# The IPCC and treatment of uncertainties: topics and sources of dissensus

Advanced Review

# The IPCC and treatment of uncertainties: topics and sources of dissensus

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Characterizing uncertainty in the assessment of evidence is common practice when communicating science to users, a prominent example being the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (ARs). The IPCC guidance note is designed to assist authors in the assessment process by assuring consistent treatment of uncertainties across working groups (WGs). However, debate on this approach has surfaced among scholars on whether applying the guidance note indeed yields the desired consistent treatment of uncertainties thus facilitating effective communication of findings to users. The IPCC guidance note is therefore a paradigmatic case for reviewing concerns regarding treatment of uncertainties for policy. We reviewed published literature that outline disagreement or dissensus on the guidance note in the IPCC assessment process, structured as three distinct topics. First, whether the *procedure* is reliable and leads to robust results. Second, whether the broad *scope* of diverse problems, epistemic approaches, and user perspectives allow for consistent and appropriate application. Third, whether the guidance note is adequate for the *purpose* of communicating clear and relevant information to users. Overall, we find greater emphasis placed on problems arising from the procedure and purpose of the assessment, rather than the scope of application. Since a procedure needs to be appropriate for its purpose and scope, a way forward entails not only making deliberative processes more transparent to control biases. It also entails developing differentiated instruments to account for diversity and complexity of problems, approaches, and perspectives, treating sources of uncertainty as relevant information to users. 

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## INTRODUCTION

Established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), the Intergovernmental Panel on Climate Change (IPCC) is recognized as the preeminent boundary organization on climate change. It aims at providing policymakers and other stakeholders (henceforth *users*) with an assessment of the most recent scientific, technical, and socioeconomic information produced worldwide relevant to the understanding of climate change. The IPCC does not conduct any original research or monitor trends related to climatic parameters. Instead, the IPCC enlists scientists to participate in the assessment of this body of knowledge and report their findings in Assessment Reports (ARs). The assessment process takes place within the terms

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and scope of three working groups (WGs), namely: physical science basis for climate change (WGI); its impacts, including vulnerability and adaptation (WG II); and mitigation (WGIII). As an institution that corroborates and synthesizes knowledge on climate change, it catalyzes important public policy decisions that also inform negotiations as part of the United Nations Convention on Climate Change (UNFCCC). Yet, guidelines issued by the IPCC to its authors as part of the assessment process (see Ref 1) are said to be inconsistently applied across WGs, with insufficient internal critical evaluation of their effectiveness in the assessment process. In more recent developments, the UK government initiated a Parliamentary Inquiry into the IPCC's Fifth AR (AR5), prompted by criticisms directed at the IPCC assessment process and concerns regarding robustness of conclusions reached.[2]

Using the IPCC's guidance note as an example, the aim of this review is to uncover and structure the diversity of topics and multiple reasons given in peer reviewed papers for dissensus in the treatment of uncertainty. The term 'dissensus' is defined in the Oxford dictionary as '*widespread dissent or disagreement in opinion; absence of collective unanimous opinion*'.[a] Accordingly, we find the terms 'disagreement',[3] 'dissent'[4,5] and 'dissensus'[6,7] being used synonymously in the debate on treatment of uncertainty by the IPCC. In this review, we have opted to interchangeably use the terms 'dissensus' and 'disagreement'. Our motivation is spurred by calls that action on '*climate change can only be understood from a position of dissensus, rather than artificially solved by creating consensus*' (Ref 8, p. 220). Such calls question the purpose and procedure of the guidance note, namely to achieve consensus among experts on the characterization of uncertainty of findings for policymakers. Therefore, our focus in this review relates to dissensus on the general procedural treatment of uncertainty, rather than delving into the specific assessment of uncertainties associated with a particular research finding.

## PREMISE AND PROBLEM-DEFINITION

The IPCC guidance note is '*intended to assist Lead Authors of the Fifth Assessment Report (AR5) in the consistent treatment of uncertainties across all three Working Groups*' (Ref 1, p. 1). The guidance note provides two metrics that are used in the assessment of evidence, namely a quantitative likelihood scale and a qualitative confidence scale. The guidance note should, in principle, enable authors to attribute a degree of certainty to scientific information as evidence for the description, attribution, or prediction of events occurring in the real-world. Therefore, the degree of certainty is an assessment of the external validity of scientific results. There are various reasons for critically assessing external validity, particularly in light of insufficient or imperfect knowledge or limits of scientific methods in a given context. For example, spatial heterogeneity may pose problems for assertions on global scales based on bottom-up approaches (upscaling), or assertions on regional scales based on top-down approaches (downscaling). Furthermore, temporal dynamics, for instance in the climate system or socioeconomic systems, may pose problems for predictions of future events. Information relevant to users, and degrees of certainty attributed to this information, are decided on the basis of expert judgments. Since there may be reasons to judge differently on relevance and evidence of information for policy, the IPCC has established a deliberative process among authors to come to an agreement, where this is possible. Consensus as inter-subjective agreement is crucial, given that for assessment findings to count as scientific requires inter-subjectivity of methods and results. However, any consensus builds on common ground. So, in view of the scope of problems, as well as scientific approaches and perspectives involved, one may ask where and to which extent common ground exists. In addition, agreement is not a guarantee for having taken the right decisions. A collective agreement might also be mistaken.

