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Mini-me: Climate scientists' (mis)perceptions of users and their needs

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ICAD Project, Informing Climate Adaptation Decision Making, is funded by the ERC and began April 2012. This interdisciplinary research programme aims to significantly advance knowledge systems to enable society to adapt effectively to an uncertain climate. The programme is divided into two domains: 1.Understanding climate information needs across society and 2. The social status of techno-scientific knowledge in adaptation to climate change.

More information about the ICAD project can be found at: http://www.icad.leeds.ac.uk/

Table of Contents

Abstract

Increasingly climate scientists and the users of climate information are being asked to deliberately co-produce knowledge to improve decision-making about adaptation to climate change. To do this, scientists not only need to be committed and willing to interact with users but also have the capacity to listen, understand, and respond to their needs. Yet little is known about how climate scientists perceive users and respond to their needs when deliberately co-producing knowledge. Using the case study of the UK Climate Projections 2009 (UKCP09) we seek to address this gap. Drawing on interviews with climate scientists, boundary workers, and government officials involved in UKCP09, we investigate how perceptions of users and their needs are constructed as well as the difficulties in responding to them. Our research shows that climate scientists struggle to respond to users other than a small cadre of actors like themselves – highly technical and highly numerate – mini-mes; as what constitutes ‘credible, usable, and relevant’ science is different for users and scientists. Others involved in UKCP09 considered a broader set of users, with more heterogeneous capacities, as the target audience. We find that the climate scientists’ narrow perceptions of users were strongly influenced by (i) their past experiences; (ii) the level and type of scientist-user interactions; and (iii) the institutional setting in which the science took place. This research suggests that climate scientists need broader social support from other experts as well as institutional goals geared towards a broader set of users if they are to successfully co-produce climate knowledge.

Keywords

Adaptation, climate change, scientists, users, perceptions, information, projections, UKCP09 and decision-making

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1. Introduction

As science finds itself increasingly interwoven with, and answerable to, society at large, new demands over its accountability have arisen. Long gone are the days where scientists received money from the state, shielded from political interference, simply in return for producing discoveries to advance the nation's health, welfare and prosperity. That social contract has now been heavily revised. Climate science, for instance, has left the exclusive realm of 'basic' science and has become 'policy-relevant'. Climate scientists are, as a result, asked to adjust their role to accept new societal responsibilities. Acknowledging the need to provide answers to pressing problems, calls have grown louder for climate scientists and users to deliberately co-produce knowledge (Briley et al 2015; Meadow et al 2015; Sarewitz & Pielke 2007). By involving those affected by, or with a stake in, climate change it's hoped that the implementation deficit in adaptation today can be overcome (Dupuis & Knoepfel 2013) by improving the uptake and use of climate information (Feldman & Ingram 2009; Lemos et al 2012). If users of climate information explain more clearly what makes it usable, and in turn, scientists deliver exactly what is needed, then policy paralysis or inaction could be avoided, in theory. All of this assumes that scientists are able to listen, understand, and importantly, respond to user needs as well as more or better climate information leading to improved decision-making.

To foster new or lasting dialogues between science and decision-making, knowledge brokers (Meyer 2010), boundary organizations (Agrawala et al 2001), and most recently climate service specialists (Brugger et al 2015), are increasingly asked to bridge the cognitive and institutional gap between the two (Dilling & Lemos 2011; Lemos & Morehouse 2005). Yet the success of these interventions is intricately linked to the level and quality of scientist-user interactions achieved (Lowrey et al 2009). Scientists and users have often very different ideas about what constitutes usable or relevant climate information (Lemos et al 2012). For instance, scientists make a number of assumptions about what they think users need without always fully understanding the needs, limitations, or pressures faced by users (Feldman & Ingram 2009; Lemos & Rood 2010). Likewise users may define their needs differently or ignore new information because it conflicts with existing working practices, despite its potential usefulness (Rayner et al 2005; Rice et al 2009). As a result, disappointment can ensue on both sides. Users are left frustrated that scientists have not listened to or acted upon what they were told whilst scientists are left frustrated that their efforts to satisfy user needs have gone (largely) unappreciated.

