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Learning about climate change solutions in the IPCC and beyond

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ABSTRACT

There has been much debate about the assessment process of the Intergovernmental Panel on Climate Change (IPCC). Yet two of the most fundamental challenges that directly threaten the ability of the IPCC to fulfill its mandate have been largely neglected so far. Firstly, the magnitude and rapid expansion of the climate change literature makes it increasingly impossible for the IPCC to conduct *comprehensive* and *transparent* assessments without major innovations in assessment practices and tools. Secondly, the structure, organization and scientific practices across the social sciences and humanities prohibit systematic learning on climate change solutions and increasingly limit the *policy-relevance* of IPCC assessments. We highlight the need for responses along three avenues to prepare the IPCC for continued success in the future: 1) IPCC assessments must make better use of big-data methods and available computational power to assess the growing body of literature and ensure comprehensiveness; 2) systematic review practices need to be enshrined into IPCC procedures to ensure adequate focus and transparency in its assessments; 3) a synthetic research culture needs to be established in the social sciences and humanities in order to foster knowledge accumulation and learning on climate solutions in the future. As policymakers become more interested in understanding solutions, the future prospects of global environmental assessment enterprises will depend heavily on a successful transformation within the social sciences and humanities towards systematic knowledge generation. This article is part of a special issue on solution-oriented Global Environmental Assessments.

1. Introduction

It is the mandate of the Intergovernmental Panel on Climate Change (IPCC) "*to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation* […]" (IPCC, 2013a: p. 1). The assessment reports produced by the IPCC have provided a crucial scientific foundation for international climate policy negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) and have had countless other impacts and influences on science and policy over the past 25 years.

Compiling an IPCC assessment requires a substantial collective effort by a diverse team of experts over many years to assemble, review and synthesize of the available scientific knowledge. To ensure that reports are compiled in accordance with the mandate, guidelines on conducting assessments are formally laid out in the IPCC's principles and procedures (IPCC, 2013a,b). The authority of IPCC assessments has precipitated heated debates about its assessment procedures and their practical implementation. These discussions, on topics ranging from simple procedural matters to more thorny governance issues, have taken place both externally through academic publications as well as within the IPCC itself (IPCC, 2015c).

The first strand of these discussions is concerned with assessment procedures and practices in the broadest sense. Issues include how to deal with the growing burden on IPCC leadership and authors in a volunteer processes (Carraro et al., 2015; Schulte-Uebbing et al., 2015; Stocker and Plattner, 2014; Stocker, 2013), the format of IPCC assessments (IPCC, 2015a, b), the establishment of more systematic review practices to protect the organization from attacks in the long-run (Berrang-Ford et al., 2015; Petticrew and McCartney, 2011), and mechanisms to ensure better participation of authors from developing countries (Carraro et al., 2015; IPCC, 2015c; Petersen et al., 2015).

A second strand of the debates emphasizes the need for a shift towards solution-oriented IPCC assessments to maintain policy-relevance in the future. 20 out of 32 submissions from governments to the task group on the future of the IPCC demanded more explicit focus on assessing solution options for climate policy (Kowarsch et al., 2016),

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including technological options, behavioral options, and in particular, policies (e.g., regulatory measures or market-based instruments) (IPCC, 2015a,c). Disciplinary bias towards the natural sciences and economics (Bjurström and Polk, 2011; Carey et al., 2014; Corbera et al., 2015; Vasileiadou et al., 2011), a lack of alignment with social science communities (Victor, 2015), geographical bias towards authors from and located in developed countries (Corbera et al., 2015), the lack of inclusion of practitioners (Viner and Howarth, 2014), a systematic exclusion of indigenous knowledge (Ford et al., 2016, 2012) and a dysfunctional Working Group structure (Carey et al., 2014; Carraro et al., 2015) have been identified as barriers that must be overcome to improve the assessment of solutions.

Questions about IPCC communications comprise the third strand of discussions. This broad debate covers the impact of the IPCC on scientific knowledge production (Vasileiadou et al., 2011), the readability of IPCC products (Barkemeyer et al., 2016; Field and Barros, 2015; Mach et al., 2016), the media impact of IPCC assessments (Oneill et al., 2015) and the usefulness, transparency and perception of IPCC uncertainty statements (Adler and Hirsch Hadorn, 2014; Budescu et al., 2009, 2014).

The fourth strand critically reflects on the IPCC as a science-policy interface. Recent discussions have focused on the politicization of IPCC approval sessions (Dubash et al., 2014; Edenhofer and Minx, 2014; Field and Barros, 2015; Victor et al., 2014; Wible, 2014). There is also literature more generally concerned with the appropriate division of labor between science and policy and what this implies for assessment practices (Beck et al., 2014; Edenhofer and Kowarsch, 2015; Hulme, 2010, 2016).

