A Topography of Climate Change Research - Results

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1 Results

1.1 Literature growth

The literature on climate change has grown rapidly (Grieneisen and Zhang, 2011). The implications for the IPCC are discussed in (Minx et al., 2017). Since that study's publication, growth has continued (see SI figure x.)

Not only are more articles being published, the range of themes being discussed in the context of climate change (see for example recently zika and biochar, which were not to be found at all before ARs 6 and 5 respectively) has expanded.

	AR1	**AR2**	**AR3**	**AR4**	**AR5**	**AR6**
Years	1986-1989	1990-1994	1995-2000	2001-2006	2007-2013	2014-
Documents	1,167	8,539	21,716	38,750	134,413	201,606
Words	2000	12480	23346	34637	71867	94746
New words	change (560)	oil (287)	downscaling (217)	sres (234)	biochar (1791)	mmms (313)
	climate (428)	deltac (283)	degreesc (187)	petm (95)	redd (1113)	cop21 (234)
	co2 (318)	whole (256)	ncep (130)	amf (88)	cmip5 (679)	c3n4 (214)
	climatic (289)	tax (254)	fco (107)	sf5cf3 (86)	cmip3 (587)	sdg (187)
	model (288)	landscape (249)	pfc (98)	clc (81)	mofs (299)	zika (182)
	atmospheric (281)	alternative (243)	otcs (98)	embankment (81)	sdm (297)	ndcs (168)
	effect (280)	availability (242)	dtr (95)	cwd (79)	mof (275)	indc (164)
	global (224)	life (239)	nee (89)	etm (75)	biochars (252)	indcs (134)

Table 1: Growth in climate change literature

Topic modelling helps us to map out the literature, and make sense of broad patterns in the distribution of documents and their words. In this way, we can answer questions about the growth of the climate change literature, and its representation in IPCC assessment reports. The answers to these questions can help inform IPCC processes, and understand how the IPCC functions.

1.2 Topic structure of literature maps to broad disciplinary categories

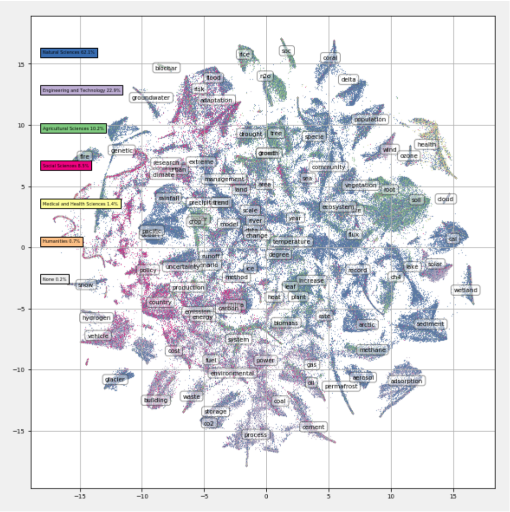

Figure 1: A map of the literature on climate change. Document positions are obtained by reducing the topic scores to two dimensions via t-SNE Documents are coloured by web of science discipline category. See SI table for topic composition of each grid square

- The thematic structure of the topics reflects journal disciplinary categories.
- Different disciplines clearly deal with different themes, although some topics are more interdisciplinary
- Topics in the south of the map (coal, oil, gas, cement, power) show a strong mix of social sciences and engineering

Show disciplinary entropy of topics in SI, give examples

1.3 Contrary to suggestions, the social sciences are over-represented in IPCC reports, while agricultural sciences and engineering are under-represented

(Bjurström and Polk, 2011) and (David G. Victor, 2015) point to an under-representation of social science literature within the IPCC, and a dominance of the natural sciences

