Expert reports by large multidisciplinary groups: the case of the International Panel on Climate Change

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Abstract. Recent years have seen a notable increase in the production of scientific expertise by large multidisciplinary groups. The issue we address is how reports may be written by such groups in spite of their size and of formidable obstacles: complexity of subject matter, uncertainty, and scientific disagreement. Our focus is on the International Panel on Climate Change (henceforth IPCC), unquestionably the best-known case of such collective scientific expertise. What we show is that the organization of work within the IPCC aims to make it possible to produce documents that are indeed expert reports. To do so, we first put forward the epistemic norms that apply to expert reports in general, that is, the properties that reports should have in order to be useful and to help decision-making. Section 2 claims that these properties are: intelligibility, relevance and accuracy. Based on this analysis, section 3 points to the difficulties of having IPCC reports indeed satisfying these norms. We then show how the organization of work within the IPCC aims at and to a large extent secures intelligibility, relevance and accuracy, with the result that IPCC reports can be relied on for decision-making. Section 4 focuses on the fundamentals of IPCC's work organization--that is, division of labour within the IPCC--while section 5 investigates three frameworks that were introduced over the course of the functioning of the IPCC: the reviewing procedure of IPCC reports, the language that IPCC authors use to express uncertainty and the Coupled Model Intercomparison Project (CMIP). Concluding remarks are offered in section 6.

1. Introduction

Recent years have seen a notable increase in the production of scientific expertise by large multidisciplinary groups. Topics range from radioactive waste management to biodiversity, to genetically modified crops and, of course, climate change. The typical output consists in a written report that addresses multiple dimensions of the topic, displays a serious effort to assess and communicate the associated uncertainties and, most importantly, is supposed to help decision-making. The issue we address is how such reports may be written in spite of formidable obstacles: complexity of subject matter, uncertainty, and scientific disagreement.

Our focus will be on the International Panel on Climate Change (henceforth IPCC), unquestionably the best-known case of such collective scientific expertise. Whatever one thinks of IPCC reports, it must be acknowledged that the IPCC is used as a model for more recent instances of scientific expertise by large multidisciplinary groups, such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and that its reports serve as a reference in many discussions about climate change. IPCC reports have also been much discussed themselves. One stance, which we may characterise as political, is that the content of IPCC reports is fixed somehow independently from their writing process and that the composition of the reports essentially demands that authors align their public beliefs with a set of predefined claims. By contrast, we consider that IPCC reports should be seen as genuine epistemic objects, resulting from a true effort at producing useful and informative documents. Under such a conception of IPCC reports, their very existence calls for an explanation. If not by belief alignment, how is it possible that a group as large as the community of IPCC authors deals with the difficulties inherent in the challenge of writing expert reports on as complicated a topic as climate change? We provide an answer to this question that is half normative and half empirical, showing that the organisation of work within the IPCC aims to achieve the standards of scientific expertise along lines that are compatible with IPCC's productions carrying epistemic weight.

What we show, more precisely, is that the organisation of work within the IPCC aims to make it possible to produce documents that are indeed expert reports. To do so, we first put forward the epistemic norms that apply to expert reports in general, that is, the properties that reports should have in order to be useful and to help decision-making. Section 2 claims that these properties are: intelligibility, relevance and accuracy. Based on this analysis, Section 3 points to the difficulties of having IPCC reports indeed satisfying these norms. We then show how the organisation of work within the IPCC aims at and to a large extent secures intelligibility, relevance and accuracy, with the result that IPCC reports can be relied on for decision-making. Section 4 focuses on the fundamentals of IPCC's work organisation—that is, division of labour within the IPCC—while Section 5 investigates three frameworks that were introduced over the course of the functioning of the IPCC: the reviewing procedure of IPCC reports, the language that IPCC authors use to express uncertainty and the Coupled Model Intercomparison Project (CMIP). Concluding remarks are offered in Section 6.

2. Epistemic norms for expert reports

Decision-makers ask for expert reports when they want information on which they may ground their decisions. For this to be possible, expert reports have to display certain features or, in other words, to fulfill some epistemic requirements. To the best of our knowledge, no ready-made list of such requirements is available. Indeed, from the seminal papers of Hardwig (1985) and Goldman (2001) to the most recent contributions (e.g. Goldman 2018), the epistemology of expertise has been focused on the relationship between laypersons and experts, with a marked emphasis on the problem faced by the former of how to identify and choose the latter (see e.g. Selinger and Crease 2006). What we are after is more basic, somehow presupposed by the epistemological literature on expertise. Moreover it is focused on the products of expertise (Quast 2018) and therefore of relevance primarily to emitters of purported expertise. We are looking for properties that a document should satisfy to serve as a useful expert report and that experts should therefore aim for. The literature in epistemology contains several lists of traits of expertise or of clues that may be used to track it (e.g. Goldman 2001, Scholz 2018, Martini 2014 and 2019) out of which some such properties can be inferred. Based on this and with no claim to a proper analysis of the concept of expertise (something many authors identify as a misguided project), we offer that, to be of use to decision-makers, an expert report must meet, at a minimum, the three following requirements:

