

# A Topography of Climate Change Research

Max Callaghan



February 22, 2018



**Figure:** Portrait of map-makers, Gerard Mercator and Jodocus Hondius (Jodocus Hondius) source: [https://commons.wikimedia.org/wiki/File:Hondius\\_Portrait\\_of\\_map-makers.jpg](https://commons.wikimedia.org/wiki/File:Hondius_Portrait_of_map-makers.jpg)



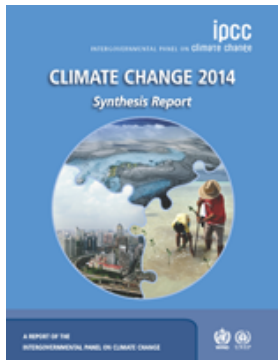
- Topography is a description of a landscape

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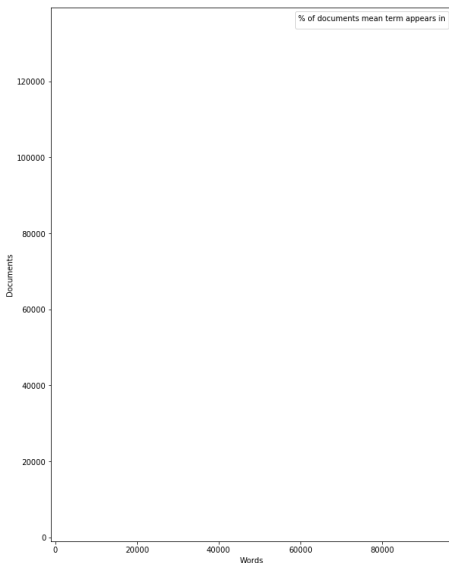


- Topography is a description of a landscape
- Topics (from the Greek τόπος, place) can describe the features of body of text

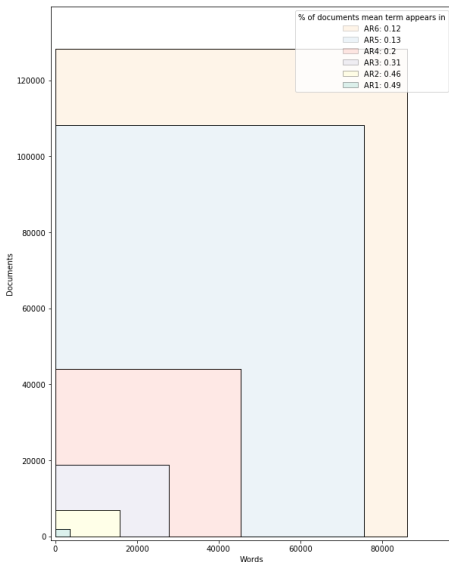
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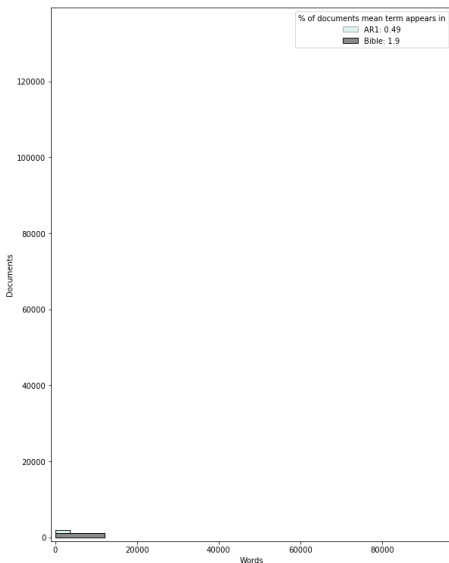
- To contribute evidence-based policy-making on climate change, the IPCC aims to *comprehensively* assess scientific literature on climate change
- These assessments should be aim to balance legitimacy, credibility and relevance (Cash and Clark, 2001)



