Supplementary Material: Learning about climate change solutions in the IPCC and beyond

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Methodology

Scientometric methods inform researchers about trends and patterns in scientific research. In this section we describe the methods used to analyse research in the field of climate change. We take data from two sources: the Web of Science (WoS), and the 5 IPCC assessment reports. WoS provide bibliometric data (such as author, journal, publication year, number of citations) for scientific literature. IPCC assessment reports contain scientific and technical assessments of climate change, produced by the Intergovernmental Panel on Climate Change. These reports run to thousands of pages and contain several thousands of references.

Web of Science Results

Bibliometric data are obtained by querying the WoS database. We replicated the WoS query used by Grieneisen and Zhang (2011), but extend the time horizon to the period 1986-2016. The query is given below:

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SO=(Climate Alert OR Climate Dynamics OR Climate Policy OR Climatic
Change OR Global and Planetary Change OR Global Change Biology OR
International Journal of Greenhouse Gas Control OR Mitigation and
Adaptation Strategies for Global Change)
OR
TS=(((CO2 OR "carbon dioxide" OR methane OR CH4 OR "carbon cycle" OR
"carbon cycles" OR "carbon cycling" OR "carbon budget*" OR "carbon
flux*" OR "carbon mitigation") AND (climat*)) OR (("carbon cycle" OR
"carbon cycles" OR "carbon cycling" OR "carbon budget*" OR "carbon
flux*" OR "carbon mitigation") AND (atmospher*)))
OR
TS=("carbon emission*" OR "sequestration of carbon" OR "sequester*
carbon" OR "sequestration of CO2" OR "sequester* CO2" OR "carbon
tax*" OR "CO2 abatement" OR "CO2 capture" OR "CO2 storage" OR "CO2
sequester*" OR "CO2 sequestration" OR "CO2 sink*" OR "anthropogenic
carbon" OR "captur* of carbon dioxide" OR "captur* of CO2" OR
"climat* variability" OR "climat* dynamic*" OR "chang* in climat*"
OR "climat* proxies" OR "climat* proxy" OR "climat* sensitivity" OR
"climat* shift*" OR "coupled ocean-climat*" OR "early climat*" OR
"future climat*" OR "past climat*" OR "shift* climat*" OR "shift in
climat*")
OR
TS=("atmospheric carbon dioxide" OR "atmospheric CH4" OR
"atmospheric CO2" OR "atmospheric methane" OR "atmospheric N2O" OR
"atmospheric nitrous oxide" OR "carbon dioxide emission*" OR "carbon
sink*" OR "CH4 emission*" OR "climat* policies" OR "climat* policy"
OR "CO2 emission*" OR dendroclimatolog* OR ("emission* of carbon
dioxide" NOT nanotube*) OR "emission* of CH4" OR "emission* of CO2"
OR "emission* of methane" OR "emission* of N2O" OR "emission* of
nitrous oxide" OR "historical climat*" OR IPCC OR "methane
emission*" OR "N2O emission*" OR "nitrous oxide emission*")
OR
TS=("climat* change*" OR "global warming" OR "greenhouse effect" OR
"greenhouse gas*" OR "Kyoto Protocol" OR "warming climat*" OR "cap
and trade" OR "carbon capture" OR "carbon footprint*" OR "carbon
neutral" OR "carbon offset" OR "carbon sequestration" OR "carbon
storage" OR "carbon trad*" OR "changing climat*" OR "climat*
warming")
```

SO refers to the journal title, and TS looks for the given terms in the title, abstract and keywords of each article. The full WoS records for all articles matching the query were downloaded, and those articles published later than 2016 were removed.

Our search query can broadly reproduce the results shown in Grieneisen and Zhang (2011). In fact, we obtain slightly more articles for the period of their study (1990-2009). This is reasonable due to the expansion in the coverage of WOS. Over the entire time horizon we obtain a similar number of publications than Haunschild et al. (2016), who develop an independent search query. Therefore, our results for WOS should be in the right order of magnitude.

Each article is assigned to an OECD Field of Science (FoS) subject category according to the WoS topic to FoS map provided by Thompson Reuters (http://ipscience-help.thomsonreuters.com/incitesLive/globalComparisonsGroup/globalComparisons/subjAreaSchemesGroup/oecd.html).

