Global Environmental Change 32 (2015) 11–17

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Polarized frames on "climate change" and "global warming" across countries and states: Evidence from Twitter big data

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ARTICLE INFO

Article history:
Received 29 August 2014
Received in revised form 18 February 2015
Accepted 23 February 2015
Available online 22 March 2015

Keywords:
Climate change
Global warming
Framing
Big data
Twitter
Comparative analysis

ABSTRACT

Environmental communication researchers have focused on the role of media frames in the formation of public opinion. Yet, little is known about how citizens incorporate such frames into everyday conversations. We address this issue by examining the stream of Twitter conversations about climate change over two years. We demonstrate that hoax frames that question the reality of climate change prevail in the US, particularly in "red states" compared to the UK, Canada, and Australia or "blue states" in the US. We also investigate the use of terms, "global warming" and "climate change." We find that red states prefer "global warming" to "climate change" compared to blue states and "global warming" is particularly associated with hoax frames.

1. Introduction

Despite urgent warnings emanating from the scientific communities, climate change remains a low priority for many global citizens (Johnson and Levin, 2009; Pew Research Center for the People, 2013). As most people have limited resources to assess the accuracy of the data on global climate change and have yet to feel its effects directly, their scientific perceptions are likely to be swayed by framing or messaging strategies (Hart and Nisbet, 2012; Jang, 2013; Nisbet, 2009; Rickard et al., 2014; Weber and Stern, 2011). Acknowledging the significance of media framing in climate change contexts, many studies have examined the ways in which mass media interpret global climate problems in terms of definitions, causes and remedies (Boykoff and Boyokff, 2004; Entman, 2004; Feldman et al., 2012; Hart and Feldman, 2014).

Although most scholarship on science communication has focused on the role of "media frames" in the formation of public opinion, little work has examined how the public embraces such frames and incorporates them into everyday conversations (Guggenheim et al., 2015; Kirilenko and Stepchenkova, 2014; McCright and Dunlap, 2011; Scheufele, 1999). Indeed, the framing literature points out the insufficient scholarly attention paid to frames naturally occurring from casual conversations despite their effects on the public perception of social problems (Boykoff, 2007; Eveland and Hively, 2009; Lee et al., 2015). The dearth of literature stems from the methodological difficulty of capturing interpersonal discussions that are deeply embedded within everyday life.

To fill this gap in the literature, we analyze social media content using digital trace data. By virtue of new tools of data collection and analysis, it is now possible to empirically analyze online conversations that are voluntarily generated and shared by users (Brossard and Scheufele, 2013). In the present study, we analyze data from one of the most popular social networking platforms – Twitter – where users talk about personal and public matters (Hermida, 2013; Kwak et al., 2010; Veltri, 2013). By looking into the full body of social media content over two years in four English-speaking countries, we examine which frames and terms people use when they discuss climate change and variations in the frequency pattern of issue frames across countries and states.

This study illustrates how certain frames that promote skepticism about climate change are widely circulated by users within specific regional and political contexts (Boykoff, 2007). For example, critics claim that the American public, particularly some Republicans' passive stance toward climate change initiatives may result from their preoccupation with hoax frames that may significantly compromise trust in scientific authorities

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http://dx.doi.org/10.1016/j.gloenvcha.2015.02.010
0959-3780/

(Hmielowski et al., 2014). To address this concern, we present a series of comparative findings between the United States (US) and other Western countries as well as between Democratic leaning (blue) and Republican leaning (red) states in the US. Furthermore, this study examines the usage pattern of the seemingly interchangeable terms, "climate change" and "global warming." Previous studies suggest that climate change skeptics tend to use "global warming" instead of "climate change" to discredit the authenticity of scientific claims (Schuldt et al., 2011; Villar and Krosnick, 2011; Whitmarsh, 2009). We examine this trend on the Twittersphere. We illustrate how traditionally Republican leaning states compared to Democrat leaning states prefer "global warming" to "climate change" and how "global warming" has a particular association with skepticism of the scientific evidence.