Usability also suffers when a misalignment emerges between who scientists think the user of climate information is and who really ends up using it (Lemos & Rood 2010). Reconciling the two can be very hard, though. Indeed, when producing climate information experts often construct a mental model of their idealized user (de Bruin & Bostrom 2013; Dawes & Mulford 2004; Nickerson 1999). This can lead to what Sofoulis (2011: 805) comically terms 'Mini-Me-ism'[1]. That is, where experts 'assume that users will (or ought to) think just like they do, and value the kinds of rational and technical knowledge that [they] consider important' (ibid). An overly simplistic, if not one-dimensional, rendering of users is imagined. Users are all assumed to have the same capacities, resources, and time needed to make sense of technical knowledge, which is rarely the case. Some user needs get prioritized over others (Wyatt 2008), non-use or resistance can arise (Oudshoorn & Pinch 2008), and particular forms of power and rationality are left unchallenged (Akrich 1992; Porter & Demeritt 2012). Such realities are shaped, in large parts, by climate scientists' value judgements over what they think is 'good' science and what users need to know (Shackley et al 1999). If scientists are to co-produce climate information with users, it's crucial we understand what influences their perceptions of users and the barriers faced by scientists. Otherwise the existing 'friction, antagonism, and power' imbalances in delivering science for adaptation decision-making will only be preserved, rather than challenged (Klenk & Meehan 2015: 161; see also Castree et al 2014).

In this paper, we explore how climate scientists' perceptions of users of climate information and their needs are constructed, and the constraints they face in meeting their needs. We draw on in-depth interviews with climate scientists, boundary workers, and government officials involved in the UK's latest climate projections, UKCP09. These projections are aimed at a very broad set of users, with different needs and different capacities, and paint a picture of how the UK's climate may change in the future (Jenkins et al 2009). Over seven years, Met Office scientists and users worked together to co-produce the projections (Steynor et al 2012; Street et al 2009). Yet since the projections were released opinion on their usability has been divided (Heaphy 2015; Frigg et al 2014; Kelly 2014; Tang & Dessai 2012). After providing a brief overview of the UK's climate projections and the role they have historically played in adaptation decision-making, we explain our data and methods. We then explore whom exactly Met Office scientists' had in mind as the user of the projections, what they thought that user needed, and how the projections should be used. Following on, we focus on what has influenced scientists' responses to users and their needs. To close, we ask whether scientists are getting the support or incentives they need, socially and institutionally, to successfully co-produce climate information with users.

2. Case Study: The UK climate projections 2009

Since 2008, a strong regulatory regime in the UK has formed around the assessment and management of climate risks. Under the Climate Change Act, the UK Government must assess the risks posed by climate change and develop policies to reduce them every five years. The Secretary of State for the Environment can also

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[1] Mini-me is a character who first appeared in the comedy film *Austin Powers: The Spy Who Shagged Me*. He is the clone of one of the main protagonists: Dr. Evil, and is as such identical to him in every way, except being one-eighth of Dr. Evil's size.

use this legislation to direct private companies responsible for critical infrastructure, utilities, and transport networks, to report on how they manage climate risks. All these adaptation activities have one thing in common: they share the same starting point for evidence - the UK's climate projections, UKCP09.

The UK has a long history of producing climate projections and/or scenarios (Hulme & Dessai 2008). Dating back to the early 1990s, these projections have sought to inform adaptation and mitigation decision-making by showing how temperature or rainfall may change over the next century, under different conditions (e.g. emission scenarios). Yet the UK's latest climate projections are markedly different to what came before. Users are now given greater choice over the spatial resolution, timeframe, and level of risk they wish to use in their decision-making (Jenkins et al 2009). Instead of giving users single, averaged figures for say temperature change, the new projections provide probability distributions to account for model uncertainty and detail the extent to which different outcomes are supported by different lines of evidence (e.g. climate science, observations, and expert judgment) (Parker 2010). The projections aim to 'give government and other organizations [the] evidence [needed] to help them take informed, cost-effective, and timely decisions to prepare for the changing climate' (Defra 2015).