A matrix of documents  $\times$  words

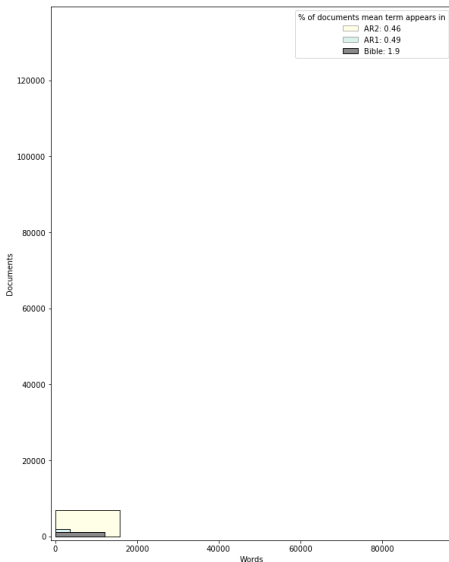


AR1: 1,848 documents × 3,528 words

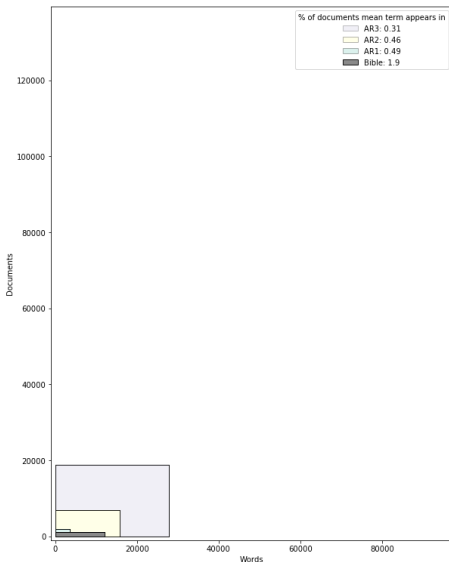


The Luther Bible: 1,189 documents  
(chapters)  $\times$  11,973 words

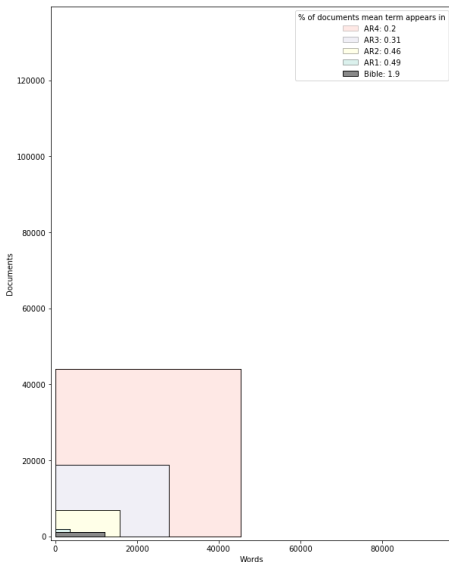




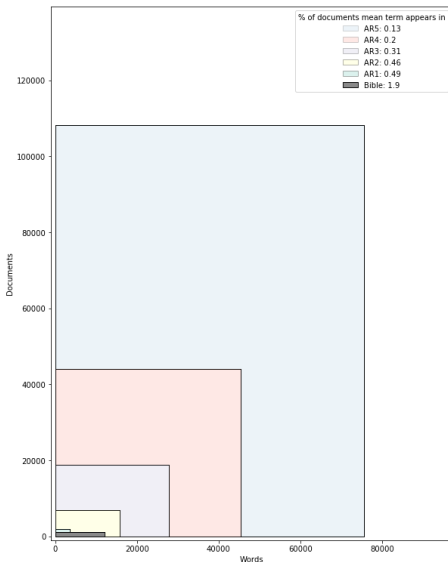
AR2: 6,941 documents  $\times$  15,781 words



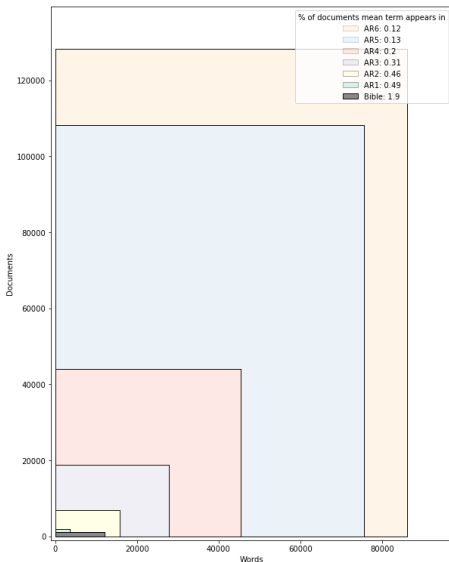
AR3: 18,728 documents  $\times$  27,730 words



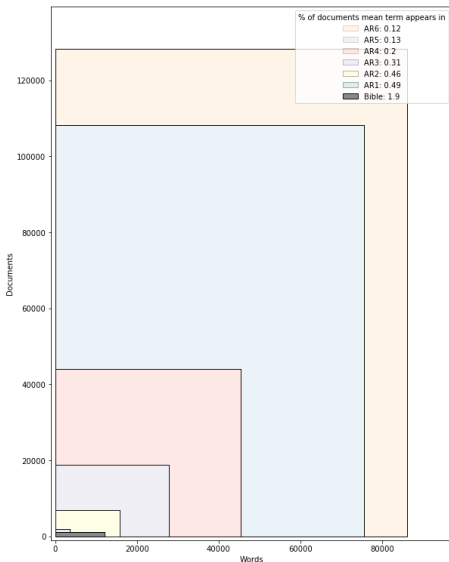
AR4: 44,000 documents  $\times$  45,388 words



AR5: 108,277 documents  $\times$  75,553 words



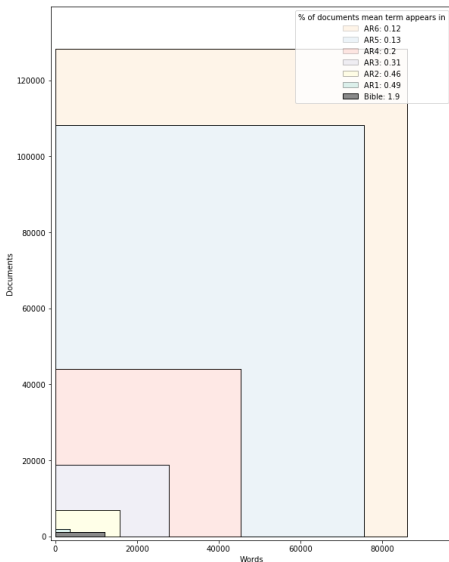
AR6: 128,357 documents × 86,149 words



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- Comprehensive, credible and relevant assessments become more challenging as the literature grows (Minx et al., 2017)

*To understand, and to aid, scientific assessments of climate change, we need to machine read the literature*



## Topic Modelling

- Topic modelling is a way of reducing the dimensionality of a corpus of documents
- A large matrix of documents  $\times$  words is factorised by a matrix of topics  $\times$  words and a matrix of topics  $\times$  documents (Lee and Seung, 1999)
- Topics describe the latent structure of the document corpus (What is the matter?)

