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COMMENT

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Science on social media

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During the February 2023 Turkey-Syria earthquakes, people looked for explanations. As scientists, we did our best to share our knowledge in a way that reached and connected with people beyond the scientific community. We did this through communicating uncertainties, and by listening to and learning from our audiences' questions, concerns, and ideas.

On February 6th, 2023, a tectonic chain reaction began at the plate boundary between the Anatolian, Arabian, and African plates. The figures are unfathomable: more than 50,000 people dead, some 150,000 injured, thousands missing, millions homeless. Two major earthquakes (Mw7.8 on the East Anatolian Fault and Mw 7.6 on the Çardak Fault[1,2] rocked Turkey and Syria and turned entire cities into mounds of rubble. According to estimates of the World Bank, the immediate damage in Turkey and Syria is estimated at US$34 billion[3] and US$5 billion[4], respectively, which equals around 4% of Turkey's and 10% of Syria's annual economic output. But the indirect cost of the quake is much higher, and recovery will be neither easy nor quick.

As the 19th-century essayist Ralph Waldo Emerson wrote, "We learn geology the morning after the earthquake"[5], and indeed, the events in Turkey and Syria set off a parallel chain reaction of interaction between scientists and the public: seismologists, geologists, geophysicists, and engineers from around the world shared data and interpretations on social media; Turkish colleagues on the ground contributed field observations (Figs. 1 and 2) and expertise. The shaking had barely stopped, when data sharing and discussion on Twitter amongst scientists began.

Social media platforms offer scientists opportunities to publish content quickly and widely, well beyond their networks of peers. As three Earth scientists who work on timescales ranging from minutes to millions of years, we share our personal experiences with communicating science on social media, for an audience beyond our scientific networks following the sequence of earthquakes in Turkey and Syria. We discuss the opportunities and challenges with this fast-paced media landscape, suggest strategies we found useful, and highlight pitfalls that face researchers interested in science communication in the wake of disasters.

Pre-peer-review science

As Earth scientists, understanding an earthquake event means incorporating knowledge from seismology, paleoseismology, remote sensing, structural geology, archaeology, tectonics, computational geophysics, and more; no one person can be expert in all these subdisciplines. This alone is a compelling reason to have scientists from different fields freely sharing their respective sources of information and expertise[6]. In the recent earthquakes, we witnessed an additional dimension: the suffering and uncertainty of millions who suddenly experienced violent fault movement. The impact of an earthquake creates both a need for reaching the population that was immediately impacted, and addressing the heightened interest in earthquakes by people around the world, especially people in other earthquake prone regions. This attention post-disaster can be an important opportunity to start scientific conversations about earthquake science, preparedness, and resilience.

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Fig. 1 Distributed surface faulting caused by the 2023 Kahramanmaraş Earthquake Sequence. Offset roads, railroad tracks and farm fields near the epicenter of the M7.8. Photo by Sinan Akciz, California State University, Fullerton.

Fig. 2 Surface ruptures caused by the 2023 Kahramanmaraş Earthquake Sequence. Dirt roadway offset near the epicenter of the Ekinozu earthquake. Photo by Sinan Akciz, California State University, Fullerton.

In these recent earthquakes, preliminary scientific results in the form of pixel displacement maps, unwrapped InSAR images, double-difference relocated seismicity, Coulomb stress change maps, and back-projection were posted on Twitter within a matter of days by scientists working singly or in groups across the globe. This communal approach to data sharing, and its subsequent translation into less-technical terminology and interpretations, allowed for a vibrant discussion that linked the voices of those working on geophysical products with the geologists, archeologists, and historians most familiar with the past activity of a fault system - all in a sphere uniquely visible to the public, including the media and policy makers.

Although this situation leads to a faster and more productive understanding of the event as a whole, it also raises questions about how credit should be assigned. In the academic world, scientists (especially junior scientists) rise or fall on publication numbers of scientific articles and citations. One task for the community is therefore to determine how the sharing of science at critical moments like this can be credited. Additionally, if initial results are all visible without peer review almost immediately, perhaps the

