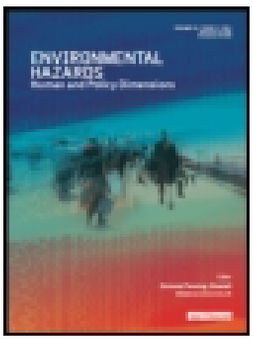

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Extreme weather and climate change: social media results, 2008–2017

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ABSTRACT

The link between extreme weather and climate change is being highlighted in ever more countries. Increased public understanding of this issue is essential for policymaking, both in terms of climate change mitigation and adaptation. As social media are becoming central to the exchange of information in society, the purpose is to analyze what generates intensified attention to the connection between extreme weather and climate change in digital communication. This is done by examining periods of intensified co-occurrence of mentions of extreme weather and climate change on English-language Twitter ($N = 948{,}993$). Our quantitative analysis suggests that during the period 2008–2017 the years 2010, 2011 and 2017 exhibit a considerable increase in 'causality discourse', i.e. tweets that articulate the topic of climate change + extreme weather, in comparison with earlier years. These periods of significant growth are interpreted as involving dynamic relationships between three factors, namely mediated highlighting of previous or ongoing extreme-weather events (extreme-event factor); connection of extreme weather to climate change by traditional media or other intermediaries (media-driven science communication factor); and actions of individual users (digital-action factor). Through a qualitative discourse analysis, how these factors jointly generate increasing attention to 'causality discourse' is more closely explored for the case of 2017.

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Introduction

The connection between different types of extreme weather and climate change has been emphasised in several IPPC reports (IPPC, 2014, etc.) and is viewed as an increasingly important aspect of global, national and regional environmental and sustainability work. Explaining and predicting different types of extreme weather from a climate-change perspective is complex, however. It is difficult to attribute singular extreme-weather events to climate change (Hulme, 2014), and uncertainty is taken-for-granted

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among climate scientists, or at least ought to be (Hulme, 2017; Janković & Schultz, 2016). It is common to emphasise that climate change does not simply cause heavy precipitation or abnormal heat, but rather increases the probability of such events. Experts tend to represent different perspectives, with some employing an 'A was caused by B' rationale, and others sticking to the probability principle.

The public understanding of the link between extreme weather and climate change, which is essential for legitimising further policymaking concerning both climate-change mitigation and adaptation planning and practices, is characterised by cross-sector communication processes. This means that the above-mentioned scientific discourse is travelling across and between institutions and knowledge contexts, which are dominated by different traditions, ideologies, and interests (Hulme, 2017). Scientific discourse on the link between extreme weather and climate change thus comes to be commented, reused, and transformed by politics, education, popular culture, art, everyday life discourse, and not least mass media, in which partly new ideas and ways of reasoning might develop. In this respect, social media platforms such as Facebook or Twitter are increasingly important spaces for such *recontextualized communication* (Fairclough, 1995), and give important clues about society's awareness of the link between extreme weather and climate change (Cody et al., 2015). Social media platforms are *discursive melting pots*, characterised by different perspectives on extreme weather and climate change (scientific, political, religious, lay opinion, etc.), which meet and/or potentially also clash (expert knowledge vs. disinformation, etc.). In short, while the digital platforms do not determine society's political handling of this issue, they do potentially influence it, which makes them relevant objects of empirical studies.

During the last decade, there has been an increase in the number of studies about climate change and social media. Scholars have, for example, concentrated on interpersonal communication and conflicts (Olausson, 2019); how users share information about climate change and the role of psychology (Veltri & Atanasova, 2017) on the viral dimensions (Hansen et al., 2011) of climate-change communication; the hierarchical character of climate-change discourse (Liu & Zhao, 2017); and the issues of echo chambers and polarisation (Anderson & Huntington, 2017). When it comes to extreme weather and climate change, most contributions still focus on traditional mass media (Berglez & Lidskog, 2019; Cordner & Schwarz, 2018; Morehouse & Sonnett, 2010, etc.). Exceptions include Kirilenko et al. (2015), who examine to what extent extreme temperature anomalies influence climate-change discussion on Twitter in different local regions in the USA. One of the findings is that users did connect extreme weather anomalies to climate change, although mass-media information played a less important mediating role than expected. Yeo et al. (2017) examine to what extent regional experiences of anomalous temperature (heat waves) generate climate-change discussions on Twitter, and find more or less similar correlations as Kirilenko et al. (2015).

In several cases, previous studies thus employ advanced geotagging approaches to examine how weather anomalies in defined places generate increased social media activity, especially in those specific places (e.g. Kirilenko et al., 2015; Yeo et al., 2017). Simultaneously, there is a lack of research examining social media activities in spaces that are not restricted to defined geographical territories. What motivates such research is that the production, exchange and reception of 'causality discourse' (Veltri & Atanasova, 2017), i.e. social media content on the connection between extreme weather and climate change,

also operate within a wider digital space or sphere. Such spheres are based on national culture (e.g. in the Brazilian or Japanese Twitterspheres) or a common language (i.e. in the German-language or Arabic-language Facebook spheres). When it comes to such less place-centered social media spaces (cf. Morley, 2000), our assumption is that national or international mass media and social media influencers or activists will play a more prominent role in a significant increase in 'causality discourse' during certain periods, by serving as important intermediaries for connecting and engaging users across numerous places. However, what more exactly it is that generates intensified social media engagement (i.e. peaks) in this context, and what the communication looks like, need to be analyzed more deeply.

Therefore, this study examines a particular language-based social media sphere, namely the English-language Twittersphere. English is the dominant language on Twitter, accounting for 40% of all of Twitter's content as of 2013 (Leetaru et al., 2013). Here, media globalisation theory (Sparks, 2007) would predict the communication to be centred around Anglo-Saxon countries and to derive from English-language communities and actors, primarily in the USA, where Twitter Inc. is located.

Hence, this study aims to be relevant for those who are, from different perspectives (policy, science, politics, etc.), interested in how the topic of extreme weather and climate change is developing in society, and the role of networked technology in this development. The article is outlined as follows. First, our theoretical approach will be presented, and three interrelated factors (the extreme-event, media-driven science communication and digital-action factors) are suggested to be important for analyzing 'causality discourse' on social media. This is followed by a description of the research questions, the empirical data, and the mixed-methods approach (combining quantitative and qualitative methods). The results are divided into two sections. The first presents the diachronic development of the co-occurrence of extreme weather and climate-change related terms in English-language tweets during 2008–2017 in terms of relative frequencies. Based on the results from this, the other section focuses in detail on the periods of significant increases in activity, and particularly the year 2017. Qualitative discourse analysis (Fairclough, 1995) is employed to get a more detailed understanding of the causal mechanisms behind the relative increase in 'causality discourse' during this period. The article concludes with a discussion of the results and suggestions for further research.