2. Background

2.1. Climate change frames in the US, UK, Canada, and Australia

Climate change is an environmental problem with global causes and consequences. Human activities contribute to carbon dioxide (CO_2) emissions, which alter global climatic conditions and are likely to cause substantial harm to ecosystems and humans in the future (Intergovernmental Panel on Climate Change, 2007). To mitigate such a globally shared problem, global consensus on the issue is a prerequisite. However, there are significant variations about how to approach global climate change across countries, and that hinder the implementation of an international climate policy (Brossard et al., 2004; Schmidt et al., 2013).

Research has indicated that national-level differences are often derived from varying media representation practices – how mass media frame climate change issues (Boykoff, 2007; Shehata and Hopmann, 2012). Because issue frames provide audience members with "interpretive packages" that may define social problems, identify causes, and suggest solutions (Entman, 2004), it is critical to assess how different media environments privilege some frames at the expense of others. Prior research indicated that the prevalence of certain frames is problematic if they may confuse rather than clarify the scientific understanding of climate change (Entman, 2004; Hart and Feldman, 2014; Shih et al., 2008). For instance, it may be easier to initiate climate mitigation policies in societies with greater consensus on the existence and anthropogenic causes of climate change than societies preoccupied with hoax frames that question the reality of the issue (Bord et al., 2000).

Previous studies have provided comparative findings about media coverage and public perceptions of climate change (Antilla, 2010; Grundmann and Scott, 2014; Nerlich et al., 2012). As the US has, to date, failed to pass substantive policies to address climate change, it has often been the target of comparison and contrasted with other industrialized countries. Following this trend, the current study focuses on four English-speaking countries, including the UK, Canada, and Australia. Empirical findings suggest that skepticism of the scientific evidence is more deeply entrenched within the US media than in the European media. Grundmann and Scott (2014) found that although views that endorse climate change (real frames) outnumbered skeptical views (hoax frames) in the US media, skepticism is much more visible in the US than in the UK. In addition, according to an analysis of news coverage between 2000 and 2009 in *New York Times* (US) and *The London Times* (UK), the US media were still presenting climate change as controversial whereas the UK media focused on how to confront established environmental problems (Nerlich et al., 2012).

Other industrialized countries such as Australia and Canada also differ from the US in their media framing. Both the US and Australia are highly dependent on fossil resources, and climate change is fiercely contested (Fielding et al., 2012). Fossil industry lobbyists and conservatives (e.g., Jim Inhofe, Tony Abbott) highlight uncertainties in climate science and question the causes and consequences of climate change. However, although the US media are still debating the authenticity of scientific claims, Australian media mostly focus on how to minimize the economic and environmental impact of climate change (Schmidt et al., 2013). Research indicates that Australian society has benefited from intensive discussions with a variety of societal actors including industry representatives, environmental groups, religious groups, and labor unions (Schmidt et al., 2013). As a result, the Australian government adopted progressive gas emission regulations relatively earlier although the current Abbott government is reevaluating the priority of climate change policies. As in Australia or European countries, Canadian media generally do not question the scientific consensus on climate change (Good, 2008). Although Canada maintains a close relationship with the US in many aspects, Canadian media are critical of the US's lukewarm attitudes toward global climate mitigation efforts.

Taken together, five common themes that frequently appear in the mass media include whether the risk is present, whether the scientific claim of the risk is a lie, whether the risk is caused by human activities, the potential consequences of the risk, and how to handle the risk (Bord et al., 2000; Krosnick et al., 2006). These five frames are all associated with how the public perceives and handles a potential environmental risk. In general, US coverage focuses on whether climate change is a legitimate social problem that deserves public attention whereas the media in other industrialized countries center on how to confront a known environmental challenge. Prior research has indicated that these media practices in the US press hamper climate mitigation efforts (McCright and Dunlap, 2011). Corbett and Durfee (2004) demonstrated that exposure to news stories that describe climate change as a controversial claim significantly amplifies readers' perceptions of scientific uncertainty. Additionally, Boykoff and Boyokff (2004) argued that the US press' adherence to "balanced reporting" in both endorsing and rebutting the evidence of climate change might have created a biased public understanding of this environmental problem. Issue frames that emphasize conflict over established scientific evidence decrease trust in authority at the individual level and signal potential challenges ahead in finding global solutions at the country level (Nerlich et al., 2012).

