves among decision-makers is high, assisted by adaptation networks and recent heatwaves. Despite this recognition, adaptation efforts need to take into account that an expert's knowledge is always only partial and fragmented, as the study by Olazabal et al. (2018) emphasises. By mapping the knowledge of individual actors as a proportion of the collectively available knowledge, they find that the diversity of knowledge on heatwave adaptation is so large that no single 'super-stakeholder' is able to possess – and thus integrate – it all. Thus, there is a need for continued interactions between policy-makers and scientists to exchange their respective knowledge. Still, climate awareness does not necessarily lead to prioritising heatwaves in planning (Eliasson, 2000).

Lastly, papers how heatwaves impact ecological and human livelihoods and available adaptation options have been published for all four compared sectors. For building technology, heatwaves affect the thermal comfort within buildings adversely, leading to overheating (e.g., Roaf et al., 2009). Spatial planning has to deal with larger and intensified urban heat islands, in particular during the night(e.g., Roaf et al., 2009). Calls to public health officials for more awareness on heatwaves have been made (Winkler et al., 2015), while health warning systems (WMO and WHO, 2015) have been developed to reduce the observed excess mortality during heatwaves (Ragettli et al., 2017). Lastly, trees in cities are also being impacted by heatwaves, with species resistant to heat and drought now being preferred (Blaser et al., 2017).

5.3 Case description and methods

5.3.1 Sector selection and description

I adopted a case study approach to analyse how a range of relevant experts perceive, frame and appropriate knowledge on urban heatwaves, and importantly, why integration of urban heat into experts' thinking differs from sector to sector. The four sectors *greenspace management*, *building technology*, *spatial planning*, and *health* were selected because they are not only portrayed as being vulnerable to heatwaves (e.g, Akademien der Wissenschaften Schweiz, 2016), but have also been identified as key sectors in Switzerland's national climate adaptation strategy (FOEN, 2012b; BAFU, 2018). Climate change affects cities in particular through an exacerbated urban heat island effect, increasing cities' temperature further compared to its surroundings (BAFU, 2018). This is because cities exhibit proportionally more sealed surfaces and fewer greenspaces, as well as reduced air circulation capacity between buildings. As much of the population and economic activity is in cities, the consideration of heatwaves by greenspace managers, building technicians, spatial planners, and health specialists is becoming increasingly important.

The four selected sectors exhibit similarities as well as differences. For instance, all four sectoral specialists work in public administration departments, for which an academic degree is a prerequisite. However, while the education and range of work of greenspace managers, building technicians and spatial planners was similar within their sectors, the health specialists interviewed had more diverse academic backgrounds, including medicine, epidemiology, health promotion and health economics. Further, health specialists' work focus is more diverse too, ranging from emergency management in the event of a pandemic, overseeing medical doctors, and arranging medical check-ups in schools. Thus, all four sectors have their designated and politically legitimated area of work and expertise, and are guided and assisted by formal academic training and knowledge when carrying out their duties.

The case study was conducted in Switzerland, whose governance is described as the archetypical 'consensus model of democracy', a term applicable also to the European Union (Lijphart, 2012). *Not* a synonym for harmony, 'consensus' denotes a politics of bridging societies divided by religion, ideology, language, culture or ethnicity. Characteristically, Swiss policy-making includes both the proportionally represented parties as well as a public consultation where well-organised interest groups react to policy proposals. Compared to its majoritarian antagonist – the 'Westminster model' found in the UK and in many of its former colonies – national executive power in Switzerland is comparably low (Lijphart, 2012). Further, similar to other federal states such as Germany or the US, Switzerland places a high premium on governing at subnational tiers, a principle termed 'subsidiarity' (Ritaine and Papeil, 2014). Overall, studying Swiss cities' action is thus particularly insightful as they retain governing, legislation and implementation power over services such as schooling, social security, health care, spatial planning, and taxation. Compared to centralised nations such as the UK or France, Swiss cities need to resolve many tense issues and contested policies themselves. This might also explain why Swiss climate scientists are at the forefront of customising global climate science into local climate information (cf. Skelton et al., 2019b). Intriguingly, the political culture on 'consensus' also influenced how and what climate science was tailored to Switzerland, similar to how the British and Dutch political cultures influenced their national climate information(Skelton et al., 2017).

5.3.2 *Data and methods*

To obtain a detailed picture of how the four sectors appropriate knowledge on heatwaves into their thinking and work, I collected and triangulated three data sources from the two Swiss cities of Schaffhausen and Zurich. *First*, a desk-based web search identified relevant documentary materials, such as briefing reports or municipal strategies of the two case cities. Being a public record and guideline for action, these documents reflect discussions within the administrations and sectors. 33 documents were obtained from the two case sites, complemented by 26 relevant national reports.

Second, I conducted semi-structured interviews with 20 sectoral experts working in the local governments of Schaffhausen and Zurich, as well as one expert per sector working in an applied university department. The semi-structured interviews, conducted in German, included questions such as 'what distinguishes a 'good' sectoral expert?', 'what are the implications of 'urban heat' for your work?', and 'what type of action could be taken to lessen the impact of heatwaves?' (full interview protocol in Supplementary Materials). With six and five interviewees respectively, greenspace managers and building technicians were relatively accessible for interviews[9]. Spatial planners were more difficult to motivate, often stating time pressure as a reason. Four planners could be interviewed in person and one answered key interview ques-

9 I aimed for n=5 interviewees per sector. However, a pair of greenspace specialists wanted to be interviewed together.

tions in writing. Lastly, it proved particularly difficult to recruit the four health specialists with any work experience concerning heatwaves at a local level.

Third, following up from the interviews, I organised two transdisciplinary workshops with 29 experts from all four sectors together with four Swiss climate scientists. Aided by an external and professional facilitator, the participants discussed past and future impacts of urban heatwaves as well as fruitful adaptation options. These workshops also explored potential uses of the Swiss climate change scenarios CH2018 (cf. Bresch et al., 2018). While the participants recorded the results themselves, two social scientists also observed the group discussions. Both data sources were then circulated in a workshop report for approval by the participants.

All three data sources – the documentary materials, the semi-structured interviews and the workshop report – were imported into the qualitative coding software MAXQDA and manually coded during two cycles to identify emergent themes. Based on the central research question, the questionnaire, and initial reflections after the interviews , I first sketched out recurrent themes, topics, emotions and experiences. With these designated codes, I assigned similar text passages with the same code. I then paraphrased each code according to sectors to find key similarities and differences. In the second cycle of coding I double-checked the original material to see whether in my paraphrasing I had overlooked any contradictory statements, or whether my summary over-simplified key aspects of the sectors' work. If this was the case, I changed the summaries accordingly. The key quotes in this manuscript have been translated by the author from German into English.

5.4 Formative knowledge: How experts linked up heatwaves to their sectoral concerns and aims

Using the interviewees' responses and the descriptions of their sectors' vulnerability in the documentary brochures, this section analyses how experts in the four sectors differ in recognising heatwaves as a legitimate concern for their work, and how far this concern is shared within each sector. Two aspects crystallised as being dissimilar: how differently the impacts of heatwaves were described by the four sectors; and how specific examples and technical vocabulary employed in such descriptions were. Both elements pinpoint the importance of the *formative* dimension of knowledge as a social activity: the shared knowledge together with the encompassing shared goals and aims demonstrated how 'collective' and 'social' knowledge can form the basis for organising and distinguishing groups.

Greenspace managers were keen to emphasise two issues. First, several interviewees mentioned that heatwaves have negative impacts on trees and other plants. While intensified watering schemes are too costly as an adaptation strategy, many specialists stated that they are currently reconsidering which tree species to plant in cities, focusing on those species with greater heat tolerance and drought resistance (#GM1, #GM4, #GM5). Second, many interviewees emphasised how public greenspaces can bring about cooler temperatures during hot spells. 'Urban greenspace is of enormous importance to the respite quality of public spaces when it is getting hotter' (#GM4). There was widespread agreement among the interviewees that trees in particular can lower the surrounding temperatures by providing shade and through evapotranspiration (#GM1, #GM2, #GM4, #GM5), as the following exchange indicates:

> '[Considering climate change in greenspace management] started with selecting different plants. A forest tree [species] has a limited survival expectancy in a city. The urban climate is just different. Now we plant other [heat-resistant] species. This just started further action against the overheating of cities.' 'Exactly. And another topic which has been on the agenda for a long time are green roofs. Now façade greening is trending since a few years. But how [tree] shading, evaporation, and greenspace influences the urban climate [and not vice versa] is a newer topic' (#GM1, #GM5).

Questions on heatwaves quickly triggered discussion of another area of concern for greenspace managers, namely biodiversity. Not only the positive effects of plants on urban climate, but also the larger 'loss of vegetation mass' (#GM4) due to new developments have led experts to call for more greenspaces in cities, including space out of reach of humans (#GM2, #GM3). 'Green roofs' (#GM2, #GM3) have been described as one of the few areas in cities left where diverse habitats for both plants and birds can be created, and heatwaves is reinforcing the imagination of the public and ecologists of greening cities (Grün Stadt Zürich, 2018). One specialist was, however, doubtful whether such roofs can provide significant cooling benefits during heatwaves, as the rainfall would quickly evaporate (#GM3). Overall, greenspace managers similarly recognised heatwaves, describing the impacts on their work with many professional examples.

Building technicians perceived heat as a 'key topic' (#BT4). Widely and primarily understood as a problem of 'overheating of buildings' (#BT4), heatwaves lead to a reduction in thermal comfort which building technicians see as their responsibility to avoid (#BT1, #BT2, #BT5, cf. AFC et al., 2016). With key terms such as 'cooling', 'indoor climate', 'energy', 'heat pumps' and 'free cooling' frequently being used in the interviews, building technicians shared a considerable number of terms with climate scientists. However, technicians were clear that these were themes in their work independently of heatwaves, as 'building users have rising expectations on thermal comfort' (#BT2). Intriguingly, sustainable building norms managed to create a win-win situation:

> 'We know that houses which are... really well built have a high [thermal] comfort. Even have a low energy consumption. This is no contradiction! ... The decisive thing we managed to show with the Minergie label [sustainable building norm] is to show that better houses have higher security, better preservation of value, more ancillary benefits. ... And that is widely desirable – everyone wants a higher comfort. And thermal insulation is an important aspect of that comfort' (#BT5).

While all profit from indoor thermal comfort, many of the interviewees nuanced priority areas: '[heat protection] is a topic in particular in the municipalities' schools and homes for the elderly. There are fewer discussions concerning apartments and offices, as these have less vulnerable uses [and users]' (#BT4). In banks and insurances, however, 'it is also a matter of prestige to have 23°C indoors when it is 30°C outside' (#BT2, also #BT1. #BT5). Overall, building technicians had similar views to those of greenspace specialists and they also described heatwave impacts consistently using similar vocabulary. The details provided – in one case even sketching a complete energy-efficient cooling system (#BT1) – demonstrated that these experts are highly aware of how heatwaves affect their work. This climatic knowledge has thus already altered the work focus of building technicians, thereby changing the infrastructure underlying each city.

Spatial planners' descriptions of how heatwave impacts their work were generally more diverse, with fewer common technical terms than those of greenspace specialists or building technicians. For instance, only a single interviewee mentioned the term 'urban heat islands' (#SP3), despite sealed surfaces and dense building designs being widely recognised as exacerbating local temperatures (#SP1, #SP2, #SP4). Planners were also less favourable towards increasing the amount of greenspace in cities compared to greenspace managers. While spatial planners acknowledged the positive effect of greenspace lowering the surrounding temperature, some planners also took the position that a rise of a few degrees in inner cities is tolerable in order to ensure city aesthetics and qualities (#SP2, #SP4).

> "I tell [greenspace manager] again and again: We want to have different urban spaces... Citizens and visitors should be able to enjoy the urban space from façade to façade. That is a trademark of cities. For instance, Zurich's [main shopping street] is typical, it does not have front yards. I am in an urban space – in which one can plant trees – but what we [spatial planners] do not want is that we start creating greenspaces, allotments, because of climatic considerations. I think we need to think twice where we add greenspace, and where we have urban spaces which have higher temperatures during some weeks in summer" (#SP4).

Similar tensions were raised concerning public spaces with few trees (#SP1, #SP3, #SP4, #SP5). In both Zurich and Schaffhausen some large sealed squares have been criticised in the local media by residents and local restaurants with outdoor seating for being so hot that people could no longer enjoy them. Spatial planners saw heatwaves as leading to a goal conflict between greenspace managers' biodiversity goal and cultural events: planting trees would provide shade and cooler temperatures, but would make it impossible to host cultural events such as music festivals, which require open space.. Thus, the appropriation of climatic knowledge into spatial planners' thought style is less pronounced and more ambivalent, triggering active discussions also with greenspace managers.

Health specialists' descriptions of heatwave impacts were the most diverse of all four sectors, but there was still unity in the way they talked about them, being hesitant to see heatwaves as a legitimate public health issue. As one interviewee put it, 'the negative effects of heat on health were a prominent theme in the newspapers, but I had the feeling that this was so because of the summer slump' (#HS4). Another health official added that 'there weren't any information requests by politicians or media outlets' (#HS2). A third said: 'Heat is often not really an issue. I mean, half of the Swiss population go on holidays in hotter areas… Some people love it, others hate it' (#HS3). This hesitance was, however, only for those people 'who can sweat and who can drink… Those who cannot look after themselves, such as infants, or those with reduced heat and thirst sensitivity, the elderly, are at risk' (#HS1; also #HS2, #HS3, #HS4).

While the majority of answers were about dehydration and sweating, the indirect effects of heatwaves on human health were rarely mentioned. For instance, when one health specialist mentioned prolonged asthma suffering due to the longer pollen season and the spread of new illnesses, the interviewer enquired why in prior mail exchanges she had written that 'heat is not a topic in the area of health promotion' (#HS4). She responded that 'at that moment, I didn't think that heat was a health issue', but in preparation for the interview she had done some research, and realised that there are various indirect effects, such as increased skin cancer risk. This illustrates that heatwaves elude the causal illness framings such as bacteria or toxic substances. The additional effort required to understand how heat affects people's behaviours or how new diseases can spread could be an explanation why the various indirect effects of heatwaves were only mentioned by a single health official. Thus, knowledge on heatwaves lacks formative character for health specialists, and as such has not altered their recognition and work priorities .

To sum up, this comparison of the four sectors has shown not only that they differently understood heatwaves as an issue, but also that within the sectors the examples given by the experts could diverge. For instance, greenspace managers and building technicians described heatwave impacts similarly, giving first-hand examples. These two sectors not only used similar concepts to describe how heatwaves influence their work, but many of their technical terms correlate closely with climatologists' descriptions of heatwaves. Among spatial planners and health officials, however, knowledge on heatwave impacts was more fragmented. Not only were there fewer shared concepts and examples within these sectors, but the used terms linked much less with physics-based notions of heatwaves, such as temperature and energy. However, there was still some common ground between spatial planners and health officials: both sectors were hesitant in recognising and legitimising heatwaves as a significant issue and a priority for their work. For health officials this critical interaction with the issue of heatwaves resulted partly out of scepticism grounded in the way heatwaves have been characterised as a health issue in the media. For spatial planners the problem arose from goal conflicts when designing public spaces. As such, while knowledge on heatwave impacts was not always shared within a sector, experts within their sectors largely agreed on how relevant, or not, heatwaves are for their work.

5.5 Performative knowledge: How a sector's decision-making capabilities influenced its style of adaptation

Experts of all four sectors gave examples of adaptation options to lessen the impacts of heatwaves on their cities' inhabitants. While knowledge about the impacts of heatwaves on their work guides which adaptation measures the experts proposed, this section emphasises that the experts' adaptation options are much influenced by the physical properties of their areas of work: plants, machines, space, humans. As such, how keen the different sectors are on taking adaptation to heatwaves depends not only on their knowledge of the phenomenon, but on their ability to take meaningful action.

When greenspace managers plan greenspace accessible to the public, they 'consider three core claims: use, design, and ecology' (#GM4, #GM5, #GM6) and 'try to find the intersection between these [three claims]' (#GM6; also #GM4). Their general aim is to have 'more greenspace' as a synonym for 'more quality of life' (Grün Stadt Zürich, 2018: 2), an aim also politically mandated in Zurich's long-term 'greening strategy' (Grün Stadt Zürich, 2019). While this is also supported by planning and health (e.g., #SP2, #SP3, #HS2, #HS3, BAFU, 2018), greenspace managers still 'need to lobby for our work and need to receive political legitimation' (#GM4) to manage the parks, cemeteries, sports grounds, and playgrounds entrusted to them. With heatwaves becoming more frequent, greenspace specialists are reconsidering which trees to plant, opting for species offering more heat and drought tolerance (Blaser et al., 2017). They are also experimenting with different soil substrates to ensure optimal conditions for growing the trees (Heinrich and Saluz, 2017).

The choice and depth of substrate matter are also of crucial importance when greening roofs: 'you do not even need to tend it [the green roof], because you have already botched it up if you select the wrong substrate ... such as a cheap recycled clay brick' (#GM3, cf. Stadt Zürich, 2013). After intensively deliberating and finding agreement with building technicians among others, greenspace managers working in administration and research institutions updated an official (though voluntary) building norm for green roofs (Brenneisen, 2015),), while both case cities have defined their own 'native' seed mixtures (Stadt Schaffhausen, 2006; Stadt Zürich, 2013). Both ensure that green roofs are a practical and eco-friendly adaptation option, forming 'wildlife corridors' between eco-habitats (Grün Stadt Zürich, 2019). Thus greenspace managers saw heatwaves as a legitimate means to promote action they are concerned with anyway: more high-quality and biodiverse greenspaces in cities.

Building technicians' adaptation options to heatwaves were widely known and shared amongst the experts, revolving around the cornerstones of 'thermal protection, mass, and efficient cooling' (#BT5; cf. AFC et al., 2016). *Thermal protection* includes 'renovating windows' (#BT2) with an appropriate 'g-value' (#BT4) indicating energy transmittance. While external shading options provide some thermal protection, they 'are quickly exhausted' (#BT2) and trigger 'architectural discussions' (#BT2). One architectural way of preventing buildings from overheating is through the increased use of mass, as mass can absorb thermal energy fluctuations, thus 'letting rooms warm up only slowly' (#BT5). 'Solid buildings are like bunkers, they never get really hot' (#BT2). Interestingly, green roofs were seen as possible adaptation options when buildings were not adequately insulated:

> 'For a concrete roof [without insulation], having a green roof in summer would be extremely influential. But if I have a roof with a good, modern heat insulation then I do not feel inside what is on top [of the insulation]... But green roofs have the benefit of retaining rain, important against flash floods... Then it also reduces the urban heat islands effect minimally... And then it is also pleasant for insects and plants. I support green roofs, but for indoor temperature they hardly matter' (#BT1).

Cooling of buildings was seen as a major adaptation option and likely to increase in future (e.g., BFE, 2017), but all interviewees and brochures were in agreement that conventional air-conditioning units are not a desirable or viable solution. While 'night time air circulation' is one way of cooling buildings (#BT2, #BT3), 'free cooling' is the widely preferred technique, transporting heat out of a building to a cooler source using energy-efficient circulation pumps (#BT1, #BT4, #BT5; Rohrer et al., 2018). Cooling sources include lakes, larger rivers and near-surface geothermal units (#BT1). However, to work efficiently, such technologies need to be combined with adequate thermal protection: 'Already with these [double-glazed] windows building technicians can install systems with which one can both heat or cool a building' (#BT1). This has the benefit that the thermal source is regenerated in summer, thus acting as a seasonal energy reservoir. Overall, building technicians exhibited a strong commitment to implement adaptation options, potentially using a 'simple simulation tool to calculate how warm a room can get' (#BT4; cf. AFC et al., 2016). Knowledge on heatwaves thus changes building technicians' practice by adding different ways of keeping buildings cool, often requiring in-depth and long-term interactions with heritage conservationists, building users and house owners.

Spatial planners described their work using many more verbs indicating interaction and communication than the other sectors. 'One needs to communicate very well' (#SP3), 'reconciling, coordinating as well as getting through all the commissions' (#SP1), 'being open-ended in the beginning, listening at the start' (#SP5), 'integrate what is happening outside of this city' (#SP4), and 'not always showing solutions top-down, but stating that this is the problem to be addressed' (#SP3). Likewise, a 'good' spatial planner needs to 'adjust well to one's counterparts and know what their interests are' (#SP3), to be able to 'mediate' (#SP3) and be 'cooperative and diplomatic' (#SP5). Examples of 'goal conflicts' (#SP4, #SP1) triggered by heatwaves include sealed squares getting so hot that staying on them during heatwaves is uncomfortable. Two adaptation options were mentioned: choosing a surface which is brighter and reflects more sunlight (#SP4, also #GM2); and the installation of temporary shading and artistic awnings (#SP1, #SP4; Stadt Zürich, 2017).

Two legal tools are available to spatial planners to guide adaptation to heatwaves (#SP1, #SP3, #SP4; ARE, 2013; BAFU, 2018). Some are only legally binding for public authorities, such as the 'structure plan' or thematic strategies (e.g., ARE and AWEL, 2015; Stadt Zürich, 2016), which define which issues and actors have to be considered in the planning process. In addition, there are instruments which also private actors need to adhere to, such as the municipal 'building and zoning regulations'. Defining the use of plots and associated building sizes, Zurich's recent regulation revision now includes legally binding obligations on green roofs (Stadt Zürich, 2013) and the reduction of sealed surfaces wherever possible (BAFU, 2018). Although building and zoning regulations are open to intense scrutiny, sometimes also accompanied by judicial appeals, there are efforts underway to 'prescribe climate adaptation as binding for landowners, so that we can demand adaptation measures' (#SP4) even if developers oppose them. In other words, the success of spatial planners' adaptation options is conditional on the support of other actors, but is nonetheless assisted by certain legal tools. Certainly, climatic knowledge acts as a legitimate concern for intersectoral interactions, accentuating discussions on the design and function of urban landscapes.

Health specialists' style of adaptation is an intriguing mixture of resistance to and avoidance of responsibility for adaptation measures. A common take among the interviewed specialists was that 'we assume that they [the healthy and adult population] know about them [heat impacts] themselves' (#HS2). As such, 'the wider public has not so far been targeted by any particular measures' (#HS3). The interviewed health specialists were overall reluctant to describe the majority of the population as being at risk from heatwaves, wanting to treat people as being responsible for themselves. Underlying such reasoning is the question whether

> 'this [prevention measure] is really justified...? Or shouldn't everyone decide on their own? Yes, that is the challenge [in our work]: where is one too patronising, just provoking an attitude of total defiance to all prevention measures? And where is [it] justified to look after the general public, to ensure that individuals do not go over the top?' (#HS3).

The elderly and infants were, however, not judged as self-reliant, but as vulnerable. The dangers of heatwaves for these groups are addressed by raising awareness amongst their caretakers, for example through home care organisations (#HS3), pharmacies (Städtische Gesundheitsdienste, 2019) and schools (Schulgesundheitsdienste Stadt Zürich, 2017). Health officials were, however, quick to shift the responsibility for ensuring that people have options to avoid heat stress on to other specialists. This includes insisting on building technicians being responsible for indoor climate (#HS1), greenspace managers for shading (#HS2) and those who promote cultural festivals for the provision of free drinking water (#HS3). Overall, health specialists' approach to heatwave adaptation is to see themselves not as responsible for implementing any measures, but for communicating with specialists, vulnerable people and their caretakers. But with health largely perceived to be a matter of private responsibility, health specialists were hesitant to propose health promotion measures which to most people might be seen as patronising. Thus, the work of health specialists has not really changed because of climatic knowledge, and intersectoral interactions remained low.

To sum up, while the four sectors differed in the specific adaptation measures they proposed, certain characteristics were shared between certain sectors. For instance, the three sectors greenspace management, building technology and spatial planning proposed mainly *physical* measures. However, many of these experts also brought up individual or social adaptation measures (#GM1, #GM4, #GM5, #BT2, #BT4, #SP1, #SP3, #SP5), such as shifting work hours during heatwaves or selecting leisure options which cool one down. Meanwhile, health specialists focused more on *socio-cognitive* measures such as campaigns to raise awareness, as well as insisting on physical measures being undertaken by the three other sectors (#HS1, #HS2, #HS3). Another key difference is the degree to which the experts themselves have decision-making power over implementation. While the scope of action is relatively large for greenspace management and building technology, spatial planners and health specialists rely on the approval of, even implementation by, other actors for fostering climate adaptation. Lastly, climatic knowledge was highly *performative* for greenspace managers and building technicians, whose sectoral aims were reinforced by heatwaves. Spatial planning and health experts, on the other hand, consider the implementation of heatwave measures more often as a complication, critically reflecting and questioning such options.

5.6 Discussion: cognitive links and high sectoral decision scope co-constitute appropriation of heatwave knowledge

This comparative analysis emphasises that the degree to which sectoral experts appropriate knowledge on urban heatwaves is mutually influenced by two factors: (a) availability of *cognitive links*, that is, whether concepts and vocabulary are shared with climate scientists' descriptions of heatwaves; and (b) the different decision scope experts have in implementing adaptation options. The distinction between these two factors is similar to Zerubavel's description of knowledge having *formative* and *performative* dimensions in structuring human collectives and action (Zerubavel, 2015).