Attributing a degree of certainty to scientific information for policy remains a major challenge and issue of debate. Aware of this challenge, the IPCC continuously improves its guidance for authors in their assessment of uncertainty in scientific information. Starting with its first guidance document for the Third Assessment Report (TAR),[9] the second guidance document provided for the Fourth Assessment Report (AR4) proposed a quantitative likelihood scale and a qualitative confidence scale.[10,11] In its third version for AR5, the guidance note[1] was updated concurrently with reviews undertaken by the InterAcademy Council[12] (IAC) on the uncertainty assessment in AR4. The improved elaborations on terminology, construction and use of the likelihood and confidence scales are expected to allow '*consistent treatment of uncertainties across all three Working Groups,* [since the metrics are seen] *as a common approach and calibrated language that can be used broadly for developing expert judgments and for evaluating and communicating the degree of certainty in findings of the assessment process*' (Ref 1, p. 1). In 2011, the Journal *Climatic Change* published a special issue to enable '*wide-ranging discussion of IPCC's* *past and possible future approaches to the evaluation, characterization, and communication of uncertainty*' (Ref 13, p. 630–631), therefore attempting to clarify on problems voiced by the scientific community on the utility of the two metrics to assess and communicate uncertainty of findings.

## FRAMING THE REVIEW

Two questions guided our appraisal of concerns raised: *What are the topics of dissensus? and what reasons are given for dissensus?* In the course of the review, we focused our attention on discussions regarding three broad topics of dissensus: (1) the procedure to attribute a degree of certainty to a finding, (2) the scope of application of the metrics, and (3) the purpose of the uncertainty assessment to inform users. In his review of the guidance note for the TAR, Moss[14] grouped dissensus comments on specific aspects of the guidance note into four categories. His first category, '*failure to communicate with intended audiences*' relates to ***purpose*** of information for users. His second category, '*failure to harmonize the "confidence" language or develop a clear approach to "likelihoods" or probabilities*', relates to ***procedure*** of uncertainty assessment for an intended purpose. His third and fourth categories, namely '*inappropriately forcing one uncertainty characterization process onto three very different epistemologies*' and '*process problems that contributed to the application of the approach in the different working groups*', relate to ***scope*** of application (Ref 11, p. 649). While each of the categories by Moss combine a topic and a source of dissensus regarding TAR, we structure our review first based on topics of dissensus, namely: procedure, scope, and purpose, then elaborate on the various sources of or reasons for dissensus regarding each of these topics.

In order to substantiate these three topics, and identify respective sources of dissensus, we expanded our review of the 16 papers in the special issue of *Climatic Change* by searching both *Web of Science*™ and *Scopus* electronic databases. Details of the specific search protocol applied, including search terms and results obtained are provided in Table 1. The final sample extracted for this review amounted to 39 articles ($n = 39$; see Table 2). Given that the latest IPCC guidance note was published in 2010, we restricted and defined the temporal range for eligible articles to include articles published between January 2010 and the time this review was finalized (October 2013). An appraisal of the additional 23 papers confirmed that no further topics or reasons for dissensus were raised that were not already covered by the three broad topics identified, therefore deeming this structure as sufficiently stable for the purposes of this review. We note that approximately half of the articles were authored by individuals involved in IPCC assessment processes spanning TAR through to AR5, including two special reports: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)[50] and Special Report on Carbon Dioxide Capture and Storage (SRCCS).[51]

According to the guidance note,[1] consistent treatment of uncertainties entails three key aspects as part of the assessment process. First, authors are urged to '*treat issues of uncertainty*' by considering how to communicate the 'degree of certainty in key findings'. Second, authors '*review the information available*' through synthesis of all plausible sources of uncertainty concerning this body of evidence, including risks to the extent possible. Third, authors '*evaluate and communicate* [the body of evidence] *at the appropriate level of precision*'. Here, authors procedurally apply calibrated language to '*communicate the degree of certainty in key findings*'. As suggested in the guidelines, this assessment process is neither arbitrary nor deterministic, but rather a deliberative process that seeks to limit or 'correct' subjectivity of individuals by providing traceable accounts of that deliberation (see also Ref 16). However, the extent that this procedure can be considered reliable, in that it delivers an inter-subjective assessment of uncertainty, is contingent on agreements based on value judgements, for instance on spatiotemporal resolution, parameterisation of models, or significance level for accuracy in empirical studies. Value judgements at every step of the assessment process give rise to dissensus.

## DEBATE ON TOPICS AND RELATED SOURCES OF DISSENSUS

### Procedure

The idea of a systematic treatment of uncertainty consists of assembling and aggregating relevant information and related uncertainties, then translating the aggregated result into a degree of certainty about this result. This idea is exemplified by ensemble modeling studies, which have become prominent not least because of the tasks of the IPCC.[52] Ensemble modeling studies produce a set of simulation results, e.g., on future conditions, based on variations of steps and/or elements in the modeling and/or computer simulation procedure to provide a spread of simulation results.[52] All sorts of uncertainties feed into the result. Having assigned probabilities to results typically by Bayesian techniques, these probabilities (be it single values or interval probability specifications) indicate a degree of experts' judgment, e.g., on future change