These comparative findings have revealed the difference in the prevalence of climate change frames in mainstream media, but little is known about how the difference is reflected in conversations among ordinary people. Indeed, research indicates that public opinion relies heavily on elites cues and interpersonal exchanges with others (Druckman and Nelson, 2003). Twitter data offer new research opportunities to capture networked conversations that naturally occurred in everyday life. Twitter content is produced by a diffuse group of users (Kwak et al., 2010); metadata associated Twitter accounts enable us to compare the patterns of issue frames across different countries and political contexts; and measurement concerns about inaccurate recall and reporting biases are alleviated (Kirilenko and Stepchenkova, 2014). Thus, to examine frames in social media content, this study uses the stream of Twitter data compiled from four English-speaking countries (US, UK, Canada, and Australia). Following extant comparative findings, our first set of hypotheses posits that tweets from the US, compared to those from the UK, Canada, and Australia, will focus relatively more on issue frames that concern the legitimacy of climate change phenomenon (e.g., real or hoax frames; H1a) and relatively less on issue frames that consider the cause, impacts, or solutions of climate change issues (cause, impact, or action frames; H1b).

2.2. Polarized views on climate change in red and blue States

Global climate change has become a highly polarizing issue in the U.S. with public opinion generally divided along politically partisan lines (Brulle et al., 2012; Dunlap and McCright, 2008). While most Democratic leaders support government policies to mitigate the environmental threat, most Republicans do not. Instead, Republican leaders often express skepticism of the scientific claims of environmental decline. Partisan media sources often deliver such framed narratives in line with their political leanings (McCright and Dunlap, 2011). For example, Fox News promotes hoax frames by taking a cynical tone toward the issue and interviewing more climate change skeptics than believers compared to CNN and MSNBC (Feldman et al., 2012). As the political differences over climate change intensify, more public opinion may become polarized along partisan lines. Poll results confirm that this partisan gap has persisted over the last decade (Dunlap and McCright, 2008; Pew Research Center for the People, 2013). The Pew Research Center for the People and the Press (Pew Research Center for the People, 2013) shows that only 11% of Democrats but 46% of Republicans think that there is no solid evidence of global warming. In addition, 66% of Democrats but only 24% of Republicans say that human activity contributes to global warming.

Our second investigation considers the partisan division on Twitter. A growing body of research indicates that social media have the potential to exacerbate what is already a polarized public opinion (Stroud, 2011 but also see Jang, 2014). If Twitter users tend to interact with those having similar views and establish political homophily, the partisan gap may deepen over time (Colleoni et al., 2014). Specifically in climate change contexts, recent evidence shows that selective media use and climate change perceptions mutually reinforce each other, leading to opinion polarization (Feldman et al., 2014). In line with this idea, we expect Twitter users to rely on issue frames that help reinforce their political positions on climate change issues. Thus, we hypothesize that Twitter users from Republican-leaning (red) states compared to those from Democratic-leaning (blue) state in the US tend to focus more on real and hoax frames (H2a) but less on cause, impact, and action frames (H2b).

2.3. "Climate change" vs. "global warming"

Previous research suggests that the terms, "climate change" and "global warming" have different political connotations and result in significant question wording effects (Schuldt and Roh, 2014a; Villar and Krosnick, 2011; Whitmarsh, 2009). According to an analysis of partisan websites, Republicans favor the term "global warming" because it discredits the scientific claim on anthropogenic climate change (Schuldt et al., 2011). Because "global warming" involves a directional commitment to temperature changes, Republicans often hype their skeptical views by using the incongruities between the literal meaning of "global warming" and temporary cold spells happening in a real world (Schuldt and Roh, 2014b). In contrast, "climate change" is perceived as more neutral and accommodates all kinds of extreme weather conditions. Experimental evidence also demonstrates the effects of the two terms on the public understanding of climate change (Schuldt et al., 2011; Schuldt and Roh, 2014b). Schuldt et al. (2011) found that that although Democrats were not influenced by question wordings, Republicans' belief in the existence of global climate change sways from 44.0% ("global warming") to 60.2% ("climate change") depending on the terms used in survey questionnaires. As a consequence, the partisan gap widens from 26.2 percentage points under a "climate change" condition to 46.2 percentage points under a "global warming" condition.