(a). The two sectors *greenspace management* and *building technology* exhibited most clearly what Zerubavel (1999) dubs a 'collective memory': similar descriptions and recognition of heatwaves (see Table 5.1). Characteristically, these two sectors used similar terminology to describe the impacts of heatwaves on their work. Terms, moreover, which are also used by climate scientists, such as 'climate', 'heat', or 'energy'. Both green specialists and building technicians thus share what I dub *cognitive links* with climate science, allowing the sectoral experts to recognise relatively uniformly the relevance of more intense and frequent heatwaves. Such cognitive links between sectors reveal that both communities share certain 'socio-attentional patterns' which mark elements to be foregrounded against those which remain largely unnoticed (Zerubavel, 2015). Such 'socio-attentional patterns' guide and facilitate knowledge appropriation while also ensuring that heatwaves are similarly understood, memorised and described within the sector. Overall, in both sectors knowledge on heatwaves has been successfully integrated, adding and updating a shared set of knowledge and concern. Successfully appropriated climatic knowledge can thus be *formative* to a sector's work aim and focus.

Within planning and health, the interviewees in both cities were less able to describe the impacts of heatwaves consistently and similarly, evidenced in particular by a variety of terms. While together they mentioned almost all the issues discussed in the academic literature, individually they covered only parts of the entire corpus of knowledge. Such a situation was also described by Olazabal et al. (2018), mapping individual expert's knowledge as a proportion of the total knowledge on heatwaves in Madrid. As such, this study finds that many of the interviewees are still trying to

Table 5.1: Key results of how experts appropriate and frame knowledge on heatwaves as relevant for their work.

	Greenspace management	**Building technology**	**Spatial planning**	**Health**
Formative				
Cognitive links with climate science	'micro climate', 'bioclimate'	'indoor climate', 'energy', 'heat', 'temperature', 'cooling'	'urban heat islands'	–
Similarity of responses among experts	High, with specific examples from professional contexts	High, with many specific examples from professional contexts	Intermediate, some examples given. Descriptions based on both personal and professional experiences.	Intermediate, with few concrete examples. Descriptions mainly based on personal experiences (e.g., guided holiday tours, festival visits).
Performative				
Proposed adaptation options	Green roofs & green facades; more greenspace; different types of trees; different soil substrates	Thermal insulation; sun radiation protection; building with more mass; free cooling	Adjusting building and zoning regulations for improved air circulation; adequate greenspaces; prevention of sealed surfaces; reflective surfaces	Awareness campaigns for vulnerable groups (elderly, children) and their caretakers; urge other sectors to provide greenspaces and free drinking water
Style of adaptation	instrumental	instrumental	participative	persuasive

find adequate sectoral concepts to, literally, make sense of heatwaves for their work. Echoing the finding of Eliasson (2000), interviewees *knew about* what intensifies heatwaves in cities, but descriptions of the *relevance* of heatwaves for their work were ambiguous. Planners' and health officials' 'socio-attentional pattern' (Zerubavel, 2015) is more geared towards social, epidemiological or aesthetic concerns, into which climatic knowledge cannot be so easily integrated. Thus, the unavailability of dominant and shared concepts with climate science – or cognitive links – made it difficult for planners and health specialists alike to appropriate heatwave knowledge similarly. Wu and Dunning (2018) write that such 'hypocognition' also impairs what gets memorised. Compared to greenspace management and building technology, knowledge on heatwaves does not resonate with prior concerns and aims, and is unable to form a common understanding among planners and health specialists. Other concerns and worries seem to have priority over heatwaves (cf. Weber, 2006). According to the Zerubavel, however, a shared set of assumptions and recognition patterns are necessary in order for climatic knowledge to have *formative* character of expert communities.

(b). My comparative analysis further revealed three different *styles of adaptation*, largely determined by experts' scope for deciding to implement a measure or experts' reliance on external support (see Table 5.1). For example, the *instrumental* style of adaptation exhibited by greenspace managers and building technicians is largely due to the fact that these two sectors can deliberately employ – or manipulate – material and matter to provide the desired services and amenities. That is, both plants and cooling devices have only a limited ability to resist the expert, allowing these experts to exhibit what Gillard et al. (2016b) dub a 'managerial' approach. Those two sectors whose experts enjoy greater decision scope were also keener to actively integrate urban heat into their core work. They not only had the means and *performative* knowledge to implement adaptation options, but heatwaves legitimised their *prior* work aims further, gaining approval from a wide range of actors. Thus, climatic knowledge has shifted intersectoral discussions on public spaces and indoor climate in favour of greenspace managers and building technicians' *instrumental* adaptation.

However, dealing with human actors rather than materials, spatial planners and health specialists do not enjoy such possibilities. Planners' *participative* style of adaptation restricts the treatment of single topics, such as heatwaves, from dominating urban design decisions, as the diverse set of actors scrutinise and possibly resist adaptation measures. Thus, the conclusion of Eliasson (2000) that 'climate knowledge had low impact on planning process' seems still to be valid 20 years on. But this does not need to be the case, with Hebbert and Webb (2012) describing Stuttgart (Germany) as an exception to the rule that 'city planning became less climate-aware in the decades after 1950.' Lastly, health officials exhibit a *persuasive* style of adaptation, raising awareness of options to lessen the impacts of heatwaves. But, with conscious and self-responsible people possibly adhering or overreacting to health promotion, health officials often need to strike a delicate balance between patronising or neglecting people. As such, the decision scope by spatial planners and health specialists is smaller than for the other two sectors, as conscious humans need to support planning and health officials' work. This can explain why planners and health specialists exhibited a more questioning and resistant attitude towards heatwaves and their adaptation: heatwaves complicate – rather than legitimise – their work further. While spatial planners' *participative* style led them to discuss climatic impacts with greenspace managers, health specialists' *persuasive* style did not lead to significant intersectoral exchanges.

This result pinpoints an important finding: that knowledge is *not inherently* of value, as discussions revolving around climate services implicitly suggest (e.g., Willows and Connell, 2003a; Lemos et al., 2012). The *formative* value of knowledge emphasises that its integration – or its refusal – into a thought style reassures and updates how a peer community of experts understands itself and positions its tasks against other actors and discourses. The *performative* aspect of knowledge highlights how knowledge can change expert practices as well expert interactions with other sectors. In practice, expert discussions on heatwaves within the administrations of both Zurich and Schaffhausen have increased substantially. While in less decentralised countries such local discussions are likely to be of different legal character than in Switzerland (cf. Lorenz et al., 2017), this comparison revealed sectoral differences in climate knowledge transfer likely applicable in other political contexts where experts shape adaptation action, as sectoral thought styles and work foci are largely similar across civic cultures and governance forms.

Further, the present study serves as a useful illustration just how different appropriating heatwaves into sectoral thinking and work can take place beyond Switzerland too: while it might yield rewards for some experts, it might trigger frustration for others. This situation is similar to that which Rayner (2012) dubs 'uncomfortable' knowledge. For planners and health officials heatwaves are clearly more 'uncomfortable' than for green specialists and building technicians. Not only do they lack cognitive links with climate scientists, but knowledge on heatwaves is perceived more as a complication than as a further legitimisation of their work, for instance as another issue which needs to be deliberated and balanced against other legitimate interests (cf. Eliasson, 2000). Lastly, the effectiveness of health promotion is not controlled by health specialists, but depends on people's willingness and ability to change their behaviour during heatwaves. This indicates that even if climate scientists communicate their findings in language more familiar to planners and health officials – thereby establishing cognitive links – the comparatively low agency will still restrict how effectively this knowledge can be used in these two sectors. Bearing this in mind increases the awareness of how complicated narratives can get about which 'evidence-based approaches' are favoured by whom (cf. Heaphy, 2018).

This comparative study extends current academic discussions on scientific climate knowledge uptake and urban climate adaptation in various important ways. By drawing on Zerubavel's cultural cognitive conception of knowledge as a *formative* and *performative* guide and structure to human activity, it makes explicit how actors asked to appropriate scientific climate knowledge make use of their particular thought style and prior experiences in making sense and producing relevance for their work. However, this is trickier for some sectors. This confirms the findings of other studies which have shown that climate adaptation options are primarily accepted or resisted due to underlying values, priorities and institutional cultures (e.g., Ryghaug and Solli, 2012; Rotter et al., 2016). By comparing four sectors rather than one, this study has, however, been better able to conceptualise how knowledge transfer between different sectors takes place, and to describe under what circumstances the integration of climate science into adaptation occurs or not. This also bears upon the academic discussions focused on climate information, such as its usability (Lemos et al., 2012). Making sure that climate information builds upon 'cognitive links' allows experts with different socio-attentional patterns to recognise the importance of climate change better and more alike. However, it also highlights that not all sectors are able to implement adaptation action similarly. Thus, while we ought to applaud those instances in which spatial planners and health officials have managed to implement adaptation measures, a more critical stance towards building technicians and greenspace managers is warranted when they fail to do so.

5.7 Conclusion

In this study, I compared the transfer and appropriation of heatwave knowledge into four sectors' style of thinking and adapting. On the one hand, with the concept of *cognitive links* I emphasise the profound importance of shared concepts in recognising the relevance of knowledge on urban heatwaves for four sectors' area of responsibility. On the other hand, experts' ability to implement a particular adaptation action is largely directed by the degree of expert authority in implementation. While some sectors can act upon heatwaves more *instrumentally* through materials, others interact with human actors through *participative* or *persuasive* approaches to adaptation. Both these findings have far-reaching implications for envisaging the knowledge transfer between climate scientists and various sectoral expert communities. For scientists looking at evidence-based policies, closer attention ought to be paid to how knowledge legitimises or complicates experts' work. For communication specialists, forging cognitive links between climate science and thought styles with different 'socio-attentional patterns' (Zerubavel, 2015) might well lead to a greater shared understanding. And lastly, the cognitive–practical duality influencing knowledge appropriation allows a clearer articulation and critique of the lack of adaptation options: my research shows that for greenspace managers and building technicians acting on heatwaves is easier, while planners' and health specialists' inaction is if not entirely excusable, at least understandable.

6 Orders of social science: Understanding social-scientific controversies and confluence on what 'high-quality' knowledge and 'good' adaptation is

In review as Skelton M (in review, b) Orders of social science: Understanding social-scientific controversies and confluence on what 'high-quality' knowledge and 'good' adaptation is.

Abstract

Various scholars have noted – and experienced – tribal tendencies between social-scientific 'schools of thought' or 'paradigms'. The intensity and fervour of such controversies has led some scientists to compare them with frictions between religious *orders*. In the research domain focused on the use of climate science for climate adaptation, such disputes revolve around the what 'high-quality' climate knowledge and 'good' adaptation is or should be. Emphasising this diversity of *orders of social science and the humanities*, this article describes five distinct ways social scientists and humanities scholars have thought and written about climate adaptation: *descriptivists* aim to empirically portray climate adaptation as objectively as possible from an outsider perspective; *ameliorists*' research wants to increase climate resilience through usable climate information; *argumentivists* strive for assessing the justification of climate scientific findings, as well as adaptation decision-making that is based on these findings; *interpretivists* seek to empirically redescribe how the use of climate science for adaptation is shaped by, and shapes, various other social processes and political actors; and *critical* scholars work towards revealing how pervasive powerful interests and marginalising discourses shape adaptation projects negatively. By comparing these five orders' respective scientific, environmental and social aims and concerns, this article pinpoints to how epistemological, ontological and methodological priorities not only drive scientific controversies on issues such as what 'high-quality knowledge' is, but also how interdependent orders' methodological choices are with their epistemological and ontological positions. However, this analysis also reveals that while some scholars implicitly stick to their order, others are comfortable to collaborate across such borders. Overall, the diverging aims, priorities and methods are unlikely to be ever fully reconciled. A better understanding of why academics from different orders differ in the approaches they take and the issues they care about will likely lead to a larger appreciation of the differences of

other orders' research and broaden our understanding of key dynamics in studying 'good' climate adaptation and 'high-quality' climate knowledge.

6.1 Introduction: a diversity of research styles among social scientists and humanities scholars

While most social scientists and scholars from the humanities are keen to emphasise that their research benefits both climate science and climate adaptation, some can also be harsh towards and intolerant of research undertaken by researchers with other styles. As such, descriptions of 'tribalist tendencies amongst academics, such that researchers must cluster into schools of thought and create possibly fake factional conflicts amongst themselves' recur (Dunleavy, 2003: 15). This article explores five distinct research styles with which social scientists and humanities scholars frequently describe, analyse and critique social phenomena around the use of climate science in climate adaptation. By comparing the distinct aims, interests, concerns, and methodology of each *order of social science and the humanities*, I show how these five *orders* differ in what they judge 'high-quality' knowledge and 'good' adaptation to be. Such an understanding is important in several ways, including an appreciation of the diversity of perspectives research by social scientists and humanities scholars are able to offer for climate science and adaptation; noticing what blind spots and preoccupations different orders have; being able to more critically reflect by what academic calls-to-action are triggered; what insights and conclusions different orders are likely to offer; being a workable framework through which to group academic literature in one's reference management; as well as giving an oversight as to what issues are currently debated across a range of social-scientific strands.

Appreciating social-scientific frictions and understanding confluence in what 'high-quality' knowledge and 'good' adaptation is carries also important practical, social and political implications: the combination of climatic changes dramatically changing livelihoods and lived experiences around the world, together with the prominence of science in shaping and underpinning policies makes both agreements and antagonisms among social scientists relevant to a range of issues, practices and actors. If indeed 'today 'science' is the theology of the 'developed world' and technology serves as its religion', as Roy (1993: 247) writes, then the intensity and fervour with which some social scientists and humanities scholars exhibit their trade in (dis)respect to each other is similar to the frictions between religious *orders*. While some scholars see the frictions between these *orders of social science and the humanities* as worsening environmental controversies (e.g., Sarewitz, 2004), others worry that a unified approach to science may produce too many societal controversies (Jasanoff, in Horgan, 2019) or is harmful to science itself (Feyerabend, 1993 [1975]).

This article is influenced by similar comparative research coining terms such as 'thought styles' (Fleck, 1979[1935]), 'paradigms' (Kuhn, 1996 [1962]) or Foucault's 'episteme' (cf. Gutting and Oksala, 2019). More recent research has focused on the ways social scientists and humanities scholars not only fertilize each other's research, but also on 'paradigmatic controversies'. Guba and Lincoln (2005), for instance, conclude that frictions and differences between scholars emerge from different ontological, epistemological and methodological preferences. While some such assumptions are irreconcilable – or 'incommensurable' (Kuhn, 1996 [1962]) – with each other, paradigms can also fertilize each other's research. In similar fashion, the scholar of qualitative research methodologies Freeman (2016) introduces five distinct 'modes of thinking' social scientists and humanities scholars employ in order to produce their findings. She further emphasises the importance of the researchers' own personal commitments in mediating which mode of thinking a researcher is drawn to. Freeman (2016), however, also makes explicit that many social scientists employ more than one mode in a research project. For instance, 'categorical thinking' – the creation of criteria to identify and describe phenomena – is present in almost every piece of research. But while some stick to that mode, others venture into other modes including 'dialectical' or 'diagrammatical' thinking (cf. Table 6.1). All these works thus pinpoint to the observation that a rich yet frictional diversity of scholarship exists, each one offering different perspectives on climate science and climate adaptation.

In the domain of climate science and climate adaptation, frictions among social scientists recur around the role of climate science for decision-making, the aims and processes of 'good' climate adaptation projects, and what criteria climate knowledge ought to have in order to be 'high-quality'. For instance, the knowledge dimensions of 'credibility, saliency and legitimacy' put forward by Cash et al. (2003) as well as the distinction by Lemos and Morehouse (2005) between the 'usefulness' and 'usability' of climate knowledge have had a lasting effect on the way climate knowledge for adaptation is envisaged. However, this contrasts with other calls for taking more socially situated perspectives of climate change, emphasising the role of institutions and actors rather than that of knowledge (Hulme, 2011; Castree et al., 2014). Disturbed about inequalities and power reproduced through science-informed policies, critical scholars call for more inclusive knowledge production reflecting local people's experience more (Forsyth, 2003; Agrawal, 2010) as well as a different understanding and depiction of people inhabiting this earth (Chakrabarty, 2009; Latour, 2017).

This study thus takes this Special Issue as an opportunity to illustrate and produce appreciation on the diversity of perspectives five *orders of social science and the humanities* have adopted and offered in their research on what I elsewhere dubbed 'adapting climate science': the production, customisation, use and appropriation of climate science for climate adaptation (Skelton, 2020). Clustering research articles into such *orders of social science and the humanities* is based on the shared and different motivations and problem definitions academics bring to their research. These influence not only the choice of data, methods and topics, but at a deeper level the different ontological, epistemological and methodological commitments made by the researchers. Describing of the *descriptivist*, *ameliorist*, *argumentivist*, *interpretivist* and *critical* orders, this article then discusses how these distinct positions and aspirations influence different notions of 'high-quality' climate knowledge and 'good' adaptation. A more thorough understanding of the differences allows not only a more conscious way of doing research, it could also allow to appreciate how other perspectives offer complimentary insights into the social dynamics climate change produces.

6.2 The descriptivist order: mirroring climate science and climate adaptation

Descriptivist scholars show a particular desire to mirror how climate science is produced and used, and which adaptation processes have been adopted. This order is composed of political scientists, psychologists, economists as well as environmental social scientists who share a similar understanding of social science and its aims: providing undistorted descriptions and explanations. Three features recur frequently (see Table 6.1): *Methodologically*, an empiricism predominantly carried out with a so-called *etic* approach favouring an outsider's perspective on study subjects, relying mostly on the use of quantitative data such as surveys, or the creation of quantitative metrics from qualitative source material such as government reports for statistical purposes. *Ontologically*, a belief that the phenomena of interest are imperfectly apprehensible and measurable through pre-existing categories and stable classifications, such as age, wealth, geography or gender. And *epistemologically*, that unless falsified, descriptivist research produces findings probably true and empirically accessible. The following paragraphs give a flavour what phenomena social scientists in the descriptivist camp have explored.

The production and origin of climate science is one prominent descriptivist account. Such largely quantitative studies use bibliometric methods to assess the growth of climate science, its expansion into other disciplines, or the producers' geography (e.g., Pasgaard and Strange, 2013). All find that a minority of countries – richer and with higher carbon emissions – produce the bulk of climate research. More qualitative accounts of how climate projections informing about future climatic changes were jointly produced with a number of actors (e.g., Jacobs and Buizer, 2016), how such projections are made available across the globe (Hewitson et al., 2017), or how the boundary organisation UK Climate Impacts Programme UKCIP aimed to mainstream climate adaptation (Hedger et al., 2006).

Descriptivist research also illustrates climate adaptation policies, climate service practice and their use of climate science is. This includes mapping of stakeholders working on climate adaptation and services (e.g., Lorenz et al., 2019), the positive effect designated climate adaptation officers have on governmental policy (Stiller and Meijerink, 2016) or case studies on what role institutions and 'boundary organisations' play (e.g., Ekstrom and Moser, 2013). Lorenz et al. (2017) analysed how differently German and British local authorities used climate information in decision making, relating differences back to contrasting regulatory and fiscal governance systems. Similarly, Porter et al. (2014) describe what adaptation action UK households have taken, adding descriptions of less institutionalised and expert-driven adaptation processes.

Descriptivist attention is also focused on the differences of governmental adaptation policies. Comparing different national adaptation strategies in Europe, Albrecht and Arts (2005) found a convergence to a similar understanding of adaptation policy across countries. Similarly, Biesbroek et al. (2010) compare European countries' national adaptation plans across six dimensions, including how adaptation is both implemented and linked up with other policy domains. Still, climate adaptation is understood differently across sectors (Widmer, 2018). Also the uncertainty so prominent in climate scientific discussions is often simplified in such governmental documents (Füssel and Hildén, 2014).

Evaluating adaptation efforts across countries has also gained scholarly attention. Methodological discussions concern how to meaningfully compare the diversity of adaptation practices across countries (Dupuis and Biesbroek, 2013), including what indicators are useful to assess the effectiveness of particular adaptation options (Arnott et al., 2016). Others have developed indicators to track countries' adaptation progress, using the availability of climate science or the existence of national adaptation plans as proxies (Ford et al., 2013). This methodology has then been applied to describe climate adaptation progress globally (Berrang-Ford et al., 2014), and, controversially, labelling countries explicitly into adaptation 'leaders' and 'laggards' (Lesnikowski et al., 2015).

Psychologists, among others, have assessed both the public's ability to comprehend climate information, their attitudes towards climate adaptation and their knowledge on climate change. The comprehension of texts, tables or figures depicting the uncertainty attached to climate information has been a common study theme, in order to empirically find which are the most influential (e.g., Taylor et al., 2015; McMahon et al., 2016). This also includes analysing how readable scientific reports are, such as the IPCC's summary for policymakers (Barkemeyer et al., 2015). Other psychologists have undertaken empirical studies on how UK residents understand climate change impacts and climate adaptation (Harcourt et al., 2019), as well as conducting a meta-analysis to understand what motivates people to adapt (van Valkengoed and Steg, 2019). In particular, norms, negative emotions, and the perceived efficacy of climate adaptation outcomes were found to be key indicators. However, numerous such studies suggest that many people do not distinguish between climate adaptation and mitigation (e.g., Harcourt et al., 2019).

Descriptivists thus understand 'high-quality' climate knowledge to be empirical and explanatory, often using statistical analysis to characterise their study subject through other categories (Table 6.1). An implicit assumption is that knowledge derived in one origin is also valid in others. This is also mirrored in notions of 'good' adaptation as being harmoniously understood by different sets of actors, as well as similarly enacted and legislated in different countries. While adaptation policy-making is squarely seen as politicians' task, consulting the latest research findings and experts is a key feature in 'good' adaptation.

6.3 The ameliorist order: making climate science *for* and *with* society

Characteristically, *ameliorist* academics produce research aimed at increasing the social, ecological and technological resilience towards climatic impacts by improving adaptation decision-making through the production of more usable climate science. Initiated in the 1990s by calls for more issue-driven rather than curiosity-driven science (e.g., Funtowicz and Ravetz, 1993), *ameliorists* advocate science–stakeholder collaborations to produce relevant and usable knowledge as a required first step in triggering climate action. Table 6.1 shows that *ameliorist* research shares many methodological, ontological and epistemological positions with *descriptivists*. For instance, although *ameliorists* are focused on participatory research, their articles still predominantly take an *etic* outsider's perspective. But, importantly, ameliorists see their research output as contributions to a larger transformation, and see themselves as strategic facilitators of environmental action, often taking vocalising their positions in calls-to-action.

Echoing throughout the ameliorist literature is the proclamation that climate science has to play a dominant role in addressing climate change societally. Such scholarship is often quite upfront about this, even stating these ambitions in the title, such as to 'Using climate predictions to better serve society's needs' (Hewitt et al., 2013: 105) or 'Science for successful climate adaptation' (Preston et al., 2013). In line with such assertions, a whole research field has formed based on *ameliorist* motivations. For instance, 'climate services' have been prominently pushed by the World Meteorological Organization WMO, national meteorological agencies as well as the European Commission (cf. Vaughan and Dessai, 2014). Dominated by goals of increasing resilience, ameliorist research puts climate science in the service of climate adaptation.

A range of barriers to using climate science for adaptation decision-making have been identified. Moser and Ekstrom (2010), for instance, developed a diagnosis framework to find, and possibly solve, barriers to adaptation planning. Assuming an 'idealised, rational' decision-making process – labels that they themselves use – the authors propose a process asking two questions: What could act as a barrier? And how do the actors contribute to this barrier? This diagnosis then allows them to find 'points of intervention' fostering climate action (Moser and Ekstrom, 2010: 22026). Similarly, Ernst et al. (2019) identify three clusters of constraints – production, dissemination, and stakeholder engagement – in producing climate services. Ironically, two of these clusters were already strategically employed to promote and facilitate adaptation decision-making in Sweden, yet failed to adequately produce the intended results. Similar challenges with producing usable and thus 'high-quality' knowledge are reported from a US-based regional climate service centre (Briley et al., 2015). Cvitanovic et al. (2015), meanwhile, turn the perspective around, looking at the barriers scientists perceive in stakeholder engagement. Overall, the aim of identifying – and thus overcoming – barriers in the use of climate science for adaptation is a recurring *ameliorist* research theme.

Interestingly, climate services only came into fashion after research highlighted that the existing climate and social science is hardly used. Calls for the reconciliation of the 'demand and supply' of climate information (e.g., McNie, 2007), the closure of the 'science–action gap' (Moser and Dilling, 2011) or the 'usability gap' (Lemos et al., 2012) all tried to foster broad awareness and public action on climate change. Or, as Swart et al. (2014: 1) put it: 'while an abundance of adaptation strategies, plans, and programmes have been developed, progress in turning these into action has been slow. The development of a sound knowledge basis to support adaptation globally is suggested to accelerate progress, but has lagged behind.' The normative assumptions and policy preferences of many ameliorist research papers crystallise in aims such as: fostering climate action on the basis and primacy of science.

To produce the required 'sound knowledge base' (Swart et al., 2014), 'usable science' (Lemos et al., 2012) and 'actionable knowledge' (Kirchhoff et al., 2013) to accelerate climate adaptation efforts around the globe, various academics have argued for engaging stakeholders in research projects. This process was labelled 'co-production of knowledge'[10] (e.g., Lemos et al., 2012), 'co-creation' (e.g., Mauser et al., 2013), 'co-design' (e.g., Moser, 2016a) or 'co-development' (e.g., Leitch et al., 2019), while in Continental Europe it continued to be recognised under the independently established research paradigm of 'transdisciplinarity' (e.g., Pohl, 2008). By doing so, the ameliorists' perceived need to advance global action on climate change with their

10 The term 'co-production' enjoys two different meanings (Bremer and Meisch 2017). On the one hand, ameliorists understand it as *doing* co-production with stakeholders, whereas the interpretivists take to the *studying* co-production in its initial sense as coined by Elinor Ostrom in the 1970s, i.e. examining the ways science and society influence each other's practices and phenomena.

research has joined earlier calls for a new type of science (Funtowicz and Ravetz, 1993).