**TABLE 1** | Overview of Protocol Applied to Search for Literature for Review

| Review Protocol Stage | Review Procedure | Result |
|---|---|---|
| 1. Initial sample of papers for review | Search for relevant papers were conducted in two stages:<br>(1) Papers initially reviewed as part of *Climatic Change*'s 2011 special issue on the IPCC Guidance note, with additional relevant papers citing and/or discussing papers in the special issue and/or the IPCC's guidance note, since 2010.<br>(2) Additional search for papers conducted 25 July 2013 using the bibliographic databases Scopus and Web of Science. Search terms were as follows:<br>Scopus<br>(TITLE-ABS-KEY(ipcc) AND TITLE-ABS-KEY(uncertain*) AND TITLE-ABS-KEY(climat* change) AND TITLE-ABS-KEY(assess* OR judg* OR evaluat* OR guid*)) AND PUBYEAR > 2009.<br>Web of Science<br>Topic = (IPCC) AND Topic = (uncertain*) AND Topic = (climat* change) AND Topic = (assess* OR judg* OR evaluat* OR guid*), Timespan = 2010–2013, Search language = English. | Output from stage 1 ($n = 28$)<br>*Climatic Change* 2011 special issue ($n = 16$) and additional papers citing and discussing the guidance note ($n = 12$)<br>Output from stage 2) ($n = 417$)<br>Web of Science ($n = 213$)<br>Scopus ($n = 204$) |
| 2. Sample screening | Papers arising from search stages (1) and (2) were compared and checked for duplicates. Unique papers were combined into a single list. The papers were screened by title, and where necessary by abstract, whether they refer to the IPCC assessment process and/or direct reference to the guidance note. Papers downloaded for detailed review. | Number of papers identified as suitable ($n = 39$). |
| 3. Paper classification and review | Each paper is read and reviewed in detail, bearing on topics, and sources of dissensus. Each paper independently reviewed, compared, and verified for consistency. Final paper selection for review. | Final paper selection for review ($n = 39$). |

conditional on some emission scenario. Probabilities or interval probability specifications are then translated into a degree of likelihood. The qualitative confidence scale in the IPCC guidance note reflects the basic idea behind this construction. First, it proposes to assemble and aggregate the type, amount, quality, and consistency of evidence regarding various types of information, such as mechanistic understanding, theory, data, models, and expert judgment. Second, it proposes to attribute a qualitative degree of evidence and agreement on this aggregation, which is then combined into a degree of confidence. The procedure is based on a deliberative process, since both metrics do not work in the way of a deterministic algorithm. Instead, they need to be interpreted in application, i.e., they are contingent on value judgments in the course of application. Reasons for dissensus on this procedure rest on whether relevant results can be reliably classified with the proposed metrics. Some go further in their critique, voicing disagreement on the construction of the metric scales, or with the idea of aggregating different sorts of uncertainty. We further elaborate on these reasons as sources for dissensus.

First, the position that a degree of certainty is precise if it is attributable on a quantitative basis, as in the case of the likelihood scale, has been criticized.[14,34] The basis for this criticism stems from lack of traceability as to what evidence is included or left out.[22,26] Furthermore, given the inevitable role of value judgment,[49] the understanding of terms such as '*very likely*' is ambiguous.[22,31,39] In addition, the attribution of a certain degree of likelihood or confidence is not without doubt, thus giving rise to inconsistent characterization of uncertainties. Degree of certainty may differ depending on whether or not probabilistic methods were used,[26] types of methods used to calculate consistency of ensemble modeling results,[38] or on the choice of spatial aggregation scale.[38] Biases or inconsistencies in expert judgments may relate to characteristics of the events described,[27] or they may be due to group dynamics and heterogeneity of contributing authors.[41]

**TABLE 2** | Sample of Articles Reviewed

| | Reference | Article Title | Journal |
|---|---|---|---|
| 1. | Beck[15] | Moving beyond the linear model of expertise? IPCC and the test of adaptation. | *Regional Environmental Change* |
| 2. | Betz[16] | In defense of the value free ideal. | *European Journal for Philosophy of Science* |
| 3. | Bjurström and Polk[17] | Physical and economic bias in climate change research: a scientometric study of IPCC Third Assessment Report. | *Climatic Change* |
| 4. | Bray[18] | The scientific consensus of climate change revisited. | *Environmental Science & Policy* |
| 5. | Brysse et al.[19] | Climate change prediction: Erring on the side of least drama? | *Global Environmental Change* |
| 6. | Budescu et al.[20] | Effective communication of uncertainty in the IPCC reports. | *Climatic Change* |
| 7. | Curry[21] | Reasoning about climate uncertainty. | *Climatic Change* |
| 8. | Curry and Webster[22] | Climate Science and the Uncertainty Monster. | *Bulletin of the American Meteorological Society* |
| 9. | Ebi[23] | Differentiating theory from evidence in determining confidence in an assessment finding. | *Climatic Change* |
| 10. | Ekwurzel et al.[24] | Climate uncertainties and their discontents: increasing the impact of assessments on public understanding of climate risks and choices. | *Climatic Change* |
| 11. | Fischhoff[25] | Applying the science of communication to the communication of science. | *Climatic Change* |
| 12. | Gosling et al.[26] | A review of recent developments in climate change science. Part II: The global-scale impacts of climate change. | *Progress in Physical Geography* |
| 13. | Harris and Corner[27] | Communicating environmental risks: Clarifying the severity effect in interpretations of verbal probability expressions. | *Journal of Experimental Psychology: Learning, Memory, and Cognition* |
| 14. | Harris et al.[28] | Lost in translation? Interpretations of the probability phrases used by the Intergovernmental Panel on Climate Change in China and the UK. | *Climatic Change* |
| 15. | Hulme and Mahoney[29] | Climate change: What do we know about the IPCC? | *Progress in Physical Geography* |
| 16. | Hultman et al.[30] | Climate risk. | *Annual Review of Environment and Resources* |
| 17. | Jonassen and Pielke[31] | Improving conveyance of uncertainties in the findings of the IPCC. | *Climatic Change* |
| 18. | Jones[32] | The latest iteration of IPCC uncertainty guidance-an author perspective. | *Climatic Change* |
| 19. | Katzav et al.[33] | Assessing climate model projections: State of the art and philosophical reflections. Studies in History and Philosophy of Science Part B. | *Studies in History and Philosophy of Modern Physics* |
| 20. | King and Goodman[34] | Defense community perspectives on uncertainty and confidence judgments. | *Climatic Change* |
| 21. | Kuhtz[35] | Challenges posed by climate change: is environmental protection an ethical issue? | *Environment Development and Sustainability* |
| 22. | Mastrandrea and Mach[36] | Treatment of uncertainties in IPCC Assessment Reports: past approaches and considerations for the Fifth Assessment Report. | *Climatic Change* |
| 23. | Mastrandrea et al.[37] | The IPCC AR5 guidance note on consistent treatment of uncertainties: a common approach across the working groups. | *Climatic Change* |
| 24. | McSweeney and Jones[38] | No consensus on consensus: the challenge of finding a universal approach to measuring and mapping ensemble consistency in GCM projections. | *Climatic Change* |