- intelligibility: laypeople can understand the report. Of course this implies local intelligibility: the meaning of all the words used in the report (including technical terms) and of the sentences that make it up is clear. But intelligibility also requires logical coherence, as the overall meaning of a document involving contradictions cannot be grasped.[1] What is more, an intelligible report is consistent, by which we mean that it is uniform as regards formal matters and the use of terms. Finally, the main conclusions of the report taken as a whole are easily identifiable and unequivocal—a property we may call "global intelligibility";
- relevance: the material provided by the report helps solve the decision problem at stake and no important dimension of this problem is overlooked. This implies that the questions that prompted the commission of the report are answered, but it often requires that some further questions are answered, too. Relevance is a delicate matter in general because of the dual nature of expert reports: on the one hand they should help answer a specific question or set of questions, but on the other hand they are meant to serve as reference documents, which can be consulted in case of uncertainty on any issue related to their subject matter. The first goal

[1] Notice that freedom from logical contradictions is compatible with the presentation of incompatible theories (but not with their assertion) and (to anticipate a bit) that, as a matter of fact, presenting incompatible theories is an essential part of what IPCC reports do.

prescribes informational concision or non-cluttering, which runs counter the informational richness required by the second goal;

- accuracy: the report is true to the best of our evidence and theories regarding the issues it broaches. This requires that the author of the report takes into account and fairly assesses the relevant theories or sources of evidence on the topics addressed by the report.

An important difference between these three properties is the extent to which laypeople can reckon whether or to what degree they are met. Laypeople can tell whether they understand or think they understand what a given report says, thereby assessing its intelligibility. They can also state whether all the questions they deem relevant with regard to a given demand are addressed. However, they usually cannot fully assess accuracy directly from the report, as they do not know what are the best among the available evidence and theories. Accuracy is therefore mostly inferred from what one knows about the author of the report, for instance from her track record, that is, her past successes and failures at cognitive tasks akin to the one under consideration. Conversely, the choice of an expert primarily aims to secure accuracy—with the consequence that the elements identified by Goldman (2001) as useful to choose an expert can also serve to assess the accuracy of her report.

Intelligibility, relevance and accuracy are not the only requirements that one may think of as bearing on expert reports. Other candidate requirements include confidence-arousing, trustworthiness, indisputability, objectivity or unbiasedness. However, we claim that intelligibility, relevance and accuracy are fundamental as properties of the reports themselves (as opposed to their authors). Accuracy is crucial in this respect. Indeed, as we understand it, accuracy is not compatible with bias with regard to the selection or assessment of theories or evidence. It also requires that the report is objective in the sense of taking into account the most salient perspectives on the problems at stake. Moreover, an accurate report is worthy of trust and, therefore, whatever hints at accuracy arouses confidence by the same token. It should finally be noted that intelligibility, relevance and accuracy are ideal properties of expert reports. A given report may fail to fully satisfy all three of them, however it should satisfy each of them to a substantial degree.[2]

But even this is in no way easy to achieve, not the least because our three requirements may clash with one another or with other desiderata. For example, technical terms which are hard to understand for non-experts often occur in the formulation of theories and therefore accuracy is noticeably more difficult to achieve under the constraint of intelligibility than otherwise. Moreover, intelligibility, relevance and accuracy may not suffice to elicit confidence, or ensure that the report be indisputable to such a degree as to deflect criticism inspired by intentional misunderstanding proffered in bad faith. For instance, intelligibility often calls for simplification, which in turn may provide an opening for criticism—be it made in good or bad faith—, or for the charge of bias. Last but not least, there is the overall constraint of timeliness: an otherwise excellent report that comes too late is of limited use; but timeliness puts additional pressure on the satisfaction of the other demands.

The difficulties in reaching intelligibility, relevance and accuracy are particularly acute in the case of scientific reports by large multidisciplinary groups. Moreover, the sheer number of contributors precludes that the norms of expertise be successfully pursued without an appropriate organisation of work. We now turn to IPCC reports and explain why it is difficult to have them fulfill the three requirements we have identified. IPCC's work organisation is investigated in the sequel of the paper.

3. IPCC Assessment Reports

[2] This formulation suggests that intelligibility, relevance and accuracy come in degrees. We think that this is indeed the case. However, we will usually refer to them as to all-or-nothing properties, in order to avoid unnecessarily complex formulations.

IPCC Assessment Reports (henceforth ARs) aim to assess the state of climate knowledge, evaluating the risks associated with climate change and human action on the environment, and developing different scenarios according to the type of action taken to decrease CO_2 and other greenhouse gas emissions. This assessment is based on the review of the relevant corpuses of scientific literature. As Jones (2015) also stresses, it is epistemically significant that the IPCC is not meant to lead original research—nor, for that matter, to produce new data.