Theory and research questions

In this context, the generation of 'causality discourse' on social media is theoretically interpreted through retroductive inference (Danermark et al., 2002; Glynos & Howarth, 2007). Retroduction, which is primarily associated with critical realist theory (Bhaskar, 1977), can be viewed as a middle ground between inductive and deductive forms of inference, in which the basic idea is to achieve ' … a reconstruction of the basic conditions for anything to be what it is' (Danermark et al., 2002, p. 206). This requires that one seeks to understand more precisely under what conditions a social phenomenon, in this case 'causality discourse' on Twitter, can exist and operate. Through retroductive inference, one is interpreting networked processes on Twitter as partly predictable and partly unforeseen dynamic relations between multiple factors, which together generate a particular outcome (Glynos & Howarth, 2007, p. 19). In this context, based on previous

research and theories on how social media function (Castells, 2009; Marwick, 2013) and their intermediate relations with traditional media (Anderson, 2014), it is suggested that the following factors are central to understanding the prevalence of 'causality discourse' on Twitter (Table 1): the extreme-event factor, the media-driven science communication factor, and the digital-action factor (cf. Al-Saqaf & Berglez 2019). These serve as a point of departure for the analysis, although one needs to leave the door open for the detection of further factors. Even if a factor might be endowed with autonomous power, the focus is on how they, in different constellations, generate 'causality discourse'. Intensified engagement could then be viewed as the result of *unusually dynamic relationships between two or three of the factors*.

The extreme-event factor. This involves the generation and publishing of social media discourse (statements, opinions, information, eyewitness stories, data, etc.) about some type of extreme weather, such as flooding or heatwaves. What makes such discourse appear on social media has to do with different actions within the media ecology as a whole, including the publishing by mass media or other communicating organisations of their own material on social media platforms, as well as the generation and publication of such discourse by individual Twitter users. This could involve more general kinds of discourse about extreme weather without focusing on any particular event or previous events. However, due to media society's emphasis on instant information (Broersma & Graham, 2012; Hansen et al., 2011), *ongoing* extreme weather as well as numerous Twitter users' commenting and sharing of mass media's *news* about extreme weather events are essential in this context (Anderson, 2014, p. 36). More precisely, extreme weather qualifies as 'attractive news' because of the devastation it causes for humans/societies and nature. The theory of news value informs us that the media tends to favour negative over positive information (Galtung & Ruge, 1965). A catastrophic flood is likely to become a media event (Anderson, 2014), but positive news about the decreasing risk of future wildfires in a certain region will not achieve a similar level of media attention. Another important aspect is geographical and cultural proximity; on English-language Twitter, an extreme weather event occurring in the USA, Australia or Europe is more likely to be highlighted than similar events in other parts of the world.

Media-driven science communication refers to different media channels' articulations of 'causality discourse', i.e. explicit mentioning on social media of the scientific topic of a possible link between extreme weather and climate change. These channels are primarily newspapers, television, and radio, but also include widely popular websites, digital campaigns and blogs, whose contents are distributed and disseminated through social media platforms. For example, the former might involve the *Washington Post* writing about the potential connection between a hurricane event and climate change, or discussing extreme-weather events in relation to global warming more generally. The latter could involve publicly established organisations (e.g. environmental organisations, activist

Table 1. Approach for analyzing 'causality discourse' on social media.

Extreme-event factor: the mediated highlighting of extreme weather, in a general sense or with a focus on previous or ongoing events. *Media-driven science communication:* media information mentioning 'causality discourse' deriving from parallel media channels/platforms, be they traditional news channels, newspapers, or broadcast-radio news, but also political campaigns, blogs, think tanks, organisations, etc. *Digital-action factor*: individual users' networked generation of 'causality discourse.'

networks, think tanks, etc.) that create self-produced media information, and whose social media messages are also often highlighted in traditional mass media's coverage (for instance, a *Greenpeace* press release being covered by a newspaper). Whether or not the connecting of extreme weather to climate change receives wider attention depends on the authority and reputation of the media producers as well as the above-mentioned news-media logic (Galtung & Ruge, 1965), i.e. whether there are elements of novelty, cultural/geographical proximity, conflict, or elite sources such as celebrities, influential politicians, and environmental activists (Anderson, 2011; Boykoff & Goodman, 2011).

The digital-action factor consists of user-driven generation of 'causality discourse'. Mass media, researchers or environmental organisations might highlight the link between extreme weather and climate change but cannot have a broader effect without the digital actions of (masses of) individual users who communicate, discuss, re-use, share, and disseminate 'causality discourse'. The two above-mentioned factors serve as important context and 'fuel' for these users' generation of 'causality discourse'. When it comes to the role of individual users, Lin et al. (2014) distinguish 'rising tides' from 'rising stars'. The former refers to cases in which significant attention to 'causality discourse' is generated horizontally, i.e. through the networked activity of many users in many-to-many communication. The latter instead involves elite concentration and the particular importance of a few users in hierarchical one-to-many communication (Berglez, 2016), i.e. what Castells defines as 'mass self-communication' (Castells, 2009, p. 55). This involves social media influencers, including public figures and celebrities, i.e. users with excellent reputations and large networks in the social media landscape who often make viral things happen (Anderson, 2011; Marwick, 2013), such as by ensuring that their status updates are widely noticed and further disseminated by many users.

In sum, it is important to consider the potentially overlapping and dialectically intertwined relations between the factors. For example, an ongoing extreme weather event might generate extensive media attention including on Twitter (the extreme-event factor). This may include an article in *The Guardian* which mentions the potential connection with climate change (media-driven science communication). The article also becomes accessible and widely shared via the Guardian journalists' own Twitter account (digital-action factor), which has numerous followers and therefore generates great publicity.

Research questions

In light of the above-formulated theoretical framework, the purpose of the study is to analyze what generates intensified attention to the connection between extreme weather and climate change in digital communication. To begin with, we decided to collect and analyze longitudinal data to identify considerable shifts in activity (the ups and downs over time), focusing on Twitter during 2008–2017:

> RQ1: During the period 2008–2017, to what extent do mentions of extreme weather (or related terms such as 'weird weather') include climate change or some related term (e.g. global warming, CO_2)?