$V_{i\mu}$  is a term frequency-inverse document frequency matrix of *stemmed* terms

V: 8769 x 3495

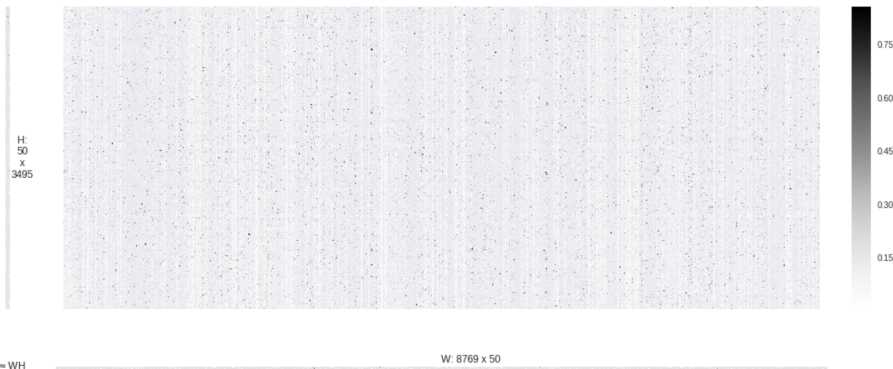


**Figure:** A topic model of 3495 documents on climate change from the year 2000



$$V_{i\mu} \approx (WH)_{i\mu} = \sum_{a=1}^r W_{ia} H_{a\mu}$$

V: 8769 x 3495



**Figure:** A topic model of 3495 documents on climate change from the year 2000

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- 2 Match documents to reference lists from IPCC reports

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## Steps

- 1 Download documents from Web of Science (WoS)
- 2 Match documents to reference lists from IPCC reports
- 3 Topic model stemmed document abstracts

(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")) NOT PY=2018

- (Haunschild et al., 2016)
- 309,697 documents

## Caveats

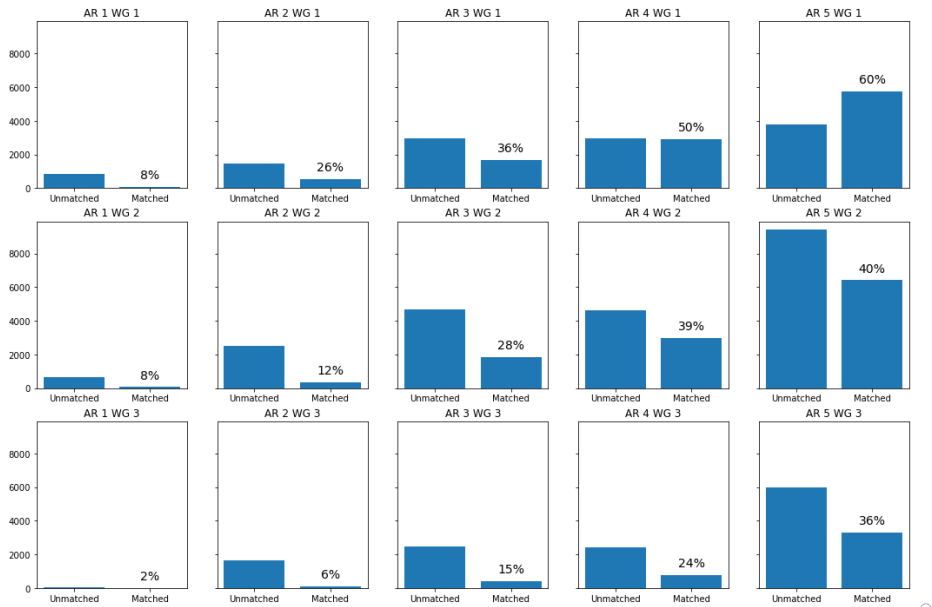
- Not perfect query
- WoS not all peer-reviewed literature
- Missing grey literature
- Missing relevant literature not directly about climate change



## Matching process

For each Reference:

- Check for case-insensitive title matches
- Calculate the Jaccard similarity score for two word shingles every database document containing the first word and from the same year. Match if the Jaccard score is above 0.45



AR	WG	text	authors	year
2	2	Landfill gas: working with Gaia. Biodeterioration Extracts no. 4, Energy Technology Support Unit, Harwell Laboratory, Oxfordshire, UK.	Richards, K.M.	1989
1	1	Longwave cloud radiative forcing as determined from Nimbus-7 observations J Cltm , 2, 766 799	Ardanuy, P E , L L Stowe, A Gruber, M Weiss and C S Long	1989
3	2	Climate change: overview and implications for wildlife. In: Wildlife Responses to Climate Change: North American Case Studies [Schneider, S.H. and T.L. Root (eds.)]. Island Press, Washington, DC, USA, (in press).	Root, T.L. and S.H. Schneider	2001
2	3	The impact of global warming on the United States: A survey of recent literature, mimco. Institute for International Economics, Washington, DC (April).	Cline, W.R.	1993
3	2	Population-environment relations at the forested frontier of Nepal. Applied Geography, 20, 221-242.	Conway, D., K. Bhattarai, and N.R. Shrestha	2000
3	2	The Cities Project. Australian Geological Survey Organisation, Australia. Available online at <a href="http://www.agso.gov.au/geohazards/grm/cities2.html">http://www.agso.gov.au/geohazards/grm/cities2.html</a> .	AGSO	1999
4	1	CLIMBER-2: A climate system model of intermediate complexity. Part I: Model description and performance for present climate.	Petoukhov, V., et al.	2000
5	1	A skill-score based evaluation of simulated Australian climate. Australian Meteorol. Oceanogr.	Watterson, I., A. C. Hirst, and L. D. Rotsteyn	2013
5	1	Enhanced aerosol backscatter adjacent to tropical trade wind clouds revealed by satellite-based lidar. Geophys. Res	Tackett, J. L., and L. Di Girolamo	2009
5	3	Promoting long-term investments by institutional investors. OECD Journal: Financial Market Trends 1, 145 – 164	Della Croce R, F Stewart, and J Yermo	2011

37% of IPCC References could be matched to the database of climate-relevant documents

**Reasons for not matching**

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## Observations

- The size of the literature appears to be *much* bigger than our estimate



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- The size of the literature appears to be *much* bigger than our estimate
- WG3 refers to more literature not directly about climate change, or not in peer-reviewed publications, than WG2, which refers to more than WG1

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- Dynamic Topic Modelling (DTM) (Blei and Lafferty, 2006) assume that a constant number of topics exists over all topic models, but allows the words in the topics to evolve from one time period to another
- Dynamic Non-negative Matrix Factorisation (Greene and Cross, 2016) has varying numbers of topics in each window and allows for topics to emerge and/or disappear.