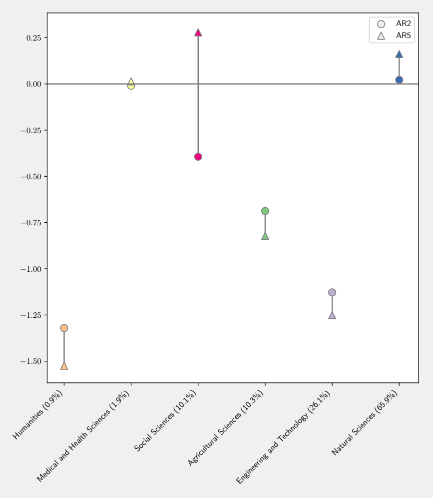

Figure 2: The representation within the IPCC of each discipline over time

- The natural sciences have always made up the greatest share of IPCC citations and documents about climate change
- The ratio of these two proportions tells us whether a certain discipline is over-represented or under-represented
- The natural are indeed slightly over-represented
- Although the Social sciences were under-represented in the past, by AR5, they were the most over-represented discipline

1.4 Solution oriented topics have seen rapid growth, which has not been matched by coverage in the IPCC

The topic model allows us to dig deeper into the content of the types of documents which are under-represented in the IPCC, as well as helping us understand how the thematic structure of the literature has developed.

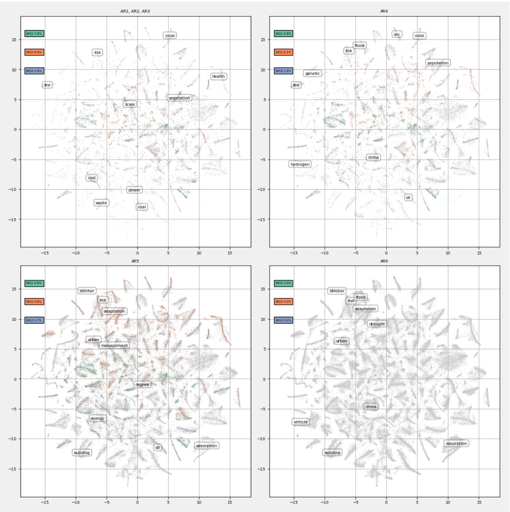

Figure 3: A map of the literature on climate change. Document positions are obtained by reducing the topic scores to two dimensions via t-SNE Documents are coloured by working group citations. In each assessment period, the largest cluster of documents relating to each of the 10 fastest growing topics is outlined.

- The thematic structure is also reflected in the division of labour between IPCC working groups. Documents cited by each working group appear in discrete parts of the map (which correspond also to the disciplinary structure)
- A number of different patterns of growth are visible. Adsorption was a fast growing topic in AR5, but had few IPCC citations, while risk and adaptation were fast growing, with many WGII citations

By plotting each topic's newness and IPCC representation, we can dig down into the types of topics which are over or under represented

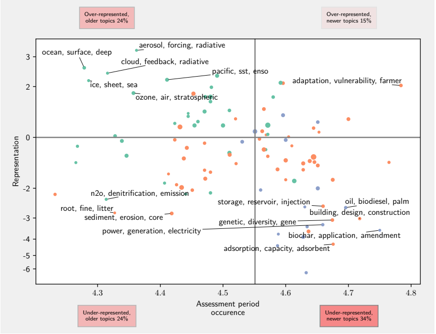

Figure 4: The IPCC representation and age of the topics. Representation shows the log of the share of topic documents in IPCC citations divided by the share of topic documents among all documents. Assessment period occurence shows the assessment period in which the mean topic document was published

- Those topics that deal with working group III issues (negative emissions, buildings) are in general fast growing and under-represented in IPCC reports
- Working group I topics are in general older and better represented.
- Of the newer topics that are well represented, many are on WG II issues

Within working group III, those topics which have more citations from the social sciences are better represented (SI figure x.) These are general topics about policy options, and international politics. Those topics which are not well represented are on specific solutions, such as vehicles, buildings, and negative emissions.

While there may be a need for more social science knowledge in IPCC assessments, this analysis makes it clear that this is rather a task for social scientists to produce more knowledge, than for the IPCC to reflect it better.