**TABLE 2** | Continued

| | Reference | Article Title | Journal |
|---|---|---|---|
| 25. | Morgan[39] | Certainty, uncertainty, and climate change. | *Climatic Change* |
| 26. | Moss[14] | Reducing doubt about uncertainty: Guidance for IPCC's third assessment. | *Climatic Change* |
| 27. | Narita[40] | Managing uncertainties: The making of the IPCC's Special Report on Carbon Dioxide Capture and Storage. | *Public Understanding of Science* |
| 28. | Nicholls and Seneviratne[41] | Comparing IPCC assessments: how do the AR4 and SREX assessments of changes in extremes differ? | *Climatic Change* |
| 29. | O'Reilly et al.[42] | The rapid disintegration of projections: The West Antarctic Ice Sheet and the Intergovernmental Panel on Climate Change. | *Social Studies of Science* |
| 30. | Power et al.[43] | Consensus on twenty-first-century rainfall projections in climate models more widespread than previously thought. | *Journal of Climate* |
| 31. | Risbey and O'Kane[44] | Sources of knowledge and ignorance in climate research. | *Climatic Change* |
| 32. | Smithson et al.[45] | Never say "not": Impact of negative wording in probability phrases on imprecise probability judgments. | *International Journal of Approximate Reasoning* |
| 33. | Socolow[46] | High-consequence outcomes and internal disagreements: tell us more, please. | *Climatic Change* |
| 34. | Sterman[47] | Communicating climate change risks in a skeptical world. | *Climatic Change* |
| 35. | Tol[48] | Regulating knowledge monopolies: the case of the IPCC. | *Climatic Change* |
| 36. | van der Sluijs[4] | Uncertainty and Dissent in Climate Risk Assessment: A Post-Normal Perspective. | *Nature and Culture* |
| 37. | van der Sluijs et al.[5] | Beyond consensus: reflections from a democratic perspective on the interaction between climate politics and science. | *Current Opinion in Environmental Sustainability* |
| 38. | Vasileiadou et al.[49] | Exploring the impact of the IPCC Assessment Reports on science. | *Environmental Science & Policy* |
| 39. | Yohe & Oppenheimer[13] | Evaluation, characterization, and communication of uncertainty by the Intergovernmental Panel on Climate Change—an introductory essay. | *Climatic Change* |

Second, criticism has been raised on how both the quantitative likelihood scale and the qualitative confidence scale are constructed and expected to be used. The construction of the qualitative scale is a source of dissensus, given that it is not clear whether and how to conceptually distinguish between agreement, evidence and consistency, or whether these concepts are appropriate for the purpose.[32,46] Furthermore, both scales are criticized for being incomplete, since they do not systematically circumscribe areas of ignorance or controversy.[21,44] Ignorance may be due, for instance, to a lack of resolution on relevant scales or to controversy on hypotheses among experts who build on different assumptions or theoretical perspectives. If no degree of certainty can be attributed, information that is nevertheless relevant may be excluded or given minor attention. However, ignoring information which does not meet the conditions for attributing a degree of certainty may further lead to overestimation or underestimation of events (see also ***purpose***). Furthermore, the relation between the two scales seems unclear. In AR4, the two scales had two different purposes, namely to qualify on the one hand the level of scientific understanding (confidence scale) and on the other hand the level of specific findings (likelihood scale). This distinction seems to be blurred for AR5,[14,21] where the focus is put on the different requirements for application, namely the quantitative or qualitative characterization of information.

Third, arguments have been put forward to show that explicit distinctions between different sorts of uncertainties are important to avoid misinterpretations of uncertainty characterizations. This is exemplified with regard to structural model uncertainty, i.e., assumptions that enter modeling and scenarios.[21,26,30] In this context, it is worth noting that robust results, i.e., if different models or methods lead to similar results, do not provide a sufficient basis for high probability because robustness might be due to models which are not independent from each other or do not account for important variables or parameters.[43,52] Mastrandrea and Mach[36] summarize this critique by stating that, '*to this date, the theoretical and empirical foundation of model types within economics remains* *insufficient to allow for a consensus within the scientific community according to these principles. In other words, under the present state of the art, the uncertainties about the appropriate economic model structure would remain even if there is a consensus on the stylized facts*' (Ref 36, p. 688). O'Reilly et al.[42] criticize the very idea of assembling and aggregating information, then translating this aggregated result into a degree of certainty, given the diversity within a group of authors.