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Where the size and variety of the literature we want to model has increased exponentially, we need an approach that allows for the emergence of new topics.

Window Topics: 1991



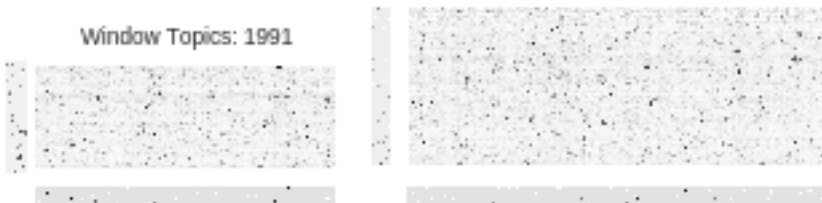
Window Topics: 1991



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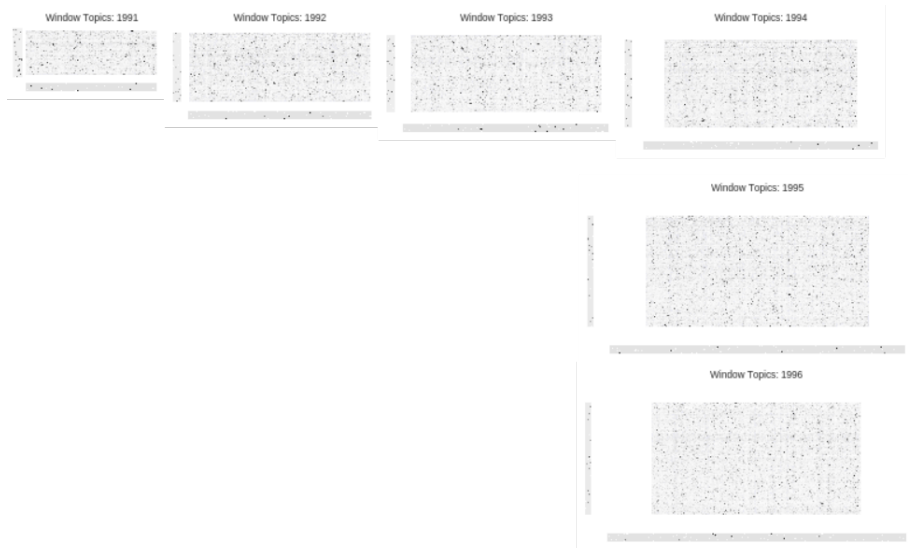
Window Topics: 1992

