Clouding Climate Science:

A Comparative Network and Text Analysis of Consensus and Anti-Consensus Scientists*

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There is a clear consensus among climate scientists about the reality and serious consequences of anthropogenic climate change. However, a vocal minority challenges this consensus. While some research has drawn attention to how conservative foundations support these anti-consensus scientists, less is known about how these scholars are embedded within the broader scientific community. Here, we analyze the networks of anti-consensus and consensus scientists and observe the extent to which these groups are maintained through peer collaborations (e.g. co-authorship) or substantive focus (e.g. research specialization). Using bibliometric data, we construct co-authorship and bibliographic networks linking scientists that appear in two key reports representing the consensus and anti-consensus positions. We identify specialty areas using text analysis and model participation in either series of reports. Results indicate that anti-consensus scientists are not in the same network as consensus scientists and have somewhat different research specializations than consensus scientists although there is substantive overlap. Additionally, anti-consensus scientists do not form a coherent network among themselves, which suggests they do not constitute a separate scientific community, but rather are composed of a disparate group of idiosyncratic scientists.

While there is a clear consensus among climate scientists about the anthropogenic causes and severe ecological and societal consequences of climate change, many nations have failed to take substantial actions to mitigate these causes and prepare for these consequences. This is apparent in the United States where, more often than not, federal, state, and local governments have avoided addressing or even acknowledging climate change with some attempting to silence conversation about the topic. In the United States, attempts to limit the conversation about climate change mitigation have been supported by the "anti-reflexive" movement that challenges the scientific consensus (McCright and Dunlap 2010). The conservative, anti-reflexive movement seeks to maintain the prevailing industrial order, and thus debate, question, and attempt to discredit environmental impact science (McCright and Dunlap 2010). An important part of this larger movement to discredit impact science is the role of prominent scientists being involved in or lending their name (and status) to contrarian positions. From a range of public scientific debates such as tobacco and cancer, acid rain, and now, climate change, Oreskes and Conway (2010) emphasize how some prominent scientists serve as "merchants of doubt" granting scientific legitimacy to these issues. Science, in other words, is at the center of public debates on an array of issues, including climate change. Previous research examines the role of funding sources for anti-consensus climate science (Oreskes and Conway 2010), how media coverage differs between consensus and anti-consensus scientists (Petersen, Vincent and Westerling 2019), and other issues connected with the "merchants of doubt" frame. However, less is known about the factors that relate to how the structure of scientific activity differs between the consensus scientists who comprise the overwhelming majority and the small minority of scientists who advocate an anti-consensus position. To address this issue, here, we assess network factors and scientific specialization between anti-consensus and consensus science within the context of climate science.

Scientists are generally ill-equipped to take a central role in public debates as the norms of science discourage overt political action. The Mertonian norm of disinterestedness continues to influence how scientists think about public engagement (Merton 1973[1942]). The typical framework for scientific communication involves significant mediation as ideas are funneled through journalists and other non-scientific actors to preserve the sense that scientists are "above the fray." Yet, this norm - even in Merton's framework - has always been more aspirational than realistic. Science has been read as a public and political actor for centuries and this is no less the case in contemporary society where science and technology continually confront the public. Scientists have taken public stances on issues ranging from nuclear weapons to genetics (Scheufele 2014). The factors related to how scientists differ on these debates is important for several reasons. First, consensus around such important societal issues - when possible - can have dramatic implications for whether and how they are addressed. For example, legal claims-making involving science includes consensus at its core (Acker 1990; adams and Light 2015). Second, development of new ideas within science can be impeded or encouraged through legitimate debate. Prior work on scientific debates identifies at least two major factors in how sides may develop (Edelmann, Moody, & Light 2017; Shwed and Bearman 2010): Scientists may cohere around the content of their research or substantive specialization, or they may inform one another through social mechanisms, such as social influence among co-authors.

In this article, we analyze the relationship between consensus and anti-consensus scientists. We identify consensus scientists as those who participated in authoring the 2007 Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC). The charge for the scientists contributing to IPCC reports is explicitly to identify points of consensus regarding climate change. Anti-consensus scientists developed an organization funded by conservative interests called the Nongovernmental International Panel on Climate Change that published the 2009 Climate Change Reconsidered (NIPCC). To view the substantive and network factors related to each of these camps, we construct a corpus of scientific records from the Web of Science, a key bibliometric database for quantitative science studies. The final corpus consists of 7,354 scientific records authored or co-authored by 327 scientists who contributed to the NIPCC and IPCC documents. As we present in detail below, results suggest that the anti-consensus scientists publish on somewhat different topics than the consensus scientists and are outside of the community of scholars widely considered expert on climate science. In addition, NIPCC authors do not form a coherent scientific community outside the context of NIPCC. In conclusion, we draw attention to how outsider scientific movements seek to influence public debates over science. We follow calls for sociologists to attend to climate change (Klinenberg, Araos, and Koslov 2020) by using the sociology of science and social network analysis to understand the social and network underpinnings of participation in public statements on the state of consensus on climate science.

Scientific Communities, Norms, and Debate

Science is a profoundly social sphere with scientists embedded in social networks and social worlds that carry with them properties analogous to other workplaces, such as organizational cultures, politics, and inequalities (Xie 2017). However, science is tasked with engaging broader publics which brings additional challenges as scientists may be reluctant or ill-equipped to engage non-scientific audiences. The public is not a blank slate when it comes to reception of scientific knowledge, which can be neglected in broader conversations about scientific communication and public engagement. Specifically, the public - or a substantial portion of it - views science and/or scientific communities with a political lens, which may shape trust in and general attitudes towards scientific research and scientists themselves (e.g., Brulle, Carmichael & Jenkins 2012; Gauchat 2012; Scheufele 2014). For example, Mann and Schleifer (2019) find that political identity affects attitudes towards science in subtle ways with consistently conservative individuals simultaneously holding positive attitudes towards scientific research and negative attitudes towards the scientific community itself. Climate science is a central site for debate about public engagement and how science intersects with politics drawing attention to questions of how scientific communities function, what norms govern them, and what factors influence their structure.