There are not only critiques, but also suggestions for how to move forward and improve on the current application of the guidance note metrics. However, just as the reasons for dissensus are heterogenic, so are the solutions proposed. Regarding possible group bias, it is suggested to go for more formal expert elicitations,[13] while others propose measures that focus on group composition and rules to improve common understanding through dialog. For instance, maintaining continuity within large author groups,[41] maintaining heterogeneity across WGs to promote mutual understanding of approaches,[14] or including risk communication professionals in the process.[47] Suggestions of more technical substance include improvements to the construction and application of the scales. For instance, '[combining] *uncertainty metrics at each stage of the synthesis process and move to a system of independent tracking of findings and their attendant uncertainties during the writing process*' (Ref 31, p. 751), or '*consistent application of agreed categories, along with accompanying explanations of the principal lines of evidence*' (Ref 23, p. 698). Others suggest using hierarchical logical hypothesis models as a structure for assembling the evidence and arguments in support of the main hypotheses or propositions.[21]

## Scope

Pluralism is a source of dissensus stemming from the broad scope of information covered in the IPCC ARs. IPCC findings cover not only the physical aspects of the climate system, but also vulnerabilities and adaptation of socioeconomic and natural systems to climate change, as well as policy and technology options for mitigation.[12] This broad scope of information comes with pluralism on many fronts (for a more general discussion of pluralism, see Refs 53, 54). First, there is pluralism with regard to topics or problems in diverse regions on multiple spatial and temporal scales. Second, IPCC assessment findings are based on diverse conceptual approaches and methods with different epistemic standards in diverse scientific communities in cross-disciplinary and cross-cultural settings. Third, there are multiple values and perspectives implicated in the review of scientific findings regarding impacts, risks and measures related to climate change. Different types of problems may call for different scientific approaches, e.g., risk analysis and assessment should account for diverse user values by appropriate scientific approaches, such as interpretative social sciences and humanities and their epistemic standards (see Box 1). Here, evidence has to be based on conceptual clarity in accounting for user values and perspectives, not only whether an event is probable or possible. Therefore, plurality of problems, scientific approaches, and user perspectives give rise to dissensus about whether it is appropriate to use a general procedure for uncertainty assessment across WGs.

BOX 1

### PLURALISM OF EPISTEMIC STANDARDS AND VALUES OF USERS

To determine a degree of certainty on inferences from scientific results about events in the real-world, not only the evidence but also the relevance of results for users must be considered.[55,56] For example, not only whether modeling results are robust, but also whether models have appropriate complexity and spatiotemporal resolution to support a certain statement of prediction or attribution. Relevance is about whether models represent those aspects of reality, which are of interest for a given purpose, while evidence is about how well models and results from simulations or experiments do in representing these aspects. Epistemic standards to assess evidence and relevance of results must be appropriate for the methodological approach and the problem or purpose of research. So, accuracy is an appropriate epistemic standard for evidence only in case of standardized empirical investigations, while robustness serves in case of ensemble modeling to provide information about the future. Evidence from case-studies does not inform about generalizable causal relations, but rather it is their diversity and complexity in the cases investigated that count for assessing effectiveness of proposed policies in a given context.[57] Epistemic standards that account for value perspectives of users are diversity and clarity, since the users' diversity has to be reflected, for example in reviewing evidence on risks related to impacts, adaptation, and mitigation measures. This requires that conceptual differences between value perspectives are clear, which is an analytical task of interpretative social sciences and humanities, such as philosophy.

There are various positions with regard to this critique. Morgan[39] takes an anti-pluralist position, arguing that '*the same uncertainty word can mean different things to different people and can also mean different things to the same person in different contexts … if one only uses words, with no linked probabilities, assessments can become almost meaningless*' (Ref 39, p. 708). However, focusing solely on probabilities restricts the scope of problems, approaches and perspectives to those amenable to reasonable quantification of uncertainty. Jonassen and Pielke[31] seem to take a weaker position, treating pluralism as an insufficient reason against a universal treatment. They argue that '*it seems unlikely that all differences in uncertainty treatment across WGs can be attributed to disciplinary idiosyncrasies, that is, differences in subject matter and methodology*' (Ref 31, p. 750).

Pluralists, contrary to the two aforementioned positions, would argue for multiple understandings of uncertainty to account for diverse problems, approaches, and perspectives. For example, Ebi[23] argues that the rationale behind both metrics in the guidance note has considerable plausibility when it comes to assessing information provided by the physical sciences. With regard to information for review by the IPCC, Hultmann et al.[30] argue that risk assessment has to be different, since there are multiple scientific approaches which frame risks differently due to diverse risk perceptions among users. Along similar lines, Beck[15] and Bjurström and Polk[17] argue that a disciplinary bias in uncertainty treatment leads to relevant information for policy being ignored. Hulme and Mahony[29] show there are very few contributions from social sciences if one excludes economics, while interpretative social sciences are completely missing. In tracing the impact of the IPCC in science itself, Vasileiadou et al.[49] track citations of IPCC ARs in different disciplines and regions. Their study finds that despite decreasing differences in representation of diverse disciplines, as well as in representation of authors from developed and developing countries, the different parties are still far from being connected to on an equal basis.

