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From "Knowledge Brokers" to Opinion Makers: How Physical Presence Affected Scientists' Twitter Use During the COP21 Climate Change Conference

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Professional norms of science have played an important role in discouraging scientists from raising their voices in public. However, they are increasingly using social media to discuss and publicize their research. This study investigates the 2015 United Nations Climate Change Conference summit and examines scientists' social media use by analyzing "digital traces" that scientists left on social media during the summit. Using geolocated tweets, we compare the Twitter use of scientists who attended the conference with those who did not. Combining automated, quantitative, and qualitative content analysis, the study shows how scientists participating in the conference provided live reporting and formed a transnational network. Scientists at the conference and elsewhere engaged in political advocacy, indicating a shift toward a new pattern of hybrid science communication, which includes characteristics that have formerly been attributed to journalism and advocacy.

Keywords: science communication, social media, climate change, Twitter

In December 2015, world leaders gathered in Paris to negotiate and sign a new climate change mitigation agreement. Journalists, civil society actors, and scientists also took part in the summit. After several climate summits that produced no significant results or consequences, the 2015 United Nations Climate Change Conference (COP21) was seen as decisive—especially given that the Kyoto Protocol is set to expire in 2020. As climate science and scientific data have always been at the heart of climate change debates, scientists have become important actors in climate politics and public debates on climate change.

The statement, "The scientists have spoken, now it is time for leaders to act," was frequently repeated during the Paris summit, which means that scientists have completed their task by providing evidence that anthropogenic climate change exists. However, the field of climate change can be considered "postnormal" science, "where facts are uncertain, values in dispute, stakes high and decisions

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urgent" (Funtowicz & Ravetz, 1993, p. 744). In such postnormal situations, science is expected to actively manage the uncertainties associated with its findings and to be transparent about the value questions involved when formulating policy advice. Yet, scientists debate whether they should advocate certain policies (Nerlich & McLeod, 2016), as this requires, to some extent, deviating from the deeply rooted—but not undisputed—communicative role of scientists as "honest brokers" of scientific knowledge (Pielke, 2007) who present facts rather than interpretations (Peters, 2013).

Today, the vast majority of scientists consider explaining their work to the public to be an important part of their social role (Frankel, 2015; Wyndham et al., 2015). However, their engagement in public (online) discussions is often limited to disseminating research findings. Active participation in public policy deliberations in their area of expertise—and thus directly expressing their own opinions—remains one of the fields of duty for which scientists feel the least responsible (Frankel, 2015; Wyndham et al., 2015). This perception seems to be influenced by more traditional norms of science communication, which emphasize scientists' role in explaining research findings rather than advocating certain values or policy positions. Current science communication is best characterized by the coexistence of various communication models and different conceptions of the role of scientists in public communication (cf. Pielke, 2007), which depend on the scientist's cultural, organizational, and situational context (Bucchi & Trench, 2014b).

Many scientists frequently use social media to publicize their research (van Noorden, 2014). Some have even argued that scientists must use social media to disseminate their research findings because it gives them the opportunity to communicate to a broad audience, including the general population (van Eperen & Marincola, 2011). However, the increasing use of social media might encourage the expression of personal views rather than just facts, particularly in a field of postnormal science, such as climate change.

"Global political media events" (Brüggemann & Wessler, 2014) such as international climate conferences that involve actors from different fields, where the future global policy agenda on climate change is at stake, might also encourage deviations from traditional professional norms. In this study, we investigated how scientists use social media to share information or their personal opinions on climate change in the context of COP21.

We first explored how scientists used social media during COP21 by analyzing "digital traces" that scientists left on social media during the summit. Digital traces are "'footprints' of our digital media use" (Couldry & Hepp, 2016, p. 161), which serve as lasting evidence of all actions and interactions that users leave in the digital world, either deliberately or unintentionally. We examined Twitter use in part because these digital traces are deliberately produced and publicly visible. Furthermore, Twitter is a professional rather than a personal platform, which is widely used by scientists (van Noorden, 2014) and has the potential to connect actors from different spheres on a current topic or event.

These digital traces should be put into context by taking into account the likelihood that scientists' social media practices might differ depending on the context in which they use such media. The climate conference presented a special situation for (climate) science communicators. As a global media event, it might have given scientists the opportunity to showcase themselves and their research at a time when climate change featured prominently on the public agenda. Furthermore, the conference enabled scientists to meet, network, and communicate with other actors interested in climate change, such as journalists, politicians, and civil society activists. In sum, the conference might have facilitated further deviations from traditional norms and fostered higher personal engagement from scientists.

We next examined whether the Twitter use of scientists who attended the conference differed from those who did not attend. The analysis enhances our understanding of the extent to which social contexts can impact how scientists communicate on social media and the role that social media play in bypassing traditional gatekeepers and changing scientific norms.

Science Communication and the Role of Social Media

This section provides an overview of how scientists' professional norms regarding their involvement with the public have developed over time and what role social media play in this process. In the past, scientists' active engagement with the public would have contradicted the professional norm that scientists should refrain from public involvement (Dunwoody & Ryan, 1985; Schneider, 1986). Directly addressing the public—and thus transgressing the boundaries of the profession—was seen in the past as deviant behavior by scientists that should occur only in "marginal situations" (Bucchi, 1996, p. 375). It was furthermore seen as a distraction from "real" scholarly work (Hoffman, 2015). These views, which emerged during the increasing specialization of the sciences in the 19th century, have changed in recent decades (Dunwoody, 2014), but have not completely vanished (Bucchi & Trench, 2014b; Peters, 2013; Rödder, 2012).

