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Mapping the climate sceptical blogosphere

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Abstract
While mainstream scientific knowledge production has been extensively examined in the academic literature, comparatively little is known about alternative networks of scientific knowledge production. Online sources such as blogs are an especially under-investigated site of knowledge contestation. Using degree centrality and node betweenness tests from social network analysis, and thematic content analysis of individual posts, this research identifies and critically examines the climate sceptical blogosphere and investigates whether a focus on particular themes contributes to the positioning of the most central blogs. A network of 171 individual blogs is identified, with three blogs in particular found to be the most central: *Climate Audit*, *JoNova* and *Watts Up With That*. These blogs predominantly focus on the scientific element of the climate debate, providing either a direct scientifically-based challenge to mainstream climate science, or a critique of the conduct of the climate science system, and appear to be less preoccupied with other types of scepticism that are prevalent in the wider public debate such as ideologically or values-motivated scepticism. It is possible that these central blogs in particular are not only acting as translators between scientific research and lay audiences, but, in their reinterpretation of existing climate science knowledge claims, are filling a void by opening up climate science to those who may have been previously unengaged by the mainstream knowledge process and, importantly, acting themselves as public sites of alternative expertise for a climate sceptical audience.

KEY WORDS: climate scepticism, knowledge, network, blog, social network analysis

1. Introduction

Evidence supporting the reality of climate change and its anthropogenic cause is overwhelming in the peer-reviewed literature (J. Cook et al. 2013; Doran and Zimmerman 2009). However, outside the paradigm of mainstream climate science[1], and particularly in online environments, climate change knowledge is actively disputed (Corner et al. 2012; Hobson and Niemeyer 2012; Jacques et al. 2008; Poortinga et al. 2011; Washington and Cook 2011). Arguments that may be considered as "climate sceptical" include, *inter alia,* that climate science is factually incorrect in terms of its scientific basis, a conspiracy among scientists to maintain or increase funding opportunities, or a politically-based rationale to increase regulation or taxes (Oreskes and Conway 2010). This debate about climate science, as well as controversy regarding mitigation or adaptation policies, provides fertile ground for blogs[2]. While most previous research has focused on the expression of climate scepticism in traditional media outlets (Antilla 2005; Hoffman 2011a; Painter and Ashe 2012), this research contributes towards the small but growing body of literature addressing the role of virtual spaces in climate sceptical knowledge production (Cormick 2011; Gavin and Marshall 2011; Koteyko et al. 2012). It maps the climate sceptical blogosphere and uses social network analysis (SNA) to identify those blogs which are the most central within the overall blog network. It also uses thematic analysis to understand why those blogs identified as the most central occupy such positions of importance.

Over a decade ago, Rogers and Marres (2000) mapped the online climate change debate issue network, yet their focus on official websites (such as URLs ending with .org or .gov suffixes) means that still, to date, little is known about the climate sceptical blogosphere[3]. Climate sceptics are perceived to be 'very present online and particularly in the blogosphere' (Schäfer 2012: 529) yet this perception has yet to be addressed with empirical research. Moreover, understanding blogs as sites of knowledge formation and contestation is critical because, as Hsu and Lin (2008: 65) note, they can 'attract tremendous attention and exert great influence on society', resonating with different groups according to their content, format and authorship (Bar-Ilan 2005). Focusing on the blogosphere as a network also enables key sites of influence to be identified and to understand whether information or viewpoints are widely generated and dispersed, or shaped by a smaller number of attitudinal influencers. As blogs become an increasingly important contributor to public discourse (Carlson 2007) and inspire reflection on the use of knowledge in decision-making (Ravetz 2012), identifying the main sites of sceptical opinion formation and the arguments employed is also valuable to those engaged in science communication or climate policy decision-making. Finally, this paper aims to make a wider contribution to the literature on alternative knowledge networks by highlighting the potentially significant role of central blogs as knowledge gatekeepers, and also how

[1] Mainstream climate science is defined here as agreement with Section 2 (Causes of change) of the IPCC Fourth Assessment Report: Climate Change 2007.
[2] Blogs are internet pages comprising a series of entries known as posts, most often arranged in reverse chronological order, either authored by a single author known as a "blogger" or by multiple contributors.
[3] The blogosphere is the network of blogs and their linkages to one another.

attempts are made to disrupt traditional understandings of how knowledge is both formed and accepted as legitimate.

A final point before proceeding is to note that this paper uses the terms "climate sceptic/ism" for brevity, despite recognising the non-trivial multitude of problems such a label entails. Along with similar terms such as "denier" or "contrarian", the label of climate sceptic is problematic as it can be dismissive or limiting, as well as inadequately specific. Forthcoming research will address this issue in more detail.

2. Knowledge, networks and contestation

Traditional frameworks of scientific knowledge production limited its creation to official spaces such as universities, and as the domain of those who were formally qualified as arbiters of knowledge by virtue of their academic credentials (Martin and Richards 1995). These actors, closely networked within small epistemic communities of practice, were perceived as creating scientific knowledge that was 'objective and context-free' (Wynne 1992: 282), with a clear distinction between the legitimacy of the knowledge created by the scientist and the 'man-in-the-street' [*sic*] (Merton 1973: 277). Contemporary interpretations of knowledge production challenged these frameworks, with theories such as Mode-2 knowledge production or post-normal science explaining that knowledge is created across multiple sites and by multiple actors (Funtowicz and Ravetz 1993; Gibbons et al. 1994; Nowotny et al. 2003). Crompton (2007) explains that these new knowledge networks involve the public speaking back to science, creating new public arenas ("agoras") where scientific information is contested to make it more socially robust. The climate sceptical blogosphere, as a site of active knowledge contestation, could therefore be understood as a (virtual) site of Mode-2 knowledge production. However, it is unclear whether it is a "functioning" agora as Crompton suggests is the case in her description of the orphan drug network. The mutual learning necessary for a functioning agora where the 'public [is] accepted as a legitimate partner exerting democratic rights of participation' (Crompton 2007: 201) appears to be less apparent overall in the case of climate change, with Hoffman (2011a: 9) identifying a 'logic schism' between different actors in the debate, across which dialogue is extremely challenging. Climate scepticism, as a challenge to mainstream climate science and policy, does not reflect 'an absence of certainty, but rather of *contradictory certainties*: several divergent and mutually irreconcilable sets of convictions both about the difficulties we face and the available solutions' (Hannigan 2006: 29, emphasis in the original). As well as policy debates, the scientific evidence itself is actively disputed, with, for example, knowledge claims presented within the climate debate as either "sound" or "junk" science (McCright and Dunlap 2003). Sound science first emerged as a term during the bovine spongiform encephalopathy health scare in the USA in the early 2000s when scientific—instead of economic—rationales were employed to defend policy responses. Evidence that does not fit the desired policy frame is conversely labeled as "junk science", although critics using the sound science argument often refer to incomplete data and scenario modeling (two things inherent to climate science) as key elements of junk science, rather than engaging in a direct debate about the quality of the extant data itself. As McGarity (2003-2004: 901) argues, 'stripped of their rhetorical flourish, "junk science" means "their science" and "sound science" means "our science"'.