Jones[32] and Beck[15] argue that assessing socioeconomic and natural systems vulnerabilities and adaptation to climate change, as well as identifying mitigation options, is effectively dealing with 'wicked problems'.[58] Wicked problems manifest where there is not only disagreement on the framing of a problem, but also no solution that appropriately answers to any given construction of the problem. A reason for wicked problems is value uncertainty. Value uncertainty means that the diversity of what is at stake for the public is unclear, controversial, or not appropriately accounted for. In addition, policy options are not easily rankable due to trade-offs or unequal distribution of benefits and losses for different regions or social groups.[39] Agreement on the problem framing is, however, a necessary precondition for applying the metrics proposed by the guidance note. To differentiate this kind of uncertainty, the term 'deep uncertainty' is used[4,32] (see also Ref 39). 'Deep' does not indicate a degree of uncertainty, due for instance to a poor state of knowledge, but an entirely different uncertainty problem.

Another principal obstacle comes from diverse and variable contexts and causes, creating a problem for general statements across regions on spatial and temporal scales.[42] Although this problem is rarely mentioned among the sample of papers reviewed, it seems to be an ubiquitous issue given how statements from WGIII in the AR4 Summary for Policymakers state possibilities, e.g., that '*changes in lifestyle and behaviour patterns can contribute to climate change mitigation across all sectors. Management practices can also have a positive role (high agreement, medium evidence)*' (Ref 59, p. 12). Attributing a degree of uncertainty to generalized statements of a possibility is unclear and of not much value to policymakers in negotiating appropriate actions.[60]

## Purpose

Purpose deals with a general contention toward the linear model of expertise enshrined in the IPCC process.[4,5,15] In this linear model, the IPCC is said to privilege scientific knowledge as the authority on climate change, thereby constraining political deliberation on whether to react to this information and address problems on the ground.[15] In this context, the contested issue rests on how adequate the linear model of communication is at delivering perceived relevant knowledge, versus how the receiver understands this information.[4,5,15,29] Reaffirming this point, Hulme and Mahoney,[29] citing Jasanoff,[61] state that knowledge '*claimed by its producers to have universal authority is received and interpreted very differently in different political and cultural settings.* [Therefore], *revealing the local and situated characteristics of climate change knowledge … becomes central for understanding both the acceptance and resistance that is shown towards the knowledge claims of the IPCC*' (Ref 29, p. 714). The content of information that is communicated, and how it is interpreted by users, manifest as sources of dissensus.[32]

### *Content of Information*

Content refers to the substance and format of the information being communicated to users of ARs. With respect to content, the critiques expressed in the papers reviewed center primarily on skewed, biased, and incomplete knowledge provided by experts,[15,17,32,44] versus vague and irrelevant knowledge for context-specific needs from the perspective of the user.[5,13,25,26,30,32,34,39,40,46,48]

Concerning incomplete knowledge, Bjurström and Polk[17] state that preferential treatment is given to physical sciences as evidence for policy, resulting in a synthesis assessment that lacks sensitivity toward political, normative, and cultural contexts. Bjurström and Polk also contest the lack of knowledge from fields such as anthropology to inform on evidence for adaptation, despite its long tradition on the study of human adaptation to changing environments.[17] Jones describes a different take on the content that is privileged in the IPCC assessment reports, in that the guidance note is a source of bias for the information that is assessed. He states that the guidance note '*is most suited to communicating uncertainty in the natural sciences and natural hazard risks, but less suited to communicating social science findings, complex risks, and policy*' (Ref 32, p. 741). Risbey and O'Kane[44] as well as Curry and Webster[22] raise yet another shortcoming, where ignorance is not characterized or discussed in terms of implications for robust decision-making.[22,44]

As for content being relevant for users, the discussion is much more heterogeneous and broad, with most papers reviewed having stated a position on the IPCC's apparent lack of appreciation of relevance to users. Without understanding and integrating multiple and diverse user needs, attempts to further improve and standardize language for communicating uncertainty are taken for being insufficient or even misleading in meeting user requirements.[13,25,32] Fischhoff[25] explains that '*focusing attention on uncertainties may encourage people to think that nothing can be done until they are resolved. Science advances by confronting uncertainties. However, uncertainties critical to science may not only matter little for decision making, but actually distract from it*' (Ref 25, p. 703). Tol[48] suggests that the application of the guidance note only serves an internal need for consistency within the IPCC, and it is therefore less important to users of ARs who may only refer to excerpts of information.[48]

Given the emphasis on and importance of relevance to users in meeting their information needs, it begs the question just what would make this information relevant. There are several aspects of relevant knowledge discussed in the material reviewed. One aspect centers on what Gosling et al.[26] characterize as a temporal mismatch between publication of assessment findings and when information is needed to meet key policy deliberations and inform stages of the policy cycle. This is also a key issue raised by users, such as nation states, in their statements regarding the future of the IPCC.[60,62] Another aspect of relevance centers on the spatial resolution and aggregation of global versus regional findings. McSweeney and Jones[38] raise concerns regarding model outputs that may consistently indicate no detectable changes at a certain coarse resolution, yet may convey inappropriate information for users who need much higher resolutions relevant to their regions. Similarly, Morgan[39] asserts that '*despite years of modelling that seeks an optimal global climate policy, it should be obvious to all that what is optimal for the Inuit of Northern Canada, the Quechua and Aymara-speaking peoples of the Andes, or the Anglo population of Australia will not be the same*' (Ref 39, p. 717). Narita[40] argues on spatial and regional relevance for policymakers in developing countries with regard to the assessment process for the SRCCS. Narita[40] notes that major beneficiaries of carbon capture and storage (CCS) technologies, such as China and India, would have found limited information about the specificity of potential application of CCS in their regions, given that assessment findings were largely detached from those local contexts. Narita[40] concludes by asserting that the '*SRCCS has done little about building a consensus or shaping perception about CCS as a practical tool to be used in policy*' (Ref 40, p. 96).