While these discussions have provided important reflections, we argue that two additional challenges pivotal to a successful future for the IPCC have been largely overlooked in these debates. *First*, the large size and rapid expansion of the relevant scientific literature − henceforth referred to as 'big literature' phenomenon (Nunez-Mir et al., 2016) − fundamentally challenges the IPCC's assessment practices and ultimately threatens the organization's ability to *comprehensively* and *transparently* assess the available literature. *Second*, a lack of progress in accumulating knowledge on climate solutions in the social sciences and humanities risks undermining the *policy-relevance* of IPCC reports as policymakers increasingly demand robust evidence on how to address the climate problem through mitigation and adaptation. Unless the IPCC addresses these challenges, its assessments will increasingly struggle to meet their mandate and will become progressively irrelevant in the future. In the remainder of the article we will analyze these two challenges and discuss some ways forward both within and external to the IPCC.

2. The literature explosion

In this section we employ scientometric methods to study literature growth in the field of climate change and the response of the IPCC to this problem so far. Scientometrics comprises an established set of methodologies to measure and analyze scientific research (Leydesdorff and Milojević, 2015). We follow the approach of Grieneisen and Zhang (2011) to track the number of publications on climate change as recorded in the Web of Science (WoS). The WoS database provides a wide range of peer-reviewed articles, books and conference proceedings across disciplines. For the period 1991–2009, our results closely match those of Grieneisen and Zhang (2011) as well as the results of a recent independent study by Haunschild et al. (2016). We extend this analysis further to 2016 and compare those results with the material used by the IPCC. A detailed description of our methodology and search query can be found in the Supplementary material (SM).

The literature on climate change has grown exponentially over the last thirty years, as shown in Fig. 1, turning IPCC assessments into an exercise in managing 'big literature.' While in the mid-1980′s there were less than 1000 annual publications on climate change, we find more than 33,000 annual publications for the most recent year (2016). So far, there is no sign of a decline in this trend. With an annual rate of 16%, growth in publications on climate change has been substantially faster than the 4% growth observed for the scientific enterprise as whole. Overall, we find about 273,000 publications in WoS on the topic of climate change.

The challenge of conducting comprehensive IPCC assessments has grown exponentially, too. As the IPCC should assess the most recent science, here we adopt the total number of new publications emerging across an assessment cycle as a rough approximation of this challenge. During the first assessment report (AR1) cycle, less than 1500 studies on climate change appeared; for the most recent AR5 cycle, this number is approximately 110,000. In fact, the about 30,000 new publications on climate change published in 2015 are almost equivalent to the entire body of literature available for the first three IPCC assessments, spanning the period 1988–2001, combined. We project a total of 200,000–300,000 new publications during the on-going AR6 cycle (lower and upper bounds defined by projections of zero growth and continued exponential growth, respectively). This is roughly the size of the entire WoS literature on climate change prior to 2014. We include this and additional analysis on the evolution of the disciplinary composition of the climate change literature in the SM.

To what extent has the IPCC been able to address this growing challenge and comprehensively review the most recent science? Fig. 2 compares the number of publications on climate change published during each assessment cycle with the number of unique references made in the respective IPCC assessment reports. In fact, IPCC reports draw from a much wider body of literature comprising publications, (a) about climate change not included in WoS (e.g. other peer-reviewed publications, most of the "grey literature" including books, reports etc.) or (b) not explicitly about climate change (and therefore not covered by our query) but relevant to its understanding. In light of this, the WoS estimates presented here provide an extremely conservative lower-bound estimate of the relevant literature, and the share of relevant literature covered by IPCC in Fig. 2 is a highly optimistic upper-bound estimate, which nevertheless serves to show the trend over the five assessment periods.

The first important aspect to note is that not only has the body of literature on climate change grown, but so has the number of unique citations made in IPCC reports: from AR1 to AR5 there has been a steady increase from about 1600 to about 31,000 citations. This is not only due to the increased length of each report, but also to an increase in citation density (citations per written page), from 1.6 citations per page in AR1, to 6.4 citations per page in AR5. IPCC authors have also been increasingly successful in focusing on the most recent science in IPCC assessments. Of the citations in the AR5 report, 72% refer to literature published in that cycle. This has risen gradually from 64% in AR1 (see SM for details).

However, despite all efforts, the ratio of references in IPCC reports to the newly emerging literature in WoS has been declining rapidly. While this publication share was 63% in AR1, it steadily declined to 23% by AR5. Despite this being a very optimistic estimate, it suggests that at least 80% of the most recent scientific literature could not be directly reviewed by IPCC authors in AR5 and was thus not included in the synthesis of scientific knowledge. Taken together, the sheer size of the current body of literature and the much higher share of publication coverage in earlier IPCC assessments suggest that reliance on expert judgement in selecting which of the literature to assess has become increasingly pronounced over time. The bias introduced by this expert selection and therefore the impact of 'big literature' on the assessment outcomes remains unclear and a discussion of procedural options to deal with it has so far been notably absent.