Normative scientific frameworks remain important to scientific debate, especially in considering how the scientific community negotiates dissent. Scientists still draw upon sociologist Robert Merton's work when discussing the "core values" of science (Kidwell et al. 2016). Much like the contemporary moment, Merton (1973[1942]) develops his "normative structure of science" in response to rising anti-intellectualism and "incipient and actual attacks upon the integrity of science" (267). In his normative framework, Merton identifies four institutional imperatives. Each of these imperatives offers a path to how scientists negotiate conflict either in ordinary times or in moments of acute debate originating from inside or outside their community. Disinterestedness, for example, is a social act by which "cultism, informal cliques, prolific, but trivial publications" and other means of generating individual acclaim are sanctioned by one's scientific peers (Merton 1973[1942]:276). These imperatives provide an institutional framework and not solely a normative structure for individual conduct (Wunderlich 1974). In doing so, they emphasize the role that the scientific community plays in certifying knowledge. This implies that, for understanding how public scientific debates evolve, we may rightly focus on how non-scientific actors influence the production and reception of scientific knowledge, but we crucially also need to account for how the scientific community itself negotiates dissent.

Consensus - a centerpiece of the climate science debate - consists of a type of closure or stabilization that indicates agreement around a particular set of ideas or facts (Pinch and Bijker 1984). Consensus is dynamic and subject to some change, although change may not occur easily (adams and Light 2016). Shwed and Bearman (2017) describe how consensus and contestation follow formal trajectories where contestation resolves into consensus and stabilizes or persists. Their strategy leverages the bibliographic record to observe how scientists engage previous research. The community closes around sets of ideas as visible in citation patterns that indicate the extent of consensus. Yet, the factors that influence how scientists position themselves within the scientific community when consensus is questioned remains under-examined.

These norms of science are reinforced in communities structured by numerous factors, including specialty area, social networks, geography, and also gender, race, and class. Co-authorship provides one tractable piece of evidence of the social world of science, but it is a conservative one as scientific communities, like other occupational fields, extend beyond scientists' most immediate work relationships. A broader view of community accounts for the substantive content of science itself as science is often structured around the questions and problems that scientists hope to answer and address. Edelmann, Moody, and Light (2017) evaluate how these factors influence scientists' public policy positions on the contentious issue of gain-of-function experimentation. Gain-of-function experiments involve genetically-altering potentially pandemic pathogens to encourage mammalian transfer when this property was previously not known to exist. Two camps of scientists developed in reaction to these experiments: one camp argued for the continuation of these experiments given sophisticated biosafety protocols and the potential payoffs of learning more about how dangerous pathogens evolve, while another camp disapproved of these experiments over safety concerns that the scientists were creating a potentially pandemic pathogen in their labs. Edelmann, Moody, and Light (2017) find that those most closely embedded within the substantive fields related to the experiments were more likely to be supporters of the research, while peer association positively related to both opponents and proponents. In this case, public position-taking was influenced by both substantive field and peer relations.

In sum, science takes place in communities shaped by social factors including norms. Consensus occurs through processes of closure established by relevant scientific communities. These communities - and the positions that scientists take within them - are structured around numerous factors, including specialization.

The Case of Climate Science

Prior research on climate science indicates that the vast majority of published papers endorse the climate change consensus (Oreskes 2004; Cook et al. 2013; Cook et al. 2016). The building of consensus led to the formation of the Intergovernmental Panel on Climate Change (IPCC) by the United Nations, representing an international recognition of the existence and potential severity of climate change. However, while the science may be settled within the scientific community, public debate continues to rage surrounding climate politics (Kluger 2016; Will 2015). The social construction of doubt, encouraged in substantial part by the fossil fuel industry, reflects the potential of climate change to transform formerly precious assets (e.g., gas, oil, and coal) into social and environmental liabilities (Reusswig 2013). Put simply, fossil fuel corporations have a vested interest in perpetuating and propagating climate skepticism.

The “anti-reflexive” conservative movement sets out to obfuscate and cloud environmental impact science focused on how industry affects the climate, convince the public that climate change is a non-problem, and maintain the prevailing industrial order (McCright and Dunlap 2003, 2010). It seeks to undermine critical self-analysis by societies (hence the label “anti-reflexive”) and to subvert science. Ironically, it often does so by strategically deviating from a narrow definition of scientific method in order “to justify the wholesale rejection of scientific expertise” (Vardy et al. 2017:61). In a time of heightened political polarization (Pew Research Center 2017, 2019), anti-reflexive forces are particularly effective in influencing public opinions on policy. This is because party sorting, or the correlation of political party with policy views, is a primary mechanism through which individuals form political opinions (Fiorina and Abrams 2008). For example, Democrats and liberals have an increased likelihood of believing in climate change relative to Republicans and conservatives (McCright and Dunlap 2011b). Indeed, “elite cues” diffused through media outlets exacerbate polarization and serve as the medium through which political elites communicate with their constituents (Brulle, Carmichael, and Jenkins 2012). Prior work using network analysis has illuminated how anti-reflexive forces control the discourse in climate contrarianism. Corporate funding of climate organizations influences the content of their reports and is more prevalent in those organizations espousing an anti-consensus position (Farrell 2016a). Specifically, organizations funded by ExxonMobil and Koch family foundations (a branch of Koch industries) are more centrally located in the contrarian climate network, thus having more influence over the messaging of contrarian climate science as a whole (Farrell 2016b). Yet, while much research has focused on how corporations influence political action (Dietz, Shwom, and Whitley 2020), less has focused on the organizations that mediate the corporate-policy relationship.

Sowing doubt also requires scientific authority to legitimize anti-consensus claims. Thus, "merchants of doubt" are enlisted to combat established science in favor of alternative or outsider science (Oreskes and Conway 2010). In the case of climate science, S. Fred Singer (who previously promoted the interests of the tobacco industry by questioning the health effects of secondhand smoking) is a well-documented skeptic who founded the Science & Environmental Policy Project (SEPP) to combat mitigation efforts for climate change (Oreskes and Conway 2010). Singer later went on to found NIPCC, which directly challenges the reviews of IPCC. Singer also publicly discouraged U.S. involvement in the Paris Agreement of 2015, urging Chuck Hagel (who co-wrote a resolution specifying terms for the U.S. to adopt the Kyoto Protocol) to take action based on scientific merit:

> On the climate-energy issue, Mr. Hagel can point to increasing evidence that nature rules the climate - and always has - not human activities. He can point to the disastrous record of Kyoto and scandalous waste of resources and human efforts - and how 'saving the climate' detracts from genuine world problems… We know of the shoddy science of the United Nations Intergovernmental Panel on Climate Change, exposed in independent Non-governmental Panel on Climate Change reports… (Singer 2015)[1].