As the media have increasingly paid more attention to science since the 1980s (Bauer, 2012), interactions between scientists and journalists have increased. Surveys of scientists show that they take media logics into account when communicating in public (Peters, 2013). There is an increasing professionalization of organized public relations activities in science organizations (e.g., Borchelt & Nielsen, 2014) and a more proactive approach to "selling science" (Nelkin, 1987) that involves the close cooperation of scientists and journalists. But the professionalization of science communication should not necessarily be interpreted as an indication of the mediatization of science. For example, public relations professionals act according to the rules and logics of journalistic attention, but they also shield scientists from having to adapt to media logics (Peters, Heinrichs, Jung, Kallfass, & Petersen, 2008).

Yet, studies suggest that if scientists interact with journalists and the public, they still imagine a model of separate (scientific and public) arenas: The former produces scientific knowledge that can be explained to broader audiences in the latter. The public is not expected to interfere in the scientific arena. This model has been rather stable across different surveys of scientists in recent decades (Peters, 2013). Studies have detected only a moderate mediatization of science compared with other social domains (Rödder & Schäfer, 2010), as only a few visible scientists (Goodell, 1977) or even "celebrity scientists" (Giberson & Artigas, 2007) have developed a more intimate relationship with the media. This alleged mediatization process has raised concerns about the loss of scientific autonomy: Scientists are drawn into political conflicts as experts who serve political purposes (Bauer & Bucchi, 2007; Holliman, Whitelegg, Scanlon, Smidt, & Thomas, 2009; also see a number of contributions in several edited volumes on science communication, such as Bucchi & Trench, 2014a; Rödder, Franzen, & Weingart, 2012; Weingart, 2002). As scientists have become more visible, there is a debate over whether they should take part in the public dialogue only in their capacity as "knowledge brokers," or whether they should also voice their opinions and values.

Not only have scientists' views on public engagement changed, but they also have more diverse means of communicating with the public and other actors. As a professional community, scientists acknowledge the general importance of online media, and social media in particular. In a survey of neuroscientists from the United States and Germany, half of the respondents indicated that they thought social media content can strongly influence how the public thinks about science (Allgaier, Dunwoody, Brossard, Lo, & Peters, 2013). Although in 2012 only one in 40 scientists was actively tweeting, the number of scientists with Twitter accounts is rising (Priem, Costello, & Dzuba, 2011). Social media use, and Twitter in particular, has become part of the professional life of many scientists (van Noorden, 2014). It enables them "to communicate their research quickly and efficiently throughout each corner of the world" (van Eperen & Marincola, 2011, p. 1). They follow scientific discussions, comment on their own and others' research, and post (work-related) content, without relying on intermediaries (van Noorden, 2014). The visibility of scholarly work on social media is also seen as a measure of the social impact of (and public attention to) scientific work (Eysenbach, 2011). Therefore, a scientist's construction of a public "digital identity" (Couldry & Hepp, 2016) for herself as an active and productive member of the scientific community can be important for her reputation and success.

During the production of scientific output, social media also can be helpful for scientists, as they can increase connections with other researchers, develop ideas with new collaborators, receive prereview feedback, and disseminate and discuss results (Darling, Shiffman, Côté, & Drew, 2013). Furthermore, live tweeting from conferences has become a widespread habit among scientists (Darling et al., 2013; Shiffman, 2012), and can even inspire global discussions about the research being presented (Shiffman, 2012). Previous work has shown that scientists use Twitter during conferences to "make notes, share resources, hold discussions and ask questions as well as establishing a clear individual online presence" (Ross, Terras, Warwick, & Welsh, 2011, p. 214).

By connecting scientists with journalists and political actors, social media such as Twitter can also organize "connective action" (Bennett & Segerberg, 2012) across traditional boundaries. They can connect users with peers who have diverse and opposing opinions who would otherwise be entrenched in their own like-minded networks (Himelboim, McCreery, & Smith, 2013). Social media networks may thus reveal "discourse coalitions" (Hayer, 1993) or "interpretive communities" (Zelizer, 1993) that influence public debates beyond the social media sphere. In summary, social media use has different potential benefits for scientists: It helps them with some aspects of their work, connects them with actors from other societal fields, and allows them to construct a "digital self." Yet, we know little about the extent to which scientists use these different social media-enabled functions.

Hypotheses

As outlined, the role of scientists has broadened and new practices such as the use of Twitter have become established. This also leads to a diversification of the content published by scientists: Whereas they previously only "produced knowledge" in the form of scientific publications and perhaps gave expert interviews to media outlets, they can now also convey information directly to the public, provide live reporting about their research activities (e.g., field trips, meetings, conferences), and give personal updates on their private lives. This article analyzes how the context—that is, COP21—is related to scientists' tweeting behavior. Our hypotheses are outlined below.

Previous studies have shown that the "conference environment is conducive to academic Tweeting" (Ross et al., 2011, p. 229). The general trend of scientists publicly sharing updates about their research, personal lives, or online content is therefore likely to be reinforced by COP21 as an event. Attendance at the conference might give scientists the opportunity to publish updates about what is happening there and how they think about it, thus deliberately leaving digital traces. Scientists participating in the summit might also use social media to promote their online identities (Ross et al., 2011), given that being "on site" might enhance their reputation. We hypothesized that:

H1: Scientists who attended COP21 would be more active on social media, that is, would publish more climate change-related tweets per person, than those who did not attend.