In contrast to controversies such as the health impacts of tobacco smoking which is no longer widely publicly disputed, the scientifically abstract nature of climate science and its inherently values-laden character means that scientific evidence alone is inadequate to drive policy decision-making (Hulme 2009). Hoffman (2011b) argues that the climate debate may have entered into the realm of what Pielke (2007) coins "abortion politics", that is, a situation where no amount of *scientific information* can reconcile the different values held on a certain topic. While a speaking truth to power model would suggest that climate change could resolved by systematically uncovering factual knowledge, this "rational-instrument" approach whereby science is seen as providing 'verifiable facts about reality on which rational policy decisions can be based' (Gulbrandsen 2008: 100) is inadequate. The range of potential policy responses to climate change each hold deeply embedded ideological implications, with Hoffman providing the example of attendees at a climate sceptics' conference in 2010 stating that 'the issue isn't the issue'; instead, that 'climate change is just another attempt to diminish our freedom' (2011b: 3).

While the academic literature to date has focused on the manifestation of climate scepticism in mainstream media forums (Boykoff 2007; Schmidt et al. 2013), little work has been done to understand why climate sceptical blogs exist and what their role may be as public sites of knowledge contestation. Several elements are relevant to consider, including conflict over the legitimacy of the public's ability to contribute valid climate change knowledge—particularly where it disputes mainstream climate science (Douglas 2009), mistrust by some regarding the data and methods used to create climate predictions (exemplified by the "Climategate"[4] controversy), or a desire for greater transparency overall in the scientific process (Nerlich 2010). The notion of knowledge networks under Mode-2 conditions provides a useful analytical framework, as the production of knowledge and specifically, its *re*production by different actors in a network helps to identify which types of information are most relevant to a particular debate, as well as showing how framing and sources contribute to knowledge legitimacy. For example, Kahan et al. (2011) suggest that even the perception of whether a scientific consensus *exists* on a certain topic is determined by both the source of the information in question, and the side on which consensus forms. This flow of knowledge enables the creation of what Cope and Kalantzis (2009: 5) term 'dispersed communities of expertise', with the format of online networks in particular promoting near instant feedback on knowledge claims (Koteyko et al. 2012).

Furthermore, while the ways in which mainstream science and policy is organised and interacts have been the subject of considerable attention (Berryman 2006; Daviter 2007; McCright and Dunlap 2003; Zuckerman and Merton 1971), correspondingly little is known about contemporary online sites of knowledge contestation and the ways in which this knowledge is created and disseminated across virtual space. These new sites of knowledge production and reproduction that blogs embody are important to address because they facilitate 'a shift in the balance of textual agency between the author and reader' (Cope and Kalantzis 2009: 6) by enabling contested knowledge to be freely circulated (as opposed to the time and financial constraints inherent to the

[4] "Climategate" refers to over 1000 emails and documents stolen or leaked from the University of East Anglia in 2009.

peer reviewed literature), and to act as direct challengers to "official" expertise. While it is possible that these climate sceptical blogs are not making a significant impact on public discourse outside the online environment, this seems increasingly unlikely, as blogs are increasingly recognised as important contributors to the public debate about climate change (Guimaraes 2012). It is thus also possible that climate sceptical blogs may be filling a void in the climate debate, enabling those who dispute mainstream climate science or policy to voice their opinions and network with like-minded people to suggest alternative explanations and arguments. Blogs' low entry barriers compared to access to peer-reviewed journals, which are generally too expensive to access for non-institutional readers (Harnad 1998) or written in an overly obtuse or technical style (Culler and Lamb 2003; Eagle et al. 2012), may also give them a unique position as a mediator of public discourse.

3. A networked blogosphere

As a tool to express opinions and disseminate ideas, blogs are an increasingly popular online phenomenon (Wei Lai 2009). The rise of free blogging platforms which require little technological know-how have helped to reduce entry barriers to potential authors (Hookway 2008), contributing to a rise in total blog numbers worldwide from fewer than 20,000 in 2002 to over 180 million by 2012 (Bar-Ilan 2005; Hurst 2012). Blogospheres, as networked user communities, contribute to the creation of attitudes and transfer of information and ideas (Bruns et al. 2011; Etling et al. 2010; Moe 2011; Tremayne et al. 2006; Tremayne 2007). However, while individual blogs have been recognised as significant disseminators of knowledge, particularly knowledge which may be deemed partisan (Lowrey 2006), comparatively little work has been undertaken that examines these sites of knowledge contestation as a networked whole.

Social network analysis (SNA) is a useful method to examine blogospheres as it provides a coherent mechanism to interrogate their structure. A social network may be thought of as a 'collection of social actors and their interconnections… [which] consists of nodes (social actors) and links between the nodes (the interconnections)' (Sun and Qiu 2008: 1769). SNA is used to analyse these links, emphasising the interconnections between actors rather than the characteristics of the actors themselves (S. P. Borgatti et al. 2009). Centrality is a core concept within SNA, with a variety of approaches (such as degree, closeness or betweenness) used to measure 'the locations of individuals in terms of how close they are to the "center" of the action in a network' (Hanneman and Riddle 2005: 147). Those nodes in particularly central positions are also understood in SNA as potentially powerful, with power in this context existing as a result of the advantageous position of a node in comparison to others. While the 'question of how structural position [i.e. centrality] confers power remains a topic of active research and considerable debate' (Hanneman and Riddle 2005: 168) in SNA, this research will follow the lead of Brass (1984: 520) who argues that, 'actors or units occupying central positions in a network are viewed as potentially powerful because of their greater access to and possible control over relevant resources'.

In addition to centrality, clustering is also argued to be an important characteristic of a blogosphere (Barabási et al. 2000; Newman et al. 2002; Watts 1999) where relationships are indicated by bloggers linking to or commenting on others' blogs, or via the existence of "blog-rolls" which are links to other blogs displayed on either the

home-page or links page of a blog (Adamic and Glance 2005). Bruns et al. explain the importance of blog-roll links:

> *Patterns of interlinkage between contemporaneous blog-rolls indicate the existence of a long-term network of recognition between peers. Sites with many incoming and outgoing links may be understood as* hubs *for communication in this network; sites with many incoming, but limited outgoing links may be understood as central* sources *for information; sites with many outgoing but few incoming links may be understood as (not necessarily central)* distributors *of attention to other members of the network* (2008: 3, emphasis in the original).

