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Integrating user values into climate science through Co-production

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Abstract

Transdisciplinary approaches such as co-production are gaining prominence for their ability to improve the actionability of sciences and support solutions to complex societal problems. Yet effectively operationalizing co-production processes continues to be a significant challenge and a time-intensive effort. Particularly, there is limited understanding of how the various elements of science evolve during co-production, and how the values and priorities of non-academic societal partners can be robustly integrated into scientific research. In this manuscript, we examine the case study of a long-term transdisciplinary co-production project aimed at improving the credibility of climate modelling and developing actionable climate science for resource management. Drawing on a systematic longitudinal analysis of over 3 years of iterative engagements, we articulate a change pathway that describes how choices in scientific research evolved and transformed through interactions with non-academic partners. We also identify six distinct types of value negotiations that we confronted during the co-production engagements and provide examples of each negotiation-type, including cases where diverse values were easily assimilated, where practical challenges constrained value integration, where values were differently interpreted, as well as cases where values were incompatible. These results extend the philosophical discussions of value negotiations in climate science by providing empirical evidence on how iterative deliberations on values play out in practice. The change-pathway as well as the negotiation-types that we developed offer valuable lessons to other researchers, practitioners or boundary spanners, seeking to facilitate value negotiations and to make co-production processes more effective and efficient.

Introduction

Researchers across the world are increasingly using transdisciplinary approaches such as co-production, to develop actionable science that can inform society's most pressing climate and environmental challenges (Bremer et al. 2019; Bremer and Meisch 2017). The term co-production has many definitions and interpretations (Bremer and Meisch 2017; Chambers et al. 2021; Mach et al. 2020), and draws from several other closely-related forms of engaged research such as participatory research, community-engaged research, transdisciplinarity, and action research (Mach et al. 2020; Meadow et al. 2015). Here we define co-production as a process where researchers work collaboratively and iteratively with science users and other non-academic societal partners, to frame research questions, decide how to answer the questions, analyze the findings, and develop actionable knowledge that meets users' needs (Meadow et al. 2015). There is increasing evidence that co-production processes have been successful not only in developing

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actionable science but also in increasing the use of science for decision-making, and in catalyzing beneficial societal outcomes (Chambers et al. 2021; Jagannathan et al. 2020; Karcher et al. 2021).

As co-production gains popularity and momentum, there is a need to understand effective ways to scale-up what is often a time and resource intensive process with many trials and errors (Collins et al. 2023; Gill et al. 2024; Kolstad et al. 2019; Redman et al. 2021). Scholars and practitioners are hence calling for the development of frameworks and lessons learnt from existing projects, particularly on the nuts and bolts of operationalizing engagements, that can help to better direct and guide future efforts (Bamzai-Dodson et al. 2021; Jacob et al. 2025; M. C. Lemos et al. 2025). One critical knowledge gap in co-production is that there is limited understanding of how different elements of scientific research change or evolve during the process, and specifically how societal values and priorities get incorporated into the scientific process and its outputs (Jebeile 2024; Laursen et al. 2021; M. Lemos et al. 2018; Mach et al. 2020). Literature on philosophy of science offers some theoretical framings about how user engagement can help to incorporate societal values into research (Jebeile and Roussos 2023; Parker and Lusk 2019; Tuana 2017). However, these theories have not been elucidated in detail or empirically tested through case studies or real-world examples (Jebeile 2024). Much of this literature also analyzes values at a distance rather than through directly engaging with and intervening in the scientific process (Ankeny et al. 2011). Since one of the primary premises of co-production is that it enables science to become more actionable and usable, the inability to clearly articulate and provide evidence of how societal values get integrated into science and where in the research process these changes occur, represents a significant drawback.

Using the case study of a long-term co-production project, in this paper we trace how research evolves through engagement with practitioners, and derive a change-pathway for co-produced science. We also identify six different ways in which scientists' and practitioners' values were negotiated within the co-production process and discuss how they led to different outcomes in terms of changes in science. The change-pathway as well as the types of negotiations we developed, provide empirical evidence for some of the theoretical framings surrounding the topics of value diversification and value negotiations in science. Overall, these results provide an improved understanding of how science changes through co-production, and where and how societal values are incorporated in the process. These results can also help to direct and focus engagement efforts on specific anchor-points (i.e., aspects of science that most benefit from incorporation of societal values and perspectives), thereby increasing the efficiency of the overall co-production process (Gill et al. 2024; M. C. Lemos et al. 2025).

Role of Values in Climate Science

Choices and Values

Throughout the course of scientific inquiry, researchers are faced with a range of consequential decisions—from identifying which questions to pursue and selecting appropriate methods, to determining what constitutes sufficient evidence for accepting or rejecting hypotheses (Douglas 2009). In climate science, these decision points—or "choices"—can be especially complex and impactful, for instance when determining which types of models to use, and how to interpret findings amidst scientific uncertainty and incomplete data (Jebeile and Crucifix 2021). Since different choices can lead to widely divergent research paths and outcomes, transparency about choices and their reasoning is critical throughout the research lifecycle (Parker and Lusk 2019).

In all these decisions, values play a significant role in how scientists make choices, an occurrence that is especially evident in scientific modeling (Douglas 2000; Elliott 2022; Parker 2014; Winsberg 2012). While the idea that values play a role in science remains contested in some scientific communities, in particular, by those committed to the strict separation of science and policy (Borie et al. 2021), many streams including philosophy of science and transdisciplinary research, have largely moved beyond this debate (Brown 2024). The "value-free ideal", according to which values should have no influence on the internal working of science, has been substantially challenged (Brown 2024; Douglas 2009; Longino 1996). The current focus is on how to include values responsibly, i.e., distinguishing legitimate from illegitimate value influence, identifying which social and ethical values should inform scientific practice, and making value-laden decisions transparent and subject to critical scrutiny (Baldissera Pacchetti et al. 2024; Brown 2020; Elliott 2017; Intemann 2015; Pulkkinen, Undorf and Bender 2022).

Literature has broadly described values are those considerations of priorities that influence what is judged to be important, good or right, and these values guide activities in pursuit of particular goals (Brown 2020; Elliott 2017). In practice, values are expressed through the interests and preferences that actors bring to, and prioritize in, specific research contexts. For example, a practitioner's interest in understanding certain management-relevant processes reflect underlying values about decisions-relevance and societal responsiveness, just as a scientist's interest in understanding broader physiological phenomena reflect epistemic values about accuracy and representational fidelity. Pulkkinen, Undorf and Bender (2022) note that how values appear in climate modeling can be examined through structured attention to the interests and priorities that shape technical decisions in research. That is, peoples' interests can act as contextualized or concretized values, especially in cases where the underlying values are more abstract (Elliott et al. 2025). Philosophers of science have increasingly acknowledged that values are a necessary and important component of scientific inquiry and have analyzed the different ways in which values can explicitly or implicitly influence science (Douglas 2023; Tuana 2017). For example, the prioritization to study one region over another, or near-term versus long-term, may reflect the values of researchers or funding bodies (Pulkkinen, Undorf, Bender et al. 2022).

It is important to distinguish between values and choices, as they perform different explanatory work. Choices are the observable decision-points in research, i.e., the actions that scientists take at methodological junctures. Values are the underlying commitments, interests, and priorities that make particular choices preferable to others in specific contexts (Brown 2020; Elliott 2017), and this is the specific definition of the term that is most applicable to this paper. As Pulkkinen, Undorf, Bender et al. (2022) argue, *"developing an awareness of values can be aided by developing an awareness of choices"* because values operate through choices, but the two concepts are not interchangeable. When researchers disagree about a choice, the disagreement is intelligible only by reference to the differing values, which are expressed in terms of competing interests, risk preferences, or priorities, and are brought to the decision. As Douglas (2000) notes, values shape not only hypothesis acceptance, but also *"choice of methodology, characterization of data, and interpretation of results"*.

Values span both epistemic and non-epistemic dimensions. Epistemic values are those that are central to science and the pursuit of knowledge, such as accuracy, methodological rigor, and adherence to scientific norms, while non-epistemic values encompass social, ethical, economic and other considerations, such as societal relevance of science, publishability and accessibility of results (Douglas 2000; Longino 1996; Pulkkinen, Undorf, Bender et al. 2022; Undorf et al. 2022). In making research choices, climate scientists must balance a complex interplay of scientific, practical, and social values, and recent scholarship argues that acknowledging and reflecting on these value-laden choices is crucial for maintaining integrity, transparency, and social relevance in climate science (Douglas 2023; Tuana 2017). For instance, climate model developers may prioritize some metrics of model performance over others. Modeling teams may prioritize the accurate simulation of changes in surface temperature, droughts and other weather extremes, because they have greater social and economic importance, over other quantities such as the average height of the 200 mb pressure surface (Parker 2014). Since this prioritization may likely lead to varying degrees of predictability of different quantities that are relevant to downstream users, acknowledging values transparently is important.

Engagement with users and practitioners

Traditionally, most choices in climate modeling are made solely by scientists based on their own values and value judgements on epistemic and non-epistemic considerations (Jebeile 2024; Jebeile and Roussos 2023). However, climate model outputs are often used by a multitude of downstream users to support policy, impact assessments, and decision processes. These users have different values and priorities that may or may not be adequately integrated into modeling choices (Deitrick et al. 2021; Pulkkinen, Undorf and Bender 2022). Depending on the context, there are instances where this can be problematic, as a representation of a certain process or property in a system can be inadequate for downstream users' purposes (Harvard and Winsberg 2022). For example, use of a model that inadequately represents sea surface temperatures can underestimate the intensity of tropical cyclones. If this model is then used by a coastal community for infrastructure planning, the underestimation could mislead adaptation decisions.

The values and insights of users and experts with knowledge of the downstream application of climate research are increasingly recognized as pivotal to the development of climate modeling and the production of actionable climate information (Parker and Lusk 2019). Engaging with users, such as policymakers, sectoral professionals, regional planners, or scientists working in adaptation and impact assessment, enables climate modelers to better align the focus and output of their research with the practical needs and decision contexts of those who will ultimately use the data (Helgeson et al. 2024). Users often have specialized knowledge about the types of data, models, projections, risks and uncertainties that are most relevant to specific practical contexts (Jebeile 2024; Winsberg et al. 2020). For example, because of their deep understanding of regional contexts and knowledge gaps, users may be better equipped to shed light on whether to focus on time-series of precipitation data or understanding of rare but high-impact extreme events or both. Therefore, integrating user values in upstream modeling decisions can improve the relevance and inclusiveness of research, and ensure that the work being done is reflective of the interests and concerns of those who are tasked with using climate data for decision-making (Helgeson et al. 2024).

Value negotiations and trade-offs

While the importance of integrating user values into climate science and modeling is well acknowledged, there are only broad discussions in the literature on how this integration can be successfully achieved (Deitrick et al. 2021; Helgeson et al. 2024; Laursen et al. 2021; Pohl et al. 2021) and what types of changes in science this integration may lead to (M. Lemos et al. 2018). This is because value integration often requires difficult trade-offs among diverse, competing, and contested values i.e. they require value negotiations (Helgeson et al. 2024; Undorf et al. 2022). For instance, researchers might have interest in examining longer-term climate projections as a statistically significant signal is more likely to emerge at decadal (or longer) time-scales, while local managers may be interested in shorter-term projections which are more aligned with their decision-making needs. Here there may be tradeoffs between credibility (i.e., robustness of information) and salience (i.e., relevance of the information) which need to be managed or negotiated carefully (Jebeile 2024). Another example could be where researchers value publishability over actionability because of institutional priorities and evaluation metrics (Undorf et al. 2022). There is also a knowledge gap regarding the specific elements or aspects of science where such complex trade-offs often arise, and where value negotiations are most critical and could lead to the most impactful outcomes (Shenk et al. 2025).