Further, given Policymakers' demands for more solution-oriented knowledge, the IPCC may do well to make efforts to cover more of the literature on individual solutions.

It may be argued that the technical solution-oriented knowledge is not yet in a proper form for synthesis by the IPCC. Although this is not an argument made for WGII (where the relationship between social science percentage and IPCC coverage for topics is not found), it would then be a task for the social sciences to produce research on solution oriented topics: increasing, for example, the less than 5% of the research on biochar that is published by social scientists.

2 SI

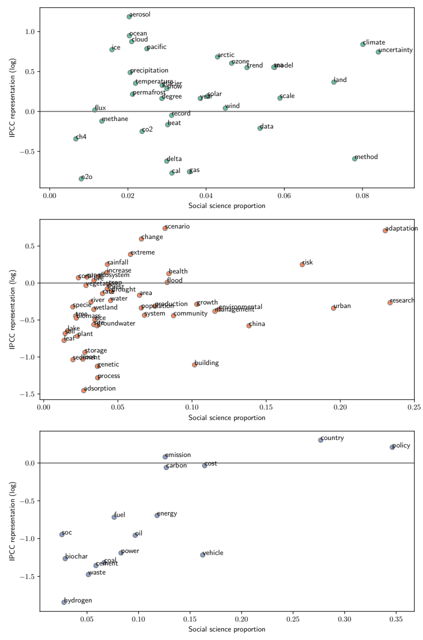

Figure 5

2.1 Glossary

ncep: National Centers for Environmental Protection

fco: Fugacity of Carbon Dioxide

pfc: Perflourocompound

otcs: Open Top Chambers

dtr: Diurnal Temperature Range

sres: Special Report on Emissions Scenarios

petm: Paleocene Eocene Thermal Maximum

amf: Arbuscular Mycorrhizal Fungal

sf5cf3: trifluoromethyl sulfur pentafluoride (A Potent Greenhouse Gas Identified in the Atmosphere, 2000)

clc: Chemical Looping Combustion

cwd: Coarse woody debris

etm: Enhanced Thematic Mapper (NASA satellite sensor)

cmip5: Coupled Model Intercomparison Project 5 (Starting 2008)

cmip3: Coupled Model Intercomparison Project phase 3 (first published 2007 Meehl et al. (2007))

mofs: metal-organic frameworks (for CO2 storage)

sdm: statistical-dynamical model

mmms: Mixed Matrix Membranes (for CO2 capture)

cop21: 21 Conference of Parties (Paris 2015)

c3n4: Carbon nitride (a synthetic nanomaterial used for hydrogen production)