From this brief excerpt we gather that (1) the founder of NIPCC denies anthropogenic climate change and (2) that he claims IPCC is illegitimate, espousing "shoddy science" that cannot withstand "independent" review.

Previous research at the intersection of network analysis and sociological studies of climate science has been fruitful. Individuals tend to select information sources that confirm their predisposed beliefs, influencing the structure of climate-knowledge transmission (Jasny, Waggle, and Fisher 2015), complemented by media portrayals of climate science that tend to overemphasize anti-consensus relative to consensus science (Peterson, Vincent, and Westerling 2019). Moreover, scholars have shown that popular anti-consensus blogs use scientific framing to establish credibility and thus gain traction in their claims-making (Sharman 2014). Widely published reports thereby are a core medium to distribute and gain acknowledgement for their positions. To better understand this, we, therefore, examine the network and social factors

[1] Chuck Hagel went on to write an op-ed in Time Magazine advocating for the adoption of the Paris Agreement for the purposes of national security (Hagel 2015).

predicting contributions to the report of the IPCC as an organization acknowledging climate change and to the reports of the NIPCC as a contrarian climate science organization. While previous work has focused on differences between the reference lists of both reports (Jankó, Pappné-Vancsó, and Móricz 2017), we examine how their actual contributors themselves differ in terms of their published works and social factors, including collaboration network composition. In so doing, we aim to illuminate the relative expertise and scientific authority of both IPCC and NIPCC contributors. In the next section, we provide a brief background of IPCC and NIPCC.

The IPCC and NIPCC

The scientific consensus on climate science is well-established (Oreskes 2004; Shwed and Bearman 2010; Cook et al. 2013). However, international panels of scientists make competing claims about the legitimacy of this consensus. IPCC holds the consensus position, is recognized as a world leader in climate science, and makes policy recommendations for international and national governmental bodies. Meanwhile, NIPCC challenges the climate consensus in general and IPCC in particular.

IPCC was established in 1988 after being endorsed by the United Nations General Assembly. As climate science was beginning to formulate a consensus at the time (Oreskes 2004), there was an international demand to study and review the science on climate change, estimate the environmental, economic, and social impacts of climate change, and draft recommendations for governments worldwide to mitigate and adapt to impending environmental change (Bolin 2007). To select scientists, IPCC gives a call for nominations to governments and IPCC observer organizations and evaluates the expertise of nominees to include a range of organizational and scientific backgrounds, as well as balance in terms of gender and geographical representation, to avoid bias in the reports. Since its inception, there have been five assessment cycles culminating in five reports. In the process of drafting the reports, "an open and transparent review by experts and governments around the world" is conducted "to ensure an objective and complete assessment and to reflect a diverse range of views and expertise" (IPCC n.d.). Transparency, scientific authority, and representational membership are important parts of the objective science claims-making of IPCC.

NIPCC was organized in 2003 by S. Fred Singer's SEPP in response to the release of the IPCC's Fourth Assessment Report (AR4). It is composed of scientists and scholars who seek to provide an alternative scientific assessment of the relationship between carbon dioxide emissions and global warming. Often, NIPCC publishes reports responding to IPCC, with 14 reports published from 2008 to present. Main sponsors of NIPCC include the Heartland Institute, SEPP, and the Center for the Study of Carbon Dioxide and Global Change. The Heartland Institute is a well-known think tank that publishes the reports of NIPCC. Their stated mission "is to discover, develop, and promote free-market solutions to social and economic problems" (The Heartland

Institute 2020). Nonetheless, NIPCC claims to advance an objective review of climate science, largely because "NIPCC has no formal attachment to or sponsorship from any government or government agency. It is wholly independent of political pressures and influences and therefore is not predisposed to produce politically motivated conclusions or policy recommendations" (NIPCC 2017). The lack of formal political affiliation drives the claim to promoting objective science by NIPCC, despite the group's attachment to think tanks explicitly promoting conservative political and economic aims.

Both IPCC and NIPCC claim to be objective in reviewing the evidence associated with climate change. Both organizations are also composed of scientists who claim to be politically impartial, upholding rigorous scientific standards. To examine these competing claims, this paper therefore turns to the scholarship produced by the scientists preparing the reports. A naive perspective would suggest that claiming objective science by both sides should promote homogeneity in network composition and area of specialty - indications of a common community. Yet, prior research emphasizes that climate contrarian organizations are influenced by corporate interests outside of the scientific community (Farrell 2016a). To situate consensus and anti-consensus claims-making within the literature, we ask: Does network composition and specialization differ between contributors to the consensus IPCC and the anti-consensus NIPCC?

Competing Communities of Climate Science?

Climate science is often discussed in terms of consensus. Consensus is regarded as important for public understanding especially in light of concerted efforts towards misinformation (Cook et al. 2016). Consensus shapes and is shaped by shared rules and standards within scientific communities, one key dimension of scientific paradigms (Kuhn [1962] 2012:11). The prevailing scientific model of anthropogenic climate change is the dominant paradigm within the community of climate scientists explaining, among other phenomena, increases in average global temperature. Necessarily, there are disagreements within the confines of the climate science community, for example competing explanations regarding "tempo and mode" (Oreskes 2007), or the rate and manner, of human-caused climate change. This is consistent with the open-endedness of paradigms (Kuhn [1962] 2012:10). Yet, the severity of NIPCC's criticisms go beyond the confines of the anthropogenic change paradigm. Taken seriously as a scientific enterprise and especially in their criticisms of IPCC, NIPCC essentially proposes to replace anthropogenic climate change as a paradigm altogether. This challenge involves substantial work towards developing a new paradigm - and even a new community - based on research independent of NIPCC publications.