We furthermore assumed that physical presence affects the extent to which scientists engage with other users, as conference attendance might serve to initiate discussions. An international conference with participants from all over the world and from different professional backgrounds offers an opportunity to connect people who would not have met otherwise. This can lead to a "camp feeling," as "the temporal and spatial confines of the conferences as well as the mutual acquaintance between the actors—many of them have attended previous conferences together—can lead to a temporary blurring of professional roles" (Wozniak, Wessler, & Lück, 2016, p. 4). Being on site allows scientists and other actors to talk to each other in person, but they might also interact via social media. Thus, we assumed that the users' locations would influence their communication networks. We hypothesized that:

H2: On site, scientists would engage in more interactions with other users compared with those who did not attend the conference.

We furthermore anticipated the content of their tweets to vary. We expected that:

H3: Scientists who attended the summit would provide more live reporting than those who did not.

Although scientists who did not attend the conference might also report from other events they attended, we expected them to do so to a much smaller extent. Thus, we assumed that scientists who went to COP21 would diverge more noticeably from traditional norms and would behave more like journalists. Twitter users have the opportunity to include links in their tweets to external sources (e.g., news articles or scientific papers). We expected that:

H4: *Scientists "on location" would share more photos as part of their live reporting.*

H5: *Scientists who were not present would share more links to websites, such as media outlets.*

Because COP21 was a global political event at which the future of climate change was at stake:

H6: *Scientists who attended the summit might also have been more inclined to tweet about their opinions, personal views, judgments, and calls to action than scientists who did not attend—that is, engaging in behavior that is usually attributed to civil society activists such as trying to influence opinions.*

This could be seen as an even bigger shift from the traditional role of scientists as distant observers.

Method and Data Collection

We investigated scientists' social media use by analyzing the digital traces they left behind during COP21. Digital traces "are a form of digital data which becomes meaningful only when a sequence of 'digital footprints' is related to a certain actor or action" (Couldry & Hepp, 2016, p. 162). The data lack meaning on their own; the context is crucial to the analysis. In our case, the collection of a large number of messages is worthless if it does not give information about the communicators and their social context. This is why Stephansen and Couldry (2014), for example, argue that a qualitative approach to social media data, and Twitter in particular, is needed to understand how social media "become embedded within particular contexts and used by social agents for their own purposes" (p. 1224). Furthermore, big data approaches often neglect how social actors and practices differ depending on their settings (Couldry & Powell, 2014).

As mentioned previously, we concentrated on Twitter because it is a professional rather than a private network; it focuses on current events and is relatively widely used by scientists (van Noorden, 2014). Twitter not only allowed us to analyze the content of tweets and scientists' interactions, it also provided user information (e.g., scientific affiliations), which was crucial for the purpose of this study. For a two-week period during COP21 (November 30–December 12, 2015), we gathered geolocated tweets covering the area of the conference venue to capture the tweets of people who attended the summit. Previous research has shown that it is "difficult from Tweet postings to ascertain who is actually attending an event without close study of the content" (Ross et al., 2011, p. 223). Geolocation is a convenient indicator for attendance, so we assumed that people who were at the conference venue also participated in the summit. We gathered 113,366 geolocated tweets using the R package streamR (Barberá, 2015).

We narrowed down this large number of tweets to analyze scientists' social media use. First, we formed a subset of 32,306 English-language tweets, which included 2,473 tweets with climate-related Twitter handles (#COP21, @COP21, #climatechange, #globalwarming), as we were interested in scientists' contributions to the climate debate rather than their general tweeting behavior. Despite having specified the exact coordinates of the conference venue, the area from which tweets were collected exceeded the coordinates and had to be manually limited after the data collection, leading to 1,765 tweets with the exact coordinates. In this data set, we identified 418 unique users. We used automated content analysis, or more specifically a dictionary method using the quanteda R package (Benoit & Nulty, 2017) to classify Twitter users based on their user description as scientists (*N* = 57), who sent a total of 246 tweets: We refer to this data set as "at conference venue." We compared the automated coding with a manual coding of a random subsample and gained highly reliable results (Krippendorff's α = .90).

We compared our first sample with tweets sent by users who did not attend the conference. These tweets were collected using the following handles: #COP21, @COP21, #climatechange, #globalwarming (*N* = 1,558,163). We formed a subset of geolocated tweets (*n* = 1,550)[1] and excluded those with the geolocation of the conference venue (leading to *n* = 1,240) to make sure that the scientists included in this data set did not attend the summit. Furthermore, only English-language tweets were included (*n* = 921). In this second data set, we found 555 unique users, 77 of whom we were able to classify as scientists (for further information on their user descriptions, see the Appendix). We double-checked whether any users were included in the initial geolocated data set because it was possible that users changed locations, and we had to exclude 25 scientists from the sample. Hence, the second data set (which we call "someplace else") consisted of 48 scientists, who sent a total of 83 tweets.

In the next step, two coders conducted a qualitative content analysis of a subsample of 150 randomly chosen tweets to determine what communicative function the tweet fulfilled. The two categories "live reporting" and "opinion making" were deducted from the conceptual reasoning outlined above as "a priori categories" (Kuckartz, 2014). Tweets that did not fit into either of these categories were categorized using open-ended descriptions; afterwards, the descriptions were summarized into recurring categories. Based on this inductive structuring content analysis (Schreier, 2014), we identified seven content categories (described in more detail in the Results section), which were subsequently used for a manual quantitative content analysis of the scientists' tweets. Furthermore, we analyzed the content of all hyperlinks in the scientists' tweets and classified them into seven categories (photo, media website, civil society website, academic website, business website, governmental website, other), which were used for the quantitative analysis.[2] For both variables, it was possible to code multiple categories. The tweets were coded by two coders. After two training sessions, intercoder reliability was tested and produced sufficiently reliable results (content of tweet: Krippendorff's α = .67; links: Krippendorff's α = .75).

