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From products to processes: Academic events to foster interdisciplinary and iterative dialogue in a changing climate

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Key points

Uncertainties are inherent to climate change but are challenging to handle

Fostering interdisciplinary dialogue is key for robust adaptation strategies

We show that academic events can generate new bases for this dialogue

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Abstract

In the context of climate change, both climate researchers and decision-makers deal with uncertainties, but these uncertainties differ in fundamental ways. They stem from different sources, cover different temporal and spatial scales, might or might not be reducible or quantifiable, and are generally difficult to characterize and communicate. Hence, for adaptation strategies and planning to progress, mutual understanding between current and future climate researchers and decision-makers needs to evolve. Iterative two-way dialogue can help to improve the decision-making process and bridge current top-down and bottom-up approaches. One way to cultivate such interactions is by providing venues for these actors to interact and exchange about the uncertainties they face. We use a workshop-seminar series including academic researchers, students, and decision-makers as an opportunity to put this idea into practice and evaluate it. Seminars, case studies and a round table allowed participants to reflect upon and experiment with uncertainties. An opinion survey conducted before and after the workshop-seminar series allowed us to qualitatively evaluate its influence on the participants. We find that the event stimulated new perspectives on communication processes and research priorities, and suggest that similar events may ultimately contribute to the mid-term goal of improving support for decision-making in a changing climate. Therefore, we recommend integrating interdisciplinary bridging events into university curriculum with the goal of exposing researchers, decision-makers and students to these concepts.

1. Introduction

"There are many approaches to conceptualising uncertainty" – Pete Fisher

Uncertainty is an inherent component of research on climate change and of adaptation to its impacts. It spans from projecting future climate change (e.g., Hawkins and Sutton, 2009), to assessing regional impacts and vulnerabilities (e.g., Füssel and Klein, 2006; Bosshard et al., 2013) and designing adaptation policies (e.g., Dessai and Hulme, 2004). Despite the presence of uncertainty throughout these fields, both its sources and the methods for handling it are heterogenous. Uncertainty regarding climate change is often conceptualized as a cascade rather than a singular problem (Wilby and Dessai, 2010), with uncertainties from the climate system at the top of the pyramid cascading to lower levels representing impact modeling and then adaptation (the so-called "top-down approach"). Moving down this chain, uncertainties that principally stem from physical processes and can be quantified (e.g., Knutti and Sedláček, 2012) may compound with uncertainties of a social, political or economic nature, which are often more qualitative and less quantifiable (e.g., Demeritt et al., 2007). Incorporating these uncertainties into decision processes is challenging, in particular because of the different nature of these uncertainties, the distinct structures in which climate researchers, impact modelers and decision-makers operate (e.g., Dabelko, 2005; Vogel et al., 2007) and the different conceptions of these actors regarding what information is useful for decision-making (Dilling and Lemos, 2011). In an attempt to overcome these limitations, scholars have advocated a better consideration of end-users' vulnerability before incorporating climate information (e.g., Prudhomme et al., 2010). Finally, in order to progress with decision-making in the presence of uncertainties, there is a growing body of literature suggesting that scientists, policy makers, and concerned publics should go beyond one-way approaches (either top-down or bottom-up) and instead engage in interdisciplinary and iterative dialogue, hereafter referred to as IID (e.g., McNie, 2007; Dilling and Lemos, 2011).

To foster IID, several channels have been proposed and are now operational. They include boundary organizations, climate services agencies and informal knowledge networks, which we describe below. There is, however, little discussion in the literature about how people involved in these institutions gain the understanding and skills necessary to make IID occur. In this commentary, we propose to develop academic events with the goal of familiarizing researchers, decision-makers and students to IID. We use outcomes from a workshop we organized to reflect on the following question: how can academic events set the basis for interdisciplinary and iterative dialogue to occur?