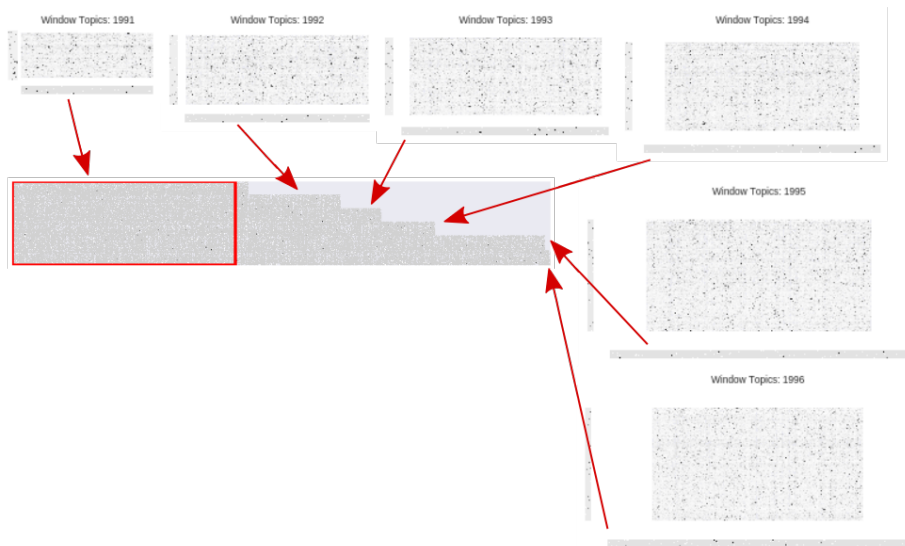


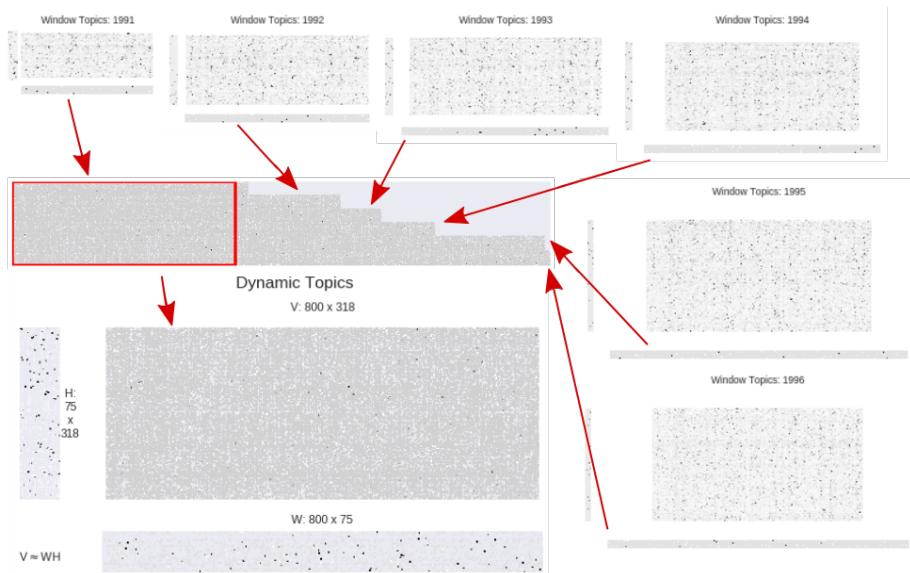
Window Topics: 1993





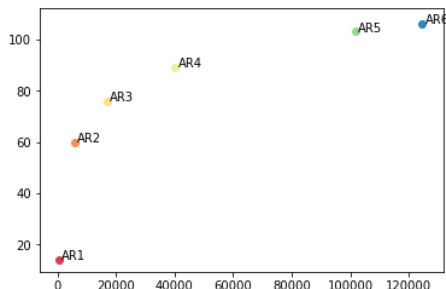






- Choosing the number of window topics is non-trivial. Data-driven approaches are limited (see below), and human selection is time consuming.
- To facilitate the description of trends over the assessment periods of the IPCC, and to minimize the number of modelling decisions, I consider each IPCC assessment period as a time window.

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- To facilitate the description of trends over the assessment periods of the IPCC, and to minimize the number of modelling decisions, I consider each IPCC assessment period as a time window.
- Starting from a logarithmic relationship between the number of documents and the ideal topic number, I compare 5 runs with varying numbers of topics for each window



## Human topic number criteria

- Intelligibility

## Data-driven topic number criteria

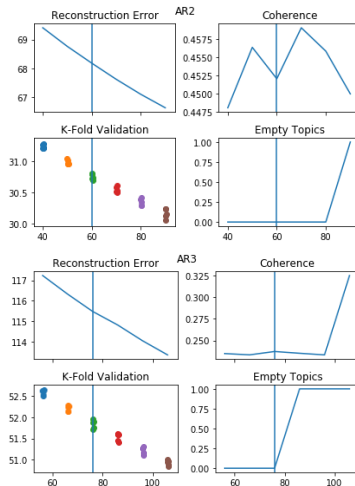
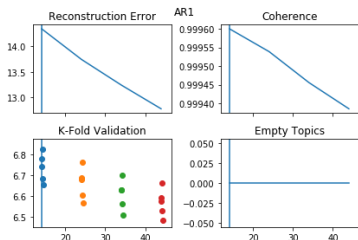
- Reconstruction accuracy
- Predictive capacity

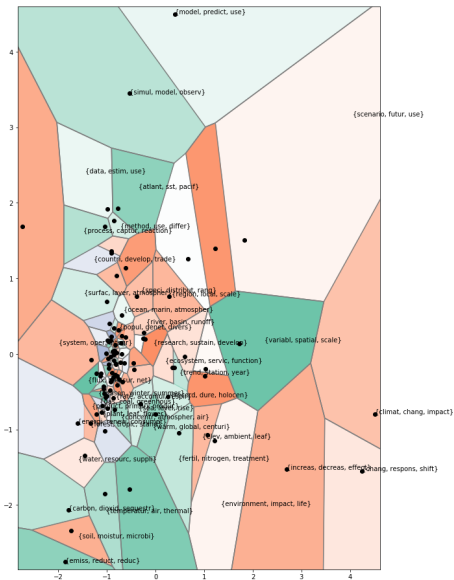
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## Outline