However, more recently a strong proponent of the co-production paradigm questioned its efficiency in tailoring science (Lemos et al., 2019). An alternative approach has been taken by research on 'user needs', offering a way to produce usable knowledge without costly face-to-face interaction. Some such use(r) requirement studies are noteworthy for their specificity, for instance for Australian vineyards (Dunn et al., 2015). Others have mapped sectoral information requirements, such as water (e.g., Mehta et al., 2013), policy-makers' climate information preferences (Hanger et al., 2013) or information needs for community-level adaptation (Srinivasan et al., 2011). The findings of such studies can illuminate what specific information – for instance, drought indicators – is desired by users, or through which channels it can be accessed. Such studies are thus another ameliorist example of producing 'high-quality', 'usable' climate knowledge for 'good' adaptation.

Drawing on much descriptivist scholarship analysing climate science communication and comprehension, various ameliorist studies have highlighted how to improve the consideration of climate science in climate adaptation. For instance, conveying climate science through stories is one such recommendation, such as the 'tales of future weather' (Hazeleger et al., 2015) and 'narratives' (Dessai et al., 2018). In reviewing climate change communication from 2010 onwards, Moser (2016b) emphasises that opportunities for communicating the impacts of climate change, also within politicised contexts, arise increasingly not only from IPCC's Assessment Reports and UNFCCC COPs, but also from extreme weather events, statements by business associations or religious leaders, and political events such as elections and even pandemics.

Ameliorist scholarship emphasises issue-driven, instrumental and scientific knowledge as particularly able to effectively foster climate action (Table 6.1). 'High-quality' knowledge is often equalized to being 'actionable' or 'usable'. Further, ameliorists widely understand 'good' adaptation as a process underpinned by geophysical climate science, allowing the anticipating management of climate risks. Often prioritising human – and, in the case of climate services, business – needs over nonhumans, such scholarship also assumes that environments can be effectively managed through expertise and technology.

6.4 The argumentivist order: analysing knowledge, demarcating science

Academics following the *argumentivist* order usually use a purely conceptual approach to both meticulously analyse what climate knowledge claims can be validly derived from certain research activities, as well as to propose ways in which decision-makers can successfully navigate and incorporate not only climate science's uncertainties, but also their own values and risk preferences in climate adaptation projects. Composed mainly of analytic philosophers of science (to use a pleonasm), methodologically they are unified by their commitment to work predominantly conceptually in order to logically and argumentatively dissect, reconstruct and critique arguments. In line with such an emphasis, argumentivists take – and critique – a variety of ontological and epistemological positions. Such internal debates should be understood as an exemplary case of the unifying theme of this order, namely meticulous focus on arguments. Overall, *argumentivist* philosophers of climate science engage with philosophical and conceptual issues that arise in the practices of climate science.

Various analytic philosophers discuss the adequacy of climate simulations for making reliable predictions and for understanding aspects of the climate system (e.g., Smith, 2002; Parker, 2014). A climate scientist by training, Held (2005) worries that the attempts to create realistic models makes them so complex that it is impossible to trace why they behave the way they do. Thus, the complexity of climate models – made possible by ever increasing computer power – might make it difficult to actually assess whether model results are reliable. Further, with data and observations becoming more abundantly available, machine learning and big data applications provide new opportunities for climate scientists to research and understand climate change. However, Knüsel et al. (2019) argue that in big data-only approaches, the data alone is insufficient to warrant an assumption of constancy (ceteris paribus). Theory-based knowledge is thus still relevant to climate predictions produced by machine learning algorithms. Overall, analytic philosophers carefully analyse to what extent such modelling approaches are able to provide high-quality knowledge.

With climate scientists increasingly using multiple climate models to assess some of the inherent uncertainties attached to climate change, and the prominence climate models have in informing adaptation decisions, *argumentivists* have been actively engaged in discussions on combining models in ensembles. For instance, Parker (2010) has characterised the different types of 'model ensembles' which exist. As such, perturbed-physics ensembles, multi-model ensembles and initial condition ensembles help analysing different sources of uncertainty. Baumberger et al. (2017) argumentatively follows up the implications of how to appropriately select and weight climate models. More recently, with datasets playing an important role in calibrating and validating climate models, Zumwald et al. (2020) propose to extend the use of ensembles to multiple datasets in order to better assess climate science's uncertainties.

However, how to obtain and interpret quantified uncertainty estimates from climate model ensembles has been a source of friction between climate scientists and argumentivists. For instance, some analytic philosophers strongly objected to how the climate scientists producing the British climate projections UKCP09 (Murphy et al., 2010) communicated their findings as probabilities. The criticism of British climate scientists' 'myopia' (Frigg et al., 2013) was caused by disagreements on how to interpret the 'probabilities' derived from climate simulations. The British climate scientists assumed that these probabilities are a good way of expressing their actual uncertainty. But Frigg et al. (2013) caution against interpreting the British climate projections UKCP09 as being able to be reliable expressions of uncertainty of future climates up to the end of the 21st century. Therefore, this argumentivist analysis has implications for how adaptation projects ought to take up and integrate climate science, in particular for high-risk events.

With 'unknown unknowns' (Parker and Risbey, 2015) making it impossible to know the full event space and the corresponding probabilities with certainty, decision principles and tools have been proposed which consider these constraints. Betz (2010, 2016) argues decision-makers need to focus more on their risk preferences when judging 'worst-case' and 'best-case' scenarios of climate change, rather than its probabilities Similarly, thoughtfully integrating uncertainty explicitly in policy deliberations, both Bradley and Steele (2015) and Hirsch Hadorn et al. (2015) discuss decision strategies to analytically decide whether to accept, revise, or postpone adaptation and mitigation decisions. Roussos et al. (2020) consider three dimensions for more confident decisions using model ensembles: the models' output as probabilities; an expert judgement of confidence in these probabilities; as well as an actor's stakes and cautiousness. These three dimensions allow to characterise and deal with different sources of uncertainty. As such, argumentivists have offered ways in which climate science could be more appropriately taken up in current adaptation decision-making, to ensure 'good' adaptation by 'high-quality' knowledge.

Argumentivists also contributed to the ameliorist discussions of how to co-produce actionable knowledge. Thompson et al. (2016) argue that climate services too often treat climate models' unmodified output as real-world probability distributions. To avoid the pitfalls associated with such unwarranted confidence in climate models while taking climate science seriously in climate adaptation, they propose that structured expert elicitation processes would allow a range of experts to systematically discuss climate science with other available knowledge in order to produce more scientifically justified as well as decision-relevant climate services. In a similar vein, Parker and Lusk (2019) enrich the ameliorist studies of including user values in the co-production of climate knowledge by highlighting that the types of errors which users want to avoid – risk of overestimating or underestimating particular climatic changes – is of importance when producing actionable knowledge. Parker and Lusk (2019) enrich co-production discussions by emphasising that users can also guide scientists' methodological choices: knowing whether under- or overestimation is of greater consequence to users can favour one approach over another.

Argumentivists are thus bound together by their commitment to 'high-quality' knowledge being produced by appropriate methods or flawlessly argued, always explicitly dealing with science's uncertainties (Table 6.1). This is mirrored in their understanding of 'good' adaptation as adequately acknowledging yet still incorporating these uncertainties meaningfully. Often, argumentivists take care in demarcating where the expertise of scientists end and the role of politicians start.

6.5 The interpretivist order: re-conceptualising co-constitutive influences

Interpretivist scholarship aims to unhinge established forms of thinking and descriptions, by redescribing collective behaviours and discourses as products of complex encounters between cultural norms, collective aspirations, socio-political pressures and technological innovations. Composed of Science and Technology Students, empirical human geographers, and qualitative interdisciplinary researchers, *interpretivist* scholarship shares the following three features (see Table 6.1). *Methodologically*, interpretivists favour an empirical *emic* insider's perspective, drawing for instance on ethnographic accounts and semi-structured interviews. Often comparative in nature, much scholarship uses inductive reasoning to bring often unnoticed yet stable patterns into focus. *Ontologically*, interpretivists see social practices, meaning and realities as being the product of multiple influences – beliefs, fantasies, technologies, knowledge, politics. And *epistemologically*, a subjectivist view of findings being collectively mediated by reciprocal interactions of society, science, politics and technology dominates. With such a background, interpretivist research has emphasised how various practices around 'high-quality' climate science and 'good' climate adaptation are socially negotiated and stabilised, and so subject to human fascinations, manipulations and fallacies.

Interpretivist scholars have had continuing interest in the way socio-cultural factors shape climate scientists' work. Shackley (2001) and contributions edited by Heymann et al. (2017) empirically compare the 'epistemic lifestyles' or 'cultures of prediction' of climate modelling centres as a sociological phenomenon. This includes, for instance, the mutually beneficial interplay between modellers and experimentalists through parametrisations (a method for replacing sub-scale atmospheric processes in climate models with empirical observations), thus also socially – and not only epistemically – legitimising climate models as an accepted research mode (Shackley et al., 1998; Sundberg, 2007). Further, Mahony and Hulme (2012) describe how the UK regional climate model PRECIS was motivated by the wish to make the climate centre's science globally available while simultaneously collecting the knowledge of the regional expert stakeholders to reduce obvious model errors. Further, climate scientists often imagine users of climate information to be either similarly numerate as themselves (Porter and Dessai, 2017) or through other simplified categorisations, such as being an academic, practitioner or by sector (Skelton et al., 2019a). Both studies show how powerful imaginations – yet empirically inadequate descriptions – legitimise and guide much development of climate services.

How science and politics mutually influence each other is another intriguing research topic for interpretivist researchers – confusingly also known as the *study* of 'co-production' rather than ameliorists' *doing* co-production with stakeholders (cf. Bremer and Meisch, 2017). With the concept of 'civic epistemologies', Jasanoff (2005) emphasises that democracies have distinct preferences as to which kind of science and expertise is seen as legitimate for policy-making. For instance, Skelton et al. (2017) found patterns of judging 'good' climate science and 'good' stakeholder participation in climate projections matching the political cultures of the UK, Switzerland and the Netherlands respectively. Another such comparative study is the evidence-based research on the politics of climate adaptation in the UK and Australia (Tangney, 2017). Other interpretivist studies focus on single countries, such as how Germany established political consensus on climate change (Beck, 2012), or the goals of the UK Met Office as a world-leading climate science centre also being fuelled by political ambitions to support the UK's climate negotiation position (Mahony and Hulme, 2016).

Another interpretivist research strand investigates how the relationship between climate science and climate action is framed and politically embedded. For instance, Gillard (2016a) highlights the significant rhetorical shift between two consecutive British governments, from one dedicated to being a 'climate leader' in both adaptation and mitigation to one sceptical of the state's role in orchestrating policy targets. Similarly, Tangney (2017) critically examines how ideas and fascinations with evidence-based approaches in decision-making politicizes climate science, in particular by asking science to be the *only* source of answers on the normative policy dimensions. On a global level, the lack of democratic legitimacy of supranational knowledge bodies such as the IPCC have led Bäckstrand (2003) to call for a wider stakeholder interaction in the synthesis of climate science for decisions. Overall, there is thus widespread interpretivist interest in how changes in how environmental governance is perceived shift policy responses.

Interpretivists have also noted how the use of climate science is part of a wider societal concern with anticipating the future. Enserink et al. (2013) show that decision-makers and scientists understand 'scenarios' differently, so much so that what was meant to clarify led to confusion. Social and emotional factors also play a role in interpreting climate simulations, including a certain 'seductive power' in acknowledging the model's uncertainty (Lahsen, 2005). Further, Groves (2017) examines how 'anticipation' and the fascination of desired futures shapes climate politics today. In a similar vein, Hulme (2015) discusses how discussions on geoengineering have not only opened up new ideas of 'cultivating' the sky as a type of adaptation, but fascinations with intentionally managing the atmosphere too. This interpretivist strand of research thus highlights how prospective knowledge on future climate change has already significantly altered our perceptions and thoughts today.

Further, cautioning against dominant *ameliorist* fascinations is a common interpretivist practice – even a *raison d'etre* for some (cf. Horgan, 2019). Many scholars critique the dominance of the 'interaction imperative' embedded in climate services, either because it is too consensual (Klenk and Meehan, 2015); because joint co-design of knowledge does not necessarily lead to trust (Lahsen, 2007); because too often stakeholder engagements are just 'lip service' (Klenk et al., 2015); or because participation often perpetuates rather than challenges existing power dynamics (Chilvers and Kearnes, 2016). Others critique the 'managerial' intentions prominent in adaptation discourses prominent in both socio-technical as well as socio-ecological paradigms (Gillard et al., 2016b). Further, interpretivist scholars see the shift of climate services from the public to the private domain critically (Keele, 2019), and have scrutinised the way the World Bank has produced and circulates 'best practices' for adaptation (Webber, 2015). In general, being wary of other social science orders' efforts, the study of discourses and fantasies is a distinguishing feature of interpretivist scholarship.

Thus, *interpretivists*' understand 'high-quality' climate knowledge to consider the interrelated factors stabilising human practices and sense-making in a particular way (Table 6.1). Such an understanding of 'high-quality' knowledge then translates into 'good' adaptation action as being mindful of the profound influences individuals, institutions, ideas, practices, materials, and nonhumans have on human action. Interpretivists are thus wary of technocratic fallacies of control possibly producing severe unintended consequences.

6.6 The critical order: revealing injustices reproduced by science

Working towards increased social emancipation, the *critical* order aims to reveal how actors and institutional practices stabilise a particular understanding and framing of climate change – the so-called discourse – and so maintain and reproduce social injustices and privileges enjoyed only by few. These ways are often underhand, either depicting the privileged as benevolent scientific, political or economic leaders able to effectively manage environmental pollution, or shift the locus of problem and need to act onto less responsible actors by blanking out key dimensions in the discourse. Although comparatively few *critical* studies on climate have been published, key similarities between postcolonial, feminist and political ecological scholarship are, *methodologically* an often distanced *etic* approach, applying prior thinking to climate science and climate adaptation. *Ontologically*, critical scholarship is shaped by political, economic, ethnic and gender values, while *epistemologically*, critical thought is subjectivist, where findings are collectively mediated and thus changeable.

Postcolonial studies take a close and critical look at how ideas and discourses on climate adaptation have neo-colonial underpinnings of Western superiority and a disregard of nations' policy-making sovereignty. Bankoff (2001), for example, points out that discourses of vulnerability updates, and so maintains, older conceptions of Africa, Asia and South America being dangerous and/or requiring 'Western' support. Between the 17^{th} and early 20^{th} century, such places were framed as disease-stricken lands in need of Western medicine, before being portrayed as impoverished and in need of Western investment and aid after World War II. The current discourse, as Bankoff (2001) argues, is one in which these countries are vulnerable to natural hazards, with science seen as its remedy. As such, his study demonstrates how persistent such marginalising framings are. Further critique has been directed at *ameliorist* discourses romanticising so-called indigenous knowledge, not only by seeing it as being of distinctly different quality than scientific knowledge, but by subjugating such knowledge to the ameliorists' aims rather than respecting those of its original holders (Agrawal, 2010; Klenk et al., 2017). Such studies thus emphasise how other *orders*' judgements of 'high-quality' knowledge and 'good' adaptation can be problematic.

Climate models have received critique for their embedded neocolonial assumptions underpinning their development and deployment. For instance, the UK established the Met Office Hadley Centre also because of a political concern that without its own, national climate model, the UK would be unable to independently act in international climate negotiations, relying instead on knowledge produced in the US and continental Europe (Mahony and Hulme, 2016). Inversely, Anglosaxon climate scientists were at the forefront for producing one-size-fits-all tools for generating climate projections *for* poorer countries, further circulated through workshops held by UNFCCC while continuing to fund own climate scientists rather than adaptation elsewhere (Skelton et al., 2019b). Climate projections and their models thus carry colonial connotations of power and influence over sovereign, national adaptation policy-making (Mahony and Hulme, 2018). Similarly, Lahsen (2007) reminds that Brazilian policy-makers do not automatically trust climate science just because Brazilian scientists were involved. Rather, joint climate research projects are often eyed suspiciously for their goals favouring US over Brazilian interests. While not a *subaltern* view developing a narrative independent of more powerful actors common in postcolonial scholarship (e.g., Chakrabarty, 2012), Miguel (2017) shows that emerging economies such as Brazil have started to develop their own national climate models in an explicit effort to be more scientifically independent in their national climate policies. Overall, both explicit and implicit postcolonial studies illuminate how neocolonial conceptions of 'good' adaptation are manifested in climate models as favouring a distinct perspective on what 'high-quality' scientific knowledge is.

How a discourse mirrors the interests and perspectives of more powerful actors is also revealed by feminist scholars. Seager (2009) traces how the 2°C target was first coined and subsequently internationally endorsed through a politics with 'gendered political and ideological underpinnings', as climate risks below 2°C are acceptable and manageable only for temperate, mid-latitude and richer countries. 'Many ecosystems and peoples will hit limits to adaptation long before 2°C, and some already have' (Seager, 2009: 15). Such a 'mechanistic' and 'masculinized' understanding of humans' ability to effectively manage their environment is, in many *critical* eyes, an unwarranted fallacy of control. By endorsing the 1.5°C target in 2015, however, in particular poorer nations successfully changed the climatic discourse in their favour, and the orthodox science–politics relationship topsy-turvy. Taken by surprise, climate science had to catch up – rather than inform – climate policy (cf. Livingston and Rummukainen, 2020).

Drawing on feminist geography and feminist political ecology, Sultana (2014) uses her own research in South Asia to show how divisions of labour, cultural norms of 'proper' behaviour for women, and unequal rights and decision-making power exacerbate women's vulnerabilities and workload when climate impacts hit. Specifically, even in crises certain 'lines of work', such as fetching drinking water, remain almost exclusively the burden of women. 'Notions of shame, honor, and dignity are strongly enforced by both men and women in maintaining social practices even during disasters', and with it the '[p]roper decorum and constructions of feminized subjectivities result in women being unwilling to associate with unknown men, be alone in public places, and be outside of familiar kinship structures' (Sultana, 2014: 376). The combination of women being less likely to seek refuge and male elders not always supporting women in sheltering tragically produces higher mortality rates for women during catastrophes. Consequently, Jost et al. (2016) find that due to such patriarchal factors the adaptive capacity of women is lower than that of men.

Taking an intersectional perspective – a notion that emphasises that multiple sociocultural strands of influence (e.g., religion, ethnicity, ability) intersect and so produce a person's identities and cultural roles – Carr and Thompson (2014) argue that a binary lens of gender is a too simplistic category to base policies aiming to foster 'good' adaptation. Similarly, Ravera et al. (2016) show that identities based on caste, wealth, age and gender produce different adaptation strategies in two Indian states. They show that 'a priori assumptions on the basis of male/female dichotomy are unable to lead to a comprehensive understanding of farmers' choices, vulnerability, adaptation process and barriers to adoption' (Ravera et al., 2016: S346). In other words, the intra-gender variability of experiences and adaptation practices is too large to be explained solely by a single binary, revealing how intersectional thinking can better capture such multi-factorial differences.

Paying close attention to how powerful economic interests influence discourses so as to retain their privileges, Forsyth (2003) elaborates how a 'critical political ecology' can help to understand and address the adverse effects 'environmental orthodoxies' – widely held inaccurate and simplistic explanations of environmental problems – have when they underpin environmental policies. Motivated by how many policies worsen rather than improve local livelihoods in particular in poorer regions, Forsyth (2003) draws on recent *argumentivist* (!) and *interpretivist* scholarship to trace back how actors and institutions stabilise 'environmental orthodoxies' which inadequately underpin many policies and so reproduce local inequalities. Taylor (2014b: 11) uses such a perspective to critique how simplified and biased the dominant conception – or 'discursive apparatus' – of climate adaptation is, with 'its grounding notion of climate as an external system that provides exogenous stimulus and shocks to which society must then adapt'. Rather, 'lived environments' such as rice paddies are 'actively yet unequally' produced by interlinked and coupled human and meteorological forces. Such a binary nature–society perspective often successfully veils issues of power and ethics in policies. For instance, talking to Indian farmers about climate adaptation in the orthodox way blanks out that these farmers effectively have to respond to greenhouse gas emissions produced largely by wealthy actors elsewhere, often blaming instead local farming practices as inadequate.

Many critical scholars thus pay attention to how uncomfortable knowledge gets omitted and lost when people stabilise ideas. Chakrabarty (2009: 216, emphases in original) asks blatantly '[wh]y should one include the poor of the world—whose carbon foot print is small anyway—by use of such all-inclusive terms as *species* or *mankind* when the blame for the current crisis should be squarely laid at the door of the rich nations in the first place and of the richer classes in the poorer ones?' With such normative efforts of 'denaturalising' discourses, critical political ecologists aim to bring into focus – and therefore attention – 'the uneven distribution of gains and risks arising from deeply fused social and ecological processes' (Taylor, 2014b: 16). Critically reminding that dominant solutions might just be an easy way to shift responsibilities of blame and action elsewhere is thus a key characteristic of political ecologists.

Critical scholars understand 'high-quality' knowledge as having high revelatory and emancipatory potential for social change (Table 6.1). Such knowledge is often geared around how powerful interests shift the discourse, responsibilities and action in their interests. 'Good' adaptation action thus pays tribute to more local experiences and is more inclusive of marginalised sections of populations. Often, too, 'high-quality' knowledge aims to promote a more situated understanding of people in their environments (e.g., Latour, 2017).

6.7 Discussion: understanding why different notions of 'high-quality' knowledge and 'good' adaptation exist among the five *orders of social science and the humanities*

This article has compared five distinct ways social scientists and humanities scholars study climate adaptation and climate science, illustrating both different academic perspectives as well as the diversity of social, cultural, and political facets in 'adapting climate science' (cf. Skelton, 2020). However, novice scholars are unlikely to be the only ones potentially baffled how to adequately make sense of and order this diversity. This study shows that grouping by topic, even method, is not always meaningful to understand how, and more importantly why, social science research is driven by different motivations, critiques different elements, and takes different ontological and epistemological positions. The five *orders* portrayed here – *descriptivist*, *ameliorist*, *argumentivist*, *interpretivist*, and *critical* – aims to produce an understanding of the wealth of social scientific thinking, as well as their respective areas of frictions and confluence. Drawing on research by Guba and Lincoln (2005) and Freeman (2016), Table 6.1 summarises the above sections, enabling straightforward comparison of the orders' different aims, concerns, positions as well as different notions of what 'high-quality' climate knowledge and 'good' adaptation is.

My analysis revealed that what is understood as 'high-quality' climate knowledge is different between, yet similar within, *orders* (Table 6.1). Influenced largely by orders' inquiry aim and posture, *ameliorists* favour instrumental, issue-driven, usable knowledge which is able to foster climate action, while *descriptivists*' notion is less activist and more curiosity-driven, aiming to mirror social phenomena. *Argumentivist*, *interpretivist* and *critical* scholarship, however, is united by a more wary stance towards knowledge in general. There similarities end though, with *argumentivists* in strong favour of explicit treatment of knowledge's uncertainties. For *interpretivists* meanwhile 'high-quality' knowledge re-describes – re-orders, so to speak – our stable social practices, often revealing a mismatch between how people speak describe something and how an anthropologist would describe this behaviour. To end, for *critical* scholars 'high-quality' climate knowledge is emancipatory by being concerned about how dominant discourses mask political, economic and cultural ways injustices, veiling responsibilities and shifting the action imperative to other peoples.

Consequently, the five orders also contrast as to what 'good' adaptation is. While for instance *critical* scholars are concerned with emancipatory adaptation which fosters equality and is more inclusive of people's lived experiences, for many *interpretivists* 'good' adaptation is more democratic and less technocratic, with a more succinct acknowledgement of how science helps stabilising a particular way of 'good' adaptation over others, but itself being embedded with value assumptions. Similarly, argumentivists emphasise that climate science's uncertainties ought to be appro-

Table 6.1 – Characteristics of and positions taken by different orders of social science and humanities. Adapted from Guba and Lincoln (2005: 194f).

Issue	Descriptivist order	Ameliorist order	Argumentivist order	Interpretivist order	Critical order
Inquiry aim	Undistorted descriptions and explanation through the use and creation of criteria and categories. Propositional knowledge intrinsically valuable.	Production of issue-driven, actionable knowledge fostering environmental resilience.	Establish validity of scientific knowledge and decision support tools adequately incorporating uncertainties.	Challenging orthodox descriptions through reconceptualising phenomena as products of interacting forces.	Social emancipation and transformation through revealing how societal injustices are stabilised.
Inquirer posture	Scientist as distanced honest broker informing decision makers.	Transformative researcher as strategic facilitator of environmental action.	Meticulous analyser of scientific knowledge and decision-making.	Wary yet intrigued commentator of social behaviour and aspirations.	Transformative intellectual as an advocate for social emancipation.
Notion of 'high-quality' climate knowledge	Empirical, explanatory knowledge (statistically) characterising study subject with other categories; etic perspective.	Instrumental knowledge able to foster adaptation action; often actively co-produced between scientists and practitioners.	Produced by appropriate scientific methods and/or logical arguments. Explicit treatment of knowledge's uncertainties.	Co-constitutive knowledge critically aware of how particular practices and imaginations are products of a particular constellation of human, nonhuman, institutional, material and conceptual entities.	Revelational, emancipatory knowledge revealing pervasiveness of powerful and marginalising cultural practices through discourses.
Notion of 'good' adaptation	Harmoniously understood by actors. Enacted and legislated similarly across countries. Anticipatory policies and action consulting latest scientific and experts, yet decided by politicians. Includes environmental, social and legislative changes.	Anticipatory, effective and widely implemented action upon environment. Risk management with anthropocentric and technocratic tendencies; primacy of co-produced (geophysical) climate science.	Decision-making appropriately dealing with climate science's uncertainties; with proper demarcation of roles of scientists and decision-makers.	Adaptation action mindful of entities shaping – and thus limiting – human abilities in consciously managing its environment. Wary of human fallacies of control and unintended consequences; critical of technocratic adaptation options.	Transformative and emancipatory; challenging orthodox ways of policy-making; local and inclusive process; primacy on people's livelihoods and experiences.