There is dissensus on whether certainty of information is relevant to users. Hultman et al.[30] advise that despite '*advances in modelling, however elegant and useful for targeted analysis, may not satisfy the political demand for certitude*' (Ref 30, p. 292). Curry[21] on the other hand, contests whether this demand should be appealed to, stressing that '*when working with policymakers and communicators, it is essential not to fall into the trap of acceding to inappropriate demands for certainty*' (Ref 21, p. 730). Finally, from a security and risk perspective, other critics voice concerns regarding lack of knowledge and assessment on 'worse case scenarios', considered highly relevant in policy contexts, i.e., those high consequence yet low probability events that can result in considerable losses, rather than focusing on information on most likely scenarios.[5,34,46]

### *Interpretation of Information*

Interpretation of information refers to users' perception and understanding of the assessment findings in IPCC ARs. The assumption here is that simplified communication of facts, highlighting consensus, raises confidence in users that they have suitable and unambiguous information for policies formulation. However, arguments presented in the papers reviewed disagree with this assumption on two fronts.

First, simplification of complex information on degrees of certainty masks and down-plays the importance of nuanced and fine-grained reporting of diverse value judgements on evidence,[4,15,19,21,42,49] a point also raised by users who support reporting on dissensus to better interpret evidence presented.[60] Vasileiadou et al.[49] affirm that the logic of reasoning that underpins assessment of evidence, including where and how disagreements manifest, is not sufficiently transparent in the IPCC assessment process. Improving this transparency would better serve deliberation, interpretation, and reflexivity on evidence presented—among scientists and users alike, improving confidence in the quality of the IPCC ARs (see also Refs 4, 14, 18, 21, 23, 32). According to van der Sluijs[4] assessment findings that lack details on deliberation make policies vulnerable to scientific errors, insisting that robust and flexible policy strategies should take into account uncertainty and plurality in science.

Secondly, using calibrated language to report assessment findings does not necessarily remove the inevitable ambiguity on how this information is interpreted, given numerous factors for diverse understandings on a degree of certainty.[14,18,20,24,25,27,29,31–33,45,47] Several aspects are raised. One aspect is that the use of calibrated language to communicate degrees of certainty in findings is not sensitive to or congruent with nontechnical perspectives.[14,20,24,41,45] For instance Budescu et al.[20] in their study of understandings of IPCC probabilistic statements, find that *'the gap between the authors' intentions and readers' understanding of the probabilistic communications are large and systematic*' (Ref 20, p. 194). Furthermore, diverse assessments of uncertainty across all WGs, or inconsistencies between summary text versus full texts,[31] lead to confusion and misunderstanding in the eyes of information users.[29,32] Moss[14] warns that conflicting and diverse views on findings, without adequate disclaimers on the basis for this disagreement, provide an opportunity for special interests to further confuse and divert public discourse that would otherwise be more supportive of policy action. However, lack of standards with which to guide and frame deliberations on assessment can be problematic for the resulting findings that are then interpreted by users. As Katzav et al.[33] suggest, accepting a model as being fit-for-purpose is contingent on shared standards and understandings of what counts as 'fit-for-purpose'. In the absence of shared standards, agreement is reduced to arbitrary preferences, rendering the assessment process unreliable. Cross-cultural interpretations and diverse world views also provide additional complexity to the understanding of assessment findings, which may not match with IPCC intentions for unequivocal and unambiguous risk communication through probabilities. For example, translational and cultural nuances regarding language have been found to significantly influence the interpretation of findings.[27,28] Likewise, political ideologies act as powerful filters through which facts are perceived and therefore result in diverse interpretation.[47]

## DISCUSSION

Despite efforts to provide guidance on attributing a degree of certainty in findings, varying perceptions of whether and if so how the metrics in the guidance note are to be applied, persist. The focus of both IPCC's guidance note[1] and the special issue of the Journal *Climatic Change* in 2011 were on the consistent application of the likelihood and the confidence scale across WGs. However, our review has shown that the scope of application of the metrics is addressed in about half of the papers reviewed. Most papers reviewed elaborate on the procedure to attribute degrees of certainty to findings as well as on the purpose of the metrics in communicating to users. We summarize our review findings on topics and sources of dissensus in Table 3.

Regarding procedure for attributing degrees of certainty to findings, dissensus is on whether the metrics allow for a reliable process and robust results. Scholars have put forward arguments that question whether relevant results can be reliably classified with the proposed metrics, because of lack of traceability and differences between experts' judgments

**TABLE 3** | Summary of Topics and Sources of Dissensus Regarding the Utility of the IPCC Guidance Note[1]

| Topic of Dissensus | Utility of Guidance Note | Sources of Dissensus |
|---|---|---|
| Procedure | To attribute a degree of certainty (likelihood, confidence) to scientific information, based on consensus among experts | Reliability in procedure and robustness of results |
| Scope | To be consistently applicable across all three working groups | Consistency across and appropriateness for plurality of problems, epistemic approaches, and user perspectives |
| Purpose | To communicate clear and credible information to users | Relevance and clarity of information for users |

and biases in the deliberation process. These issues are highlighted in the guidance note, so we propose to consider how to improve the existing procedure, for example by providing more structure for synthesis and deliberation. Further arguments that have been put forward rest on the construction of the scales, for instance in that they currently exclude topics of ignorance or controversial information, are unclear in terminology or conditions for the application of the metrics. We see these points as arguments to reconsider which aspects of uncertainty have to be covered and how to adjust the metrics accordingly.