The UK Met Office, an executive agency responsible for making meteorological predictions across very different timescales from weather forecasts to climate change, put the projections together. The UK Government funded the work on the proviso that it delivers policy-relevant knowledge that is also 'world-leading', so that it makes an original contribution to science for inclusion in the IPCC process (Defra 2007; see also Shackley 2001). A sharp distinction between basic and applied science is unhelpful here as a hybrid mix is often practiced. To ensure that user needs were considered, the United Kingdom's Climate Impacts Programme (UKCIP) – a boundary organization working at the interface of climate science and policy – became responsible for bringing scientists and users closer together (Steynor et al 2012; Street et al 2009).

Initially UKCIP ran workshops, and conducted an online survey, before a user panel was convened where scientists and users could discuss developments in the projections and offer feedback. Meeting every three months over a period of three years, scientists met users, often for the first time, and learnt how climate information is used and what users needed. Yet, why certain users were invited onto the user panel in the first place, and what they were able to contribute thereafter, often remained unclear. A preference was given to those that had already used the UK's previous climate scenarios, UKCIP02. As a result, researchers, water companies, and other highly numerate and highly capable actors became the dominant voice on the user panel compared to the more modest needs of others.

3. Data and methods

To understand how climate scientists, modelers, and other experts perceive users' needs, and what influences those perceptions and responses, we conducted forty-five in-depth interviews relating to the production of the UK's 2009 climate projections, over the summer of 2013. A purposeful sample was used to select actors who had played different roles at different stages in the development of the projections. We interviewed Met Office staff tasked with delivering the climate projections (n=15); scientists who were either part of the independent review panel for the projections or who had extensively applied them (n=15); and the United Kingdom's Climate Impacts Programme (UKCIP) staff and government officials responsible for championing the voice of decision-makers throughout the production process (n=15). This allowed us to trace how users and their needs were constructed, and in turn, why the projections took the particular form they did.

We adopted a conversational approach, using open-ended questions, to encourage interviewees to express their views and experiences in their own words. They were asked: Who was the intended user of the projections? And what did that user need, or call for? Whenever possible, interviews were held in the workplace of participants, digitally-recorded (with consent) and transcribed. Once imported to qualitative data analysis software, the transcripts were manually coded to identify emergent themes. In what follows, we focus primarily on data related to the Met Office scientists, UKCIP staff, and government officials as they were most heavily involved in efforts to engage users when developing the projections and consequently were chiefly responsible for listening, understanding and responding to user needs (Steynor et al 2012; Street et al 2009).

4. Results

4.1. Are scientists listening to users and understanding their needs?

The question of who the intended user of the UK's climate projections was, and what exactly they needed, speaks to a growing divide between how climate scientists, modelers, and other experts think about users. Two very different perceptions emerged. On the one hand, Met Office scientists offered a very clear and simple description of the potential user: technically competent actors like themselves. Met Office scientists (14 of the 15) agreed that 'the user [they] had in mind were academics and consultants' who could translate the projections 'into something with a bit of more impact… that's relevant to other users' (Met Office Scientist 3, Interview). On the other hand, climate experts including UKCIP staff and government officials saw the potential user very differently. A much more complex, and at times, contradictory picture was presented. UKCIP staff and government officials (12 of 15) believed the projections should be aimed at 'researchers to decision-makers, and everyone in-between' (UKCIP Officer 2, Interview) from the water, agriculture, energy, transport to building sectors.

These different user perceptions are important to understand as each comes with its own set of tacit assumptions about what users need and can do. For instance, whilst the majority (11 of 15) of Met Office scientists felt that they had ‘never met any real users’ they were still generally aware of the wide diversity of potential users. It was felt, nevertheless, that ‘everyone needs the same thing: relevant, robust, and reliable outputs’ (Met Office Scientist 3, Interview). For them, the best way to meet user needs, whilst remaining scientifically credible, was through ‘higher spatial resolution data’ as users are ‘interested in their local patch’ (Met Office Scientist 9, Interview), and ‘explicit treatment of uncertainty’ to give users greater ‘confidence and control’ over the outputs they use (Met Office Scientist 4, Interview). That impression was bolstered following the release of the UK’s previous climate scenarios, UKCIP02. Met Office staff were often contacted for advice and further information on how those scenarios should be used:

> ‘We’d get regular calls about how the data [from UKCIP02] should be used… from that me, and others here, were invited to give talks at workshops… and had offers to collaborate on research projects like ENSEMBLES… So by meeting these users face-to-face I think we really understood what they needed’ (Met Office Scientist 5, Interview).