sdg: Sustainable Development Goals

indc: Intended Nationally Determined Contributions

	ipcc_share	share	representation	primary_wg	title	year_av
0	0.006262	0.006395	0.979211	3	{ghg, greenhouse-gas, mitigation}	4.780488
1	0.000650	0.002675	0.243124	3	{biochar, amendment, application}	4.758621
2	0.002171	0.005588	0.388425	3	{storage, reservoir, injection}	4.652174
3	0.001689	0.005016	0.336741	3	{oil, palm, biodiesel}	4.644444
4	0.001909	0.004702	0.406082	3	{electricity, generation, demand}	4.634146
5	0.009932	0.007924	1.253431	3	{policy, government, maker}	4.634146
6	0.001355	0.005430	0.249488	3	{power, generation, nuclear}	4.627907
7	0.000772	0.003433	0.224982	3	{vehicle, electric, battery}	4.625000
8	0.004662	0.007966	0.585245	3	{technology, cc, development}	4.617021
9	0.001251	0.005314	0.235373	3	{cement, material, concrete}	4.615385
10	0.004078	0.008273	0.492982	3	{energy, demand, source}	4.595238
11	0.006233	0.006769	0.920846	3	{price, market, tax}	4.577778
12	0.004963	0.005667	0.875751	3	{sector, industry, industrial}	4.571429
13	0.001154	0.003121	0.369613	3	{soc, stock, soil}	4.568182
14	0.000780	0.003826	0.203874	3	{waste, landfill, solid}	4.568182
15	0.005659	0.005908	0.957905	3	{cost, benefit, abatement}	4.568182
16	0.000812	0.003718	0.218338	3	{coal, combustion, mine}	4.562500
17	0.011040	0.008608	1.282596	3	{country, develop, international}	4.543478
18	0.010841	0.010172	1.065744	3	{reduction, reduce, target}	4.533333
19	0.002695	0.005586	0.482466	3	{fuel, fossil, engine}	4.500000
20	0.048400	0.043462	1.113604	3	{emission, greenhouse-gas, inventory}	4.500000
21	0.011413	0.005391	2.117184	2	{adaptation, vulnerability, strategy}	4.783784
22	0.003123	0.004452	0.701476	2	{urban, city, urbanization}	4.757576
23	0.001268	0.004327	0.292959	2	{building, construction, design}	4.702703
24	0.006544	0.005171	1.265452	2	{risk, disaster, hazard}	4.684211
25	0.000978	0.004770	0.205070	2	{adsorption, capacity, adsorbent}	4.676471
26	0.003577	0.004542	0.787517	2	{household, income, consumption}	4.676471
27	0.005267	0.008168	0.644840	2	{habitat, conservation, biodiversity}	4.674419
28	0.003701	0.004579	0.808288	2	{food, web, supply}	4.650000
29	0.003152	0.002859	1.102456	2	{coral, reef, bleaching}	4.645833
30	0.005709	0.005180	1.102186	2	{health, public, mortality}	4.634146
31	0.005419	0.007802	0.694545	2	{management, resource, practice}	4.634146
32	0.008456	0.011061	0.764468	2	{research, science, issue}	4.634146
33	0.006236	0.007047	0.884940	2	{economic, development, economy}	4.625000
34	0.004594	0.006687	0.687020	2	{population, size, survival}	4.622222
35	0.001609	0.005459	0.294757	2	{genetic, diversity, gene}	4.619048
36	0.004486	0.010488	0.427700	2	{network, design, problem}	4.615385
37	0.004747	0.005479	0.866385	2	{fish, fishery, marine}	4.613636
38	0.007463	0.011144	0.669715	2	{environmental, impact, life}	4.609756
39	0.002422	0.004786	0.506071	2	{farm, animal, milk}	4.609756
40	0.004245	0.006343	0.669241	2	{community, microbial, composition}	4.609756
41	0.013609	0.009337	1.457572	2	{project, cdm, projection}	4.595745
42	0.004632	0.004635	0.999354	2	{disease, vector, host}	4.595745
43	0.003979	0.004463	0.891546	2	{drought, severe, severity}	4.589744
44	0.005927	0.008607	0.688619	2	{specie, native, invasive}	4.586957
45	0.001539	0.003043	0.505532	2	{groundwater, recharge, aquifer}	4.581395
46	0.002316	0.005242	0.441717	2	{landscape, erosion, disturbance}	4.577778
47	0.003614	0.003665	0.986025	2	{flood, flooding, damage}	4.575000
48	0.005727	0.008737	0.655430	2	{system, performance, hybrid}	4.568182
49	0.014225	0.006807	2.089702	2	{scenario, future, impact}	4.568182
50	0.005689	0.009700	0.586482	2	{process, chemical, base}	4.568182
51	0.007445	0.007451	0.999162	2	{human, activity, natural}	4.555556
52	0.004140	0.006229	0.664684	2	{flow, stream, low}	4.555556
53	0.005146	0.005176	0.994293	2	{crop, agricultural, irrigation}	4.547619
54	0.008942	0.006187	1.445342	2	{extreme, event, weather}	4.534884
55	0.016558	0.017701	0.935400	2	{index, vulnerability, correlation}	4.523810
56	0.007844	0.007612	1.030470	2	{stress, response, gene}	4.511628
57	0.009577	0.012434	0.770286	2	{area, study, high}	4.511111
58	0.003715	0.004875	0.761937	2	{river, discharge, basin}	4.510638
59	0.007486	0.007414	1.009739	2	{ecosystem, net, productivity}	4.510638
60	0.003211	0.003116	1.030511	2	{fire, burn, wildfire}	4.510204
61	0.005322	0.005042	1.055661	2	{runoff, catchment, basin}	4.489362
62	0.007941	0.008078	0.982939	2	{distribution, range, niche}	4.479167
63	0.005792	0.008245	0.702468	2	{production, primary, produce}	4.478261
64	0.002472	0.003512	0.703775	2	{wetland, coastal, marsh}	4.468085
65	0.006171	0.004839	1.275431	2	{rainfall, monsoon, rain}	4.458333

