Citizen science initiatives in high-impact weather and disaster risk reduction

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Abstract

High-impact weather events cause considerable social and economic harm, with these effects likely to increase as climate change drives extremes and population growth leads to commensurate growth in exposure. As part of the World Meteorological Organization's World Weather Research Programme, the 10-year High-Impact Weather (HIWeather) Project facilitates global cooperation and collaboration to improve weather prediction, forecasting, and warning. As part of this, the HIWeather Citizen Science Project identifies and promotes activities which involve citizens in the warning value chain, from "sensors" where they passively provide data, through to "collaborators" where they are involved in designing, running, interpreting, and applying the research. As well as benefitting global efforts to reduce societal impacts of weather and other natural hazards, citizen science also encourages hazard awareness and scientific literacy and interest. This editorial introduces the HIWeather Citizen Science Project special issue, summarizing the three papers in this issue in the broader context of high-impact weather and citizen science.

Keywords: *Citizen science, high-impact weather, earthquakes, disaster risk reduction*

This editorial introduces a special issue exploring the role of citizen science in understanding impacts and improving warnings for natural hazards, namely high-impact weather and earthquakes. Citizen science offers ways to collect large amounts data to inform research and communication around natural hazards as well as to engage and educate the public. Given the potential of citizen science and the increasing impacts of natural hazard events, particularly those which are weather-related, it is important to highlight the work happening in this space. First, we briefly introduce the challenge of high-impact weather and the global High-Impact Weather (HIWeather) project. Following this, we define citizen science and the typologies used to develop projects. We then summarize the papers in this special issue which include: 1) the use of weather sensors in schools (Kox et al., 2021), 2) an app to crowdsource weather impacts (Kempf, 2021), and 3) an overview of the development and use of citizen reports of earthquake shaking (Goded et al., 2021).

High-Impact Weather

High-impact weather covers a vast range of meteorological events including flooding, drought, severe wind, thunderstorms, hailstorms, heatwaves, blizzards, tornadoes, and cyclones. In 2020 alone, there was at least 389 extreme weather events which in total claimed over 15,000 lives, affected 100 million people, and led to at least US$171 billion of economic loss (UNDRR, 2020). Last year saw 201 flood-related disasters, up from a yearly average across the previous two decades of 163 events, and 127 storm-related disasters, up from 102 on average per year between 2000 and 2019 (UNDRR, 2020). Although extreme weather-related fatalities were lower in 2020 than previously, potentially due to COVID-19 restrictions limiting the number of people outside, there is a clear pattern of extreme weather events increasing in intensity and frequency due to both anthropogenic climate change (Tippet, 2018) and global population growth exposing more communities to risk (Paton & Buergelt, 2019).

High-impact weather events. While the weather-related research in this special issue focuses on Europe, the work is relevant to the primary audience of this journal in Australasia. Aotearoa New Zealand has experienced numerous high-impact weather events in recorded history, typically involving flooding, severe winds, snow, ex-tropical cyclones, and occasionally tornadoes. Severe events causing limited fatalities and moderate levels of damage occur nearly yearly in New Zealand. More extreme impacts are fortunately relatively rare, such as the storm in April 1968 which led to the capsizing of a ferry in Wellington and 53 fatalities (Ministry for Culture and Heritage, 2014). Extreme weather events in Australia are typically drought, which contributes to extensive wildfires, and flooding, but the country also experiences many other types of weather including cyclones, heatwaves, cold snaps, dust storms, and thunder storms. Extreme weather in Australia has led to at least 5,000 deaths in the last 130 years (Coleman, 2016) with recent events also causing billions of dollars of damage, such as the 2019-20 bushfire season which led to losses of up to AU$100 billion (Bushfire & Natural Hazards Cooperative Research Centre, 2020). Island nations in the Pacific and Southeast Asia are particularly prone to tropical storms and related impacts including flooding and heavy wind. In 2017 alone, 198 weather events in Indonesia were classed as health crises with 198 fatalities and over 200,000 people made homeless (Haryanto et al., 2019).

The HIWeather Project

In response to identified gaps in the application of scientific understanding of weather to societal problems, in 2015 the World Meteorological Organization's (WMO) World Weather Research Programme launched the 10-year High-Impact Weather Project (HIWeather; WMO, n.d.). This project enables international collaboration to improve global resilience to extreme weather events through maximizing the timeliness and usefulness of predictions, forecasts, and warnings (Golding et al. 2019; Ruti et al. 2020; WMO, 2017; Zhang et al. 2019). There are five thematic areas: user-oriented evaluation; human impacts, vulnerability, and risk; communication; multi-scale forecasting; and predictability and processes. Across these themes is the flagship Citizen Science Project. The main aim of this project is to identify and promote existing citizen science projects, predominantly but not exclusively within the weather space, to provide tools for others interested in undertaking similar work (WMO, 2021).