Met Office scientists felt these efforts illustrated the great lengths they had gone to listen to, and understand, user needs. UKCIP staff and government officials (11 of 15) agreed that users needed more information on uncertainty and higher spatial resolution data, but argued that users also needed ‘simple storylines that less technical users could follow’ (UKCIP Officer 3, Interview); called for climate variables beyond ‘temperature and rainfall… such as solar radiation, wind speed, wind direction etc’ to be included so that ‘building engineers can assess energy performance of buildings’ (UKCIP Officer 1, Interview); and expressed a preference for ‘single values or numbers’ they could plug directly into existing decision processes (UKCIP Officer 2, Interview). Less than half (6 of 15) of the Met Office scientists were aware of these additional user needs, with some noting:

> ‘Top-level policymakers basically want a number to give to the Minister… and they’re convinced the Minister can’t cope with 3 numbers. Here’s the upper, middle, and lower, ‘No we can’t have that... Just tell us what we should use!’’ (Met Office Scientist 5, Interview).

Concerns were raised about ‘how far [scientists] should go in providing those answers’ (Met Office Scientist 6, Interview). Whether this is what users are asking for, or needed, was not always clear. Indeed, scientists and users often use the ‘same vocabulary’ to mean ‘very different things’ (UKCIP Officer 4, Interview). Inevitably, much gets lost in translation. Moreover, scientists then have the unenviable task of figuring out how to meet user needs:

> 'I see part of my role as turning what I think users want into something that is scientifically [doable]... There are going to be things [users] won't ask for because it's not something they necessarily think they need. They

just say, 'I can't do this and I can't do that'. So I have to ask: What does this mean? Why can't they do it? Why aren't they getting it?' (Met Office Scientist 3, Interview).

Translating user needs, which are expressed using non-technical language or are poorly articulated, into something that is scientifically credible and usable is far from easy. To simplify things, a distinction was drawn between what users may ‘want’ and what Met Office scientists think they actually ‘need’.

> ‘I wouldn’t say that users were coming to us saying ‘please can we have a complex PDF [Probability Density Function]’. No I don’t think many did. But it was our judgment really, if we wanted to supply something that would provide the basis for users looking at a set of storylines then having a PDF was the most robust way of doing that… so if they wanted to use all 10,000 realizations they could, or just 3 they could. But at the cost of putting the decision back on them’ (Met Office Scientist 6, Interview).

It is assumed here that users all have the required level of knowledge, capacity, and resources to make informed decisions about how they use climate information. Only a handful (3 of 15) of the Met Office scientists felt that the projections could be ‘too complex’ for some users (Met Office Scientist 1, Interview), while the majority (12 of 15) showed little ‘sympathy with people who say… “I find it impossible to use them” because they’re not that difficult to use’ (Met Office Scientist 6, Interview). Indeed, the complexity of the projections was seen as a potential learning opportunity. It could help users to experience firsthand the ‘limitations’ of the outputs so that they understand ‘how they should or shouldn’t be used’ (Met Office Scientist 8, Interview). For instance, higher spatial resolution data has two main drawbacks. First, confidence in the data is highest at continental scales but lowest at the local scale that most interests users (Jenkins et al 2009). Second, the outputs are not spatially coherent. Data from more than one location cannot be merged to create a larger area, which can confuse users who are told ‘here’s a map, but don’t think of it as a map’ (Met Office Scientist 1, Interview). Only when these limitations are fully understood do scientists think users should even consider using the projections.

Aware of different users with different needs, Met Office scientists still treated users as if they were a mirror image of themselves or highly numerate like them. Already possessing, or capable of quickly acquiring, a strong understanding of the strengths and weaknesses of climate modelling, this ‘user’ can assess future risks and source the climate information needed to adapt. Yet tensions emerge here as credible science is interpreted differently by scientists and users. Efforts by scientists to translate the needs of users such as the treatment of model uncertainties and push for higher spatial resolution data, in scientifically credible ways, often speak to a curiosity-driven desire for better scientific understanding, not necessarily informing decision-making per se (Porter & Dessai 2016). This raises the question as to why

Met Office scientists did not cater for the different needs of different users, beyond the small cadre of like-minded climate modelers and consultants?