Issue	Descriptivist order	Ameliorist order	Argumentivist order	Interpretivist order	Critical order
Ontology	Post-positivist: reality imperfectly apprehensible; relatively stable categories and classifications also within the social domain to describe phenomena of interest.		Notions of 'reality' debated, with post-positivists and anti-realists of various hues.	Constructivist: realities and meaning co-constructed through a variety of human and nonhuman factors.	Historical-realist: shaped by political, economic, ethnic, and gender values.
Values in research	Values deemed insignificant for research findings.	Explicit in pro-environmental values, yet rarely critically debated.	Debated; with efforts to differentiate them.	Formative to study aim and focus.	
Epistemology	Objectivist: findings probably true and empirically accessible.		Degrees of 'objectivity' debated.	Subjectivist: findings are collectively yet implicitly mediated, in particular through science, politics and technology.	Subjectivist: findings are collectively mediated. Emancipatory values guide validity of results.
Methodology	Empirical, predominantly quantitative. Distanced etic approach. Deductive reasoning; with falsification of hypotheses.	Distanced etic problematizing – yet not necessarily empirical. Can draw on both quantitative and qualitative data; with participatory workshops.	Logical argumentative analysis; deductive and etic perspective. Mostly conceptual, some empirical studies.	Empirical, mostly qualitative research including ethnographic accounts and interviews. Emic insider perspective. Inductive reasoning.	Empirical, mostly qualitative research. Predominantly emic perspective. yet with strong a priori theoretical foundations and deductive reasoning.
Dominant 'mode of thinking' (cf. Freeman, 2016: 11)	Categorical thinking: 'to create criteria from which to identify and organize data units' in order 'to determine what something is in relation to the conceptual scheme that gives it meaning'.		(no equivalent)	Diagrammatical thinking: 'to engineer new articulations of the effects of turbulent encounters between diverse human and nonhuman practices' by 'unhing[ing] established forms of thinking'	Dialectical thinking: 'to put into action a theory of change and rectify oppressive structures and practices' by 'uncover[ing] inherent tensions that are assumed to exist in humans and societies'

Issue	Descriptivist order	Ameliorist order	Argumentivist order	Interpretivist order	Critical order
Controversies and critiques (from)	· not issue-driven enough (ameliorist) · overconfident with findings' validity (argumentivist) · technocratic tendencies; assumes stable categories (interpretivist, critical) · maintains social injustices (critical)	· too normative (descriptivist) · overconfident with findings' validity (argumentivist) · technocratic tendencies (interpretivist) · increases social injustices (critical)	· Not enough focus on environmental action (ameliorist) · maintains science's hegemony; constrains research (interpretivist, critiques)	· activist tendencies (descriptive, argumentivist) · too conceptual (ameliorist) · speculative on cause and effect (argumentivist)	· activist tendencies (descriptive, argumentivist) · Not enough emphasis on environment (ameliorist) · speculative on cause and effect (argumentivist)
Confluence & learnings(-from)	· stronger epistemological argument (argumentivist)	· attention to social injustices (critical) · problem descriptions (descriptivist)	· external empirical validity (descriptivist) · attention to role of values in science (interpretivist, critical)	· discourses stabilising social behaviour (critical) · descriptions (descriptive)	· values stabilising social behaviour and science (interpretivist) · descriptions (descriptive) · uncertainty of science (argumentivist)
Preferred journals	Global Environ Change; Climatic Change; Clim Policy; P Natl Acad Sci USA (PNAS); Reg Environ Change; Phil Trans R Soc A	Climate Services; Climate Risk Management; Nat Clim Change; Weather Clim Soc; WIREs Clim Change; Mitig Adapt Strat Gl; PNAS; Environ Res Lett	WIREs Clim Change; Philos Sci; Philosophy Compass; Synthese; B Am Geogr Soc (BAMS); Perspect Sci; PNAS	Nat Clim Change; Environ Sci Policy; Climatic Change; WIREs Clim Change; Climate Services; Futures; Reg Environ Change; Sci Technol Hum Val	Geography Compass; Dev Change; Minerva; Prog Hum Geog; T Institute Brit Geogr; Gend Dev; Clim Dev; Geoforum; WIREs Clim Change

priately integrated in order to ensure 'good' adaptation – often also by emphasising where and how decision-makers' own value and risk preferences should be centre stage. *Ameliorists* have a broader take on 'good' adaptation, as one which actually takes place and is grounded in mostly geophysical climate science. *Descriptivists* are less upfront about what criteria are required for 'good' adaptation, apart from that measures and policies need to be in place, and effectively reduce geophysical climate risks.

Thus, this research emphasises that numerous distinct notions of 'high-quality' climate knowledge and 'good' adaptation exist among social scientists and humanities scholars. Uniting and differentiating features of these five *orders* are diverging aims and concerns – categorical description, knowledge for climate action, knowledge quality check, redescriptions of established patterns, exposing of power. Interestingly, these aims are mirrored – likely even required to be precipitated – in deeper ontological and epistemological positions. Table 6.1 emphasises that orders favouring social change employ an *emic* insiders' lived experience perspective to describe their phenomena as something inter-subjectively constructed and delicately maintained collective process – and thus changeable through the subjects' values and norms. Orders with an *etic* distanced perspective work less towards social change, and therefore require categories to be more stable. Similarly, in studying phenomena around 'adapting climate science', the five orders also employ methods particularly able to actively produce the insights supporting the order's aim or sharing its concern. In previous scholarship on 'research paradigms' (Guba and Lincoln, 2005) or 'modes of thinking' (Freeman, 2016), the intricate links as how methodological, ontological, and epistemological positions and research aims largely require and complement each other gets less attention. As this article argues, however, internally consistent links within an order are dominant. This is likely not random. My own experience using data collected in a *descriptivist* and *ameliorist* fashion yet wanting to write in an *interpretivist* or *critical* style was frequently challenging: Too often the qualitative source material was missing which would allow the production of *emic* insights.

Further, these differences have been the source for some misunderstandings and friction between orders (cf. Guba and Lincoln, 2005; Freeman, 2016). Table 6.1 gives examples for what a particular order is critiqued and criticised, and by whom. Fault lines appear most often when two orders' key aims not consider each other adequately at best, or remain largely incommensurable at worst. For instance, *argumentivists* frequently take issue with other order's epistemic overconfidence; while *critical* scholars often object to other orders' flippancy as to how scientific knowledge can exacerbate livelihoods and reproduce injustice by legitimising technocratic rather than democratic governance. However, from my reading, such critiques often reverberate mostly within one's own order, strengthening one's own argument and clarifying one's position – rather than engaging in a constructive way. Still, critique is likely unavoidable, as some differences are not easily resolved. Even if unaware, readers will take cues from the way the text is written, how results are collected and described, and how authors positions themselves within the literature (Dunleavy, 2003). Thus, working towards an order's aims is still mostly taking place within orders, with specialising journals and conferences assisting such specialisation.

While some differences in aims and opinions are unlikely to be fully resolved, careful readers will have noted that some social scientists and humanities scholars are associated with more than one *order*, in particular when co-authoring articles. However, more common than such inter-*order* collaborations are cross-fertilizations and learnings between distinct orders. Such confluence is particularly visible for the pairs descriptivist–ameliorist and interpretivist–critical, bound by a shared etic or emic approach. For the latter pair, this includes for instance attention to ideas' and discourses' 'performativity': the effect that language not only describes, but also orders, structures and encodes a particular way of thinking and therefore acting. In practice, such (diagrammatical) thinking 'brings to the analytic task a way of reading, or a form of intervening, into this moving matter [of reality]' (Freeman, 2016: 105). But characterising the five *orders* also reveals that learning takes place across this dichotomy. For example, taking input from *critical* scholarship, *ameliorists* increasingly recognise issues of social justice as important in fostering adaptation action (see Table 6.1). Similarly, *argumentivists'* focus on uncertainties in science has helped *critical* scholars to reveal that powerful actors promote, consciously or not, their interests through describing science as being more certain than epistemically warranted.

This classification of social-scientific orders may, however, at least help to understand where such frustration arise, and while scholars do not need to share another order's opinion, understanding one's own and other academics' behaviour could produce more tolerant reviews and possibly fruitful collaborations. Castree et al. (2014) have argued for the importance of a more socially situated view of climate change. Such a focus would allow to extend the knowledge of human impacts on the environment with a more profound awareness of how these environmental changes produce new – as well as reinforce old – assumptions and conceptions for people's lives and well-being. While both Castree et al. (2014) and Hulme (2011) lament the marginalisation, even absence, of the social sciences and the humanities in many scientific climate change discussions, this review also highlights that not all *orders* are similarly interested in collaborating with biophysical climate scientists or assisting climate policies and governance in achieving climate resilience. While some dear-held aims might be at odds with such a collaborative approach, a more profound understanding of the diversity and wealth of social-scientific perspectives can crystallise the manifold social, political and cultural dimensions climatic change has.

7 Discussion & outlook

The four previous chapters have featured four ways in which climate science has been adapted. In the present chapter I first summarise how chapters 3–6 contribute and extend the academic debates on global customisation, national use and local appropriation of climate science for adaptation, at the same time illustrating the different perspectives which social scientists bring to the subject. When drawn together in this doctoral thesis, the three empirical research papers highlight further differences. In section 7.2 I analyse how notions of climate information's agency and geographical scale influence the way climate science is adapted and understood. Section 7.3 spells out the practical implications of this research for climate services and the co-production of knowledge. In section 7.4, I briefly introduce promising areas for further studies which have emerged from the collected data. In section 7.5, I indicate future research avenues opened up by the recent youth strikes for climate. While all of their political targets have so far focused on more ambitious climate mitigation efforts, the impact that this more emotional grassroots movement is having on knowledge-intensive, expert-driven climate adaptation action remains unclear. In particular, such research could examine how far societal support shifts experts' understanding of climate change.

7.1 How the thesis chapters extend academic debates

The three empirical studies and the conceptual classification which this doctoral thesis presents all contribute to, extend and open up new academic discussions around our understanding and adaption of the impressive corpus of knowledge assembled by climate scientists. In these studies, written in accordance with the *interpretivist* order of social scientists, this thesis has used what Melissa Freeman (2016) described as 'categorical' and 'diagrammatical' thinking extensively. That is, the research presented here aims to repackage and redescribe *own* observations, and contrasts these with the dominant academic debates on the customisation, use and appropriation of climate science for climate adaptation.

Chapter 3 described how countries across the world differ in their ability to customise climate models for national adaptation, influenced in particular by their respective climate science publication competency. In so doing this study reveals a neglected perspective in current debates of climate models, seeing their use as as a form of scientific dependency (e.g., Mahony and Hulme, 2016; Miguel, 2017). In particular, it points out that *descriptivist* bibliometric studies and *critical* scholarship on the geopolitics of climate models have remained focused on the territorial origin of climate science. Both research strands thus implicitly assume that 'good' science for decision-making is best if it is based on one's own climate model. Such assumptions have not, however, been made by all climate scholars (e.g., Knutti et al., 2010; Parker, 2010). For instance, Swiss scientists *customised* climate science for their national context according to its particular political cultures – but only using climate models produced elsewhere (cf. Skelton et al., 2017). Critically analysing geographies of climate knowledge is certainly required, but a shift towards the ability to customise climate science may reveal it to be a more pressing scientific dependency than aspirations of producing one's own climate model.

Chapter 4 analyses who actually uses climate projections and how. In particular, it finds a more heterogeneous use of climate information within academia, practice or sectors than the current *descriptivist* and *ameliorist* debate would have it. By introducing the typology of *sailors*, *divers* and *observers* to distinguish between qualitative, quantitative and interested uses of climate projections, I and my co-authors highlight that the prevalent categories of explaining use, such as by sectors, the research-practice binary or numeracy, cannot account for the diversity of use of climate science within the Swiss adaptation community. As such, this research piece presents a very strong case for asserting that previously used and/or dominant categorisations are empirically inadequate. With this study, I hope to introduce a more adequate terminology to discussions of who 'the users' of climate services and co-production projects are, and what type of climate information they prefer.

Chapter 5 compares how four sectors have appropriated and understood knowledge on urban heatwaves differently. Drawing on Eviatar Zerubavel's cultural cognitive sociology, I have aimed to show what factors influence the particular way this knowledge is appropriated, deliberated, valued and/or resisted. As such, this study is another example of how a different perspective can enrich the currently dominant practice of understanding knowledge transfer on climate change. By drawing on the conceptual work of Zerubavel (1999) on knowledge and memory as a formative and performative social activity, this study aims to illuminate why certain professional communities of practice are quick and keen to appropriate climate change into their 'thought style' (Fleck, 1979[1935]), while others seem to resist incorporating such knowledge as a core aspect of their work. This chapter complements other interpretivist perspectives from the 'public understanding of science' literature (e.g., Irwin and Wynne, 1996). In particular, this study demonstrates how prior knowledge and experiences influence whether and how heatwaves are appropriated.

Chapter 6 is the result of my journey reading and relating to other academics' work on adapting climate science. It rearranges – orders, so to speak – the vast amount of literature according to significant differences in research aims, concerns and associated methodological, epistemological and ontological preferences. By describing five archetypal *orders of social science* this piece gives an overview of the various ways in which the relationship between climate adaptation and climate science has been characterised. More importantly, this piece demonstrates that while some scholars feel comfortable using different orders, there are also tribal dynamics, rivalries and disagreements between these orders. I hope that my rearrangement of others' published works highlights essential yet underlying differences which a topic-based description such as that in chapter 2 cannot adequately capture.

To sum up, the three empirical research papers together with the literature review all employ 'categorical thinking' to produce novel typologies emerging from the data. Yet, by amplifying contrasts often overlooked in current academic discussions, and by rearranging these into new categories, I want to diagrammatically highlight how partly known phenomena can also be described differently. In this process, I found fascinating ways in which various actors have adapted and understood climate science, and the different ways relevance is created to prior expertise and experiences.

7.2 Further issues manifesting themselves in this thesis

Two 'elephants in the room' (cf. Zerubavel, 2008) are not explicitly discussed in the individual chapters, but crystallise together when combined in a doctoral thesis. One, the degree of agency the actors in the studies have in shifting and producing awareness on climate change. And two, the effect scale – from global to local – has on how abstract and pure, or specific and messy, climate adaptation and climate science can be envisaged or negotiated.

First, much research is based on the assumption that climate science ought to inform climate adaptation to ensure long-term societal resilience, for instance through the production of national climate projections. But, as various of my findings illustrate , the provision of climate change has not linearly influenced adaptation. That is, while much of the research described is about using the impetus and credibility of science to foster climate action, it seems that these cognitive, methodological or conceptual contributions are subdued by, for example, societal inertia or active resistance. In other words, the account by John Law (2004) in chapter 3 of science producing or shifting 'realities' is not quite as straightforward as he depicts. It requires the support of many other actors to stabilise and appropriate a particular method or concept.

As such, this research suggests that a more honest discussion of the degree of agency both social and climate scientists can realistically achieve is needed. So far, this discussion seems to have been avoided, partly as the results might pose a problem as 'uncomfortable knowledge' (Rayner, 2012). However, such a discussion could, I believe, trigger more credible accounts of what knowledge can achieve in both the *ameliorist* and *critical* order (e.g. Lemos et al., 2012), the degree to which both descriptivist and interpretivist studies can influence, detect and amplify realities (e.g., Taylor et al., 2014a; Lahsen, 2007), or how critical scholarship on continued or renewed inequalities is integrated into adaptation (e.g., Bee et al., 2015).

Second, comparing the global, national and local scales, distinct differences as to how climate knowledge is envisaged can be identified. For instance, on the global level a more abstract and 'pure' conception of climate science dominates, with notions of climate adaptation being vaguer. In the national study, however, climate adaptation is prioritised and climate knowledge is understood in more diverse ways. In the local study, by contrast, the point of departure for the different specialists was neither climate science nor climate adaptation, but their services' priorities, concepts, and responsibilities. For instance, heatwaves were mostly understood as a corollary of biodiversity or thermal comfort – not about distinct changes in weather phenomena.

In addition, the scale comparison demonstrates that climate knowledge becomes more and more selectively adapted, and possibly resisted, the lower down the scale one goes. This interpretation is in line with other scholarship demonstrating that local and sectoral adaptation often interweaves with other institutional, political, financial, and professional priorities (e.g., Irwin and Wynne, 1996; Ryghaug and Solli, 2012; Lorenz et al., 2017; Heaphy, 2018; Olazabal et al., 2018). Or, to phrase it in Latourian terms, where so-called inert and unconscious actors also possess agency (Latour, 2017), the local sites produce more frictions and reconfigurations of climate knowledge. This is because thermal insulations, spatial planning laws, trees, and people's way of looking after their health are all agencies influencing and fixing experts' decisions scopes. On the global level, these specific agencies are subsumed in larger categories and become thus less important, allowing scientists – both the natural and the social – to produce more abstract conceptualisations and idealisations of climate adaptation and climate science.

7.3 Practical implications for climate scientists and adaptation specialists

7.3.1 Recommendations for climate scientists producing science for climate adaptation

The research carried out within this doctoral thesis makes several important and timely points relevant for climate scientists producing climate science for adaptation. One, the study of national uses of climate information shows that it is very hard to predict what data users will employ in adaptation projects. A promising approach would be to supplement qualitative findings, presented for example in brochures, with easily accessible raw data underlying the climate information. This would allow stakeholders to themselves choose which data source is most adequate for their purposes.

Second, I would like to recommend communicating climatic change to those expert communities which share few or no concepts with climate science – health and spatial planning, for instance – by finding suitable research partners to make the relevance of climate impacts on their work explicit. In particular, the communication should build on 'cognitive links' which allow experts to similarly appropriate this knowledge into their thinking.

Third, the local appropriation study also showed that experts have different ways of keeping up-to-date with other people's work. I would like to recommend climate scientists to become more aware of less well-known channels for communicating climate change. These include, for instance, guided tours for expert audiences, advisory committees for particular adaptation projects, lectures to students of other departments, and talks at professional associations' annual conferences. Furthermore, many practitioners may not know whom to contact within universities, so that pinpointing or, even better, establishing contact to relevant people could help practitioners make sense of the 'black box' university.

Fourth, my findings could promote a deeper reflection on often-voiced assumptions underpinning climate services. I would like to encourage climate scientists in co-production projects to reflect on how they imagine the ways users operate. This could be aided by questions such as: 'On what basis have you described what users do and need? What knowledge or experience would be required to change your particular description?'. Such questions aim to trigger underlying assumptions, and can reveal how certain producers of climate services operate.

Fifth, my research also serves as a reminder that understanding climate science may not be the reason why adaptation action gets bogged down, as is sometimes suggested. It may also be that climate knowledge projects, such as climate projections, can be a good vehicle to foster discussions and bring different experts together. A scientist's presence at a workshop and project meetings may have more effect than the climate information itself. Climate scenarios can thus be 'heuristic tools' (Heaphy, 2018) to begin a collaboration, rather than its closure.

7.3.2 Recommendations for practitioners on adapting climate science

The research findings from the chapter 4 on national use and chapter 5 on local appropriation holds key lessons to be learnt by practitioners to make easier and better use of climate science for adaptation. First, I would like to recommend that all involved sectoral experts should consider how changing weather patterns, from more intense heatwaves and torrential rain to prolonged droughts, changes sectoral priorities and concerns. More awareness of how both average and extreme weather impacts experts' work helps in understanding and making sense of climate science.

Second, experts ought to inform themselves about how climate changes local weather conditions. Various information brochures and websites have been created and curated by climate scientists to include such information. I would also like to recommend the participation in workshops dedicated to such topics. It might well be the case that other local governments and sectoral experts may well have started implementing adaptation action already. Finding out what worked well, what was challenging and why helps to understand how climate adaptation action is also intertwined with other legitimate concerns or priorities.

Third, sectoral experts should not shy away from climate scientists and their research. Make your needs, priorities and questions heard and known. My research shows that in particular public or professional meetings where climate scientists attend are good places to start conversations.

7.4 Further opportunities for research based on the collected data

By applying an interpretivist approach to research, and by amplifying emergent themes from the data collected, it has been possible for me to participate in academic discussions which I did not envisage in the first place. (This opportunity is less common in theory-based approaches aimed at bringing pre-defined issues into sharper contrast). The following paragraphs present some of my findings and thoughts based on three further manuscripts, using data collected as part of the study on the local appropriation of heatwave knowledge.

The Swiss civic epistemology and its influence on knowledge transfer. My initial analysis of the interviews points to an organic, 'rhizomatous' way (cf. Smith and Protevi, 2018) in which environmental knowledge – whether produced by scientists or by practitioners – is transferred, evaluated, transformed and legitimised in Switzerland. A federal state with strong local identities and a distinctly participatory political culture, the challenge Switzerland faces is one in which experts working on different levels still need some degree of coordination, for instance on heatwave adaptation. Therefore, the way knowledge and experience are memorised and transferred between cantons, municipalities, the federal government, professional associations, environmental consultancies, engineering firms and friendships is sociologically fascinating. As such, the collected data could provide details on how the Swiss 'civic epistemology' and on the way in which semi-institutionalised knowledge transfer takes place. Such an account could fill the gap between the interpretivist account by Jasanoff (2005) comparing the US, UK and Germany, and the political scientists' main comparison between Switzerland and the UK as two prototypical cases for 'consensus' and 'majoritarian' democracies (Lijphart, 2012).

Bringing Goffman's study of face-to-face interactions to the co-production of knowledge discussion. Erving Goffman is well-known for his analysis of the dynamics underlying human face-to-face interactions. In particular his magnum opus, *The presentation of self in everyday life*, portrays the underlying patterns guiding and restricting people's interactions (Goffman, 1990 [1956]). Famously using the metaphor of the theatre to illustrate how humans have particular expectations of appropriate social behaviour, he describes the delicacy of starting conversations with strangers, the way offensive remarks are avoided, or the subtle signs that are sent out or received to stop conversations slowly rather than abruptly. In co-production projects, face-to-face engagements between climate scientists and users are often judged essential to their success. During my own process of interviewing sectoral experts and inviting them to two co-production workshops, a clear pattern of either refusing or keen participation, depending on the particular sector, emerged. By drawing on Goffman's insights on face-to-face interactions, I want to explain the particular attitude invited participants brought towards transdisciplinary workshops. In particular, I want to point out that workshops and interviews come with widely accepted forms of appropriate behaviour. While this can lead to some people being eager participants; for other experts fulfilling this designated role is more difficult. Thus, with my research I want to expand on how workshop dynamics select and favour the participation of some over others, and discusses the implications of this for co-producing climate knowledge.

Tensions between adaptation options favouring resilient or 'good' cities. A surprising result of the research for me was the resistance of some sectoral experts to climate adaptation action because of their concerns that it would negatively affect other valued amenities. In particular, spatial planners are much concerned to improve the quality of life which city inhabitants enjoy. However, some interviewees raised objections to the greening of cities, as this not only changes the cityscape, giving it a more suburban feeling, but could also be an impediment to cultural events taking place. Similarly, for fear of reducing the quality of living within neighbourhoods, the priority given to architectural and thermal issues surrounding buildings may not always be in alignment with each other. Thus, this research serves as a reminder that the contribution of 'local' knowledge can be a legitimate and important reason for not limiting discourses on resilience to an academic context (cf. Wynne, 1996).

7.5 Outlook: promising future research avenues

In the last year, the global climate strikes organised by the Fridays for Future movement and spearheaded by Greta Thunberg have, where others have so far struggled, produced widespread support for more ambitious climate mitigation efforts. The mass demonstrations, political activities and acts of civil disobedience witnessed across the globe are huge, numbering up to four million participants in 2000 cities and 125 countries (*Vox*, 2019). Numerous climate scientists were quick to support the grassroots movement's core objective as scientifically and ethically valid (Hagedorn et al., 2019; Warren, 2019).

Since then, the climate movements' stickers calling for 'net zero until 2030' or 'make love not CO2' have been prominently placed on rucksacks, laptops, or traffic signposts. In the last Swiss national election, the green parties could secure a historical landslide win (*Schweizer Radio und Fernsehen*, 2019b). In addition, various cantonal and municipal parliaments have symbolically declared a 'climate emergency' (*Neue Zürcher Zeitung*, 2019). More ambitious mitigation policies have been passed, including fuel taxes for flights which had previously long been controversial (*Tagesanzeiger*, 2019b).

The change climate strikers have achieved is not only of political but also of cultural nature: from a framing of climate change as *a problem to be solved* to a feeling of climate change being *a problem being lived with*. Or, in the words of Dougald Hine (2019), talking of the rhetorical shift from Al Gore's *An Inconvenient Truth* to Greta Thunberg's speeches on panic:

> 'Here's what I've been picking up from the people I meet, the audiences I speak to and the stories that come back to me: on a scale not seen before, people are having an encounter with climate change not as a problem that can be solved or managed, made to go away, or reconciled with some existing arc of progress, but as a dark knowledge that calls our path into question, that starts to burn away the stories we were told and the trajectories our lives were meant to follow, the entitlements we were brought up to believe we had, our assumptions about the shape of history, the kind of world we were born into and our place within it' (Hine, 2019).

What Hine (2019) describes is that climate change has unsettled some people *emotionally*. For instance, at a recent public event alongside the Zurich Film Festival, actor Javier Bardem was moved to tears by a question from a young audience member (Tagesanzeiger, 2019a). Further, climate change has appealed to people's inherent sense of justice and equality to the degree that young climate activists have consciously taken the risk of being arrested and confined for up to 48 hours when protesting outside of Swiss banks' headquarters (Schweizer Radio und Fernsehen, 2019a). Similarly, the Extinction Rebellion action week in September 2019 also attracted pensioners outside of London, some of whom had until then been apolitical and had never attended political rallies (The Guardian, 2019). And this particular protest took place during Brexit, the largest political crisis the UK faced in decades.