Similar to IPCC, NIPCC reviews scientific evidence in their reports. Like IPCC contributors who study climate science, we should expect NIPCC contributors to collaborate in venues outside of NIPCC to establish and showcase their evidence and legitimacy, as well as propagate their scientific interpretations of whether and how the climate is changing. Indeed, producing scientific evidence, and not merely reviewing work, would be necessary to reveal the “shoddy science” of IPCC. Such a new paradigm could emerge from outside, that is from a community entirely unconnected to the one following the established paradigm, or from within, that is from a faction that is part of and in interaction with an existing community but actively contests and challenges its domain. If not the bearer of a new scientific paradigm, it could also be that NIPCC is simply a “merchant of doubt,” a force of anti-reflexivity challenging climate change not through scientific inquiry for the sake of establishing knowledge as such but using its authority for political purposes instead (Oreskes and Conway 2010; McCright and Dunlap 2003). If that were the case, the scientific network on climate science would look like a single, dominant community with some attempts of these merchants of doubt to “discredit” its view but without a discernible second community. In other words, a lack of collaborative science outside NIPCC may indicate that NIPCC functions to provide scientific legitimacy to the political climate contrarian movement. To examine these possible structures, we examine the scientific co-authorship networks among the IPCC and NIPCC authors as traces of scientific engagement to answer whether NIPCC authors develop a scientific community challenging anthropogenic climate change or engage in rather isolated attempts to discredit anthropogenic climate change, without forming a cohesive, distinct community.

Data and Methods

To build a comprehensive understanding of the position of IPCC versus NIPCC scientists, we constructed a dataset consisting of scientific records from the Web of Science (WoS). We collected names of coordinating lead authors and lead authors of the IPCC report Climate Change 2007 (AR4) (IPCC 2007) and contributors to five NIPCC reports (Climate Change Reconsidered (CCR) (2009), CCR: Interim Report (2011), CCR II: Physical Science (2013), CCR II: Biological Impacts (2014), CCR II: Fossil Fuels (2018)). While NIPCC reports cover a span of ten years, the CCR series responds directly to IPCC’s AR4, so we include all five of these reports. Additionally, given that fewer people contribute to NIPCC reports, more reports were required to build a comparable dataset to IPCC. We searched for research produced by the authors of these reports by their full name in the Web of Science. The Web of Science is widely used within quantitative science studies and provides an extensive view of the scientific record with several known limitations (e.g., lower humanities and social science representation and different coverage than alternative databases; see Mongeon and Paul-Hus 2016 and Singh et al. 2021). We limited articles to those indexed in the Science Citation Index Expanded database to reduce false positives from authors in the humanities and social sciences and given report claims based on expertise in the natural sciences.

Name disambiguation is a particular challenge when using the WoS because the majority of authors are identified solely by last name and first initial (e.g., Light, R.) prior to 2006. We systematically matched names with the refsplitr package in R (Fournier et al. 2020). Specifically, we used full names and location to identify report authors in the database and then used common characteristics, such as institution, to connect abbreviated names to the full name records. Next, we leveraged references, where pre-2006 records that match imperfectly to complete names were matched via reference overlap where common first initial and common last name and at least two references in common were linked in the final dataset. As these scientists draw from a variety of scientific fields and we are interested in the report authors' expertise generally, we include every article identified whether specifically on climate science or not. These data represent a conservative sample of the scientific record reducing the likelihood of false positives in the matching process with some unknown risk of false negatives. The final dataset consists of 7,354 scientific articles written by 57 anti-consensus and 270 consensus scientists published between 1970 and 2008.

Analytic Strategy

Our goal is to identify how network factors and substantive topics relate to IPCC and NIPCC scientists. To do so, we use logistic regression to predict belonging to the NIPCC group. Next, we describe the construction of the substantive topics, the co-authorship network, and key independent variables derived from the bibliographic record and metadata.

Estimating Content

Structural topic models were run over the 7,354 article records that included abstracts using the stm package in R (Roberts, Stewart and Tingley 2014). The text field for the topic models combined abstracts, titles, and keywords. After preprocessing (e.g. punctuation removal, stemming terms to common roots, and the removal of common substantively meaningless words), terms used at least 10 times in the corpus were retained for a vocabulary of 4,603 terms and 662,891 total tokens.

Topic models "reverse engineer" the writing process assuming that scientists typically write scientific articles with a small set of ideas, or topics in mind (Mohr and Bogdanov 2013). The goal is to locate those topics by observing how words are used across articles. The model's result is a distribution of words over topics and topics over articles. So, each topic is a distribution of terms, and each article is a distribution of topics with some articles identified with one topic and others with many. Structural topic models are a specific form of topic model that introduces a multivariate term in the estimation process allowing topics to vary by an independent variable. In this case, we include the document age within the dataset as a continuous variable to account for changes within the corpus over time. We iteratively evaluated model performance over numerous values of k, or number of topics, indicating that a 10-topic solution might be an acceptable fit to the data. The labelling of topics is in part interpretive and, therefore, should not be reified, but nevertheless systematic and easily explained. In this case, we systematically evaluated the top-loading words, top-loading article titles, and the top-loading WOS subject areas and assigned a label to each topic based on commonalities across these words, titles, and subject areas.

While one aspect of evaluating this community of scholars includes the topics themselves as an overview of the substantive field, we include the mean of each topic per author in the logistic regression models as a classification of the work from each scholar that is included in this corpus. Because the topics consist of proportions, they sum to one across each author resulting in linear dependence, or the “dummy variable trap.” To address this issue, we suppress the intercept in our regression models consistent with prior work that focuses on comparison across these proportions and avoid the *ad hoc* construction of a reference category (see Haynes and Jacobs 1994; Helms and Jacobs 2002; Light and Odden 2017; Small and Winship 2007).

We also include a measure of each scientist’s breadth of scholarship through the niche width of their specialization. Niche width captures the extent to which a scientist is specializing in one versus many topics (Hsu et al. 2009; Negro et al. 2010). The niche width is calculated using Simpson’s Index of Diversity,

$$D = 1 - \sum_{i=1}^{k} p_i^2$$

where p_i equals the proportion of each author’s overall loading in topic i ($i = 1...k$) (Argesti and Argesti 1978; Simpson 1949). A scientist whose work is evenly distributed across each topic will have a niche width of .9 when there are 10 topics (the maximum value of this type of measure approaches 1 as the number of topics grows larger), while one who is focused on a single area or topic will have a niche width approaching 0.