4.2. What influences scientists' perceptions of users and responses to their needs?

Several factors strongly influenced how Met Office scientists saw users and responded to their needs. These included past experiences where scientists have met or worked with users before; the level and quality of scientist-user interactions during production; and the institutional setting in which science takes place. Acting alone, or in tandem, these factors help to construct a particular kind of 'user' for climate information.

Met Office scientists (13 of 15) felt 'past experiences', from 'old projects' to the UK's 'previous climate scenarios', played a key role in shaping how they perceived users (Met Office Scientist 4, Interview). Through the familiarity with the small network of users from the previous climate scenarios, UKCIP02, Met Office scientists imagined users as being highly numerate and capable actors in need of highly robust, reliable, and relevant knowledge. 'PDFs were the obvious next step' (Met Office Scientist 3, Interview). Met Office scientists found it hard to understand 'why anyone wouldn't want to use a PDF' (Met Office Scientist 6, Interview). Whilst Met Office scientists (12 of 15) agreed that there are potentially 'different users [who] need different things', having 'listened' to a small group of so-called UKCIP02 'super users' they were sure that the 'vast majority of users' shared their views (Met Office Scientist 2, Interview). This is perhaps understandable as UKCIP acted, unintentionally, as a firewall between scientists and users. Only when UKCIP was unable to answer user questions did the Met Office become involved (UKCIP Officer 3, Interview). This resulted in a skewed perception of UKCIP02 users by Met Office scientists, as they only came into contact with the users asking technical questions.

Efforts by UKCIP to shake-off Met Office scientists' perceptions that all users share high technical capacities, or at least broaden out that view, by introducing regular face-to-face user-scientist meetings met with limited success, however (Steynor et al 2012). Every three months the user panel meetings were held to bring scientists and users closer together so that better understandings could develop between the two. While Met Office scientists (12 of 15) felt that these user-scientist meetings were 'valuable' for learning what 'users need, from users themselves' (Met Office Scientist 3, Interview), this did little to change how they saw users. Met Office scientists (10 of 15) told us that these meetings could be 'very confusing' (Met Office Scientist 7, Interview). Some felt 'a little overwhelmed' and 'a little daunted' when they met new users and 'discovered there was no way to satisfy all the different things they wanted' (Met Office Scientist 2, Interview). UKCIP tried to simplify this by grouping users into one of three categories: 'researchers, communicators, or decision-makers' (UKCIP Officer 5, Interview; Gawith et al 2009). But only a few (2 of 15) Met Office scientists understood and could give examples of this user typology. Arguing that these categories were ‘too broad’ and ‘abstract’ to make sense of, scientists relied on rules of thumb, or heuristics, that they had used before (Met Office Scientist 6, Interview).

Past experiences continued to influence how scientists perceived users and their needs as UKCIP staff and government officials (10 of 15) explained that it was difficult to get ‘the right people in the same room’ at the ‘same time’ (UKCIP Officer 3, Interview). There was a lack of continuity over which actors (from the user panel) came, how often they attended, or what they contributed. This meant ambiguities arose over what should be prioritized making it, in return, harder to change perceptions. Due to time, travel, and resource commitments, some actors ‘came just once whereas others came to every meeting’ or even ‘delegated responsibility’ to junior staff (UKCIP Officer 2, Interview). Met Office scientists (13 of 15) also felt it’s ‘not the job of scientists, but UKCIP’ and other boundary organizations to ‘understand and communicate what users need’ (Met Office Scientist 2, Interview). On one side, this distancing of roles and responsibilities preserves the professional autonomy and ‘serious scientist’ status of the Met Office so that they maintain the power and authority to distinguish between ‘what [users] need… and what [scientists] can provide’ (Met Office Scientist 9, Interview). On the other, there are a series of practical difficulties faced by a willing yet small number of scientists in meeting, assessing and responding to the individual needs of all potential users.

> ‘There is a complete disconnect between what seems to be a good understanding of the limitations of what climate science can provide and what [users] need for their work. [Users] seem to understand the limitations but then they’ll ask for things that if they really understood the limitations they shouldn’t be asking for’ (Met Office Scientist 1, Interview).