Although the usage pattern of "climate change" and "global warming" reflects and reinforces the regional and political differences and signals a significant barrier to climate change initiatives, little is known about how people use the terms in their social media conversations. Therefore, to examine how "climate change" and "global warming" are represented in the Twitterverse, our third hypothesis predicts that tweets from the US are more likely to mention "global warming" than "climate change" compared to those from the UK, Canada, and Australia (H3). Additionally, we anticipate that in the US, tweets from red states compared to those from blue states are more likely to mention "global warming" than "climate change" (H4). Finally, we hypothesize that tweets focusing on hoax frames will be more likely to use the term "global warming" than "climate change" (H5).

3. Method

3.1. Data source

Twitter data for the current study were provided by the third-party licensed firm Topsy. Twitter's open access policy via Application Programming Interface (API) has become increasingly restricted, which makes working with a firm such as Topsy necessary to capture the entire archive of Twitter data. Topsy provides open access to the Twitter "firehose" of actual tweets and metadata associated with about 100 million active accounts. As our data were free from "spam" tweets (e.g., Twitter bots), the searched data used for this study represent active accounts run by real people. We elected to include retweets in our analysis because prior literature indicates that they are an effective indicator for the extent to which messages are perceived important in the network (Larsson and Moe, 2012).

3.2. Data characteristics

Metadata allow us to filter the entire large dataset based on time and location. The current study analyzed Twitter messages geographically based in four English-speaking countries (US, UK, Canada, and Australia) from July 1, 2012 to Jun 30, 2014. To answer our research questions about frame differences between red and blue states in the US, we also filtered messages based on the states tweets originated from. Finally, to focus on tweets that were relevant to climate change issues, we included messages that mentioned either "climate change" or "global warming" within their 140 character limit. In total, we retrieved 5.7 million tweets that matched our specified search parameters for our study.

3.3. Coding frames

The respective climate change frames in tweets were identified by running a Boolean search that contained keywords and phrases unique to the frame. Previous research suggests that big data analysis based on keyword search results offer special promise for framing analysis (Neuman et al., 2014). For example, *real frames* could be identified using a Boolean search that paired "climate change" or "global warming" *with* real OR fact. A reference to one or more of these search terms anywhere in an individual posting meant that the tweet was identified as having a real frame. In other words, we assumed that any messages that mentioned "climate change" (or "global warming") and real (or fact) at the same time in a single tweet were understanding and discussing climate change in terms of its legitimacy. The key of this approach may be to identify unique components of public rhetoric that clearly represent single frames of a more complex issue. To identify relevant keywords to corresponding frames, we first looked into

top 500 tweets that were retweeted most among tweets mentioning either "climate change" or "global warming." By analyzing these tweets, we collected terms and phrases that commonly appeared and represented specific frames. Additionally, we generated a series of word clouds that show the most commonly used words in content visually arranged so that the size of a word corresponds to the frequency of its appearance in a text. This process allowed us to identify important keywords that reflect corresponding frames. We discarded keywords when they generated too few tweets (less than 1000 tweets per year) or too much noise (irrelevant to specified frames). Finally, we were able to compile the number of tweets for climate change frames over two years. We did this for all five climate change frames. The complete list of issue frames and associated search term strings is as follows: (1) *real frames* included the terms real OR fact, (2) *hoax frames* included the terms hoax OR lie OR fraud, (3) *impact frames* included the terms impact OR impacts OR threat OR threats OR consequences OR effects OR affect OR affects OR disaster, (4) *cause frames* included the terms cause OR causes OR fuel OR carbon OR CO2 OR human, and (5) *action frames* included the terms act OR action OR stop OR fight OR policy OR policies.