IPCC References

All assessment reports are publicly available at https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml, in a variety of different pdf and html formats. Although structured reference lists are not provided, each chapter of each report contains a reference list at the end. We machine read each report, using regular expressions to isolate each reference and split the reference into its constituent parts. As the references are not provided in a structured format, and the reports differ in format between working groups and assessment reports, there is some potential for missed, or misidentified, references. However, the procedure was adapted for each report, and reference counts for the first chapter were checked against manual counts to validate the approach. The numbers presented should therefore give at least a good indication of the number of references used in each assessment report.

References written by the same author in the same year, where the first parts of the title are the same are removed from each assessment report total as duplicates.

Although the WoS results consist mainly of journal articles, IPCC references include reports, books or other “grey” literature. Further, several references in IPCC reports are of a general nature, and would therefore not be picked up in the WoS query. Because IPCC references come from a wider pool, the proportions of relevant available literature shown in Figure 2 of the main manuscript are likely to be overestimated

Additional results

Literature projections

Here we discuss the projections of the literature corpus over the AR6 period. The upper bound is based on the assumption that the number of annual publications will continue to grow at the compound annual growth rate observed across WoS results between 1990 and 2016. The lower bound is based on the assumption that annual publication numbers do not increase beyond the level observed in 2016.

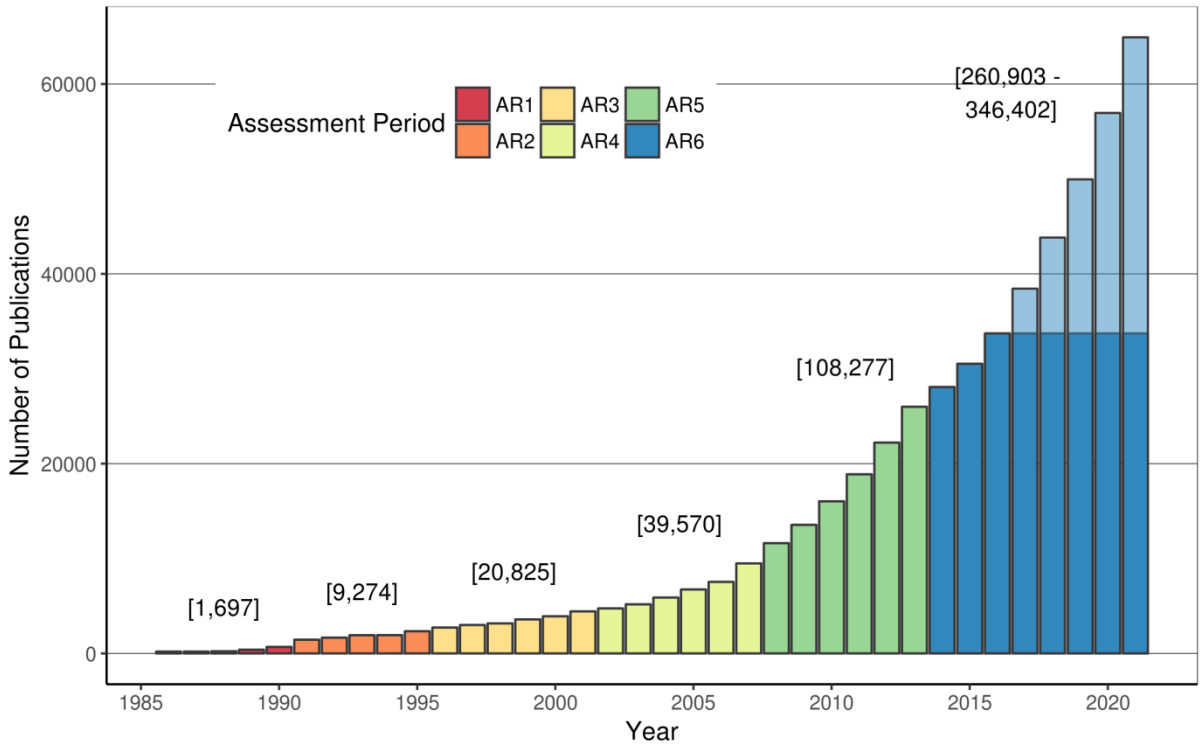

Figure SM. 1– Total number of scientific publications on climate change between 1986 and 2020 in the WOS. Values for the period 2016 to 2020 reflect our own projections described above. The bottom of the light blue bar reflect our conservative estimate and the top our higher-bound estimate assuming continued growth. We project the total number of new WOS publications within the AR6 cycle to be in the range 210,000 – 300,000.