2. Top-down and bottom-up approaches for decision-making under uncertainty

How are we to deal with uncertainties when producing climate projections, assessing impacts and vulnerabilities, and designing adaptation strategies? Two main approaches can be distinguished, usually referred to as top-down and bottom-up approaches (see Weaver et al. (2013) for a comparison). In the prevailing top-down paradigm, the backbone consists of a model chain, usually involving one or several emissions scenarios and climate models, often followed by one or several downscaling methods. Downscaling derives locally relevant climate data from the global scale predictions generated by coarser resolution climate models, which are used to drive an impact model at a finer scale. At each step, uncertainties are sampled using different models and/or parameter values and are then propagated to the next element of the model chain. Results are then presented as an ensemble of equally-weighted model runs or combined as probability distributions (e.g., Tebaldi et al., 2005; Knutti et al., 2010). Climate change impacts are then often derived from the combined effect of several parameters (e.g., Fischer and Knutti, 2012) and are typically assessed at the regional scale (e.g., Addor et al., 2014). To advance our understanding of current and future changes, there is a steady effort in the research community to increase the complexity of climate and impact models. Yet, although newer generations of models are better at representing the observed climate (e.g., Knutti et al., 2013), this does not necessarily lead to decreased uncertainty in the climate projections (Knutti and Sedláček, 2012). Further, part of the uncertainty is irreducible due to the natural variability of the climate system (Deser et al., 2012), and would remain even in the hypothetical case of unlimited computing resources and deterministic knowledge of the system. Finally, if such top-down projections inform us about *which* changes to expect, researchers have increasingly questioned whether they provide much guidance on *how* to mitigate these changes (Dessai and Hulme, 2004; Dessai et al., 2009; Prudhomme et al., 2010; Brown and Wilby, 2012). As phrased by Lemos and Rood (2010), *useful* projections, i.e., projections that scientists perceive to be relevant for user groups, are not necessarily *usable* by these user groups, i.e., do not necessarily help them advance a decision process.

In response to this mismatch, some physical and social scientists have developed so-called “bottom-up approaches”. They build on the premise that system’s sensitivities and users’ needs and vulnerabilities must be understood first, and that climate projections should be used later to inform rather than to drive the analysis. Indeed, it is not critical that uncertainties be reduced or fully characterized, but rather that their effects on decisions taken is better understood in order to better inform the decision-making process (Brown and Wilby, 2012; Weaver et al., 2013).

Such approaches commonly rely on three main steps. One starts with the evaluation of the key sensitivities of a system, or the vulnerabilities of a particular population or a community (Wisner et al., 2004; Brown et al., 2012). Direct dialogue with stakeholder and user groups is essential to establish which circumstances might alter their particular activities. For instance, in Brown et al.'s (2011) study, stakeholder groups whose activity is linked to the Lake Superior (e.g. involved in commercial shipping or wastewater management) were asked under which lake levels and for what duration they would consider their situation as either “acceptable”, posing “significant negative impacts, but survivable” or “intolerable without policy changes”. Other climate-sensitive systems include health and food supply, ecosystems, and infrastructures, with differential impacts depending upon a group’s access to resources. As a next step in the assessment, climatic conditions (typically changes in temperature and precipitation) that would lead to critical situations are determined by researchers, for instance using a stochastic framework (Steinschneider and Brown, 2013). Finally, climate information is used to determine how likely these situations might become in the future. Hence, climate change information only enters in the last stage of the approach, and although this may include climate model projections, it could just as easily include information derived from paleo-climate data or expert elicitations (Brown et al., 2012).