Keyword-based analysis may generate misleading returns by including extraneous texts and excluding relevant ones. Like Type I and Type II errors, the information retrieval literature refers to them as recall (*the ability to accurately retrieve relevant texts)* and precision *(the ability to rule out irrelevant ones)*. Using procedures described by Stryker et al. (2006), we assessed the precision of our search phrases. We did not assess recall because this study does not aim to present the accurate distribution of five chosen frames. It should be noted that our interpretation of the results focused on the relative frame popularity across countries, not on the frame distribution within each country. This is because the former analysis is less robust to the inclusion of keywords. For example, the ratio of real frames would have increased if we included more keywords related to real frames. In contrast, we expect that our keyword decisions should not affect comparative findings across countries.

The precision rate was calculated by the proportion of relevant tweets among retrieved tweets. Two coders evaluated a random sample of 500 tweets (100 tweets per frame). The precision estimate was 96%. Intercoder reliability was .781 (Cohen's Kappa) and the agreement reached 99% between two coders.

4. Results

We initially sought to examine the relative prevalence of five frames on climate change on Twitter. The analysis focused on four English-speaking countries–the US, United Kingdom (UK), Canada, and Australia. During our field period, on a typical day, four nations generated 6085 (US), 1041 (UK), 639 (Canada), and 641 (Australia) tweets that mentioned either "climate change" or "global warming." Because each country has a different number of populations or Twitter users to begin with, it is not meaningful to compare these total numbers directly across nations, but instead to use them as reference points to compare the relative ratios of the five frames within each country. The ratio value was calculated based on the number of tweets indicating a specified frame as a proportion of all the tweets mentioning "climate change" or "global warming".

4.1. Comparison of issue frames across countries and states

The results showed that tweets generally mirror much of the controversy observed in the traditional media (see Fig. 1; Boykoff, 2007; Dunlap and McCright, 2008; Grundmann and Scott, 2014). As predicted in H1a, the US displayed a higher ratio of real frames

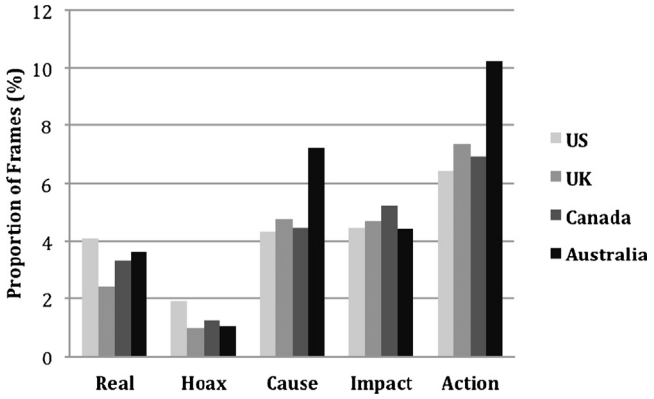

Fig. 1. Relative Prevalence of Frames by Countries.

than the UK ($\chi^2 = 4822.32$, $p < .001$, $\phi = .030$), Canada ($\chi^2 = 689.27$, $p < .001$, $\phi = .012$), and Australia ($\chi^2 = 248.97$, $p < .001$, $\phi = .007$). Hoax frames were also more prevalent in the US than in the UK ($\chi^2 = 3305.20$, $p < .001$, $\phi = .025$), Canada ($\chi^2 = 908.73$, $p < .001$, $\phi = .014$), and Australia ($\chi^2 = 1679.53$, $p < .001$, $\phi = .018$). On the other hand, American users showed different patterns when it came to the cause or consequence of climate change and how it should be treated. The US registered a lower ratio of cause frames than the UK ($\chi^2 = 339.81$, $p < .001$, $\phi = .008$), Canada ($\chi^2 = 21.70$, $p < .001$, $\phi = .002$), and Australia ($\chi^2 = 8379.18$, $p < .001$, $\phi = .041$). This pattern was commonly observed concerning impact and action frames except the fact that impact frames in the US and Australia were not significantly different ($\chi^2 = .18$, $p > .05$). Thus, H1b was partially supported. Notably, the results showed that cause and action frames are exceptionally popular in Australia. This may be attributed to the fact that the Australian government recently repealed carbon law that puts a price on greenhouse gas emissions. The coupling of cause and action frames may reflect this ongoing landscape in Australia given that the governmental action accompanied heated debates over the cause of climate change (human activities vs. nature). Overall, these results demonstrated that climate change discourse in the US tended to revolve around the substantiation of climate change compared to the UK, Canada, and Australia.