One striker recently made newspaper headlines by going on a one week-long hunger strike because progress is too slow (Blülle, 2019). Lastly, reports about students' emotional fragility and crises related to climate change have become so prominent that it already has a name: 'eco-anxiety' (Ojala, 2018; Pihkala, 2018). All these examples are indicators of a shift towards a more emotional relationship with climate change.

However, other actors and initiatives are also working towards a climate-compatible future. Climate change is increasingly also seen as a business problem (e.g., Goldstein et al., 2019), and reporting initiatives such as the Task Force on Climate-related Financial Disclosure TCFD attempt to make climate change more 'recognisable' within and across businesses (Task Force on Climate-related Financial Disclosures, 2020). Discourses of oil-producing companies and other carbon-intensive industries being 'stranded assets' from an investor's perspective have also intensified (Caldecott, 2017), even resonated among climate strikers. Other initiatives entangled with climate adaptation and climate science are the United Nation's Sustainable Development Goals SDGs (Nilsson et al., 2016), highlighting win-win efforts and tricky trade-offs for countries' intended developments around the globe. As such, the Friday for Future movement is embedded in a network of similar and distinctly different discourses and practices around mainstreaming climate change and promoting climate-compatible lifestyles.

What remains unclear, however, is the impact the climate youth movement and the associated discourse shift is having on the subject of climate adaptation and climate science on the one hand, and how the strikers' ambitions interact with other discourses and initiatives such as the Paris Agreement, the Sustainable Development Goals, or the Task Force on Climate-related Financial Disclosure TCFD on the other hand. Does the greater support for ambitious mitigation policies also assist sectoral experts and adaptation specialists to implement specific adaptation action? Are people more likely to accept larger interventions in the cityscape? Are they readier to accept health prevention efforts? At the time I collected the data the climate strikes had not yet begun. It would be interesting to contrast the responses of summer 2018 with more recent ones, trying to figure out whether proposed adaptation action is now more seriously considered and actively supported. Such studies would be promising and valuable, as they would enable us to examine the ways in which a grassroots movement and a changed discourse can, unintentionally, shape knowledge-intensive, expert-driven climate adaptation processes. In particular, specific examples could bring insights into the role social acceptance plays in experts' work, rather than only scientific climate knowledge.

7.6 Conclusion

This doctoral thesis demonstrates empirically the diversity in which climate science has been globally customised, nationally used, locally appropriated, as well as social-scientifically ordered. The studies collected here show that countries, adaptation specialists, sectoral experts and social scientists exhibit surprisingly stable and recurring patterns of behaviour in adapting climate science. As such, my findings not only describe the diversity of approaches, but also the factors influencing people's behaviour. This includes the availability of model output and expertise required to customise global climate science for adaptation as well as the perceived necessity of doing so (chapter 3); that explaining how adaptation practitioners use climate projections ought not to revert to potentially misleading categories such as the academic-practitioner binary, sector, or numeracy (chapter 4); that one's prior thought style and work focus influence to a large degree how climate knowledge is appropriated and transformed (chapter 5); and that underlying values and differing research aims produce not only different social-scientific perspectives, but also potential points of friction (chapter 6). Thus, I conclude that the interaction of adaptation actors with climate science extends and transforms how climate science is understood, indicating also how these actors prioritise and perceive their work activities. Future research ought to revisit the more local adaptation activities, in particular examining how the youth strikes for climate have affected not only climate mitigation strategies, but also the relationship between climate adaptation and climate science.

References

Neue Zürcher Zeitung (2019) «Wir beerdigen unsere Zukunft, so wie wir sie uns vor zehn Jahren vorgestellt haben» – die Zürcher Klima-Aktivisten treiben die Politik vor sich her, 25 September. Available at: https://www.nzz.ch/zuerich/klimajugend-treibt-politik-in-zuerich-vor-sich-her-ld.1511131 (accessed 23.12.2019).

Adaptation Sub-Committee (2016) *UK Climate Change Risk Assessment 2017: Synthesis report: priorities for the next five years*. Available at: https://documents.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Synthesis-Report-Committee-on-Climate-Change.pdf (accessed 12.7.2016).

AFC, AHB and AWEL (2016) *Sommerlicher Wärmeschutz: Tools zur Abschätzung in der frühen Planungsphase*. Available at: https://www.stadt-zuerich.ch/content/dam/stzh/hbd/Deutsch/Hochbau/Weitere%20Dokumente/Bauen-2000-Watt/Grundlagen-Studienergebnisse/NB/2016/2016-06-Sommerlicher-Waermeschutz.pdf (accessed 23.2.2018).

Agrawal A (2010) Why "indigenous" knowledge? *Journal of the Royal Society of New Zealand* 39(4): 157-158. https://doi.org/10.1080/03014220909510569.

Akademien der Wissenschaften Schweiz (2016) Brennpunkt Klima Schweiz. Grundlagen, Folgen und Perspektiven. *Swiss Academies Reports* 11(5).

Albrecht J and Arts B (2005) Climate policy convergence in Europe: An assessment based on National Communications to the UNFCCC. *Journal of European Public Policy* 12(5): 885-902. https://doi.org/10.1080/13501760500161571.

Archer ERM (2003) Identifying Underserved End-User Groups in the Provision of Climate Information. *Bulletin of the American Meteorological Society* 84(11): 1525-1532. https://doi.org/10.1175/BAMS-84-11-1525.

ARE (2013) *Klimawandel und Raumentwicklung: Eine Arbeitshilfe für Planerinnen und Planer*. Available at: https://www.are.admin.ch/dam/are/de/dokumente/raumplanung/klimawandel_und_raumentwicklung-einearbeitshilfefuerplanerinnenu.pdf.download.pdf/klimawandel_und_raumentwicklung-einearbeitshilfefuerplanerinnenu.pdf (accessed 7.5.2018).

ARE and AWEL (2015) *Langfristige Raumentwicklungsstrategie des Kantons Zürich: Teilprojekt Lokalklima*. Available at: http://www.raumbeobachtung.zh.ch/docs_library/lares/T10.pdf (accessed 22.2.2018).

Arnott JC, Moser SC and Goodrich KA (2016) Evaluation that counts: A review of climate change adaptation indicators & metrics using lessons from effective evaluation and science-practice interaction. *Environmental Science and Policy*. https://doi.org/10.1016/j.envsci.2016.06.017.

Bäckstrand K (2003) Civic Science for Sustainability: Reframing the Role of Experts, Policy-Makers and Citizens in Environmental Governance. *Global Environmental Politics* 3(4): 24-41. https://doi.org/10.1162/152638003322757916.

BAFU (ed) (2017) *Impulse für eine klimaangepasste Schweiz. Erkenntnisse aus 31 Pilotprojekten zur Anpassung an den Klimawandel*. Bern: Bundesamt für Umwelt.

BAFU (ed) (2018) *Hitze in Städten: Grundlage für eine klimaangepasste Siedlungsentwicklung*. Bern: Bundesamt für Umwelt.

Bankoff G (2001) Rendering the World Unsafe: 'Vulnerability' as Western Discourse. *Disasters* 25(1): 19-35. https://doi.org/10.1111/1467-7717.00159.

Barkemeyer R, Dessai S, Monge-Sanz B, et al. (2015) Linguistic analysis of IPCC summaries for policymakers and associated coverage. *Nature Climate Change*. https://doi.org/10.1038/nclimate2824.

Barrow E, Maxwell B and Gachon P (2004) *Climate variability and change in Canada: Past, present and future*. Toronto, Ont.: Meteorological Service of Canada; Environment Canada.

Schweizer Radio und Fernsehen (2019a) Basler und Zürcher Klimaaktivisten wieder auf freiem Fuss, 10 July. Available at: https://www.srf.ch/news/schweiz/nach-klima-demo-basler-und-zuercher-klimaaktivisten-wieder-auf-freiem-fuss (accessed 23.12.2019).

Baumberger C, Knutti R and Hirsch Hadorn G (2017) Building confidence in climate model projections: an analysis of inferences from fit. *Wiley Interdisciplinary Reviews: Climate Change* 8(3): e454. https://doi.org/10.1002/wcc.454.

Beck S (2012) The challenges of building cosmopolitan climate expertise: the case of Germany. *Wiley Interdisciplinary Reviews: Climate Change* 3(1): 1-17. https://doi.org/10.1002/wcc.151.

Bee BA, Rice J and Trauger A (2015) A Feminist Approach to Climate Change Governance: Everyday and Intimate Politics. *Geography Compass* 9(6): 339-350. https://doi.org/10.1111/gec3.12218.

Benestad R, Rössler O, Hübenere H, et al. (2014) *White paper on climate change data for end-user: COST ES1102 - VALUE, working group 1*. Available at: http://www.value-cost.eu/sites/default/files/value-wg1-whitepaper_04-03-2014_Benestad_etal_v2.pdf (accessed 2.9.2018).

Berkhout F (2012) Adaptation to climate change by organizations. *Wiley Interdisciplinary Reviews: Climate Change* 3(1): 91-106. https://doi.org/10.1002/wcc.154.

Berrang-Ford L, Ford JD, Lesnikowski AC, et al. (2014) What drives national adaptation? A global assessment. *Climatic change* 124(1-2): 441-450. https://doi.org/10.1007/s10584-014-1078-3.

Betz G (2010) What's the Worst Case? The Methodology of Possibilistic Prediction. *Analyse & Kritik* 32(1): 463. https://doi.org/10.1515/auk-2010-0105.

Betz G (2016) Accounting for Possibilities in Decision Making. In: Hansson SO and Hirsch Hadorn G (eds) *The Argumentative Turn in Policy Analysis:* Cham: Springer International Publishing, pp. 135–169.

BFE (2017) *ClimaBau – Planen angesichts des Klimawandels: Energiebedarf und Behaglichkeit heutiger Wohnbauten bis ins Jahr 2100*. Available at: https://www.aramis.admin.ch/Default.aspx?DocumentID=46167&Load=true (accessed 22.5.2018).

Biesbroek R, Swart RJ, Carter TR, et al. (2010) Europe adapts to climate change: Comparing National Adaptation Strategies. *Global Environmental Change* 20(3): 440-450. https://doi.org/10.1016/j.gloenvcha.2010.03.005.

Blaser J, Gardi O, Kern M, et al. (2017) *Schlussbericht Urban Green & Climate Bern: Die Rolle und Bewirtschaftung von Bäumen in einer klimaangepassten Stadtentwicklung*. Available at: https://www.nccs.admin.ch/dam/nccs/de/dokumente/klima/externe-studien-berichte/Urban_Green_and_Climate_Bern_Die_Rolle_und_Bewirtschaftung_von_Baeumen_in_einer_klimaangepassten_Stadtentwicklung.pdf.download.pdf/Urban_Green_Climate_Bern_-_Schlussbericht.pdf (accessed 13.11.2018).

Blicharska M, Smithers RJ, Kuchler M, et al. (2017) Steps to overcome the North–South divide in research relevant to climate change policy and practice. *Nature Climate Change* 7(1): 21-27. https://doi.org/10.1038/nclimate3163.

Blülle E (2019) Keine halben Sachen. *Republik*, 19 December. Available at: https://www.republik.ch/2019/12/19/keine-halben-sachen (accessed 23.12.2019).

Bogner A (ed) (2002) *Das Experteninterview: Theorie, Methode, Anwendung*. Opladen: Leske und Budrich.

Bradley R and Steele K (2015) Making Climate Decisions. *Philosophy Compass* 10(11): 799-810. https://doi.org/10.1111/phc3.12259.

Braunreiter L and Blumer YB (2018) Of sailors and divers: How researchers use energy scenarios. *Energy Research & Social Science* 40: 118-126. https://doi.org/10.1016/j.erss.2017.12.003.

Brekhus W (2007) The Rutgers School: A Zerubavelian Culturalist Cognitive Sociology. *European Journal of Social Theory* 10(3): 448-464. https://doi.org/10.1177/1368431007080705.

Bremer S and Meisch S (2017) Co-production in climate change research: Reviewing different perspectives. *Wiley Interdisciplinary Reviews: Climate Change* 8(6): e482. https://doi.org/10.1002/wcc.482.

Brenneisen S (2015) Begrünte Flachdächer, Norm SIA 312: Entstehung und Hintergrund der Norm SIA 312 «Begrünung von Dächern». *anthos*(5): 16-18.

Bresch DN, Bavay M, Burlando P, et al. (2018) *The CH2018 scenarios in use*. https://doi.org/10.7892/boris.121331.

Briley L, Brown D and Kalafatis SE (2015) Overcoming barriers during the co-production of climate information for decision-making. *Climate Risk Management* 9: 41-49. https://doi.org/10.1016/j.crm.2015.04.004.

Brönnimann S, Appenzeller C, Croci-Maspoli M, et al. (2014) Climate change in Switzerland: a review of physical, institutional, and political aspects. *Wiley Interdisciplinary Reviews: Climate Change* 5(4): 461-481. https://doi.org/10.1002/wcc.280.

Bruno Soares M, Alexander M and Dessai S (2018) Sectoral use of climate information in Europe: A synoptic overview. *Climate Services* 9: 5-20. https://doi.org/10.1016/j.cliser.2017.06.001.

Bruno Soares M and Buontempo C (2019) Challenges to the sustainability of climate services in Europe. *Wiley Interdisciplinary Reviews: Climate Change* 38(1): e587. https://doi.org/10.1002/wcc.587.

C3S (2017) *Key Survey Results: DECM (C3S_51 Lot4) | Data Evaluation for Climate Models*. Available at: https://www.climate-service-center.de/imperia/md/content/csc/projekte/decm_survey_summary_shading_corr.pdf (accessed 27.6.2018).

Caldecott B (2017) Introduction to special issue: stranded assets and the environment. *Journal of Sustainable Finance & Investment* 7(1): 1-13. https://doi.org/10.1080/20430795.2016.1266748.

Carr ER and Thompson MC (2014) Gender and Climate Change Adaptation in Agrarian Settings: Current Thinking, New Directions, and Research Frontiers. *Geography Compass* 8(3): 182-197. https://doi.org/10.1111/gec3.12121.

Cash DW, Clark WC, Alcock F, et al. (2003) Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America* 100(14): 8086-8091. https://doi.org/10.1073/pnas.1231332100.

Castree N, Adams WM, Barry J, et al. (2014) Changing the intellectual climate. *Nature Climate Change* 4(9): 763-768. https://doi.org/10.1038/nclimate2339.

CH2011 (2011) *Swiss climate change scenarios CH2011*. Zürich: C2SM; MeteoSwiss; ETH; NCCR Climate; OcCC.

CH2014-Impacts (ed) (2014) *Toward quantitative scenarios of climate change impacts in Switzerland*. Bern: Oeschger Centre for Climate Change Research (OCCR); FOEN; MeteoSwiss; C2SM; Agroscope; ProClim.

CH2018 (ed) (2018) *CH2018 – Climate Scenarios for Switzerland: Technical Report*. Zurich: National Centre for Climate.

Chakrabarty D (2009) The Climate of History: Four Theses. *Critical Inquiry* 35(2): 197-222. https://doi.org/10.1086/596640.

Chakrabarty D (2012) Postcolonial Studies and the Challenge of Climate Change. *New Literary History* 43(1): 1-18.

Chilvers J and Kearnes M (eds) (2016) *Remaking Participation: Science, environment and emergent publics*.

Copp MA (2008) Emotions in Qualitative Research. In: Given LM (ed.) *The Sage encyclopedia of qualitative research methods:* Los Angeles, Calif.: SAGE Publications, pp. 250–252.

Corbera E, Calvet-Mir L, Hughes H, et al. (2015) Patterns of authorship in the IPCC Working Group III report. *Nature Climate Change* 6(1): 94-99. https://doi.org/10.1038/nclimate2782.

CSIRO and Bureau of Meteorology (2007a) *Climate Change in Australia: observed changes and projections*. Available at: http://ccia2007.climatechangeinaustralia.gov.au/documents/resources/Summary_brochure.pdf (accessed 17.1.2017).

CSIRO and Bureau of Meteorology (2007b) *Climate Change in Australia: observed changes and projections*. Available at: http://ccia2007.climatechangeinaustralia.gov.au/documents/resources/Summary_brochure.pdf (accessed 17.1.2017).

Cvitanovic C, Hobday AJ, van Kerkhoff L, et al. (2015) Overcoming barriers to knowledge exchange for adaptive resource management; the perspectives of Australian marine scientists. *Marine Policy* 52: 38-44. https://doi.org/10.1016/j.marpol.2014.10.026.

DEA (2013) *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa: Summary for Policy-Makers*.

Defra (2018) *The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting: Making the country resilient to a changing climate*. London: Dandy Booksellers Ltd.

Dessai S, Bhave A, Birch C, et al. (2018) Building narratives to characterise uncertainty in regional climate change through expert elicitation. *Environmental Research Letters* 13(7): 74005. https://doi.org/10.1088/1748-9326/aabcdd.

Dike VN, Addi M, Andang'o HA, et al. (2018) Obstacles facing Africa's young climate scientists. *Nature Climate Change* 8(6): 447-449. https://doi.org/10.1038/s41558-018-0178-x.

Douglas M (1986) *How institutions think*. Syracuse, NY: Syracuse Univ. Press.

Dunleavy P (2003) *Authoring a PhD: How to plan, draft, write, and finish a doctoral thesis or dissertation*. Basingstoke, New York: Palgrave Macmillan.

Dunn MR, Lindesay JA and Howden M (2015) Spatial and temporal scales of future climate information for climate change adaptation in viticulture: a case study of User needs in the Australian winegrape sector. *Australian Journal of Grape and Wine Research* 21(2): 226-239. https://doi.org/10.1111/ajgw.12138.

Dupuis J and Biesbroek R (2013) Comparing apples and oranges: The dependent variable problem in comparing and evaluating climate change adaptation policies. *Global Environmental Change* 23(6): 1476-1487. https://doi.org/10.1016/j.gloenvcha.2013.07.022.

DWD (2012) *Deutscher Klimaatlas*. Available at: http://www.dwd.de/DE/klimaumwelt/klimaatlas/klimaatlas_node.html (accessed 10.2.2016).

Edwards PN (2010) *A vast machine: Computer models, climate data, and the politics of global warming*. Cambridge, Mass: MIT Press.

Ekstrom JA and Moser SC (2013) Institutions as key element to successful climate adaptation processes: Results from the San Francisco Bay Area. In: Moser SC and Boykoff MT (eds) *Successful adaptation to climate change: Linking science and policy in a rapidly changing world*. London: Routledge, pp. 97–113.

Eliasson I (2000) The use of climate knowledge in urban planning. *Landscape and Urban Planning* 48(1-2): 31-44. https://doi.org/10.1016/S0169-2046(00)00034-7.

Engels A (2019) How should we ask questions about the social status of climate change knowledge? *Wiley Interdisciplinary Reviews: Climate Change* 8(2011): e584. https://doi.org/10.1002/wcc.584.

Enserink B, Kwakkel JH and Veenman S (2013) Coping with uncertainty in climate policy making: (Mis)understanding scenario studies. *Futures* 53: 1-12. https://doi.org/10.1016/j.futures.2013.09.006.

Ernst KM, Swartling ÅG, André K, et al. (2019) Identifying climate service production constraints to adaptation decision-making in Sweden. *Environmental Science and Policy* 93: 83-91. https://doi.org/10.1016/j.envsci.2018.11.023.

The Guardian (2019) Extinction Rebellion activists arrested at Bank of England protest, 14 October. Available at: https://www.theguardian.com/environment/2019/oct/14/extinction-rebellion-activists-stage-protest-at-bank-of-england (accessed 23.12.2019).

Feyerabend P (1993 [1975]) *Against method*. London: Verso.

Fischer AM, Weigel AP, Buser CM, et al. (2011) Climate change projections for Switzerland based on a Bayesian multi-model approach. *International Journal of Climatology* 32(15): 2348-2371. https://doi.org/10.1002/joc.3396.

Fleck L (1979[1935]) *Genesis and development of a scientific fact*. Chicago, London: University of Chicago Press.

Flick U (2009) *An introduction to qualitative research*. Los Angeles: SAGE Publications.

Flick U (2011) Triangulation. In: Oelerich G and Otto H-U (eds) *Empirische Forschung und Soziale Arbeit*: Wiesbaden: VS Verlag für Sozialwissenschaften, pp. 323–328.

FOEN (2012a) *Adaptation to climate change in Switzerland: Goals, challenges and fields of action First part of the Federal Council's strategy*. Berne: FOEN (Federal Office for the Environment).

FOEN (2012b) *Adaptation to climate change in Switzerland: Goals, challenges and fields of action First part of the Federal Council's strategy*. Berne: FOEN (Federal Office for the Environment).

Fonta WM, Ayuk ET and van Huysen T (2018) Africa and the Green Climate Fund: current challenges and future opportunities. *Climate Policy* 18(9): 1210-1225. https://doi.org/10.1080/14693062.2018.1459447.

Ford JD, Berrang-Ford L, Lesnikowski AC, et al. (2013) How to Track Adaptation to Climate Change: A Typology of Approaches for National-Level Application. *Ecology and Society* 18(3). https://doi.org/10.5751/ES-05732-180340.

Forsyth T (2003) *Critical political ecology: The politics of environmental science*. London: Routledge.

Freeman M (2016) *Modes of thinking for qualitative data analysis*. London: Routledge.

Frigg R, Smith LA and Stainforth DA (2013) The Myopia of Imperfect Climate Models: The Case of UKCP09. *Philosophy of Science* 80(5): 886-897. https://doi.org/10.1086/673892.

Funk D (2015) *White paper on sector specific vulnerabilities: EUPORIAS Deliverable D11.2*.

Funtowicz SO and Ravetz JR (1993) Science for the post-normal age. *Futures* 25(7): 739-755. https://doi.org/10.1016/0016-3287(93)90022-L.

Füssel H-M and Hildén M (2014) How Is Uncertainty Addressed in the Knowledge Base for National Adaptation Planning? In: Capela Lourenço T, Street RB, van Bree L, Füssel H-M, Nilsson C, Groot A, et al. (eds) *Adapting to an Uncertain Climate: Lessons From Practice*. Cham: Springer International Publishing; Springer, pp. 41–66.

Fylan F (2005) Semi structured interviewing. In: Miles J and Gilbert P (eds) *A handbook of research methods for clinical and health psychology*: New York: Oxford University Press, pp. 65–78.

Geneletti D and Zardo L (2016) Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. *Land Use Policy* 50: 38-47. https://doi.org/10.1016/j.landusepol.2015.09.003.

Gillard R (2016a) Unravelling the United Kingdom's climate policy consensus: The power of ideas, discourse and institutions. *Global Environmental Change* 40: 26-36. https://doi.org/10.1016/j.gloenvcha.2016.06.012.

Gillard R, Gouldson A, Paavola J, et al. (2016b) Transformational responses to climate change: beyond a systems perspective of social change in mitigation and adaptation. *Wiley Interdisciplinary Reviews: Climate Change* 7(2): 251-265. https://doi.org/10.1002/wcc.384.

Giorgi F, Colin J and Asrar G (2009) Addressing climate information needs at the regional level: the CORDEX. *World Meteorological Organization (WMO) Bulletin* 58(3): 175-183.

Glaser BG and Strauss AL (1968) *The Discovery of grounded theory. Strategies for qualitative research*. London, printed in U.S.A.: Weidenfeld & Nicolson.

Gleeson E, McGrath R and Treanor M (eds) (2013) *Ireland's climate: the road ahead*. Dublin: Met Éireann.

Goffman E (1990 [1956]) *The presentation of self in everyday life*. London: Penguin.

Goldstein A, Turner WR, Gladstone J, et al. (2019) The private sector's climate change risk and adaptation blind spots. *Nature Climate Change* 9(1): 18-25. https://doi.org/10.1038/s41558-018-0340-5.

Groot A, Swart R, Hygen HO, et al. (2014) *ClipC Deliverable (D-N°: 2.1): User requirements, part 1: Strategies for user consultation and engagement and user requirements: Synthesis from past efforts*. Available at: http://www.clipc.eu/media/clipc/org/documents/clipc_deliverable2_1_final_intemplate.pdf (accessed 4.10.2018).

Groves C (2017) Emptying the future: On the environmental politics of anticipation. *Futures* 92: 29-38. https://doi.org/10.1016/j.futures.2016.06.003.

Grün Stadt Zürich (2018) *Grün am Bau: Das Magazin zur Ausstellung*. Available at: https://www.stadt-zuerich.ch/content/dam/stzh/ted/Deutsch/gsz_2/publikationen/natur-erleben/stadtgaertnerei/180514_GSZ_HeftRZ2_Korr2-Ansicht_klein.pdf (accessed 14.11.2018).

Grün Stadt Zürich (2019) *Das Grünbuch der Stadt Zürich*.

Guba EG and Lincoln YS (2005) Paradigmatic Controversies, Contradictions, and Emerging Confluences. In: Denzin NK and Lincoln YS (eds) *The SAGE handbook of qualitative research:* Thousand Oaks, London: SAGE Publications, pp. 191–215.

Gutiérrez JM, Ribalaygua J, Llasat C, et al. (2012) Escenarios-PNACC 2012: descripción y análisis de los resultados de regionalización estadística. *Publicaciones de la Asociación Española de Climatología* Serie A(8): 125-136.

Gutscher H, Hirsch Hadorn G and Werner K (1996) Vom Sinn der Methodenvielfalt in den Sozial- und Geisteswissenschaften. In: Kaufmann-Hayoz R and Di Giulio A (eds) *Umweltproblem Mensch Humanwisssenschaftliche Zugänge zu umweltverantwortlichem Handeln:* Bern: Paul Haupt, pp. 43–78.