[1] Based on extant research (Bruns & Stieglitz, 2013; Graham, Hale, & Gaffney, 2014), we know that the geolocation function is activated by only a small number of users, leading to the small number of geolocated tweets.

[2] We furthermore included a category for "broken links" (*n* = 1), which was omitted from the following analysis as it did not provide any meaningful information.

Results

Scientists on Twitter

We examined scientists’ social media use during COP21. We identified 57 scientists in our sample of 418 conference attendees using automated content analysis to detect certain keywords (e.g., *professor*, *scientist*) in the user descriptions of their Twitter profiles. Scientists made up about 13% of the users in the sample. Because the data were collected based on the users’ geolocation, we can be certain that all of the scientists in the first data set were in Paris when COP21 was taking place. Based on the locations that users specified in their Twitter account, we mapped the name of the city (if possible) or country (see Figure 1). The scientists who took part in the Paris summit were from all over the world—more than 20 different countries.[3]

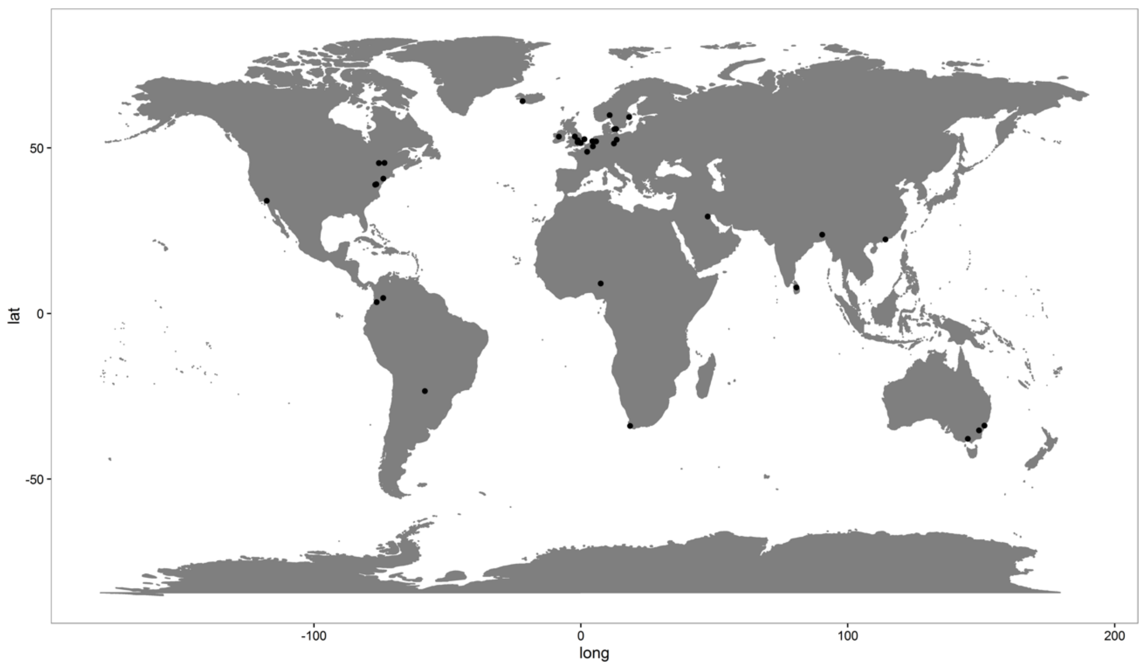

Figure 1. Map of origins of scientists tweeting from the conference venue, based on the user locations as specified by 46 of 57 users.

[3] If users mentioned more than one location, only the first location mentioned was taken into account, assuming that it indicated the most important one.

In the second data set, tweets were initially collected based on climate-related Twitter handles. To make both data sets comparable, and to verify that users in the second data set were not present at COP21, we included only users in our analysis who activated the tracking function in their devices and thus indicated their geolocation. Of the 555 unique users providing information on their geolocation in the second data set, we were able to classify 48 users as scientists who did not attend the conference (approximately 9% of the users in the second sample). Because we selected our cases based on geolocation, it was of interest to examine where the users were when they tweeted. We see that most of the scientists not present at COP21 were in North America and Europe, although some were spread over other continents as well (see Figure 2). Hence, the scientists in both data sets came from different regions of the world.