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### • Topography

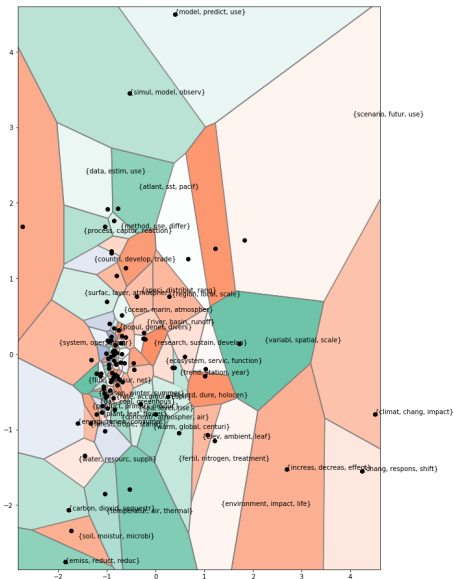


- Topography
- Structure



## Outline

- Topography
- Structure
- Development



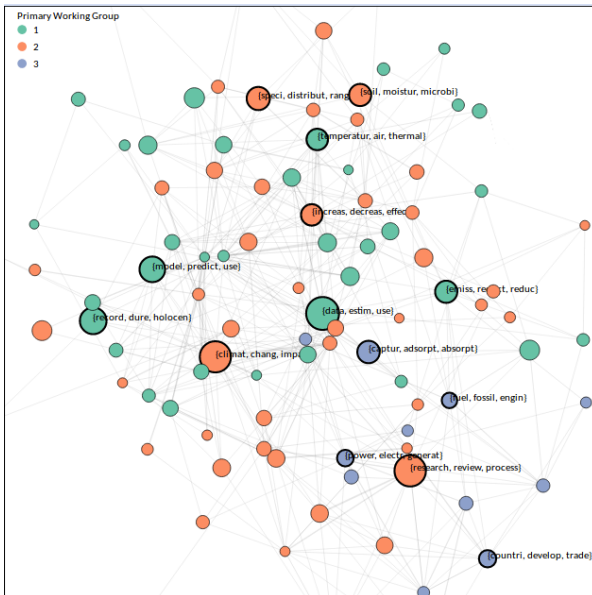
## Outline

- Topography
- Structure
- Development
- Representation in past IPCC reports

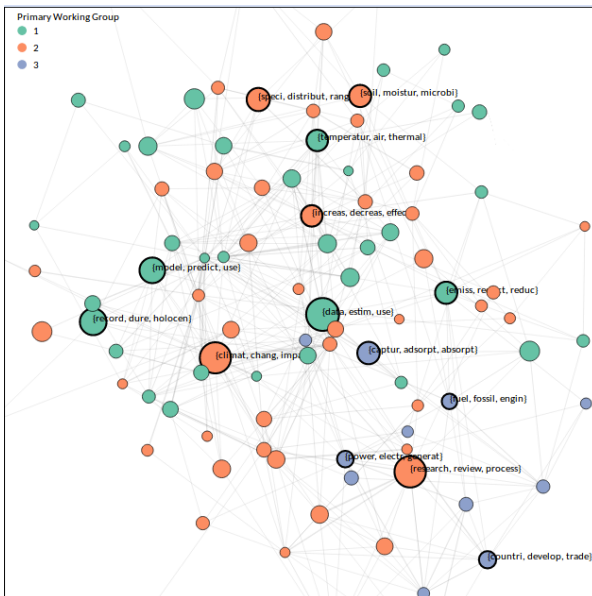


## Outline

- Topography
- Structure
- Development
- Representation in past IPCC reports
- AR6 outlook



- Topics describe comprehensible themes in climate change research



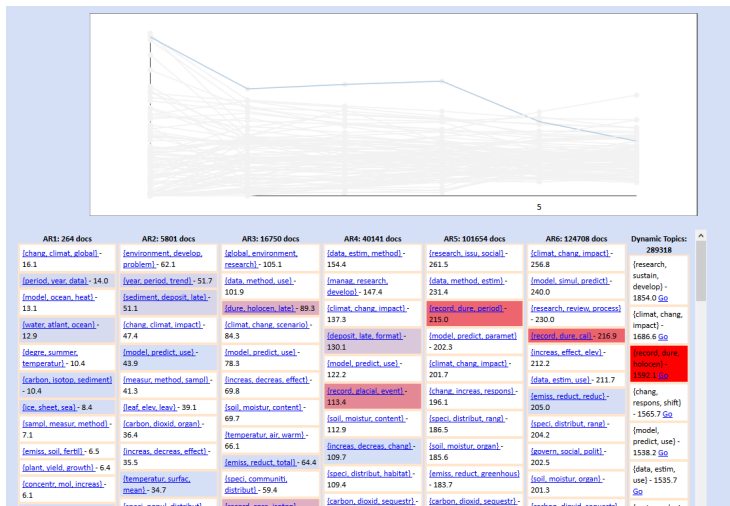
- Topics describe comprehensible themes in climate change research
- Matching topics to the IPCC working group from which the majority of the topics are referenced in, a structure is generated based on topic-document correlations

IPCC Coverage	Primary WG	Topic Title	WG 1	WG 2	WG 3
0.16%	1	{rainfal, monsoon, rain}	0.50%	0.50%	0.00%
0.10%	2	{veget, ndvi, cover}	0.41%	0.59%	0.00%
0.16%	1	{snow, cover, winter}	0.59%	0.41%	0.00%
0.17%	2	{region, local, scale}	0.41%	0.59%	0.00%
0.16%	1	{coastal, mangrov, rise}	0.57%	0.42%	0.01%

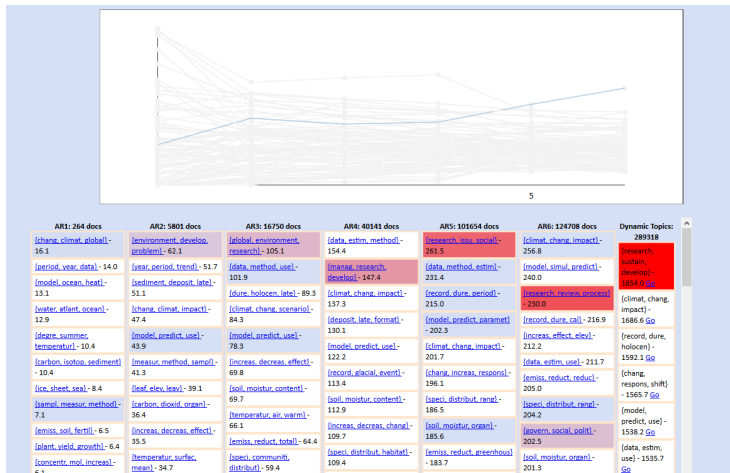


IPCC Coverage	Primary WG	Topic Title	WG 1	WG 2	WG 3
0.09%	3	{gas, coal, greenhous}	0.30%	0.15%	0.56%
0.10%	3	{transport, vehicl, road}	0.24%	0.12%	0.64%
0.13%	1	{emiss, reduct, reduc}	0.45%	0.21%	0.34%
0.09%	1	{methan, oxid, methanotroph}	0.63%	0.16%	0.20%
0.13%	3	{ghg, greenhous, gas}	0.15%	0.09%	0.75%

IPCC Coverage	Primary WG	Topic Title	WG 1	WG 2	WG 3
0.11%	2	{sustain, develop, resourc}	0.04%	0.51%	0.46%
0.08%	3	{build, construct, design}	0.03%	0.38%	0.59%
0.11%	2	{environment, impact, life}	0.06%	0.58%	0.36%
0.19%	3	{polici, tax, govern}	0.02%	0.32%	0.66%
0.16%	2	{urban, citi, plan}	0.07%	0.55%	0.38%



Basic climate science topics are not as prominent as they were previously



Sustainable development, and research agendas are more prominent

## words

research  
sustain  
develop  
review  
issu  
process  
scienc  
approach  
challeng  
paper  
discuss  
understand  
need  
social  
knowleg  
ecolog  
new  
scientif  
address  
provid  
articl  
focus  
global  
framework  
recent  
problem  
inform  
govern  
integr

## Terms across all window topics

Adjust threshold



0.1

Filter terms by the product of the term-window topic score and the window topic-dynamic topic scores.