Blog-rolls indicate long-term connectivity between bloggers, as opposed to a link found within a single blog post, and can also be understood as an indicator of ideological closeness or shared interest (Caiani and Wagemann 2009). The number of incoming versus outgoing linkages is interesting, as those blogs with 'a high number of incoming links…can be understood as the most respected blogs in the overall population' (Bruns et al. 2008: 6), whereas those blogs with many incoming *and* outgoing links are important hubs within the network, playing a role as connector nodes, and thus contributing to a tight-knit cluster formation (Sun and Qiu 2008). Rogers (2012) argues that these incoming links may serve as an indicator of reputation and, what he terms as the "politics of association". That is, blogs will only link to others with whom they want to be associated in an effort to create a coherent group (Niederer 2013).

Also of relevance is the user community's perception of the credibility of the information contained and shared within the blogosphere. This is particularly important to climate sceptical blogs providing an alternative explanation to mainstream climate science (as opposed to blogs focusing on, for example, policy choices related to climate change). In a survey of over 3,700 readers of more than 60 blogs of diverse content, Johnson and Kaye (2004) found that nearly three-quarters considered blogs "moderately" to "very" credible sources of information, with their particular strength being the provision of in-depth information. Readers did however acknowledge that the accuracy and neutrality of blogs may be questionable, with half the respondents judging blogs as either "somewhat" or "not very" accurate or fair. Yet Johnson and Kaye argue that this does not appear to be inherently problematic as blog readers tend to seek out information to support their own views (Kahan et al. 2011), and as Hsu and Lin (2008) propose, bloggers themselves are blogging because they want to share their own opinions and influence others by the knowledge they provide.

4. Method

A multi-stage process was followed in order to a) map the climate sceptical blogosphere, b) identify the most central blogs, and c) to understand why the most central blogs occupy such positions of importance. This section explains the mapping process of the climate sceptical blogosphere, with Section 5 discussing the SNA tests and Section 6 outlining the thematic content analysis.

To identify the population of climate sceptical blogs, the search string "climate blog" was entered into *WebCrawler*[5], with the initial 12 pages of results used as the basis from which all further blogs were identified via a snowball method using blog-roll links. Inclusion and exclusion criteria were implemented in order to create a coherent dataset, with all blogs identified and assessed manually, as an automated gathering programme would not distinguish between relevant and irrelevant blogs (Heath et al. 2009). First, the blog had to identify itself as a blog about climate change, either through use of the term "climate" or "global warming" in the header or title, or through substantive discussion in posts. Substantive was determined as at least 50% or more of the blog's content and was assessed in two ways. If tags were allocated to a post, a frequency analysis was undertaken and if 50% or more of the posts were tagged as "climate change" or similar, it was added to the network. Where tags were not present or were ambiguous, the first five pages of each blog were analysed using content analysis to determine whether 50% or more of the posts could be categorised as climate change-related. While this coding process is inherently subjective, it did not limit the rigour of the analysis as this process of 'recognizing (seeing) an important moment and encoding it (seeing it as something) prior to a process of interpretation' (Fereday and Muir-Cochrane 2006: 83) was based on an extensive grounding in the climate change literature. 37 blogs were excluded for not having climate change as majority content, including predominantly political blogs such as the *Australian TEA Party* or weather blogs such as the UK's *Met Office News Blog*.

Second, the blog had to be identified as climate sceptical. This was determined by individual assessment of each blog's content insofar as it employed language which agreed with Rahmstorf's (2005) typology of trend, attribution or impact climate scepticism. As Painter (2011: 54) explains, trend sceptics are 'those who say global temperatures are not warming', while attribution sceptics are 'those who say they are warming, but argue that the anthropogenic contribution to global warming or climate change is over-stated, negligible, or non-existent compared to other factors like natural variations or sun spots' and impact sceptics are 'those who accept it is happening but for different reasons question its impacts or the need to do something about it'. While this was clearly evident in most cases, a categorisation system became a necessary addition in order to distinguish between types of blogs, as there was a marked difference in language employed. Two categories were developed: openly sceptical (category 1) and self-proclaimed "open-minded" (category 2). For example, compare the following excerpts in Table 1 from *Climate etc.*, a category 2 blog authored by Judith Curry (Georgia Institute of Technology) and *GORE LIED*, a category 1 blog authored under the pseudonym "The Editor", based in Oregon, USA. In the *GORE LIED* excerpts, the phrase 'the foundation for anthropogenic global warming is fraudulent' and the suggestion of climate scientists and policy-makers personally profiting from the existence of climate change clearly identifies it as a category 1 blog. Conversely, in the *Climate etc.* excerpt, the discussion of the need for greater causal investigation into the scientific factors behind the physical manifestation of climate change is markedly different in tone, hence its classification as a category 2 blog.

Table 1: Category 1 and 2 language

Blog	*About*	*Post excerpt*

[5] WebCrawler is an integrated online metasearch engine combining Google and Yahoo! Search results. At the time of this research, it also included Microsoft Bing.

Climate etc.	'Climate Etc. provides a forum for climate researchers, academics and technical experts from other fields, citizen scientists, and the interested public to engage in a discussion on topics related to climate science and the science-policy interface.'	'In the case of main stream climate science, the physical mechanism for climate change is clearly posited as arising from external forcing: solar, volcanoes, anthropogenic greenhouse gases and aerosols. However, climate scientists have not racked their brains anywhere near hard enough to come up with other causal explanations. The main outstanding causal explanation that has been neglected is internal natural variability of the coupled ocean/atmosphere system.' (*Pseudoscience?*, 20 March 2012)
GORE LIED	'The main point here at GORE LIED is that Al Gore lied about anthropogenic global warming. It's pretty simple. I repeat that often, and prove it over and over. While that is my main quest, I also hope to entertain you along the way…The Climategate scandal has proved that the data that comprised the foundation for anthropogenic global warming is fraudulent, and as a result has tainted virtually every other study, conclusion, and public policy "solution" that had been produced or proposed. Therefore, GORE LIED firmly believes that Al Gore, and any other scientists or governmental officials that continue to fan the flames of man-made global warming alarmism to stoke public support for "solutions" that prove to enrich them in money or power be held legally liable for foisting a fraud on the public.'	'Joe Romm asks his readers, "What are you doing to prepare for climate impacts?" The beneficial-molecule-fearing Rommulans obediently reply in droves. One particular comment from a warmist blogger goes a bit beyond the question Romm posed, and predicts a very dark solution for an imagined future climate hell: *I'll also predict that laws permitting euthanasia will become commonplace in about two decades. The world will have to choose between keeping the old and ill fed and alive, and keeping the young and fit fed and alive. (Hopefully I'm exaggerating slightly in the second sentence, but maybe not.)* So, he might be exaggerating a bit about the choice of exactly who to euthanize, but he's *not* exaggerating about the actual euthanasia itself. Some of these people have lost their minds.' (*Climate death panels? Warmist blogger predicts 'laws permitting euthanasia will become commonplace in about two decades'*, 28 February 2012)

