International Journal of Communication 16(2022), 107–129 1932–8036/20220005

Convergence and Divergence: The Evolution of Climate Change Frames Within and Across Public Events

YINGYING CHEN[1]
University of South Carolina, USA

KJERSTIN THORSON
Michigan State University, USA

JOHN LAVACCARE
Independent Researcher, USA

The framing of climate change in the news over time plays a crucial role in shaping public understanding of the issue. This study examines variation in the framing of climate change in global news media across 12 high-attention climate events from 2012 to 2015. We show that events and journalistic practice interact to generate a mix of frames that collectively construct climate change discourse. Using topic modeling and network analysis, we identified six frames used in the media coverage of climate during this period. We trace the usage of these frames and show that framings related to policy struggles and economic concerns have become the "default" framing of climate change across news media. Other framings of the climate issue appear only when particular public events happen. The findings suggest that frame evolution is a socially constructed process influenced by journalistic routines and triggering events.

Keywords: frame changing, topic modeling, news frames, climate change

Scientists broadly agree on the presence and potential impact of anthropogenetic climate change, yet public opinion on the issue remains divided (Leiserowitz et al., 2021). The issue's complexity and the general public's personal distance from the topic make climate change difficult for the public to understand (Painter, Kristiansen, & Schäfer, 2018). As such, news representation of this issue plays an important role in shaping diverse stakeholders' perceptions of climate change and, thus, public opinion of this issue (Carvalho, 2010).

Yingying Chen: yychen@sc.edu
Kjerstin Thorson: thorsonk@msu.edu
John Lavaccare: jlavaccare@gmail.com
Date submitted: 2021-03-16

[1] We thank the editor, Larry Gross, and the three anonymous reviewers for their constructive comments on this manuscript.

In a meta-analysis, Schäfer and Schlichting (2014) reviewed 133 studies of media representation of climate change conducted from 1980 to 2012, with the bulk of the research published since the early 1990s. The largest cluster of articles were case studies focused on a single point in time and a particular national context. While these studies have provided important insight on (a) the different ways news media frame the issue of climate change and (b) the impact of different framings on public perceptions of the issue, few studies have examined how representations of this issue have changed over time across different events (e.g., Houston, Pfefferbaum, & Rosenholtz, 2012; McComas & Shanahan, 1999; Muschert & Carr, 2006).

One explanation for this lack of attention to temporal dynamics in climate news framing research is that much of it relies on human-coded content analysis. The research provides richness in terms of the variables that can be captured but can reasonably be conducted only with relatively small samples. In this study, we applied a computational method to examine a large corpus of news stories during 12 climate change news events over four years, conducting structural topic modeling and topic network analysis. Using this approach, we examined the evolution of climate frames over the long term as well as short-term frame dynamics during bursts of public attention on this issue. Ultimately, the findings point toward more dynamic theoretical understandings of climate framing under conditions of high-velocity shifts in public attention. The study adds nuance to theories of issue attention cycles and frame evolution by showing how triggering events and journalists' routines together construct the framing of climate change in the news.

Literature Review

Media Frames in Climate Change Coverage

Frames are the story lines generated by journalists—politicians, elites, and activists who structure the way the public thinks about an issue. Generally, frames refer to coherent interpretative packages that provide meaning and suggest the essence of an issue or event (Gamson & Modigliani, 1989). Entman (1993) provided a widely used definition of framing:

> To frame is to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described. (p. 52)

Our study focuses on news media frames,[2] a kind of emphasis frame existing in the mediated texts to contextualize a topic (D'angelo, 2017). Emphasis frames reflect *what* information that news presented (Cacciatore, Scheufele, & Iyengar, 2016), representing a "central idea, organizing principle, master narrative, macroattributes, or themes" (D'angelo, 2017, p. 638).

Framing research in communication represents a broad set of theoretical and empirical approaches (Borah, 2011). Empirical research on news effects that uses framing theory generally suggests that

[2] Media frames are news frames. These terms are often used interchangeably (D'angelo, 2017).

dominant news frames influence public opinion of an issue (Shih, Wijaya, & Brossard, 2008). However, far less work explores the production of news frames (Borah, 2011). Considering the topic of climate change more specifically, experimental research shows that the use of different climate news frames (e.g., thematic versus episodic, mortality, and gain versus loss) can influence both perceptions of the issue and support for climate-related policies (Bolsen & Shapiro, 2018; Hart, 2011; Valenzuela, Piña, & Ramírez, 2017; Wiest, Raymond, & Clawson, 2015; Wolsko, Ariceaga, & Seiden, 2016). For example, Hart (2011) found that thematic frames encouraged readers to support government action on climate change compared with episodic frames. Additionally, Wiest et al. (2015) found that framing climate change's effects positively can shape citizens' opinions about whether it is a problem in their community. Meanwhile, Valenzuela et al. (2017) concluded that morality framings positively impact social media sharing, while Wolsko et al. (2016) found that morality frames encouraged politically conservative people to support environmental conservation. Furthermore, Nabi, Gustafson, and Jensen (2018) found that gain frames (ones emphasizing possible positive effects) and loss frames (ones emphasizing possible negative effects) inspire emotional responses of hope and fear, respectively.

However, largely based on case studies, prior climate framing research shows little consensus on the dominant media frames related to climate change. For example, Broadbent et al. (2016) identified four key frame groupings in a review of worldwide climate media from 2007 to 2008, focused on the "validity of climate science, scale of ecological risk, scale of climate politics, and support for mitigation policy" (p. 1). In contrast, Wessler, Wozniak, Hofer, and Lück (2016) identified victims, society, politics, and energy as four key framing categories in coverage of the United Nations climate change Conference of the Parties (COP). Meanwhile, O'Neill, Williams, Kurz, Wiersma, and Boykoff (2015) identified yet another set of frames, including political and ideological struggle, settled science, uncertain science, and economic cost frames, in news coverage of the United Nations' Intergovernmental Panel on Climate Change (IPCC) 2013 and 2014 reports. More recently, in a review of prior research about climate framing in the U.S. news, Bolsen and Shapiro (2018) identified a list of primary climate framings over time. Their list added new primary frames, such as self-efficacy, external efficacy, and response efficacy. Using Chyi and McCombs's (2004) temporal-space framework, Houston et al. (2012) found that natural disaster news frames focused on national/societal significance and present happenings. Given the lack of consensus on the most common framings of climate change, we ask:

RQ1: What mixes of frames have appeared in news coverage of the climate change issue over time?

Theorizing Frame Evolution

The theorization of frame evolution is often based on Downs's (1972) issue-attention cycle model. According to this model, dominant framings in the news evolve cyclically as an issue or event develops. Downs (1972) proposed that issues move through a linear process of issue development, starting with a preproblem stage and moving successively through discovery, progress, public interest decline, and postproblem stages. Researchers have proposed that media frames cyclically change over time too (Guggenheim, Jang, Bae, & Neuman, 2015; Muschert & Carr, 2006).

However, Downs' (1972) theoretical approach has been criticized as too linear and, thus, unable to capture dynamics in issue and frame evolution (Brossard, Shanahan, & McComas, 2004; Hilgartner & Bosk, 1988; McComas & Shanahan, 1999). Frame evolution is not entirely dependent on the linear stages of issue development. For example, Hilgartner and Bosk (1988) argued that issues can simultaneously be in several stages of development and, therefore, may not proceed through an issue cycle in an orderly fashion. McComas and Shanahan (1999) pointed out that Downs's (1972) issue-attention model does not fully explain cycles of media attention. Instead, news narratives *construct* media attention shifts. In addition, for a long-term issue like climate change, scholars contend that the boundaries of different issue development stages are often unclear.