IPCC ARs are primarily characterised by the breadth of their topic (climate change) and the range of the associated decisions (bearing on mitigation and adaptation). Writing them down requires a colossal amount of work, bearing on a staggering variety of issues. IPCC's enterprise eludes not only, of course, a single author, but also, especially given the time constraint, any small group of scientists. Nothing short of a wide, multidisciplinary community can be up to the task. For a given AR, this community comprises several hundred members, working in a plurality of scientific disciplines and belonging to different geographical areas. The community is divided into three working groups (WGs), each of which produces a separate document: WG1 focuses on the physics of climate and climate change, WG2 on mitigation of climate change, WG3 on adaptation to climate change. We will be concerned solely with WG1 and its contribution to the report. The fifth AR, AR5 issued in 2015, on which we focus, is 5,500 pages long, of which 1,500 are contributed by WG1. This contribution covers many different transdisciplinary subject matters, from clouds and aerosols to sea-level change, or again the methodological question of how to evaluate climate models.

It seems straightforward that the mere length of ARs makes it a challenge to reach global intelligibility. How to identify the main conclusions of such lengthy documents and to make clear that they indeed follow from their content is far from obvious. The length of ARs furthermore implies that even the requirement of consistency is difficult to achieve. In particular, it is not trivial to ensure that terms are used in a uniform way throughout extremely lengthy documents with a huge number of authors. The difficulty is here compounded by the multidisciplinarity of the community of authors, which makes it likely that some terms of art are initially not granted the same meaning by all members of the community, inducing violations of the condition that Miller (2013) calls "social calibration". This is a genuine worry when authors have different scientific cultures (Knorr Cetina 1999; Andersen and Wagenknecht 2013). The worry is practical but also normative: multidisciplinary enterprises typically involve more opaque epistemic dependence, where one "does not possess the expertise necessary to carry out independently, and to assess profoundly, the piece of scientific labor her colleague is contributing" (Wagenknecht 2016, p. 118), and less translucent epistemic dependence, where one does possess this expertise, than monodisciplinary ones (Wagenknecht 2014, 2016 chapter 7).

Local intelligibility is not very much less of a problem, as scientific theories are usually expressed with the help of mathematics and specialised vocabulary. This reduces ambiguity and enhances clarity for those who are able to understand but, on the other hand, it usually makes it impossible for an uninitiated reader to make sense of the different pieces of information. A further impediment has to do with the diversity of statuses that scientific hypotheses may have relative to confirmation. Within the relevant scientific community, it is usually clear whether a given hypothesis is well-confirmed or uncertain, whether it can be safely relied upon or is a topic for active research. But this subtle and usually tacit assessment of the plausibility of the hypotheses at hand is very difficult to communicate outside the relevant community. In the case of climate science, the problem is made worse by the fact that most projections are affected by uncertainty. Indeed, uncertainty is difficult to convey to the general public and scientists usually express it in ways that may be considered as too technical or ambiguous for laypersons.

Uncertain projections are not distinctive of climate science: they also characterise most scientific fields that call for expertise by large multidisciplinary groups. In the case of climate science, however, uncertainties stem from different sources. The first one is the incompleteness of empirical data themselves, which results in persisting uncertainty regarding some empirical phenomena (in the sense of Bogen and Woodward 1988). The second source of uncertainties of the classical sort is the use of computer models and simulations. The complex computer models that climate science massively resorts to involve their share of idealisations, *ad hoc* hypotheses, parametrisation choices… all of which are necessary for computational purposes but generate uncertainties in the results of simulations. The third source of uncertainty consists in the disconnectedness of the pieces of climate science. Climate is a highly complex system regarding which exist several pieces of firmly established knowledge, but these pieces are dis-unified, concerning phenomena at very different temporal or spatial scales, and there is currently no prospect of discovering systematic connections between all of them. The problem is not only that the physical and chemical laws driving the relevant interactions are not entirely known, but that scientists are clueless as to how to fill many of the gaps in their knowledge[3]. The resulting uncertainties are not, or not only, of the kind that is most classically associated with knowledge incompleteness, but are much deeper. It is particularly hard to give a fair idea of the size and nature of these various uncertainties, which are therefore an impediment to both consistency and local intelligibility.

That climate science is loaded with uncertainties is problematic also in connection with accuracy. To see this, let us come back to the idea that choosing the author of an expert report can be seen as a means for users of the report to aim to secure that it is (or rather will be) accurate. Following this idea, reports whose authors are not chosen by their purported users must hint at their own accuracy. This is what happens in the case of the IPCC, which stems from a joint action by the World Meteorological Organisation and the United Nations and treats questions that are self-assigned by the corresponding scientific community. But the uncertainties of climate science make the task especially tricky. How can one convince the layman that a document reporting many uncertainties, some of which are severe, is accurate and indeed presents the best of our theories and evidence? This is not obvious, particularly as ARs are collectively authored. As underlined by John (2020), “standard ways of assessing a human speaker’s trustworthiness may not apply well to assessing corporate speech” (p. 132)—and, as a matter of fact, Goldman’s proposal with regard to the choice of an expert cannot be straightforwardly relied on in the context of assessing the accuracy of a collective of authors.