66	0.011976	0.011338	1.056311	2	{effect, affect, interaction}	4.456522
67	0.007983	0.010211	0.781808	2	{water, irrigation, resource}	4.456522
68	0.011411	0.008555	1.333875	2	{region, regional, south}	4.446809
69	0.051512	0.035918	1.434134	2	{increase, decrease, due}	4.428571
70	0.003390	0.005339	0.634989	2	{biomass, aboveground, bioenergy}	4.428571
71	0.006279	0.006987	0.898570	2	{yield, wheat, grain}	4.428571
72	0.012344	0.011019	1.120252	2	{term, long, short}	4.420000
73	0.008298	0.009014	0.920592	2	{season, day, grow}	4.420000
74	0.003944	0.007142	0.552150	2	{site, elevation, across}	4.411765
75	0.002282	0.004669	0.488863	2	{litter, decomposition, microbial}	4.408163
76	0.003608	0.005734	0.629128	2	{tree, ring, stand}	4.408163
77	0.006229	0.006779	0.918986	2	{forest, stand, tropical}	4.408163
78	0.003427	0.007046	0.486287	2	{plant, seed, grow}	4.400000
79	0.003690	0.006855	0.538355	2	{nitrogen, nutrient, treatment}	4.395833
80	0.019507	0.010818	1.803093	2	{change, climatic, shift}	4.384615
81	0.006852	0.007898	0.867560	2	{rate, high, accumulation}	4.380000
82	0.004288	0.006107	0.702157	2	{growth, radial, grow}	4.375000
83	0.006251	0.012730	0.491062	2	{soil, moisture, content}	4.372549
84	0.006042	0.006238	0.968498	2	{vegetation, ndvi, cover}	4.372549
85	0.002689	0.005191	0.517979	2	{lake, level, diatom}	4.358491
86	0.002031	0.005811	0.349411	2	{sediment, erosion, core}	4.358491
87	0.002397	0.003938	0.608762	2	{rice, paddy, field}	4.355556
88	0.001554	0.004251	0.365605	2	{root, fine, shoot}	4.264151
89	0.001861	0.004536	0.410171	2	{leaf, photosynthesis, photosynthetic}	4.142857
90	0.002603	0.005355	0.485996	1	{china, province, chinese}	4.729730
91	0.000328	0.003832	0.085614	1	{membrane, separation, selectivity}	4.666667
92	0.001056	0.004985	0.211908	1	{absorption, solvent, amine}	4.634146
93	0.001588	0.008110	0.195837	1	{oxygen, reaction, reactor}	4.604651
94	0.000631	0.004474	0.140983	1	{hydrogen, cell, steam}	4.571429
95	0.012275	0.006043	2.031420	1	{uncertainty, estimate, parameter}	4.565217
96	0.007506	0.012308	0.609808	1	{method, use, approach}	4.558140
97	0.004420	0.005373	0.822605	1	{heat, heating, pump}	4.547619
98	0.004159	0.004082	1.019032	1	{wind, speed, turbine}	4.520833
99	0.012651	0.007437	1.701127	1	{trend, station, significant}	4.520833
100	0.007889	0.005987	1.317745	1	{wave, coastal, storm}	4.511111
101	0.014942	0.012453	1.199858	1	{scale, spatial, large}	4.510638
102	0.008368	0.006040	1.385324	1	{land, cover, agricultural}	4.500000
103	0.009347	0.009705	0.963106	1	{carbon, low, sink}	4.468085