Addressing the limitations of the issue-attention cycle approach, researchers have argued that frame evolution is a socially constructed product (Brossard et al., 2004; Hilgartner & Bosk, 1988; Van Gorp, 2007). Hilgartner and Bosk (1988) proposed that actors involved in the issue co-construct the definition of said issue and its related events, and this creates yet another set of dynamics for the issue. They suggested that news media provide a key public arena for interested actors to negotiate the meaning of a particular issue through a competitive agenda-building process. Van Gorp (2007) pointed out that a news professional's value system, the journalistic routine in the media organization, and the interventions of non-news actors involved in the issue all shape the framing process. In addition, cultural resonance among immediate actors involved in constructing the environment issue plays a role in news discourse (Brossard et al., 2004).

Public events provide a discursive opportunity (Koopmans & Olzak, 2004) for the social construction of news frames. Lörcher and Neverla (2015) characterize events as actions undertaken by different institutionalized stakeholders who collectively construct issue attention in the public sphere. Thus, events may cause changes in the dynamics of issue attention. For example, in the topical domain of climate change, extreme weather events spark media discourse related to the harms of climate change (McAdam, 2017).

Previous studies suggest that frame evolution is a socially constructed process influenced by events, journalistic practices, and non-news actors' actions. However, they have not explicitly theorized the relationship between events and the composition of frames that become visible to the public via news stories. In what follows, we propose that triggering events and journalistic practices together help construct the evolution of climate news frames over time. We define triggering events as happenings that spark high levels of public attention to an issue and create a discursive opportunity for a diverse set of interested actors.

We first expect that news frames are likely to converge within any given event that calls attention to climate change. That is, during a high-attention climate event, journalistic framings should become more similar over time. We refer to this as *within-event* convergence. Prior research has shown that journalists use a more diverse range of frames early in a crisis and then align along a narrow set of frames after a while (Boesman, Berbers, d'Haenens, & Van Gorp, 2017; Houston et al., 2012; McComas & Shanahan, 1999). For example, Houston et al. (2012) analyzed changes of news frames of natural disaster from 2000–2010. They found that soon after a disaster happened, news media included a diverse variety of news frames. The variety of framings then declined during the following two months.

There are additional reasons to expect convergence of frames within events. Tight deadlines, competition among news outlets, and a decreasing number of news staff lead to homogeneity in the news coverage of an event (Boesman et al., 2017). To maintain the freshness of a news event, journalists refer to reports from other news outlets, producing content with little news diversity (Vliegenthart, 2018). For example, in climate news, researchers found that news narratives converged, focusing on domestic politics and economics when global media attention to climate change peaked (McComas & Shanahan, 1999).

Cognitive factors involved in journalistic frame selection also led us to expect frame convergence. Van Gorp (2007) pointed out that at the cognitive level, journalists select frames based on their individual schema—a set of organized knowledge that gradually evolves based on a journalist's experience. Influenced by their schema, journalists repeatedly apply familiar frames to construct the meaning of similar events. Thus, the framing process relies on "patterned, repeated practices, forms, and rules" (Shoemaker & Reese, 2014, p. 165) as a routine for news professionals to quickly process information when covering events (Shoemaker & Reese, 2014). We, therefore, expect to see convergence in frames within the time span of a specific triggering event. In other words, we expect to see that news frames become concentrated on a smaller set of standard frames and that the level of frame variation within each event will stabilize around the peak of public attention. We hypothesized:

H1: Within each high attention triggering event about the climate issue, news frames will converge at the peak level of attention.

In contrast, we expect to see frame *divergence across* events, creating temporal dynamics in the framing process. Events create opportunities to negotiate issue definitions by non-news actors, such as policy makers, companies, and nonprofit organizations. Such actors nudge news media by orchestrating key events, such as conferences, social movements, and press releases. Meanwhile, as news sources, non-news actors strategically promote or sponsor their frames to the public via news media (Van Gorp, 2007). Thus, triggering events mobilize news coverage of climate change (Brossard et al., 2004), in turn creating opportunities for framing or redefining the climate change issue. Entman (2003) found that frames often travel from elites to the public via a "cascading flow of influence" (p. 419). Politicians set the agenda for other elites and communicate it to news media, which turn it into news frames that the public then consumes. Sources influence frame construction in news reports (Boesman et al., 2017). Thus, we expect to see contestation among possible framings of climate change *across* events. The events provide the environment for different frames to compete and define the issue. Thus, events add temporal changes to the prevalence of frames. Accordingly, we propose:

H2: News frames temporally vary across triggering climate-related events.

In addition to the temporal variation in frame evolution, it is important to examine the frame trends across triggering events. Events, particularly those that lead to collective memory, can spur alternative frames in the media, thereby creating trends in the framing process (Van Gorp, 2007). Specifically, with other topical issues, researchers have found that events improved frame evolution by increasing frame prevalence in the news. For example, Gamson and Modigliani (1989) traced frame trends of nuclear power from 1945 to 1980. They found that after the nuclear meltdowns at Three Mile Island and Chernobyl, media

discourse showed a surge in framing nuclear power as dangerous or something to be avoided. Separately, Lawrence (2004) conducted a study of news coverage about obesity from 1985 to 2003, finding that the prevalence of systemic frames, which attribute blame for obesity to environmental rather than individual sources, had increased substantially over time. As another example, Greussing and Boomgaarden (2017) showed that frame trends varied throughout the emerging refugee crisis in Europe from 2015 to 2016.

In the climate change domain, triggering events also play roles in the careers of frames. For example, partisan polarization in response to the Kyoto Protocol increased media attention to political frames (Bolsen & Shapiro, 2018). Thus, in addition to looking for variation in frames by events, we examined the link between triggering events and frame trends and hypothesized:

H3: Triggering events predict news frame trends over time about the climate change issue.

Data Collection

Our data collection started with event detection. We used Twitter to identify events that represent high levels of attention to climate change. Previous research has used Twitter to identify a wide range of climate change events, including natural disasters, news events, international conferences, and climate rallies (e.g., Thorson, Edgerly, Kligler-Vilenchik, Xu, & Wang, 2016; Thorson & Wang, 2020). To detect high-attention climate events, we used Twitter Firehose data from Thorson et al. (2016). They used the social analytics platform Crimson Hexagon to determine the number of public tweets with the keyword "climate" on Twitter every day from 2012 to 2015.[3] Using the interquartile range approach, they identified all the days during this time that contained a volume of tweets representing a statistical outlier compared with the average tweet volume per day for each given year. These outlier days represent times of high-volume attention to the climate issue. Specifically, they found 134 such days, corresponding to 42 climate-related events (see Thorson et al., 2016 for details on the event selection process). For this study, we focused on 12 events from 2012 to 2015 that garnered significant climate change attention. This time range also includes various events initiated by either natural disasters or key negotiators—scientists, politicians, and advocacy groups. Table 1 describes the 12 events.[4]

[3] We used this constrained sampling time frame because Twitter limits access to historical data for academics. For this analysis, we needed the complete daily volume of tweets matching our search terms, which requires access to Twitter Firehose data.

[4] For the full description of events, please refer to Table 1 in the supplementary document (doi:10.7910/DVN/1WYVPB).

Table 1. Brief Description of Included Climate-Related Events.