Finally, the fact that climate science is affected by considerable uncertainty implies that rational disagreement, which is a normal feature of science in progress (Solomon 2008, Andler 2013), is more likely to occur in climate science than in other areas of science. In addition to being a potential threat to intelligibility, disagreement within climate science deepens the necessity and difficulty of showing that ARs are accurate. Indeed, as explained by Beatty (2006), disagreement between experts or within the scientific field from which they stem may be interpreted as showing that experts’ authority is usurped and their reports lack accuracy. In the case of climate change, the situation is compounded by the fact that disagreements percolate through to society at large and that, particularly in this arena, it sometimes stems from disingenuous criticism or from an irrational assessment of climate data or climate science literature. Specifically, IPCC ARs take part in the debate with so-called “deniers", that is, individuals who deny that climate change is real and/or that it has a human origin. An important episode in this debate is the “Climategate”. In 2009, a few weeks before the Copenhagen Summit on climate change, emails and files exchanged among climate scientists were leaked after the hacking of a server at the Climatic Research Unit at the University of East Anglia, and some of these documents were presented by climate change deniers or skeptics as evidencing significant manipulation of data by climate scientists, in an attempt to

[3] In fact, as Nancy Cartwright has been arguing, with increasing persuasiveness, for decades, there may be no scientific framework in which disparate pieces of science will in due time be stitched together (Cartwright 1999, 2016).

overestimate global warming. Significantly, IPCC WGI responded to this and quickly issued a statement supporting the accused authors.[4]

Relevance may seem the least problematic norm as regards IPCC ARs. Indeed, the breadth and generality of their topic seem to imply that just about any contribution to climate science addresses a question that is relevant with regard to IPCC's charge. But by the same token, the very breadth of ARs' topic, together with the fact that climate and climate change call for multidisciplinary study, makes it more of a challenge to ensure that no important question has been forgotten. More crucially, the fact the IPCC is not mandated by decision-makers aiming to solve some specific decision problems implies that ARs do not fully meet the requirement of relevance unless their content can be easily connected with every likely political query related to climate change. What this amounts to and how it can be achieved is in no way obvious.

The immensity and nature of the topic of IPCC ARs, as well as the resulting length of the reports themselves, not only contribute to make it difficult that these reports satisfy the norms that bear on expert reports. As we have seen, they also impose that ARs are authored by a very large and diverse community. Thereby, they preclude that the norms of intelligibility, relevance and accuracy be satisfied by more or less tacit and uncoordinated efforts. A well-adjusted organisation of work must be explicitly defined. We contend that in the case of the IPCC, the elaboration of such an organisation and the compliance with it were made possible by a solid common background. Climate science has solid and uncontested foundations, the climate science community has a long tradition of sharing data, methods and results at the international level, and climate scientists involved in IPCC's action share the conviction that climate change is occurring and that it is urgent to take action against it. In our view, this background has been instrumental in equipping the IPCC with procedures that organise collective work in a suitable way—that is, in a way that aims to have ARs satisfy the norms of intelligibility, relevance and accuracy and makes it likely that they do so. The remainder of the paper shows that IPCC's procedures can indeed be understood as aiming at these norms. Section 4 deals with the division of labour within the IPCC while section 5 focuses on three frameworks that were not in place at the beginning of IPCC's operations and were set up in response to perceived defects of its early production.

4. Division of labour

Since the first AR, issued in 1990, collective work within IPCC is organised by a supervising entity, the Bureau. In accordance with its "Terms of reference" (IPCC 2021c),"the purpose of the Bureau is to provide guidance to the Panel [of scientific experts] on the scientific and technical aspects of its work, to advise on related management and strategic issues, and to take decisions on specific issues within its mandate" (§1). As regards ARs, its functions primarily include advice on the work programme and on the coordination of work between the WGs, and selection of IPCC authors and reviewers.

The Bureau is currently composed of 34 members. It includes the chair and vice-chairs of the IPCC, as well as the members (co-chairs and vice-chairs) of the different WG Bureaus.[5] The Bureau of a WG is in charge of the "preparation of working group […] assessment reports", mainly through the organisation of "scoping meetings". These meetings aim to define the scope of the reports and develop draft outlines and work plans. The WG Bureau thereby supervises the definition of the table of contents of the AR's various parts, including chapter and section titles.

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[4] The text of this statement has been removed from IPCC's website but it can still be found here: http://www.climatesciencewatch.org/2009/12/04/ipcc-statement-on-stolen-emails-from-the-climatic-research-unit-at-the-university-of-east-anglia/.