Breakdowns by scientific field

The size of the body of literature on climate change that has accumulated over time varies across sub-fields, as shown in Figure SM.2. Across all the 270,000 publications considered here, 66% appeared in natural science outlets, 17% in engineering and technology, 11% in agricultural sciences, 7% in the social sciences, 2% in medical and health sciences and 0.3% in humanities. This supports previous evidence by authors suggesting a "bias[1]" towards natural sciences in the climate change literature. Equally, the contribution of the social sciences has been comparatively small – even though the body of literature in itself is substantial with over 15,000 contributions to date. However, contrary to frequent claims (e.g. Corbera, Calvet-Mir, Hughes, & Paterson, 2015; Vasileiadou, Heimeriks, & Petersen, 2011) that economics dominates the literature on climate change in the social sciences, we only find that 30% come from that domain, while 43% are from the field of social and economic geography including the fields of Environmental Studies, Geography and Planning & Development etc. (see SM for details). Climate change publications in the sub-field of humanities are still in their infancy with less than 1000 publications overall. There are two aspects that call for great care in drawing far-reaching conclusions from this analysis: first, authors from sub-fields without a strong focus on climate change, like humanities, might choose other outlets – e.g. interdisciplinary journals – for their contributions. Second, journals like Science, Nature, or Nature Climate Change among others are classified as natural science outlets here even though they invite pieces from many disciplines.

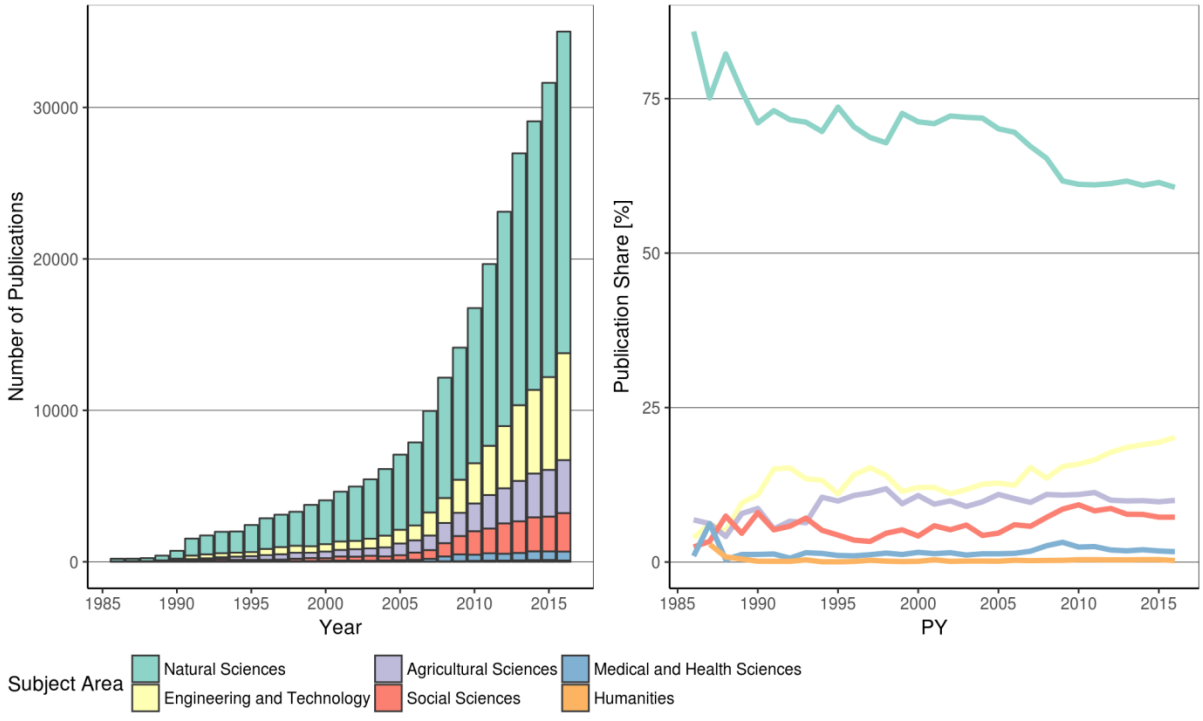

Figure SM. 2 - Scientific publications on climate change across scientific sub-fields 1986-2015. The field of climate change is dominated by natural science publications in total terms, while engineering and technology studies have seen the most rapid growth. Left Panel: Total number of publications in the ISI Web of Science by subject area. Right Panel: Publication share by subject area. Subject areas classified using the OECD Field of Science and Technology classification (OECD, 2007).