Events and description	Year
1. Hurricane Sandy.	
2. The Climate Reality Project's 24 Hours of Reality: The Dirty Weather Report, led by Al Gore, livestreams about climate for 24 hours.	2012
3. United Nations publishes the IPCC Working Group's fifth assessment report on climate change.	2013
4. People's Climate March: Worldwide protests over a lack of action to combat climate change.	
5. Group of 20 summit: At the annual conference of world leaders, two powerful nations agree to a climate deal.	2014
6. Official recognition and celebration of Earth Day as an international holiday.	
7. Papal encyclical: Pope Francis releases a statement publicly acknowledging climate change.	
8. Pope Francis visits the United States and addresses climate change.	
9. People's Climate Movement National Day of Action.	2015
10. U.S. President Barack Obama joins Facebook, with his first post addressing climate change.	
11. COP21 starts: The United Nations Climate Change Conference in Paris begins.	
12. COP21 ends: The climate conference ends, with the Paris Agreement officially negotiated.	

After identifying the 12 climate-related events, we then collected news coverage about climate change during the event period. Specifically, we collected three days of data: the day climate attention on Twitter peaked, the day before, and the day after. Using LexisNexis, we downloaded news written in English published in major world newspapers, using either of the key phrases "climate change" or "global warming"[5] over each event's three-day period (N = 4,015). Excluding repeated news stories left us with 3,779 news stories for analysis.

Analytical Approach

Frame Detection

To detect the mix of frames in climate change news (RQ1), we used a computational method combining topic modeling and topic network analysis. Topic modeling is an unsupervised machine learning method that helps scholars identify latent structures in a large volume of texts. It relies on a bag of word assumption, which means a group of topics represents each document in the data set, and a group of words represents each topic (Blei, Ng, & Jordan, 2003). Similar to Walter and Ophir's (2019) mix-method approach for frame detection, we applied topic modeling to identify topics as frame variables and then topic network analysis to examine topic communities as frames.

[5] Climate change doubters and people from Republican-leaning states in the United States tend to use "global warming" more than "climate change," whereas climate change activists tend to use the term "climate change" more often (Jang & Hart, 2015, p. 11). Therefore, we included both phrases to avoid possible bias in our data collection.

Our method extends Walter and Ophir's (2019) approach in three ways. We first performed structural topic modeling (STM) using Roberts, Stewart, and Tingley's (2019) stm R package. STM assumes that topics can be correlated with one another (Roberts et al., 2014). The correlations among topics produce an adjacency matrix for further topic network analysis. We identified 74 topics from the news corpus (see our supplementary materials for more detail). Second, we manually inspected whether each topic was irrelevant information and ruled out 16 topics and 440 news documents highly associated with book reviews, TV program introduction, and news roundups.[6] This step improved the quality of community detection by reducing noise in the data. We included opinion pieces because they are also types of "mediated text" (D'angelo, 2017, p. 638) where news frames exist. Last, we used the estimated topic prevalence (θ), or the probability of each topic, in every news report, to examine the relationship between time and frame changes. STM assumes that the estimated topic prevalence can be a function of document-level features (e.g., events and publishing time) that covary in a standard regression model (Roberts et al., 2014).

We built a topic network based on an adjacency matrix with the positive correlations between each pair of 58 relevant topics identified by STM. Each node in the network was a topic, and each edge was a positive correlation between topic pairs. We applied the spinglass community detection algorithm and identified six topic communities (see Table 2 in the supplementary materials for more detail). To interpret each topic community, we analyzed frame elements (i.e., problem definition, cause, solution, and moral judgment), main sources, topics, and languages in news documents highly associated with topics in each community. Two researchers came together and discussed each frame's definition. As a validity check, we also benchmarked our definitions against prior climate framing studies (i.e., Bolsen & Shapiro, 2018; McComas & Shanahan, 1999; O'Neill et al., 2015). Tables 3 and 4 in the supplementary materials detail the process and framework of frame interpretation.

Frame Dynamics

We estimated frame proportion in each news document by combining the proportion of its subset topics. To test whether frames became concentrated on a smaller set of frames and stabilized within events (H1), we plotted the prevalence of frames by each event and day. Day one represents the day leading up to the spike in Twitter attention for that event's public attention, day two in each event represents the highest level, and day three is the day after the attention spike. We conducted Kruskal-Wallis tests to compare whether each frame substantially changed around the attention spike stage regardless of events. To test whether frames varied significantly among triggering events (H2), we conducted another set of Kruskal-Wallis tests to compare the prevalence of each frame of events. We calculated the effect size of each Kruskal-Wallis test to delineate the level of temporal variation of each frame. Last, to test whether events were associated with frame trends over time (H3), we used OLS regression with 36 total time points to predict the estimated frame proportions of each document.

[6] We calculated the prevalence of all topics for each news document and excluded news documents with the highest probability of irrelevant topics.

Results

Frame Detection

Using STM and topic network analysis, we identified six topic communities as visualized in Figure 1. The communities are representations of six frames: the morality frame, partisan struggle frame, policy struggle frame, science of climate consequences frame, international cooperation/conflicts frame, and economic frame. Below, we discuss each frame and its definition, major sources, and comparison with prior benchmark studies.

The Politics of Climate Change: Partisan Struggle and Policy Struggle

The largest community (blue nodes in Figure 1) included 12 topics and a closely related small community with three topics (green nodes). The topics are all associated with the politics of the climate change issue. We interpreted the small community as the partisan struggle frame. This community focuses on partisan division and debates whether climate change exists and should be prioritized in policy agendas. Additionally, this frame is highly associated with news about U.S. elections, election debates, and partisan conflicts between Democratic and Republican politicians. Common sources in the news coverage are U.S. politicians such as Hillary Clinton, Barack Obama, Mitt Romney, Bernie Sanders, and Donald Trump.