Bottom-up approaches offer several advantages. Since they involve users in the first stages of the study (i.e., including in problem definition, choice of scope, and selection of credible climate information), they are expected to increase the legitimacy accorded to climate projections, improve the relevance of outputs, and ultimately raise the chances of success of adaptive action (Vogel et al., 2007). They can contribute to the emergence of more robust decisions, i.e., solutions that perform well under a wide range of climate outcomes (Dessai et al., 2009; Wilby and Dessai, 2010). Further, bottom-up approaches respond to calls from social scientists for climate change research to engage with contextual or "starting-point" vulnerability rather than with outcome vulnerability (Kelly and Adger, 2000). In the latter, vulnerability is an end-result of projected impacts on a particular exposure unit; in the former, it is the present incapability to cope with a variety of external changes as a result of interacting social, political, economic, and environmental conditions (Wisner et al., 2004; O'Brien et al., 2007). The bottom-up approach is better suited to integration with contextual vulnerability assessments such as community-based self-assessment of coping capacities and participatory risk mapping exercises (Smith et al., 2000; Tschakert, 2007). Indeed this approach significantly expands the definition of who is considered to be a relevant "decision-maker" to include community-level organizations that are too often left on the receiving end of decision-making. If a vulnerability analysis reveals that the system or community is not particularly sensitive to changes in climate, or that the impact of other stressors far outweighs climatic impacts, then model projections may be irrelevant to the decision-making and their time-consuming processing may be avoided (Brown and Wilby, 2012). Similarly, once vulnerabilities to changes in climate are established, new climate projections may be compared to these vulnerabilities as they become available, without the need to rerun the impact model (Prudhomme et al., 2010).

As discussed earlier, top-down approaches typically fall short when the information provided by climate researchers does not correspond to the needs of decision-makers. Yet, adopting a bottom-up approach does not automatically lead to an improved understanding between the parties. In fact, similar communication problems can occur, in which the expectations of the user groups are beyond the reach of the climate community. For instance, in a bottom-up framework, a sensitivity analysis might be carried out to determine under which climate conditions the reliability of a water supply system will be compromised. Although these conditions might be clearly identified, quantifying their probability under a changing climate can be at the very edge of, and often beyond, the present understanding of the climate system under global warming. Uncertainty is higher at smaller spatial scales, and is higher in parameters like the variance than it is in the mean. Yet it is often precisely the changes in complex parameters at small spatial scales that are relevant for impact studies and decision-making. One-way bottom-up requests from practitioners to climate scientists can end up in a dead end, if it turns out that available climate data and our present understanding of the climate system cannot provide the required information. In such cases, bottom-up approaches fall short. In summary, uncertainty acts as a barrier to decision-making when future changes in critical parameters are poorly defined, yet an equally important issue is the typical lack of a convergence between the information that can be derived from climate data and the information needed to support decision-making.

3. Fostering interdisciplinary and iterative dialogue to aid decision-making under uncertainty

To overcome the limitations of purely one-way approaches, scholars have advocated an increased two-way dialogue. Brown and Wilby (2012) propose to adopt a "top-down meets bottom-up" framework, McNie (2007) calls for a "reconciliation of the supply of scientific information with user demands", and Dilling and Lemos (2011) argue that "co-production of knowledge requires iterativity between scientists and potential users/stakeholders". Similarly, Nowotny et al. (2001) argue that in order to generate knowledge that remains valid outside the confines of purely theoretical and experimental science, new modes of communication subject to "frequent testing, feedback, and improvement" are required. Two key characteristics are crucial to sustain future dialogue: interdisciplinarity and iterativity. Interdisciplinarity should be understood here in a broad sense, such that it is not restrained to exchanges across academic disciplines, but instead includes exchanges between climate researchers and decision-makers. We conceptualize decision-makers in the broadest terms, including practitioners within organizations, "end users" of projections, communities considering adaptation options, as well as more traditional policy-makers and planners. Furthermore, dialogue between these actors should also be iterative, that is, not only two-way but also ongoing and open-ended. For such exchanges to maintain salience, credibility, and legitimacy for multiple audiences and actors, “true dialogue” requires that “scientists and users be brought together with equal standing for setting agendas, designing products, and evaluating successes” (Cash et al., 2006). We follow Lemos and Morehouse's (2005) definition of iterativity as “(a) the extent to which the interactions between scientists and stakeholder participants influence how scientists pursue science and how stakeholders understand the possibilities and limits of science, (b) the range of uses to which the scientific knowledge may be put, and (c) the practical value of such knowledge.” Such iterative modes of knowledge production about climate change contain greater possibilities for innovation and societal impact (Lemos and Morehouse, 2005).