The institutional setting in which UKCP09 was produced was the final factor cited for influencing how scientists saw users and their needs. Met Office scientists (14 of 15) explained that they prioritize basic science due to their training, but as part of the Met Office’s ‘contract’ with government departments, they are also expected to deliver ‘world-leading science’ (Met Office Scientist 2, Interview). In return for government funding, the Met Office provides policy-relevant knowledge but has to contribute original research for inclusion in the IPCC’s assessment reports (Defra 2007). But to do this, Met Office scientists (13 of 15) have to meet institutional-political targets that involve ‘publishing in high impact journals’ (Met Office Scientist 6, Interview). The user of these outputs is primarily the scientific community, not decision-makers. Similarly, the daily lives of scientists pushes them to emphasize their intellectual contribution, as this criterion is still used for career advancement within the Met Office and outside of it in academia or industry (Met Office Scientist 9, Interview). Disentangling these competing practical, social and institutional considerations can make it difficult for scientists to gain the distance to be reflexive about the future use of climate information. Expert judgments, for instance, over the exclusion of ‘wind data' reflect tacit values about what scientists think makes climate information 'robust enough' to be used in adaptation decision-making (Met Office Scientist 7, Interview).

Knowingly or not, a series of practical considerations, both socio-technical and institutional-political, have strongly influenced how Met Office scientists see users and respond to their needs. The perception that users are highly numerate, and in turn, need highly robust, reliable, and relevant knowledge, is in no small part related to scientists' value judgments about what they think makes climate information credible and usable for adaptation decision-making. Changing these perceptions has proved challenging. UKCIP efforts to bring scientists and users together played out differently to what as planned. This may help explain, at least in part, why the gap between what users may want, and what scientists think they need, is still yet to be bridged.

5. Discussion and conclusion: Do scientists listen, understand and respond to user needs?

Our research highlights some concerns over the ability of climate scientists to listen, understand, and respond to the informational needs of different users. Scientists are not indifferent to, or simply ignore, the needs of other users, however. We found that scientists struggle to see beyond the very narrowly defined set of users already constructed for them or the simplified set of users they constructed themselves. Yet even if scientists were able to push past this, the end result can still be disappointing for users This is because when scientists and users co-produce knowledge they often have very different, if not irreconcilable, ideas about what constitutes credible, relevant, and usable science.

To create usable science, scholars have increasingly focused on how to improve the level and quality of interactions between scientists and users (Dilling & Lemos 2011; Kirchhoff et al 2013; Lemos et al 2012). But how this should be done is not always clear (Meadow et al 2015). Deliberately co-producing knowledge requires considerable time and resources as well as the full commitment of those involved. Rather than hoping these interactions will happen spontaneously, boundary workers and organizations have attempted to bridge the cognitive and institutional gap in science and decision-making (Brugger et al 2015; Kirchhoff et al 2013). The UK has embraced such thinking (Gawith et al 2009). UKCIP brought scientists and users together over several years to inform the UK's latest climate projections. Despite initial reluctance to engage with users from some scientists , who were concerned that they had neither the skills nor time to do it, by the end scientists felt that working with users was a very rewarding experience (Steynor et al 2012; Street et al 2009).

First, climate scientists found it difficult to see beyond the 'user' of climate information constructed for them or the 'one' they had created themselves. For instance, Met Office scientists are incentivized to deliver research that's not only policy-relevant but also makes an original contribution to knowledge (Defra 2007; Shackley 2001). The audience of that work is researchers, not decision-makers per se. Disciplinary training and reward systems reinforce this very narrow conception of users by keeping alive and well the scientific maxim ‘publish or perish’ (Jacobs et al 2005; Shanley & Lopez 2009). Modeling styles also exert an influence over how scientists see users (Shackley 2001). They embody tacit values about what is ‘good’ science, and by extension, what do (or don’t) users need (Shackley et al 1999). UKCIP, and other boundary organizations like them, may (unintentionally) add to this by creating a firewall between scientists and users. A skewed picture of users can develop for scientists when they are only faced with those asking technical questions. Emotional attachment can, in addition, make it hard for scientists to acknowledge the limits of their work and its application (Lahsen 2005). This may explain why scientists find it difficult to accept a more heterogeneous user due to its repercussions for way they do science and their role within it.

