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How uncertainty interacts with ethical values in climate change research

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Much climate change research aims to inform decision making in one way or another. A common vision of how science and ethics work together in this decision making has science spelling out the (probable) consequences of different policy options, while ethical judgments determine which option's consequences are most desirable. For example, climate projections and impact studies may suggest the likely consequences of different mitigation pathways, but ethical judgments are required to evaluate how good or bad those consequences are and how preferrable one possible future is over another.

While correct as far as it goes, this standard picture can encourage an overly sharp distinction between scientific activities and ethical deliberation. Far from entering only at the policy-making stage, ethical judgments often shape scientific research itself. This is most obvious in the choice of research questions. The choice of what to study ultimately affects what knowledge can be brought to bear in real-world decisions, including consequences for which (and whose) decisions can be made with the benefit of scientific insight. Such considerations are routinely referenced when motivating funding proposals and research articles. Of course, more purely scientific motivations such as fundamental discovery and filling gaps in knowledge are also critical in choosing research questions. In this way, a researcher's choice of what to investigate illustrates a central concept of this chapter: *coupled ethical-epistemic* choices [1].

A little terminology is needed to unpack this jargon. We use the word *values* as a general term for the reasons or perspectives from which one evaluates something as good or bad. Applying this notion of values very broadly, any goal judged worthy of pursuit will be done so on the basis

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of values. Sometimes these will be *ethical values* such as concern for justice, human welfare, or environmental protection. (The overlapping concept of *social values* includes things valued by communities or individuals—like greenspaces or social services—even if these may not be recognizably ethical in nature. Here we use “ethical values” broadly to also include these social values.) In contrast, scientific findings can be valued for how they advance understanding, and scientific methods or models can be valued for their accuracy, reliability, or generality. These aspects of research are valued because they are thought to promote (or constitute) a central aim of science: gaining knowledge. Such values are often called *epistemic values*.

Many decisions made in the course of scientific research are coupled ethical-epistemic choices in the sense that their consequences can be judged both from the perspective of epistemic values (i.e., what are the contributions to scientific knowledge) as well from the perspective of ethical values (i.e., what are the upshots for policy, society, and the environment). Coupled ethical-epistemic choices can be found at any spot along the continuum of research-design choices from the broad end of choosing and refining research questions to narrower decisions regarding approaches to answering those questions, specific methods, and interpretation of results.

Scientific training tends to focus on epistemic values—especially when it comes to the narrower, finer-grained research choices. In this chapter, we draw attention to the ethical values that are often linked to the same choices. Our aim is to encourage more deliberate and more reflective engagement with the ethical components of these choices. The topic of this volume is uncertainty in climate change research, and decisions about how to address sources of uncertainty in research provide a particularly rich arena for interaction between epistemic and ethical values. We present a series of examples of such interaction followed by a short list of recommendations on how to approach coupled ethical-epistemic choices in research.

ATTRIBUTION METHODS AND PUBLIC COMMUNICATION

Our first example concerns extreme event attribution [2]. Increasingly, climate scientists are investigating the extent to which particular extreme weather events, such as floods, droughts and heat waves, can be linked to anthropogenic climate change. Depending on the choice of method, different pictures can emerge regarding what can and cannot be attributed to climate change, with implications for public communication and litigation for damages.

The standard “risk-based” approach has been adapted from epidemiology [3–5]. Researchers attempt to quantify the change in likelihood of a weather event like the one observed, given rising greenhouse gas concentrations. This is done via climate modeling studies that compare the frequency of such event types across simulations driven by different greenhouse gas concentrations. In one set of simulations, historical (i.e., increasing) greenhouse gas concentrations are used; in the other, concentrations are held (counterfactually) at pre-industrial levels.

For a variety of reasons, studies following the risk-based approach can be inconclusive. These reasons include the difficulties and uncertainties in simulating the atmospheric circulation driving some types of extreme events [6], use of null-hypothesis significance testing to interpret simulation results, and use of “no change in likelihood” as a null hypothesis [6,7]. Failure to reject such a null hypothesis means that the possibility of no change in likelihood cannot be excluded at the chosen significance level, given available evidence. But careful and cautious statements such as this are sometimes misinterpreted in public discourse as saying something stronger and more conclusive, namely that there is no connection between anthropogenic climate change and the weather event in question.