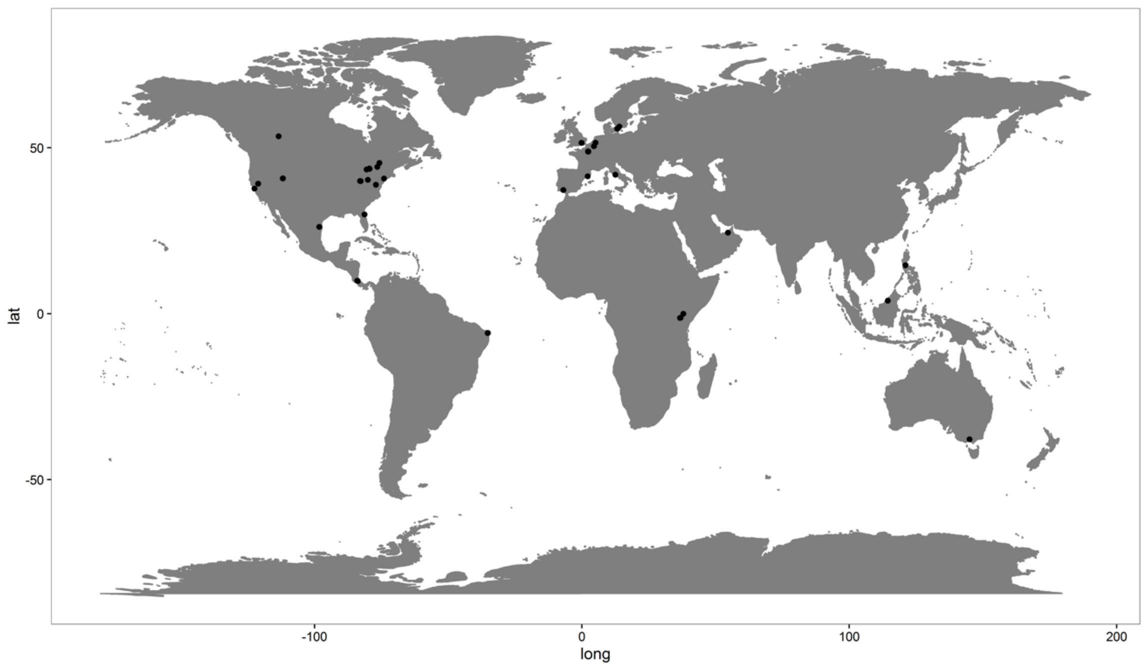

Figure 2. Geolocation of users from someplace else, based on the geocoordinates of all 48 users in the sample.

Figure 3 shows how the scientists' climate-related Twitter activity developed over the course of the summit. The solid line indicates tweets sent by scientists from the conference venue, and the dashed line indicates those that were sent by scientists from someplace else. COP21 started on November 30, 2015. At the beginning of the summit, there was relatively little Twitter activity. At the end of December 5, the final version of the draft agreement was completed and the ministerial-level political negotiations started. On December 6, no tweets were sent by scientists from COP21, perhaps because it was a Sunday and, with the exception of closed-door meetings, no activities took place at the conference venue (United Nations Framework Convention on Climate Change, 2015). One day later, on December 7, the environment, energy, and foreign ministers came to Paris to take over from the delegates and to reach a final agreement. On Twitter, there was a sharp increase in attention, and the number of tweets per day reached its maximum. Attention peaked again when the summit ended, which was scheduled for December 11, but was prolonged at the last minute for one more day until December 12, when the Paris Agreement was finally agreed by the 192 states.

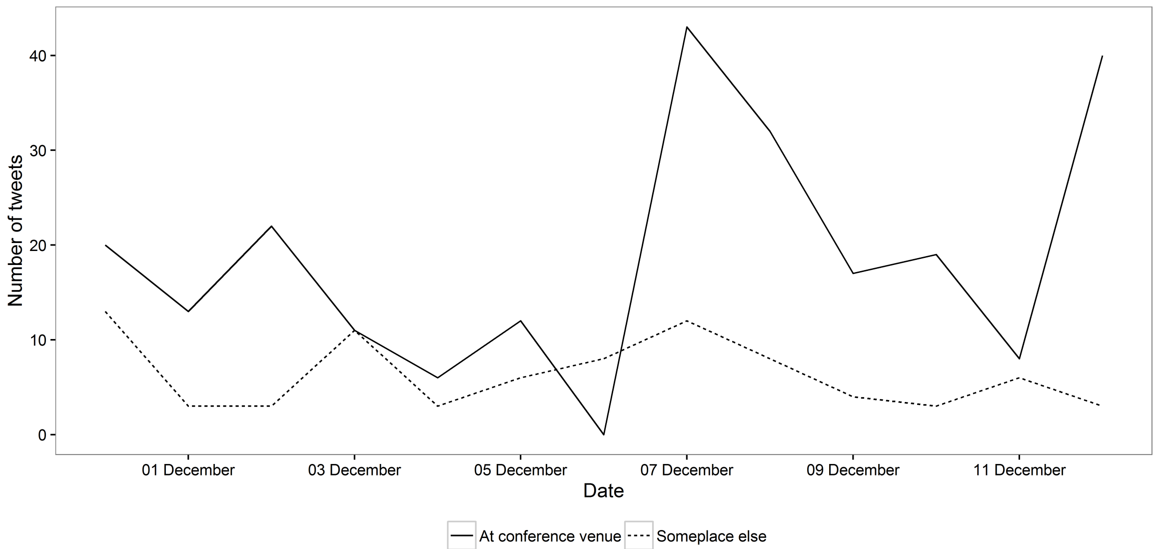

Figure 3. Tweets by scientists over time. The solid line is based on 246 tweets; the dashed line is based on 83 tweets.

Overall, the scientists who participated in the summit were much more active on Twitter than those who did not, sending a total of 246 climate-related tweets or an average of four each. In contrast, the scientists from the second sample sent only 83 tweets, for an average of two each. This finding supports our first hypothesis that scientists on location were more active on social media and sent more tweets per person than those who did not attend the summit (H1).

Yet, this does not necessarily mean that conference attendees also engaged in more interactions with other users. We used network analysis measures to examine their interactions (including @ mentions and retweets). Figure 4 shows the network of scientists who tweeted from the summit in Paris, and Figure 5 shows the network of scientists who were not there in person. Gray nodes with a label indicate scientists in the network, and white nodes represent other users they interacted with.

Figure 4. Network of scientists at the conference venue. Gray nodes with a label indicate scientists in the network, and white nodes represent other users they interacted with.

Although the number of scientists in both networks was relatively similar (57 in the conference data set and 48 from someplace else), the networks widely differed regarding the number of other users the scientists interacted with. In the network of scientists at the conference venue, we found 201 nodes (i.e., Twitter users) and 174 edges (i.e., connections between users). In the network of scientists from someplace else, we found 107 nodes and 62 edges.