A growing recognition of these complex trade-offs between values of researchers and users has led to calls for iterative engagements between the two groups, to increase transparency around the influence of values and subjecting the values to critical reflection and deliberation (Douglas 2023; Pulkkinen, Undorf, Bender et al. 2022; Roussos 2024). Such a proactive management or negotiation of values has the potential to lead to tangible changes in the relevance of science and increase the usability of climate information (Jebeile and Roussos 2023; Laursen et al. 2021; Parker and Lusk 2019). However, literature also recognizes that value management or negotiations can be arduous because value judgements in scientific inquiry are often implicit making it hard to tease out underlying value diversity, divergences or disagreements (Helgeson et al. 2024; Jebeile 2024). Some studies have offered strategies to aid in the management of values. Laursen et al. (2021) advocate for the use of philosophical dialogues to make values explicit, where trained facilitators aid the actors involved in a scientific project in the articulation of the values that drive their work and in engaged reflection of their roles. Helgeson et al. (2024) use values-informed mental modeling in the early design of research to ensure that stakeholders' values and perspectives are included in the conceptualization of the system of study that grounds the research. Outside of these few case studies, much of the literature focuses only on providing reasons for why value negotiations are necessary in science, hypothesizing that co-production could provide a means for value management, or recommending simplified principles that should be applied in practice.

The philosophy of science literature, however, recognizes that values need not be explicitly articulated to be operative in scientific practice (Elliott et al. 2025). Value negotiations frequently manifest through the interests and preferences that scientists and practitioners express when advocating for a particular research choice, even when the actors themselves do not frame their reasoning in explicit value terms (Pulkkinen, Undorf and Bender 2022). Douglas (2000, 2009) shows that *"many decisions in the process of scientific inquiry may conceal implicit value judgments"*, with Pulkkinen, Undorf and Bender et al. (2022) similarly noting that the identification of values can happen through attention to interests and priorities in scientific choices. This implicit operation of values is why studying their role in technical scientific choices, as we do in this paper, is important, as it makes visible the competing priorities and commitments that would remain hidden if one attended only to the surface choices themselves. Empirical studies of what values and value negotiations actually look like in practice, and what changes in science they may lead to, are very rare (Ankeny et al. 2011; Deitrick et al. 2021; Pulkkinen, Undorf, Bender et al. 2022). This paper adds to the literature by describing in detail the many ways in which diverse values among researchers and users can present themselves while making research choices in a climate science context, and how value negotiations and management can unfold in practice. Using the examples, we also synthesize an overall change pathway for co-produced science and identify 6 different types of negotiations that provide valuable real-world context for scientists, practitioners and boundary spanners who are engaging in co-production or other transdisciplinary approaches.

Methods

About the project

HyperFACETS is a US Department of Energy funded project that aims to advance the understanding of processes at the atmosphere-water-energy-land interface and improve the fundamental ability to perform credible climate modeling for management-relevant processes. The project seeks to develop data, methodological approaches, process understandings and best practices, that are informed by practitioners' needs and expertise. Co-producing research with practitioners is a key underlying principle of the project. The main goals of the project's co-production are to work iteratively with practitioners at each step of the research, to promote mutual learning between scientists and practitioners, and to ensure that the eventual research is useful for practitioners' regional planning and decision-contexts.

The project started in 2016 and is currently in its third phase (at the time of writing of this manuscript). Phase-1 of the project focused on evaluating the credibility of regional climate datasets and improving the ability of models to predict decision-relevant outcomes. Three manuscripts discussing the Phase-1 co-production engagements have been published (Jagannathan et al. 2021; Jagannathan et al. 2023; Reed et al. 2022). This current manuscript focuses on engagements in Phase-2 (2019-22) of the project. Based on practitioner feedback, Phase-2 focused primarily on examining 'storylines' which are physically based model recreations of impactful events, that are then simulated under plausible past and future climate scenarios (Shepherd et al. 2018; Sillmann et al. 2021). Examining historical extreme events through high-resolution storyline recreations can be valuable for both practitioners and scientists. They can help practitioners to better understand how extreme events might unfold in the future, and also help the scientific community assess whether cutting-edge modeling approaches are fit for purpose for analyzing extremes (Rhoades et al. 2023; Rhoades et al. 2024). Overall, Phase-2 consisted of 8 sub-projects each targeting a different type of storyline or related topical area.

Co-production Engagements

Due to resource and time limitations, not all 8 sub-projects were equally iterative in nature. All 8 sub-projects engaged in the initial kick-off workshop, developed a co-produced research plan with practitioners, and gathered practitioner feedback on their interim or final results. However, based on practitioner interest in the topical areas, only

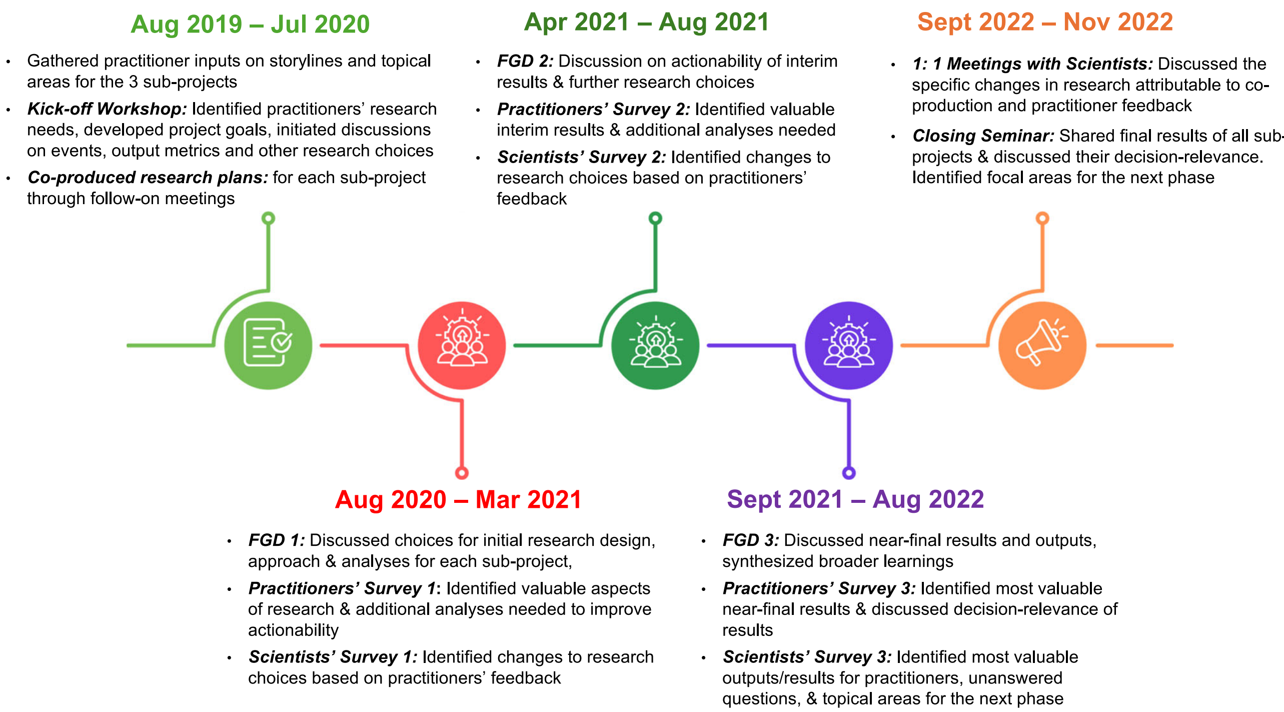

Fig. 1 Co-production timeline highlighting different engagements for the 3 sub-projects. Engagements started with a kick-off workshop and follow-on meetings to develop project goals and co-produce research plans. This was followed by a series of 3 focus group discussions (FGD) for each sub-project where ongoing plans, research choices and results were discussed and iterated on. Each FGD was complemented with a follow-on survey for both practitioners and scientists. This phase of the project concluded with a seminar to share final results from all the sub-projects and identify topics for next phase. More details of the engagements (and data collected in each) are in Supplementary Sections 1-6.

3 out of the 8 sub-projects had more regular iterative engagements (in terms of number of engagements over the course of the research). Each of these 3 sub-projects had 3-8 scientists working with 3-8 practitioners from the relevant regions. This current manuscript focuses on these 3 sub-projects and how their research evolved over time. Figure 1 presents a more detailed time-line of co-production engagements for these 3 sub-projects. The engagements that are a part of this research have received approval from Lawrence Berkeley National Laboratory's (LBNL) Human Subjects Committee (HSC) which is LBNL's Institutional Review Board (IRB #00006447). Informed consent was obtained from all participants prior to the research engagements. More details are in the sections on Ethical Approval and Informed Consent.

The co-production engagements for the 3 sub-projects brought together ~25 climate scientists with ~27 practitioners who are users of climate science. The scientists include atmospheric and Earth systems scientists, climate and hydrology modelers, energy systems researchers, and social scientists, spanning 10 different research institutions in the United States. Several of the scientists were also part of Phase-1 and therefore had experience in co-production and an existing understanding of practitioners' needs. They were also keenly interested in making their research useful and actionable to the practitioner community. The project's practitioners include water, energy, and land managers from 18 resource management agencies across the US, although most of them are from the water sector. The practitioners have high levels of technical expertise and have some experience with using climate information for decisions. These practitioners were purposefully recruited because of the interest in informing new climate research to make it more actionable, and their ability to dedicate time to co-production engagements. In addition, the project also has three boundary spanners (who are also co-authors of this paper) whose primary role is to design and facilitate the co-production engagements.