To further support improved dialogue and better accommodate uncertainty, various channels exist that help to foster interdisciplinary, iterative and more complex (multi-party) forms of dialogue (e.g., Bidwell et al., 2013; Hoppe et al., 2013). These include channels such as boundary organizations, workshops and informal knowledge networks (Dilling and Lemos, 2011; Lemos et al., 2014; see Figure 1). Boundary organizations, for instance, help to foster dialogue by providing a network to broker information between scientists and practitioners with a focus on the science-policy interface (Lemos and Morehouse, 2005; Vogel et al., 2007). Additional channels to support dialogue and the flow of information include publicly funded projects or branches within federal organizations that have been launched to guide adaptation strategies, as well as university centers that help to bridge the gap between researchers and practitioners (e.g., UKCIP at the University of Oxford, Stockholm Environment Institute, Oregon Climate Change Research Institute, Pacific Climate Impacts Consortium at the University of Victoria, and

African Climate & Development Initiative at the University of Cape Town, among many). Other informal information sharing takes place, for instance, on internet platforms that disseminate information on adaptation, allowing users to both access and share information and data (e.g., http://climate-adapt.eea.europa.eu, http://weadapt.org/) and via courses organized to guide the use of climate model output and appropriate use of downscaled projections for adaptation and policy development (e.g., Using Regional Climate Model data for Alpine impact research; Salzmann et al., (2013) and CSAG Winter School, University of Cape Town). This type of information sharing during a course or workshop can often have more impact and result in better application of the information than if learned elsewhere (e.g., via internet or journal article; Bidwell et al., 2013).

Despite the growing number of channels facilitating communication and dialogue between climate researchers, users, and practitioners, critical gaps still exist. In particular, many forums for exchange primarily engage already-established researchers and decision-makers within traditional networks. Communities of climate researchers and decision-makers are also evolving rapidly and new models that facilitate communication will need to take this into consideration, for example, through the development of bridging organizations that act to support and strengthen independent smaller networks and de-centralize the flow of information, as is being done with the Great Lakes Integrated Sciences and Assessments Center (Bidwell et al., 2013). We propose that one way to expand both the range of participants and the content included in this dialogue, and thereby improve traditional communication channels, is through training and pedagogical responses introducing students and early stage academics, from a wide range of backgrounds, to interdisciplinary dialogue (shown in Figure 1).

4. A workshop on "Uncertainty in Decision-Making in a Changing Climate"

We introduced an innovative workshop-seminar series at the University of Zurich to demonstrate the form such a response might take. Our workshop is used here as an example of how such events can be used to facilitate current and future dialogue between evolving groups of climate researchers and decision-makers. The event was designed to generate interactions between a wide range of participants: nine expert speakers from academia, industry, government, and humanitarian aid and development, as well as bachelor, master, and PhD students (i.e., undergraduate and graduate students) and academic staff. The main goals were to:

i. provide participants with an overview of the current research on uncertainty and on how uncertainty is dealt with by decision-makers,

ii. overcome existing barriers to communication (e.g., limited opportunities for informal face-to-face interactions) and thereby enhance mutual trust and understanding on which collaborations can be based (Dabelko, 2005; Vogel et al., 2007),

iii. expose students at an early stage of their professional life to multidisciplinary collaborations (e.g., Gornish et al., 2013) and real-world problems involving decisions under uncertainty.

The event began with a two-day workshop and was followed by case study assignments in which participants spent two months grappling with uncertainties with implications for decision-making. This led to the incorporation of the material into an existing course that is mandatory for all masters students in the Department of Geography. More details on the workshop-seminar series are provided in the Supporting Information.