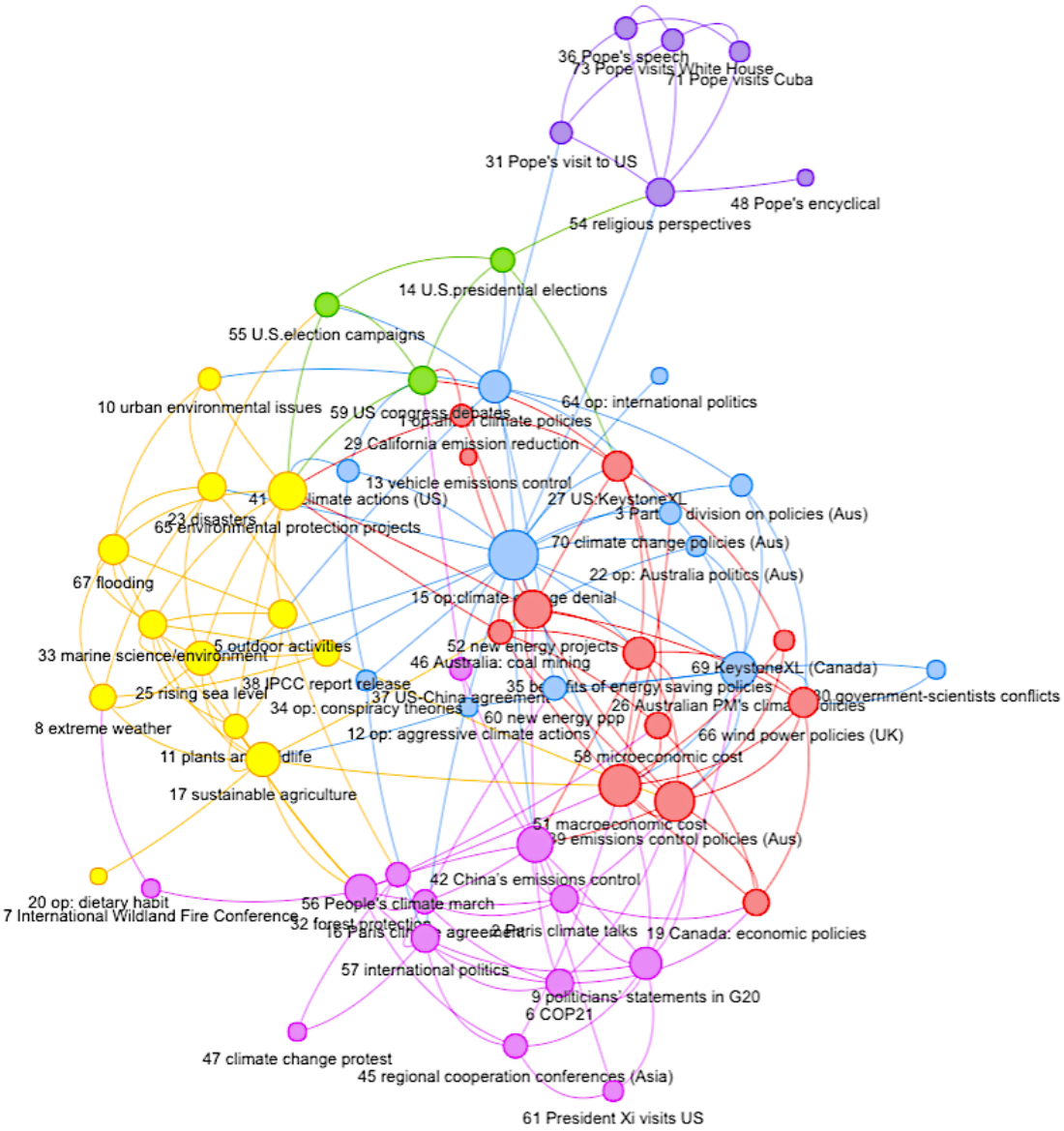

Figure 1. Visualization of topic network analysis. The topic network shows the result of community detection using the spinglass algorithm. The color of a node represents the community to which the topic belongs. The size of a node indicates the topic's prevalence, calculated by the structural topic model where K = 74. Each edge represents a positive correlation between two topics.

The large political topic community reflects a broad policy struggle among politicians. We interpreted the community as the policy struggle frame. Unlike the partisan struggle frame, the policy

struggle frame emphasizes debates and the evaluation of action (or nonaction) to combat climate change. The frame is closely associated with news covering conflicts between politicians and scientists as well as partisan conflicts on specific climate change policies (e.g., new energy), particularly in the United Kingdom, Australia, and other major Commonwealth countries. The common sources are politicians (e.g., Malcolm Turnbull and Tony Abbot, who are both former Australian Prime Ministers), government officials, scientists, and nongovernmental organizations (NGOs). The frame is also highly associated with polarized opinion pieces on climate change. Some of the news reports raised climate change denial and referred to climate change as a hoax and a part of government control. Others criticized climate change deniers, evaluated current policies as inefficient, or called for more aggressive actions from governments and policy makers.

Similar politicized frames on climate change appear in previous climate framing studies. O'Neill et al. (2015) identified a political frame focused on political conflicts and struggles among partisans, politicians, and polarized audiences on the issue and its policy solutions. Extending their generic political conflict frame, our method detected partisan and policy conflict as two distinct aspects of political conflicts. Our analysis showed that news media focused on political conflicts on specific policies in the political contexts of the UK and Australia, whereas in the U.S. political context, news tends to focus on partisan debates about whether climate change exists and policies are necessary. This finding aligns with Bolsen and Shaprio's (2018) definition of political frame. Their review study showed political frames that emphasized the partisan struggle among political elites and political strategies as one of the primary climate frames in U.S. news.

International Conflicts and Cooperation

The topic community with pink nodes has 13 topics. We interpreted the community as international cooperation and conflict. The frame emphasizes multiple aspects of climate change as a global issue, including global and regional cooperation on environmental consequences such as deforestation and cross-country wildfires. News reports related to the frame reflect a multilateral commitment from superpower nations in emissions reduction. Meanwhile, news also shows the power bargaining, mistrust, and negotiation of responsibilities in emissions control among superpowers, particularly between China and the United States. News reports in this frame were highly associated with international conferences like the COP21, Group of 20 summit, regional cooperation conferences, and the global climate change movement. The typical sources for the news reports were political leaders, intergovernmental organizations, international think tanks, and foreign affairs agencies.

The frame is consistent with the international relations theme in the global news coverage of climate change analyzed by McComas and Shanahan (1999) and the generic political conflict frame identified by O'Neill et al. (2015). Their generic political conflict frame includes power battles in both domestic and international political contexts. Unlike their study, our method revealed the distinctive interpretations of climate change under two different political contexts. News and opinion pieces about domestic politics advocated for more aggressive climate policies. However, news and opinion pieces covering international politics affirmed existing climate-related policies and the commitments from Western superpowers. News called for more responsibilities from the developing countries with rapid economic growth. News also described the United States as the leader in the global combat of climate change, whereas China created a threat to the U.S. leadership.

Science of Climate Consequences

The topic community with yellow nodes has 12 topics associated with the consequences of climate change. We interpreted this community as representative of the science of climate consequences frame. The frame reflects that environmental consequences are scientific evidence of climate change negatively impacting human life. For example, news reports with high prevalence of this frame discussed rising sea levels, extreme weather, natural disasters, and threats to wildlife. Also, news reports associated with the frame covered food security, urban environmental issues, hurricane-related damage, and outdoor activities. Common sources for the news reports were scientists, research organizations, NGOs, government agencies, local politicians, and celebrities.

This frame echoes Bolsen and Shapiro's (2018) environmental consequences frame and O'Neill et al.'s (2015) disaster frame. Both frames are related to negative environmental effects and consequences. Although O'Neill et al. (2015) treated settled science (science consensus) and climate impacts as two separate frames, we did not detect any independent frame focusing on perceiving climate change as a scientific consensus. Our analysis revealed that news associated with the frame often linked environmental consequences to the scientific evidence of climate change. This finding is consistent with McComas and Shanahan's (1999) multidimensional scaling analysis. They showed that news emphasized consequences of climate change and often also mentioned new scientific evidence or research.

Economic Frame

The economic frame (red nodes) has 12 topics. The frame emphasizes economic policies, ways that the promotion of new energy can mitigate climate change, and economic costs of climate remediation measures. News stories highly associated with the frame mentioned carbon tax, carbon emission, and new energy support policies. News stories also mentioned the macro- and microeconomic costs of aggressive climate actions, such as rising production costs, the impact on fossil fuel companies, rising oil prices, and global economic growth. Common sources for such news reports were economic analysts, government officials, economic development advisors, think tanks, corporate executives, and news spokespersons for companies. Similar to our findings, prior studies have also identified economic frames in climate news (e.g., Bolsen & Shapiro, 2018; McComas & Shanahan, 1999), as well as frames focused on the economic costs of taking actions to fight climate change (e.g., O'Neill et al., 2015).

Morality Frame

The community with purple nodes has six topics highly associated with news and opinion pieces covering Pope Francis's encyclical and his visits to Cuba and the United States in 2015. The frame highlights moral, ethical, and religious aspects of dealing with climate change. News reports and opinion pieces associated with the frame symbolized the natural environment as the mother and the sister and the universe as God's place. At the same time, the news also mentioned debates about whether the religious perspectives of climate change were political or based on scientific evidence. Common news sources with this frame were religious leaders like Pope Francis. News stories also quoted comments from politicians as interpretations of the pope's speech. Similar to our finding, previous studies also identified morality and ethics frames, which

called for action from the religious, moral, and ethical perspectives (e.g., Bolsen & Shapiro, 2018; O'Neill et al., 2015).