Uncertainties about circulation notwithstanding, broad thermodynamic changes in the climate system such as rising sea surface temperature and increased moisture content are well understood as anthropogenic. Moreover, it is very plausible that these thermodynamic changes can make weather events, when they do occur, more intense than they would otherwise be. Critics thus worry that the (often inconclusive) risk-based approach to attribution will miss some valuable opportunities to communicate to the public, via salient events such as extreme floods, that climate change is already having negative impacts [8,9]. This line of thought has led to a second approach to attribution, sometimes referred to as the “storyline” approach. (Though note that the storyline concept is also used more broadly for communication, uncertainty characterization, and risk management beyond the context of attribution science [10,11].)

In general terms, the storyline approach to event attribution offers descriptive narratives of specific past events, with emphasis on understanding the driving factors that were involved in those events and that may shape future events as well [10]. Such an approach would typically ask: how did “known” thermodynamic changes in climate make a difference to the intensity of this particular weather event? To address this question, the first step is to simulate the extreme event as it occurred. The second step is to re-simulate the event removing the human-caused thermodynamic changes, e.g., making the nearby sea surface temperature cooler by a specified amount in the simulations. These studies very often do find a link between anthropogenic climate change and an extreme event of interest—specifically, an increase in intensity. For example, the conclusion might be that rising greenhouse gas concentrations, via their effects on sea surface temperature, increased a flood-causing storm’s precipitation by at least 30% [see e.g., 12,13].

The risk-based and storyline approaches ask different questions [7]. One asks whether increasing greenhouse gas concentrations have, all things considered, changed the probability of a given event type. The other brackets anthropogenic circulation changes and asks whether the thermodynamic consequences of increasing concentrations affected the intensity of a specific event, holding fixed the actual circulation that led up to the event. When applied to the same case, the two methods can give different answers (e.g., “no” and “yes” respectively) with no logical contradiction.

Given limited time and resources, which approach should attribution researchers prioritize? The considerations that have been aired in discussions contrasting the two approaches include not only aspects subject to epistemic values (different kinds of insights; different degrees of uncertainty in results) but also consequences judged by ethical values. The latter include purported differences in: messaging to the public regarding “links” from climate change to extreme weather; potential for misinterpretation of results; relevance of results for climate risk management; long-term effects on public trust in science; and potential for reputational damage to individual scientists [7,14].

Each approach to attribution thus comes with a bundle of features and consequences, some of which are important for epistemic reasons and some of which are important for ethical reasons. The ethical and epistemic merits of an approach can be judged separately, yet they are bound together in the same scientific choice. In this way, attribution methods illustrate the concept of coupled ethical-epistemic choices in research.

PARAMETER CHOICES AND THE CONSEQUENCES OF ERROR

A second example concerns the way in which method choices can affect the balance of *inductive risk*: the risk of erring in one’s scientific conclusions [15]. The errors at issue could be Type I (“false positives”) versus Type II (“false negatives”) or could concern overestimating versus underestimating a quantity of interest. A classic example is the choice of significance level used in null-hypothesis significance testing. This significance level (often fixed conventionally at .05) affects the balance between the relative risks of Type I and Type II errors. More broadly, choices between alternative datasets, modeling assumptions, or statistical algorithms can have analogous consequences for the risk of different types of error in the findings of a study [see e.g., 16,17].

As an example, consider the assignment of numerical values to uncertain parameters in a climate or impacts model (i.e., model calibration). When model output is compared to observations across a suite of performance metrics, some parameter assignments result in better model performance on some important metrics, while other assignments result in better performance on others [18]. A number of different model versions might fit the observations reasonably well and yet differ substantially in their projections. With different projections come different inductive risk profiles: for a given quantity of interest (e.g., precipitation extremes, heat stress, or crop loss), higher projections come with greater risk of overestimating that quantity while lower projections risk underestimation to a greater degree.

One approach to managing inductive risk is to make one’s method choices while giving some consideration to the potential consequences of erring in one way versus another. Would overestimating future precipitation extremes or crop losses be *worse* than underestimating them? If so, this could be factored in as the researcher chooses among the scientifically reasonable approaches to addressing the research question. Indeed, it has been argued that doing so helps the researcher fulfill her obligations as a moral agent, which include taking due care to avoid errors with particularly bad consequences [15,19]. Of course, the question of which consequences are particularly bad is informed by ethical values, not epistemic ones. In this way, consideration of the risks of error can generate coupled ethical-epistemic choices. (Approaches to transparently incorporating ethical values in the model-calibration example include risk-based calibration [e.g., 20] and careful definition of loss functions [21] when comparing model performance with observations.)