Box 1 | Guiding principles for science communication

1. Focus on your core expertise. Refer to colleagues in neighbouring disciplines, local scientists and resources where needed.
2. Help people grasp what happened and why. In the wake of a disaster, uncertainty contributes to anxiety.
3. Science can be complicated. Avoid jargon and explain technical terms if they are at risk of misinterpretation. We used multi-part tweets (threads), with images and links, to explain background and evidence.
4. Clearly communicate uncertainties and timescales. Be clear in the use of words e.g. risk, uncertainty, "natural" disaster, "unprecedented".
5. Read your comments carefully before sending them out. Could they be misinterpreted? If they will frighten (or reassure) people, are you confident in your message? Avoid words that express happiness or excitement - scientific results can be exhilarating, but a post-disaster period is sensitive.
6. Keep the focus on what people want to know and temper your comments with empathy and compassion. Communicator credibility, especially during high stress situations, is assessed quickly and based most heavily on whether the communicator seems to be empathetic, caring, and compassionate[19].
7. If a journalist asks for an interview, it is a good idea to assess the news outlet, to ensure they will present your comments in a fair and unbiased way. Ask in advance for information on the format, the audience, and questions to prepare for. If you are not comfortable, feel free to say no.
8. Clearly flag where information is preliminary.
9. The impact of disasters can best be mitigated by preparedness. Once the urgency has passed, consider using your platform to share information (by referring to expert colleagues if needed) that can help the public become better informed about and prepared for future events.
10. Your messages will at some point be misunderstood or misinterpreted. Do your best to correct misunderstandings, maintain your scientific integrity, and don't give up!

traditional format of the first peer-reviewed publications, which arrive months later, needs to change.

A shifting media landscape

Social media has fundamentally changed the way that people find and receive information on disasters. Now, there is an expectation for expedited scientific information, as well as real-time updates on both the unfolding disaster and the science behind it. The traffic on social media demonstrates the intense desire of the public to become better informed. For instance, Twitter posts by this article's authors about the earthquakes in Turkey and Syria amassed over 26 million impressions (with multiple individual posts exceeding 500k), and TikTok videos received more than 650k views across platforms. Requests for traditional media interviews soar after large earthquakes, and many of the experts who are asked to speak are now found via social media. In the weeks after the quakes we spoke with nearly 20 different news agencies world-wide, including The Washington Post[7–10], The New York Times[11], Süddeutsche Zeitung[12], TRT[13,14], Al Jazeera[15], and NPR[16,17], and referred dozens of requests to other scientists.

The way people engage with information has also changed. Social media platforms, especially in the wake of events like the recent earthquakes, can have profound benefits. However, they also carry tremendous risks: viral misinformation can spread rapidly. This can lead to the spread of conspiracy theories, damaging misinformation, and anxiety. In this media landscape anyone can provide updates and information, which can make it difficult for people to assess who is an actual expert. These issues can partially be solved by scientists communicating with the public before a crisis, so that people have their own pre-vetted and trusted experts to turn to when a crisis arises. Other solutions involve sharing and amplifying the voices of other scientists and organisations, sharing lists of trustworthy sources, and debunking misinformation, ideally without spreading it (this can be accomplished on Twitter by taking screenshots and sharing those instead of sharing the post itself).

At the same time, social media platforms provide researchers with the opportunity to communicate science to a wide audience in the wake of catastrophes. Scientists interested in public science communication should take the time to make their public presence professional, with links pointing to their affiliations, to help the public identify them. In the recent earthquakes, Twitter was particularly effective because it accommodated instant translation of written text, and therefore communication with impacted people in both Turkey and Syria, as well as neighbouring Cyprus and Lebanon. Twitter, in particular, has an important history in Turkey. Introduced in 2011, it became the main platform for sharing information during the Gezi Park protests (#occupygezi) in 2013. A decade later, the social media platform remains a source of information for Turks beyond state-controlled media, although the platform occasionally gets blocked, and did so briefly in the wake of the earthquakes[18]. That said, in recent years social media itself has been in crisis, and many scientists are starting to rethink the many tools available for public science communication.

The personal impact

Of course, the cascade of requests for information can be overwhelming. Together, we received hundreds of direct messages, along with comments on posts, primarily asking about what to expect in specific cities. Communicating uncertainty is difficult at all times, and more so when people are frightened and looking for answers. In Box 1, we share our experience of challenges we have faced and how to overcome them. One strategy we found successful was to create threads for specific regions (Fig. 3). These can acknowledge and validate the fear of potential new events, whilst also presenting relevant scientific data for those regions. Another approach is to describe multiple possible scenarios (e.g., most likely: slowly diminishing aftershocks; also possible: large aftershocks; less likely: new triggered mainshock); this can be an effective strategy for helping people grasp the uncertainties involved. These posts (Fig. 3) reached hundreds of thousands of individuals, demonstrating that people are willing to engage with scientific complexity when it feels important.