[5] The Task Force on National Greenhouse Gas Inventories also has a Bureau, which has the same status as WG Bureaus and which we therefore include in the reference of "WG Bureaus".

The definition by the Bureau of the main questions to be addressed by IPCC authors serves different goals. In particular, it implies that authors are not individually responsible for ARs' scope and will not have to personally bear the burden of a debate with people claiming that a subject matter has been unduly neglected or highlighted. As regards the content of ARs, the role of WG Bureaus implies that they take charge of relevance. They also contribute to their global intelligibility and to the absence of contradictions, as dividing up from above the scientific content of an AR efficiently limits overlaps between the different chapters or sections. Whatever overlaps remain are also taken care of by the Bureau, which provides "guidance on crosscutting scientific issues related to the drafting of the reports" (ibid., §5, c). Finally, the existence and terms of reference of the Bureau also indicate a concern for accuracy, through the selection of IPCC authors (see IPCC 2021b, Section 4.3.2). The hierarchical dimension is present not only at the level of the full ARs but also at the lower level of their chapters. Each chapter is under the responsibility of two or three "coordinating lead authors", who integrate the contribution of "lead authors", who themselves use the material provided by "contributing authors".

Work within the IPCC has features that pertain to several of the types of interdisciplinary collaboration distinguished by Rossini and Porter (1979) and discussed by Andersen and Wagenknecht (2013). Actual writing is ensured by very small units of people who can interact along the lines of "common group learning", that is, in such a way that the resulting epistemic production can be seen as common knowledge in the group. Coordinating lead authors integrate the contributions provided by lead authors, much along the lines of the "integration by leader" framework. Work is distributed among coordinating lead authors according to their area of expertise, as in the "negotiation among experts" model. However, IPCC as a whole does not conform to any of these models, and neither can it be analysed as a combination of collaborations that may be thought of along these lines. Crucially, although it is true that WG Bureaus can be seen as leaders with regard to contributing lead authors, their participation in the production of ARs relies on dividing labor rather than on integrating contributions. We contend that this original, idiosyncratic organisation is instrumental in ARs satisfying the norms of expertise.

To start with, actual writing work is divided into small bits that are taken care of by small units of people. Within such groups, it is much easier than at the level of the entire Panel to spot disagreements and it is likely that the disagreements that are reducible by rational discussion are indeed eliminated. This contributes to having reports that are intelligible and hint at their own accuracy (or at least do not contain one type of material that may be used to put this accuracy into question). What is more, the "task and responsibilities" of contributing lead authors include that they take care of potential disagreements between the contributions of different lead authors—even though IPCC's documentation does not specify how they are supposed to do so. Contributing lead authors also complement the work of the Bureau with respect to "crosscutting [...] issues" and ensure that they are indeed "addressed in a complete and coherent manner" (IPCC 2021b, Annex 1: Tasks and responsibilities for lead authors, coordinating lead authors, contributing authors, expert reviewers and review editors of IPCC reports and government focal points, Section 2 about coordinating lead authors). It is also incumbent upon them to deal with the threat to intelligibility that arises from the fact that one and the same topic may have to be addressed in different places in the AR.

Social calibration can be pursued along the same ascending pathways that are taken by contradiction tracking, from actual written contributions, to the sections, and then to the chapters and finally the ARs. The convergence of these pathways or, in other words, the pyramidal organisation of the IPCC, is very helpful. It entails that the larger the interactional expertise needed to competently occupy a position of a given type, that is, the more expertise is necessary to communicate and "interact interestingly" with the relevant participants (Collins and Evans 2002, p. 254), the fewer positions of this type in IPCC's organisational structure. Many authors work as contributing authors, alone or within groups where social calibration is not a problem or can be secured by explicit discussion. This requires little, if any, interactional expertise. A smaller but still important number of authors serve as lead authors, a position that requires at the minimum to master the different subject matters broached in one section and be able to communicate with other lead authors of the same chapter. This is more demanding but still a quite common feature among scientists. Finally, coordinating lead authorship calls for interactional expertise over large domains, but is taken up by only a small number of authors. The pyramidal organisation of the IPCC thus divides up the work load of ensuring social calibration but does so in a way that does not require that all participants have interactional expertise covering the scope of the whole AR or even of an entire chapter. It thereby helps to overcome the threat to consistency that comes from multidisciplinarity. This pyramidal division of labor also limits the epistemic impact of interactions that involve opaque epistemic dependence: typically, contributing authors with substantial expertise in distant areas will not interact directly.