Third, the blog had to present new content, thus excluding three blogs that that collated posts originally published elsewhere such as *Climate Depot*. Fourth, it had to present itself in a blog format, requiring elements typical to a blog such as post headings, dates, tags, and contributing author identification (Bar-Ilan 2005). This excluded 57 websites. Fifth and finally, four blogs were excluded because they were not written predominantly in English. This is a recognised limitation of this research, as the presence of non-English language blogs in the identified network, and an unknown number of non-English language blogs that were not identified via blog-roll links, constitute a missing space of unknown size. However, this research is predominantly interested in English language blogs, building on previous research in the communication of climate scepticism which emphasises the Anglo-American or Anglo-Saxon nature of the phenomenon (Niederer 2013; Painter 2011). Six blogs were retired or appeared inactive, yet were included in the network as potential sources of static information. A blog containing pornographic images as well as

climate sceptical posts was excluded, despite being linked to by several other blogs. Three parody blogs which purported to be climate sceptical, but on closer investigation were actually satirical in nature, were also excluded from the dataset such as *The Climate Scum*.

To carry out the SNA, a one-mode network adjacency matrix was created based on blog-roll linkages and analysed using the computer programme UCINET and its accompanying graphical visualisation software, NetDraw. As Borgatti et al. (1999: 15) explain, 'the rows and columns of the adjacency matrix [in UCINET] correspond to the nodes of the graph [in NetDraw], and the cells in the matrix correspond to pairs of nodes or *dyads*. A matrix value X(i,j) = 1 indicates the presence of a link between node *i* and node *j*, and X(i,j) = 0 indicates the absence of a link'. In this case, the matrix value of 1 indicated the existence of a blog-roll link. The inclusion and exclusion criteria were particularly important to the adjacency matrix, as to list all the blogs included on the identified blog-rolls without focusing on a particular topic would have resulted in a (likely ever-expanding) network of blogs. Some of the blog rolls differentiated their blog-roll links into groupings (such as "climate" or "politics") as well as identifying fellow sceptical blogs and those on the "other side" of the debate. *The Global Warming Heretic* provides a good example of this, with its blog roll divided into the following sections:

- Data (5 links)
- Fellow heretics (87 links)
- Mostly impartial (1 link)
- GW/CC [global warming/climate change] news (16 links)
- True believers, Hangers-on, Folks who don't know any better, and folks who should know better (54 links)
- Carbon brokers (4 links)
- Heretic sympathizers (1 link)
- Other heretics (non-AGW [anthropogenic global warming]) (5 links)

The Global Warming Heretic also provided a fascinating note about its link classification system, with the categories explained as follows:

> *I have done my best to classify the links into the stated categories based on my impression about the general thrust of each of these sites. Sites classified as 'Fellow Heretics' will not necessarily agree with me on all issues related to climate change—they merely contain content that unapologetically diverges from the consensus. Sites classified as 'True Believers' are those that have accepted the essence of the AGW hypothesis—but some present their views reasonably rather than in the hysterical fashion of the CoGW [Church of Global Warming].*

In such cases, only those blogs identified as sceptical by the blogger themselves were added to the adjacency matrix. Both the adjacency and attribute matrices were

analysed using UCINET and NetDraw, with the results explained in the following section.

5. Results

In total, 171 blogs were identified[6], 155 of which are allocated to category 1 (openly sceptical) with the remaining 15 identified as category 2 (self-proclaimed "open-minded"). Of those blogs whose authorship could be determined (155 blogs, with authorship identified via the blogger naming their location[7] on either the About page or other part of the blog), nearly half (76) are authored from within the USA. In descending order of prevalence, the authorship of the remaining blogs is: Australia (32), United Kingdom (26), Canada (8), New Zealand (5) and the Czech Republic, Denmark, Germany, India, Ireland, Israel, Italy and Sweden each contributing a single blog to the tally. It is interesting that seven of the blogs whose authorship could be determined come from predominantly non-English speaking countries, yet are written in English. This may be due to these bloggers' desire to connect with the predominantly Anglo-Saxon manifestation of climate scepticism (Painter 2011).

Of the 171 blogs, 114 list links in a blog-roll. Only one blog (found via the initial scoping process using *WebCrawler*) is not linked somehow to the remainder of the network. The geodesic distance of the entire network is measured at 2.71, that is, only 2.71 blogs on average separate each blog from another. While this may seem like a densely connected network, employing UCINET's density algorithm shows a density rating of only 0.0561. The density of the network examines the proportion of possible ties that are present. A density rating of 1 means that every blog would be directly connected, with a density rating of 0.9 or less considered to be low (Faust 2006). This result means that of all possible ties (i.e. every blog linked to every other blog) only 5.61% are present, suggesting, as can be seen in Figure 1 which visualises the blogosphere using an ego network display, that other clusters of relationships, for example through particularly central nodes, may be more important. The reciprocity of the network (how many blogs link to each other) was also analysed using the arc method, as it provides a mechanism to assess the interdependency of the blogosphere. The reciprocity measure for the climate sceptical blogosphere is 19.93%. This result, where less than a quarter of the blogs provide reciprocal links on their respective blog rolls, in addition to the low network density, appears to provide further evidence for a blogosphere that depends on central nodes. Three centrality tests were selected to achieve the goal of determining the most central nodes within the blogosphere. Those blogs either that appear in the top 10 of each reciprocal test (for example, both in- and out-degree ratings) were placed on a short-list of central blogs for subsequent analysis. Table 2 outlines these tests and the blogs that, by virtue of their test results, were placed on the short-list of blogs identified for further analysis.

[6] This is a snapshot of the blogosphere created during the period March to April 2012. It is expected that several of these blogs will no longer be in existence by at the time that this article is published and concomitantly, that many others will have been created.

[7] Where both author location and nationality were identified but were different, author location was chosen.

