Climate Change Consensus and Skepticism:
Mapping Climate Change Dialogue on Twitter and Facebook

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comprop@oii.ox.ac.uk

Ana Grouverman
Oxford University
@anagrouv

Bence Kollanyi
Oxford University
@bencekollanyi

Phil Howard
Oxford University
@pnhoward

Vlad Barash
Graphika
@vlad43210

Thomas Lederer
Graphika

1. Botometer API

As listed on its website, Botometer (formerly BotOrNot) is a collaboration between Indiana University Network Science Institute (IUNI) and the Center for Complex Networks and Systems Research (CNetS). Botometer checks the activity of a Twitter account and assigns it a score based on how likely the account is to be a bot. Higher scores indicate behavior more closely resembling a bot. Read more about the tool or contact the team at https://botometer.iuni.iu.edu/.

2. Hashtag Selection Methodology for Twitter Data Collection

Table 1: Hashtags Tracked for Twitter Data Collection on Climate Change Dialogue

Tentative Sentiment Affiliation	*Hashtags*	
Consensus	#ActOnClimate	#SavePlanet
	#ClimateAction	#ScienceBasedTargets
	#Go100RE	#StopAdani
	#GoVegan	#ThinkGreen
	#MeatlessMarch	#Uniting4Climate
	#OnePlanet	
Skeptic	#ALEC	#ChemTrails
	#CarbonTax	#FossilFuels
	#CoalFleet	#GeoEngineering
	#ChemTrail	#MeatyMarch
Neither	#AlGore	#Environment
	#Arctic	#EPA
	#ArcticDavos	#GlobalGoals
	#ArticRefuge	#GlobalWarming
	#Biomimicry	#GPWX
	#CitiesIPCC	#IPCC
	#CleanEnergy	#MayTheFactsBeWithYouAll
	#CleanTech	#ParisAgreement
	#Climate	#RenewableEnergy
	#ClimateChange	#Renewables
	#Coal	#SDGs
	#COP22	#Solar
	#COP23	#Sustainability
	#Drought	#TodaysClimateFact
	#Energy	#Water
	#Enviroment	#Weather

The list of hashtags used for Twitter data collection was compiled using a grounded, multistep approach. First, qualitative research yielded 70 hashtags relevant to both Consensus and Skeptic narratives. In addition, a combination of journalistic accounts, NGO reports, and databases maintained by watchdog organizations was used to compile a list of 250 prominent accounts that engage in either Consensus or Skeptic commentary. One week of Twitter data collection on both these seed lists yielded an expanded list of 350 hashtags, of which the most frequently used were prioritized by relevance. For example, hashtags like #health, #agriculture, and #Trump were too ambiguous and broad for the purpose of this study, and would have picked up too much traffic not related to climate change. Removing such hashtags resulted in a final list of 52 hashtags.

Table 1 gives a full list of hashtags used for data collection in this study. Because hashtags were selected based on their frequency of use, this list would change based on the timeframe when it was compiled, and naturally excludes some well-known hashtags relevant to climate change.

Additionally, it is important to note that the Sentiment Affiliation listed was a tentative assessment made by the subject matter expert prior to the data collection period. Consequently, the affiliation listed does not account for social media strategies and phenomena like hashtag hijacking, protest mobilization, or ironic use.