Frame Variation

Hypothesis 1 proposed that frames converge within each event. Figure 2 visualizes the changes of frame prevalence in each event in the prespike, attention spike, and postspike days. It shows that within each event, the majority of language used in the news was associated with only two or three frames. For example, for the Hurricane Sandy event, most lexicons used in the news were associated with three frames (i.e., the science of environment consequence frame, the economic frame, and the policy struggle frame) over the three days. In general, the economic and policy struggle frames were among the top three in almost every event. Although we observed that some frames replaced others in a few events during the three days, Kruskal-Wallis test results showed that the average frame prevalence did not vary substantially over the three days (see Table 5 in the supplementary document). Figure 2 indicates that the results are not just because the same frames were dominant in each event. All findings suggest that new frames concentrated on fewer standard frames and remained stable around the attention peak time, supporting Hypothesis 1.

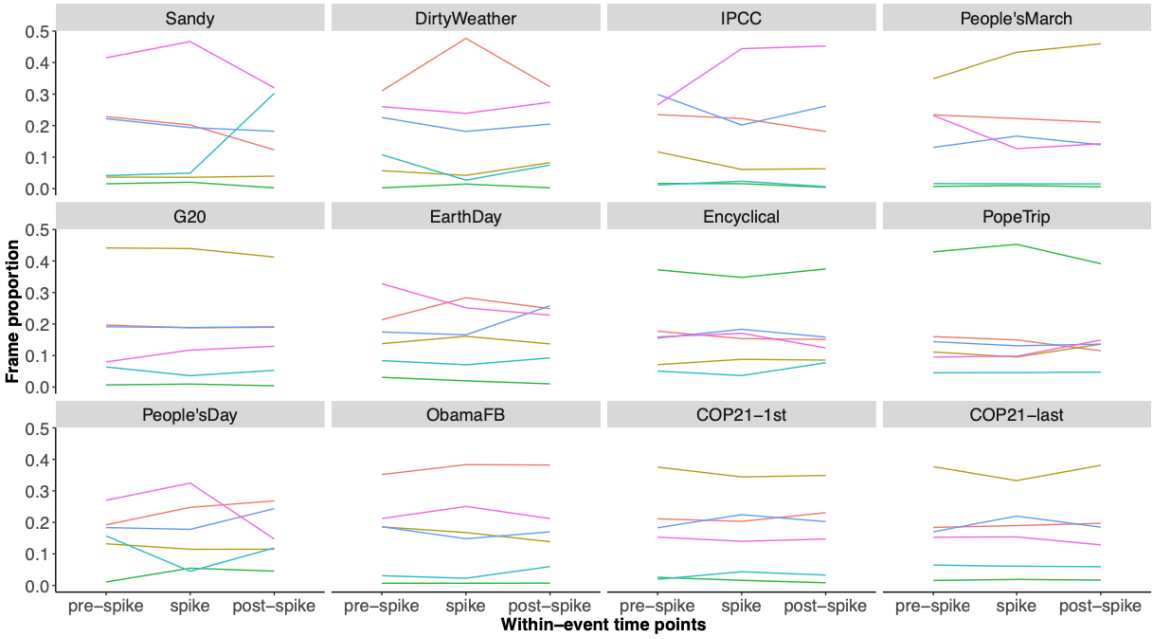

Figure 2. Mean frame prevalence in the prespike, spike, and postspike days for all events. The numbers are based on the average topic prevalence across the 3,338 news documents.

Hypothesis 2 proposed that the prevalence of frames varies among events. Kruskal-Wallis test results showed that, in general, frame prevalence varied substantially across events. There is a significant between-event difference for the prevalence of the economic frame ($H(11) = 266.64$, $p < 0.01$, effect size = 0.07), policy struggle ($H(11) = 66.05$, $p < 0.01$, effect size = 0.01), partisan struggle ($H(11) = 171.64$,

p < 0.01, effect size = 0.05), morality (H(11) = 528.35, p < 0.01, effect size = 0.16), international cooperation/conflicts (H(11) = 759.01, p < 0.01, effect size = 0.22), and the science of climate consequence frame (H(11) = 393.1, p < 0.01, effect size = 0.11). Thus, the results support Hypothesis 2. Figure 3 visualizes the average frame prevalence by event (also, see Table 6 in the supplementary document).

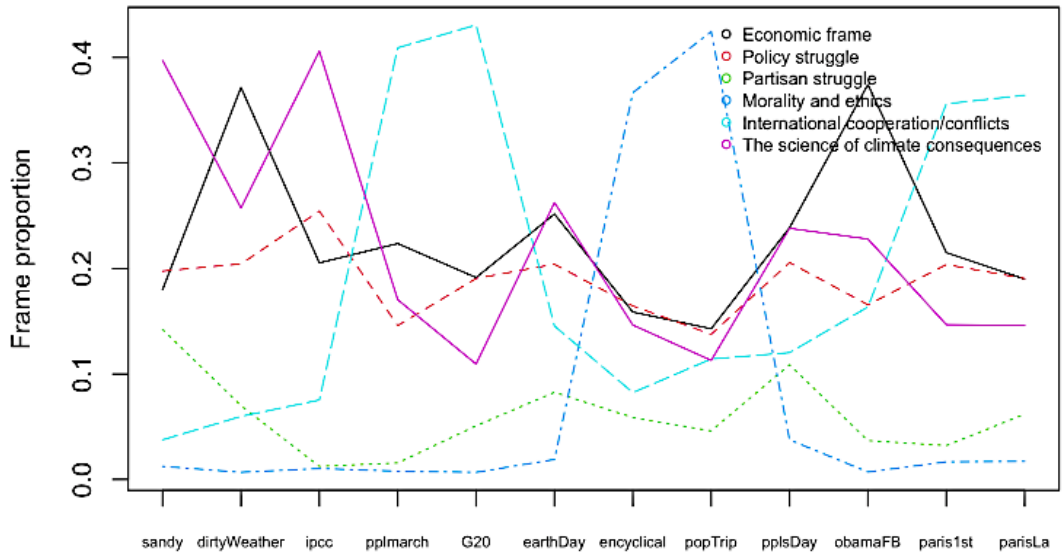

Figure 3. Changes of frame prevalence by events over time. The graph shows the frame proportion of each frame in 12 high climate change attention events. Frame proportion in the y-axis indicates the prevalence of each frame, calculated by averaging the percentage of underlying topics in each event.

The effect sizes showed that the morality frame and the international cooperation/conflict frame had larger temporal variations than other frames. The prevalence of the morality frame dramatically increased as the news mentioned Pope Francis and his speech during his visit to the United States (when he discussed climate change) and the release of the papal encyclical about climate change in 2015. The international cooperation/conflict frame increased as the news increasingly mentioned international politics and quoted global leaders during the G-20 summit and COP21 conference.

Other frames showed less variation. The science of climate consequence frame had the highest prevalence during Hurricane Sandy and following the release of the IPCC report. The policy struggle, partisan struggle, and economic frames showed the least temporal changes across events, although their prevalence corresponded to different types of events. The partisan struggle frame stayed the highest during Hurricane Sandy and revived slightly on Earth Day and the People's Climate Movement National Day of Action in 2015. The policy struggle frame reached a small peak in the news during the IPCC report release and then revived with several similar peaks. The frame had the smallest effect size, likely because it was the least common. The economic frame peaked in the news during The Dirty Weather Report released in 2012 and when Obama

addressed climate change in his inaugural Facebook post in 2015. Although Obama's Facebook post did not highlight economic aspects of climate change, his rejection of the Keystone XL project around this time may have propelled the presence of the economic frame.