Here, the data includes all types of articulated standpoints concerning 'causality discourse', including those that might question or deny a causal link between extreme

weather and climate change. Therefore, the results will not confirm a potential increase or decrease in public support for the scientific certainty that extreme weather and climate change are connected (cf. Dixon et al., 2018), but rather whether or not climate change is becoming an increasingly important aspect when tweeting about extreme weather (see Cody et al., 2015). In addition to RQ1, we also examine the proportion of the group generating 'causality discourse' throughout the examined period:

> RQ2: During the period 2008–2017, what proportion of the group of users combine extreme weather and climate-change related terms, in comparison with the group of users who only mention the former?

The third question then focuses on qualitatively understanding examples of significant growth of tweeting 'causality discourse', in which particular periods of time are selected for analysis:

> RQ3: How can periods of intensified production of 'causality discourse' be understood as dynamic relationships between the extreme-event, media-driven science communication and digital-action factors?

Materials and method

The Mecodify Twitter data analysis and visualisation tool (http://mecodem.eu/mecodify/) was used to retrieve publicly accessible information from twitter.com through a combination of web search data extraction and API calls. Once retrieved, the data is stored locally for analysis.[1] Mecodify starts out by deploying the classic Twitter search mechanism on the web (available at https://twitter.com/search) and the results are queried page by page in batches of 20 tweets per page as per Twitter's standard pagination. From those pages, a unique tweet ID number is obtained for each tweet. These IDs are then fed into Twitter's Tweet API to obtain the tweet's metadata, such as when it was published, etc.

For the period 2008–2017, which covers almost all the years of Twitter's existence until 2018 (it was launched in 2006, but we excluded the two first years due to minimal activity), two different keyword search combinations were used. We first collected tweets using the following search query: ('extreme weather' OR 'weird weather' OR 'wicked weather' OR 'extreme weather event' OR 'extreme weather events'). Then we collected tweets using the following search query: ('extreme weather' OR 'weird weather' OR 'wicked weather' OR 'extreme weather event' OR 'extreme weather events') AND ('climate change' OR 'global warming' OR IPCC OR CO2 OR 'greenhouse gas' OR 'greenhouse gases' OR 'carbon dioxide'). This enabled us to examine to what extent extreme weather and climate-change oriented terms were combined, i.e. 'causality discourse', in terms of relative frequencies (RQ1). We also calculated the aggregated number of users combining extreme weather and climate-change related terms (RQ2).

The central unit for the quantitative examination of the development over time is *tweets* (RQ1 and RQ2), since this function (tweeting) has been part of Twitter from the very beginning and is therefore possible to compare from year to year. Given that the number of Twitter users increased significantly over the years, our method does not use absolute figures when comparing yearly activities, since there will clearly be more tweets over time. Instead, we compare ratios rather than absolute figures. For each year, we calculate the total number of tweets about extreme weather*, and then focus

on the percentage of tweets that also mention climate change*. Socio-technological functions which have become increasingly important during the second half of the studied period, such as retweeting, are less relevant for yearly comparisons, but more important for the qualitative study (RQ3) presented below, which concentrates on a single year (2017).

Collection and selection of empirical data for the qualitative analysis (RQ3)

For RQ3, we decided to concentrate on 2017, more precisely the second half of 2017. 2017 is among the years representing considerable growth of 'causality discourse' in comparison with the previous year (2016) (see Table 3). During the second half of the year, the production of 'causality discourse' is characterised by very low valleys and high peaks (see Figures 5 and 6), which is a prerequisite for qualitative studies of volatility processes (i.e. of intensified activity from one period to another). Here, the focus is on analyzing the most active months, although specific days during these months are zoomed in on when necessary. Two months, September and December, stand out from the rest and therefore supply the bulk of the material for analysis. Original tweets published during these two months alone represented 38% of all original tweets during 2017, and when retweets are added they represent 79% of all the activity during the year. For the analysis of September and December, to begin with we collected and made use of the following empirical material:

- the ten most frequently used words in the tweets[2]
- the ten most retweeted tweets
- the ten most frequently occurring web links, shared (i.e. actively inserted in users' own tweets) or retweeted (re-posting of others' tweets)

During September and December, the frequency of tweets, retweets and sharing practices is thus considerably higher than during the other months in the second half of 2017. The selected data provided us with more precise information about what spurred the engagement in 'causality discourse', in cases where a few tweets/words/web links were extensively circulated in comparison to the remaining activities in September and December. These examples were then examined through qualitative analysis. The discourse analysis (Fairclough, 1995; Reisigl & Wodak, 2012) focused on the symbolic meaning of what was articulated, and more precisely the style of writing, e.g. the role played by humour, expertise, style, etc., and interdiscursive combinations of different styles (Berglez, 2016, p. 5; Fairclough, 1995, pp. 76–77) in the viral breakthrough of certain tweets. Furthermore, as tweets are viewed as texts (expressions of meaning-making), a third aspect was to pay attention to how these …

> " … texts are linked to other texts, both in the past and in the present. Such connections are established in different ways: through explicit reference to a topic or main actor; through references to the same events; by allusions or evocations; by the transfer of main arguments from one text to the next, and so on." (Reisigl & Wodak, 2012, p. 90)

The intertextual processes, i.e. how texts are linked to other texts, were then analyzed in terms of *presence and absence* (Fairclough, 1995, p. 203), or what critical realists refer to as

transfactual mechanisms (Danermark et al., 2002, p. 232). In what way does the articulated text (a tweet) potentially connect with previous texts (tweets) that may be explicitly mentioned or may instead be absent from the present social media flow though still contextually important? (Previous extreme weather, previous discussions about climate change, and so forth.)

Methodological and ethical considerations

To assess the reliability of the data fetched through Mecodify, we have employed random searches using the Twitter.com web search function. This enabled us to confirm that the results obtained from Mecodify were identical to those from the Twitter web search. However, this is not an absolute guarantee that the dataset includes every tweet that may be a match, because Twitter's search algorithm is proprietary and not transparent (Al-Saqaf, 2016, p. 4).

In our dataset, the identified number of users represents the accounts producing original tweets only. This has to do with restrictions imposed by the Twitter application programme interface (API) and Mecodify. This means that the data does not account for users who were only engaged in retweeting and thus never posted a single original tweet.

Individual retweets are thus primarily relevant for the qualitative analysis of 2017 (RQ3), and are not included as separate entries in the dataset, although their total number is added to show how many times each original tweet was retweeted. This means that it is not possible to know if the retweets were made minutes, hours or even days after the tweet was first published, but it is reasonable to assume that most retweets were made in the first hour after the tweet was posted. This is due to the fast pace at which Twitter works, and has also been proposed in earlier studies.[3]

Finally, the data used in the quantitative study (RQ1 and RQ2) has been anonymized by aggregating the results and redacting any personal information. The qualitative analysis (RQ3) does reveal the identities of the authors of four tweets by public figures/celebrities, namely Al Gore, Katie Mack, Donald Trump and Chelsea Handler.