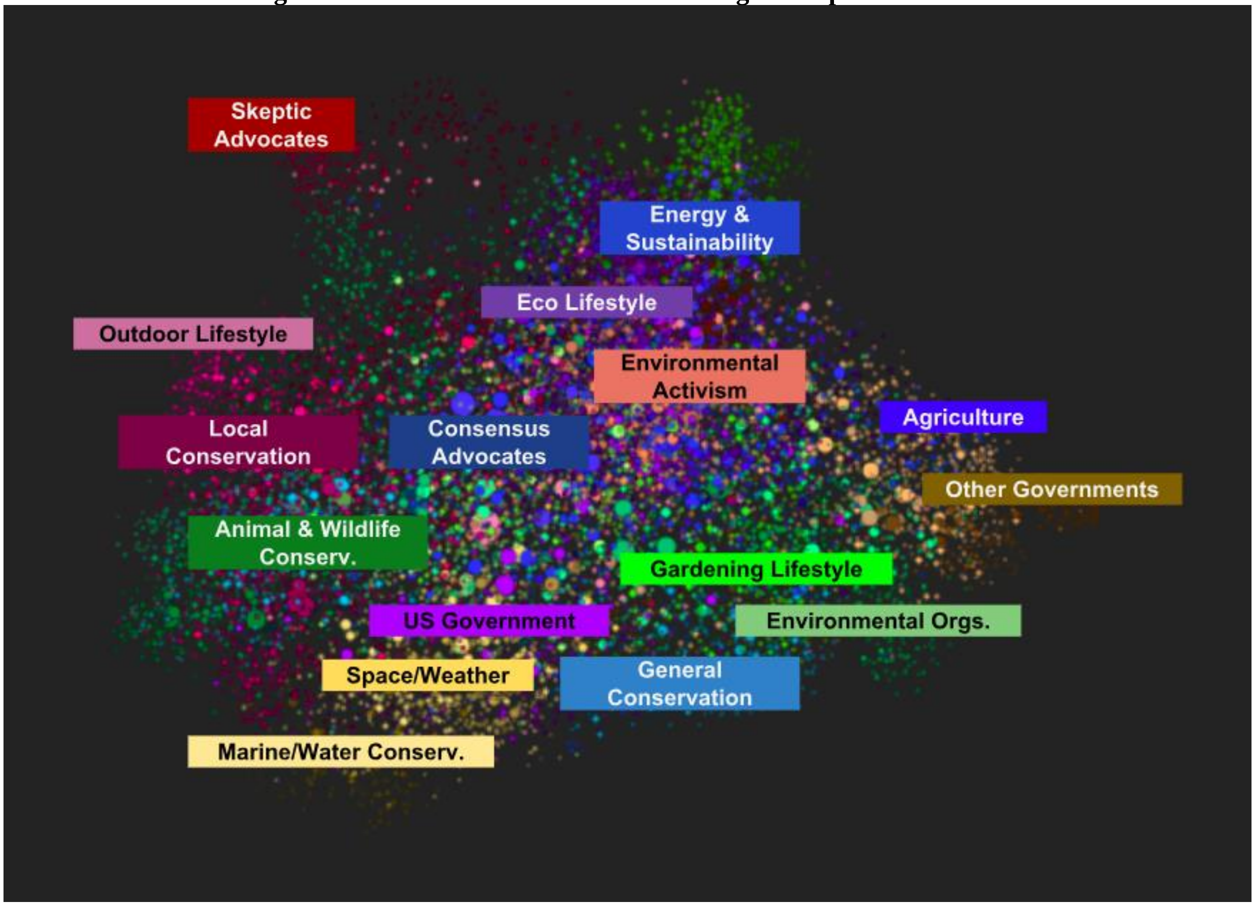
3. Clustering Algorithm for Determining Facebook Clusters and Groups

In order to generate clusters and groups for each network map it is necessary to employ a clustering algorithm. This involves first building a bipartite graph between nodes in the map and the rest of the social medium in question. This bipartite graph provides a structural similarity metric between nodes in the map. This was then used in combination with a hierarchical agglomerative clustering algorithm in order to segment a map into distinct communities, or *groups*. This is a 'bottom up' approach whereby each observation starts in its own cluster, and pairs of clusters are merged as one moves up the hierarchy. Facebook networks are clustered based on page *likes*.

4. Facebook Network Map

Each node in this network (Figure 1) represents a public page on Facebook. The size of each node corresponds to the number of other nodes that like the page on Facebook. Each node belongs to both a broad group and a smaller cluster within that group. A cluster is a collection of nodes with a shared pattern of interest, while a group is a collection of clusters that are politically, culturally, or socially similar.

Figure 1: Full Illustration of Climate Change Groups on Facebook



Source: Authors' calculations from data sampled between 19/1/18—17/4/18. Note: Groups are determined through network association and our interpretation of the kinds of content these users distribute.

The nodes are placed within the map using a Fruchterman-Reingold visualization algorithm. This works to place nodes on the map according to two principles: first, a "centrifugal force" acts upon each node to push it to the edge of the canvas; second, a "cohesive force" acts upon every connected pair of nodes to pull them closer together. Table 2 gives a full list of Facebook groups and associated segments considered in this study.

Table 2: List of Groups and Clusters for Facebook Visualization

Groups	*Clusters*
Agriculture Industry	International Agriculture Research Organizations
	US Animal Agriculture
Animal & Wildlife Adv.	Africa Wildlife Activism
	Animal Advocacy
	Bee & Insect Enthusiasts
	Birding Interest
	Florida Wildlife Conservation
	Species Conservation
	Texas Wildlife & Conservation
	UK Wildlife Trusts & Conservation
	US Dog Rescue Activism
	US Predator Conservation
	US Wildlife Habitats & Agencies
	Vegan Activism & Brands
Consensus Advocates	US Progressive Media & Business
Eco Lifestyle	Eco Business & Activism
	Eco Food Brands
	Eco Parenting
	Eco Spiritual & Inspirational Accounts
	Food Blogs
	Health Food Experts
	US Farm-to-Table Organizations
Environmental Activism	Spanish Eco Interest
	US Anti-Fracking Activism
	US Anti-GMO Activism
	US Eco Brands & Experts
	US Eco Agricultural Organizations
	US Recycling Activism
Environmental Organizations	German Environmental Concern Organizations
	International Eco Activism
	International Environmental Organizations
	International Greenpeace Activists
Energy & Sustainability	Canada Green Energy & Conservation
	Green Energy
	Permaculture
	Solar Industry
Gardening Lifestyle	Australia Gardening Interest
	US Gardening Interest
General Conservation	Anti-Plastic Activism
	Australia Conservation Organizations
	US Conservation Education
	US Nature Conservancy
Local Conservation	Colorado Outdoor & Conservation
	Illinois Environmental NGOs
	Oregon Conservation Nonprofits
	San Francisco Conservancy & Parks
	Washington State Conservation
Marine & Water Conservation	Marine Conservation Organizations
	Shark Conservation
	Surfing & Aquatic Conservation
	US Marine Conservation – Sea Grants
Other Governments	EU Government Agencies
	International Development Organizations & Agencies
	International Diplomacy Agencies
	UN Agencies
Outdoor Lifestyle	Africa Safari Business
	Nature Photographers
	Outdoor Apparel
	Travel Interest
	US Fishing Enthusiasts
	US Hiking & National Parks