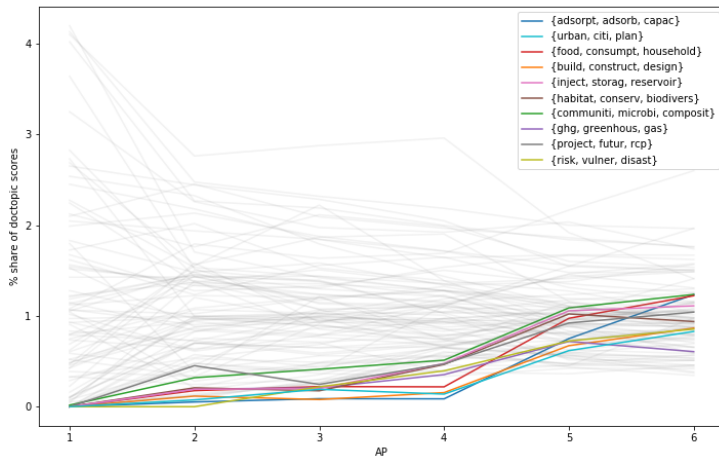
2	environment	develop	problem	research	polici	issu	intern	need	system	global
3	global	environment	research	issu	problem	impact	develop	manag	paper	human
4	manag	research	develop	sustain	issu	approach	process	need	understand	scienc
5	research	issu	social	sustain	scienc	challeng	paper	govern	articl	develop
6	research	sustain	review	process	approach	develop	knowledg	challeng	scienc	discuss

## Terms in window topics where the primary dynamic topic is this one

View	0.42	2	[environment, develop, problem]	environment	develop	problem	research	polici	issu	intern	need	system	global
View	0.74	3	[global, environment, research]	global	environment	research	issu	problem	impact	develop	manag	paper	human
View	1.33	4	[manag, research, develop]	manag	research	develop	sustain	issu	approach	process	need	understand	scienc
View	2.24	5	[research, issu, social]	research	issu	social	sustain	scienc	challeng	paper	govern	articl	develop
View	2.61	6	[research, review, process]	research	review	process	approach	develop	knowledge	challeng	scienc	discuss	understand
View	1.3	6	[sustain, develop, econom]	sustain	develop	econom	resourc	social	tourism	environment	goal	framework	challeng
View	0.61	6	[govern, social, polit]	govern	social	polit	public	articl	local	action	institut	particip	engag

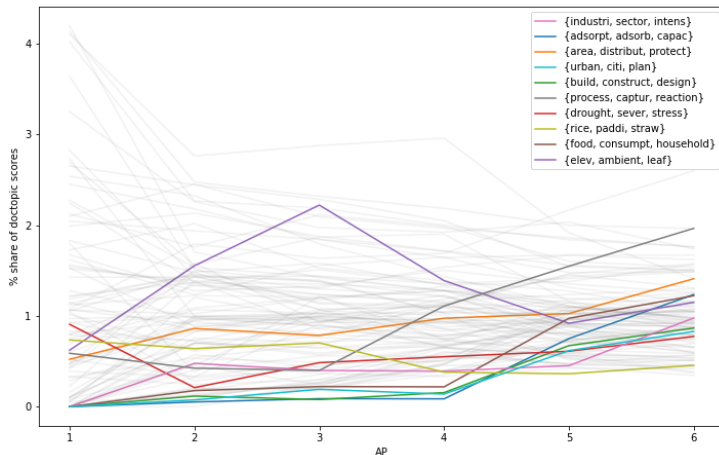
PY	Title	Topic Score
2011	<a href="#">Structuring sustainability science</a>	0.1131
2016	<a href="#">Developing a quantitative index system for assessing sustainable forestry management in Heilongjiang Province, China: a case study</a>	0.1008
2007	<a href="#">The implications of complexity for integrated resources management</a>	0.0983
2001	<a href="#">Africa and global climate change: critical issues and suggestions for further research and integrated assessment modeling</a>	0.0950
2017	<a href="#">Sustainability</a>	0.0865
2006	<a href="#">An integrated framework for science-based arid land management</a>	0.0843
2017	<a href="#">A methodological approach for the design of sustainability initiatives in pursuit of sustainable transition in China</a>	0.0829

Fast growing topics in AR5



Fast growing topics in AR5 were on urban systems, negative emissions, buildings, consumption, biodiversity and risks

Fast growing topics in AR6



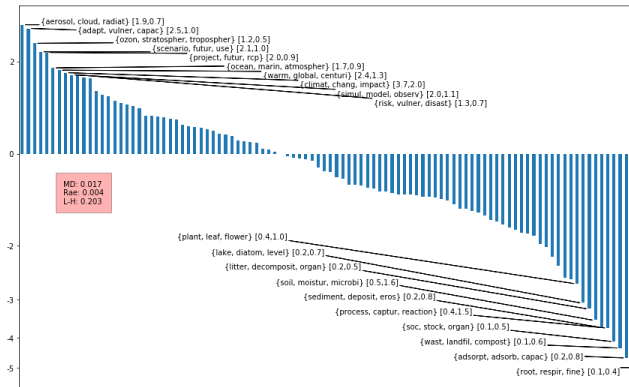
Negative emissions topics continue to grow,

- How can we get a sense of which topics are better covered in IPCC reports?