Admittedly, caution should be exercised in drawing any conclusions that would evaluate the extent to which public opinion of a country is pro- or anti-environmental based on the current findings. For example, the popularity of action frames in Australia may result from the government's anti-environmental policies.

Next, we turned our attention to the political or regional division within the US. Prior research has shown that the US public does not reach a consensus on anthropogenic climate change primarily due to the division between political elites and partisan media (Feldman et al., 2012; Nisbet et al., 2013; McCright and Dunlap, 2011). To investigate such divisions in social media arenas, we looked at how Twitter users in red and blue states employed different frames to discuss climate change problems. We categorized 50 states and Washington DC into 3 categories based on the results in the 2012 US presidential election. First, we created a middle category to include 15 states in which the voting margin between the two major party candidates – Barrack Obama and Mitt Romney – was less than 10%. Then, 16 states including Washington DC were categorized into blue states when they showed strong preference (more than 10%) for the Democratic candidate, and finally, the other 20 states belonged to red states.

As illustrated in Fig. 2, the results showed systematic differences between red and blue states. Red states were more

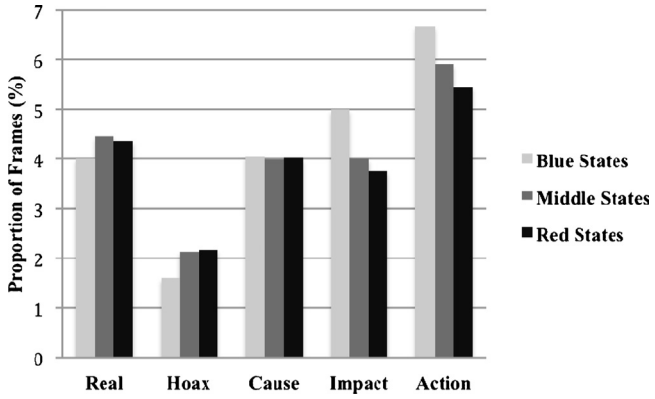

Fig. 2. Relative Prevalence of Frames by States.

likely than blue states to include real ($\chi^2 = 172.86$, $p < .001$, $\phi = .010$) and hoax frames ($\chi^2 = 575.03$, $p < .001$, $\phi = .019$), resulting in support for H2a. In contrast, blue states were more likely than red states to focus on impact ($\chi^2 = 797.12$, $p < .001$, $\phi = .023$) and action frames ($\chi^2 = 801.58$, $p < .001$, $\phi = .023$). Interestingly, there was no difference in cause frames between red and blue states. It is possible that blue states focus on human causes and red states focus on natural causes, but the current findings cannot attest such differences. Therefore, H2b was partially supported. Generally, these findings indicated that social media conversations in the respective red and blue states largely mirrored the respective emphases of conservative and liberal political elites on climate change in the US.

4.2. "Climate change" vs. "global warming"

We explored how the terms, "climate change" and "global warming" were used in varying contexts of climate change messages. We first calculated the frequency ratio of "global warming" to "climate change." Then, we looked at the ratio varies across four countries depending on related frames. Whereas a ratio value of 1 indicates that "climate change" and "global warming" were equally used concerning each frame, higher values indicated that "global warming" was more likely to be associated with certain frames than "climate change." The results were illustrated in Fig. 3. Although there were some variations across four countries, all of them used "climate change" more frequently than "global warming" on Twitter (see Total in Fig. 3). However, as anticipated in H3, American users showed the greatest preference of "global warming" over "climate change" among four countries. The ratio values of "global warming" to "climate change" in the US were higher than the UK ($\chi^2 = 26224.07$, $p < .001$, $\phi = .072$), Canada ($\chi^2 = 12771.69$, $p < .001$, $\phi = .051$), and Australia ($\chi^2 = 54873.36$, $p < .001$, $\phi = .106$) respectively.