Co-authorship Network

To capture one social aspect of scientific work or to observe the structure of the community of climate scientists, we constructed the co-authorship network between scientists in this dataset. A scientist is connected to another scientist if they authored a paper with one another. This results in an undirected network between scientists with each edge weighted by the number of co-authored papers. To capture a scientist’s level of involvement within the network, we focus on their degree centrality (number of co-authors). While this is a basic measure of network centrality, it sufficiently captures whether and to what extent scientists are connected to one another through collaboration identifying the amount of community involvement.

Bibliographic Network

Co-authorship networks do not capture the full spectrum of ways scientific communities cohere as scientists may support and collaborate with one another without co-authoring (Katz and Martin 1997). Bibliographic networks provide an alternative cultural sense of community within scientific fields as they reflect engagement with a common literature or base of knowledge (Shwed and Bearman 2010). We construct a bibliographic coupling network (see Hummon and

Doreian 1989 and others) where articles in our corpus are connected to one another based on overlapping references. So, if Article A and Article B within this report author publications dataset share a reference in common, a tie will be drawn between them. Next, to capture author-level engagement with common literature, we calculate the degree of each paper and then average the paper bibliographic coupling network degree scores for each author.[2]

Control Variables

We capture additional factors that may influence how scientists are situated within this community. The number of articles published by each scientist serves as an indicator of their scientific experience. Based on their address and/or affiliation listed in the WoS records, we coded the organization scientists are most affiliated with as either a university or not as well as whether they primarily work in North America or not. Average journal impact factor was included as an indication of overall publication quality. Age of publishing career is included by identifying an author's oldest publication in the dataset and subtracting from 2009. Gender was excluded in the logistic regression models due to the lack of women among NIPCC scientists (see Table 1).

Results

To observe how network factors and scientific specialization are associated with anti-consensus vs. consensus science within the context of climate science, we first introduce the descriptive statistics for the variables in our models and construct a climate science co-authorship network. Next, we analyze the specialty areas in which the scientists work by building structural topic models. Last, we analyze how these factors, net of controls, influence whether a scientist is a member of the anti-consensus, NIPCC group or not.

An Overview of IPCC and NIPCC Scientists

Table 1 provides the means and standard deviations for each of the non-topic variables included in the statistical models and offers some indication of how these two groups of scientists differ. 17.4% of all authors in the dataset contributed to the NIPCC report and 82.6% contributed to the IPCC report, with no authors contributing to both organization's reports. These descriptive statistics suggest differences between the consensus and anti-consensus groups including initial evidence of differences in participation in co-authorship between report authors with the consensus group averaging a degree of 3.4 and the anti-consensus averaging a degree of 0.26.

<Table 1 about here>

[2] Alternative centrality measures for both the co-authorship and bibliographic coupling network result in substantively similar findings.

Figure 1 provides further evidence of the difference between the consensus and anti-consensus scientists. Here, we see the largest connected component of the co-authorship network - or the largest group of scientists who are connected by at least one tie - almost exclusively consists of IPCC scientists. Over 50% of the scientists in this analysis are included in this component (173 out of 327). However, only one of the scientists in this component are members of the anti-consensus group. Smaller components consist solely of triads - groups of three scientists - or dyads - groups of two scientists. These smaller groups are also primarily IPCC scientists. There are a significant number of isolates in each of these groups: 80 IPCC scientists and 48 NIPCC scientists are isolates. This provides initial evidence that the NIPCC scientists may not be participating in the same community as the IPCC scientists, or with each other, through co-authorship, a means of observing traditional research communities.[3]

<Figure 1 about here>

The Substance of NIPCC and IPCC Scientists Research

Co-authorship is ultimately a conservative measure of scientific fields and communities whereas substantive area provides a more relaxed summary of how scientists might group together. Indeed, specialization is one of the most consistent ways that critics of the anti-consensus position have accounted for their anomalous research. The structural topic model of the articles written by these scientists summarizes the substantive fields of all of the scientists. Table 2 provides an overview of the 10-topic structural topic model. We see a range of substantive areas that one might expect from these experts from research on forestry to the atmospheric sciences. The topics seem quite distinct for the most part as indicated by their top-loading words and top-loading articles. Importantly, we see a mix of scientific fields, like meteorology and oceanography, and broader knowledge domains, like methods and a topic centering on policy implications. Only two of the top-loading articles were authored by NIPCC authors - the articles top-loading on Topic 5: Genetics and Topic 10: Atmosphere. Topic 5 is of particular note as many of the top articles in this topic are not directly related to climate science, but are written by a prolific geneticist, an NIPCC scientist, who seems to explore climate science in addition to his primary area of expertise.

<Table 2 about here>

Figure 2 depicts the expected topic proportions for each of the topics. Topic 8: Methods is the most popular topic followed by Topic 6: Meteorology and Topic 9: Oceanography. Two topics related to the earth sciences - Topic 4: Ecology and Agronomy and Topic 1: Forestry and

[3] One can formally test for differences in role positions within the climate-science collaboration network using pre-specified blockmodels (Batagelj, Doreian and Ferligoj 1992). These tools are effective at identifying differences in positions over time (Cugmas, Ferligoj and Kronegger 2016). Here the collaboration contrast between IPCC and NIPCC is so clear that a broad difference between integrated and not is directly observable from inspection of Figure 1.

Ecosystems - are the least popular consistent with the more concerted focus by the research community on the consequences of climate change on meteorological conditions and the effects on oceans, glaciers, and so on.

<Figure 2 and 3 about here>

Figure 3 provides an overview of the relationship between these topics. In this correlation network, positive edges - any correlation above 0 - were retained.[4] We can see that topics, for the most part, are not strongly related to one another. Those that are related, such as Topic 2: Water and Geology and Topic 3: Ice and Glaciers, share significant substantive overlap as one would expect. While the structural topic model clearly identified major thematic areas within this corpus of scientific texts, the relationship between specialization and the consensus and anti-consensus groups, beyond perhaps Topic 5: Genetics, is not clear. Next, we turn to our statistical models that examine these relationships. While we built time - age of publication - as a factor into the construction of the topic models, analyses of the predicted probability of topic by time indicate relatively little change across topics in this period with the exception of the Topic 5: Genetics that experienced a pronounced increase from 1990-2008.