The project's scientists and practitioners work collaboratively and iteratively throughout different stages of the research, starting from identifying research gaps and questions of relevance, to developing results and outputs. Co-production engagements are both formal and informal, and include workshops, virtual focus group discussions,

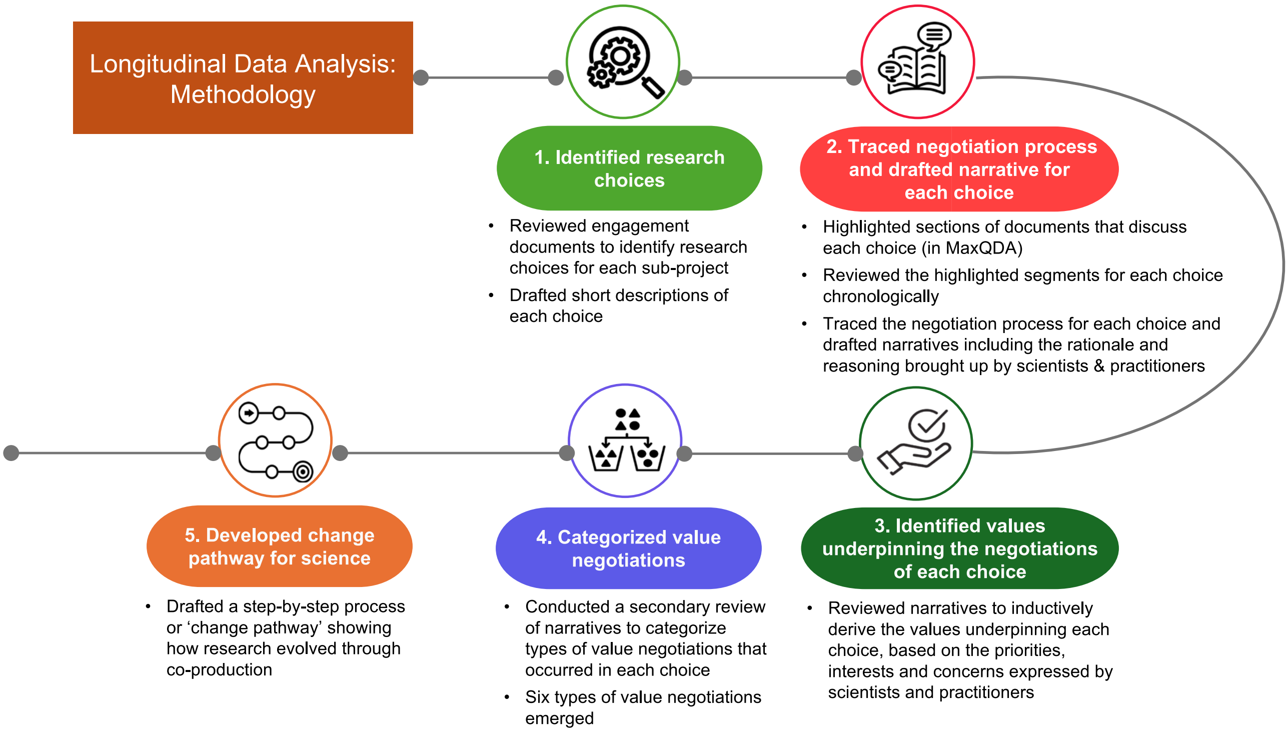

Fig. 2 Longitudinal data analysis methodology. We started with reading the engagement documents to identify research choices made within each sub-project. Using MaxQDA, we coded/highlighted the sections of the documents that discussed each choice. To analyze how the negotiations unfolded, we took each single choice as our unit of analysis and chronologically reviewed the coded discussions surrounding each choice. Based on the review, we drafted a detailed narrative about how the negotiations evolved which included the rationale and reasoning provided by the scientists and practitioners for why they favored certain choice options over others (Supplementary Section 8). We then inductively derived the values underpinning each choice by reviewing the priorities, interests and concerns expressed by scientists and practitioners. Sometimes these values were taken verbatim from discussions, other times they were inferred [e.g., when a scientist would say that "this might be a different project", we inferred the value as a lack of time or resources, "ability to well-simulate" was inferred as valuing model skill or predictive skill, "metrics that are generally used in our field/sector/discipline" was inferred as valuing scientific/engineering/ infrastructure norms]. We then conducted a secondary review of the narratives and inductively identified six types of value negotiations that occurred. Finally, we also identified the overall change pathway for the project's research.

surveys, online meetings, as well as soliciting feedback via Google documents or email. Our initial kick-off workshop was planned as an in-person event for March 2020, but changed to virtual a week before the event due to COVID-related travel restrictions which continued throughout the duration of this phase of the project.

Longitudinal Data Analysis

In order to ascertain how the project's research changed with co-production, we longitudinally reviewed all the engagement documents for the 3 sub-projects which had the most number of iterative engagements - namely Hurricanes in Florida (hereafter termed simply as 'Hurricanes'), Northeast Drought (or 'Droughts'), and Atmospheric rivers in California (or 'ARs'). The main goal of the engagements in the initial stages of the research, was to co-develop the research questions, approach, and intended outputs, and then in later stages of the research to collectively iterate and refine the preliminary analyses and results. To fulfil these goals, each engagement included discussions on the different choice options for research questions, approach, scales, metrics, preliminary results to prioritize, actionability and relevance of potential results/outputs (Supplementary Sections 1-6). These discussions were facilitated by boundary spanners, where both scientists and practitioners had a space for back-and-forth discussions on their preferences and interests for the research, and to detail the rationale or reasoning for their choices (where values underpinning choices were revealed and negotiated on). "Does this fulfill both science and practice needs?"

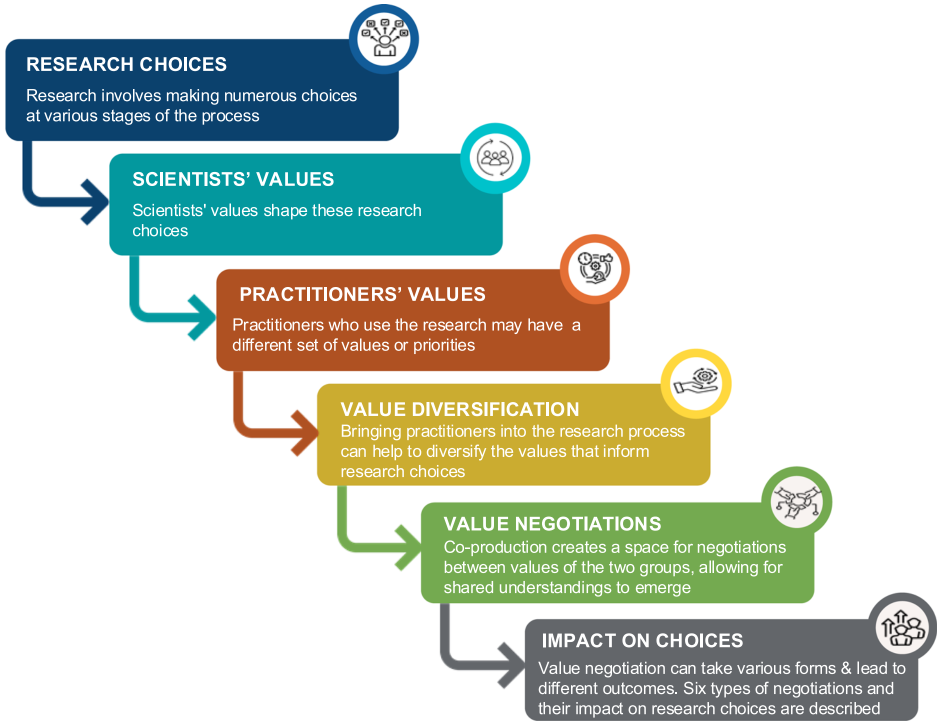

Fig. 3 Change pathway for co-produced science. All research involves several choices, and these choices are shaped primarily by scientists' values and priorities. Co-production helps to bring in a new set of practitioner values into the process and diversifies the types of values that are under consideration. But diversification of values does not imply that those values are immediately integrated into research choices. These diverse sets of values need to be deliberated and negotiated on, to come to shared understandings and prioritizations. Co-production engagements provide a space for scientists and practitioners to negotiate and manage the various values that underpin research choices. We identified 6 types of value negotiations and provide examples of how these types of value negotiations impacted the research choices of the project.

and "What should we change?" were constant themes and questions within each engagement. These discussions were both verbal and written where practitioners directly responded on scientists' initial choices or on preliminary results in a google document to indicate if there was something they would change or add in the research (and why). In addition, a follow-up survey specifically asked the practitioners what the most useful outputs or results from the research would be, and asked scientists specifically what changes in choices arose based on the conversations with practitioners. The engagement documents (discussion transcripts, notes, and survey responses) follow these iterative and regular discussions about each sub-project - so they represent how the negotiations played out and research choices evolved over time. Details of the specific engagement documents that were reviewed for each-sub-project are provided in Supplementary Section 1. Supplementary Section 7 provides an illustrative example (with quotes) of how the negotiations played out in the discussions.

Overall, we reviewed 20-22 unique engagement documents for each of the three sub-projects (numbers differed based on how many people attended the focus groups and filled out the follow-on surveys). We collated a total of ~60 engagement documents into MaxQDA, and this formed the base data for our longitudinal analysis. Figure 2 details our methodology for the longitudinal analysis of engagement data.

Table 1 Examples of some of the research choices as well as choice options that were encountered in the project.

Question	Illustrative Examples of Choice Options
What type of extreme event to focus on?	Floods, storms, extreme precipitation
What type of analysis to conduct?	Whether to pursue a storyline, retrospective case study, climatological or other type of analysis for the type of extreme
Which specific extreme event/s in the regions were most relevant to further examine or create storylines for?	Hurricane Irma versus Hurricane Agnes
Which characteristics of the extremes to focus on?	Whether to focus on storm track and/or intensity and/or driving conditions
How to design the research experiment?	Which models, datasets, spatio-temporal domains, types of simulations, etc.
Which of the preliminary results were most salient for further analyses?	Whether to further examine intensity of worst storms or compounding storms, etc.
Which output metrics to present results on?	Whether to focus on more physical/dynamical metrics like storm intensity or more impact-driven metrics like storm total or hourly precipitation or streamflow
How to connect the results about the drivers of extreme events to downstream impacts?	Connecting extreme precipitation events to flooding or streamflow

Note that this only describes choice options that were considered within the sub-projects.

Results

Change pathway for science

Through a systematic longitudinal examination of the evolution of three sub-projects (Hurricanes, Atmospheric Rivers, Droughts), we inductively identified the 'change pathway' (Fig. 3) for the project's science. Here we define 'change pathway' as the sequence of steps and processes through which the project's science evolved and transformed. This pathway focuses on how key research choices changed through co-production engagements with practitioners. In the subsequent sub-sections, we detail some of the key steps of this pathway, focusing specifically on providing empirical examples for 6 types of value negotiations.

Research Choices

Research entails a series of choices that researchers make throughout the scientific process. Our analysis revealed that each of our sub-projects were making many choices relating to research questions, scope, approach & methods, and results analyses. Each choice often represented a completely different research direction and therefore had a significant impact on the eventual actionability of the results. These choices also provided a natural opening for co-production engagements with practitioners. Table 1 illustrates some of the key choices that our researchers encountered considering the scope and goals of the project.

Another interesting observation was that several of our key choice options were brought up in later stages of the research process, once scientists were able to present preliminary findings to the practitioners. This was because practitioners were able to better identify specific research directions that would be actionable when they were presented with the magnitude and direction of change in climate that was expected, as opposed to at the beginning when research was first being conceived and expected results (or hypotheses) were still speculative. For example, in the drought sub-project's research journey (Fig. 4), the research question focused on how the characteristics of the 1962-66 Northeast drought might look like in the future. Once initial analyses were conducted, three preliminary results stood out: (1) Overall the precipitation increased in the region, (2) the 1962-66 drought is less likely in the future, and (3) shorter and flashier droughts were more likely. Once these were presented, the practitioners said that rather than focusing on how less likely the 60 s drought would be or how much more precipitation the region would receive in the future, it might be more useful to explore flash droughts in detail as they could have significant impacts on how agriculture, ecosystems, and reservoirs would be managed. They also suggested that timing and frequency of such flash droughts could be important for management, as these events were not typically experienced in the region.