Figure 5. Network of scientists from someplace else. Gray nodes with a label indicate scientists in the network, and white nodes represent other users they interacted with.

To examine the extent to which scientists interacted with other users, we analyzed the out-degree of scientists in both networks. Out-degree centrality measures the number of outgoing ties (i.e., the number of users scientists mentioned in their tweets). The average out-degree for scientists who participated in COP21 was 3.14, and it was 1.29 for scientists who did not attend. Hence, the finding supports our hypothesis that scientists who took part in the summit interacted more with other users on Twitter than those who did not attend (H2). In line with this finding, we also found more isolated nodes (i.e., Twitter users who did not interact with others at all) among scientists who did not attend (n = 30) compared with those who did (n = 15).

Tweet Content

We manually coded the climate-related tweets sent by scientists during COP21 to analyze their content. In the initial qualitative coding, seven content categories emerged:

Live Reporting. This category includes user reports of what is happening or has just happened, using a neutral perspective without giving background information or a judgment. Live reporting often occurred in the context of the climate conference, as in the following examples:

> Standing ovation in plenary and all overflow rooms #COP21 #climatechange

> President Hollande and UNSG Ban Ki-moon just joined the plenary. #COP21 #climatechange.

Here, scientists acted as impersonal reporters on site and did not refer to themselves in their tweets. Some scientists who did not attend COP21 reported live from other contexts concerning climate change (e.g., from a demonstration in Sweden or other presentations):

> I think they heard us. . . . @FossilFreeLU #manifestation outside the main building of @lunduniversity #climatechange

> #today #FES welcomes Chaminade College to #yorku #yesforaday #whales #climatechange #oceans [Link to photo of presenter in front of slide]

Information Sharing. If a user provided information not as a witness, but instead shared or relayed information from other sources, the tweet was coded as information sharing. Scientists mostly shared media content or quoted from news stories: "'Women Are the Key to a Successful Climate Strategy' @TIME #climatechange [Link to article from *TIME Magazine*]."

Dissemination of Own Research. Tweets in which a user wrote about or shared links related to their own research activities and publications were coded as dissemination of own research. Researchers used these tweets to publicize their own work and increase their reach. Scientists at COP21, for example, announced their upcoming presentations: "I'll present our 'decarbonizing development' report tomorrow in the China Pavilion, 10:30 am, #cop21." Nonattendees instead rather linked to their publications: "#climatechange is real. Just ask my environmental science final (& the temp in December) [Link to screenshot of paper]." These preliminary findings indicate that the context of the conference was related to how scientists use Twitter as "acts of self-affirmation" (Murthy, 2013, pp. 27–30) because it gives them new opportunities to present themselves and their work.

Personal Updates. We coded tweets that reported personal activities or emotions (rather than neutral information) unconnected to their research as personal updates. Those usually referred to everyday or leisure activities. Personal updates from the conference dealt with, for example, food or the emotional effect of "being there":

> Crepe break in the sun at #cop21paris2015 - if not for #climatechange, life is beautiful!

> Thrilled to finally be at Le Bourget for #COP21 . . . my first #climatechange conference!

Nonattendees tweeted about other aspects of their personal lives in relation to climate change:

> My tulips believe in #globalwarming, but what do they know? #70indecember @Philadelphia [Link to photo]

> Climate change #yolo #icecap #globalwarming #rechauffementclimatique. . . . [Link to photo of herself drinking iced coffee]

Opinion Making. The a priori category of opinion making was split in two new categories because these tweets differed in their choice of wording. A tweet was coded as a *call to action* if the user explicitly called on others to take any kind of action:

> Join @elonmusk — #DemandClimateAction and a better future [Link to picture of Elon Musk] #cop21 #climatechange

> The world must act now to save the planet for future generations #COP21 #climatechange.

Tweets coded as a *value judgment* involved the user stating his or her own opinion, feeling, or judgment on a matter:

> Proud to see mentions of "intergenerational equity" in #COP21 decision as well as legal agreement. #climatechange

> Future generations won't be satisfied that we only waited on our political leaders to take action #climatechange #COP21 #ParisClimateTalks

There were no apparent differences in the language used between calls to action and value judgments from scientists on site in Paris versus elsewhere.

Other. In the final category, we collected tweets that made no sense on their own or that were an incomplete fragment of a discussion:

> Memories ???? #TentCity #ClimateChange @ Manila Hotel

> @yfreemark #COP21 Amen!

The categories derived by the qualitative analysis of tweets were consequently used for a quantitative content analysis. The results show that scientists on location at COP21 mainly used Twitter for "live reporting" (73% of tweets; see Figure 6, left column). The scientists in the second sample were unable to tweet live about what was happening at COP21, but they informed their followers live about other events or conferences they attended related to the climate change debate, such as demonstrations:

"#Peopleclimatemarch in #Rome thinking about #cop21paris2015 #climatechange one earth, one planet. . . . [Photo of protesters]." For scientists absent from the conference, live reporting was significantly less important and occurred in only 32% of their tweets, thus confirming that scientists on location provided more live reporting than scientists elsewhere (H3). Both groups equally used Twitter to share photos with their folloowers, which is contrary to our initial expectation (H4).