Figure 1: The climate sceptical blogosphere, where round nodes are category 1 (openly sceptical) and square nodes are category 2 (self-proclaimed 'open-minded')

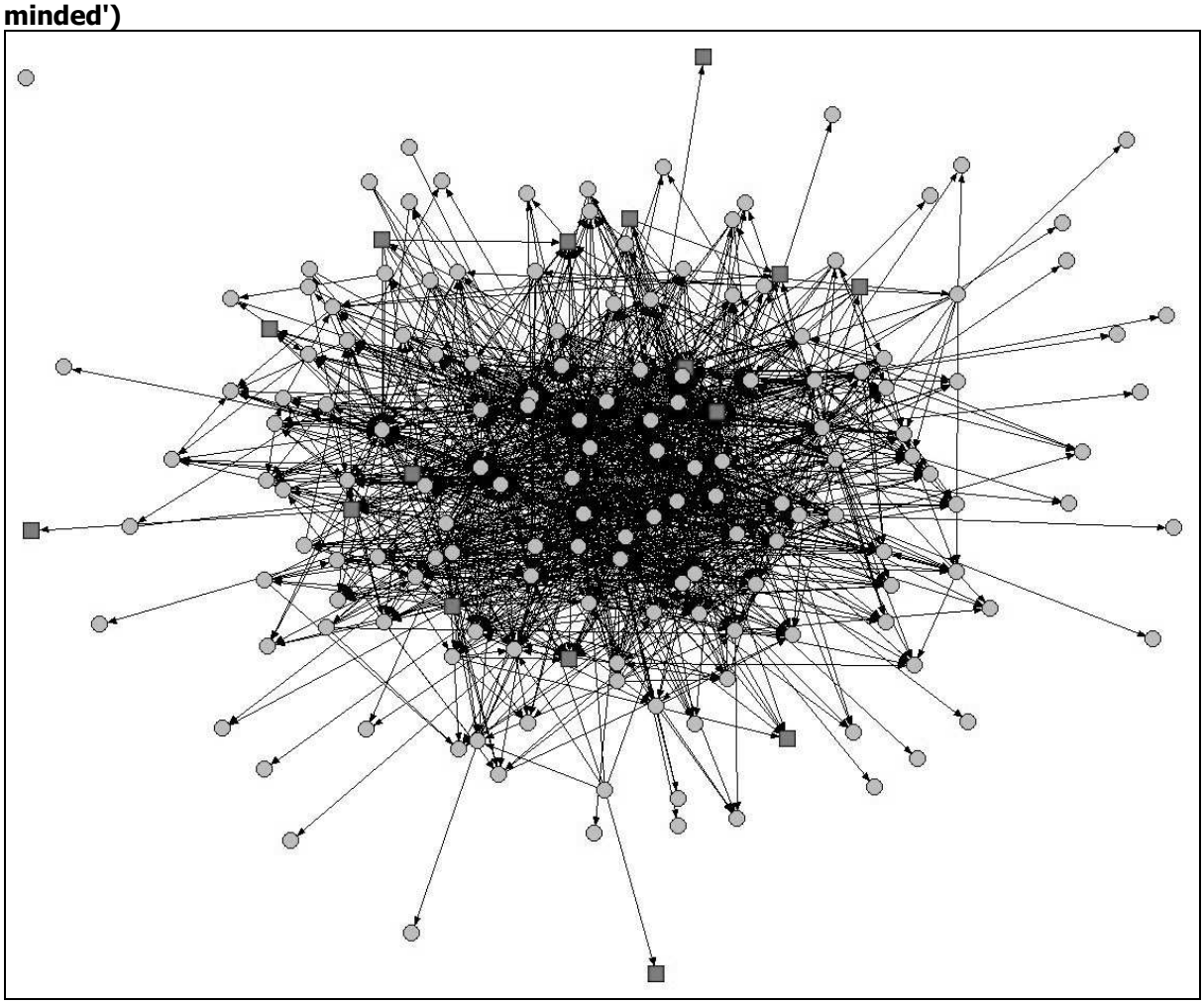

Table 2: Centrality tests

Test	*Description*	*Detail*	*Most central blogs according to test results*
Degree centrality (Freeman's approach)	Measurement of incoming and outgoing linkage (also known as in- and out-degree rating).	In-degree rating determines the most linked-to blog. Out-degree rating determines which blogs' blog-rolls are the most extensive.	• Bishop Hill • WUWT

Degree centrality (Bonacich's approach)	Measurement of centrality and power according to number of connections within the network.	A positive co-efficient of 0.5 determines centrality. Centrality is achieved if the blogs that are linked to on a blog-roll have themselves many subsequent links. A negative co-efficient of -0.5 determines power. Power is achieved if a blog is connected to many blogs without further links themselves.	• GORE LIED • The Friends of Carbon Dioxide • The Global Warming Heretic
Betweenness centrality	Measurement of centrality that shows those nodes upon which others depend to make connections.	A blog is central if it is situated on the shortest path between other pairs of actors in the network.	• Climate Audit • JoNova • ICECAP • No Frakking Consensus

Two tests for degree centrality (Freeman's and Bonacich's approach) were chosen as 'very simple, but often very effective measure[s] of an actor's centrality' (Hanneman and Riddle 2005: 148). Freeman's approach shows the centrality of a node based on its degree, that is, the number of connections a node has. In this case, the rating score represents the number of other blogs linking to that blog on their respective blog rolls. The blog with the highest in-degree rating according to Freeman's approach is *Watts Up With That (WUWT)*, authored by California-based Anthony Watts, with 54% of the climate sceptical blogosphere linking to *WUWT*. *WUWT* itself claims it is the 'world's most viewed site on global warming and climate change' and the results of this test appear to support this assertion. Freeman's approach may also be used to analyse out-degree linkages, that is, examining which blogs' blog-rolls are the most extensive. While out-degree score is usually seen as a measure of how influential an actor is in a network, in this case, a blog has no control over whether or not it is included in another blogs' blog-roll. It is thus possible that out-degree score in the context of a blogosphere may instead be regarded as an indicator of desire to enhance the network, for example, by ensuring readers are aware that there are multiple other blogs that support the position of the original blog. Interestingly, only two blogs show both high in- and out-degree linkages (*WUWT* and *Bishop Hill*). Tables 3 and 4 show the top 10 Freeman's approach scores for in- and out-degree linkage.

Table 3: Degree centrality (Freeman's approach) in-degree results

Rank	*Blog*	*Score*	*Category*	*Blog-roll*
1	Watts Up With That	93	1	Yes
2	Climate Audit	76	2	Yes
3	JoNova	55	1	Yes
4=	Bishop Hill	46	1	Yes
4=	ICECAP	46	1	Yes
6	Tom Nelson	42	1	Yes
7	No Frakking Consensus	37	1	Yes
8=	JunkScience	34	1	No
8=	Science and Public Policy Institute	34	1	Yes
10=	Climate etc.	32	2	Yes
10=	Climate Realists	32	1	No

10=	Roy Spencer	32	1	No
10=	the reference frame	32	1	No

Table 4: Degree centrality (Freeman's approach) out-degree results

Rank	*Blog*	*Score*	*Category*	*Blog-roll*
1	C3 Headlines	67	1	Yes
2	GORE LIED	57	1	Yes
3	Global Warming Science	51	1	Yes
4	Climate Change Dispatch	43	1	Yes
4=	Global Warming: A Worn-Out Hoax	43	1	Yes
6	Web Commentary	42	1	Yes
6=	Bishop Hill	42	1	Yes
8	Climate Research News	38	1	Yes
9=	ecomyths	36	2	Yes
9=	Watts Up With That	36	1	Yes
9=	Rajan's Take: Climate Change	36	1	Yes