5. Shifting conceptions about decision-making under uncertainty

To explore the impact of our two-day workshop on participants' perspectives about communication between scientists and decision-makers, we conducted an anonymous opinion survey before and after the workshop. Participants were asked "What information and tools should be exchanged between researchers and decision-makers to better address uncertainty?". The responses visualized in Figure 2 show a shift in perspectives regarding the relationship between researchers and user groups as a key outcome (see Supporting Text S2 for methodology). This shift is from a pre-workshop vertical conceptual model of interactions between researchers and user groups to a post-workshop horizontal model. Before the event (Figure 2a), participants' responses paralleled the dominant approach of top-down climate change impact modeling, prioritizing *outputs* that could be generated by academic researchers based on their expertise and their apparently more direct access to climate information. For instance, better data visualizations, quantifications of uncertainty, and metadata were each suggested in approximately 20 percent of responses. In this vertical model, researchers bestowed data-based products to decision-makers, who were minimally involved by specifying the kinds of information they require. This model resembles the classic "pipeline model" or "loading-dock approach" of science-society relationships identified and critiqued by social studies of science and expertise (Nowotny et al., 2001; Cash et al., 2006) and indeed some respondents even used the term "pipeline".

In contrast, participants' responses after the event (Figure 2b) tended to prioritize *processes* rather than *products*. For instance, previously prioritized outputs such as visualizations were virtually discounted (appearing in only one response), and recommendations to produce quantifications of uncertainty and metadata were only half as frequent as before the event. Instead, the most common recommendations were for dialogue (35 percent) and more frequent and improved channels for communication (30 percent). In this "flatter" model, researchers and decision-makers engaged in institutionalized dialogues and frequent communication, exchanging their needs, expertise, and even personnel. There was increasing recognition that such exchanges must allow for decision-makers to specify and iteratively define what kind of information they need (mentioned in 20 percent of post-workshop responses versus 10 percent of pre-workshop responses). Responses also suggested that the local knowledge and priorities of affected communities struggling with the uncertainties surrounding climate change should inform both researchers and decision-makers and shape the design and co-production of relevant outputs – a concept that was completely absent from pre-workshop responses but appearing in 15 percent of post-workshop responses. This conceptual model of interaction, which we characterize as "horizontal", is neither a strict bottom-up nor a top-down relationship. Rather, it is an iterative and flexible relationship that may assume different forms based on the needs, priorities, and data available.

A second set of qualitative evidence gathered from the workshop corroborates this perceptual shift among participants. The workshop ended with a spirited round table discussion and budgeting exercise that included the speakers and the audience. All participants were asked "*What are the most urgent cross-cutting challenges posed by uncertainty in a changing climate, and how can researchers and user groups collaborate to address them?"*. To gauge responses, we deployed a mock "participatory budgeting" exercise in which participants were asked to allocate hypothetical grant money among eight proposals, derived from speaker presentations and discussions throughout the workshop (see Supporting Text S3 and Figure S2). Participants' budget allocations prioritized proposals that facilitated processes (e.g., dialogue, developing novel communication channels, acknowledging and engaging local knowledge) over proposals that resulted in end-products (e.g., better projections, better data, or insurance). These responses implied a shift away from a "deficit model" of science communication and decision-making, in which members of the public are conceptualized as simply lacking knowledge that scientists should produce and provide (Locke, 1999; Crow and Boykoff, 2014), and towards an iterative model of problem definition and research design that engages with multiple forms of knowledge, including local and indigenous "uncertified" expertise about environmental change (Wynne, 1996; Collins and Evans, 2002; Vogel et al., 2007). They also reflected a recognition that some types of uncertainty are irreducible, and thus that social values inevitably enter into environmental decision-making.

It is important to note that neither the two-round opinion survey nor the participatory budgeting activity were controlled experiments, but rather workshop exercises. As such, our results do not permit us to definitively assign causality for the patterns observed. As demonstration research, they do allow us to suggest a relationship and form hypotheses that such academic events can lead to perceptual shifts about how best to address uncertainty in a changing climate, away from prioritizing “pipeline” top-down models towards to more horizontal, iterative and interdisciplinary dialogue. These hypotheses remain to be tested in future research.