Results

The first RQ concerns to what extent mentions of the extreme-weather terms have also included terms related to climate change during 2008–2017 (Table 2).

Table 2 shows that during 2008–2017, 13% of all tweets mentioning 'extreme weather' (or related terms) also include 'climate change' (or related terms). Figure 1 and Table 3 indicate that the years 2010, 2011 and 2017 all exhibit a considerable increase in 'causality discourse' compared to the immediately preceding years. In 2010, the proportion of 'causality discourse' tweets jumped from 2.9% (in 2009) to 7.3% and made another significant increase in the following year (2011), reaching 15.6%. After several years of gradual

Table 2. The proportion of 'causality discourse' during 2008–2017.

	Extreme weather only	Extreme weather AND climate change	Percentage including climate change
Tweets	948,993	123,675	13%
Retweets	786,421	238,087	30%
In total	1,735,414	361,762	21%

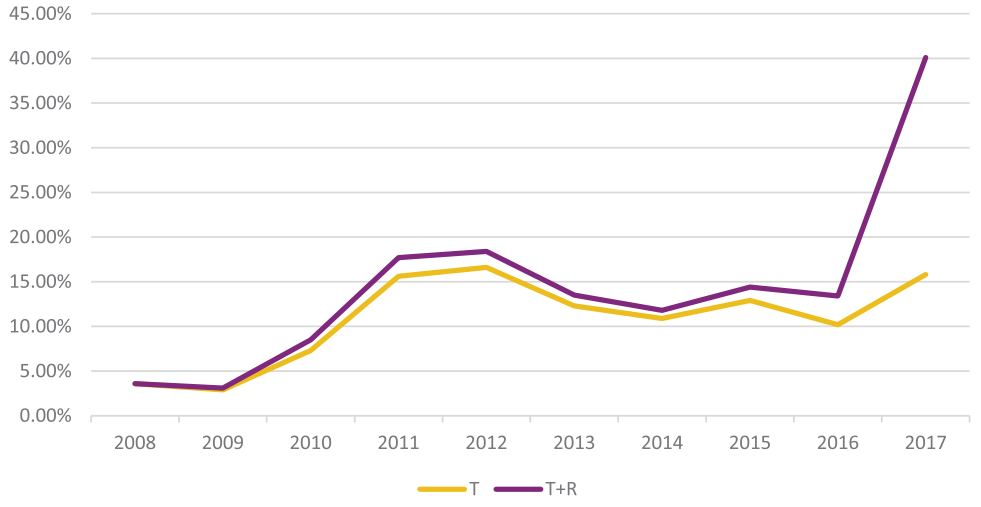

Figure 1. Development of 'causality discourse', 2008–2017.

decline, or only moderate increase, the proportion of 'causality discourse' rose from 10.2% in 2016 to 15.8% in 2017. The rising frequency of retweets witnesses to the growing importance and impact of this practice, which becomes particularly evident in the year of 2017 (40.1%).

Figure 2, which involves RQ2, examines the proportion of the group of users combining extreme weather and climate-change related terms throughout the studied period. In this context, it is possible to imagine a development where a smaller group of, for example, environmental activists and influencers becoming more active and productive, causing the proportion of 'causality discourse' tweets to intensify more clearly in relation to the proportion of the users producing them. However, Figure 2 suggests a generally positive correlation between the proportion of 'causality discourse' tweets and the proportion of users combining extreme-weather and climate-change related terms, which also applies to 2010, 2011 and 2017 (i.e. the three years with considerable increase in 'causality discourse' compared with the years immediately preceding each of them).

Table 3. Tweets and retweets combining 'extreme weather' (or related terms) and 'climate change' (or related terms), 2008–2017.

Year	Extreme weather (tweets)	'Causality discourse' (tweets)	'Causality discourse' tweets in percent (%)	Year	Extreme weather (tweets and retweets)	'Causality discourse' (tweets and retweets)	'Causality discourse' tweets and retweets in percent (%)
2008	1,676	61	3.6	2008	1,676	61	3.6
2009	16,785	491	2.9	2009	16,953	523	3.1
2010	41,657	3,044	7.3	2010	46,125	3,921	8.5
2011	96,403	15,043	15.6	2011	115,871	20,602	17.7
2012	161,031	26,661	16.6	2012	209,331	38,603	18.4
2013	158,500	19,561	12.3	2013	222,282	30,082	13.5
2014	154,656	16,983	10.9	2014	272,409	32,157	11.8
2015	115,214	14,875	12.9	2015	215,298	31,181	14.5
2016	92,772	9,491	10.2	2016	198,778	26,686	13.4
2017	110,299	17,465	15.8	2017	436,691	177,946	40.1

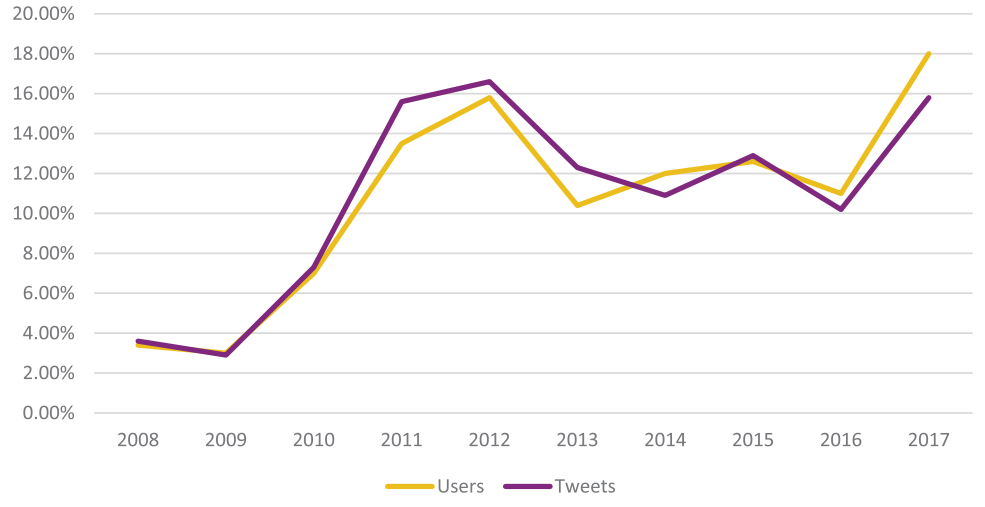

Figure 2. Percentage of tweets including extreme weather AND climate-change related terms, and percentage of users who include extreme weather AND climate change related terms.