Second, even if climate scientists are aware of different users, and are keen to cater for their different needs, the ability to do so is often constrained. Scientists use themselves as the model audience: mini-mes (de Bruin & Bostrom 2013; Nickerson 1999; Sofoulis 2011). Climate information, therefore, reflects the scientists’ own tacit assumptions and value judgments about what they think is important and interesting. Confirmation bias can then set in, as scientists feel unable to make sense of the range of new users they are now faced with and retreat to a default user from the past. UKCIP efforts to make different users more understandable to scientists by dividing them into three categories: communicator, decision-maker and researcher, did not work as intended. They were deemed too vague, abstract and confusing. The risk here is that simplifying the user, via heuristics, can lead to climate information that speaks only to the needs of some over others, or in this case is too complex for some users to use (Tang & Dessai 2012). Our research suggests that climate scientists are often aware of different users, with different needs, but feel unable to respond to them due to a lack of institutional rewards and priorities or due to the practical difficulties involved in satisfying the different needs of different users. This raises an awkward question about how scientists balance responses to user needs so that they do not tailor exclusively to only one group, on the one hand, whilst managing unrealistic expectations of delivering everything for everyone, on the other.

But are these social, epistemological, and institutional considerations, and in turn, previous experiences, emotions, and cognitive capacities, the only factors that influence how scientists perceive user needs and respond to them? No is the short answer. Even if scientists feel they have done things differently, unless users feel the right things have changed a disconnect between will remain. As shown by Skelton et al (2016), Dutch scientists were only able to overcome the barriers cited above when creating usable science through a strong personal motivation to see their work used by as many people as possible even if this meant sacrificing world-leading science to do it. This suggests that the socio-technical and institutional-political barriers identified may serve a more strategic role in helping Met Office scientists to justify why science can only be done in particular ways (e.g. secure funding, safeguard professional autonomy). A subtle form of boundary work is at play here (see Gieryn 1999). By appealing to the new public management dictum for evidence-based decision-making, scientists are able to point to the need for them to deliver 'good' objective science, which involves keeping interactions with users at hands-length. If scientists are expected to co-produce knowledge with users then not only will the institutional constraints for doing science differently, but also the personal motivations to experiment, will need addressing.

Another crucial, if not unsung, factor in shaping how scientists listen, understand and respond to user needs is the institutional geography or scale of the work involved. The remit of the UK's climate projections for a national decision-support tool that meets the needs of very different users was always challenging (Steynor et al 2012). With the Met Office and UKCIP located nearly 150 miles apart, the time and costs involved in bringing actors together affects the level and quality of interactions achieved (see Lemos et al 2012). Indeed, the work of Kirchhoff et al (2013) on the RISA program in the US, and the research of Skelton et al (2016) on the Dutch climate projections, both show that closeness either in the form of small geographical scales or the number of organizations involved helps scientists build more meaningful relationship with users. The UK Government has even implicitly acknowledged this limitation by disbanding UKCIP and launching the new climate services agenda within the Met Office (Met Office 2016). New expertise and professionals are now entering the climate arena who are incentivized to work with, and learn from users. This suggests that there are limits to the extent that climate knowledge produced at a national scale can be truly co-produced. Deliberately co-producing science, therefore, may face fewer challenges at smaller-scales where multiple constructions of users and tensions over how to credibly meet their needs can be quickly resolved.

Our research shows that funding agencies and science-policy actors who call for knowledge to be co-produced to tackle the implementation deficit in adaptation today (Dupuis & Knoepfel 2013), and ensure public money is spent effectively (Sarewitz & Piekle 2007), may need to rethink exactly how they support and incentivize scientists. Whilst it's certainly possible for world-leading science to also be usable science, there is often a trade-off. This need not be a problem but requires those involved to have agreed on the purpose and expectations beforehand; to accept that tensions will always exist between what makes science credible, relevant and usable for some actors opposed to others; and for all actors to be reflexive about how they construct users and the limitations this creates. If climate scientists are to effectively co-produce knowledge with users, then not only will greater social and institutional support be needed but greater humility is needed in what we expect can be delivered (Jasanoff 2003; Stirling 2010).

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