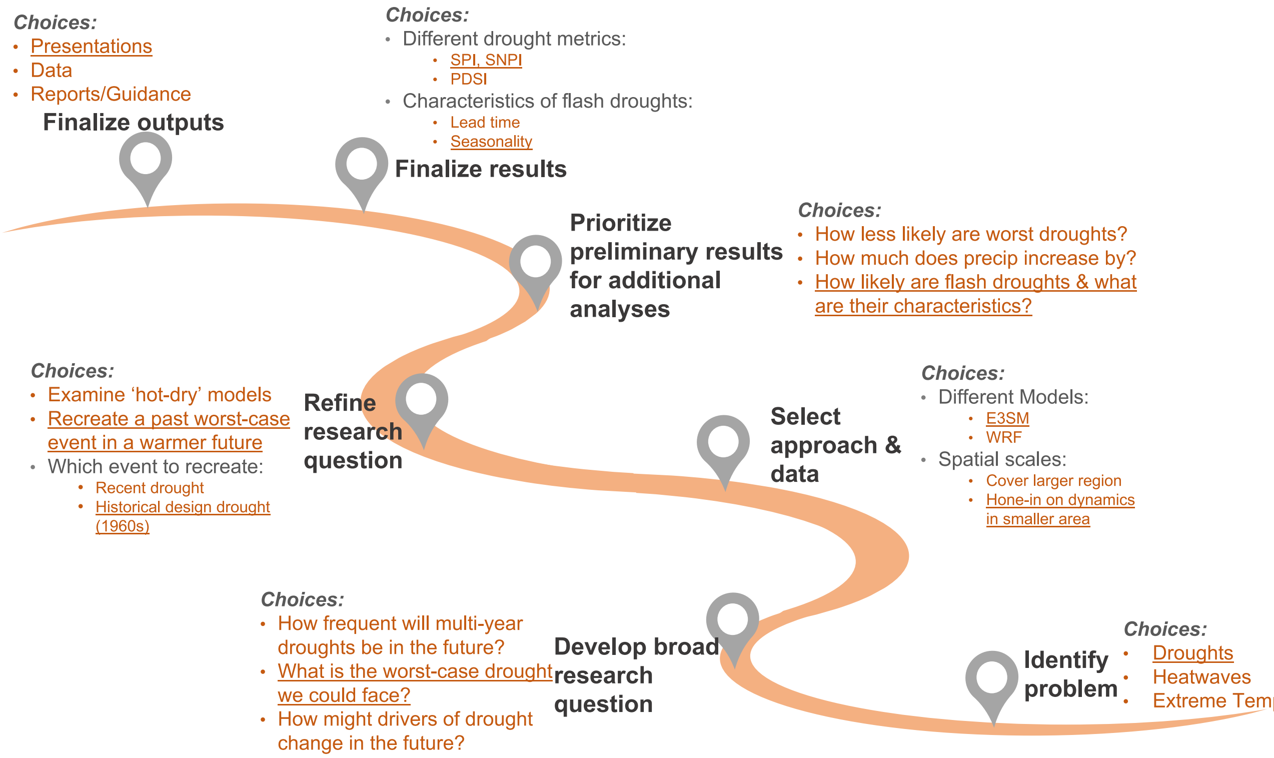

Fig. 4 Generic research process along with specific choice options encountered in the Drought sub-project. The figure showcases the generic research journey that was broadly followed by all our sub-projects starting from identifying the problem, developing a broad research question, to prioritizing preliminary results and finalizing outputs. We also illustrate a sample of the specific choice options (orange text) that were faced in the Drought sub-project at different stages of this research journey. The underlined options were the ones that were finally chosen among the various options. Overall, the figure shows how each option could lead to very different types of research pathways.

This led to several new analyses that specifically focused on the flash drought periods (rather than of the longer drought). This direction was motivated primarily by the practitioners' interest and stemmed from conversation at the preliminary results stage (and could not have been anticipated at earlier stages of the research journey).

Diversification of values

Our longitudinal analysis confirmed that co-production had a significant impact on how research choices were being made in the project. Our results showed that in the absence of co-production engagements (for instance, in the initial stages of the project), scientists typically relied on their own values and judgments to make key research choices. Many of these values were scientific or epistemic in nature (guided by their disciplines), such as methodological soundness, research innovativeness, scientific standards, computational feasibility, publishability, etc. To a smaller extent, actionability-relevant values such as scientists' interest in improving the societal impact of the research and their perceptions of practitioner relevance for their work, also underpinned some of these choices. But when we sought practitioners' feedback on the research choices, it was apparent that while practitioners highly regarded the consideration of scientific values, they also suggested the consideration of a broader set of values while making these choices. These included values such as suitability for decision-making, standards in engineering/infrastructure management, relevance for resource management, etc. This led to a diversification of the types of values that were brought into consideration while making research choices. Figure 5 illustrates some of the most common values and interests that were held by scientists and practitioners. Over time, we saw many more instances where scientists automatically incorporated practitioner relevant values into their research even before engagements (such as considering standards in engineering/infrastructure), while practitioners had an increased appreciation for the epistemic

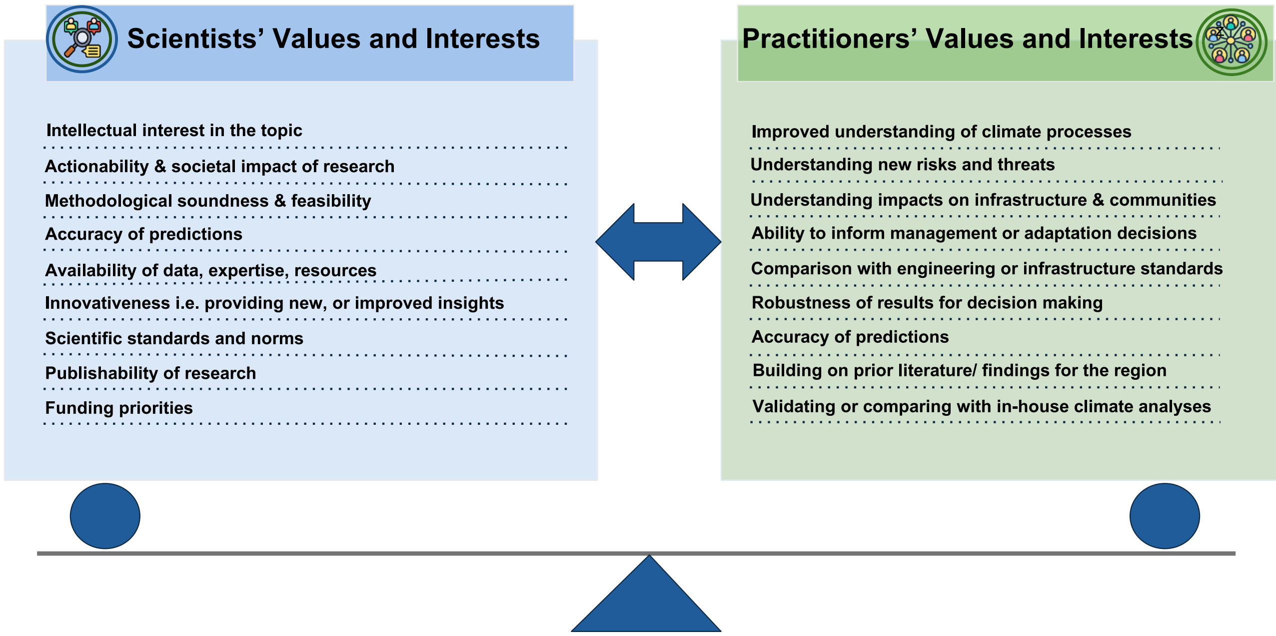

Fig. 5 Scientists' and Practitioners' Values and Interests. The figure provides a short list of the key values, interests and priorities that were brought up by practitioners and scientists during the co-production discussions.

values brought up by scientists (such as an increased value for credibility and skill assessment of models). Note that hereafter we refer to the term values to encompass both values and interests (i.e. contextualized values), since both together hold more explanatory power of the specific types of priorities and preferences that influence decisions on research choices.

Although we focus primarily on values associated with making key research choices here, some broader values that our scientists and practitioners held are also noteworthy. Both groups had mutual respect for each other's expertise, as well as an intention and commitment to making the project's research more actionable. The project's practitioners had an openness to deliberating about new scientific innovations, and how those could be useful in their decision-contexts. Finally, institutional priorities and preferences of the funder was also a key value that underpinned some critical aspects of the project. While they were not as prevalent in individual research choices of each sub-project, they played a significant role in the choice of broader areas of focus for the project, i.e., the focus on fundamental climate modeling. While it is possible that other structural factors beyond funding and institutional priorities might have also played a role in research choices, our work did not examine those specifically.

Value negotiations and impact on research choices

As a diverse set of values was brought to the table in the co-production engagements, this did not automatically imply that all these values were able to be considered or incorporated in making the research choices. The new values brought in by practitioners sometimes were compatible with scientists' values, but at other times clashed or were unclear, or were interpreted differently, and therefore needed further deliberations and negotiations for shared values or prioritizations on choices to arise (See Supplementary 7 for an example of how the negotiations played out in practice). After reviewing the negotiations that took place for each of the research choices for each sub-project, we identified 6 different types of value negotiations that played out within the project (Fig. 6). Below, we further discuss each of these 6 types along with examples of how they changed (or did not change) the research choices in our sub-projects.

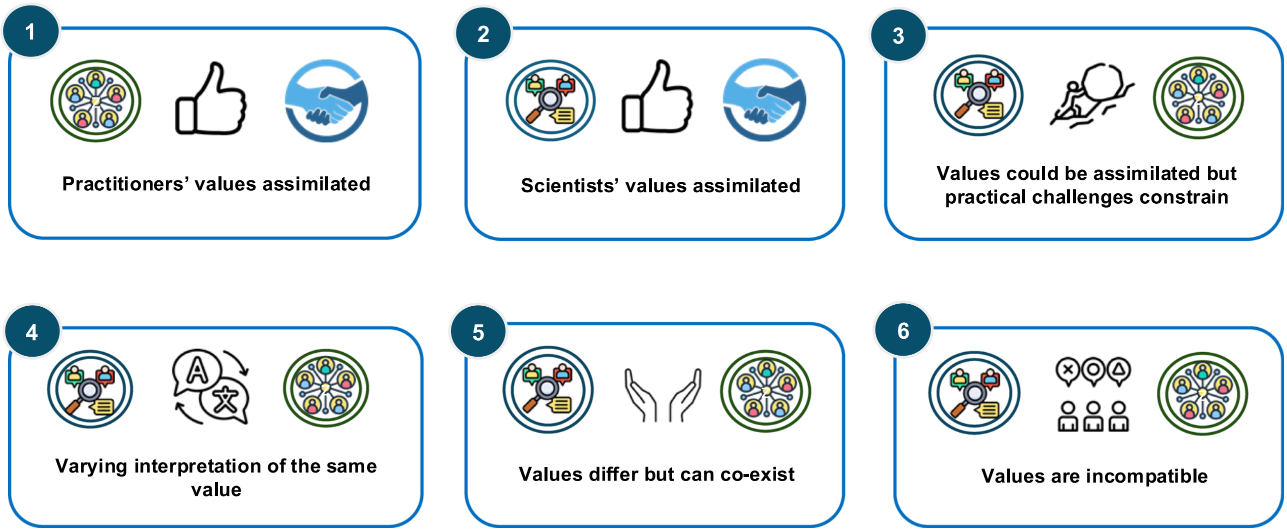

Fig. 6 Six types of value negotiations that were prevalent in the project. 1. *Practitioners' values assimilated by scientists:* Scientists acknowledged the importance of practitioners' values for the research choice and integrated their priorities into the research choice 2. *Scientists' values assimilated by practitioners:* Practitioners acknowledged the importance of the scientific principles and priorities suggested by scientists for the research choice, despite initial reluctance 3. *Values could be assimilated, but practical challenges constrain*: Scientists and practitioners agree (principally) on a set of values, but practical challenges constrained the integration of these values into research choices 4. *Varying interpretation of the same value*: Scientists and practitioners held the same values, but their definition or interpretation of that value differed 5. *Values differ but can co-exist:* Scientists and practitioners maintained differing perspectives even after negotiations, but both their differing priorities could be incorporated into the research choice (i.e., there was passive assimilation of values as opposed to the active assimilation in 1 & 2) 6: *Values are incompatible:* Scientists and practitioners continued to have differing perspectives on the research choice even after negotiations, and a shared path could not be reached within the context of the project.