Bonacich's approach for degree centrality is a more nuanced mechanism to determine both centrality and power based on the number of secondary connections attributed to a node. A positive coefficient of 0.5 is used to determine centrality, that is, whether the blogs that are linked to on a blog-roll have themselves many subsequent links. Centrality is achieved because the node is linked to nodes that are well-connected. A negative coefficient of -0.5 is used to determine power, with the concept of power understood in this test as whether a blog is connected to many blogs without further links themselves. Power is implied because a node that is connected to few other nodes is more dependent on them than if it was connected to many others (Hanneman and Riddle 2005). The positive coefficient test to determine centrality provided some very different results to both the Freeman's approach tests, with Table 5 showing *The Friends of Carbon Dioxide* as the most central. The blogs to which *The Friends of Carbon Dioxide* links on its blog-roll have themselves many subsequent links, indicating that it is well-attuned to the key nodes in the climate sceptical blogosphere. The negative coefficient test to determine power assigns negative values to well-connected nodes and positive values to weakly connected nodes. In the case of a blogosphere, the results for this test may indicate that high-scoring blogs are serving as key sources of inspiration and information. According to the negative coefficient results (Table 6), *The Friends of Carbon Dioxide* is less powerful, only ranking sixth. The blogs *GORE LIED*, and *The Global Warming Heretic* scored in the top 10 results of both the positive and negative coefficient tests.

Table 5: Degree centrality (Bonacich's approach) positive coefficient (centrality) results

Rank	*Blog*	*Score*	*Category*	*Blog-roll*
1	The Friends of Carbon Dioxide	50.48	1	Yes
2	iloveCarbonDioxide.com	27.45	1	Yes
3	The Global Warming Heretic	21.08	1	Yes
4	Impact of Climate Change	20.34	1	Yes
5	hauntingthelibrary	19.54	1	Yes
6	Tory Aardvark	19.53	1	Yes
7	CO2 Insanity	18.96	1	Yes
8	Climate Change Denier	18.88	1	Yes
9	Global Warming	18.81	1	Yes
10	An Honest Climate Debate	17.68	1	Yes

Table 6: Degree centrality (Bonacich's approach) negative coefficient (power) results

Rank	*Blog*	*Score*	*Category*	*Blog-roll*
1	Climate Nonconformist	-430.62	1	Yes
2	Global Shamming	-324.14	1	Yes
3	False Alarm	-280.37	1	Yes
4	The Global Warming Heretic	-222.19	1	Yes
5	Kiwi Thinker	-200.96	1	Yes
6	The Friends of Carbon Dioxide	-192.02	1	Yes
7	Errors in IPCC Science	-182.42	1	Yes
8	Climatequotes.com	-175.84	1	Yes
9	Digging in the Clay	-160.21	1	Yes
10	GORE LIED	-159.55	1	Yes

In order to test the results for degree centrality (as the number of connections may not necessarily indicate the relative importance of a node within a network), a test for betweenness was also conducted. Betweenness centrality is used to highlight those nodes upon which others depend to make connections. In traditional SNA, this is a measure of whether a node is "between" other nodes in a network, for example, how many people depend on an individual actor to make connections with other people. In the case of a blogosphere, a blog may achieve a high score if it is linked to by many other blogs (thus results for this test are expected to be similar to the results for in-degree rating using Freeman's degree centrality). Table 7 shows that *WUWT* is an extremely central node according to this test. The results of this test are interpreted against the mean betweenness score. *WUWT* has a score of 3971.52, significantly higher than the mean score of 180.31. As anticipated, there was a large overlap between the results for this test and those for Freeman's in-degree centrality, with six blogs appearing in both sets of results. Accordingly, *Climate Audit*, *ICECAP*, *JoNova* and *No Frakking Consensus* also join the short-list of the most central blogs.

Table 7: Freeman's betweenness node centrality results

Rank	*Blog*	*Score*	*Category*	*Blog-roll*
1	Watts Up With That	3971.52	1	Yes
2	ICECAP	2638.08	1	Yes
3	Bishop Hill	1948.08	1	Yes
4	Global Warming Science	1805.80	1	Yes
5	No Frakking Consensus	1790.30	1	Yes
6	GORE LIED	1672.28	1	Yes
7	C3 Headlines	1365.88	1	Yes
8	Climate Audit	1221.18	2	Yes
9	JoNova	1084.35	1	Yes
10	Australian Climate Madness	1016.16	1	Yes

6. Analysis

The results of the three centrality tests show that nine blogs from the total network of 171 blogs could be considered to be the most central nodes within the climate sceptical blogosphere: *WUWT*, *Bishop Hill*, *Climate Audit*, *GORE LIED*, *ICECAP*, *JoNova*, *No Frakking Consensus*, *The Friends of Carbon Dioxide* and *The Global Warming Heretic*. However, while a blog may appear to be influential to the blogosphere as a result of high centrality scores, this position may be illusory, created through mathematical analysis rather than actual influence. Delving deeper is a vital part of good SNA, as the data presented through the analysis should not be viewed in isolation, or necessarily meaning that the 'measured relationships and relationship strengths as accurately reflecting the "real" or "final" or "equilibrium" status of the network' (Hanneman and Riddle 2005: 13) in question. In nearly all respects, apart from all having blog-rolls, they are heterogeneous. *Climate Audit* is a category 2 blog, whereas the remainder are category 1. Five are USA-authored, three in Australia, and one in the UK. *WUWT* and *JoNova* receive hundreds of comments per post, whereas *The Friends of Carbon Dioxide* regularly receives either none or fewer than five comments per post. *GORE LIED* and *The Global Warming Heretic* appear to both be infrequently updated (or retired) which is an important discount factor in the blogosphere, where quick turnaround of information is critical to retain readers' attention and get repeat visits. In order to test the SNA results, reader statistics were employed to indicate the blogs' relative importance to blogosphere user community. Google's *Ad Planner* was used to estimate site traffic. Very little research is available that compares the accuracy of publicly-accessible (both free and subscription) site-traffic estimation services (Vaughan and Yang 2013). In the absence of such research, *Ad Planner* was chosen as it yielded the most data on the short-listed blogs as compared to other services. Moreover, it does not provide information for low-traffic websites, thus suggesting that if any of the nine blogs were not tracked by *Ad Planner*, they are unlikely to receive significant traffic. Only four of the nine blogs appeared in the *Ad Planner* results: *Climate Audit*, *ICECAP*, *JoNova* and *WUWT*. Table 8 shows that *WUWT* is the most visited site, followed by *JoNova* and *Climate Audit*. *ICECAP* receives significantly fewer estimated page views per month than the other three blogs and was thus excluded from the final three blogs subject to further analysis.