Frame Trends

Hypothesis 3 proposed that events predict the trends of frames. We plotted the smoothed trend lines of the estimated prevalence as a function of the 36 time points for the subset topics by each frame, as shown in Figures 4A–Figure 4D (also, see Table 7 in the supplementary document for statistics). The results only partially support hypothesis. The policy conflict frame ($\beta = -0.01$, $t(3382) = -0.8$, $p = 0.41$) and the economic frame ($\beta = -0.003$, $t(3382) = -0.13$, $p = 0.90$) do not show any significant trend over time. This finding suggests that events failed to spark much variation or trends for these two frames. The policy conflict frame and the economic frame are more stable than other frames over time.

The morality frame ($\beta = 0.07$, $t(3382) = 4.18$, $p < 0.01$) and the international conflict/cooperation frame ($\beta = 0.14$, $t(3382) = 8.31$, $p < 0.01$) show uptrends, whereas the partisan conflict frame ($\beta = -0.04$, $t(3382) = -2.36$, $p = 0.02$) and science of climate consequences frame ($\beta = -0.17$, $t(3382) = -10.10$, $p < 0.01$) both show decreasing trends. The results suggest that within the 36 time points we observed, events like the papal encyclical and Pope Francis's international visits were significantly associated with the increasing trend of the morality frame. International conference events were associated with the growth of the international cooperation/conflict frame.

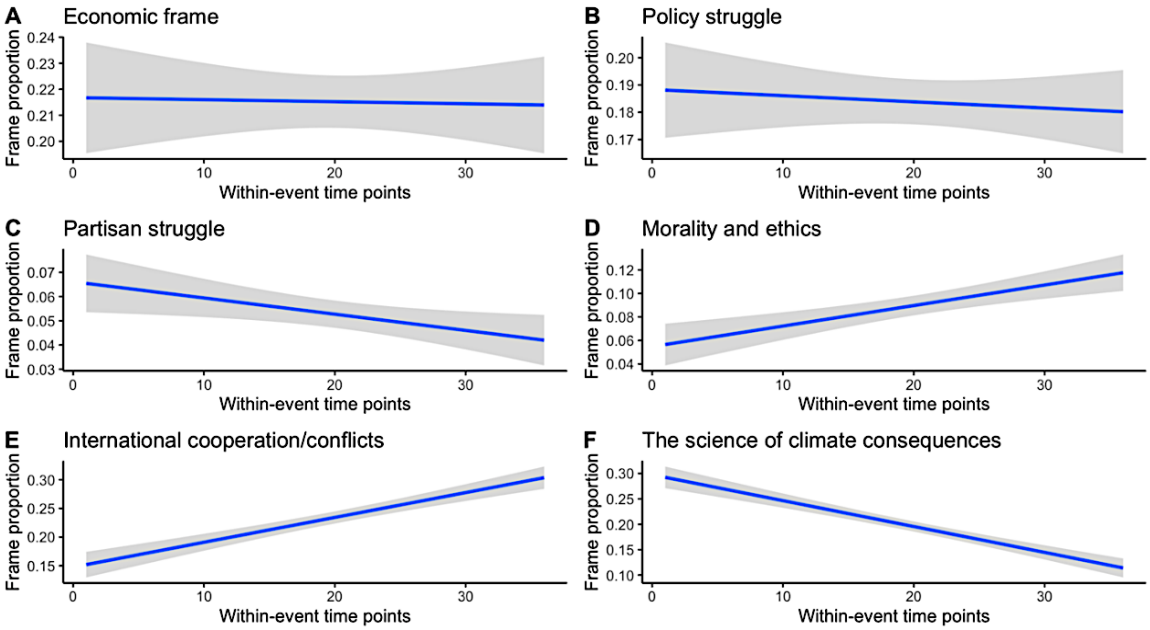

Figure 4. Frame trends over time. Figures 4A–4F display topic prevalence. They show the prevalence of subtopics in each frame as a smooth function of the 12-event timeline with 95% confidence intervals. These topics have a positive trend with statistical significance.

Discussion

This study examined the evolution of news frames about climate change over time. We identified six climate frames: economic, policy struggle, partisan struggle, morality and ethics, international conflicts and cooperation, and the science of climate consequences. Frames showed convergence within a climate change event and divergence across events. We also found that high public-attention climate events can boost the trends of certain frames over time. Our findings imply that climate news frame evolution is coproduced by triggering events and news professionals. The use of standard frames by journalists influences frame evolution. Meanwhile, triggering events are discursive opportunities for non-news actors to influence frame evolution. In our study, the morality frame, for example, was little used by journalists until two Pope-related events. These events provided opportunities to define climate change in a way that had happened only infrequently during previous periods.

The morality frame's growing career also illustrates its dependency on triggering events. In fact, morality had the lowest prevalence across events before Pope Francis's encyclical. This frame shift seems to have mattered for public opinion. Maibach et al. (2015) found that after Pope Francis's encyclical, more Americans came to see climate change as a moral or religious issue, and more were likely to see the relationship between climate change and social justice. Of note, however, conservative ideology moderated these shifts in opinion: Cross-pressured conservative Catholics were more likely to shift their opinions on the pope's credibility than their opinions on climate change (Li, Hilgard, Scheufele, Winneg, & Jamieson, 2016).

Although the overall effect over time is a slight upward trend in use of the frame in the events following Pope Francis's visit to the United States, the morality frame receded from the news coverage on climate change. A study also found that morality frames infrequently appeared in the news of other topic domains (Burscher, Odijk, Vliegenthart, Rijke, & de Vreese, 2014). Thus, the presence of moral frame in climate change news is consequential, particularly considering the framing effects literature. Valenzuela et al. (2017) found that morality framings promote social sharing of news stories. Their findings suggest that the rate of frame usage in news media coverage could be related to the visibility of news stories over time, at least in the context of social media.

A very different story exists in the economic frame and the policy struggle frame. Over time, their prevalence was less varied than other frames. This suggests that these two frames represent something of a default approach to climate news framing. The fact that the two frames overlapped with news values may explain their larger presence over time. Presenting both economic costs and solutions reflects journalistic norms of balancing news by reporting both sides of an issue. Highlighting controversies and conflict is also a way for media to gain more public attention. Commercial pressures on news media to focus on the novel and the dramatic create the likelihood that coverage of issues will focus on aspects likely to heighten public interest (McComas & Shanahan, 1999). However, emphasizing political disagreement and the costs of climate change actions as default frames may reinforce the politicization of the issue and add to public doubt. Researchers have raised concerns that news media have failed to educate citizens and build consensus about the scientific truth of climate change (e.g., Boykoff, 2011; Nabi et al., 2018).

There are parallels here to broader research on framing in political communication. The policy struggle frame in our data focused on controversy and political conflict among stakeholders. This resembles the strategy or game frame dominant in the coverage of political campaigns (e.g., Cappella & Jamieson, 1997). Similarly, economic framings of social issues have been documented in topical domains, including health and disease coverage, childcare access, fracking, and political campaigning (Metze, 2017). Political conflict and economic framing are generalized metaframes whose use extends beyond a single issue (Boydstun, 2013).

Although the six frames in our study overlapped with the generic frames identified in previous studies, news attention to the policy struggle and the economic frame was sustained across events. Thus, perhaps we can further propose routine-based frames and the event-based frames as a new frame taxonomy based on frames' temporal variations and trends. We propose two hypotheses for future studies: (a) The dominance of an event-based frame in a single event does not predict its future trajectory, and (b) over time, event-based frames converge to routine-based frames as the metaframes for an issue in the news.