Practitioners' values assimilated by scientists

Discussions surrounding the choice of the extreme event that the sub-projects would focus on, were some of the most prominent examples of practitioners' values and priorities directly being integrated into a research choice. Following are two examples of this type of value negotiation:

- In the Hurricanes research, initially, the scientists were looking to analyze a single prominently impactful event that had historically caused a lot of destruction in the regions of interest (i.e., Hurricane Irma in 2017), and that was methodologically feasible to examine within the project's approach. However, when this choice was discussed with the practitioners, they clarified that from a management perspective, many different types of extreme events (including other hurricanes with different characteristics from Irma) could potentially cause destructive impacts to ecosystems, infrastructure and/or communities. These were not only the most extreme and well-known events but also the near-miss events, the lower-than-tropical storm-threshold rainfall events, events that were untimely, or events that occurred when antecedent conditions were already saturated (e.g., sequential events). Overall, they cared about a larger range of extreme storm types than only the most extreme or most prominent. Taking heed of these values, the scientists expanded the analysis to focus on not only a single event but all of the hurricanes that occurred in the 2020 hurricane season as well as the evaluation of synthetic gray swans (i.e. high impact, rare but plausible events) that fit the practitioners' relevance criteria.
- In the ARs research, the initial discussions also focused on whether to pick a worst-case AR event (such as a black-swan event or what is referred to in California as an ARKstorm (Porter et al. 2011)) or a moderately extreme one (such as a design storm) for the storyline analysis. Upon discussions, practitioners revealed that for the Western US, ARs were seen as both beneficial and destructive. That is, ARs were important not just in terms of their destructive flooding but also in terms of their beneficial contribution to water supply. Therefore, they wanted a

better understanding of how the entire distribution of AR events may shift in the future (including both tails of extremes, and everything in-between) rather than only understanding how one single type of worst-case storm scenario will play out in the future. While the scientists acknowledged and agreed with these practitioner values, focusing on the entire distribution of ARs also meant that the team needed to de-prioritize the storyline-type analysis at that time (since studying the distribution of AR events required a different methodological approach and research scope). While there was initial hesitation to change the research direction, the scientists eventually decided to prioritize studying the impacts of climate change on the distribution of different types of AR events from beneficial to destructive, and delay the storyline analyses (which were done later in the project).

Scientists' values assimilated by practitioners

In some cases, as discussions progressed, practitioners would assimilate the values and priorities that scientists would bring up even when these values were not initially considered by the practitioners. This type of value negotiation was seen during discussions about presenting our sub-project's results at different Global Warming Levels (GWLs) rather than at different time periods. Representing regional climate responses at different global warming levels (e.g., at 0.5°C, 1.0°C, 1.5°C, 2.0°C of warming above a specified baseline, typically preindustrial climate) rather than at different time-periods (i.e. at 2050, 2070 or 2100) is increasingly regarded as an improved approach for climate change examinations (Goldenson 2023; Jagannathan et al. 2024). Scientists preferred the GWL approach because it is more robust to examine or isolate physical phenomena (such as AR responses) at warming levels rather than certain times. This also leads to more robust consideration of uncertainty by allowing for a comparison of physical process changes between models (e.g., AR characteristic changes) in a more "apples to apples" way since all model results are examined at a specific warming level (and not varied levels of warming as is the case in the time-period based analysis). The GWL framework also helps to avoid some other pitfalls and problems encountered in a time-based approach such as reducing dependence on emission scenario assumptions or taking care of the 'hot-model problem' (defined in (Hausfather et al. 2022)). Overall, scientists understood this to be a clearer and more robust framework to providing practitioner-relevant results and hence wanted to see if this new scientific standard would be amenable to practitioners. Practitioners appreciated the reduced uncertainty, and ability to include more model data in this framework, and also suggested that the framework was compatible with some approaches they have been working with such as the flexible adaptation pathways (in terms of signposts of when change in adaptation strategies is needed) or design standards examinations (such as deciding by when a changed design standard should be in place). But they simultaneously also said that the GWL framework would truly be actionable only if it was possible to also identify a time-period of when a particular warming level would occur, as most of their planning decisions are made on time horizons. In other words, practitioners suggested that converting warming levels to probable time-periods was essential for GWLs to be useful in a practical context. They also said that the utility of the framework may depend on the type of decisions, some types of decisions may be more amenable to this framework and others not as much. This was an example where practitioners assimilated a scientific value and made it amenable to their practical needs, so the decision was made to use the GWL framework for results but also provide parallel time-based answers. Over time the scientists have also been working on better ways of assigning time-periods to different warming levels to assist the practitioners in moving from warming level to time more seamlessly.

Values could be assimilated but practical challenges constrain

One of the most common value negotiations that we encountered was when the scientists agreed with the practitioners' values but were unable to integrate these priorities or considerations immediately, due to practical challenges. Most often these practical issues had to do with the scope of the effort required to integrate practitioner values. The changes needed, while of interest to scientists, were broader research efforts which required a completely new scope outside of the current analyses that were planned or conducted. For instance, as the initial AR results were presented, the main feedback from practitioners was that examining warm AR events leading to rain-on-snow events would be of interest. They suggested that understanding how rain-on-snow events may be impacted with future warming could be valuable particularly for watersheds where there are reservoir operations. They also wanted to identify the time-period when decreasing snowpack could lead to reduced risk from rain-on-snow events. The scientists agreed that this could be an interesting scientific area of inquiry, and that the available high-resolution model runs were well suited to examine these nuanced and specific water management domains more effectively. However, this was not a small add-on to the current AR research, but required a whole new scope & methodology, additional computational resources, and expanded personnel and funding to accomplish this in a timely manner. Therefore, the scientists could not immediately pursue this direction until these additional resources were available. However, we were able to propose this topic as a key focal area for the next phase of the project, and rain-on-snow was chosen as a key storyline for Phase 3 of the project.

We encountered similar practical challenges for other topical areas as well. In both the hurricane and drought sub-projects, when results were presented, practitioners suggested that in addition to knowing how much more intense these events would be in the future (which are typical results from a storyline analysis), they would also want to know how frequent those types of intensive events would be. While the scientists agreed with the importance of knowing frequency in addition to intensity, they explained that assigning probabilities to storylines presents conceptual and methodological challenges that would need a whole new research effort to properly examine. It was decided that this would also be a worthwhile topic to explore in the next phase of the project.

While the examples presented above highlight situations when we were able to pursue the suggestions from practitioners in the next phases of the project, there were also examples where we could not overcome the practical challenges in either finding the right expertise or resources to integrate the practitioner values, even though the scientists largely agreed with the practitioner values. For instance, several practitioners in California brought up the need to further examine streamflow temperatures and how they might challenge the management of endangered species. Although our scientists agreed that this is an important topical area, we have not yet been able to pursue this due to other competing priorities for the time and resources of the project.

Further, although this type of value negotiation most often played out as cases where the scientists faced practical challenges in incorporating practitioners' values, we sometimes also encountered the flip side, i.e., where practitioners agreed with scientists' values but could not fully incorporate these due to practical barriers relating to their institutional roles. For instance, practitioners would often state that they needed to work within established climate frameworks or institutional models or metrics that were historically used in their agencies even if they (in principle) agreed with scientists' values that more innovative and improved approaches, models or metrics could be better suited to their needs.

Varying interpretation of the same value

In some cases, co-production engagements highlighted that both practitioners and scientists held the same value, but their interpretation of what that value meant differed. So, negotiations involved deliberating and reconciling these different meanings, and coming to a common understanding about a value that reflected both the scientists' and the practitioners' perspectives. One example that occurred often in our project was that both groups brought up 'credibility' of the climate projections as a key value. In our discussions we noted that scientists looked at credibility of a climate model from a historical performance perspective, but practitioners looked at credibility in terms of whether management decisions can be made on future projections from the model. From a scientists' perspective, if a model was able to predict the past climate appropriately, then it was a strong basis for arguing the model is credible for future projections (from a scientific stand-point). However, practitioners required a lot more confidence on model performance for the results to be sufficiently credible for decision-making. For the results to be credible enough for decisions, practitioners needed these results to be compared to projections from other models or other estimations of change. As we interpreted from some conversations, science can be done (credibly) with one well-performing model (e.g. you can learn a lot about processes and how they change over time even with one model), but practitioner's decisions often have a higher bar on credibility, and hence cannot always be based on just one well-performing model unless those results are compared or corroborated against a broader set of credible models. This differing interpretation of credibility of our analyses, was by-far one of the toughest challenges that our project faced in terms of improving actionability of our results. Eventually, this discussion on credibility morphed into a new focal area of research where we are now exploring potential approaches to incorporate multi-model ensemble analyses (to add value to the single model analyses) thereby examining credibility from both the perspective of the scientists and the practitioners.

Values continue to differ but can co-exist

This type of value negotiation occurred during the discussions surrounding the choice output metric in which the modelling results should be presented. For instance, in all our sub-projects, initially, scientists chose output metrics that most appropriately describe the physical phenomenon that was being studied. For example, in the ARs research scientists focused initially on metrics such as Integrated Vapor Transport, AR path, intensity, etc., and for the Droughts sub-project they focused on metrics of low-flow, of meteorological droughts, etc. However, during the co-production, practitioners reiterated that they preferred results to be discussed in metrics that were more connected to the management relevant impacts. For instance in the ARs sub-project this included metrics such as AR category scale (Ralph et al. 2019), inter-annual variability in ARs, seasonality of ARs, AR-rich versus deficit years, timing between ARs, etc., and in the droughts sub-project this included very regionally specific drought metrics such as the Standardized Precipitation Index or metrics relevant to fish ecosystem health. The practitioners said that the more physically oriented metrics, while informative about the dynamics of the phenomenon, were not sufficient to inform issues such as reservoir operations, water supply adaptation planning, prioritization of investments, species management, etc.

In response to this feedback, the scientists brought up a key point, that there was a difference in the scale at which the physical phenomena (that drive the eventual impact on water management) play out, versus the scale at which management impact is experienced. Often the metrics scientists probe initially are the ones that are most tuned to the scales that drive the physical phenomena which are being studied, and the scales that can be credibly resolved with the computational resources and modeling capabilities of the team. In the purely scientific sense, there were discussions about how some of these more management-relevant metrics (e.g. threshold-based metrics) might not be as robust in capturing the results of the research as the more physically-driven metrics. Scientists reiterated that the model performance metrics for large-scale physical drivers are crucial to examine and understand, particularly if the model projections will be used to estimate future impacts on infrastructure and management decisions. Despite discussions about these two perspectives, the values of both groups continued to differ. However, the scientists agreed to additionally analyze some of these practitioner-relevant metrics along with the more physically-relevant metrics, showing how values could co-exist even if they continue to differ after discussions.