104	0.008119	0.004261	1.905300	1	{arctic, permafrost, warm}	4.448980
105	0.009826	0.006145	1.598856	1	{precipitation, annual, moisture}	4.446809
106	0.007645	0.009833	0.777451	1	{data, use, satellite}	4.446809
107	0.007591	0.006672	1.137725	1	{degree, day, latitude}	4.434783
108	0.022381	0.009859	2.270102	1	{climate, future, warm}	4.431373
109	0.021865	0.012745	1.715519	1	{model, simulation, simulate}	4.428571
110	0.003086	0.006655	0.463646	1	{gas, natural, hydrate}	4.428571
111	0.002026	0.005943	0.340879	1	{carbonate, mineral, rock}	4.420000
112	0.013955	0.009888	1.411387	1	{temperature, warm, mean}	4.420000
113	0.004515	0.005048	0.894359	1	{transport, road, transportation}	4.416667
114	0.012788	0.008996	1.421430	1	{winter, summer, spring}	4.415094
115	0.013202	0.007618	1.733013	1	{sea, level, rise}	4.411765
116	0.006158	0.006395	0.962925	1	{air, pollution, quality}	4.408163
117	0.004523	0.003533	1.280060	1	{snow, cover, depth}	4.400000
118	0.008692	0.007754	1.121041	1	{per, thousand, part}	4.384615
119	0.002843	0.006255	0.454437	1	{cal, pollen, holocene}	4.379310
120	0.012002	0.009752	1.230792	1	{year, period, annual}	4.377358
121	0.004178	0.003051	1.369399	1	{glacier, mass, balance}	4.372549
122	0.004935	0.004158	1.186828	1	{solar, radiation, irradiance}	4.372549
123	0.012949	0.005949	2.176902	1	{pacific, sst, enso}	4.351852
124	0.025289	0.011214	2.255153	1	{global, earth, world}	4.346154
125	0.015417	0.004451	3.463820	1	{aerosol, forcing, radiative}	4.345455
126	0.002264	0.004672	0.484521	1	{delta, isotope, value}	4.339286
127	0.009276	0.010024	0.925337	1	{record, late, early}	4.298246
128	0.014874	0.009238	1.610133	1	{surface, layer, albedo}	4.296296
129	0.007488	0.009212	0.812887	1	{co2, mol, carbon-dioxide}	4.294118
130	0.008833	0.007248	1.218694	1	{glacial, last, interglacial}	4.271186
131	0.011542	0.009860	1.170620	1	{concentration, doc, high}	4.264151
132	0.016337	0.006185	2.641400	1	{ocean, circulation, deep}	4.258621
133	0.005594	0.005752	0.972513	1	{flux, measurement, net}	4.258621
134	0.001581	0.003654	0.432735	1	{n2o, denitrification, nitrous-oxide}	4.254902
135	0.007908	0.003266	2.420887	1	{cloud, feedback, radiative}	4.254545
136	0.010994	0.005111	2.151092	1	{ice, sheet, sea}	4.229508
137	0.003641	0.004293	0.848013	1	{methane, oxidation, source}	4.218182
138	0.002656	0.003766	0.705170	1	{ch4, oxidation, peat}	4.208333
139	0.010688	0.003800	2.812635	1	{ozone, stratospheric, tropospheric}	4.203390

Table 2: Topics and their representation

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