We propose another layer of frame divergence influenced by international relations. The presence of international cooperation/conflict frame is evidence of news politicizing climate change. News attention shifted from blaming domestic politics to emerging countries. Such analysis seems to be missing in current communication studies. Future studies should examine how a country's foreign policies explain shifting climate discourses related to emerging countries.

In general, our examination of frame divergence reveals that the climate issue frame space is characterized by event-to-event volatility over time, except for default frames. These findings add nuance to theories of issue cycles and issue framing. As in previous studies, we found that news media coverage of climate fits the pattern of punctuated equilibrium, with bursts of attention accompanying triggering events. This is somewhat different from the linear pattern of attention growth and decline predicted by Downs's (1972) issue-attention cycle. This also differs from the issue competition suggested by Hilgartner and Bosk (1988). The competition metaphor implies that one framing of climate could crowd out another. Our findings suggest that journalists eventually settle on a narrow set of frames to characterize a particular issue over time. Some frames become core sets of default frames used consistently over time, surrounded by other peripheral frames used only when the triggering event happened.

Our study also makes a methodological contribution. We tested and showed the reliability and validity of a computational method combining topic modeling and topic network analysis. Frames detected by the computer-assisted approach matched the primary recurring frames in previous studies (e.g., Bolsen & Shapiro, 2018; McComas & Shanahan, 1999; O'Neill et al., 2015). Moreover, we were able to understand richer aspects of the generic political frame than those previous studies.

The study does not come without its limitations. Our emphasis on events means that everyday variation in climate issue framings is unclear. An alternative formulation would be to examine frame careers by looking at frame usage year by year rather than event by event. The trade-off in such a study would be the ability to capture the roles of triggering events in shaping the mixes of frames used in coverage. Within the issue attention cycle, the study focused only on the frame dynamics around the peak days of high-

attention events. However, sampling more time points before and after the peak of attention for each event may reveal more frame shift dynamics.

In addition, the climate issue has a longer life span than our data collection. Choosing events creates the possibility to observe event variation over a lengthy period but makes it difficult to directly test any hypotheses related to issue life cycle. The climate issue began before our data collection and shows no sign of resolving or leaving the public eye. The life spans of the triggering events also extend beyond the three days around attention spikes, as we observed. Our analysis of only news written in English also limits the possibility of observing global variation in news coverage for what is most certainly a worldwide issue. Finally, our study does not approach possible ideological divides within the broader news data sets. We expect that news frames may differ alongside partisan leanings of different news outlets. One way to approach this question might be to consider framing differences in news coverage mentioning "climate change" versus "global warming," as these terms have become politically polarized.

Conclusion

Despite its limitations, the study extends the understanding of the evolution of climate frames. Our findings showed convergence and divergence in frame evolution. Within and across climate change events, the news converged on policy struggle and economic frames—the default frames that consistently appeared over time. In contrast, international cooperation and conflict, partisan struggle, morality, and the science of environmental consequences were more event driven. These findings suggest that frame evolution is a socially constructed process influenced by journalists' routines and triggering events.

References

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent dirichlet allocation. *The Journal of Machine Learning Research, 3*(4–5), 993–1022. doi:10.5555/944919.944937

Boesman, J., Berbers, A., d'Haenens, L., & Van Gorp, B. (2017). The news is in the frame: A journalist-centered approach to the frame-building process of the Belgian Syria fighters. *Journalism, 18*(3), 298–316. doi:10.1177/1464884915610988

Bolsen, T., & Shapiro, M. A. (2018). The U.S. news media, polarization on climate change, and pathways to effective communication. *Environmental Communication, 12*(2), 149–163. doi:10.1080/17524032.2017.1397039

Borah, P. (2011). Conceptual issues in framing theory: A systematic examination of a decade's literature. *Journal of Communication, 61*(2), 246–263. doi:10.1111/j.1460-2466.2011.01539.x

Boydstun, A. E., Gross, J. H., Resnik, P., & Smith, N. A. (2013, September). Identifying media frames and frame dynamics within and across policy issues. Study presented at New Directions in Analyzing Text as Data Workshop, London, UK. Retrieved from http://faculty.washington.edu/jwilker/559/frames-2013.pdf

Boykoff, M. T. (2011). *Who speaks for the climate? Making sense of media reporting on climate change*. Cambridge, UK: Cambridge University Press.

Broadbent, J., Sonnett, J., Botetzagias, I., Carson, M., Carvalho, A., Chien, Y. J., . . . Hasegawa, K. (2016). Conflicting climate change frames in a global field of media discourse. *Socius: Sociological Research for a Dynamic World, 2*, 1–17. doi:10.1177/2378023116670660

Brossard, D., Shanahan, J., & McComas, K. (2004). Are issue-cycles culturally constructed? A comparison of French and American coverage of global climate change. *Mass Communication and Society, 7*(3), 359–377. doi:10.1207/s15327825mcs0703_6

Burscher, B., Odijk, D., Vliegenthart, R., de Rijke, M., & de Vreese, C. H. (2014). Teaching the computer to code frames in news: Comparing two supervised machine learning approaches to frame analysis. *Communication Methods and Measures, 8*(3), 190–206. doi:10.1080/19312458.2014.937527

Cacciatore, M. A., Scheufele, D. A., & Iyengar, S. (2016). The end of framing as we know it. . .and the future of media effects. *Mass Communication and Society, 19*(1), 7–23. doi:10.1080/15205436.2015.1068811

Cappella, J. N., & Jamieson, K. H. (1997). *Spiral of cynicism: The press and the public good*. New York, NY: Oxford University Press.

Carvalho, A. (2010). Media (ted) discourses and climate change: A focus on political subjectivity and (dis) engagement. *Wiley Interdisciplinary Reviews: Climate Change, 1*(2), 172–179. doi:10.1002/wcc.13

Chyi, H. I., & McCombs, M. (2004). Media salience and the process of framing: Coverage of the Columbine school shootings. *Journalism and Mass Communication Quarterly, 81*(1), 22–35. doi:10.1177/107769900408100103

D'angelo, P. (2017). Framing: Media frames. In P. Rössler, C. A. Hoffner, & L. van Zoonen (Eds.), *The international encyclopedia of media effects* (pp. 1–10). London, UK: John Wiley & Sons Inc.