Regarding the scope of application of the guidance note, dissensus is on whether the metrics allow for appropriate and consistent understanding by authors when metrics are applied across diverse problems, epistemic approaches or perspectives. In the reviewed articles, it is argued that there are scientific approaches and problems to be covered by WGs that do not meet conditions for meaningful application of the metrics. Regarding impacts or measures, which strongly depend on the regional complexity and user values that typically vary in space and time, we want to highlight that general statements can only tell what possibly might occur. Furthermore, it is argued that one has to acknowledge that climate change presents problems of persisting deep uncertainty. We see these points firstly as arguments to reconsider the type of statements used to characterize different kinds of problems, such as contextualized statements about complex causes or impacts as information to judge where some impact would occur or some proposed policy would work.[57] Secondly, regarding uncertainty, these points speak for developing a more diversified structure to make explicit different kinds of uncertainties as relevant to users, and to account for epistemic standards of other scientific paradigms such as case-studies or interpretative approaches.

Regarding the purpose of the guidance note, dissensus is on whether or to which extent the metrics therein assist in constructing information that is relevant for and clear to users. In the reviewed articles, arguments are put forward that center on the metrics' influence on what is communicated to users, namely skewed, biased, and incomplete knowledge, if the focus is on what can be dealt with by the procedure while ignoring what is relevant to users. Other arguments question whether degrees of uncertainty can be clearly understood by users as information to be considered for taking decisions on policy, or whether policymakers may be misled, for instance when focusing on information with high degree of certainty while ignoring information on wicked problems. We conclude that both arguments feed into a basic critic, to reconsider the intended impact of uncertainty communication, captured in the phrase 'predict-then-act', and instead reframe the science-policy interface as a joint task of adaptive governance.

Taken together, these topics and sources of dissensus first and foremost reflect the immensely challenging task that is to be addressed in a manageable way, requiring trade-offs. This leaves us to ponder on how these trade-offs can be reduced by keeping the task manageable.

### BOX 2

#### FACILITATING POLICY-RELEVANT KNOWLEDGE THROUGH ADAPTIVE GOVERNANCE

The IPCC example is one of many instances that exemplifies 'scientific management' of knowledge and participation in the science-policy interface.[64] New frameworks and methods for opening up and democratizing deliberation on knowledge and its policy relevance are emerging.[65] Not surprisingly, numerous and diverse terminology to describe this movement are also emerging.[64,65] Despite this diversity, they are not necessarily inconsistent in their objective to propose pragmatic alternatives to the 'predict-then-act' model as strategies for reform.[64] Adaptive governance offers one such strategy, which aims at integrating science, policy, and decision making in flexible and robust systems (see Refs 64, 66–70 for examples of application and learned experiences). Dealing with deep uncertainties means exposing and working with the diverse values and interests embedded in the scientific knowledge given, as well as within political deliberations for policy and action. In this context, it is also worth noting calls to focus on context-specific effectiveness of policies, where conditions for transferability between cases are of greater relevance for institutional learning than generalizable assertions.[57] However, as Stirling[71] aptly warns, strategies such as adaptive governance are no panacea, in that '*it cannot promise escape from the deep intractabilities of uncertainty, the perils of group dynamics or the pertubating effects of power*' (Ref 71, p. 1031). Nevertheless, it offers tractable means to make these influences 'democratically accountable',[71] as appealed to by the types of reforms that are called for the IPCC in future ARs.[60]

## FUTURE DIRECTIONS

Any procedure for assessing uncertainty should be appropriate for its purpose. So, what can be learned from dissensus on whether communicating findings with a degree of certainty is what is relevant for and is clear to users? To the extent that WGs have to assess information on wicked problems with persisting deep uncertainty, there are good reasons for different judgments on which information is relevant and how certain findings are. As a way forward, we suggest to go beyond Hulme's[8] position that '[action on] *climate change can only be understood from a position of dissensus*' (Ref 8, p. 220). We propose to proceed from dissensus on a singular position toward consensus on a plurality of relevant, even controversial positions or findings, as assessment results for users. This accounts on the one hand for the purpose of consensus, which is to reach inter-subjectivity, and on the other hand for its limits, since any consensus may be mistaken, especially when it comes to problems with deep uncertainty. A consequence for the science-policy interface would be to interact on a different assumption, namely within frameworks such as adaptive governance (see Box 2).

Learning from dissensus on procedures for attributing a degree of certainty to findings serves several purposes: not only to make deliberative processes more transparent and consequently enabling control of bias,[63] but also to develop more differentiated instruments that treat sources of uncertainty as relevant information to users. Last but not least, a broader understanding of relevant information for policy, together with fostering a culture of learning about uncertainty in the policy process, better accommodates for plurality in uncertainty assessment to account for diverse problems, approaches, and perspectives.

## ENDNOTE

[a] http://www.oed.com/view/Entry/242116?redirectedFrom=dissensus#eid

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