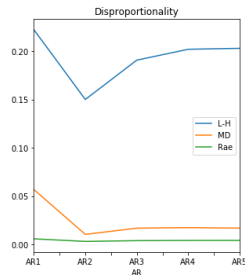
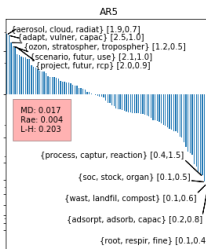
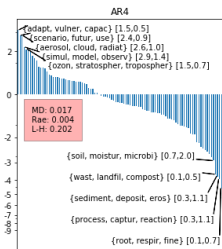
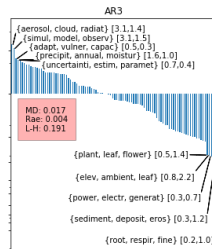
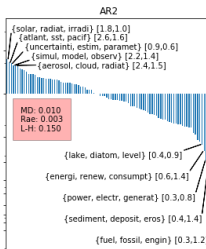
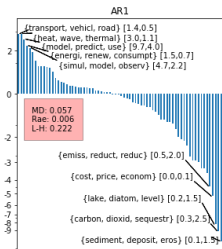
- How can we get a sense of which topics are better covered in IPCC reports?
- We get a measure of proportionality between two distributions by dividing the each topics share in the IPCC sample by its share in the whole corpus

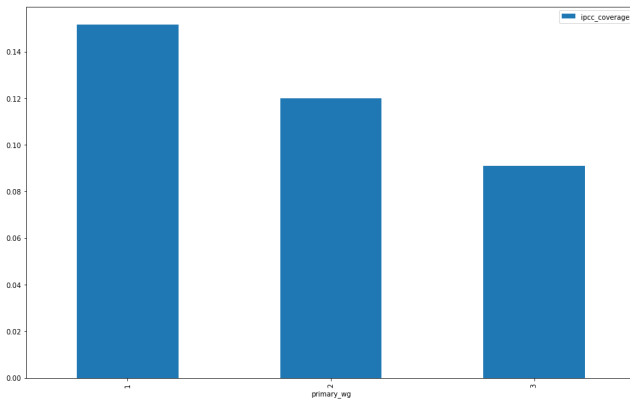
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- This and other measures come from literature on the proportionality of electoral systems (e.g Karpov, 2008)



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- Topics on specific technological solutions (particularly NETs), as well as soils and plants are less well represented

# Results - topic representation in IPCC reports





- On average, topics that are primarily referenced by working group I report have a higher proportion of constituent documents matching IPCC references

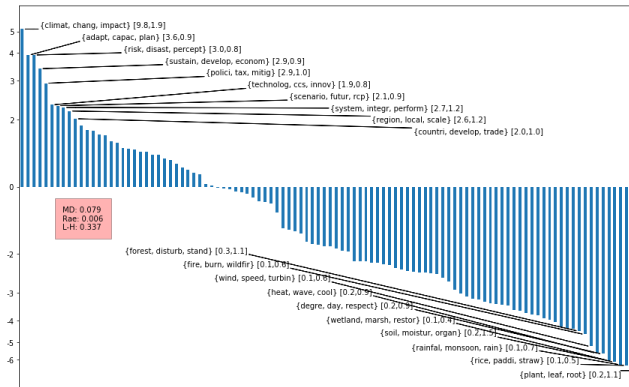
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- These scores were summed and were compared to the corpus in general in the same way as with past reports



# Results - topic representation in IPCC reports

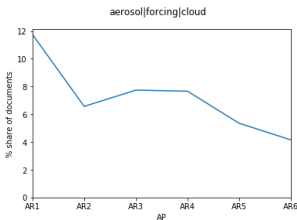


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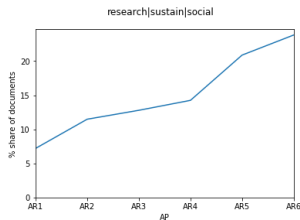
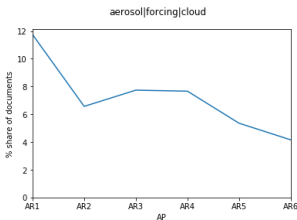
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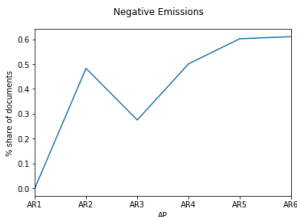
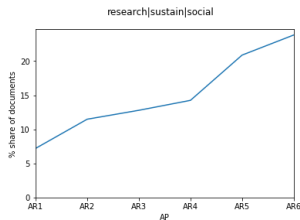
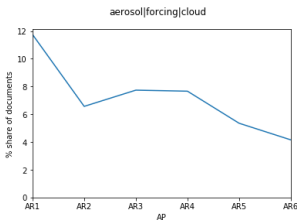
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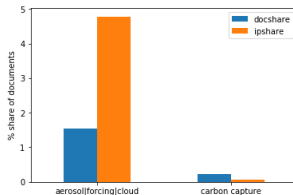
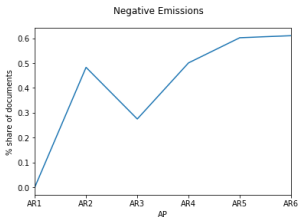
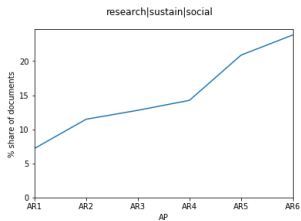
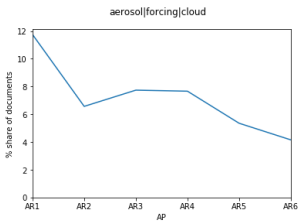
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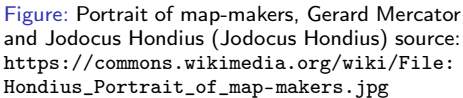
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- Topic modelling discovers over-arching topics such as that on sustainability and research priorities, as well as specific, fast growing topics such those on negative emissions
- Some quantitative evidence is found to support policy makers' dissatisfaction with a lack of 'solution orientation' in IPCC reports (Kowarsch et al., 2017)

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- A topography of the literature helps to address issues of emphasis from a point of understanding, and to make decisions clear and transparent
- More generally, maps like this present exciting opportunities to aid the process of literature selection, and to understand the science policy process



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