When facing research design choices, instead of choosing a single approach, sometimes several options can be tried, producing a range of results. Ensemble modeling studies, for instance, involve multiple simulations that incorporate different options for modeling equations, parameter assignments, or initial conditions. But ensemble studies can still involve uncertain method choices, such as specifying the boundaries of the “plausible” ranges for the parameters (or model structures) to be sampled. For these choices too, there may be a range of scientifically reasonable options with different associated risks of error. Indeed, it seems likely that almost every modeling study in the climate-change context will involve uncertain method choices with potentially different risks of error.

This does not mean, however, that ethical values ought to influence method choices in every modeling study, even if one is persuaded by the reasoning above. The inductive risk implications of some choices will be unforeseeable in practice [22,23]. And there might be overriding reasons for making choices on other grounds. For example, researchers might stick with “default” parameter assignments for the sake of more meaningful model intercomparisons, tractability, or to avoid upsetting an existing “balance of approximations” among model components. The case for ethical values influencing method choices seems most compelling when modeling is done in support of particular decision-making tasks, and where some method options have clear inductive risk implications that align better with the aims and values of stakeholders or clients. Such situations may arise, for instance, in the context of climate services [24,25]. In any case, whenever such precautionary thinking does lead to ethical values shaping method choices, this should be communicated clearly and transparently [24,26].

Ultimately, even if one remains unpersuaded that ethical judgments about potential errors ought to influence method choices, there is a crucial insight here that should not be overlooked: method choices that are not directly influenced by ethical values can nevertheless affect the balance of inductive risk in ways that serve the needs and interests of some stakeholders better than others. That is, even method choices that are not value-*influenced* can in an important sense fail to be value-*neutral*.

MODEL COMPLEXITY AND HIGH-IMPACT EVENTS

High-impact, low-probability events provide another example of interaction between ethical values and the treatment of uncertainties in research. By definition, high-impact events are those that are particularly dangerous or concerning—a judgment based on ethical values. Because they are of such concern, learning about the likelihood of high-impact events can be particularly important for understanding climate change impacts and assessing risk management strategies. (In the terms of specific decision-support frameworks, the probability of extreme, high-impact outcomes can, for example, have an outsize impact on expected damage calculations [27] and can shape the range of possibilities across which satisficing strategies are sought in robustness-based frameworks [28].)

The highest-impact events also tend to be low-probability occurrences, which can complicate uncertainty assessment [29]. For example, where uncertainty in projections is characterized through an ensemble of simulations, use of computationally expensive models can limit ensemble size and impede estimation of the small probabilities associated with high-impact outcomes [30–32]. A state-of-the-art Earth System Model may be the richest and most complete encapsulation of knowledge relevant to, e.g., sea-level rise by century's end. Yet the large number of model runs needed for ensemble-based uncertainty quantification of extreme sea-level rise may be feasible only using faster, more idealized models [33–35]. In this way, some of the scientific or epistemic merits of models can, in practice, trade off against the *relevance* of the questions that can be addressed using those models, where relevance is a question of ethical values.

DISAGGREGATION AND DISTRIBUTIVE JUSTICE

So far, we have discussed examples that specifically concern the treatment of uncertainties. Here we relax this focus somewhat in order to provide an indication of the broader character of coupled ethical-epistemic research choices in climate change research (which need not always link directly to the treatment of uncertainties).

There is a particularly rich and explicit role for ethical values when it comes to designing and assessing climate risk management strategies. To be relevant for decision makers and stakeholders, such analyses should characterize potential futures in terms that allow those actors to apply their own values to the decision problem [36]. What are these values? Climate change impacts people in many ways, and people care about those impacts from many different perspectives [37,38]. To give just one example, an interview-based study with community members in the city of New Orleans found that stakeholder views on coastal flood risk encompassed values such as concern for personal safety, property damage, broader economic impacts, sense of place, perception of safety, non-human welfare, distributive justice, intergenerational justice, and having a say in risk management decisions [39]. Each of these concerns provides a perspective from which projected outcomes and impacts can be evaluated (except for the last one, which is about *process* rather than outcomes).