The Relationship between Consensus and Anti-consensus Scientists

We evaluate the network factors and scientific specialization associated with anti-consensus versus consensus science in models estimating which factors predict NIPCC authorship. We present these models in the following order in Table 3: The first model observes the factors associated with specialization drawn from the structural topic model; The second model observes the network variables; And the third model combines the specialization and network factors as well as the control variables. We focus on model 3 which provides the most complete picture. Here, we see that specialization is related to the consensus versus anti-consensus positions. Those scientists specializing in Topic 1: Forestry and Ecosystems are unlikely to be members of the anti-consensus group. Specializing in Topic 7: Policy and Prediction is also negatively associated with participating in the NIPCC, anti-consensus reports.[5] The other topics, however, do not significantly differ between these two groups.

<Table 3 about here>

A large network effect also differentiates these two groups. Co-authorship degree is negatively associated with participation in the NIPCC reports. The effect of bibliographic coupling - or drawing from similar literature - is also negative but is not statistically significant. Region, perhaps another key social factor, plays a differentiating role with NIPCC authors being

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[4] See the appendix for a correlogram displaying both positive and negative relationships.
[5] Given dependence across observations, we used a bootstrapping technique to adjust our standard errors to check the robustness of Model 3. The bootstrapped results are substantively similar with the exception of a somewhat increased standard error for Topic 1: Forestry and Ecosystems.

statistically more likely to be from North America. The consensus IPCC report consists of a more global authorship. Lastly, gender was excluded from the logistic regression models due to the lack of women scientists contributing to NIPCC reports. Nevertheless, as shown in Table 1, IPCC has more female authors relative to NIPCC. Interestingly, NIPCC is primarily composed of men from North America, consistent with prior research concerning climate denial among the United States general public (McCright and Dunlap 2011a). In terms of region and gender, IPCC is more diverse relative to NIPCC, reflecting their claims-making surrounding objective science.

Conclusion

This comparative network and text analysis evaluated differences and similarities between anti-consensus and consensus scientists contributing to public documents on climate science. Results indicate substantial differences between these scientists. First, they are not in the same community as indicated by co-authorship. Second, anti-consensus scientists do not appear to form a coherent community of their own, rather, being composed of individuals who are not connected to one another through co-authorship, with each being largely unconnected to any climate science community. Third, while claims that anti-consensus scientists are not at all participating in scientific debate on specialized issues related to climate science may be overstated, the text analysis provides evidence that differences exist between the areas of research specialization of these two camps. However, the main difference is that the consensus group consists of scholars more likely to discuss prediction and policy implications. Fourth, geography influences group membership, as North American contributors are more likely to belong to NIPCC. In terms of co-authorship, area of specialty, gender, and geography, IPCC and NIPCC authors differ.

While the reaching of consensus in climate science has been empirically demonstrated (Oreskes 2004; Cook et al. 2013), debate over its existence and political implications continues in the public sphere. However, less attention has been paid to the scientific implications of the formation of consensus. How have anti-consensus scientists attempted to build an alternative to the prevailing climate science paradigm of anthropogenic climate change within the scientific record? The published content of anti-consensus scientists, as evidenced through NIPCC scientists indexed in the Web of Science, engages some of the same thematic content of mainstream scientists with notable differences, especially related to work that addresses prediction and policy implications.[6] The NIPCC scientists do not participate in co-authorship networks - either with one another, or with IPCC scientists - to the degree that IPCC scientists do. With this in mind, the NIPCC scientists do not appear to be engaged in shifting the consensus scientific paradigm of climate science as insiders or outsiders, as the NIPCC scientists are engaging in somewhat different areas of research and are not especially involved in a research

[6] Future research may consider alternative venues for publication, including journals that are not indexed by the Web of Science or reports not subject to peer review.

network. This begs the question: to what ends does NIPCC exist, if not to shift research away from the dominant climate science paradigm?

Prior research highlights the anti-reflexive forces at work in the American conservative movement that seek to counteract environmental impact science focusing on how industry contributes to environmental degradation and human health issues (McCright and Dunlap 2010). This broad theoretical approach for understanding challenges to environmental impact science is crystallized in the "merchants of doubt" framework, which details how corporate interests use scientific authority and legitimacy to produce organized denial on issues with economic implications (Oreskes and Conway 2010). One of the central scientists sowing seeds of doubt highlighted by Oreskes and Conway's work is S. Fred Singer, whose organization, SEPP, founded NIPCC. While NIPCC claims scientific objectivity due to its lack of affiliation with government agencies, the Heartland Institute, a conservative think tank, funds it. Moreover, the Heartland Institute has reportedly received funding from ExxonMobil (Revkin 2009), a claim that is consistent with research on corporate funding of climate contrarian organizations (Farrell 2016a).

Our research shows that NIPCC scientists do not appear to be contributing to an effort in shifting the consensus paradigm within the scientific community. Therefore, it is likely the case that it serves to give the appearance of scientific legitimacy to the climate contrarian movement, despite its authors not contributing to climate science in non-NIPCC venues. In this way, NIPCC may act as a part of the anti-reflexive movement, representing a "merchant of doubt" aimed at preventing meaningful public policy on climate change through influencing public opinion and political actors. Future research should continue to examine how outsider scientists leverage social movement tactics and exogenous social movement organizations to affect public scientific debate by investigating how scientists negotiate dissent within their communities.