Values are incompatible

One of the biggest clashes in our project was whether our sub-projects should focus on cutting-edge innovative modelling approaches (such as new high-resolution dynamically downscaled simulations) or evaluating the more established and commonly used modelling products for which a legacy of trust building has already occurred (such as statistically downscaled datasets like Localized Constructed Analogs or LOCA, or dynamically downscaled products like the Weather Research and Forecasting Model or WRF). The main aim of this phase of the project was to undertake a rich and nuanced examination of how extreme events might play out in future climate scenarios (largely using storyline methodological approaches). Examining such nuanced physical feedbacks that shape extremes (such as orographic or hurricane-induced precipitation) require the use of high-resolution simulations which, often due to computational and/or personnel limitations, result in the use of a single climate model. While practitioners really valued the ability to look at key extreme event processes in a much more physically realistic and nuanced manner (it was one of the reasons they engaged with the project), they said that to make decisions based on the science, they need results to be compared or evaluated against more models as well as more established and commonly used datasets like LOCA or WRF. For several important (and often costly) decisions, they need to know whether the sign and magnitude of change across multiple models/datasets are broadly in agreement before altering currently employed management and risk profile estimates. However, scientists argued that some of these established datasets (like LOCA) were not at a high-enough resolution to probe the nuanced dynamics of these extremes at decision-relevant scales. Scientists also said that there was less innovation in "corroboration of results" through multiple models/datasets, therefore, such work tends to be less publishable in journals that were highly regarded in their disciplines. They also mentioned that the reward structures of their universities or research organizations often prioritized new and innovative research more heavily than corroborative research (even if the scientists personally found such work to be important). Further, there were also discussions on whether the scope of such comparisons are most effective within a project like ours, or they are better suited to other agencies such as different modelling centers/ groups, model intercomparison projects, national or regional climate assessments, that are often tasked with such comparative assessments.

Although this issue remained a significant incompatibility between scientists and practitioners of the project, we transparently discussed these issues. We engaged in critical discussions on when an innovative high-resolution model analysis can still be helpful (i.e., to help better understand how rare extreme events may impact their watershed), and when they might fall short in their usability (i.e., cannot ascertain how to change reservoir operations based on one model's projections). Finally, it was mutually decided that since the project's focus is to probe the nuanced physical dynamics of extremes, the project will proceed with using a single high-resolution model while also supplementing with ideas on how to broaden these examinations to other models or datasets. In fact, the practitioners urged our scientists to continue probing and improving the physical representation of key processes like landfalling AR characteristics or hurricane tracks in high-resolution models, as such fundamental research gaps were not being tackled in many other places. The degree to which these examples are 'truly' incompatible is debatable as some of these incompatibilities could potentially be overcome if some practical or institutional challenges were overcome (i.e., if there were more resources available to do the work, and also if there were research staff who did not worry about publishability of the results in high-impact journals). However, within the scope and context of the project - these were value differences that could not be overcome or maneuvered.

Discussion

Based on longitudinal empirical data from a long-term co-production project, we articulate a change pathway that describes how choices and underlying values in scientific research evolve through engagement with practitioners. While literature has alluded to some of the concepts within this change framework, in this paper we clearly articulate the sequence of steps through which science evolves in practice with co-production. Our work further advances literature on philosophies of climate modelling, by highlighting (and categorizing) real-world examples of value negotiations between scientists and practitioners, which is often discussed as a prominent gap (Pulkkinen, Undorf, Bender et al. 2022; Roussos 2024). Overall, our study demonstrates that co-production provides a conducive space for negotiations between scientists' and practitioners' values that leads to significant changes in research choices, thereby impacting the eventual actionability of research.

Messy nature of choice and value identification

For climate science to be actionable, users' values and priorities need to be integrated into the science (Maraun et al. 2026; Parker and Lusk 2019). Philosophers of science argue that in order to do this, scientists must first develop a critical awareness of research choices they make (Pulkkinen, Undorf, Bender et al. 2022), and then also be transparent about the values that underpin those choices (Roussos 2024). While our case study reiterates this importance of choice and value transparency, it also highlights that the process of identifying choices and values is far from straightforward. Often research choices occurred more organically and were hard to pin-point even for the scientists themselves. Much of the literature on choices and values is based on ex-post assessments of projects to conduct value mapping through mental models or surveys or interviews (Deitrick et al. 2021; Helgeson et al. 2024; Tuana 2013; Tuana 2017; Undorf et al. 2022) rather than monitoring values during the co-production process (Deitrick et al. 2021) as we did here. As we reviewed the engagement transcripts, we found that identifying broad choices (i.e., the broad research approach or question) was easy, but the specific nuances/options within those choices (i.e., choice between high-resolution model or a multi-model ensemble, or choice between studying the worst case storms or the moderate storms) were more difficult to reveal, as these were often implicit (Mayer et al. 2017). Further, not all choices were ex-ante identified by scientists alone, co-production served as a means to bring up and reveal key research choices. For example, practitioners in the project would provide ideas on using a different model or an analysis approach or examining a different type of phenomenon or region, which presented choices that were previously not considered by scientists in the context of that research.

Similarly, the nuanced value/s (or reasoning) underpinning each choice, as well as the types of value negotiations, were also harder to identify. Often multiple choices and values were being discussed simultaneously, and many different types of value negotiations were also occurring parallelly in the same conversation - making the entire process very messy and hard to discern (Deitrick et al. 2021). Even upon directly questioning the scientists (after the engagements) on their rationale for specific choices, it was hard for them to recall the specifics of the co-production conversations and how they played out (Arnott, Neuenfeldt et al. 2020; Elliott et al. 2025). Although the authors of this paper had a front-row seat to the engagements, tracing how a single choice and value negotiation evolved over time was still tricky. Our neat categorizations of the values and subsequently the value negotiations were a result of several rounds of ex-post review, analysis and synthesis of the engagement documents which enabled us to simplify some of the messiness to bring to light these patterns. Despite these tribulations, our decision to anchor the co-production engagements on key research choices was critical (Jebeile and Roussos 2023). Anchoring on choices not only provided a natural opening for practitioners' values to enter into the research but also provided a productive space for value negotiations to lead to course-corrections and refinements that impacted specific research choices in a tangible manner. Without anchoring on choices, value mapping and negotiations could simply end up being conceptual exercises without having traceable impact on the specifics of the research.

Our experience confirms what the philosophy of science literature has long argued: that values typically operate implicitly, through the interests and preferences that actors express rather than through explicit declarations of principle (Douglas 2009; Longino 1996; Pulkkinen, Undorf and Bender 2022). The fact that researchers could not always articulate the values driving their choices does not mean those values were absent, it means they were operating tacitly, which is the norm rather than the exception in scientific practice (Elliott et al. 2025). Pulkkinen, Undorf and Bender et al. (2022), in their empirical study, similarly found that structured reflection on values was most productive when grounded in deliberations on interests, options, priorities, etc. shaping technical decisions, rather than through abstract value-identification exercises that are divorced from practice. Our approach, which was anchoring on choices and then tracing the values expressed through preferences, priorities and interests in co-production discussions, represents a methodologically grounded way to surface value dynamics as they actually unfold in practice.

From value transparency to value negotiations

Further, some of the philosophy literature seems to allude that simply bringing practitioners and scientists together to transparently discuss different values and priorities, will lead to integration of different values in modelling (Undorf et al. 2022). However, we found that value transparency alone was not sufficient to diversify values underpinning research (Helgeson et al. 2024; Laursen et al. 2021; Schneider et al. 2019). Iterative value negotiations were critical for helping to understand what these values meant in the context of a choice and the tradeoffs involved in incorporating them into research.

The negotiations we experienced were not merely about selecting among alternative courses of action, they were negotiations between the competing interests, priorities, and commitments—that is, the values—that made particular choices contested in the first place. These negotiations clearly highlighted that scientists and practitioners typically perceive and handle environmental issues by different rationalities and thought styles (Fleck 1979; Pohl et al. 2017). When the practitioners advocated for management-relevant metrics and scientists advocated for physically-grounded metric, it was a negotiation around competing conceptions of what the research should prioritize and serve, each of which is grounded in distinct values. As Elliott (2017) argues, surfacing values enable scrutiny and accountability, even if it happens through attention to interests, priorities, and preferences. The added benefit of framing our analysis in terms of values is that it makes apparent why the disagreements arose, and what was at stake in the discussions and their resolution. Further, by categorizing the process and outcome of such value negotiations, our work also contributes to enhanced understanding of what actually happens (in terms of consensus, compromises, tradeoffs and negotiations) when bridging diverse perspectives into research, which has long been highlighted as a critical gap (Ankeny et al. 2011; Pohl et al. 2021).

We also found that having incongruous values (initially) was not always an insurmountable problem, but rather an opportunity for mutual learning of nuances and inspiring new and innovative research directions setting the stage for long-term co-productive benefits (Worsley et al. 2022). Particularly in a case like ours, where the group was generally committed to co-production, our negotiation examples were not always about whether a scientist considers the practitioners' values to be valid or vice versa (Dunlap et al. 2021; Roussos 2024). Rather, they were about creating a space to learn about and deliberate on the tradeoffs between scientists' and practitioners' values, and finding a mutually beneficial way to incorporate all relevant perspectives (Schneider et al. 2019). This process is where some of the co-production 'magic' happens, where certain tightly held perspectives from each group were deliberated, refined and broadened with a more diverse set of values and evidence (Jebeile 2024; Tuana 2013). For instance, these negotiations led to the scientists broadening their definition of extremes to include practitioner-relevant thresholds, and the practitioners now had an increased appreciation for epistemic values brought up by scientists.

As elucidated by other scholars (Bednarek et al. 2018; Goodrich et al. 2020; Goolsby et al. 2023), we also noted that the ability to interpret what value negotiations meant in terms of changes to research choices, was highly dependent not only on the mindset of scientists, but also on the ability of the boundary spanning facilitators to identify real action items from value negotiations and regularly follow up on them. Overall, our findings reiterate other papers that also suggest that well-executed user engagement that provides iterative avenues for reconciliation of tradeoffs (Jebeile 2024) and balancing values (Undorf et al. 2022) in various stages of the research (Helgeson et al. 2024), is critical in the quest for improving user-relevance of climate research. We also noted that, over time, scientists and practitioners integrated each other's values into their thinking. This was by far one of the most prominent successes of our project although it is yet to be rigorously evaluated.

Barriers and Limitations

Good intentions and co-productive engagements notwithstanding, two major barriers to successful value management were: (1) the practical and pragmatic considerations of scope and timing of research (Undorf et al. 2022) and (2) limited incentives for actionable sciences in current academic merit structures (Jebeile and Roussos 2023). In many instances, the main constraining factor for integrating practitioner priorities into research was not value disagreement, but rather the ability to pursue practitioner-relevant directions within the scope, time and expertise available within the project as well as within the university/research agency merit-systems that scientists needed to work in. A primary reason that we were successful in incorporating practitioner priorities (such as focusing on rain-on-snow or on assigning probabilities to storylines), was that the long-term fundamental nature of our project allowed us the time and flexibility to re-position and re-direct our work in every subsequent phase, based on practitioner input. In addition, the project leadership and funders strongly encouraged practitioner engagement and placed high value to the actionability of the science being produced.