Understanding the dynamics of intensified activity

In 2010, it is possible to observe that the proportion of 'causality discourse' rose considerably, in particular in August, focusing on severe heatwaves in eastern parts of the USA, Africa and Russia and flooding in the USA and Pakistan, together with a viral engagement in climate science by Hollywood celebrity Leonardo DiCaprio. In 2011, the increasing share of 'causality discourse' seems mainly to be linked to the UN-led conference on climate change in Kampala, Uganda, which was held in November. (This month represents more than a third of all tweets including 'causality discourse' during the year.) In connection with the conference, an IPCC report was published, emphasising that anthropogenic greenhouse gas emissions lead to more flooding and extreme precipitation. The IPCC report received support from Al Gore, whose tweet about the report went viral and became the most retweeted tweet in November 2011: @algore: New IPCC report on climate change and extreme weather (2011-11-22). In addition, the Kampala conference was held during a period of flooding in Asia and Australia and droughts and wildfires in the USA. The level of engagement in 'causality discourse' remained more or less the same in 2012 (16.6%), with activity concentrated to July and August, during one of the most severe heatwaves in modern North American history, and October, when Storm Sandy caused devastation in the eastern USA, including the New York region. A slight downtrend in 'causality discourse' followed during 2013–2016, which was characterised by the relative lack of *dynamic relationships* between the three factors (the extreme-event, media-driven science communication and digital-action factors), which will be examined in more detail below, in the qualitative case analysis of 2017.

A case study for understanding the intensified production of 'causality discourse' (RQ3)

The first half of 2017 was characterised by a rather modest production of 'causality discourse'. During January-June, the proportion of 'causality discourse' (tweets and retweets)

during all months was less than 20%. An exception is March (21%), driven by the publication and media circulation of scientific work by Mike Mann and other established climate scientists. The second half of the year witnessed greater production of 'causality discourse', both in absolute figures and in relative terms. This began in July, continued in August, and peaked in September. This was followed by lower production in October and November, but intensified again in December (Figures 5 and 6). It is noteworthy that September and December were the most active months when it comes to tweeting and retweeting extreme weather-related terms (Figures 3 and 4).

The dynamic relationships between all three factors (the September peak)

More precisely, in September, 31% of all tweets and retweets in connection to extreme weather included 'causality discourse', and this trend was already developing strongly during the second half of August (when the proportion of 'causality discourse' was 28%, thus almost reaching the September level). This slowly petered out during the second half of September. The September peak was driven by the hurricanes Irma (late August to mid-September) in the Florida region, and Harvey (late August to mid-September), centred around Texas and Louisiana in the USA, Nicaragua, and Belize. This is also indicated by the leftmost column of Table 4, which lists the most frequently used words in September.

The frequent mention of 'hurricanes', 'waves', 'Irma', and 'Harvey' thus indicates the important role that the *extreme-event factor* plays in the activation of the other two factors. The Irma and Harvey events, which attracted global media coverage, encouraged users to share and retweet (*digital-action factor*) information emanating from established media or environmental organisations that commented on and/or analyzed these events from a climate-change perspective (*media-driven science communication factor*). The ten most retweeted tweets include contributions from *BBC Newsnight* and *NYT*, but also

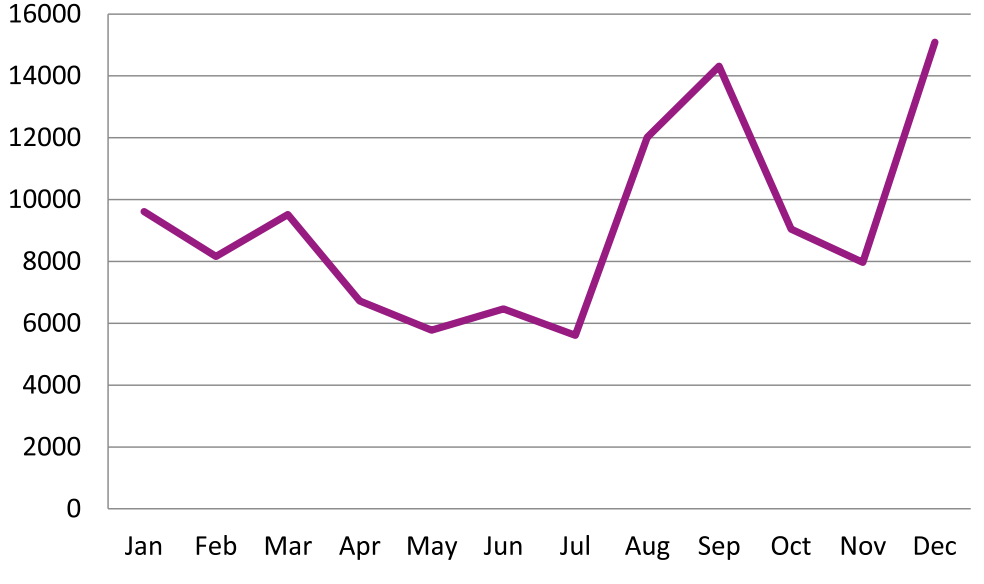

Figure 3. 2017: Extreme weather-related terms, tweets.

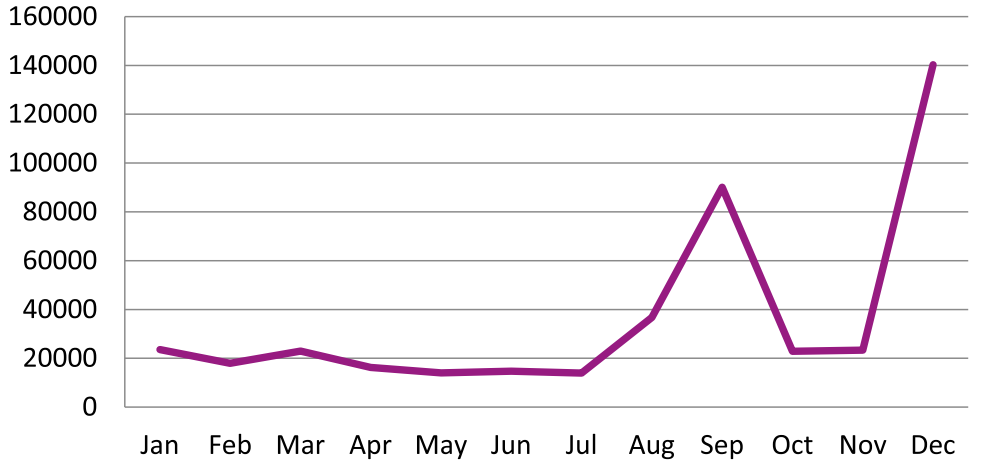

Figure 4. 2017: Extreme weather-related terms, tweets and retweets.

from Greenpeace, *Scientific American*, and the UN. The extreme weather events fuelled further criticism of President Trump's climate policies, which was an ongoing media story throughout 2017. For example, the *NYT* tweet includes an article from 14 September written by reporter Alexander Burns, 'Harrowing Storms may Move Climate Debate, if not G.O.P. Leaders', directly linking the hurricanes to domestic politics, including Trump's reluctance to accept mainstream climate science.