Table 8: Estimated site traffic using Google Ad Planner

Blog	*Estimated unique visitors per month*	*Estimated page views per month*
Climate Audit	19,000	200,000
ICECAP	14,000	84,000
JoNova	22,000	200,000
WUWT	140,000	2,100,000

In order to understand why *Climate Audit*, *JoNova* and *WUWT* occupy the most central positions in the climate sceptical blogosphere according to the SNA and site traffic results, content analysis of multiple posts from each blog was performed, with predominant themes identified based on word occurrence. 20 posts in chronological order dating from 1 March 2012 were identified from each blog, with each post categorised under either "science", or "policy". The categories of science and policy were chosen as they are the most prevalent underlying themes of climate scepticism identified in the literature in terms of both climate sceptical arguments (Rahmstorf 2005) and motivations behind climate sceptical viewpoints (Hulme 2009; Washington and Cook 2011). "Science" included all scientifically-related points, including any argument that referenced scientific data or methods, scientific theories or the role and activities of scientific institutions. No distinction was made between what has been suggested as being 'scientifically legitimate' (Freudenburg and Muselli 2010: 483) arguments as opposed to 'non-science and pseudoscience' (Cormick 2011). "Policy" included all discussions that emphasised the politics of, or policy decisions related to, climate change, such as the political appropriateness of mitigation or adaptation policies. Where neither of these categories was an accurate fit, a further category of "other" was used. In addition to the pre-determined coding framework of science, politics or other, sub-themes were also allocated to each post that identified the specific topic under discussion. These included "funding sources" or "transparency" under the overall category of science and "regulation" or "government agency" under the overall category of policy.

The most clearly apparent category across all three blogs was a focus on science. 95% of the analysed posts on *Climate Audit* were categorised as science, with the remaining post categorised as other. 50% of the posts on *JoNova* were categorised as science, with the remaining 50% split equally between politics and other. 100% of the posts on *WUWT* were categorised as science. The overall category of science was supplemented by a number of key sub-themes, with discussions of alternative scientific rationales for observed climate variability and extreme weather events, and critiques of techniques and results from mainstream climate science such as computer modelling of surface temperature data particularly prevalent. Distrust of scientists involved in mainstream climate science and associated scientific arguments was also a frequently occurring point of contestation, including the contention that mainstream climate scientists' claims were scientifically invalid. Specifically, *Climate Audit* appeared to be predominantly interested in issues of transparency, such as information access, funding sources and scientific integrity. For example, the following excerpt from a post entitled *Schmidt's "Conspiracy Theory"* dated 16 May 2012 discusses efforts that *Climate Audit*'s author Steve McIntyre made to access primary data upon which a piece of research was based:

> *Wahl and Ammann announced in May 2005 that all our claims were "unfounded". Since our codes were very close and I reconciled them almost immediately, I knew that their verification r2 results would be identical to ours. Again, I was asked to review the paper (though my review was disregarded.) As a reviewer, I asked for the verification r2 results. Wahl and Ammann refused. Rather than rejecting the paper, Schneider terminated me as a reviewer.*

As the categorisation results suggest, *JoNova* discusses a broader range of topics (for example, fake gold bars and full-body scanners at airports), yet still has a clear interest in the scientific element of climate scepticism. The key sub-themes identified were conspiracy theories (of which climate scientists' funding was a predominant element) and the behaviour of members of the media when discussing climate science. For example, in a post entitled *Monbiot—Steal things and be a "democratic" hero* dated 4 March 2012, which refers to environmental journalist George Monbiot, *JoNova*'s author, Joanne Codling argues that the 'richest of ironies is that Monbiot relies on models and opinions, while the skeptics that he looks down upon want observations and data, true to the original tenets of the scientific method. Despite not apparently knowing what makes science different from a religion, he calls skeptics "anti-science deniers"'. *WUWT* is an extremely prolific blog, with 190 posts for March 2012 alone; however, the posts analysed had several reoccurring sub-themes under the overall category of science, with a predominant interest in alternative explanations for climate models, temperature data or human-induced climate change, largely in the form of scientifically-based challenges to published science. In this sense therefore, it is a mix of both Rahmstorf's (2005) trend and attribution scepticism. For example, the following excerpt from a post entitled *Why William D. Nordhaus Is Wrong About Global Warming Skeptics Being Wrong…* dated 3 March 2012 disputes mainstream climate science knowledge claims: 'As the Earth's climate continues to not cooperate with their models, the so-called consensus will eventually recognize and acknowledge their fundamental error'. Across all three of the blogs, the two most prevalent sub-themes identified were direct scientifically-based challenges to mainstream climate science, and critiques of the conduct of the climate science system, such as individual climate scientists' actions (including issues of transparency) or institutional decision-making.

While all three of the most central blogs focus on the scientific element of the climate debate, it is possible that other, non-central, blogs also have a similar focus and that, instead of being a significant factor in the centrality of these blogs in particular, is broadly characteristic of the entire climate sceptical blogosphere. In order to test this, of the 162 blogs not identified as central in any way to the blogosphere, 20 were randomly selected, with 20 posts from each blog dated in chronological order from 1 March 2012 subject to content analysis and allocated to one of the three main categories: science, policy or other. If a blog had more than 50% of its posts allocated to a single category, that category was assigned as the overall theme of the blog. Of the 20 randomly selected blogs, the majority (65%) were allocated to the category of policy, focusing on a variety of issues such as energy policies or climate change legislation. For example, of the 20 posts analysed from *Tory Aardvark*, six focused on wind farm policies, five examined international or UK climate politics, one discussed climate science, and the remaining eight investigated topics as varied as the psychology of climate change fear and the teaching of climate change in schools. 30% of the 20 non-central blogs focused on climate science, using similar arguments

and content as was found in the most central blogs, such as discussions of the authority of climate models or IPCC predictions, with only one blog allocated to the category of other as it was solely preoccupied with the weather-related impacts of climate change.

7. Conclusion

This research aimed to identify the climate sceptical blogosphere and its most central nodes, and to investigate whether a focus on particular themes contributed to the positioning of the most central blogs. A blogosphere comprising 171 individual blogs was identified using SNA, with three blogs in particular, *Climate Audit*, *JoNova* and *WUWT* identified as the most central based on three tests of centrality (Freeman's approach for degree centrality, Bonacich's approach for degree centrality and Freeman's betweenness) and high site-traffic results. While the SNA provided varied results as to which blogs may be considered the most central, the results of one specific measure of centrality, in-degree rating according to Freeman's approach for degree centrality, appear to be particularly relevant. The three blogs identified as the most central are also the top three most linked-to sites according to Freeman's in-degree rating. This suggests that in-degree connectivity may be an important indicator when analysing the centrality of a blogosphere, although further research on different blogospheres is required to test this hypothesis. It does however accord with Bruns et al.'s (2008) contention that a blog with a high number of incoming links may be understood as highly respected by its peers.