Notably, tweets about hoax frames yielded strikingly different results from tweets about the rest of frames. As seen in Fig. 3, the ratio values for all other four frames were less than 1, indicating that "climate change" was mentioned more commonly than "global warming" on Twitter. Notably, however, the ratio values for hoax frames were 1.65 (US), 1.93 (UK), 1.43 (Canada), and 1.18 (Australia), revealing that all four countries were more likely to use the term "global warming" instead of "climate change" when tweets were related to hoax frames ($\chi^2 = 25529.40$, $p < .001$, $\phi = .064$). The results supported our prediction (H5).

Finally, we measured the ratio of "global warming" to "climate change" across three states that are categorized based on the 2012 presidential election results. The findings supported our hypothesis (H4) that red states used "global warming" more frequently than blue states ($\chi^2 = 18377.33$, $p < .001$, $\phi = .108$). In red states, "global warming" appeared only 12% less than "climate change"; in blue states, "global warming" was used 46% less than "climate change." The results also confirmed previous findings (H5) that "global warming" was more likely to be associated with hoax frames than "climate change." As shown in Fig. 4, all of three types of states showed strong preference of "global warming" over "climate change" (i.e., ratio > 1) for hoax frames ($\chi^2 = 23139.17$, $p < .001$, $\phi = .096$). On the other hand, the use of "global warming" became smaller when tweets discussed climate change in terms of its impact or action.

5. Discussion

Unlike most prior scholarship that focused on climate change frames in mainstream media, this study captured issue frames expressed in public discourse through social media conversations. In our examination of the entire archive of tweets over two years in four English-speaking countries, the results revealed that hoax frames were more frequent in the US than in the other countries and were particularly prevalent in traditionally Republican-leaning states. In addition, we found that when users discussed global climate change in terms of hoax frames, they preferred "global warming" to "climate change." The specific implications of these findings are described below.

On the one hand, American users, more than users from the UK, Canada, and Australia, tended to approach climate change issues in terms of whether global climate change is real or a lie. On the other hand, American users' attention to the cause, impacts, and solutions of the environmental problem was relatively low. This trend mirrors previous findings from a content analysis of

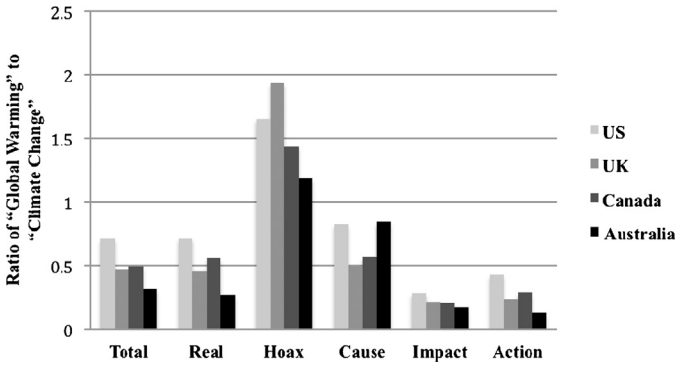

Fig. 3. Ratio of "Global Warming" to "Climate Change" by Frames in Four Countries.

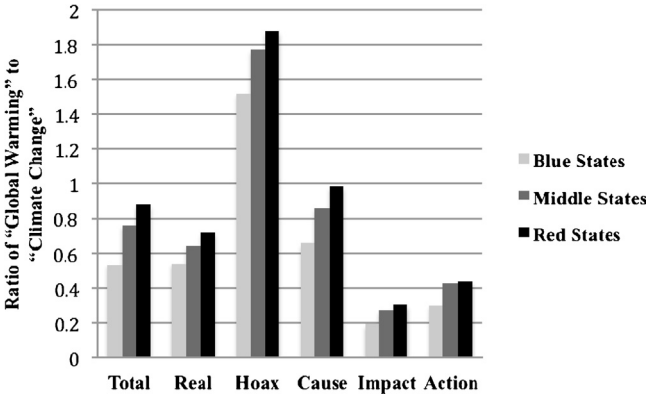

Fig. 4. Ratio of "Global Warming" to "Climate Change" by Frames in the US.