Communication under pressure

Communicating post-disaster is a high-stakes situation. We have put together our take on how best to minimise risks and maximise benefits:

Although making an impact through science communication can be personally rewarding and serve the public good, few academic institutions recognise or compensate scientists for this kind of voluntary work. Formal media interviews can be included in CVs, but informal outreach platforms like Twitter are not tracked or assessed for effectiveness. This work is done in the scientists' "spare time", it often occurs without warning or consideration for existing workloads and schedules, and often is not part of their job responsibilities. This can be discouraging, given the already high demands placed on researchers. While some funding agencies

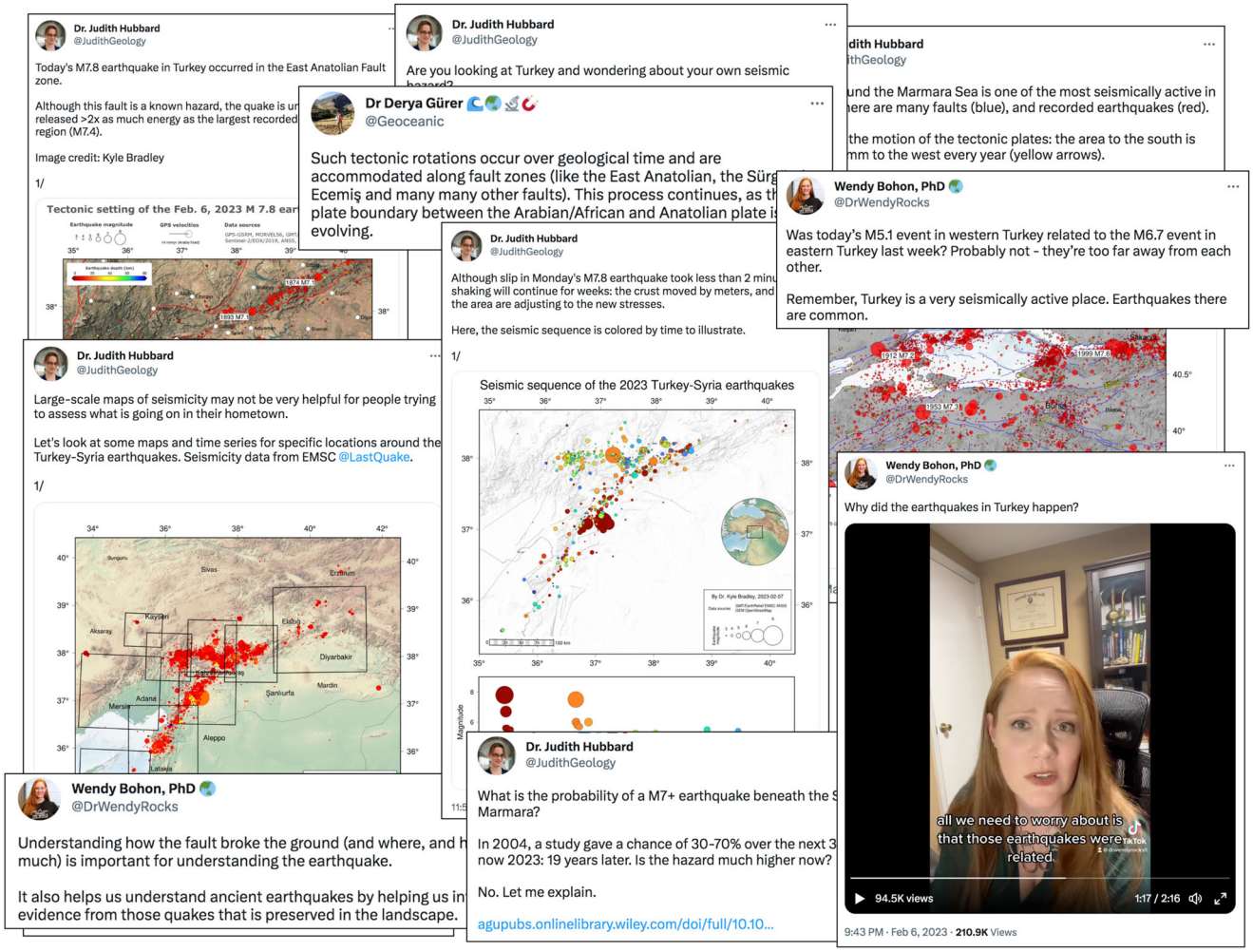

Fig. 3 Science on social media. Collage of selected Twitter posts by the authors following the recent earthquakes.

support science outreach, financial support for disaster-response communication remains rare. These kinds of efforts can help build scientific literacy in the public and showcase the relevance of the Earth sciences. Therefore, supporting this work could raise the profile of Earth Science programs worldwide. We hope that institutions recognise the value of this work to the public and to themselves and take steps to support contributing scientists.

Social media platforms like Twitter, Facebook, Instagram, and TikTok have opened a wealth of opportunities for rapid communication of science to both scientific peers and the public in the wake of disasters. However, relying on this form of media for science outreach carries real challenges, and places an often-unrecognised burden on individuals. As social media platforms and the information landscape continue to evolve, we as scientists and research communities must be willing to adapt our outreach strategies accordingly.

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