Gutting G and Oksala J (2019) Michel Foucalt. In: Zalta EN (ed.) *The Stanford Encyclopedia of Philosophy:*

Hacking I (1999) *The social construction of what?* Cambridge, Mass., London: Harvard University Press.

Hacking I (2000) 'Screw you, I'm going home': Review of Conquest of Abundance: A Tale of Abstraction Versus the Richness of Being by Feyerabend, P., edited by Terpstra, B. *London Review of Books* 22(12): 28-29.

Hagedorn G, Kalmus P, Mann M, et al. (2019) Concerns of young protesters are justified. *Science (New York, N.Y.)* 364(6436): 139-140. https://doi.org/10.1126/science.aax3807.

Hanger S, Pfenninger S, Dreyfus M, et al. (2013) Knowledge and information needs of adaptation policy-makers: A European study. *Regional Environmental Change* 13(1): 91-101. https://doi.org/10.1007/s10113-012-0317-2.

Harcourt R, Bruine de Bruin W, Dessai S, et al. (2019) Investing in a good pair of wellies: how do non-experts interpret the expert terminology of climate change impacts and adaptation? *Climatic Change* 155(2): 257-272. https://doi.org/10.1007/s10584-019-02455-0.

Haunschild R, Bornmann L and Marx W (2016) Climate Change Research in View of Bibliometrics. *PLOS ONE* 11(7): e0160393. https://doi.org/10.1371/journal.pone.0160393.

Hawkins E and Sutton RT (2009) The Potential to Narrow Uncertainty in Regional Climate Predictions. *Bulletin of the American Meteorological Society* 90(8): 1095-1107. https://doi.org/10.1175/2009BAMS2607.1.

Hazeleger W, van den Hurk BJJM, Min E, et al. (2015) Tales of future weather. *Nature Climate Change* 5(2): 107-113. https://doi.org/10.1038/nclimate2450.

Heaphy LJ (2015) The role of climate models in adaptation decision-making: The case of the UK climate projections 2009. *European Journal for Philosophy of Science* 5(2): 233-257. https://doi.org/10.1007/s13194-015-0114-0.

Heaphy LJ (2018) The challenges of aligning the scales of urban climate science and climate policy in London and Manchester. *Environment and Planning C: Politics and Space* 36(4): 609-628. https://doi.org/10.1177/2399654417723342.

Hebbert M and Webb B (2012) Towards a Liveable Urban Climate: Lessons from Stuttgart. In: *Liveable Cities: Urbanising World: ISOCARP Review 07*. London: Routledge, pp. 132–150.

Hedger MM, Connell R and Bramwell P (2006) Bridging the gap: Empowering decision-making for adaptation through the UK Climate Impacts Programme. *Climate Policy* 6(2): 201-215. https://doi.org/10.1080/14693062.2006.9685595.

Heinrich A and Saluz AG (2017) Regionale Baumsubstrate in Schweizer Städten: Stadtgartenämter setzen auf eigene Stadtbaumsubstrate. *Stadt + Grün*(4): 52-57.

Held IM (2005) The Gap between Simulation and Understanding in Climate Modeling. *Bulletin of the American Meteorological Society* 86(11): 1609-1614. https://doi.org/10.1175/BAMS-86-11-1609.

Hewitson B, Waagsaether K, Wohland J, et al. (2017) Climate information websites: an evolving landscape. *Wiley Interdisciplinary Reviews: Climate Change* 8(5): e470. https://doi.org/10.1002/wcc.470.

Hewitt CD, Buontempo C and Newton P (2013) Using Climate Predictions to Better Serve Society's Needs. *Eos, Transactions American Geophysical Union* 94(11): 105-107. https://doi.org/10.1002/2013EO110002.

Hewitt CD and Lowe JA (2018) Toward a European Climate Prediction System. *Bulletin of the American Meteorological Society* 99(10): 1997-2001. https://doi.org/10.1175/BAMS-D-18-0022.1.

Hewitt CD, Mason S and Walland D (2012) The Global Framework for Climate Services. *Nature Climate Change* 2(12): 831-832. https://doi.org/10.1038/nclimate1745.

Heymann M, Gramelsberger G and Mahony M (eds) (2017) *Cultures of prediction in atmospheric and climate science: Epistemic and cultural shifts in computer-based modelling and simulation*. Abingdon Oxon, New York NY: Routledge.

Hine D (2019) *Notes from Underground #1: Al Gore Didn't Want You to Panic*. Available at: https://bellacaledonia.org.uk/2019/11/14/notes-from-underground-1-al-gore-didnt-want-you-to-panic/ (accessed 19.12.2019).

Hirsch Hadorn G, Brun G, Soliva CR, et al. (2015) Decision strategies for policy decisions under uncertainties: The case of mitigation measures addressing methane emissions from ruminants. *Environmental Science and Policy* 52: 110-119. https://doi.org/10.1016/j.envsci.2015.05.011.

Ho-Lem C, Zerriffi H and Kandlikar M (2011) Who participates in the Intergovernmental Panel on Climate Change and why: A quantitative assessment of the national representation of authors in the Intergovernmental Panel on Climate Change. *Global Environmental Change* 21(4): 1308-1317. https://doi.org/10.1016/j.gloenvcha.2011.05.007.

Horgan J (2019) We Should All Be Science Critics: A Harvard scholar says viewing science and technology with a critical eye can make the world a better place. *Scientific American*, 5 August. Available at: https://blogs.scientificamerican.com/cross-check/we-should-all-be-science-critics/ (accessed 2.12.2019).

Horn E and Schnyder P (2016) Romantische Klimatologie. Zur Einleitung. *Zeitschrift für Kulturwissenschaften* 10(1): 9-18. https://doi.org/10.14361/zfk-2016-0102.

Vox (2019) How big was the global climate strike? 4 million people, activists estimate., 2019. Available at: https://www.vox.com/energy-and-environment/2019/9/20/20876143/climate-strike-2019-september-20-crowd-estimate (accessed 23.12.2018).

Hoyningen-Huene P (2000) Paul K. Feyerabend: An Obituary. In: Preston J, Munévar G and Lamb D (eds) *The worst enemy of science? Essays in memory of Paul Feyerabend*. New York, Oxford: Oxford University Press.

Hulme M (2010) Problems with making and governing global kinds of knowledge. *Global Environmental Change* 20(4): 558-564. https://doi.org/10.1016/j.gloenvcha.2010.07.005.

Hulme M (2011) Meet the humanities. *Nature Climate Change* 1(4): 177-179. https://doi.org/10.1038/nclimate1150.

Hulme M (2015) Better Weather? The Cultivation of the Sky. *Cultural Anthropology* 30(2): 236-244. https://doi.org/10.14506/ca30.2.06.

Hulme M and Dessai S (2008) Negotiating future climates for public policy: a critical assessment of the development of climate scenarios for the UK. *Environmental Science and Policy* 11(1): 54-70. https://doi.org/10.1016/j.envsci.2007.09.003.

Hulme M, Dessai S, Lorenzoni I, et al. (2009) Unstable climates: Exploring the statistical and social constructions of 'normal' climate. *Geoforum* 40(2): 197-206. https://doi.org/10.1016/j.geoforum.2008.09.010.

Hulme M and Mahony M (2010) Climate change: What do we know about the IPCC? *Progress in Physical Geography* 34(5): 705-718. https://doi.org/10.1177/0309133310373719.

IPCC (ed) (2014) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.: Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

IPCC (2018) Summary for Policymakers. In: Masson-Delmotte V, Zhai P, Pörtner H-O, Roberts D, Skea J, Shukla PR, et al. (eds) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty:* Intergovernmental Panel on Climate Change (IPCC).

Irwin A and Wynne B (eds) (1996) *Misunderstanding science? The public reconstruction of science and technology*. Cambridge: Cambridge University Press.

Jacobs KL and Buizer JL (2016) Building community, credibility and knowledge: The third US National Climate Assessment. *Climatic Change* 135(1): 9-22. https://doi.org/10.1007/s10584-015-1445-8.

Jankovic V (2010) Climates as commodities: Jean Pierre Purry and the modelling of the best climate on Earth. *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 41(3): 201-207. https://doi.org/10.1016/j.shpsb.2010.07.008.

Jasanoff S (2005) *Designs on nature: Science and democracy in Europe and the United States*. Princeton, N.J.: Princeton University Press.

Tagesanzeiger (2019a) Javier Bardem bricht nach Teenager-Frage zum Klimaschutz in Tränen aus, 4 October. Available at: https://www.tagesanzeiger.ch/kultur/kino/javier-bardem-bricht-nach-teenagerfrage-zum-klimaschutz-in-traenen-aus/story/28599632 (accessed 23.12.2019).

Jenkins GJ, Murphy JM, Sexton DMH, et al. (2009) *UK Climate Projections: Briefing report*. Exeter: Met Office Hadley Centre.

Jones RG, Noguer M, Hassell D, et al. (2004) *Generating High Resolution Climate Change Scenarios Using PRECIS*. Available at: http://www.metoffice.gov.uk/media/pdf/6/5/PRECIS_Handbook.pdf (accessed 29.12.2015).

Jost C, Kyazze F, Naab J, et al. (2016) Understanding gender dimensions of agriculture and climate change in smallholder farming communities. *Climate and Development* 8(2): 133-144. https://doi.org/10.1080/17565529.2015.1050978.

Karlsson S, Srebotnjak T and Gonzales P (2007) Understanding the North–South knowledge divide and its implications for policy: A quantitative analysis of the generation of scientific knowledge in the environmental sciences. *Environmental Science & Policy* 10(7-8): 668-684. https://doi.org/10.1016/j.envsci.2007.04.001.

Keele S (2019) Consultants and the business of climate services: implications of shifting from public to private science. *Climatic change* 12(Part 1): 465. https://doi.org/10.1007/s10584-019-02385-x.

Kirchhoff CJ, Lemos MC and Dessai S (2013) Actionable Knowledge for Environmental Decision Making: Broadening the Usability of Climate Science. *Annual Review of Environment and Resources* 38(1): 393-414. https://doi.org/10.1146/annurev-environ-022112-112828.

Klenk N, Fiume A, Meehan K, et al. (2017) Local knowledge in climate adaptation research: moving knowledge frameworks from extraction to co-production. *Wiley Interdisciplinary Reviews: Climate Change* 8(5): e475. https://doi.org/10.1002/wcc.475.

Klenk NL and Meehan K (2015) Climate change and transdisciplinary science: Problematizing the integration imperative. *Environmental Science and Policy* 54: 160-167. https://doi.org/10.1016/j.envsci.2015.05.017.

Klenk NL, Meehan K, Pinel SL, et al. (2015) Stakeholders in climate science: Beyond lip service? *Science* 350(6262): 743-744. https://doi.org/10.1126/science.aab1495.

Klinenberg E (2002) *Heat wave: A social autopsy of disaster in Chicago*. Chicago, Ill., London: University of Chicago Press.

KNMI (2015) *KNMI'14 climate scenarios for the netherlands: Revised edition 2015 www.climatescenarios.nl/rectification*. Available at: http://www.climatescenarios.nl/images/Brochure_KNMI14_EN_2015.pdf (accessed 8.2.2016).

Knüsel B, Zumwald M, Baumberger C, et al. (2019) Applying big data beyond small problems in climate research. *Nature Climate Change* 9(3): 196-202. https://doi.org/10.1038/s41558-019-0404-1.

Knutti R, Abramowitz G, Collins M, et al. (2010) Good Practice Guidance Paper on Assessing and Combining Multi Model Climate Projections. In: *Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Assessing and Combining Multi Model Climate Projections:* Bern.

Kreienkamp F, Huebener H, Linke C, et al. (2012) Good practice for the usage of climate model simulation results - a discussion paper. *Environmental Systems Research* 1(1): 9. https://doi.org/10.1186/2193-2697-1-9.

Kuckartz U and McWhertor A (2014) *Qualitative text analysis: A guide to methods, practice & using software*. London, UK: SAGE Publications.

Kuhn TS (1996 [1962]) *The Structure of Scientific Revolutions*. Chicago, London: University of Chicago Press.

Lahsen M (2005) Seductive Simulations? Uncertainty Distribution Around Climate Models. *Social Studies of Science* 35(6): 895-922. https://doi.org/10.1177/0306312705053049.

Lahsen M (2007) Trust Through Participation? Problems of Knowledge in Climate Decision Making. In: Pettenger ME (ed.) *The social construction of climate change: Power, knowledge, norms, discourses*. Aldershot: Ashgate, pp. 173–196.

Latour B (2013) *An inquiry into modes of existence: An anthropology of the moderns*. Cambridge, Massachusetts: Harvard University Press.

Latour B (2017) *Facing Gaia: Eight lectures on the new climate regime*. Cambridge, Medford MA: Polity.

Latour B and Woolgar S (1979) *Laboratory life: The social construction of scientific facts*. Beverly Hills, London: SAGE Publications.

Law J (2004) *After Method: Mess in Social Science Research*. Hoboken: Taylor and Francis.

Leitch AM, Palutikof JP, Rissik D, et al. (2019) Co-development of a climate change decision support framework through engagement with stakeholders. *Climatic change* 153(4): 587-605. https://doi.org/10.1007/s10584-019-02401-0.

Leitner H, Sheppard E, Webber S, et al. (2018) Globalizing urban resilience. *Urban Geography* 39(8): 1276-1284. https://doi.org/10.1080/02723638.2018.1446870.

Lemos MC, Kirchhoff CJ and Ramprasad V (2012) Narrowing the climate information usability gap. *Nature Climate Change* 2(11): 789-794. https://doi.org/10.1038/nclimate1614.

Lemos MC and Morehouse BJ (2005) The co-production of science and policy in integrated climate assessments. *Global Environmental Change* 15(1): 57-68. https://doi.org/10.1016/j.gloenvcha.2004.09.004.

Lemos MC, Wolske KS, Rasmussen LV, et al. (2019) The Closer, the Better? Untangling Scientist–Practitioner Engagement, Interaction, and Knowledge Use. *Weather, Climate, and Society* 11(3): 535-548. https://doi.org/10.1175/WCAS-D-18-0075.1.

Lesnikowski AC, Ford JD, Berrang-Ford L, et al. (2015) How are we adapting to climate change? A global assessment. *Mitigation and Adaptation Strategies for Global Change* 20(2): 277-293. https://doi.org/10.1007/s11027-013-9491-x.

Lijphart A (2012) *Patterns of democracy: Government forms and performance in thirty-six countries*. New Haven: Yale University Press.

Livingston JE and Rummukainen M (2020) Taking science by surprise: The knowledge politics of the IPCC Special Report on 1.5 degrees. *Environmental Science and Policy* 112: 10-16. https://doi.org/10.1016/j.envsci.2020.05.020.

Loibl W, Züger J and Köstl M (2009) Reclip:More: Kleinräumige Klimaszenarien für Österreich. *Standort* 33(3): 94-100. https://doi.org/10.1007/s00548-009-0121-5.

Lorenz S, Dessai S, Forster PM, et al. (2017) Adaptation planning and the use of climate change projections in local government in England and Germany. *Regional Environmental Change* 17(2): 425-435. https://doi.org/10.1007/s10113-016-1030-3.

Lorenz S, Dessai S, Paavola J, et al. (2015) The communication of physical science uncertainty in European National Adaptation Strategies. *Climatic change* 132(1): 143-155. https://doi.org/10.1007/s10584-013-0809-1.

Lorenz S, Porter JJ and Dessai S (2019) Identifying and tracking key climate adaptation actors in the UK. *Regional Environmental Change* 19(7): 2125-2138. https://doi.org/10.1007/s10113-019-01551-2.

Lourenço TC, Swart R, Goosen H, et al. (2016) The rise of demand-driven climate services. *Nature Climate Change* 6(1): 13-14. https://doi.org/10.1038/nclimate2836.

Lowe JA, Bernie D, Bett PE, et al. (2018) *UKCP18 Science Overview report: November 2018*. Exeter, UK.

MacFarlane R (2003) *Mountains of the mind*. New York NY: Pantheon Books.

Mahony M and Hulme M (2012) Model migrations: Mobility and boundary crossings in regional climate prediction. *Transactions of the Institute of British Geographers* 37(2): 197-211. https://doi.org/10.1111/j.1475-5661.2011.00473.x.

Mahony M and Hulme M (2016) Modelling and the Nation: Institutionalising Climate Prediction in the UK, 1988-92. *Minerva* 54(4): 445-470. https://doi.org/10.1007/s11024-016-9302-0.

Mahony M and Hulme M (2018) Epistemic geographies of climate change: Science, space and politics. *Progress in Human Geography* 42(3): 395-424. https://doi.org/10.1177/0309132516681485.

Mauelshagen F (2016) Ein neues Klima im 18. Jahrhundert. *Zeitschrift für Kulturwissenschaften* 10(1): 39-57. https://doi.org/10.14361/zfk-2016-0104.

Mauser W, Klepper G, Rice M, et al. (2013) Transdisciplinary global change research: The co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability* 5(3-4): 420-431. https://doi.org/10.1016/j.cosust.2013.07.001.

McMahon R, Stauffacher M and Knutti R (2016) The scientific veneer of IPCC visuals. *Climatic change* 138(3-4): 369-381. https://doi.org/10.1007/s10584-016-1758-2.

McNie EC (2007) Reconciling the supply of scientific information with user demands: An analysis of the problem and review of the literature. *Environmental Science and Policy* 10(1): 17-38. https://doi.org/10.1016/j.envsci.2006.10.004.

McSweeney CF, Lizcano G, New M, et al. (2010) The UNDP Climate Change Country Profiles. *Bulletin of the American Meteorological Society* 91(2): 157-166. https://doi.org/10.1175/2009BAMS2826.1.

Meehl GA, Moss R, Taylor KE, et al. (2014) Climate Model Intercomparisons: Preparing for the Next Phase. *Eos, Transactions American Geophysical Union* 95(9): 77-78. https://doi.org/10.1002/2014EO090001.

Mehta VM, Knutson CL, Rosenberg NJ, et al. (2013) Decadal Climate Information Needs of Stakeholders for Decision Support in Water and Agriculture Production Sectors: A Case Study in the Missouri River Basin. *Weather, Climate, and Society* 5(1): 27-42. https://doi.org/10.1175/WCAS-D-11-00063.1.

Melillo J, Richmond TC and Yohe GW (eds) (2014) *Climate Change Impacts in the United States: U.S. National Climate Assessment.*

Met Office and CNRS (2018) *Report: Copernicus Roadmap for European Climate Projections.*

MeteoSwiss (2016) *Analyse der Nutzerbedürfnisse zu nationalen Klimaszenarien.* Available at: http://www.meteoswiss.admin.ch/content/dam/meteoswiss/de/service-und-publikationen/Publikationen/doc/FB258_EBP.pdf (accessed 21.3.2016).

Michael M (2015) Ignorance and the epistemic choreography of method. In: Gross M and McGoey L (eds) *Routledge International Handbook of Ignorance Studies:* London: Routledge, pp. 84–91.

Miguel JCH (2017) The technopolitics of climate change: climate models, geopolitics, and governmentality. *Historia, ciencias, saude--Manguinhos* 24(4): 969-987. https://doi.org/10.1590/S0104-59702017000500007.

Miles J and Gilbert P (eds) (2005) *A handbook of research methods for clinical and health psychology*. New York: Oxford University Press.

Miles MB, Huberman AM and Saldaña J (2014) *Qualitative data analysis: A methods sourcebook*. California: SAGE Publications.

Moser SC (2016a) Can science on transformation transform science? Lessons from co-design. *Current Opinion in Environmental Sustainability* 20: 106-115. https://doi.org/10.1016/j.cosust.2016.10.007.

Moser SC (2016b) Reflections on climate change communication research and practice in the second decade of the 21st century: What more is there to say? *Wiley Interdisciplinary Reviews: Climate Change*. https://doi.org/10.1002/wcc.403.

Moser SC and Dilling L (2011) Communicating Climate Change: Closing the Science-Action Gap. In: Dryzek JS, Norgaard RB and Schlosberg D (eds) *The Oxford Handbook of Climate Change and Society:* Oxford: Oxford University Press, pp. 161–174.

Moser SC and Ekstrom JA (2010) A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America* 107(51): 22026-22031. https://doi.org/10.1073/pnas.1007887107.

Murphy JM, Sexton DMH, Jenkins GJ, et al. (2010) *UK Climate Projections science report: Climate change projections*. Exeter: Met Office Hadley Centre.

Nasir N, Hossain R and Huq S (2018) Post-Paris long-term climate capacity: The role of universities. In: Scavenius T and Rayner S (eds) *Institutional capacity for climate change response: A new approach to climate politics*. London, New York: Routledge Taylor & Francis Group, pp. 130–143.

Tagesanzeiger (2019b) Nationalrat stimmt Flugticketabgabe zu, 19 September. Available at: https://www.tagesanzeiger.ch/schweiz/standard/nationalrat-stimmt-flugticketabgabe-zu/story/12632594 (accessed 22.1.2020).

Nilsson M, Griggs D and Visbeck M (2016) Policy: Map the interactions between Sustainable Development Goals. *Nature* 534(7607): 320-322. https://doi.org/10.1038/534320a.

Nordgren J, Stults M and Meerow S (2016) Supporting local climate change adaptation: Where we are and where we need to go. *Environmental Science & Policy* 66: 344-352. https://doi.org/10.1016/j.envsci.2016.05.006.

Ojala M (2018) Eco-Anxiety. *RSA Journal* 164(4 (5576)): 10-15. https://doi.org/10.2307/26798430.

Olazabal M, Chiabai A, Foudi S, et al. (2018) Emergence of new knowledge for climate change adaptation. *Environmental Science and Policy* 83: 46-53. https://doi.org/10.1016/j.envsci.2018.01.017.

Pallant J (2005) *SPSS survival manual: A step by step guide to data analysis using SPSS for Windows (Version 12)*. Crows Nest, NSW, Australia: Allen & Unwin.

Parker WS (2010) Whose Probabilities? Predicting Climate Change with Ensembles of Models. *Philosophy of Science* 77(5): 985-997. https://doi.org/10.1086/656815.

Parker WS (2014) Simulation and Understanding in the Study of Weather and Climate. *Perspectives on Science* 22(3): 336-356. https://doi.org/10.1162/POSC_a_00137.

Parker WS (2018) Climate Science. In: Zalta EN (ed.) *The Stanford Encyclopedia of Philosophy:*

Parker WS and Lusk G (2019) Incorporating user values into climate services. *Bulletin of the American Meteorological Society* 100(9): 1643-1650. https://doi.org/10.1175/BAMS-D-17-0325.1.

Parker WS and Risbey JS (2015) False precision, surprise and improved uncertainty assessment. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 373(2055). https://doi.org/10.1098/rsta.2014.0453.

Pasgaard M, Dalsgaard B, Maruyama PK, et al. (2015) Geographical imbalances and divides in the scientific production of climate change knowledge. *Global Environmental Change* 35: 279-288. https://doi.org/10.1016/j.gloenvcha.2015.09.018.

Pasgaard M and Strange N (2013) A quantitative analysis of the causes of the global climate change research distribution. *Global Environmental Change* 23(6): 1684-1693. https://doi.org/10.1016/j.gloenvcha.2013.08.013.

Pihkala P (2018) Eco-anxiety, tragedy, and hope: psychological and spiritual dimensions of climate change. *Zygon* 53(2): 545-569. https://doi.org/10.1111/zygo.12407.

Pohl C (2008) From science to policy through transdisciplinary research. *Environmental Science and Policy* 11(1): 46-53. https://doi.org/10.1016/j.envsci.2007.06.001.

Pohl C, Krütli P and Stauffacher M (2017) Ten Reflective Steps for Rendering Research Societally Relevant. *GAIA - Ecological Perspectives for Science and Society* 26(1): 43-51. https://doi.org/10.14512/gaia.26.1.10.

Porter JJ, Demeritt D and Dessai S (2015) The right stuff? Informing adaptation to climate change in British Local Government. *Global Environmental Change* 35: 411-422. https://doi.org/10.1016/j.gloenvcha.2015.10.004.

Porter JJ and Dessai S (2017) Mini-me: Why do climate scientists' misunderstand users and their needs? *Environmental Science and Policy* 77: 9-14. https://doi.org/10.1016/j.envsci.2017.07.004.

Porter JJ, Dessai S and Tompkins EL (2014) What do we know about UK household adaptation to climate change? A systematic review. *Climatic change* 127(2): 371-379. https://doi.org/10.1007/s10584-014-1252-7.

Preston BL, Mustelin J and Maloney MC (2015) Climate adaptation heuristics and the science/policy divide. *Mitigation and Adaptation Strategies for Global Change* 20(3): 467-497. https://doi.org/10.1007/s11027-013-9503-x.

Preston BL, Rickards L, Dessai S, et al. (2013) Water, seas, and wine: Science for successful climate adaptation. In: Moser SC and Boykoff MT (eds) *Successful* *adaptation to climate change: Linking science and policy in a rapidly changing world*. London: Routledge, pp. 151–169.

Preston J (2016) Paul Feyerabend. In: Zalta EN (ed.) *The Stanford Encyclopedia of Philosophy:* Metaphysics Research Lab, Stanford University.

Preston J, Munévar G and Lamb D (eds) (2000) *The worst enemy of science? Essays in memory of Paul Feyerabend*. New York, Oxford: Oxford University Press.

R Core Team (2018) *R: A language and environment for statistical computing*. Available at: https://www.R-project.org/ (accessed 26.4.2018).

Ragettli MS, Vicedo-Cabrera AM, Schindler C, et al. (2017) Exploring the association between heat and mortality in Switzerland between 1995 and 2013. *Environmental Research* 158: 703-709. https://doi.org/10.1016/j.envres.2017.07.021.