Table 2: List of Groups and Clusters for Facebook Visualization

Groups	*Clusters*
	US National Historic Sites
	US Zoos
Skeptic Advocates	Conspiracy Theorists
	Libertarian Skeptic Organizations
	US Conservative Media
	US Hardline Conservatives
Space/Weather Agencies	US NASA
	US NOAA
	US Weather Services
US Government	US Government Agencies
	US Military Agencies

5. Heterophily Index

For every pairing of groups within a network map, a value of heterophily can be calculated. This is a measure of the level of connection between the groups. In order to determine this a ratio is calculated between the actual ties between two groups, compared to the expected ties between the groups if all the accounts in the map were evenly distributed. The natural log of these ratios is then taken, along with a zero correction to create a balanced index and to ensure that all values are displayed in a positive form.

This heterophily index is therefore created through a ratio of two ratios. This ratio reveals whether two nodes have about the proportion of links they should have given its size. This is displayed in Expression A, where a pairing of groups is calculated as having a measure of connections in balance with its share of all the connections.

$$Ratio\ of\ Ratios_T = \frac{\dfrac{Connections_{\text{pairing}}}{\sum_{\text{all pairings}} Connections}}{\dfrac{Connections_{\text{pairing}}}{\sum_{\text{all pairings}} Connections}}$$

Expression A: Ratio of Two Ratios

Half the distribution of possible values from this ratio of ratios ranges from 0 to 1 (corresponding to disproportionately small share of connections in a group given its size) and the other half ranges from 1 to +infinity (a disproportionately large share of connections in a group given its size). However, by taking the natural log of the ratio of ratios the index will become more balanced: from -infinity to 0 becomes less than proportionate share, and from 0 to +infinity becomes more than proportionate share. For example, take a three-group network (A, B and C). If nodes in group A have a total of ten connections, and there are ten nodes in each group, then the expected connections between A and B will be 3.33. If, in reality, the nodes in group A actually have all ten connections to nodes in group B then this connection is stronger than expected. The heterophily score for groups A and B = 10/3.33 = 3.0. The natural log of this is then taken along with a zero correction across the range of heterophily values.

A greater heterophily index indicates a denser pattern of connections between the two groups. It is important to note, however, that these scores indicate only first order connections, not second or third order connections. Table 3 shows the heterophily score between each pairing of climate change groups in our Facebook map.

Table 3: Heterophily index for Climate Change Groups on Facebook

Group	Agriculture Industry	Animal & Wildlife Adv.	Eco Lifestyle	Environmental Activism	Environmental Orgs.	Energy & Sustainability	Gardening Lifestyle	General Conservation	Other Governments	Consensus Advocates	Skeptic Advocates	Marine & Water Conserv.	Outdoor Lifestyle	Local Conservation	Space/Weather Agencies	US Government
Agriculture Industry	34.8	0.3	0.8	0.5	1.2	0.3	0.4	0.2	2.7	1.1	0.6	0.1	0.1	0.4	0.5	1.1
Animal & Wildlife Adv.	0.0	3.9	0.4	0.3	0.7	0.5	0.4	1.0	0.2	1.0	0.5	0.9	1.0	0.8	0.5	0.4
Eco Lifestyle	0.0	0.0	3.4	1.8	0.5	1.0	1.2	0.2	0.3	1.5	0.7	0.2	0.2	0.4	0.1	0.3
Environmental Activism	0.0	0.0	0.0	2.6	0.6	1.4	1.2	0.5	0.3	1.6	0.6	0.4	0.3	0.6	0.2	0.5
Environmental Orgs.	0.0	0.0	0.0	0.0	6.3	1.3	0.4	0.5	1.5	1.7	0.7	0.8	0.5	0.3	0.5	0.4
Energy & Sustainability	0.0	0.0	0.0	0.0	0.0	3.8	0.7	0.7	0.4	2.0	1.4	0.6	0.4	0.9	0.4	0.8
Gardening Lifestyle	0.0	0.0	0.0	0.0	0.0	0.0	8.3	1.9	0.1	1.1	0.4	0.1	0.2	0.4	0.2	0.2
General Conservation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	0.2	1.1	0.4	1.1	0.9	1.0	0.7	0.7
Other Governments	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	1.7	0.8	0.3	0.1	0.2	0.6	1.2
Consensus Advocates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	2.0	1.4	0.9	1.2	2.0	1.7
Skeptic Advocates	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	0.5	0.5	0.4	1.1	1.8
Marine & Water Conserv.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	0.6	0.7	2.1	0.6
Outdoor Lifestyle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	1.1	0.7	0.8
Local Conservation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.8	0.9
Space/Weather Agencies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.9	4.6
US Government	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7