Concerning the digital-action factor, one tweet in particular stands out as having had an especially important impact. More precisely, on September 8, the most active day in September, a tweet was posted by @AstroKatie (Katie Mack), an astrophysics professor at North Carolina State University who is known for her strong media and social media presence, with almost a quarter of a million followers:

> Scientific evidence suggests human-caused climate change is making extreme weather events more common. This is not a political statement.

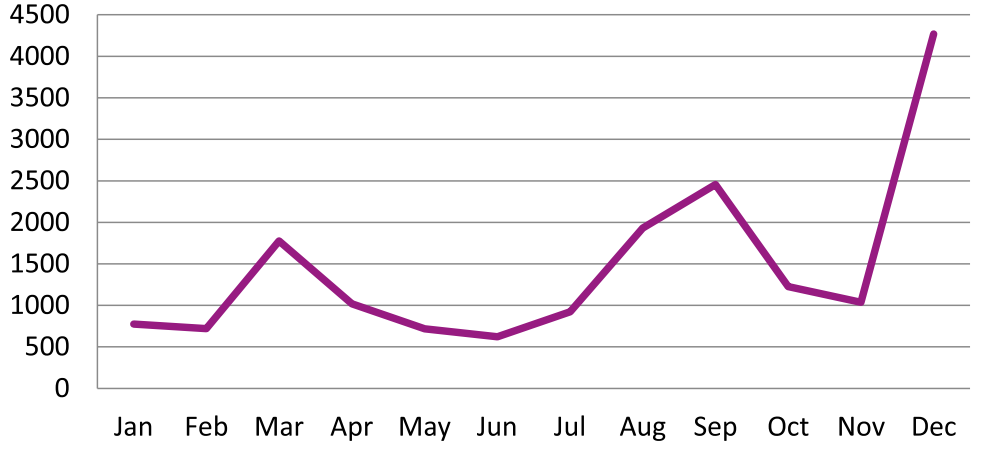

Figure 5. 2017: 'Causality discourse', tweets.

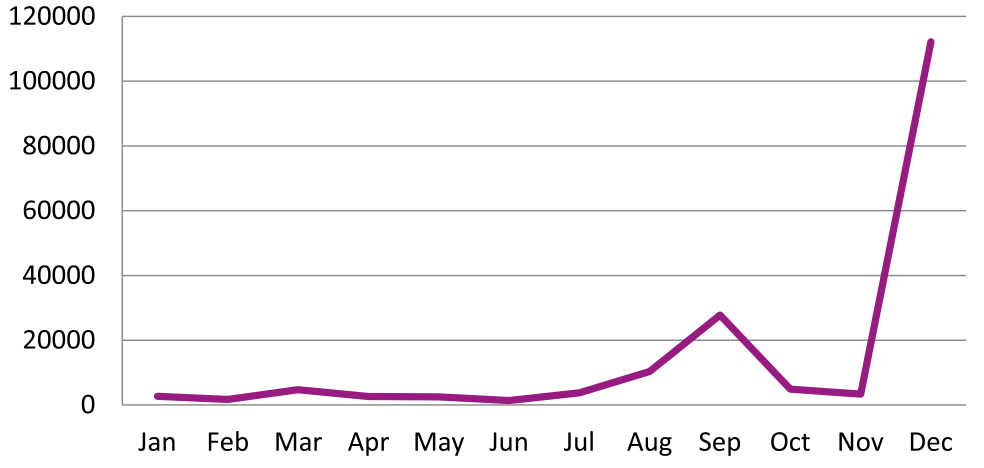

Figure 6. 'Causality discourse': 2017, tweets and retweets.

The tweet was retweeted 15,072 times, which represents more than half of the entire activity during September (54%). As the tweet does *not* mention ongoing extreme events or refer to established media, this might be interpreted as a demonstration of the *autonomous power* of the digital-action factor in relation to the extreme-event and media-driven science communication factors. However, the two latter factors are still present in so far as they serve as important prerequisites for the viral power of AstroKatie's tweet. First, the tweet was published in the midst of Irma, and secondly, the last sentence of the tweet, 'This is not a *political* [my italics] statement', which breaks with the previous sentence's scientific style, should be viewed as a critical comment on the ongoing 'politicization' of the relationship between extreme weather and climate change, and consequently as part of an ongoing mass-media narrative centred around Trump and his climate-skeptical administration.

In conclusion, when it comes to understanding the intensified 'causality discourse' activity around September 2017, the events of Irma and Harvey seem like key drivers of users' engagement. Nevertheless, extensive production of 'causality discourse' might be possible even without strong media attention on an ongoing extreme-weather event of this magnitude. In most cases, however, in the absence of extreme phenomena such as Irma or Harvey, some other 'spectacular' element is required, such as highly rhetorical Twitter content and elements of extensive antagonism between conflicting parties, as will be demonstrated below:

Dynamics of the interaction between the media-driven science communication and digital-action factors, with the extreme-event factor as underlying context (the December peak)

After a digital lull lasting some time (October and November), production of 'causality discourse' increased again in December, primarily during the second half of the month. December was by far the most active month, both in absolute figures and as a proportion of the 'causality discourse'. But here the obvious driving-force is no longer the extreme-event factor, but rather a combination of the media-driven science communication and

digital-action factors. The former concerns journalistic discourse, summarising the year in terms of extreme weather and the assumed connection with climate change, while the latter demonstrates the intensification of the so-called 'Trump discourse', which included the far-reaching conflict that arose between the Trump administration and representatives of mainstream climate science around a viral tweet from public figure Chelsea Handler.