As other researchers and practitioners seek to learn from our experiences, there are some limitations to be aware of. First, actionability and relevance to practitioners were key considerations for our scientists right from the outset of the project, despite their awareness that such work might not always be appropriately recognized within current academic incentive structures. Even the earliest of research ideas in the project were based on formal and informal discussions with practitioners, and there was mutual respect and trust between the scientists and the practitioners. This might not always be the case for other projects which are starting anew, and therefore they may face different types of value negotiations. However institutional changes such as creating better incentives for actionable sciences in academia and governmental organizations (Miyamoto et al. 2024), improving funding and administrative mechanisms to better support engaged research (Arnott, Kirchhoff et al. 2020; Bednarek et al. 2018), and better resourcing boundary spanners facilitating such collaborative research (Goodrich et al. 2020) can help to overcome some of these limitations, and make actionable and practitioner-engaged science the norm rather than the exception.

Second, although we had a diverse set of practitioners participating in each sub-project's working group (in terms of regions, decision-making roles, sectoral focus, etc.), this group was still a small and manageable number (max of 8 practitioners in each sub-project), making the value negotiation process a lot less complicated than it may have been with larger, more divergent groups (e.g., as indicated by Helgeson et al. 2024). The small sample also meant that only limited values and perspectives were being brought to the table. Finally, it is also important to note that our paper is based on 3 of the most iterative and successful sub-projects within the broader project's portfolio. Despite using the same principles and engagement strategies, there were some sub-projects where there was less interest and success in value negotiations. This could partly be because there was not enough time or boundary spanning resources available to these sub-projects for meaningful consensus or compromises to emerge.

Conclusion

This paper is a unique collaborative effort between social scientists, science philosophers as well as a diverse group of physical scientists and practitioners. Six of the co-authors of this paper are earth systems/climate modelers who were a core part of the co-production process and helped articulate our results. Through a longitudinal analysis of our long-term transdisciplinary co-production project, we developed a pathway that elucidates how and where changes in science occur and societal values can get integrated during co-production. We also extend the philosophical discussions of value management/negotiations in climate science by showcasing the nuanced roles values play and how negotiation and inclusion of user/practitioner values is not a simple one-time concern but requires iterative dialogue and deliberation across actors. The change-pathway as well as the negotiation-types that we developed can provide valuable perspective to other researchers, practitioners or boundary spanners who are interested in facilitating different value negotiation approaches, and in making their co-production processes more efficient.

The results also contribute to the growing literature in philosophy of science in practice (Ankeny et al. 2011) which calls for philosophical inquiry that engages directly with how science is actually conducted rather than analyzing it at distance. This aligns with views of philosophers of science such as Tuana (2013), who argues that bringing philosophy to the practice of science can lead to integration across disciplines and the creation of *"fluidity in our disciplined methods and expectations, and open opportunities for new knowledge production"*. Lastly, this paper responds to the call by Pulkkinen, Undorf and Bender et al. (2022) for the climate science community to engage more directly with questions of values and their management by documenting how values manifest in practice and how they can be negotiated in research meant for use in actionable contexts.

Philosophy of science brings an explanatory power to science in practice by surfacing dynamics and issues that are often hidden, in this case, the underlying "value" nature of research choices that participants themselves may experience but not articulate explicitly. Our grounded analysis of value negotiations in a co-produced climate science project can help those undertaking collaborative or transdisciplinary research approaches for environmental science and modelling, to better understand how they can embed philosophical value analysis within their scientific practices and approaches.

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Author contributions KJ led and coordinated the development of the manuscript. KJ, ADJ and SB co-led the design and facilitation of the co-production engagements that underpin this manuscript, with support from PAU. KJ and SB conducting the qualitative coding and analysis of the engagements. KJ and SB led the conceptual development and writing of the first draft of the manuscript with support from WJG, ADJ, and MM. PAU, KAR, AR, and CZ contributed to the refinement of the manuscript and provided detailed feedback on value negotiations and their influence on research choices. The broader HyperFACETS project team participated in many of the co-production engagements which form the basis of this manuscript. ADJ serves as the Principal Investigation for the coproduction engagement task within the HyperFACETS project. PAU is the overall Principal Investigator for the HyperFACETS project.

Declarations

Competing interests The authors declare no competing interests.

Ethical Approval This research has received ethical approval from Lawrence Berkeley National Laboratory's (LBNL) Human Subjects Committee (HSC) which is LBNL's Institutional Review Board (IRB #00006447). Approval was received prior to commencement of the data collection and prior to commencement of each engagement. Approval was received under two protocol IDs - Pro00023183 and Pro00023220. Pro00023183 was approved on 02/06/2020 (MM/DD/YYYY) and covered participant recruitment and data collection spanning from 02/06/2020 to 02/06/2021. Pro00023220 was approved on 01/15/2021 with participant recruitment and data collection spanning from 01/15/2021 and ongoing as the project is continuing (so this protocol covers all engagements after 01/15/2021). The scope of approval included the recruitment of participants, implementation of the engagements (focus groups and surveys), collection of data, analysis of the data, and reporting of results. This research (under both protocols) was determined to be "Exempt" Human Subjects Research by the LBNL HSC. All the research procedures and engagements were performed in accordance with relevant federal regulation, state and local laws, and the United States Department of Energy directives set forth by LBNL's Human Subjects Committee IRB. All research was conducted in the United States, so no other local approval is applicable.

Informed consent This research (under both protocols Pro00023183 and Pro00023220) was determined to be "Exempt" from the Common Rule (category 2(ii)) by the LBNL Human Subjects Committee and therefore does not require written and signed informed consent. A modified consent procedure was used according to LBNL Human Subjects Committee protocols Pro00023183 and Pro00023220. Informed consent was obtained from all participants prior to the research engagements (discussions and surveys) through sharing a consent form. All participants were above the age of 18 and therefore able to provide consent for themselves. Participants were asked to review the consent form and were notified that subsequent participation in the research engagements will be taken as consent. Engagement facilitators (KJ, SB and ADJ) shared the consent form via email as well as at the beginning of each engagement, both prior to participation in the research. The consent form included details of the purpose, background and funding for the research, the voluntary nature of the engagement, specifics of the engagement procedures, risks or benefits, storage of data and confidentiality, details of use of data for research and publications, etc. All participants were fully informed that findings from the engagements may be used in research publications but will be done in a manner that protects their anonymity. Informed consent was obtained separately for each focus group discussion and survey that form a part of this research. Dates when the informed consent was obtained are in the table below. Pre- workshop survey on storyline research ideas and feedback from practitioners: 02/28/2020, 03/03/2020; Kick-off workshop and co-produced research plan discussions for each sub-project: 03/17/2020, 03/18/2020; Focus Group Discussion 1, Practitioner Survey 1 and Scientists Survey 1 for each sub-project08/20/2020,09/04/2020, 01/22/2021; Focus Group Discussion 2, Practitioner Survey 2 and Scientists Survey 2 for each sub-project: 04/09/2021, 04/12/2021, 07/26/2021; Focus Group Discussion 3, Practitioner Survey 3 and Scientists Survey 3 for each sub-project: 05/27/2022, 06/01/2022, 08/12/2022.

References

Ankeny R, Chang H, Boumans M et al. (2011) Introduction: Philosophy of science in practice. European Journal for Philosophy of Science 1:303–307. https://doi.org/10.1007/s13194-011-0036-4

Arnott JC, Kirchhoff CJ, Meyer RM et al. (2020) Sponsoring actionable science: what public science funders can do to advance sustainability and the social contract for science. Current Opinion in Environmental Sustainability 42:38–44. https://doi.org/10.1016/j.cosust.2020.01.006

Arnott JC, Neuenfeldt RJ, Lemos MC (2020) Co-producing science for sustainability: Can funding change knowledge use?. Global Environmental Change 60: 101979. https://doi.org/10.1016/j.gloenvcha.2019.101979

Baldissera Pacchetti M, Coulter L, Dessai S et al. (2024) Varieties of approaches to constructing physical climate storylines: A review. WIREs Climate Change 15(2):e869. https://doi.org/10.1002/wcc.869

Bamzai-Dodson A, Cravens AE, Wade AA et al. (2021) Engaging with Stakeholders to Produce Actionable Science: A Framework and Guidance. Weather, Climate, and Society 13(4):1027–1041. https://doi.org/10.1175/WCAS-D-21-0046.1

Bednarek AT, Wyborn C, Cvitanovic C et al. (2018) Boundary spanning at the science–policy interface: the practitioners' perspectives. Sustain Sci 13(4):1175–1183. https://doi.org/10.1007/s11625-018-0550-9

Borie M, Mahony M, Obermeister N et al. (2021) Knowing like a global expert organization: Comparative insights from the IPCC and IPBES. Global Environmental Change 68: 102261. https://doi.org/10.1016/j.gloenvcha.2021.102261

Bremer S, Meisch S (2017) Co-production in climate change research: reviewing different perspectives. WIREs Climate Change 8(6):e482. https://doi.org/10.1002/wcc.482

Bremer S, Wardekker A, Dessai S et al. (2019) Toward a multi-faceted conception of co-production of climate services. Climate Services 13:42–50. https://doi.org/10.1016/j.cliser.2019.01.003

Brown MJ (2020) Science and moral imagination: a new ideal for values in science. University of Pittsburgh Press, Pittsburgh

Brown MJ (2024) For values in science: Assessing recent arguments for the ideal of value-free science. Synthese 204(4):112. https://doi.org/10.1007/s11229-024-04762-1

Chambers JM, Wyborn C, Ryan ME et al. (2021) Six modes of co-production for sustainability. Nat Sustain 4(11):983–996. https://doi.org/10.1038/s41893-021-00755-x

Collins M, Arienzo MM, Nieminen S et al. (2023) Effective Engagement While Scaling Up: Lessons from a Citizen Science Program Transitioning from Single- to Multi-Region Scale. Citizen Science: Theory and Practice 8(1). https://doi.org/10.5334/cstp.622

Deitrick AR, Torhan SA, Grady CA (2021) Investigating the Influence of Ethical and Epistemic Values on Decisions in the Watershed Modeling Process. Water Resources Research 57(12):e2021WR030481. https://doi.org/10.1029/2021WR030481

Douglas H (2000) Inductive Risk and Values in Science. Philos. of Sci. 67(4):559–579. https://doi.org/10.1086/392855

Douglas H (2009) Science, Policy, and the Value-Free Ideal. University of Pittsburgh Press. https://doi.org/10.2307/j.ctt6wrc78

Douglas H (2023) The importance of values for science. Interdisciplinary Science Reviews 48(2):251–263. https://doi.org/10.1080/03080188.2023.2191559

Dunlap L, Corris A, Jacquart M et al. (2021) Divergence of values and goals in participatory research. Studies in History and Philosophy of Science 88:284–291. https://doi.org/10.1016/j.shpsa.2021.06.015

Elliott KC (2017) A Tapestry of Values: An Introduction to Values in Science. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780190260804.001.0001

Elliott KC (2022) Values in Science, 1st edn. Cambridge University Press. https://doi.org/10.1017/9781009052597