The most noteworthy finding of this research however is that the blogs identified as the most central predominantly focus on the scientific element of the climate debate. Within this overall focus, providing a direct scientifically-based challenge to mainstream climate science, or a critique of the conduct of the climate science system (such as individual climate scientists' actions or institutional decision-making) appear to be particularly important themes. As highlighted above, the direct scientific challenge that the climate sceptical blogosphere provides may be thought of as either trend or attribution scepticism (Rahmstorf 2005). The blogosphere's focus on the scientific element of climate scepticism is important because it stands in direct contrast to research carried out among the general public, where the prevalence of trend and attribution scepticism is low compared to other types of scepticism, such as scepticism regarding the need for mitigation policies (Akter et al. 2012). This result also contradicts claims that climate science is 'adrift in the blogosphere' (Schäfer 2012: 529) because even though few climate scientists themselves blog—and are suggested to mainly focus on addressing the "pseudoscience" implied as existing within the climate sceptic blogosphere (Schäfer 2012)—this does not mean that science itself is not an active topic of discussion.

The climate sceptical blogosphere appears to thus be preoccupied with a particular *type* of climate scepticism—"scientific scepticism"—and is less focused on other types such as ideologically-motivated scepticism which more explicitly highlights 'attitudes and worldviews…[and] political ideology and personal values' (Poortinga et al. 2011: 1022). The expertise that appears to be the most valued in this alternative knowledge network—command of scientific knowledge and willingness to use it to critique mainstream climate science—is thus also different to that valued in other networks of alternative knowledge. For example, in the knowledge networks formed by UK mothers in response to the potential threat from the measles, mumps and

rubella (MMR) vaccine, 'personalised framings' (Poltorak et al. 2005: 717) rather than disputes over the scientific evidence were predominant. Thus building on Merritt and Jones' (2000) suggestion of climate sceptics as "agents of persuasion", this research has shown that these central nodes are key protagonists in a process of continual *expert* knowledge de-legitimisation and contestation. Interestingly however, and in opposition to the Cumbrian sheep farmers in Wynne's classic investigation of expertise, these bloggers do not appear to recognise their 'dependency upon the scientific experts as the certified public authorities on the issue' (1992: 299). It is possible that these central blogs in particular are not only acting as translators between scientific research and lay audiences, but, in their reinterpretation of existing climate science knowledge claims, are filling a void by opening up climate science to those who may have been previously unengaged by the mainstream knowledge process and, importantly, acting themselves as alternative public sites of expertise for a climate sceptical audience.

Several reasons may explain why scientifically-based challenges to, or reinterpretations of, climate science by mainstream climate science outsiders are valued within the climate sceptical blogosphere. Those whose scepticism is entirely scientifically-motivated may regard these blogs as sites of more accurate or trustworthy knowledge than exists in mainstream climate science, or indeed is available either as readily or in as detailed a format as in other sources such as the mainstream media (Boykoff 2013). This rationale would suggest that the 'relevant resource' that Brass (1984: 520) identifies as critical as to why certain nodes become more powerful than others in a network is, in this instance, command of scientific knowledge, in particular, knowledge that attempts to destabilise mainstream science. In this interpretation, bloggers are acting as gatekeepers and interpreters in an alternative knowledge network that is running in parallel to the ways in which, for example, scholarly journal editors carry out the same function in the mainstream academic knowledge network (McGinty 1999). The medium of the network is perhaps particularly relevant here, as blogs can differ from the traditional mode of academic journal publishing in several key respects, such as less-technical or jargon-heavy language or the heavy use of images or other source files to support particular claims. Visual elements are especially interesting, as graphs and models such as the "hockey stick" graph first published in 1998 (Mann et al. 1998) which suggests a strong upwards movement of the average hemispheric temperature after the Industrial Revolution, are often highly contested icons within the climate debate (Turnpenny 2012). Another possible reason is that these blogs are providing a basis upon which scepticism motivated by underlying worldviews or ideological values (such as disagreement for the need for government intervention) can be scientifically justified (G. Cook et al. 2004). It is possible that this contributes to a situation whereby these blogs serve as an "echo chamber", within which users are 'consuming news that mesh with their worldview and ideology' (Boykoff 2013: 15), thus contributing to Hoffman's (2011a) concept of a logic schism within the climate debate.

Thus, while the science-policy interface is often considered to be the most active part of the climate debate (Hulme 2009), this research has shown that in the blog environment, it is the actual nuts and bolts of the climate models, data and assumptions that are the key topics of interest. This research has also contributed to the literature on online knowledge networks by showing that these central blogs are attempting to break open Latour and Woolgar's (1986) "black box" of science, with

the lack of deference given to mainstream climate science possibly attributable again to the medium of contestation in this case. The internet enables a dramatically different type of social interaction between what Nowotny (1993: 308) terms 'knowledge experts and protoexperts', with the minutiae of the building blocks of scientific argument, particularly visual representations such as graphs and diagrams, laid bare for detailed, and rapid, critique. Ravetz (2012) even goes so far as to argue that the blogosphere has actualised post-normal science, with debates about quality—particularly quality related to scientific work—a central tenet of the climate sceptical blogosphere. The freely accessible nature of blogs is also notable, as while there is a movement in academia towards open-access journal publication (Chan 2004), it is not yet the norm. This is significant as blogs are an increasingly common source of scientific source material for mainstream media (Brumfiel 2009) and the climate sceptical arguments emphasised in these central blogs may receive a disproportionately larger audience than is perhaps warranted when compared with the knowledge claims made by the majority of mainstream climate science (Boykoff 2013).

Many opportunities exist for further research using this dataset, including examining discursive links between the blog posts (Bruns et al. 2011), or dialogical analysis when a specific scientific knowledge claim is debated by more than one blog. Investigating the transformation of an issue through this process of debate could point to ways in which participants in the climate debate are framing particular issues of contention. Another extension could be to examine the linkages between climate sceptical and non-sceptical blogs, following the example of Adamic and Glance (2005) who examined linkages between Democrat and Republican political blogs in the run-up to the 2004 USA Presidential election. Finally, it remains unclear what the centrality of these blogs means in terms of their "power" as suggested by Brass (1984), as regards their reach outside beyond the online environment. While blogs in other areas have been suggested as playing an important public agenda-setting role (see for example research by Wallsten (2007) on political blogs in the USA), more research is required that investigates how the climate sceptical blogosphere could influence the wider public climate debate.

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