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Table 1. Descriptive Statistics

	All Authors			IPCC Authors			NIPCC Authors		
Variables	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
NIPCC	0.17	0.38	327	0	0	270	1	0	57
IPCC	0.83	0.38	327	1	0	270	0	0	57
Niche Width	0.64	0.16	327	0.63	0.16	270	0.69	0.13	57
Frequency	25	36	327	26	34	270	22	44	57
Co-Authorship Degree	2.8	4.1	327	3.4	4.3	270	0.25	0.61	57
Mean Bibliographic Network Degree	137	137	327	155	141	270	51	76	57
University	0.53	0.5	327	0.5	0.5	270	0.63	0.49	57
North America	0.29	0.46	327	0.24	0.43	270	0.56	0.5	57
Female	0.15	0.36	327	0.18	0.39	270	0	0	57
Mean IF	3.8	4.6	327	4.2	4.9	270	2.2	1.6	57
Age	11	9.4	327	11	8.8	270	13	12	57

Table 2. Topic Overview

Topic	Labels	Top-5 Words	Top Loading Article Title (Abbreviated)*
1	Forestry & Ecosystems	forest, carbon, terrestri, ecosystem, veget	Europe's terrestrial biosphere absorbs 7 to 12% of European anthropogenic CO2 emissions
2	Water & Geology	river, delta, sediment, lake, reef	Late Quaternary incised-valley fill of the Yangtze delta (China): its stratigraphic framework…
3	Ice & Glaciers	ice, core, glacier, glacial, antarct	A new 27 ky high resolution East Antarctic climate record
4	Ecology & Agronomy	tree, leaf, plant, soil, phenolog	The Regulation of Clover Shoot Growing Points Density and Morphology During Short-Term Clover…
5	Genetics	cypa, gene, mice, mous, diseas	**Dioxin-Dependent Activation of Murine CIP1A-1 Gene-Transcription Requires Protein…**
6	Meteorology	summer, trend, precipit, anomali, oscil	Assessment of climate extremes in the Eastern Mediterranean
7	Policy & Prediction	scenario, polici, adapt, futur, technolog	Energy and the World Summit on Sustainable Development: what next?
8	Methods	error, method, set, data, statist	Numerical-Integration of the Shallow-Water Equations on a Twisted Icosahedral Grid
9	Oceanography	coupl, forc, convect, simul, heat	Comparison of equilibrium and transient responses to CO2 increase in eight state-of-the-art…
10	Atmosphere	aerosol, particl, ozon, stratospher, optic	**Self-diffusion coefficient distributions in solutions containing hydrophobically modified…**

***Bold** indicates top-loading article written by NIPCC author

Table 3. The Relationship between IPCC and NIPCC Authors

	Model 1			Model 2			Model 3		
Variables	Estimate	Std. Error		Estimate	Std. Error		Estimate	Std. Error	
1. Forestry/Ecosystems	-20.026	6.180	**				-13.392	6.753	*
2. Water/Geology	0.313	1.706					0.375	2.127	
3. Ice/Glaciers	-5.461	2.426	*				2.230	4.157	
4. Ecology/Agronomy	-0.456	1.610					2.072	2.362	
5. Genetics	-1.947	1.581					0.096	2.417	
6. Meteorology	-7.344	2.217	***				-3.150	3.283	
7. Policy/Prediction	-3.850	0.971	***				-3.440	1.260	**
8. Methods	1.869	2.213					2.655	2.938	
9. Oceanography	-9.768	3.174	**				0.042	4.856	
10. Atmosphere	0.885	1.691					4.165	2.919	
Niche Width	2.865	1.790					0.598	2.597	
Number of Articles				0.012	0.006		-0.002	0.009	
Co-Authorship Degree				-1.148	0.242	***	-0.699	0.256	**
Mean Bibliographic Network Degree				-0.007	0.002	***	-0.006	0.004	
Age of Publishing Career							0.029	0.031	
Average Impact Factor							-0.435	0.179	*
Region (North America=1)							2.168	0.497	***
Employment (University=1)							0.109	0.482	
Observations	327			327			327		
Log Likelihood	-102.69			-112.237			-71.172		
Akaike Inf. Crit.	227.38			230.475			178.344		