Ravera F, Martín-López B, Pascual U, et al. (2016) The diversity of gendered adaptation strategies to climate change of Indian farmers: A feminist intersectional approach. *Ambio* 45(Suppl 3): 335-351. https://doi.org/10.1007/s13280-016-0833-2.

Rayner S (2012) Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses. *Economy and Society* 41(1): 107-125. https://doi.org/10.1080/03085147.2011.637335.

Reischl C, Rauter R and Posch A (2018) Urban vulnerability and adaptation to heatwaves: a case study of Graz (Austria). *Climate Policy* 18(1): 63-75. https://doi.org/10.1080/14693062.2016.1227953.

Ritaine EC and Papeil A-S (2014) Federalism and Legal Unification in Switzerland. In: Halberstam D and Reimann M (eds) *Federalism and Legal Unification: A Comparative Empirical Investigation of Twenty Systems*. Dordrecht, s.l.: Springer Netherlands, pp. 439–460.

Roaf S, Crichton D and Nicol F (2009) *Adapting buildings and cities for climate change: A 21st century survival guide*. Oxford: Elsevier.

Rohrer S, König M and Tillenkamp F (2018) Free Cooling in der Klimakälte: Untersuchung des Potentials in der Schweiz. *IEFE Energy Papers* 7(1).

Rössler O, Fischer AM, Huebener H, et al. (2017) Challenges to link climate change data provision and user needs - perspective from the COST-action VALUE. *International Journal of Climatology* 50(46): 7541. https://doi.org/10.1002/joc.5060.

Rössler O, Kotlarski S, Fischer AM, et al. (2019) Evaluating the added value of the new Swiss climate scenarios for hydrology: An example from the Thur catchment. *Climate Services*(13): 1-13. https://doi.org/10.1016/j.cliser.2019.01.001.

Rotter M, Hoffmann E, Pechan A, et al. (2016) Competing priorities: how actors and institutions influence adaptation of the German railway system. *Climatic Change* 137(3-4): 609-623. https://doi.org/10.1007/s10584-016-1702-5.

Roussos J, Bradley R and Frigg R (2020) Making confident decisions with model ensembles. *Philosophy of Science*.

Roy R (1993) STS-I and STS-D: Disciplinary and Interdisciplinary STS. *Bulletin of Science, Technology & Society* 13(5): 247-250. https://doi.org/10.1177/027046769301300501.

Ryghaug M and Solli J (2012) The appropriation of the climate change problem among road managers: fighting in the trenches of the real world. *Climatic change* 114(3-4): 427-440. https://doi.org/10.1007/s10584-012-0449-x.

Sarewitz DR (2004) How science makes environmental controversies worse. *Environmental Science and Policy* 7(5): 385-403. https://doi.org/10.1016/j.envsci.2004.06.001.

Sarewitz DR and Pielke RA JR. (2007) The neglected heart of science policy: Reconciling supply of and demand for science. *Environmental Science and Policy* 10(1): 5-16. https://doi.org/10.1016/j.envsci.2006.10.001.

Schulgesundheitsdienste Stadt Zürich (2017) *Fit trotz heissen Sommertagen*. Available at: https://www.stadt-zuerich.ch/content/dam/stzh/ssd/Deutsch/Gesundheit%20Praevention/Schularzt/Formulare%20und%20Merkblaetter/SAD%20Startseite/Infoblatt_Hitzetage_Publikation_WAI_22.02.2017.pdf (accessed 24.5.2018).

Seager J (2009) Death by Degrees: Taking a Feminist Hard Look at the 2° Climate Policy. *Kvinder, Køn & Forskning*(3-4). https://doi.org/10.7146/kkf.v0i3-4.27968.

Shackley S (2001) Epistemic Lifestyles in Climate Change Modeling. In: Miller CA and Edwards PN (eds) *Changing the atmosphere: Expert knowledge and environmental governance*. Cambridge, Mass.: MIT Press, pp. 107–133.

Shackley S, Young P, Parkinson S, et al. (1998) Uncertainty, Complexity and Concepts of Good Science in Climate Change Modelling: Are GCMs the Best Tools? *Climatic change* 38(2): 159-205. https://doi.org/10.1023/A:1005310109968.

Shi L, Chu E, Anguelovski I, et al. (2016) Roadmap towards justice in urban climate adaptation research. *Nature Climate Change* 6(2): 131-137. https://doi.org/10.1038/nclimate2841.

Skelton M (in review,a) How sectoral experts recognise climatic relevance: the role of cognitive links and decision-making capacity.

Skelton M (in review,b) Orders of social science: Understanding social-scientific controversies and confluence on what 'high-quality' knowledge and 'good' adaptation is.

Skelton M (2020) Adapting climate science. Global customisations, national uses and local appropriations. Doctoral thesis(26651). https://doi.org/10.3929/ethz-b-000429417.

Skelton M, Fischer AM, Liniger MA, et al. (2019a) Who is 'the user' of climate services? Unpacking the use of national climate scenarios in Switzerland beyond sectors, numeracy and the research–practice binary. *Climate Services*: 100113. https://doi.org/10.1016/j.cliser.2019.100113.

Skelton M, Porter JJ, Dessai S, et al. (2017) The social and scientific values that shape national climate scenarios: A comparison of the Netherlands, Switzerland and the UK. *Regional Environmental Change* 17(8): 2325-2338. https://doi.org/10.1007/s10113-017-1155-z.

Skelton M, Porter JJ, Dessai S, et al. (2019b) Customising global climate science for national adaptation: A case study of climate projections in UNFCCC's National Communications. *Environmental Science and Policy* 101: 16-23. https://doi.org/10.1016/j.envsci.2019.07.015.

Smith D and Protevi J (2018) Gilles Deleuze. In: Zalta EN (ed.) *The Stanford Encyclopedia of Philosophy:*

Smith LA (2002) What might we learn from climate forecasts? *Proceedings of the National Academy of Sciences of the United States of America* 99 Suppl 1: 2487-2492. https://doi.org/10.1073/pnas.012580599.

Srinivasan G, Rafisura KM and Subbiah AR (2011) Climate information requirements for community-level risk management and adaptation. *Climate Research* 47(1): 5-12. https://doi.org/10.3354/cr00962.

Stadt Schaffhausen (2006) *Informationsblatt Fassaden- und Dachbegrünung*. Available at: http://www.stadt-schaffhausen.ch/fileadmin/Redaktoren/Dokumente/Baupolizei/MB_Fassaden_Dach.pdf (accessed 8.7.2019).

Stadt Zürich (2013) *Vorgaben Dachbegrünung (Checkliste)*. Available at: https://www.stadt-zuerich.ch/content/dam/stzh/ted/Deutsch/gsz/Angebote%20und%20Beratung/Publikationen%20und%20Broschueren/Beratung/Dach-%20und%20Vertikalbegruenung/Checkliste_Dachbegruenung-2013-10.pdf (accessed 8.7.2019).

Stadt Zürich (2016) *Masterplan Umwelt der Stadt Zürich 2017–2020*. Available at: https://www.stadt-zuerich.ch/content/dam/stzh/gud/Deutsch/UGZ/UGZ/Umwelt-%20und%20Energiepolitik/%3e%20Dokumente%20und%20Publikationen/MPU_2017-2020_20170112_STRB1043-2016_final.pdf (accessed 23.4.2018).

Stadt Zürich (2017) *Münsterhof 2017: Claudia Comte. «Black and White Circles in the Sky», 2017, Münsterhof Zürich*. Available at: https://www.stadt-zuerich.ch/ted/de/index/oeffentlicher_raum/kunst_oeffentlicher_raum/initiieren_produzieren/muensterhof_kunstprojekte/muensterhof_2017.html (accessed 14.11.2019).

Städtische Gesundheitsdienste (2019) *Sommerhitze! Gesundheitstipps für ältere Menschen*. Available at: https://www.stadt-zuerich.ch/content/dam/stzh/gud/Deutsch/SGD/Dokumente/Hitze/190612_GzD_GUD_Sen_Fyer_A5_Hitzetage.pdf (accessed 30.8.2019).

Stiller S and Meijerink S (2016) Leadership within regional climate change adaptation networks: The case of climate adaptation officers in Northern Hesse, Germany. *Regional Environmental Change* 16(6): 1543-1555. https://doi.org/10.1007/s10113-015-0886-y.

Sultana F (2014) Gendering Climate Change: Geographical Insights. *The Professional Geographer* 66(3): 372-381. https://doi.org/10.1080/00330124.2013.821730.

Sundberg M (2007) Parameterizations as Boundary Objects on the Climate Arena. *Social Studies of Science* 37(3): 473-488. https://doi.org/10.1177/0306312706075330.

Swart R, Biesbroek R and Lourenço TC (2014) Science of adaptation to climate change and science for adaptation. *Frontiers in Environmental Science* 2. https://doi.org/10.3389/fenvs.2014.00029.

Tang S and Dessai S (2012) Usable Science? The U.K. Climate Projections 2009 and Decision Support for Adaptation Planning. *Weather, Climate, and Society* 4(4): 300-313. https://doi.org/10.1175/WCAS-D-12-00028.1.

Tangney P (2017) *Climate Adaptation Policy and Evidence: Understanding the Tensions between Politics and Expertise in Public Policy*. London: Taylor and Francis.

Task Force on Climate-related Financial Disclosures (2020) *Task Force on Climate-related Financial Disclosures: Overview*. Available at: https://www.fsb-tcfd.org/wp-content/uploads/2020/03/TCFD_Booklet_FNL_Digital_March-2020.pdf (accessed 19.3.2020).

Taylor AL, Bruine de Bruin W and Dessai S (2014a) Climate change beliefs and perceptions of weather-related changes in the United Kingdom. *Risk Analysis* 34(11): 1995-2004. https://doi.org/10.1111/risa.12234.

Taylor AL, Dessai S and Bruine de Bruin W (2015) Communicating uncertainty in seasonal and interannual climate forecasts in Europe. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 373(2055): 20140454. https://doi.org/10.1098/rsta.2014.0454.

Taylor M (2014b) *The political ecology of climate change adaptation: Livelihoods, agrarian change and the conflicts of development*. London, New York: Routledge.

Thépaut J-N (2016) The Copernicus Climate Change Service Sectoral Information Systems. *ECMWF Newsletter*(147): 9-10.

Thompson E, Frigg R and Helgeson C (2016) Expert Judgment for Climate Change Adaptation. *Philosophy of Science* 83(5): 1110-1121. https://doi.org/10.1086/687942.

Trouet V and van Oldenborgh GJ (2013) KNMI Climate Explorer: A Web-Based Research Tool for High-Resolution Paleoclimatology. *Tree-Ring Research* 69(1): 3-13. https://doi.org/10.3959/1536-1098-69.1.3.

UNFCCC (2008) *Resource Guide for Preparing the National Communications of Non-Annex I Parties: Module 2, Vulnerability and Adaptation to Climate Change*. Available at: http://unfccc.int/resource/docs/publications/08_resource_guide2.pdf (accessed 26.3.2018).

UNFCCC (2012) *CGE Training Materials for Vulnerability and Adaptation Assessment: Chapter 4: Climate Change Scenarios*. Available at: http://unfccc.int/national_reports/non-annex_i_natcom/training_material/methodological_documents/items/349.php (accessed 20.1.2016).

UNFCCC (2016) *CGE meetings and workshops*. Available at: http://unfccc.int/national_reports/non-annex_i_natcom/cge/items/7371.php (accessed 23.12.2016).

van der Linden P and Mitchell JFB (2009) *ENSEMBLES: Climate Change and its Impacts at seasonal, decadal and centennial timescales. Summary of research and results from the ENSEMBLES project*.

van Valkengoed AM and Steg L (2019) Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change* 9(2): 158-163. https://doi.org/10.1038/s41558-018-0371-y.

Vaughan C and Dessai S (2014) Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. *Wiley Interdisciplinary Reviews: Climate Change* 5(5): 587-603. https://doi.org/10.1002/wcc.290.

Vincent K, Dougill AJ, Dixon JL, et al. (2017) Identifying climate services needs for national planning: insights from Malawi. *Climate Policy* 17(2): 189-202. https://doi.org/10.1080/14693062.2015.1075374.

Schweizer Radio und Fernsehen (2019b) Wahlen 2019, 2019. Available at: https://www.srf.ch/news/wahlen-2019-resultate (accessed 22.1.2020).

Warren M (2019) Thousands of scientists are backing the kids striking for climate change. *Nature* 567(7748): 291-292. https://doi.org/10.1038/d41586-019-00861-z.

Warrick R, Ye W, Kouwenhoven P, et al. (2005) New Developments of the SimCLIM Model for Simulating Adaptation to Risks Arising from Climate Variability and Change. In: Zerger A and Argent RM (eds) *MODSIM 2005: International Congress on Modelling and Simulation*. Modelling and Simulation Society of Australia and New Zealand, pp. 170–176.

Watson J (2009) *Guattari's diagrammatic thought: Writing between Lacan and Deleuze*. London: Continuum.

Webber S (2015) Mobile Adaptation and Sticky Experiments: Circulating Best Practices and Lessons Learned in Climate Change Adaptation. *Geographical Research* 53(1): 26-38. https://doi.org/10.1111/1745-5871.12102.

Weber EU (2006) Experience-Based and Description-Based Perceptions of Long-Term Risk: Why Global Warming does not Scare us (Yet). *Climatic Change* 77(1-2): 103-120. https://doi.org/10.1007/s10584-006-9060-3.

Welzer H, Soeffner H-G and Giesecke D (2010) KlimaKulturen. In: Welzer H, Soeffner H-G and Giesecke D (eds) *KlimaKulturen: Soziale Wirklichkeiten im Klimawandel*. Frankfurt am Main, New York: Campus, pp. 7–19.

Widmer A (2018) Mainstreaming climate adaptation in Switzerland: How the national adaptation strategy is implemented differently across sectors. *Environmental Science and Policy* 82: 71-78. https://doi.org/10.1016/j.envsci.2018.01.007.

Wigley TML (2008) *MAGICC/SCENGEN 5.3: USER MANUAL: version 2*. Available at: http://www.cgd.ucar.edu/cas/wigley/magicc/UserMan5.3.v2.pdf (accessed 29.12.2015).

Wilby RL, Dawson CW and Barrow EM (2002) SDSM — a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling & Software* 17(2): 145-157. https://doi.org/10.1016/S1364-8152(01)00060-3.

Willows RI and Connell RK (2003a) *Climate adaptation: Risk, uncertainty and decision-making*. Available at: http://www.ukcip.org.uk/wp-content/PDFs/UKCIP-Risk-framework.pdf (accessed 30.10.2017).

Willows RI and Connell RK (2003b) *Climate adaptation: Risk, uncertainty and decision-making*. Available at: http://www.ukcip.org.uk/wp-content/PDFs/UKCIP-Risk-framework.pdf (accessed 30.10.2017).

Winkler MS, Röösli M, Ragettli MS, et al. (2015) Mitigating and adapting to climate change: a call to public health professionals. *International journal of public health* 60(6): 631-632. https://doi.org/10.1007/s00038-015-0722-7.

WMO and WHO (2015) *Heatwaves and Health: Guidance on Warning-System Development*. Available at: https://drive.google.com/file/d/0BwdvoC9AeWjUb2NHYVNyQU5QaW8/view?pli=1 (accessed 26.4.2018).

Wu K and Dunning D (2018) Hypocognition: Making Sense of the Landscape beyond One's Conceptual Reach. *Review of General Psychology* 22(1): 25-35. https://doi.org/10.1037/gpr0000126.

Wynne B (1996) May the Sheep Safely Graze? A Reflexive View of the Expert-Lay Knowledge Divide. In: Lash S, Szerszynski B and Wynne B (eds) *Risk, environment and modernity: Towards a new ecology*. London: Sage, pp. 44–83.

Zerubavel E (1991) *The fine line: Making distinctions in everyday life*. New York: Free Press.

Zerubavel E (1999) *Social mindscapes: An invitation to cognitive sociology*. Cambridge, Mass.: Harvard Univ. Press.

Zerubavel E (2008) *The elephant in the room: Silence and denial in everyday life*. New York, Oxford: Oxford University Press.

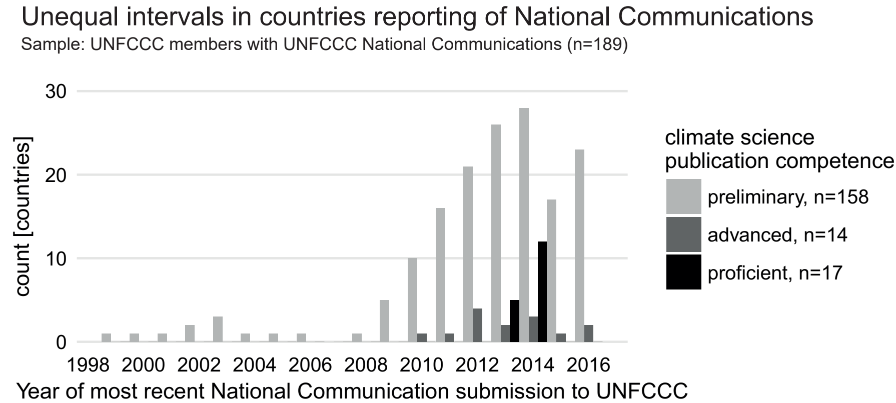
Zerubavel E (2015) *Hidden in plain sight: The social structure of irrelevance*. Oxford, NY: Oxford Univ. Press.

Zumwald M, Knüsel B, Baumberger C, et al. (2020) Understanding and assessing uncertainty of observational climate datasets for model evaluation using ensembles. *Wiley Interdisciplinary Reviews: Climate Change*. https://doi.org/10.1002/wcc.654.

Annex to chapter 3

List of characteristics assessed

- General country characteristics
- Country short name
- Full country name
- 3-letter country code
- Is the country a High Income country as classified by the World Bank? (For north-south definition as used in Blicharska et al. 2017)
- Is the country an OECD member? (for north-south definition as used in Blich-arska et al. 2017)
- Is the country classified as northern or southern? (see Blicharska et al. 2017)
- GDP per capita 2000-2009 (Pasgaard & Strange 2013)
- UNFCCC Annex I membership / UNFCCC non-Annex I membership
- Data on most recent National Communication [until 31.12.2016]
- National Communication issue, version, and submission date
- UNDP/GEF financing of National Communication efforts
- Characteristics of climate projections
- Number of sets of climate projections reported
- Total page count for climate projections
- Method & models used for climate projection
- What type of modelling complexity was used? [noCP / other / lookup / plug-and-play / GCM only / statistical downscaling / PRECIS / dynamical downscal-ing]
- What underlying type of modelling characteristics was used? [model-based / GCM / RCM]
- Count of number of GCMs used
- Count of number of RCMs used
- How many timeframes were reported?
- What is the earliest year reported?
- What is the latest year reported?
- How many emission scenarios were reported?
- If only a single emission scenario was reported, which one was?



Suppl. Figure 1 – Distribution of the submission year of UNFCCC members' most recent National Communication (as of 31.12.2016). Note the positively skewed distribution after 2012.

Suppl. Table 1 –Key characteristics of countries' climate projections, sorted first by their climate science publication competence (Haunschild et al. 2016), then alphabetically.

Country Name	ISO3 country code	Climate Science Publication Competence	National Communication issue	Submission year of NC	Sets of Climate Projections reported	Climate Modelling Complexity	number of GCMs	number of RCMs	Number of Timeframes	Number of Emissions Pathways
Afghanistan	AFG	preliminary	NC_1	2013	1	2_lookup			3	1
Albania	ALB	preliminary	NC_3	2016	1	3_plugandplay	5	0	3	5
Algeria	DZA	preliminary	NC_2	2010	3	4_GCM	1	0	2	1
Angola	AGO	preliminary	NC_1	2012	0	0_noCP				
Antigua and Barbuda	ATG	preliminary	NC_3	2016	1	2_lookup			3	3
Armenia	ARM	preliminary	NC_3	2015	1	4_GCM	1	0	3	2
Azerbaijan	AZE	preliminary	NC_3	2016	2	3_plugandplay	1	0	2	2
Bahamas	BHS	preliminary	NC_2	2015	2	3_plugandplay	21	0	1	1
Bahrain	BHR	preliminary	NC_2	2012	0	0_noCP				
Bangladesh	BGD	preliminary	NC_2	2012	1	3_plugandplay	9	0	2	2
Barbados	BRB	preliminary	NC_1	2001	0	0_noCP				
Belarus	BLR	preliminary	NC_6	2015	1	4_GCM			3	3
Belize	BLZ	preliminary	NC_3	2016	2	6_PRECIS	2	1	1	1
Benin	BEN	preliminary	NC_2	2011	1	3_plugandplay	4	0	4	2
Bhutan	BTN	preliminary	NC_2	2011	1	6_PRECIS	2	1	2	1
Bolivia	BOL	preliminary	NC_2	2009	3	4_GCM	1	0	2	1
Bosnia and Herzegovina	BIH	preliminary	NC_2	2013	1	7_dyn.downsc	2	1	2	2
Botswana	BWA	preliminary	NC_2	2013	1	3_plugandplay	10	0	1	1
Brunei Darussalam	BRN	preliminary	NC_1	2016	2	7_dyn.downsc	6	1	2	1

Country Name	ISO3 country code	Climate Science Publication Competence	National Communication issue	Submission year of NC	Sets of Climate Projections reported	Climate Modelling Complexity	number of GCMs	number of RCMs	Number of Time-frames	Number of Emissions Pathways
Bulgaria	BGR	preliminary	NC_6	2014	2	7_dyn.downsc	2	1	1	2
Burkina Faso	BFA	preliminary	NC_2	2015	1	1_no.description			1	1
Burundi	BDI	preliminary	NC_2	2010	1	1_no.description		0	5	1
Cabo Verde	CPV	preliminary	NC_2	2011	1	1_no.description		0	2	
Cambodia	KHM	preliminary	NC_2	2016	2	3_plugandplay	2	0	3	2
Cameroon	CMR	preliminary	NC_2	2016	1	2_lookup			3	1
Central African Republic	CAF	preliminary	NC_2	2015	0	0_noCP				
Chad	TCD	preliminary	NC_2	2013	1	3_plugandplay	3	0	3	2
Chile	CHL	preliminary	NC_2	2011	1	6_PRECIS	1	1	3	2
Colombia	COL	preliminary	NC_2	2010	1	6_PRECIS	5	3	2	3
Comoros	COM	preliminary	NC_2	2013	2	2_lookup		0	3	3
Congo, Democratic Republic of the	COD	preliminary	NC_3	2015	1	5_stat_downsc	3	0	2	2
Congo, Republic of the	COG	preliminary	NC_2	2009	1	3_plugandplay	5	0	6	2
Cook Islands	COK	preliminary	NC_2	2012	1	3_plugandplay	11	0	3	3
Costa Rica	CRI	preliminary	NC_3	2014	0	0_noCP				
Côte d'Ivoire	CIV	preliminary	NC_2	2010	1	7_dyn.downsc		1	3	1
Croatia	HRV	preliminary	NC_6	2014	2	7_dyn.downsc	6	12	3	1
Cuba	CUB	preliminary	NC_2	2015	1	6_PRECIS	2	1	1	2
Cyprus	CYP	preliminary	NC_6	2013	1	7_dyn.downsc	5	7	2	3
Czech Republic	CZE	preliminary	NC_6	2014	1	7_dyn.downsc		1	3	1
Djibouti	DJI	preliminary	NC_2	2014	1	4_GCM	3	0	1	1
Dominica	DMA	preliminary	NC_2	2012	1	7_dyn.downsc	3	1	4	3
Dominican Republic	DOM	preliminary	NC_2	2009	0	0_noCP				
Ecuador	ECU	preliminary	NC_2	2012	1	7_dyn.downsc	3	2	2	3
Egypt	EGY	preliminary	NC_3	2016	0	0_noCP				
El Salvador	SLV	preliminary	NC_2	2013	1	4_GCM	6		5	2
Eritrea	ERI	preliminary	NC_2	2012	2	2_lookup	21	0	3	2
Estonia	EST	preliminary	NC_6	2014	1	7_dyn.downsc	2	1		2
Ethiopia	ETH	preliminary	NC_2	2016	2	2_lookup			3	3
Fiji	FJI	preliminary	NC_2	2014	1	4_GCM	16		3	1
Gabon	GAB	preliminary	NC_2	2011	1	3_plugandplay		0	2	
Gambia	GMB	preliminary	NC_2	2013	1	4_GCM	3	0	10	1
Georgia	GEO	preliminary	NC_3	2016	1	7_dyn.downsc	1	1	2	1
Ghana	GHA	preliminary	NC_3	2015	1	7_dyn.downsc	3	8	3	1
Grenada	GRD	preliminary	NC_1	2000	0	0_noCP				
Guatemala	GTM	preliminary	NC_2	2016	1	4_GCM	1	0	4	2
Guinea	GIN	preliminary	NC_1	2002	1	4_GCM	3	0	5	3
Guinea-Bissau	GNB	preliminary	NC_2	2011	1	4_GCM	5	0	2	2
Guyana	GUY	preliminary	NC_2	2012	1	2_lookup	15		3	3
Haiti	HTI	preliminary	NC_2	2013	1	6_PRECIS		1	2	2
Honduras	HND	preliminary	NC_2	2012	2	4_GCM	5	0	3	2
Hungary	HUN	preliminary	NC_6	2014	4	6_PRECIS		1	1	3
Iceland	ISL	preliminary	NC_6	2014	1	7_dyn.downsc		3	1	1
Indonesia	IDN	preliminary	NC_2	2012	2	4_GCM	15	0	3	2
Iran	IRN	preliminary	NC_2	2011	3	3_plugandplay	2	0	4	18
Iraq	IRQ	preliminary	NC_1	2015	0	0_noCP				
Ireland	IRL	preliminary	NC_6	2014	1	7_dyn.downsc	9	3	1	2