The organisational structure of the IPCC further implies that the content of an AR cannot be consensual in the sense of every author affirming every statement in the AR. As already underlined by Beatty (2017), “there is no meaningful consensus of any kind involving the sorts of numbers that so commonly accompany the release and promotion of IPCC assessments” (p. 193). As we have seen, the division of labor within the IPCC importantly relies on a division of the content of ARs and the result is that not every author has her say on every idea, or even has considered every sentence in the AR—far from it! However, IPCC authors may and arguably do jointly accept, in the sense of Gilbert (1987), the content of ARs, through authors not in charge of a given part deferring to the ones who are. Moreover, consensus may hold in a more substantial sense among the people who share the responsibility of a given part of the report and it is indeed aimed at: “In taking decisions, and approving, adopting and accepting reports, the Panel, its Workings Groups and any Task Forces use all best endeavours to reach consensus” (IPCC 2021a, §10, p. 2).

Although it is not devoid of vagueness, this sentence suggests that decisions about actual writing should be taken as the outcomes of informal deliberations aiming for a position or formulation that is consensual in the sense of being acceptable by all or at least unobjected to any of the authors involved—a type of consensus that Beatty (2017) characterises as “less aggregative and more collective” (p. 179) than consensus associated “with some form of counting: vote tallying, opinion polling, adding-up the number of authors that endorse a particular position in their published papers” (p. 179). Consensus seeking cannot be justified by the epistemic properties of consensual positions. Indeed, consensus cannot be taken as indicative of knowledge (Miller 2013, 2019) and deference to it may fail to be justified (Miller 2016). However, in the context of the IPCC, consensus can be considered as a means toward univocity and thereby global intelligibility. More precisely, consensus, be it in the weak, collective form, is relevant for univocity to the extent that dissent remains a possibility and would be reported in case it occurred. Now, this is exactly what IPCC procedures suppose, as lead authors are “required to record in the Report views which cannot be reconciled with a consensus view but which are nonetheless scientifically and technically valid” (IPCC 2021b, Annex 1, Section 1 about lead authors). Contrary to what Curry and Webster (2013) tend to suggest, intelligibility is not meant to be achieved at the expense of an accurate presentation of the best of our current theories and evidence.

How accuracy is supposed to be actually reached remains unclear at this stage, though. For one thing the division of labour within the IPCC primarily targets the obvious requirements of logical coherence, consistency, global intelligibility and relevance but hardly takes care of local intelligibility, or accuracy. For another, the principles organising IPCC’s work remain formal. They are stated in written instructions, and in view of the breadth and dimension of the reports they cannot provide explicit answers to all the substantive questions that may arise in the process of writing reports that satisfy the norms of expertise. As is also suggested by the exceptional lightness of the IPCC’s hierarchical structure relative to its size, further procedures are needed, that help to reach local intelligibility and accuracy and also to actually avoid gaps, overlaps or inconsistencies.

5. Key add-ons

The background shared by IPCC members not only underpinned division of labour in a way that facilitates the production of reports satisfying the epistemic norms bearing on expertise. It also enabled the IPCC to set up and introduce new organisational frameworks in order to respond to perceived defects of its early production. We identify and discuss three such add-ons: a common vocabulary to express uncertainties, an open reviewing process, and an international framework for comparing models. We present them in turn and explain how they contribute to ARs satisfying the requirements of intelligibility, relevance and accuracy.

5.1. A common language for expressing uncertainty

As explained in Section 3, climate science is loaded with uncertainties whose nature and variety constitute an impediment to achieving intelligibility of ARs. The need was felt early on of a precisely defined vocabulary which IPCC authors would be required to employ systematically (Moss and Schneider 1997). Although the intent was clear from the beginning, the goal has turned out to be surprisingly difficult to meet. The sought-after lexicon has been defined in a series of evolving guidance notes that make up “a continuing tradition of iterative improvement of the treatment of uncertainties” (Mastrandrea and Mach 2011, p. 659). An initial version, for AR3, is provided in Moss and Schneider (2000) and a second one, for AR4, in Manning et al. (2004). The framework for AR5 is defined in Mastrandrea et al. (2010)’s “Guidance note for lead authors of the IPCC fifth assessment report on consistent treatment of uncertainties” and more thoroughly discussed in Mastrandrea et al. (2011).[6]

By defining a framework for the assessment and expression of uncertainties that is meant to be used throughout the whole ARs, Mastrandrea et al. (2010) primarily aims at consistency (as indicated by its title). However, the definition of this framework is available both for authors and for readers or users of ARs and can be referred to in order to clarify the meaning of expressions of uncertainty in ARs. As a consequence it leads to a significant improvement in local intelligibility too, providing IPCC authors with the means to make more of their assumptions and reckonings explicit and thereby helping to avoid a whole set of misunderstandings.[7]

The uniform treatment and expression of uncertainties is also instrumental in promoting global intelligibility. It requires authors to combine disparate evidential and theoretical claims affected by uncertainties of various types in order to produce one all-encompassing (although often dual, as we shall see) uncertainty assessment for each important statement in the AR, and this undoubtedly helps to have clear-cut conclusions. The “Guidance note” also promotes global intelligibility in another manner, by bringing into focus the nature of ARs. The note requires that authors assess confidence in the validity of their key findings, where confidence is defined as a combination of two ingredients: “the type, amount, quality, and consistency of evidence” supporting it and the “degree of agreement” of which it is the subject within the community of climate scientists. This characterisation of confidence essentially depends on ARs being reviews of scientific literature, as opposed to original research pieces. Confidence claims within ARs therefore remind readers of the status of ARs and thereby enhance their intelligibility.