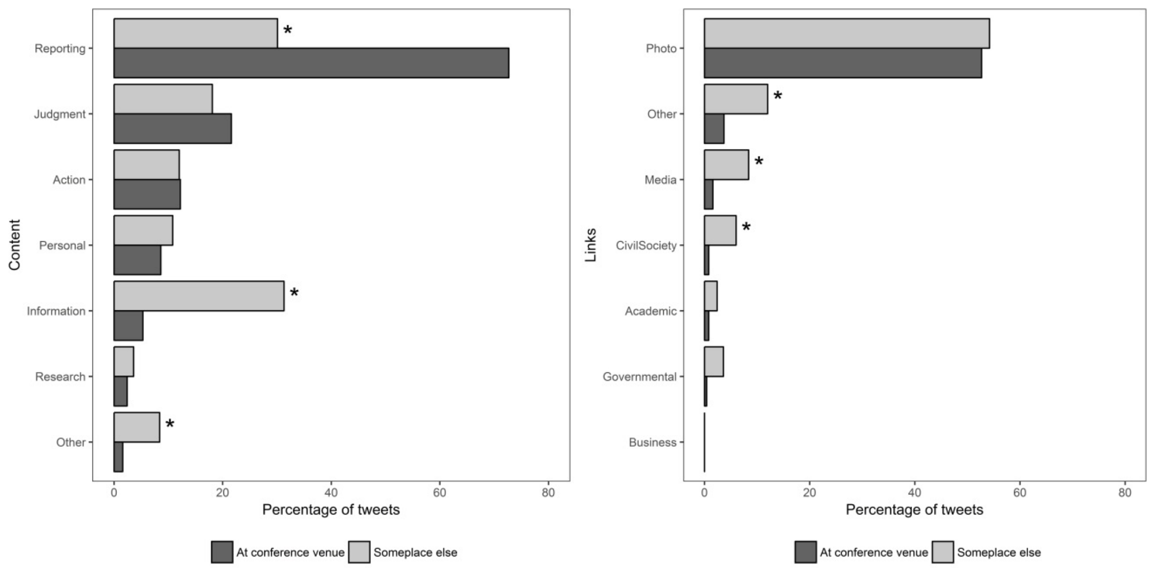

Figure 6. Content of tweets by scientists. The data set "At conference venue" (dark gray) is based on 246 tweets: Given the possibility of multiple coding, we coded a total of 307 content categories and 146 links in the first sample. The second data set "Someplace else" (light gray) is based on 83 tweets; 95 content categories and 72 links were coded. Stars indicate a significant difference between the data sets based on chi-square tests (p < .05).

For scientists absent from the conference, we found a significantly higher level of information provision (29%), which is in line with the image of scientists as "honest brokers." These users also provided more links embedded in their tweets (H5). Reporting, however, was primarily conducted by journalists before the omnipresence of social media. As mentioned previously, past research has argued that scientists have been hesitant to engage in public discussions (Dunwoody & Ryan, 1985; Schneider, 1986). Addressing the public directly—and thus transgressing the boundaries of the profession—was seen as deviant behavior by scientists, which occurred only in "marginal situations" (Bucchi, 1996, p.. 375). Today, however, scientists openly share their experiences as eyewitnesses on social media.

We furthermore assumed that scientists who attended the conference would be more inclined to take a personal stance by tweeting more judgments and calls to action (H6). Approximately 22% of the tweets sent from COP21 contained some form of value judgment, whereas calls to action were less common (12%). Contrary to our initial expectation, the results for scientists who did not attend the conference were very similar (17% of the tweets contained value judgments, and 11% contained a call to action), perhaps because of the specific context of climate change. Climate science is a postnormal issue where scientists ought to be transparent about value questions and uncertainties when formulating policy recommendations (Funtowicz & Ravetz, 1993):

> Climate scientists have been expected to take some sort of advocacy position, in fact to assume responsibility, rightly or wrongly, for at least advising on policies and their implementation. It is almost impossible for climate scientists to be "neutral" in this highly politicized context. (Nerlich & McLeod, 2016, p. 484)

Hence, to a certain extent, scientists involved in climate science might be used to providing their opinions in the form of judgments and/or calling on others to act. Given the widely shared belief that scientists should refrain from both value judgments and political calls to action, the finding that 10–20% of tweets contained at least one of these is surprising.

Discussion and Conclusion

We examined scientists' social media use during COP21 in Paris by comparing the climate-related tweeting practices of scientists who participated in person in the conference and those who did not. The analysis was based on Twitter data gathered from the geolocation of the conference venue and tweets sent from other locations. We used automated content analysis to classify Twitter users based on their user descriptions as scientists and then manually coded relevant patterns of tweeting and links to other content.

Our results derived from qualitative and quantitative manual content analyses show that the scientists in our samples used Twitter in different ways. Those who attended the summit mainly used Twitter for live reporting: They provided their followers with updates and posted photos on what was happening at the conference, thus deliberately leaving digital traces of their presence at COP21. In the past, it was argued that scientists often restrained from engaging in discussions with the public, but this seems to have changed. On social media, they now engage in tasks that have traditionally been associated with journalists rather than scientists. Scientists who were absent from the conference used Twitter significantly more often to disseminate information, which is more in line with the traditional role of scientists. However, both groups used social media surprisingly often to express opinionated judgments and/or to call on others to act, a behavior that is instead associated with political activism. In the analysis of the user descriptions (see the Appendix), we also found evidence that scientists see opinion making as an important part of their communication on Twitter given that the high frequency of the term *views* refers to scientists explicitly stating that the opinions expressed in their tweets are their own. Rather unexpectedly, neither group of scientists used Twitter extensively to disseminate their own research during COP21.

Participating in person in the summit also led to higher levels of Twitter activity and engagement in networking. However, the network analysis revealed that scientists used Twitter primarily to communicate with other users, rather than with each other. Coming from all over the world, scientists at COP21 formed a transnational network with other users.