Country Name	ISO3 country code	Climate Science Publication Competence	National Communication issue	Submission year of NC	Sets of Climate Projections reported	Climate Modelling Complexity	number of GCMs	number of RCMs	Number of Time-frames	Number of Emissions Pathways
Jamaica	JAM	preliminary	NC_2	2011	3	6_PRECIS		1	3	2
Jordan	JOR	preliminary	NC_3	2014	1	7_dyn.downsc	9	2	3	2
Kazakhstan	KAZ	preliminary	NC_2	2014	1	4_GCM	5	0	3	4
Kenya	KEN	preliminary	NC_2	2015	2	7_dyn.downsc		1	1	1
Kiribati	KIR	preliminary	NC_2	2013	4	3_plugandplay	21	0	4	3
Kuwait	KWT	preliminary	NC_1	2012	2	4_GCM	1	0	3	1
Kyrgyzstan	KGZ	preliminary	NC_2	2009	1	3_plugandplay	17	0	1	2
Laos	LAO	preliminary	NC_2	2013	1	4_GCM	14	0	2	3
Latvia	LVA	preliminary	NC_6	2013	1	1_no.description			1	2
Lebanon	LBN	preliminary	NC_2	2011	1	7_dyn.downsc	1	1	2	1
Lesotho	LSO	preliminary	NC_2	2013	1	4_GCM	6	0	10	4
Liberia	LBR	preliminary	NC_1	2013	1	7_dyn.downsc	2	10	4	1
Liechtenstein	LIE	preliminary	NC_6	2013	1	7_dyn.downsc	8	14	1	3
Lithuania	LTU	preliminary	NC_6	2014	1	1_no.description				2
Luxembourg	LUX	preliminary	NC_6	2014	1	7_dyn.downsc	8	10	1	1
Macedonia	MKD	preliminary	NC_3	2014	1	3_plugandplay	18	0	4	6
Madagascar	MDG	preliminary	NC_2	2010	1	2_lookup			3	1
Malawi	MWI	preliminary	NC_2	2012	1	3_plugandplay	4	0	4	
Malaysia	MYS	preliminary	NC_2	2011	2	6_PRECIS		1	2	
Maldives	MDV	preliminary	NC_2	2016	1	7_dyn.downsc	4	1	2	3
Mali	MLI	preliminary	NC_2	2012	1	3_plugandplay	1	0		2
Malta	MLT	preliminary	NC_2	2014	1	3_plugandplay	6	0	4	2
Marshall Islands	MHL	preliminary	NC_2	2015	1	1_no.description			2	2
Mauritania	MRT	preliminary	NC_3	2014	1	3_plugandplay	2	0	2	2
Mauritius	MUS	preliminary	NC_2	2011	1	3_plugandplay	9	0	4	4
Micronesia	FSM	preliminary	NC_2	2015	1	4_GCM	18	0	3	3
Moldova	MDA	preliminary	NC_3	2014	1	4_GCM	10	0	3	3
Monaco	MCO	preliminary	NC_6	2014	1	1_no.description			3	2
Mongolia	MNG	preliminary	NC_2	2010	2	4_GCM	1	0	3	3
Montenegro	MNE	preliminary	NC_2	2015	1	7_dyn.downsc		1	2	2
Morocco	MAR	preliminary	NC_3	2016	1	1_no.description			3	2
Mozambique	MOZ	preliminary	NC_1	2006	1	4_GCM	6	0	1	1
Myanmar	MMR	preliminary	NC_1	2012	2	3_plugandplay	4	0	3	2
Namibia	NAM	preliminary	NC_3	2015	2	5_stat_downsc	10	0	1	1
Nauru	NRU	preliminary	NC_2	2015	1	4_GCM	18	0	3	4
Nepal	NPL	preliminary	NC_2	2015	1	6_PRECIS	1	1	3	1
Nicaragua	NIC	preliminary	NC_2	2011	4	6_PRECIS		1	2	2
Niger	NER	preliminary	NC_2	2009	3	5_stat_downsc	1	0	1	2
Nigeria	NGA	preliminary	NC_2	2014	1	5_stat_downsc			2	2
Niue	NIU	preliminary	NC_2	2016	3	4_GCM	23	0	1	
North Korea	PRK	preliminary	NC_2	2013	2	3_plugandplay	1	0	8	2
Oman	OMN	preliminary	NC_1	2013	1	7_dyn.downsc	1	0	2	1
Pakistan	PAK	preliminary	NC_1	2003	1	3_plugandplay		0	2	2
Palau	PLW	preliminary	NC_1	2003	1	4_GCM	1	0	2	
Panama	PAN	preliminary	NC_2	2012	1	4_GCM	4	0	3	2
Papua New Guinea	PNG	preliminary	NC_2	2015	0	0_noCP				
Paraguay	PRY	preliminary	NC_2	2011	1	6_PRECIS	5	1	3	2
Peru	PER	preliminary	NC_3	2016	3	4_GCM	3		1	2
Philippines	PHL	preliminary	NC_2	2014	1	6_PRECIS		1	2	1
Qatar	QAT	preliminary	NC_1	2011	0	0_noCP				
Romania	ROU	preliminary	NC_6	2013	2	7_dyn.downsc	9	9	1	1
Rwanda	RWA	preliminary	NC_2	2012	1	3_plugandplay	3	0	10	1
Saint Kitts and Nevis	KNA	preliminary	NC_2	2016	1	5_stat_downsc	1	0	3	3

Country Name	ISO3 country code	Climate Science Publication Competence	National Communication issue	Submission year of NC	Sets of Climate Projections reported	Climate Modelling Complexity	number of GCMs	number of RCMs	Number of Timeframes	Number of Emissions Pathways
Saint Lucia	LCA	preliminary	NC_2	2012	1	7_dyn.downsc			3	1
Saint Vincent and the Grenadines	VCT	preliminary	NC_2	2016	2	2_lookup	15	0	3	3
Samoa	WSM	preliminary	NC_2	2010	1	1_no.description			4	
San Marino	SMR	preliminary	NC_2	2013	0	0_noCP				
São Tomé…	STP	preliminary	NC_2	2012	1	5_stat_downsc		0	1	2
Saudi Arabia	SAU	preliminary	NC_2	2011	2	6_PRECIS	3	1	1	1
Senegal	SEN	preliminary	NC_3	2016	1	7_dyn.downsc		1	2	1
Serbia	SRB	preliminary	NC_1	2010	1	7_dyn.downsc		1	2	2
Seychelles	SYC	preliminary	NC_2	2013	1	3_plugandplay	7	0	3	2
Sierra Leone	SLE	preliminary	NC_2	2012	1	3_plugandplay	4	0	4	1
Singapore	SGP	preliminary	NC_3	2014	1	1_no.description			1	1
Slovakia	SVK	preliminary	NC_6	2014	1	7_dyn.downsc	2	2	1	3
Slovenia	SVN	preliminary	NC_6	2014	0	0_noCP				
Solomon Islands	SLB	preliminary	NC_1	2004	1	4_GCM	3	0	2	1
Sri Lanka	LKA	preliminary	NC_2	2012	2	4_GCM	3	0	2	3
Sudan	SDN	preliminary	NC_2	2013	1	5_stat_downsc	9	0	2	3
Suriname	SUR	preliminary	NC_2	2016	1	2_lookup				2
Swaziland	SWZ	preliminary	NC_3	2016	2	5_stat_downsc	7	0	2	1
Syria	SYR	preliminary	NC_1	2010	2	4_GCM	1		3	2
Tajikistan	TJK	preliminary	NC_3	2014	1	4_GCM	3			3
Tanzania	TZA	preliminary	NC_1	2003	1	4_GCM	5	0		1
Thailand	THA	preliminary	NC_2	2011	4	6_PRECIS	1	1		
Timor-Leste	TLS	preliminary	NC_1	2014	2	4_GCM	20		3	4
Togo	TGO	preliminary	NC_3	2015	1	3_plugandplay	0	0	4	2
Tonga	TON	preliminary	NC_2	2012	2	3_plugandplay	1	0	3	2
Trinidad and Tobago	TTO	preliminary	NC_2	2013	1	6_PRECIS		1	3	2
Tunisia	TUN	preliminary	NC_2	2014	1	4_GCM	4	0	2	4
Turkmenistan	TKM	preliminary	NC_3	2016	1	3_plugandplay	2	0	5	2
Tuvalu	TUV	preliminary	NC_1	1999	1	4_GCM	4	0	3	2
Uganda	UGA	preliminary	NC_2	2002	1	4_GCM	20		2	2
Ukraine	UKR	preliminary	NC_6	2013	1	7_dyn.downsc	6	14	3	1
United Arab Emirates	ARE	preliminary	NC_3	2013	0	0_noCP				
Uruguay	URY	preliminary	NC_4	2016	1	4_GCM			2	2
Uzbekistan	UZB	preliminary	NC_2	2008	1	3_plugandplay	6	0	3	4
Vanuatu	VUT	preliminary	NC_2	2016	1	4_GCM	18	0	3	3
Venezuela	VEN	preliminary	NC_1	2005	1	3_plugandplay	2	0	3	2
Viet Nam	VNM	preliminary	NC_2	2010	2	3_plugandplay		0	3	3
Yemen	YEM	preliminary	NC_2	2013	1	4_GCM	3	0	1	
Zambia	ZMB	preliminary	NC_2	2014	1	4_GCM	3	0	1	
Zimbabwe	ZWE	preliminary	NC_2	2013	1	4_GCM	1	0	1	2
Argentina	ARG	advanced	NC_3	2015	5	4_GCM	42	0	2	2
Brazil	BRA	advanced	NC_3	2016	2	4_GCM	4	0	1	1
China	CHN	advanced	NC_2	2012	1	4_GCM	11	0	2	2
Greece	GRC	advanced	NC_6	2013	2	7_dyn.downsc		1	2	1
India	IND	advanced	NC_2	2012	1	6_PRECIS	1	1	3	1
Israel	ISR	advanced	NC_2	2010	2	7_dyn.downsc	1	1	1	2
Japan	JPN	advanced	NC_6	2014	1	1_no.description				3
Mexico	MEX	advanced	NC_5	2012	1	4_GCM	1	0	1	1
Poland	POL	advanced	NC_6	2014	1	7_dyn.downsc	4	8	2	1
Russia	RUS	advanced	NC_6	2014	0	0_noCP				

Country Name	ISO3 country code	Climate Science Publication Competence	National Communication issue	Submission year of NC	Sets of Climate Projections reported	Climate Modelling Complexity	number of GCMs	number of RCMs	Number of Timeframes	Number of Emissions Pathways
South Africa	ZAF	advanced	NC_2	2011	3	5_stat_downsc	9	0	2	1
South Korea	KOR	advanced	NC_3	2012	1	7_dyn.downsc		1	1	1
Spain	ESP	advanced	NC_6	2013	0	0_noCP				
Turkey	TUR	advanced	NC_6	2016	1	7_dyn.downsc	3	1	3	3
Australia	AUS	proficient	NC_6	2013	0	0_noCP				
Austria	AUT	proficient	NC_6	2014	0	0_noCP				
Belgium	BEL	proficient	NC_6	2014	1	7_dyn.downsc			3	1
Canada	CAN	proficient	NC_6	2014	0	0_noCP				
Denmark	DNK	proficient	NC_6	2014	1	7_dyn.downsc			2	4
Finland	FIN	proficient	NC_6	2013	1	4_GCM	28	0	2	2
France	FRA	proficient	NC_6	2013	1	4_GCM	2	0	3	2
Germany	DEU	proficient	NC_6	2014	1	7_dyn.downsc	8	12	2	1
Italy	ITA	proficient	NC_6	2014	0	0_noCP				
Netherlands	NLD	proficient	NC_6	2013	1	7_dyn.downsc	5	8	2	2
New Zealand	NZL	proficient	NC_6	2013	1	7_dyn.downsc	12	1	2	1
Norway	NOR	proficient	NC_6	2014	1	7_dyn.downsc	2	2	2	2
Portugal	PRT	proficient	NC_6	2014	1	7_dyn.downsc			2	2
Sweden	SWE	proficient	NC_6	2014	1	7_dyn.downsc	9	1	3	3
Switzerland	CHE	proficient	NC_6	2014	1	7_dyn.downsc	8		3	3
United Kingdom	GBR	proficient	NC_6	2014	1	7_dyn.downsc			3	3
United States of America	USA	proficient	NC_6	2014	1	7_dyn.downsc				2

Annex to chapter 4

The multi-stage assessment process of the use of CH2011

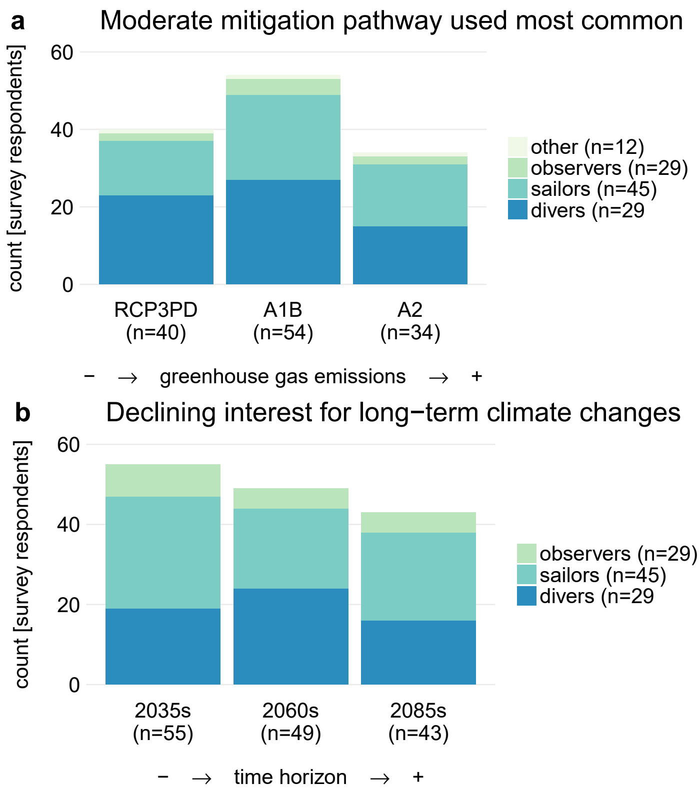
A multi-stage process was undertaken. To increase the specificity of answers – and to reduce the chances of a long 'wish list' – the elicitation process was divided into three themes: (a) use of today's climate; (b) use of the climate change scenarios CH2011, and (c) capturing recommendations and needs for the future CH2018 scenarios.

The data collection process proposed and consequently undertaken by EBP staff com-prised three work packages: In all three work packages, 'climate-primed' actors from the Swiss adaptation community (such as, the climate impacts research community, federal and cantonal administration, sectoral associations or interest groups, and media representa-tives) were targeted.

First, n=10 explorative interviews with experts from both academia and practice were undertaken in person or by phone. This explorative phase helped defining the research framework in terms of scope and selection of participants for the following steps.

Second, a survey with mostly closed questions was sent to n=256 people between June and December 2015, of which n=115 people responded (45% response rate). The target sam-ple consisted deliberately of a 'climate-primed' audience of the Swiss adaptation communi-ty. As such, the survey was sent to the participants of the group interviews (n=35/40, 88%), to the participants of the 7th Symposium on Climate Adaptation (n=70/187, 37%), as well as project managers who received funding through the Swiss Pilot Programme on Climate Adaptation (n=10/29, 34%). The survey was structured into four parts. First, use of current meteorological or climatological data. Second, use of specific products provided through the CH2011 climate scenario initiative. Third, requirements for upcoming CH2018 climate scenarios. And fourth, questions characterising the respondent. The German original as well as translated survey can be found in the Supplementary Material 1.

Third, n=9 qualitative group interviews were undertaken between August and October 2015, encompassing in total n=33 participants. In n=6 cases these group interviews were undertaken on the premises of EBP in Zurich. One group interview each took place at the Swiss Federal Office for Civil Protection in Berne (n=1), at the



Suppl. Figure 2 – Bar graph highlighting which emissions pathway (left) and time period (right) were used how often across the three user types. 3a highlights a bias towards the middle-of-the-road A1B emissions pathway. 3b indicates that the near-term time period 2035s was more often considered than the mid-term or end-of-the-century time periods.

Institute of Geography of the University of Berne (n=1), and the Swiss Tropical and Public Health Institute in Basel (n=1). These group interviews were sector-specific, encompassing between n=3 and n=6 participants each. The sectors were selected according to those identified within the Swiss Federal Adaptation Strategy (BAFU, 2014; FOEN, 2012b), such as biodiversity, energy, agriculture or natural catastrophes. As such, the intention behind this structure was to link the climate scenarios more explicitly to the national adaptation strategy, two institutionally distinct projects. Prior to the group interviews, each participant received the survey as a preparation. In the first half of the group interview, the individual results from the survey were collectively discussed. The second half was guided by an interview protocol which included a set of more open-ended questions to be discussed. These included for instance 'what were difficulties in using the provided data from CH2011?' or 'what is the value of a website compared to other formats such as workshops or a helpdesk?'. Each group inter-view lasted around 2 hours. Minutes were taken in condensed form, reflecting key state-ments from the participants.

Questionnaire

Questionnaire regarding your needs for the new climate scenarios 1

Questionnaire regarding your needs for the new climate scenarios

The Swiss climate change scenarios (CH2011) were published in 2011. MeteoSwiss is currently planning the next generation of scenarios. As the basis for this, Ernst Basler + Partner is analysing the needs of users in terms of content and provision of climate data. We would like to ask you to complete the following survey as part of this study. As the questions are addressed to very different types of users, you may not be able to answer some or many of the questions. Nevertheless, we ask you to go through the questionnaire completely and simply answer the questions that apply to you. Thank you very much!

1. How do you use meteorological/climate data (today's climate) in your work?

Which climate variables do you frequently use in your work?	Which ones? ❐ None ❐ Temperature ❐ Precipitation ❐ Wind velocity ❐ Relative humidity ❐ Global radiation ❐ Hours of sunshine ❐ Others: ________	For what purpose?
If you need such variables: In which temporal resolution do you need meteorological or climate data for your work?	Which ones? ❐ 10min. values ❐ Hourly ❐ Daily ❐ Monthly ❐ Seasonally ❐ Annually ❐ Others: ________	For what purpose?
If you need such variables: In which spatial resolution do you need meteorological or climate data for your work?	Which ones? ❐ Station values ❐ Gridded data ❐ Aggregated spatial means ❐ Others: ________	For what purpose?

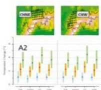
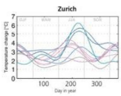
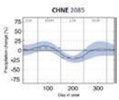
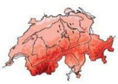
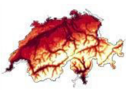
Questionnaire regarding your needs for the new climate 2

Do you work with extremes?	❐ Yes ❐ No	
If yes: Which data do you use for what purpose?		
Which climate indicators do you use?	Indicators ❐ None ❐ Heat (e.g..tropical nights) ❐ Cold (e.g. ice days) ❐ Rain (e.g. 5 days max precipitation) ❐ Dryness (e.g. consecutive dry days) ❐ Snow (e.g. days with fresh snow) ❐ Sunshine (e.g. clear days) ❐ Others: ________________	For what purpose?
You have described above how you deal with data on today's climate. Do your requirements for future climate scenarios correspond to the data you marked above?	❐ Yes ❐ No, for future climate scenarios I would like other / less / more data, namely:	
Which are the critical threshold values in your field, which could be mapped with indicators (e.g. climate for survival of the tiger mosquito, or a favourable climate for a culture in agriculture)?		
Do you know any indicators in your or other sectors that are useful for assessing impacts or that illustrate climate change well?		

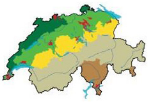
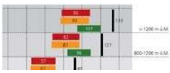
Questionnaire regarding your needs for the new climate 3

2. Which products from the latest climate scenarios (CH2011) have you used?

You can find all products from the "CH2011" climate scenarios and follow-up work in this table. Please tick which products you know / have used:

	I don't know this.	I've heard of it.	I skimmed it.	I used it.
Technical report (in English) 	○	○	○	○
Summary (D,F,I) 	○	○	○	○
Data 1: Seasonal mean changes per region 	○	○	○	○
Data 2: Change in mean annual cycle per station 	○	○	○	○
Data 3: Change in mean seasonal cycle per station 	○	○	○	○
Data 4: Change in mean seasonal cycle for 2x2 km radius 	○	○	○	○
Table of changes in weather extremes (from basic or regional report)  	○	○	○	○
Climate indicator maps, e.g. tropical nights 	○	○	○	○

Questionnaire regarding your needs for the new climate 4

Report for regions  	○	○	○	○
Present and future climate values at selected stations (from regional report) 	○	○	○	○
Current and future values of indicators (e.g. frost days) depending on altitude level (from regional report) 	○	○	○	○

3. What would you like from the new climate scenarios?

CH2011 provided *change data* (e.g. temperature increase). Did you need any additional observation data (e.g. absolute temperature during reference period)?	❒ No ❒ Yes, and I obtained this as follows:
Which of the emission scenarios offered in CH2011 have you used?	❒ A1B ❒ A2 ❒ RCP3PD ❒ Not used / don't know
How many emission scenarios do you need for your future work?	❒ Just one (middle) ❒ One low and one high ❒ One low, one middle and one high ❒ One low, two middle and one high ❒ No opinion Why?
Would you like additional information on the emission scenarios?	❒ No ❒ yes, the following for this reason:
Which of the time intervals offered in CH2011 have you used?	❒ Difference between 2020 – 2049 and 1980 – 2009 ❒ Difference between 2045 – 2074 and 1980 – 2009 ❒ Difference between 2070 – 2099 and 1980 – 2009
Which time intervals do you need for your future work and why?	Which ones and for what purpose?
Do you need transient, i.e. continuous time series?	❒ Yes ❒ No ❒ I don't understand

How should the reference period be selected?	❒ The reference period should be current (i.e. reflect "today") ❒ The reference period should remain constant ❒ No opinion Why not?
Which data formats do you want?	❒ I don't use any data, but rather figures from text, maps, graphics and other things. ❒ NetCDF ❒ ASCII ❒ GeoTIFF ❒ xls ❒ csv ❒ ESRI: ____________________ ❒ Others: ____________________

How important are the following elements for a climate services website?	Not important at all 1	2	3	4	Very important 5
– Short summary of main results	❑	❑	❑	❑	❑
– Long summary of results	❑	❑	❑	❑	❑
– Derivation of results	❑	❑	❑	❑	❑
– Associated scientific papers	❑	❑	❑	❑	❑
– User examples for application	❑	❑	❑	❑	❑
– Tutorial for use	❑	❑	❑	❑	❑
– Data download	❑	❑	❑	❑	❑
– Climate impact studies	❑	❑	❑	❑	❑
– Background information on climate change	❑	❑	❑	❑	❑

Questionnaire regarding your needs for the new climate 7

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4. What type of user are you?	
What type of user are you?	❒ "Research": User of complex climate datasets ❒ "Practice": User of specific climate information for specific purposes (e.g. maps, graphs, simple data sets by consultants / government / associations / companies) ❒ "Public": User of general climate information (interested civil society / public / media)
In which sector / area do you mainly work (select just 1)?	❒ Biodiversity ❒ Farming ❒ Forestry ❒ Health ❒ Water ❒ Energy ❒ Tourism ❒ Natural hazards ❒ Spatial planning ❒ Climate protection ❒ Not a sector, but general impacts/modification ❒ Others: ____________________

Annex to chapter 5

Interview protocol «Heatwaves in cities»

Thank you for agreeing to this expert interview. I look forward to hearing more about your work, how heatwaves relate to it, and the role of information in the next 45 minutes or so. I am interested in how heat in cities is addressed across sectors. This expert inter-view is an essential part of my doctoral thesis at ETH Zurich. To better analyse this inter-view, I would like to record it. Of course, I will make this recording anonymous and not pass it on to external parties. May I record our conversation?

Block 1: Introduction

- Please tell me in a few sentences about your background and your work.
- In your opinion, what should a 'good' sectoral expert [spatial planner / ...] be able to do? What are the criteria for a 'successful' project?
- What are the biggest challenges you face today in terms of urban development? Is there a link to heat spells in cities?

Block 2: Sector questions on «Heat in cities»

- Have you ever dealt with urban heatwaves professionally? If so, where? If not, why do you think it is not an issue? Is it an issue for other sectors?
- Have you worked on adaptation measures to deal with heat in cities?
- Suppose you have to explain to others what your work on urban heat covers. What are the five most important points that you would mention?

Block 3: Transfer of knowledge

- Do you remember how heat in cities became an issue for your sector? Did it happen in your sector in a similar way with other topics? Why/why not?
- How did you find out more about heat in cities? Is this the normal way in your working environment?
- Did you find this information helpful and understandable? What could be better? Were there criteria for or against certain sources of information?

- I asked you earlier about the 5 most important points. In my research I compare the sectors greenspace management, building technology, spatial planning, and health.
- Have you had frequent exchanges with these sectors?
- What do you consider to be the most important aspects of these sectors?

Block 4: Decision making process

- In your sector, decisions on urban development have to be made again and again. How are such decisions usually made? What was your role in this? What roles did your clients have, for example? What other factors do you think influence the decision-making process? What role does scientific information play here?
- We are in Switzerland with different levels of political decision-making. What role does the federal state in Berne, the canton and the city play in your work? Do you also make contact with associations or interest groups?
- In Switzerland, consensus / compromise plays an important role. Does this play a role in your work? Can you give an example?

Conclusion

- As you know, we are holding a workshop on «Heatwaves in cities», and based on your experience and this discussion, is there a point you would like to discuss at the workshop?
- Thank you very much, that was very informative. Is there anything else you would like to add?