6. Concluding remarks and outlook

Uncertainty will continue to be an inherent part of climate change research and to pose challenges for decision-making. When dealing with uncertainty in the context of impact modeling, vulnerability assessment, or adaptation planning, it is crucial to better understand the effects of uncertainties on the decisions in question. Interdisciplinary and iterative dialogue (IID) is therefore central, as it enables bridging of current top-down and bottom-up approaches, thus overcoming existing barriers to communication, and enhancing mutual trust and understanding on which collaborations can be based (Dabelko, 2005; Vogel et al., 2007). In this study we explored how an academic event may set the basis for IID to occur.

We conducted two short evaluations: a two-stage survey and mock budgeting exercise. Their results suggest that even a short two-day workshop can change participants’ perspectives on addressing uncertainty. In both exercises, participants prioritized processes over products. Given these findings, we suggest that the workshop helped the participants to better conceptualize the myriad constraints of data, actors, and institutions attempting to address uncertainty. We formulate three hypotheses which could be systematically tested in future studies of similar events:

i. The workshop helped the participants to better understand the sources of uncertainty inherent to climate projections, to acknowledge that these uncertainties are not necessarily reducible (natural variability), and hence to realize the importance of working with decision-making schemes that can accommodate these uncertainties.
ii. The workshop helped the participants recognize that beyond the quest for better models and less uncertain projections, it is crucial to achieve a better correspondence between the information provided by the scientific community and the information needed for decision-making by user groups. This is supported by the fact that second-round survey responses and budgeting allocations placed a higher priority on *processes* by which such needs can be reconciled than on preconceived *products* themselves.
iii. The workshop helped the participants to realize that given the difficulty – and in some cases, impossibility – of reducing uncertainty in climate projections and achieving a perfect match between available and requested data, the ability to find compromises between desirable and actually available data is critical.

In other words, although in some cases new model runs can produce the information required by user groups, quite often, the desired information cannot be provided.

> Nevertheless, other aspects of future climate changes with relevance for decision-making can be assessed, which may still enable some progression of the decision process. Although iteration allows for better understanding, it does not necessarily result in changes in the needs of decision-makers. We thus suggest that IID can enable progress by reaching intermediate goals, allowing decision-makers to articulate and revise their needs in conversation with researchers, and possibly to devise novel ways of producing proxy outputs.

We hence suggest that the contribution of academic events to IID is three-fold. Although these findings cannot be regarded as incontrovertible evidence due to the lack of experimental controls, they suggest a change in participants' perceptions and provide us with hypotheses for future controlled studies.

After the workshop-seminar series, a student evaluation showed that student participants became proactive in incorporating interdisciplinary dialogue into their existing projects. Yet, some kind of monitoring and longer-term goals are necessary to ensure that the change of perspectives observed during the workshop persists. To this end, we suggest two mechanisms: applied case studies carried out over several months, and modular integration into existing required courses within the curriculum.

These findings suggest that concerted replication of similar events is a promising way to multiply the interactions between academics and decision-makers, which are ultimately necessary to inform robust adaptation strategies. On the basis of our experience as organizers, the written evaluation of the workshop by the participants, and oral feedback gathered, we identify three key recommendations for the organization of future events: i) create an interdisciplinary environment, ii) keep case studies manageable and iii) provide concrete methods to deal with uncertainty (see Supporting Text S6).

In conclusion, we see such events as promising ways to intensify future interdisciplinary collaborations (Gornish et al., 2013) and to produce competent facilitators to broker information between scientists and decision-makers (Dilling and Lemos, 2011). Our experience shows that a workshop can reach, bring together, and benefit a wide range of participants, such as experts from industry, government, academia, humanitarian aid and development, as well as students and academic staff. As such, we argue that these workshops and classes are useful ways to complement and strengthen other channels fostering IDD (e.g., boundary organizations and informal networks). We seek to encourage the organization of similar events, with the mid-term goal of improving adaptation strategies and better mitigating climate impacts.