These results suggest that media and other social contexts can influence the communicative role of scientists. Twitter enables scientists to communicate in new ways with new audiences. In the highly politicized context of climate change, scientists use these new technological opportunities to communicate in a way that deviates from the image of scientists as mere knowledge brokers, primarily disseminating their research results and avoiding the advocacy of certain policies. Both scientists at the conference and elsewhere engaged in political advocacy. Being on site, furthermore, drew scientists into journalism. They engaged in amateur reporting and photojournalism. This indicates a shift toward a new pattern of hybrid science communication on Twitter, where scientists fulfill tasks that have formerly been attributed to journalism and advocacy.

The differences in the social media behavior of scientists who were physically present versus absent from the conference venue also raise questions about whether virtual participation in conferences can be considered equivalent to physical presence. This question becomes more and more pressing as scientists from some countries face restrictions in their ability to participate in conferences abroad. For example, in the aftermath of the attempted coup in Turkey, all academics were banned from leaving the country. Under the Trump Administration, scientists from some Muslim-majority countries (Iran, Iraq, Libya, Somalia, Sudan, Syria, and Yemen) might be unable to participate in person in future U.S. conferences. Thus, further research should investigate how physical participation offers different opportunity structures compared with virtual participation, and whether these differences are limited to Twitter or can also be found in other (social) media outlets.

Studies could also compare conference situations with "normal" times of Twitter use by scientists, and analyze scientists' Twitter use compared with that of other actors. Our study has shown how automated content analysis can be used to identify users—scientists in this context—based on the information they provide in their Twitter profiles. Methodologically, research could also build on the combination of automated and manual content analysis that we have successfully applied.

The findings of this study are limited in the sense that the data were gathered based on user geolocation, which required that Twitter users activated the function on their mobile devices. Yet, based on previous research, we know that only a limited number of users do so (cf., e.g., Bruns & Stieglitz, 2013; Graham et al., 2014). Using geolocated data was nevertheless a central requirement of this study, as we were interested in identifying users who attended COP21 and hence used the geocoordinates of the conference venue to gather part of our data. Regarding the manual content analysis of tweets, despite intensive coder training, some of the reliability scores were at the lower end of the acceptable Krippendorff alpha values. As tweets are limited to 140 characters, their content is often rather cryptic, making quantitative coding difficult for human coders. Still, our qualitative analysis serves as a further validation of our results.

Using a mixed-method approach, our study has provided information on how scientists use Twitter, and has revealed that this use significantly differs depending on the context, such as being present at an international climate summit. Our findings suggest that even in our digitalized and globalized world, and despite the communicative possibilities offered by social media, physical presence still affects how actors communicate with each other.

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Appendix

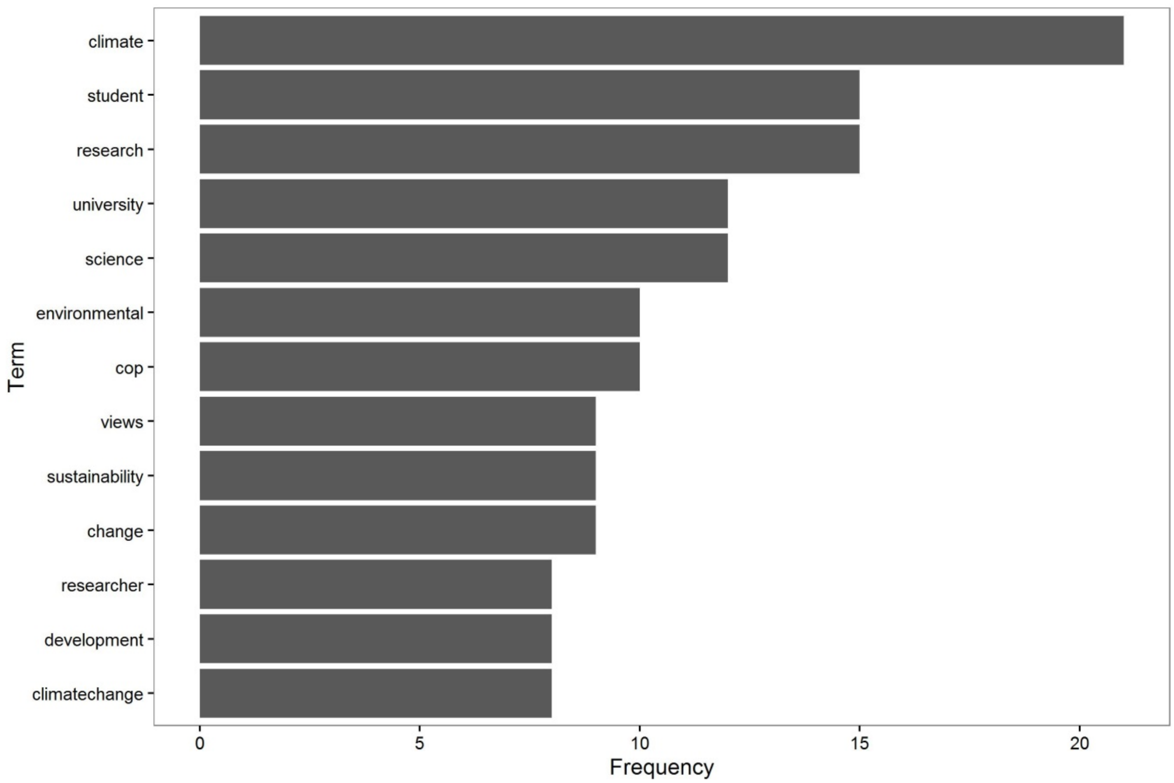

Figure A1. Most frequent words (frequency > 7) in user descriptions of scientists from both samples (N = 105).