Elliott KC, Resnik DB, Lipworth W (2025) Subconscious value influences on science. Studies in History and Philosophy of Science 114: 102079. https://doi.org/10.1016/j.shpsa.2025.102079

Fleck L (1979) Genesis and Development of a Scientific Fact (trans: F Bradley, TJ Trenn). University of Chicago Press, Chicago, IL

Gill D, Jagannathan K, Fujisaki-Manome A et al. (2024) Linking Boundary Organizations to Coproduce Actionable Knowledge: A Case Study of Ice Forecasting for Great Lakes Navigation. Weather, Climate, and Society 16(4):711–721. https://doi.org/10.1175/WCAS-D-24-0012.1

Goldenson N (2023) Understanding Climate Futures through the lens of Global Warming Levels. Cal-Adapt

Goodrich KA, Sjostrom KD, Vaughan C et al. (2020) Who are boundary spanners and how can we support them in making knowledge more actionable in sustainability fields?. Current Opinion in Environmental Sustainability 42:45–51. https://doi.org/10.1016/j.cosust.2020.01.001

Goolsby JB, Cravens AE, Rozance MA (2023) Becoming an Actionable Scientist: Challenges, Competency, and the Development of Expertise. Environmental Management 72(6):1128–1145. https://doi.org/10.1007/s00267-023-01863-4

Harvard S, Winsberg E (2022) The Epistemic Risk in Representation. Kennedy Institute of Ethics Journal 32(1):1–31. https://doi.org/10.1353/ken.2022.0001

Hausfather Z, Marvel K, Schmidt GA et al. (2022) Climate simulations: recognize the 'hot model' problem. Nature 605(7908):26–29. https://doi.org/10.1038/d41586-022-01192-2

Helgeson C, Keller K, Nicholas RE et al. (2024) Integrating Values to Improve the Relevance of Climate-Risk Research. Earth's Future 12(10):e2022EF003025. https://doi.org/10.1029/2022EF003025

Intemann K (2015) Distinguishing between legitimate and illegitimate values in climate modeling. Euro Jnl Phil Sci 5(2):217–232. https://doi.org/10.1007/s13194-014-0105-6

Jacob D, Lera St. Clair A, Mahon R et al. (2025) Co-production of climate services: challenges and enablers. Front. Clim. 7. https://doi.org/10.3389/fclim.2025.1507759

Jagannathan K, Arnott JC, Wyborn C et al. (2020) Great expectations? Reconciling the aspiration, outcome, and possibility of co-production. Current Opinion in Environmental Sustainability 42:22–29. https://doi.org/10.1016/j.cosust.2019.11.010

Jagannathan K, Buddhavarapu S, Ullrich PA et al. (2023) Typologies of actionable climate information and its use. Global Environmental Change 82: 102732. https://doi.org/10.1016/j.gloenvcha.2023.102732

Jagannathan K, Freitas N, Doherty O et al. (2024) Guidelines on appropriate use of climate projections in the Analytics Engine (v1.0). Cal-Adapt: Analytics Engine. https://analytics.cal-adapt.org/guidance/using_in_decision_making. Accessed 21 Sept 2025

Jagannathan K, Jones AD, Ray I (2021) The Making of a Metric: Co-Producing Decision-Relevant Climate Science. Bulletin of the American Meteorological Society 102(8):E1579–E1590. https://doi.org/10.1175/BAMS-D-19-0296.1

Jebeile J (2024) From regional climate models to usable information. Climatic Change 177(3):53. https://doi.org/10.1007/s10584-024-03693-7

Jebeile J, Crucifix M (2021) Value management and model pluralism in climate science. Studies in History and Philosophy of Science 88:120–127. https://doi.org/10.1016/j.shpsa.2021.06.004

Jebeile J, Roussos J (2023) Usability of climate information: Toward a new scientific framework. WIREs Climate Change 14(5):e833. https://doi.org/10.1002/wcc.833

Karcher DB, Cvitanovic C, Colvin RM et al. (2021) Is this what success looks like? Mismatches between the aims, claims, and evidence used to demonstrate impact from knowledge exchange processes at the interface of environmental science and policy. Environmental Science & Policy 125:202–218. https://doi.org/10.1016/j.envsci.2021.08.012

Kolstad EW, Sofienlund ON, Kvamsås H et al. (2019) Trials, Errors, and Improvements in Coproduction of Climate Services. Bulletin of the American Meteorological Society 100(8):1419–1428. https://doi.org/10.1175/BAMS-D-18-0201.1

Laursen BK, Gonnerman C, Crowley SJ (2021) Improving philosophical dialogue interventions to better resolve problematic value pluralism in collaborative environmental science. Studies in History and Philosophy of Science Part A 87:54–71. https://doi.org/10.1016/j.shpsa.2021.02.004

Lemos M, Arnott JC, Ardoin NM et al. (2018) To co-produce or not to co-produce. Nature Sustainability 1(12):722–724. https://doi.org/10.1038/s41893-018-0191-0

Lemos MC, Maillard L, Herbert N et al. (2025) Scaling up actionable climate knowledge. Proc. Natl. Acad. Sci. USA. 122(50):e2515771122. https://doi.org/10.1073/pnas.2515771122

Longino HE (1996) Cognitive and Non-Cognitive Values in Science: Rethinking the Dichotomy. In: Nelson LH, Nelson J (eds) Feminism, Science, and the Philosophy of Science. Springer Netherlands, Dordrecht, p 39–58. https://doi.org/10.1007/978-94-009-1742-2_3

Mach KJ, Lemos MC, Meadow AM et al. (2020) Actionable knowledge and the art of engagement. Current Opinion in Environmental Sustainability 42:30–37. https://doi.org/10.1016/j.cosust.2020.01.002

Maraun D, Bojovic D, Parker W et al. (2026) The Importance of Accounting for Stakeholder Values, Power Relationships and Language in Constructing Relevant and Trustworthy Climate Information. Earth's Future 14(1):e2024EF005618. https://doi.org/10.1029/2024EF005618

Mayer LA, Loa K, Cwik B et al. (2017) Understanding scientists' computational modeling decisions about climate risk management strategies using values-informed mental models. Global Environmental Change 42:107–116. https://doi.org/10.1016/j.gloenvcha.2016.12.007

Meadow AM, Ferguson DB, Guido Z et al. (2015) Moving toward the Deliberate Coproduction of Climate Science Knowledge. Weather, Climate, and Society 7(2):179–191. https://doi.org/10.1175/WCAS-D-14-00050.1

Miyamoto B, Mahlanza-Langer L, Tandon R et al. (2024) Engaged Research for Societal Benefit - A Call to Funders. Aspen Global Change Institute. https://doi.org/10.69925/AMXF5110

Parker W (2014) Values and uncertainties in climate prediction, revisited. Studies in History and Philosophy of Science Part A 46:24–30. https://doi.org/10.1016/j.shpsa.2013.11.003

Parker W, 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

Pohl C, Klein JT, Hoffmann S et al. (2021) Conceptualising transdisciplinary integration as a multidimensional interactive process. Environmental Science & Policy 118:18–26. https://doi.org/10.1016/j.envsci.2020.12.005

Pohl C, Krütli P, 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 K, Wein A, Alpers CN et al. (2011) Overview of the ARkStorm scenario. 2010–1312. Open-File Report. U.S. Geological Survey. https://doi.org/10.3133/ofr20101312

Pulkkinen K, Undorf S, Bender F (2022) Values in climate modelling: testing the practical applicability of the Moral Imagination ideal. European Journal for Philosophy of Science 12(4):68. https://doi.org/10.1007/s13194-022-00488-4

Pulkkinen K, Undorf S, Bender F et al. (2022) The value of values in climate science. Nat. Clim. Chang. 12(1):4–6. https://doi.org/10.1038/s41558-021-01238-9

Ralph FM, Rutz JJ, Cordeira JM et al. (2019) A Scale to Characterize the Strength and Impacts of Atmospheric Rivers. Bulletin of the American Meteorological Society 100(2):269–289. https://doi.org/10.1175/BAMS-D-18-0023.1

Redman S, Greenhalgh T, Adedokun L et al. (2021) Co-production of knowledge: the future. BMJ 372:n434. https://doi.org/10.1136/bmj.n434

Reed KA, Goldenson N, Grotjahn R et al. (2022) Metrics as tools for bridging climate science and applications. WIREs Climate Change 13(6):e799. https://doi.org/10.1002/wcc.799

Rhoades AM, Zarzycki CM, Hatchett BJ et al.(2024) Anticipating how rain-on-snow events will change through the 21st century: lessons from the 1997 new year's flood event. Clim Dyn 62(9):8615–8637. https://doi.org/10.1007/s00382-024-07351-7

Rhoades AM, Zarzycki CM, Inda-Diaz HA et al. (2023) Recreating the California New Year's Flood Event of 1997 in a Regionally Refined Earth System Model. J Adv Model Earth Syst 15(10):e2023MS003793. https://doi.org/10.1029/2023MS003793

Roussos J (2024) Managing values in climate science. Males J (ed). PLOS Clim 3(6):e0000432. https://doi.org/10.1371/journal.pclm.0000432

Schneider F, Kläy A, Zimmermann AB et al. (2019) How can science support the 2030 Agenda for Sustainable Development? Four tasks to tackle the normative dimension of sustainability. Sustain Sci 14(6):1593–1604. https://doi.org/10.1007/s11625-019-00675-y

Shenk L, Eells J, Gutowski WJ et al. (2025) Conceptualizing Coproduced Climate Research as Care: Practical Lessons Learned With Women Farmland-Owners in the Central Midwest United States. Climate Resilience and Sustainability 4(1):e70005. https://doi.org/10.1002/cli2.70005

Shepherd TG, Boyd E, Calel RA et al. (2018) Storylines: an alternative approach to representing uncertainty in physical aspects of climate change. Climatic Change 151(3–4):555–571. https://doi.org/10.1007/s10584-018-2317-9

Sillmann J, Shepherd TG, van den Hurk B et al. (2021) Event-Based Storylines to Address Climate Risk. Earth's Future 9(2):e2020EF001783. https://doi.org/10.1029/2020EF001783

Tuana N (2013) Embedding philosophers in the practices of science: bringing humanities to the sciences. Synthese 190(11):1955–1973. https://doi.org/10.1007/s11229-012-0171-2

Tuana N (2017) Understanding Coupled Ethical-Epistemic Issues Relevant to Climate Modeling and Decision Support Science. In: Scientific Integrity and Ethics in the Geosciences. American Geophysical Union (AGU)p 155–173. https://doi.org/10.1002/9781119067825.ch10

Undorf S, Pulkkinen K, Wikman-Svahn P et al. (2022) How do value-judgements enter model-based assessments of climate sensitivity?. Climatic Change 174(3–4):19. https://doi.org/10.1007/s10584-022-03435-7

Winsberg E (2012) Values and Uncertainties in the Predictions of Global Climate Models. ken 22(2):111–137. https://doi.org/10.1353/ken.2012.0008

Winsberg E, Oreskes N, Lloyd E (2020) Severe weather event attribution: Why values won't go away. Studies in History and Philosophy of Science Part A 84:142–149. https://doi.org/10.1016/j.shpsa.2020.09.003

Worsley JD, McKeown M, Wilson T et al. (2022) A qualitative evaluation of coproduction of research: 'If you do it properly, you will get turbulence. Health Expectations 25(5):2034–2042. https://doi.org/10.1111/hex.13261

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