Downs, A. (1972). Up and down with ecology: The issue-attention cycle. *The Public Interest, 28*, 38–51. Retrieved from https://fbaum.unc.edu/teaching/articles/Downs_Public_Interest_1972.pdf

Entman, R. M. (1993). Framing: Toward clarification of a fractured paradigm. *Journal of Communication, 43*(4), 51–58. doi:10.1111/j.1460-2466.1993.tb01304.x

Entman, R. M. (2003). Cascading activation: Contesting the White House's frame after 9/11. *Political Communication, 20*(4), 415–432. doi:10.1080/10584600390244176

Gamson, W. A., & Modigliani, A. (1989). Media discourse and public opinion on nuclear power: A constructionist approach. *American Journal of Sociology, 95*(1), 1–37. doi:10.2307/2780405

Greussing, E., & Boomgaarden, H. G. (2017). Shifting the refugee narrative? An automated frame analysis of Europe's 2015 refugee crisis. *Journal of Ethnic and Migration Studies, 43*(11), 1749–1774. doi:10.1080/1369183X.2017.1282813

Guggenheim, L., Jang, S. M., Bae, S. Y., & Neuman, W. R. (2015). The dynamics of issue frame competition in traditional and social media. *The Annals of the American Academy of Political and Social Science, 659*(1), 207–224. doi:10.1177/0002716215570549

Hart, P. S. (2011). One or many? The influence of episodic and thematic climate change frames on policy preferences and individual behavior change. *Science Communication, 33*(1), 28–51. doi:10.1177/1075547010366400

Hilgartner, S., & Bosk, C. L. (1988). The rise and fall of social problems: A public arenas model. *American Journal of Sociology, 94*(1), 53–78. doi:10.1086/228951

Houston, J. B., Pfefferbaum, B., & Rosenholtz, C. E. (2012). Disaster news: Framing and frame changing in coverage of major U.S. natural disasters, 2000–2010. *Journalism and Mass Communication Quarterly, 89*(4), 606–623. doi:10.1177/1077699012456022

Koopmans, R., & Olzak, S. (2004). Discursive opportunities and the evolution of right-wing violence in Germany. *American Journal of Sociology, 110*(1), 198–230. doi:10.1086/386271

Lawrence, R. G. (2004). Framing obesity: The evolution of news discourse on a public health issue. *Harvard International Journal of Press/Politics, 9*(3), 56–75. doi:10.1177/1081180X04266581

Leiserowitz, A., Maibach, E., Rosenthal, S., Kotcher, J., Wang, X., Carman, J., . . . Marlon, J. (2021). *Climate activism: A six-Americas analysis, December 2020*. New Haven, CT: Yale Program on Climate Change Communication. Retrieved from climatecommunication.yale.edu/publications/climate-activism-a-six-americas-analysis-december-2020/

Li, N., Hilgard, J., Scheufele, D. A., Winneg, K. M., & Jamieson, K. H. (2016). Cross-pressuring conservative Catholics? Effects of Pope Francis' encyclical on the U.S. public opinion on climate change. *Climatic Change, 139*(3), 367–380. doi:10.1007/s10584-016-1821-z

Lörcher, I., & Neverla, I. (2015). The dynamics of issue attention in online communication on climate change. *Media and Communication, 3*(1), 17–33. doi:10.17645/mac.v3i1.253

Maibach, E., Leiserowitz, A., Roser-Renouf, C., Myers, T., Rosenthal, S., & Feinberg, G. (2015). *The Francis effect: How Pope Francis changed the conversation about global warming*. Fairfax, VA: George Mason University Center for Climate Change Communication. Retrieved from https://www.climatechangecommunication.org/wp-content/uploads/2016/03/2015-Nov-The_Francis_Effect.pdf

McAdam, D. (2017). Social movement theory and the prospects for climate change activism in the United States. *Annual Review of Political Science, 20*(1), 189–208. doi:10.1146/annurev-polisci-052615-025801

McComas, K., & Shanahan, J. (1999). Telling stories about global climate change: Measuring the impact of narratives on issue cycles. *Communication Research, 26*(1), 30–57. doi:10.1177/009365099026001003

Metze, T. (2017). Fracking the debate: Frame shifts and boundary work in Dutch decision making on shale gas. *Journal of Environmental Policy and Planning, 19*(1), 35–52. doi:10.1080/1523908X.2014.941462

Muschert, G. W., & Carr, D. (2006). Media salience and frame changing across events: Coverage of nine school shootings, 1997–2001. *Journalism and Mass Communication Quarterly, 83*(4), 747–766. doi:10.1177/107769900608300402

Nabi, R. L., Gustafson, A., & Jensen, R. (2018). Framing climate change: Exploring the role of emotion in generating advocacy behavior. *Science Communication, 40*(4), 442–468. doi:10.1177/1075547018776019

O'Neill, S., Williams, H. T. P., Kurz, T., Wiersma, B., & Boykoff, M. (2015). Dominant frames in legacy and social media coverage of the IPCC fifth assessment report. *Nature Climate Change, 5*(4), 380–385. doi:10.1038/nclimate2535

Painter, J., Kristiansen, S., & Schäfer, M. S. (2018). How 'Digital-born' media cover climate change in comparison to legacy media: A case study of the COP 21 summit in Paris. *Global Environmental Change, 48*(2018), 1–10. doi:10.1016/j.gloenvcha.2017.11.003

Roberts, M. E., Stewart, B. M., & Tingley, D. (2019). STM: An R package for structural topic models. *Journal of Statistical Software, 91*(2), 1–40. doi:10.18637/jss.v091.i02

Roberts, M. E., Stewart, B. M., Tingley, D., Lucas, C., Leder-Luis, J., Gadarian, S. K., . . . Rand, D. G. (2014). Structural topic models for open-ended survey responses. *American Journal of Political Science, 58*(4), 1064–1082. doi:10.1111/ajps.12103

Schäfer, M. S., & Schlichting, I. (2014). Media representations of climate change: A meta-analysis of the research field. *Environmental Communication, 8*(2), 142–160. doi:10.1080/17524032.2014.914050

Shih, T. J., Wijaya, R., & Brossard, D. (2008). Media coverage of public health epidemics: Linking framing and issue attention cycle toward an integrated theory of print news coverage of epidemics. *Mass Communication and Society, 11*(2), 141–160. doi:10.1080/15205430701668121

Shoemaker, P. J., & Reese, S. D. (2014). *Mediating the message in the 21st century: A media sociology perspective*. New York, NY. Routledge.

Thorson, K., Edgerly, S., Kligler-Vilenchik, N., Xu, Y., & Wang, L. (2016). Seeking visibility in a big tent: Digital communication and the people's climate march. *International Journal of Communication, 10*, 4784–4806. Retrieved from https://ijoc.org/index.php/ijoc/article/viewFile/4703/1802

Thorson, K., & Wang, L. (2020). Committed participation or flashes of action? Mobilizing public attention to climate on Twitter, 2011–2015. *Environmental Communication, 14*(3), 347–363. doi:10.1080/17524032.2019.1666727

Valenzuela, S., Piña, M., & Ramírez, J. (2017). Behavioral effects of framing on social media users: How conflict, economic, human interest, and morality frames drive news sharing. *Journal of Communication, 67*(5), 803–826. doi:10.1111/jcom.12325

Van Gorp, B. (2007). The constructionist approach to framing: Bringing culture back in. *Journal of Communication, 57*(1), 60–78. doi:10.1111/j.1460-2466.2006.00329.x

Vliegenthart, R. (2018). The agency makes the (online) news world go round: The impact of news agency content on print and online news. *International Journal of Communication, 12*, 1768–1789. https://ijoc.org/index.php/ijoc/article/viewFile/7109/2330

Walter, D., & Ophir, Y. (2019). News frame analysis: An inductive mixed-method computational approach. *Communication Methods and Measures, 13*(4), 248–266. doi:10.1080/19312458.2019.1639145

Wessler, H., Wozniak, A., Hofer, L., & Lück, J. (2016). Global multimodal news frames on climate change: A comparison of five democracies around the world. *The International Journal of Press/Politics, 21*(4), 423–445. doi:10.1177/1940161216661848

Wiest, S. L., Raymond, L., & Clawson, R. A. (2015). Framing, partisan predispositions, and public opinion on climate change. *Global Environmental Change, 31*, 187–198. doi:10.1016/j.gloenvcha.2014.12.006

Wolsko, C., Ariceaga, H., & Seiden, J. (2016). Red, white, and blue enough to be green: Effects of moral framing on climate change attitudes and conservation behaviors. *Journal of Experimental Social Psychology, 65*, 7–19. doi:10.1016/j.jesp.2016.02.005