elite media (Nerlich et al., 2012). Previous research has documented that US media were more likely to describe climate change as a controversial claim rather than as an established fact, and this appears to be mirrored by the expressions of many Twitter users. These results may yield growing concern over the American public given that increasing attention to hoax frames may increase public perception of scientific uncertainty (Corbett and Durfee, 2004). Our state-level analysis offered more insights into the relative predominance of hoax frames in the US. The findings suggest that the popularity of hoax frames depends on the political landscape in the US. Traditionally Republican-leaning states focused more on real and hoax frames while Democrat-leaning states focused more on cause, impact, and action frames. In fact, if we compared only blue states to the UK, Canada, or Australia, the difference in the prevalence of issue frames became significantly smaller. This aligns with the observed trend that stagnant public engagement with climate change in the US is attributable to the widening partisan gaps on environmental issues (Dunlap and McCright, 2008).

Moreover, we add to the growing evidence that the terms "climate change" and "global warming" are used by different people for different reasons. Prior studies indicated that climate-change skeptics favored "global warming" to the more neutral term, "climate change" because directional meaning of "global warming" can be easily discredited (Schuldt et al., 2011). In parallel with this trend, we found that social media users from the US, particularly those from red states, preferred "global warming" to "climate change." Our findings also revealed that "global warming" was more frequently accompanied by hoax frames but rarely with impact and action frames.

Finally, by showing that polarized frames that commonly appear in partisan elite media were also manifested in user-generated media, the current research has significant policy and societal implications. Some scholars have expressed hope that social media play a role as a watchdog for mainstream media when they do not function properly (Bertot et al., 2010). However, our findings do not support this claim. Instead, if social media users simply reflect polarized views pervading mainstream media in the US and elsewhere or only interact with like-minded users (e.g., homophily), the reinforcing spiral process will be strengthened rather than attenuated (Colleoni et al., 2014; Feldman et al., 2014). Because social media content is not only a product of expressed opinions but also an important source of information, American users may end up having more chance to be exposed to hoax frames.

The findings of this study help answer important questions about climate change frames in social media content, but also raise questions for future research to explore. First, because automated keyword inquiries do not identify all the tweets that were relevant to specified frames, the actual distribution of each frame remains unclear. For example, although we identified tweets about hoax frames by using carefully selected keywords, *hoax, lie*, and *fraud*, the searched results do not necessarily include the entire volume of hoax-related tweets. Thus, the current analysis is not designed to provide full descriptive statistics of issue frames represented in the Twitterverse. Despite this limitation, as we used the same keywords and calculation methods across countries, we ensured the functional equivalence of our measurements which is essential to comparative research (Schafer et al., 2014). If future research is to examine the proportion of frames within each country, it may need to take a human-coding approach with random samples of tweets. Another critique of Boolean search analysis is that search results do not consider different cultures and norms that pervade social media conversations across four English-speaking countries. In particular, nuanced and culturally sensitive messages including humor and sarcasm are hardly captured in our analysis. Although this concern would be serious for an automated sentimental analysis, the current framing analysis is not so vulnerable to this criticism. "Climate change" and "global warming" and the other keywords have strong face validity in signifying attention to this issue.

Another direction for future work is to assess the extent to which social media develop a hierarchical structure where a few influential users dominate the flow of information in a social media world (Ausserhofer and Maireder, 2013; Meraz, 2009). For example, Twitter users commonly use retweet functions to reproduce and redistribute information that had initiated by elites or institutions (Murthy, 2013). To the extent that the ability to guide public attention is limited to these influential users, differences between social media and mainstream media could be muted. Future research should explicate whether the resemblance of media content on different outlets is because the salience of media agendas are transferred to other media (e.g., intermedia agenda setting) or simply because the elites control both media agendas at the same time.

6. Conclusion

The literature has stressed the importance of framing in public understanding of science issues (Besley et al., 2008; Druckman and Nelson, 2003; Nisbet, 2009), but methodological challenges have led to a scarcity of empirical research on framing in interpersonal conversations. Responding to this gap of literature, we consider the space of Twitter conversations to be the natural field where interpersonal conversations are unobtrusively measured and analyzed. We believe this study is the first to show geographical differences in the use of frames and terms concerning climate change using big social media data. This study also demonstrates that aggregated-level big data provide a useful method to illustrate partisan division by contrasting the prevalence of issue frames between red and blue states in the US.

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