Notes: *p < 0.05 **p < 0.01 ***p < 0.001

Figure 1. A Climate Science Co-Authorship Network

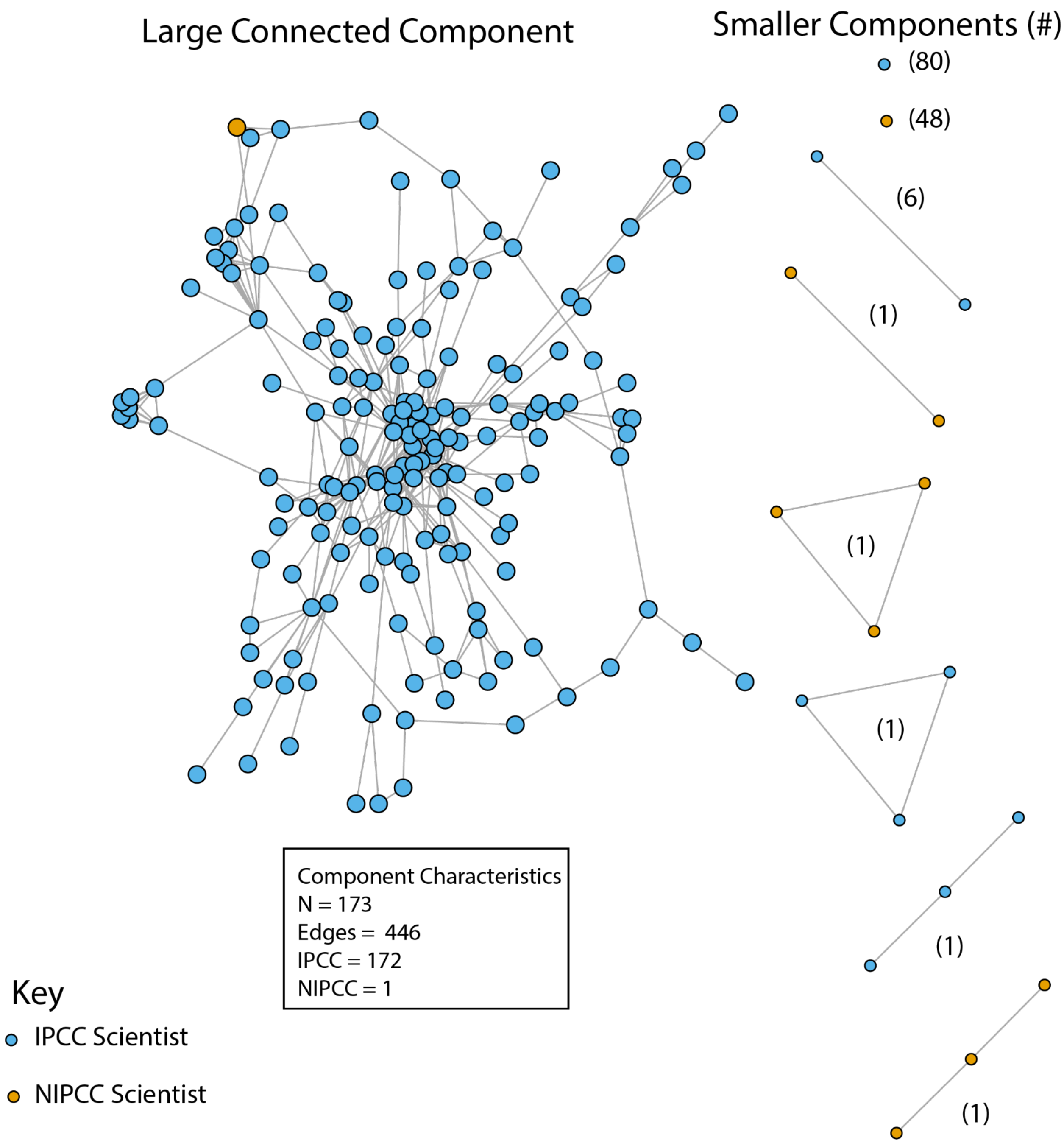


Figure 2. Topic Distribution

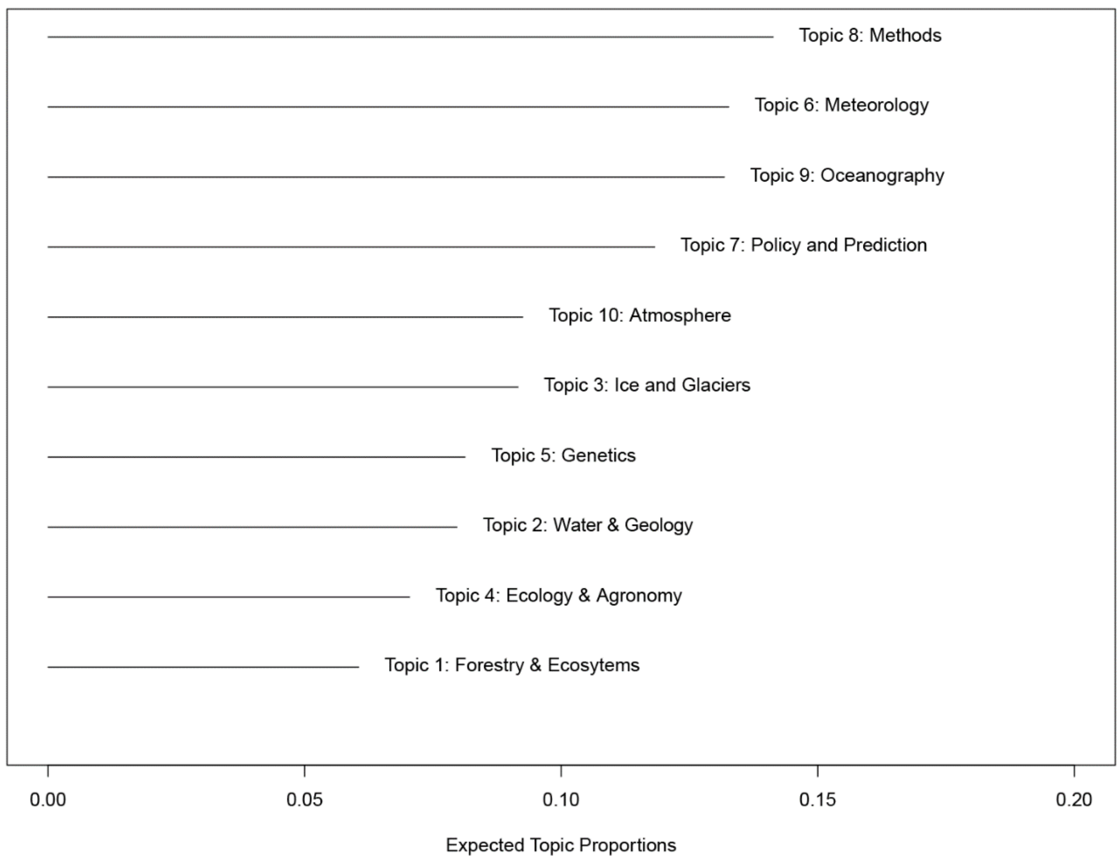
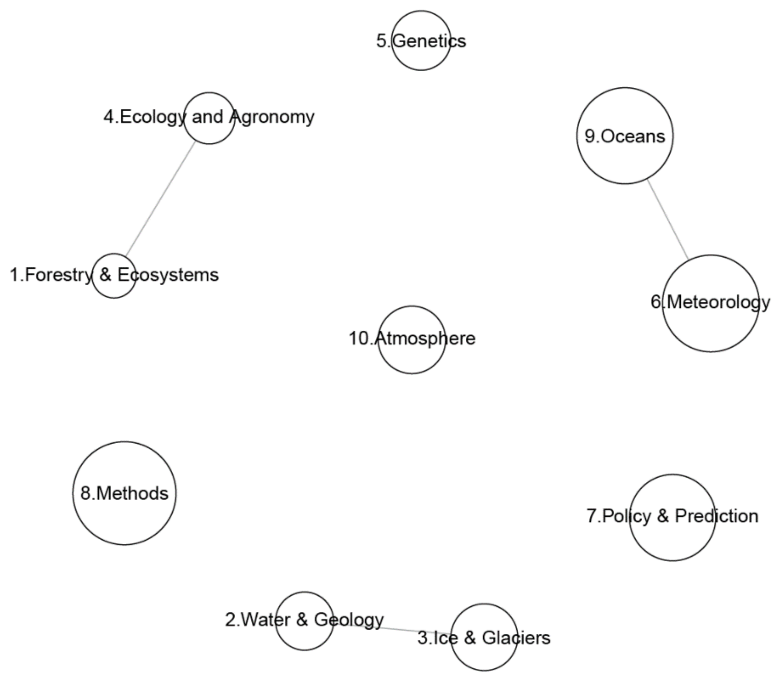


Figure 3. Topic Correlation Network



Appendix. Topic Correlogram