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Accepted Article

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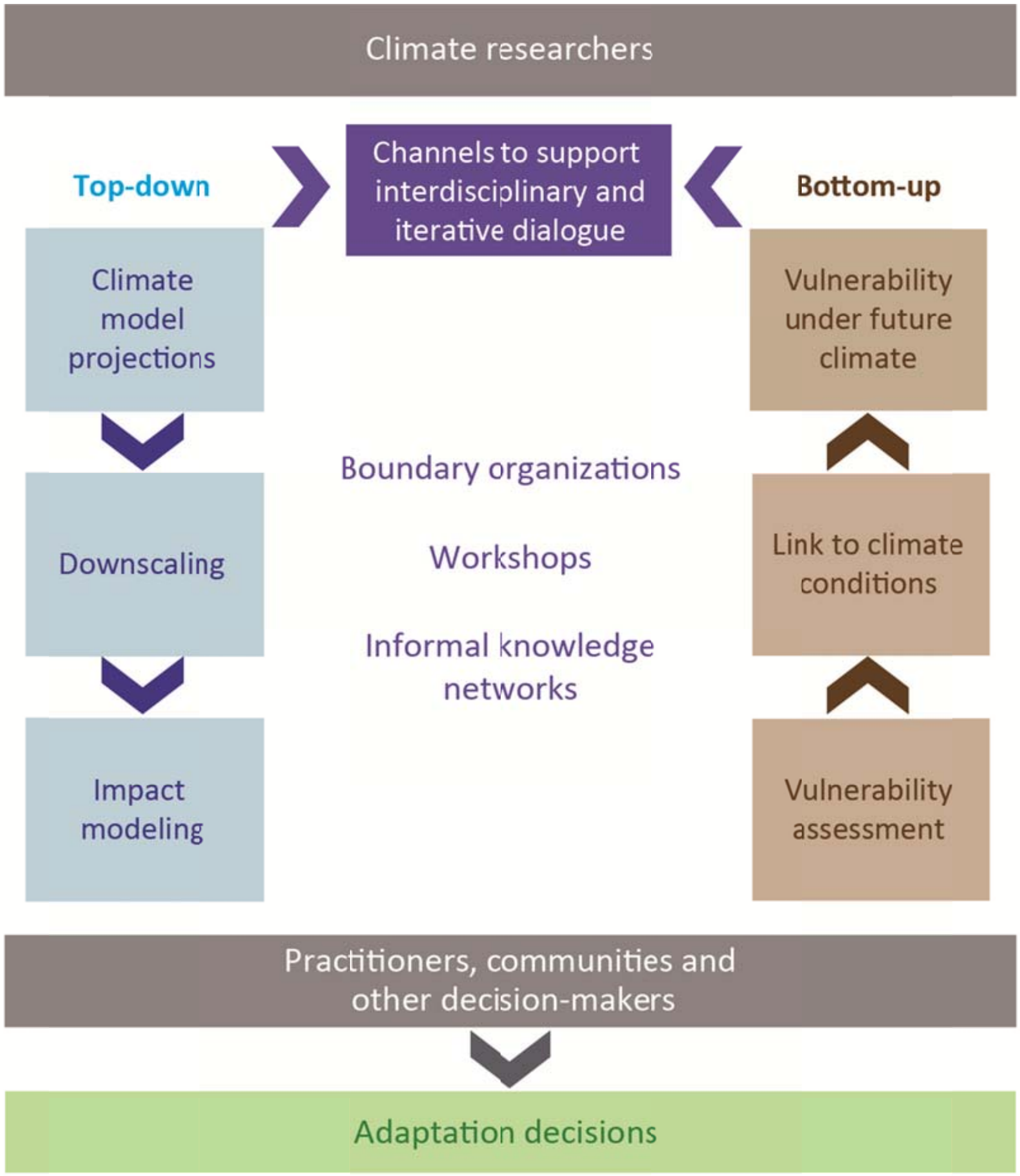

Figure 1: Schematic representation of the flow of information between climate researchers and decision-makers in the top-down and bottom-up approaches (left and right columns, respectively). As these two approaches may turn into one-way communication modes, alternative approaches relying on channels to support iterative dialogue (as shown in purple, see text for examples) have been proposed to aid knowledge production and support decision-making under uncertainty.