5.2. The CMIP

A second add-on to IPCC’s organisation is its reliance, in the last decade or so, on the Coupled Model Intercomparison Project (CMIP). CMIP is a worldwide scientific project created in 1995 by

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[6] As far as we know, this document has not been revised in preparation for AR6.

[7] Psychological studies show nevertheless that the calibrated language is ambiguous. IPCC uncertainty statements are understood differently depending on cultural differences (e.g. between British English and Chinese translations) or ideological differences (Budescu et al. 2009, 2012; Harris et al. 2013). Moreover, they are usually not understood correctly, as the table of equivalence between probabilities and verbal expressions is not intuitive. Finally, how uncertainty statements are understood depends on the context, and specifically on the severity of the events under consideration and of their consequences (Harris and Corner 2011).

the Program for Climate Model Diagnosis and Intercomparison (PCMDI) (Meehl et al., 2000), a US funded agency within the Lawrence Livermore National Laboratory. It provides a framework for studying and straightforwardly comparing the outputs of simulations of the past, present and future climate contributed by leading modelling centres around the world. The initial motivation was that although models are increasingly complex, model errors and disagreements among them remain significant and poorly understood — for instance, current general circulation models (GCMs) predict an increase of global mean surface air temperature due to a doubling of atmospheric carbon dioxide within a rather large range (1.5 - 4.5°C). The CMIP defines standards for models to have their outputs archived in its database: they must be GCMs and be run under the same given boundary conditions and idealised scenarios of global warming.

By thus enforcing standardization, the CMIP enables the scientific community to evaluate GCMs in a fair way, to compare their results, to identify those that are robust as well as whatever problematic features they may have in common, and to possibly uncover the sources of the disagreements among them. Such a process eventually helps to improve the models. Moreover, ensembles of models have proved to be more informative than singular models with respect to exploration of uncertainties about future climate change (Parker, 2010; Katzav and Parker, 2015; Katzav, Dijkstra and de Laast, 2012; Katzav, 2014; Parker, 2018), their most prominent aim now being to estimate uncertainties quantitatively.

Though a strictly scientific project, the CMIP has recently turned out to play a major role with regard to ARs. By homogenising the inputs of ARs, it has greatly increased IPCC authors' ability to reach consistency and global intelligibility. Moreover, the CMIP has a bearing on the relevance of ARs. More precisely, it encapsulates part of the answer to the question of what should be presented and discussed in ARs. As emphasised by Parker (2013), successive versions of the program "have been designed to support research relevant for IPCC scientific assessments of climate change" (p. 214), to the extent that successive versions of the program have been numbered after the corresponding ARs. Specifically, the choice of the scenarios that serve as inputs for models within the CMIP is exogenous to the scientific enterprise and has been driven by the concern of producing information that is relevant for decision-making in the context of climate change. Finally, the CMIP has the more general effect of bringing climate science and IPCC closer to each other. It comes about that IPCC has progressively become the main structuring force of international climate science research and that IPCC timing now governs the scheduling of many activities in this domain, among which the running of GCM computer simulations. ARs have become the major review papers in the various fields they cover and researchers are strongly motivated to have their own papers quoted and used in ARs. Together with the provision of a large database, the CMIP thereby promotes ARs' accuracy. Note that it also has the side-effect of consolidating and expanding the common scientific background on which IPCC's functioning relies, as research in climate science is scheduled and partially standardized by IPCC's agenda and requirements.

5.3. Reviewing procedure

Accuracy is the main target of the last organisational framework that we shall discuss: the reviewing procedure to which ARs are submitted from AR4 onwards. As detailed in Section 4.3.4 of the "Procedures for the preparation, review, acceptance, adoption, approval and publication of IPCC reports" (IPCC 2021b), ARs undergo two formal rounds of reviews. The first round is ensured by scientific experts selected by the Bureau because of their significant expertise or following the suggestion of governments or of NGOs. Comments are taken into account and a revised draft is submitted for review by the same (or similar) experts but also by governments. IPCC authors are required to consider and address all comments at both stages of the review process. The whole process is supervised by two to four "review editors" per chapter, "normally" including one member of the WG Bureau and one "independent expert based on the lists provided by governments and observer organisations". As defined in Section 5 of the above-mentioned Annex, the role of review editors is primarily to ensure that all pertinent elements and comments are taken into account and that controversies be either resolved or presented in an adequate and fair way.