The media-generated science communication factor. To begin with, journalistic summaries of the past year, usually presented around the New Year, are a well-known genre derived from mass media. In mid-December, NYT's Nadja Popovich, together with reporter Brad Plumer, published the article 'How Global Warming Fueled Five Extreme Events' (*NYT* 14 Dec, 2017), in which they list rising temperatures around the world, coral bleaching in the Great Barrier Reef, drought in Africa, wildfires in North America, and the warm 'blob' in the Pacific Ocean (a patch of unusually warm water close to Alaska). This is the most-shared web link during December and the entire year. The impact of the article is also evident in Table 4, showing that 'five', '5' and 'fueled' are among the most frequently used words in tweets during December.

Digital-action factor. Table 4 also suggests that there is an intensified focus on the 'Trump discourse', as 'realdonaldtrump' is by far the most frequently used word during the month. It begins with Trump's tweet on December 28 about 'the COLDEST New Year's Eve on record … '.

> Donald J. Trump @realDonaldTrump
>
> In the East, it could be the COLDEST New Year's Eve on record. Perhaps we could use a little bit of that good old Global Warming that our Country, but not other countries, was going to pay TRILLIONS OF DOLLARS to protect against. Bundle up!

In his characteristic Twitter style (Ott, 2017), Trump makes a sarcastic statement about the very cold December weather in the northeast USA, endowing it with rhetorical hyperbole (COLDEST, 'a little bit of that good old Global Warming', TRILLIONS OF DOLLARS). The most viral of the numerous critical responses to Trump's tweet was made by media celebrity Chelsea Handler, whose tweet generated more than 100,000 retweets. This was by far the most retweeted tweet during 2017, as is also highly visible in Figure 6:

> Chelsea Handler @chelseahandler
>
> Hey dumbass, global warming doesn't only mean extreme heat; it means extreme weather. Hot and cold. Maybe buy a thermometer and shove it up your ass. 28 Dec 2017.

Table 4. Most frequently used words in September and December.

Words Sep 2017	Frequency	Words Dec 2017	Frequency
hurricanes	224	realdonaldtrump	918
know	182	fueled	650
real	139	five	646
heat	138	cold	331
waves	131	causes	262
new	113	scientists	227
causing	110	means	226
people	96	2016	192
irma	95	hot	174
harvey	95	5	171

The reference to the ongoing cold weather might be interpreted as an impact of the extreme-event factor (i.e. the cold weather explains the generation of 'causality discourse' and the December peak) although with much less significance than what Irma and Harvey had for the September peak. More important is the Trump-Handler 'clash' as such, which is very much in accordance with the criteria defining what generates significant attention among traditional media (Galtung & Ruge, 1965): two members of the elite in conflict. Further, what paves the way for the viral effect of Handler's tweet is its humorous style (Berglez, 2016), along with how it balances between serious scientific discourse (on cold weather and climate change) and popular discourse. In December 2017, as a result of Handler's viral tweet, as many as 80% of all tweets and retweets about extreme weather and related terms included 'causality discourse'.

In summary, in the case of the September peak, where the extreme-event factor is highly prevalent (Irma and Harvey), the 'Trump discourse' was 'semi-present', while in December, it was the centre of attention. Even though the important extreme weather events of Harvey and Irma are not conspicuous in December, they are likely to have influenced the social media discourse, not least by serving as important context for understanding the viral effect of Handler's anti-Trump tweet. This kind of transfactual explanatory work is possible to do using retroductive inference (Danermark et al., 2002), that is by asking what basic underlying, sometimes less visible, factors make the gearing up of 'causality discourse' possible in the first place.

Concluding comments

The purpose of this study has been to analyze what generates intensified attention to the connection between extreme weather and climate change in the context of digital communication. Intensified co-occurrence of mentions of extreme weather (or related terms) and climate change (or related terms) on English-language Twitter during 2008–2017 have been examined. Periods of intensified activity were identified during the years 2010, 2011 and 2017, and those in 2017 have been analyzed in more detail. The discourse-analytical interpretations of the data from 2017 demonstrate intertwined relationships between the suggested extreme-weather, media-driven science communication and digital-action factors, although they tend to 'collaborate' differently in different contexts. In one case, there is a dynamic relationship between all three factors (the September peak), while in the other case (December), the media-generated science-communication and digital-action factors seem to trigger the engagement, while the extreme-event factor 'only' provides important context (the hurricanes Irma and Harvey, and the cold wave in late December).

In the field of climate mitigation and adaptation, successful and politically legitimate policymaking presupposes detailed knowledge about the development of the public understanding of climate change. In this regard, this study provides regional, national and international organisations with relevant knowledge about the development and character of the networked public understanding of the connection between extreme weather and climate change. Noteworthy aspects are the gradually increasing interest in this connection during the period 2008–2017, and the dynamic relations between real events, media reporting and digital actions.

The social media approach presented in this study, with its theoretical and retroductive framework and the suggested three-factor approach, might be developed in several ways. Qualitative analyses of other kinds of periods of intensified tweeting about extreme weather and climate change could probably demonstrate new kinds of dynamic relations between the three factors, as well as potentially revealing new factors. It is important to note that most users who tweet about 'causality discourse' do not mention terms such as 'extreme events' or 'extreme weather', but rather focus on the particular type of extreme event, i.e. heat AND climate change, or drought AND global warming. This calls for further studies concentrating on tweets that explicitly mention, for example, heatwaves, flooding, wildfires, droughts, etc. in relation to climate change or associated terms (cf. Al-Saqaf & Berglez 2019).

Finally, in order to achieve a more culturally extensive understanding of these processes, there is need for social media studies focusing on languages, or (mediated) language cultures other than English, e.g. Spanish and Arabic. Studies are also needed covering different countries and regions to examine whether/how social media interactions on 'causality discourse' potentially influence the direction of societies' and nations' climate politics and policy-making.

Notes

1. See further in Al-Saqaf (2016). To get access to the collected data, please contact the authors.
2. Here, alongside Mecodify, we used an additional web tool service, namely www.databasic.io
3. See Sysomos. Replies and retweets on Twitter [Internet]. Sysomos. 2010 [cited 2019 Jan 15]. Available from: https://sysomos.com/inside-twitter/twitter-retweet-stats/

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References

Al-Saqaf, W. (2016, November 15). Mecodify: A tool for big data analysis and visualization with Twitter as a case study. https://mecodify.org/mecodify-whitepaper.pdf

Al-Saqaf, W., & Berglez, P. (2019). How do social media users link different types of extreme events to climate change? A study of Twitter during 2008–2017. *Journal of Extreme Events*, *6*(2), Article 1950002. https://doi.org/10.1142/S2345737619500027

Anderson, A. G. (2011). Sources, media, and modes of climate change communication: The role of celebrities. *Wiley Interdisciplinary Reviews: Climate Change*, *2*(4), 535–546. https://doi.org/10.1002/wcc.119

Anderson, A. G. (2014). *Media, environment and network society*. Palgrave MacMillan.