The dominance of the natural sciences in the climate change literature appears to be a characteristic of the field since its establishment. However, natural sciences have not experienced the fastest

growth among sub-fields. In fact, the share of natural science publications has been declining since the start of the millennium. This is mirrored by growing shares for energy and technology studies, which have experienced the most rapid growth, from 10% in 2000 to 20% in 2015. In 2015, almost 6000 articles were published in this field alone. All other sub-fields – humanities, agricultural sciences, social sciences as well as medical and health sciences – have grown roughly at the same pace as the field of climate change research as a whole.

Hence, all sub-fields have witnessed a rapid growth in publications, but at extremely different scales. This implies very different assessment challenges. In the natural sciences, comprehensive assessments are becoming increasingly infeasible with about 70,000 new publications across the AR5 cycle and about 19,000 annual additions currently. But even fields like engineering and technology studies, agricultural sciences as well as social sciences can no longer be easily comprehensively assessed with 19,000, 12,000 and 8,600 publications respectively across the AR5 cycle. Conversely, the 2,500 publications in medical or health sciences over the same time period or the 350 publications in the humanities remain more manageable – even though these sub-fields might bring their own challenges related to the minimal penetration of climate change as a topic so far.

We attempt to identify systematic reviews in each sub-field by compiling a regular expression to match the review types described in Berrang-Ford et al. (2015) , detail below:

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"\'.*(systematic review)|(meta.(Berrang-Ford et al.,
2015)anal)|(narrative review)|(evidence
synthesis)|(meta.{0,1}ethnography)|(model\w*
inter.{0,1}comparison).*\'",
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Any article where the title, abstract or keywords match the expression above are tagged as reviews: The following table describes the percentage of reviews in each field.

Subject Area	Review %
Agricultural Sciences	1.01
Engineering and Technology	0.18
Humanities	0.26
Medical and Health Sciences	1.37
Natural Sciences	0.72
Social Sciences	0.57

Literature

Berrang-Ford, L., Pearce, T., & Ford, J. D. (2015). Systematic review approaches for climate change adaptation research. [journal article]. *Regional Environmental Change, 15*(5), 755-769. doi: 10.1007/s10113-014-0708-7

Corbera, E., Calvet-Mir, L., Hughes, H., & Paterson, M. (2015). Patterns of authorship in the IPCC Working Group III report. [Article]. *Nature Clim. Change, 6*, 94-99. doi: 10.1038/nclimate2782

http://www.nature.com/nclimate/journal/vaop/ncurrent/abs/nclimate2782.html#supplementary-information

Grieneisen, M. L., & Zhang, M. (2011). The current status of climate change research. [10.1038/nclimate1093]. *Nature Clim. Change, 1*(2), 72-73. doi: http://www.nature.com/nclimate/journal/v1/n2/abs/nclimate1093.html#supplementary-information

Haunschild, R., Bornmann, L., & Marx, W. (2016). Climate Change Research in View of Bibliometrics. *PLoS ONE, 11*(7), e0160393. doi: 10.1371/journal.pone.0160393

OECD. (2007). Revised Field of Science and Technology (FOS) Classification in the Frascati Manual. Paris: OECD.

Vasileiadou, E., Heimeriks, G., & Petersen, A. C. (2011). Exploring the impact of the IPCC Assessment Reports on science. *Environmental Science & Policy, 14*(8), 1052-1061. doi: http://dx.doi.org/10.1016/j.envsci.2011.07.002