Consider one specific concern mentioned above: distributive justice. In the context of local flood risk management, distributive justice addresses the fairness of how flood risk, or related costs and benefits, are distributed across communities and populations. Analysis of adaptation strategies (such as levees, evacuation planning, or funding programs for home elevation) that estimates costs and benefits only in the aggregate—e.g., for a whole city or region—will be blind to differences in the way that alternative strategies distribute risk across smaller units such as neighborhoods or households. For stakeholders who care about distributive justice, a distribution-blind analysis will fail to provide relevant decision support because those stakeholders will be unable to apply their values to the evaluation of the adaptation strategies [40,41]. (For related illustrations, see Khosrowi [42]; Parker and Winsberg [43].)

Estimating the effectiveness of adaptation measures with attention to distributive justice may require a more complex or disaggregated modeling framework that resolves neighborhoods or even households [40]. For example, Vezer et al. [41] contrasts two specific models used for coastal flood risk analysis in the state of Louisiana, including the city of New Orleans. Both models take flood hazards and adaptation measures as inputs and project the success of those measures as outputs. But one model [44] includes detailed and disaggregated spatial information while the other [45] works with a simplified and highly aggregate representation of the study system. The models also differ in their usability, adaptability, and transparency [41]. At the same time, model choice is, as always, subject to a range of *epistemic* considerations concerning the accuracy and trustworthiness of a model's representations and projections. Like previous examples, here a single choice in the design of a study can have consequences both for the epistemic or purely scientific side of a study (including but not limited to the treatment of uncertainties) and also for the treatment of ethical values in the analysis.

CONCLUSION

We have presented a series of examples illustrating how choices made during the conduct of research can carry implicit value judgments or create side effects and consequences with ethical import. These consequences include what (and whose) questions receive scientific attention, how mitigation and adaptation strategies are evaluated, which impacts are prioritized, how science is communicated, and what kinds of errors are avoided. We have focussed on examples in which the research choices in question also shape how uncertainties are addressed: alternative attribution methods can subtly recast the research question and shift the burden of proof; model complexity can enable or constrain the characterization of ethically important uncertainties, and model calibration plays a key role in determining which uncertainties and which types of futures are characterized and how.

Many research choices are like these examples. On the one hand, they have consequences that might be judged from the perspective of ethical values, and on the other hand, they have consequences—regarding, e.g., the depth of insight or reliability of findings—that can be judged by scientific standards that express epistemic values. In other words, many research choices (perhaps even most) are *coupled ethical–epistemic choices* (see [46] and [47] for further illustrations). Scientific training naturally focuses on the epistemic side. Here we have highlighted the ethical side and the coupling of the two sides.

Once this coupling is recognized, many further questions arise, such as: whose or which values should be considered? How should we balance epistemic and ethical considerations when they are in tension? What are the best approaches for representing the tradeoffs between value considerations? How should the connections between epistemic and ethical considerations be discussed in scientific publications? For views on some of these questions, readers can consult [24,26,48,49]. Here, we close with some brief recommendations on first steps toward engaging with coupled ethical-epistemic choices (see [50] for related, complementary recommendations).

- **Develop an eye for the ethical side of research choices.** Make a habit of thinking through how your findings might be used and by whom. Ask questions like: Whose information needs does my research design serve? What value system does my policy-evaluation framework assume? Whose vulnerabilities does my approach to hazard mapping prioritize? Who might be disadvantaged by my research findings? What kinds of errors have I been most/least careful to avoid?
- **Discuss ethical values explicitly in research outputs.** Answers to questions like those listed under suggestion (1) can help readers to contextualize your findings and assess whether they are useful for a given purpose. Be transparent about your explicit and implicit working assumptions. Briefly explain how your research design balances relevant ethical and epistemic values. Note any tradeoffs between value considerations. Declare any motivating ethical priorities and, especially if the rationale for these priorities is not obvious, defend them.
- **Engage with end users and/or boundary organizations.** While there are many reasons to engage with decision makers, stakeholders, and boundary organizations, one important reason is to facilitate the alignment of research with stakeholder values and priorities [24,36].

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