Anderson, A. A., & Huntington, H. E. (2017). Social media, science, and attack discourse: How Twitter discussions of climate change use sarcasm and incivility. *Science Communication*, *39*(5), 598–620. https://doi.org/10.1177/1075547017735113

Berglez, P. (2016). Few-to-many communication: Public figures' self-promotion on Twitter through 'joint performances' in small networked constellations. *Annals for Istrian and Mediterranean Studies. Series Historia et Sociologia*, *26*(1), 171–184. https://doi.org/10.19233/ASHS.2016.15

Berglez, P., & Lidskog, R. (2019). Foreign, domestic, and cultural factors in climate change reporting. Swedish media coverage of wildfires in three continents. *Environmental Communication*, *13*(3), 381–394. https://doi.org/10.1080/17524032.2017.1397040

Bhaskar, R. (1977). *A realist theory of science*. Harvester Press.

Boykoff, M. T., & Goodman, M. K. (2011). Conspicuous redemption? Reflections on the promises and perils of the 'celebritization' of climate change. *Geoforum; Journal of Physical, Human, and Regional Geosciences*, *40*(3), 395–406. https://doi.org/10.1016/j.geoforum.2008.04.006

Broersma, M., & Graham, T. (2012). Social media as beat. Tweets as a news source during the 2010 British and Dutch elections. *Journalism Practice*, *6*(3), 403–419. https://doi.org/10.1080/17512786.2012.663626

Castells, M. (2009). *Communication power*. Oxford University Press.

Cody, E. M., Reagan, A. J., Mitchell, L., Dodds, P. S., & Danforth, C. M. (2015). Climate change sentiment on Twitter: An unsolicited public opinion poll. *PLOS ONE*, *10*(8). https://doi.org/10.1371/journal.pone.0136092

Cordner, A., & Schwarz, E. (2018). Covering wildfires: Media emphasis and silence after the Carlton and Okanogan complex wildfires. *Society & Natural Resources*. https://doi.org/10.1080/08941920.2018.1530816

Danermark, B., Ekström, M., Jakobsen, L., & Karlsson, J. C. (2002). *Explaining society. Critical realism in the social sciences*. Routledge.

Dixon, G., Bullock, O., & Adams, D. (2018). Unintended effects on emphasizing the role of climate change in recent natural disasters. *Environmental Communication*. https://doi.org/10.1080/17524032.2018.1546202

Fairclough, N. (1995). *Media discourse*. Arnold.

Galtung, J., & Ruge, M. H. (1965). The structure of foreign news. The presentation of the Congo, Cuba and Cyprus crises in four Norwegian newspapers. *Journal of Peace Research*, *2*(1), 64–90. https://doi.org/10.1177/002234336500200104

Glynos, J., & Howarth, D. (2007). *Logic of critical explanation in social and political theory*. Routledge.

Hansen, L. K., Arvidsson, A., Aarup Nielsen, F., Colleoni, E., & Etter, M. (2011). Good friends, bad news – affect and virality in Twitter. In J. J. Park, L. T. Yang, & C. Lee (Eds.), *Futuretech 2011, part II, CCIS 185* (pp. 34–43). Springer.

Hulme, M. (2014). Attributing weather extremes to 'climate change': A review. *Progress in Physical Geography: Earth and Environment*, *38*(4), 499–511. https://doi.org/10.1177/0309133314538644.

Hulme, M. (2017). *Weathered. Cultures of climate*. Sage.

IPCC. (2014). Climate change 2014. Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Working group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. https://ipcc.ch/report/ar5/wg2/

Janković, V., & Schultz, D. M. (2016). Atmosfear: Communicating the effects of climate change on extreme weather. *Weather, Climate, and Society*, *9*(1), 27–37. https://doi.org/10.1175/WCAS-D-16-0030.1

Kirilenko, A. P., Molodtsova, T., & Stepchenkova, S. O. (2015). People as sensors: Mass media and local temperature influence climate change discussion. *Global Environmental Change*, *30*, 92–100. https://doi.org/10.1016/j.gloenvcha.2014.11.003

Leetaru, K. H., Wang, S., Cao, G., Padmanabhan, A., & Shook, E. (2013). Mapping the global Twitter heartbeat: The geography of Twitter. *First Monday*, *18*(5-6), 1–31. https://doi.org/10.5210/fm.v18i5.4366

Lin, Y.-R., Keegan, B., Margolin, D., & Lazer, D. (2014). Rising tides or rising stars?: Dynamics of shared attention on Twitter during media events. *PLOS ONE*, *9*(5), 1–12. https://doi.org/10.1371/journal.pone.0094093

Liu, J. C., & Zhao, B. (2017). Who speaks for climate change in China? Evidence from Weibo. *Climatic Change*, *140*(3-4), 413–422. https://doi.org/10.1007/s10584-016-1883-y

Marwick, A. (2013). *Status update: Celebrity, publicity & branding in the social media age*. Yale University Press.

Morehouse, B. J., & Sonnett, J. (2010). Narratives of wildfire: Coverage in four U.S. newspapers, 1999–2003. *Organization & Environment*, *23*(4), 379–397. https://doi.org/10.1177/1086026610385901

Morley, D. (2000). *Home territories. Media, mobility and identity*. Routledge.

Olausson, U. (2019). Meat as a matter of fact(s): The role of science in everyday representations of Livestock production on social media. *Journal of Science Communication*, *18*(06), A01. https://doi.org/10.22323/2.18060201

Ott, B. L. (2017). The age of Twitter: Donald J. Trump and the politics of debasement. *Critical Studies in Media Communication*, *34*(1), 59–68. https://doi.org/10.1080/15295036.2016.1266686

Reisigl, M., & Wodak, R. (2012). The discourse-historical approach (DHA). In R. Wodak & M. Meyer (Eds.), *Methods of critical discourse analysis* (2nd ed., pp. 87–121). Sage.

Sparks, C. (2007). *Globalization, development and the mass media*. Sage.

Veltri, G. A., & Atanasova, D. (2017). Climate change on Twitter: Content, media ecology and information sharing behaviour. *Public Understanding of Science*, *26*(6), 721–737. https://doi.org/10.1177/0963662515613702

Yeo, S. K., Handlos, Z. J., Karambelas, A., Su, L. Y.-F., Rose, K. M., Brossard, D., & Griffin, K. S. (2017). The influence of temperature on #ClimateChange and #GlobalWarming discourses on Twitter. *Journal of Science Communication*, *16*(5), A01. https://doi.org/10.22323/2.16050201