It seems clear that this weighty multi-stage reviewing procedure smooths the path towards intelligibility. Indeed, be it in or out of the context of the IPCC, one remit of reviewers is to ensure that the documents under review can be locally understood, that they are free from logical contradiction and consistent, and that their main conclusions are easy to locate and unambiguous. Similarly, reviewers are in general expected to check that the scope of the reviewed document is in keeping with its stated goals, thereby contributing to its relevance. However, the reviewing process of ARs essentially aims at their accuracy. The "function" of reviewers is indeed defined as "to comment on the accuracy and completeness of the scientific/technical/socio-economic content and the overall scientific/technical/socio-economic balance of the drafts" (IPCC 2021b, Annex 1, Section 4 on expert reviewers). Fairness with regard to evidence and available theories is also taken care of in an exogenous way, through the choice of reviewers: "in selecting Review Editors, the Bureaus should […] aim for a balanced representation of scientific, technical and socio-economic views" (IPCC 2021b, Section 4.3.4).

IPCC's reviewing process is mentioned in relation with accuracy concerns in the statement that was issued by WGI in the context of the Climategate. The primary aim of this statement was to argue in favour of the trustworthiness of the conclusions of AR4, a consequence of the AR being accurate, and to this effect it stressed the openness of IPCC assessments. Openness is promoted by the reviewing procedure to the extent that some governments (including the US government) made the second draft of the report freely available online, with the possibility for any reader to submit comments. It contributes to accuracy by bringing to a completion the movement of widening the circle of people who can have a say on the content of the ARs, which in turn raises the probability that no important piece of evidence or theory is neglected and that not all participants in the writing process are biased in the same way. Notice however that openness does not only serve the primary purpose of enhancing accuracy. It also helps in the secondary task of arousing confidence and pointing to AR's accuracy, by indicating that ARs are not meant to be produced by a closed lot of people sharing a hidden and arguably largely political agenda. What is essential here is not so much openness itself as its publicity. This is the sense of the concomitant IPCC efforts towards transparency, specifically with regard to the review process, meant to be "objective, open and transparent" (IPCC 2021b, Section 4.3.4). In fact, in the wake of the Climategate (and also of the publication in 2010 of an independent review of the processes and procedures of the IPCC[8]), the reviewing procedure was not so much strengthened as it was formalised, while the role of review editors was more clearly delineated.

6. Concluding remarks

Producing reports that assess the state of climate knowledge while satisfying the norms of intelligibility, relevance and accuracy is a formidable challenge. We contended that in view of the size and diversity of the group of IPCC authors, and also of the length of IPCC ARs, this challenge cannot be taken up without procedures that suitably organise collective work. This part of our analysis, developed in Sections 2 and 3, can be used as a framework to study other cases of collective scientific expertise. The organisation of work within the IPCC is composed of a hierarchical division of labour supplemented by three more recent add-ons: language calibration as regards uncertainty, coupling with the CMIP and a thorough reviewing process. By describing these different elements and showing how they aim to and make it possible that ARs have the epistemic properties of expert reports, we provide support to the view that IPCC's undertaking is primarily epistemic rather than political.

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[8] This review was published by the InterAcademy Council under a contract signed with the UNO in 2010. It can be found here: http://www.interacademies.org/33365.aspx.

While there is little doubt that these elements strongly help IPCC authors in their effort to produce ARs that meet the epistemic requirements bearing on expertise, IPCC ARs are arguably not perfectly intelligible, relevant and accurate. Global intelligibility largely remains an open problem, due mainly to the length of ARs. For this reason, ARs are supplemented by “Summaries for policy-makers”. We did not study them because they are not part of the ARs *per se* and, more importantly, because they raise a whole new set of philosophical questions: they are openly political objects, whose content is negotiated and approved line by line following a process that is open to all governments.

Whether ARs are relevant is also a vivid issue. Relevance as we defined it is a matter of fit between the questions broached in an expertise report and the decision problems on which this report is meant to bring light. Now, in the case of the IPCC no specific decision problem is targeted: ARs aim to provide a generic expertise basis to be relied on for climate related decisions. Relevance therefore comes down to a matter of covering the entire scope of climate science and of laying emphasis on the theories or hypotheses that seem more useful for policy-making. Delineation from above of the scope and outline of ARs, thorough review and coupling with the CMIP help to achieve it, as we saw. It may be argued, though, that the very task of the IPCC is too broad and insufficiently specific to be of any use for actual decision problems in real political life. This probably explains why local analogs of the IPCC are developing, at the national or subnational levels. These groups should not be seen as alternatives to the IPCC; they rather supplement and expand upon IPCC’s work. To this effect, they can rely not only on the same common scientific background that enabled the IPCC to organise work in an efficient way, but also on the consolidation and expansion of this background by IPCC’s activities themselves. As for work organisation itself, IPCC’s structure and added frameworks can serve as references which have proved to be helpful as regards the satisfaction of the epistemic norms of expertise.

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