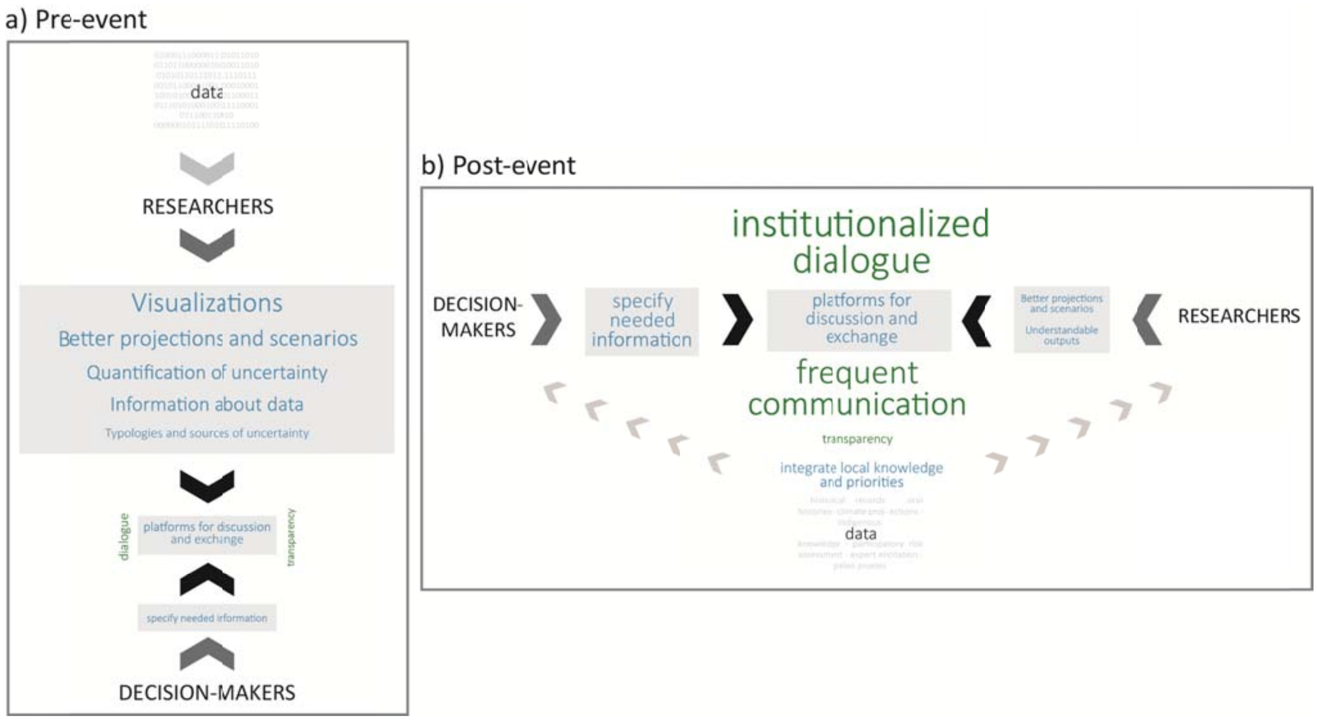

Figure 2: Shifting perspectives on the communication of uncertainties in the decision-making process, before and after an organized two-day workshop promoting dialogue exchange. Here, results from an opinion survey conducted before and after the workshop (a: n=53, b: n=42) are visualized, where font size is scaled based on the code's relative frequency in each set of responses. Items in blue are concrete outputs or deliverables, while items in green are processes; note the shift from the former to the later, from pre- to post-event responses.