Citizen Science

Citizen science involves "the participation of individuals or groups in generating new scientific knowledge" (WMO, 2021, p. 2). Members of the public participate in research projects, typically with varying involvement of professional scientists. The role of citizens can range from passive data collectors, through interpreters contributing to data analysis, to engagers and collaborators involved in all aspects of the project including design and implementation (Haklay, 2013). Similarly, the role of scientists can range from largely leading the project, to collaborating with citizens, to co-creating the project (Bonney et al., 2009; Doyle et al., 2020; Shirk et al., 2012). Given the wide range of definitions of citizen science and accompanying terms, it is important for terminology to be considered and explained in the specific context of the project, including what to call people involved in citizen science (Eitzel et al., 2017). For example, public familiarity with the concept of citizen science tends to be higher than their familiarity with the specific term "citizen science" (Lewandowski et al., 2017).

Citizen science as it is currently commonly understood can be traced back to the start of the 20th Century (Bonney et al., 2016). Recently, there has been a growth in the popularity of citizen science due in large part to technology development including the Internet, personal computers, and smartphones (Aristeidou & Herodotou, 2020; Silvertown, 2009). Such tools are particularly useful (from a professional scientist perspective) for projects which need a large amount of data over a large area (Silvertown, 2009). There is also good evidence for improvements in science knowledge and awareness among the citizens who participate (Bonney et al., 2016) and well-developed projects can help to reduce inequities in science (Soleri et al., 2016). Projects which aim to have a greater impact, particularly broader social and societal benefits, are more effortful and resource intensive (Bonney et al., 2016). Despite a recent proliferation of interest in and use of citizen science, there is still both considerable unexplored potential (Aristeidou & Herodotou, 2020) and scientific challenges including ensuring appropriate data quality and ethical considerations around using public data (Riesch & Potter, 2014).

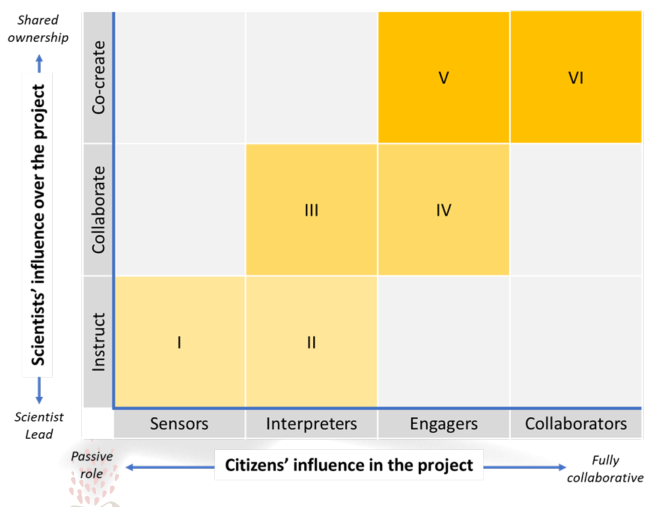
While modern citizen science likely originated at the start of the 20th Century in the field of ecology (see Silvertown, 2009 for an overview), citizen science has also been considered in the domain of natural hazards with efforts to produce frameworks for citizen science projects in disaster risk management including motivations, technicalities, and ethics (Hicks et al., 2019; Orchiston et al., 2016). This special issue presents examples of citizen science projects relating to high-impact weather (Kempf, 2021; Kox et al., 2021) as well as relevant considerations from an earthquake-related project (Goded et al., 2021). These projects also present different *typologies* of citizen science (explained in the next section), with one project more intensively engaging its participants (Kox et al., 2021) and the others presenting examples of crowdsourcing large amounts of data (Goded et al., 2021; Kempf, 2021).

Typologies of Citizen Science

Citizen science projects vary widely and have different levels of engagement from both scientists and the citizen volunteers. Some projects are led by scientists who instruct volunteers in data collection, while others are co-designed with communities. Projects along this spectrum are useful for creating new scientific discoveries, for raising awareness about weather-related issues, and for improving the science-society dialogue. Project typologies (classifications based on categories) have been created which aim to define citizens' roles within a project. Two commonly used typologies are from Haklay (2013) and Shirk et al. (2012). McLaren et al. (in prep) constructed a matrix (see Figure 1) which combined and adapted categories from these two typologies to explore the distribution of influence scientists and citizen volunteers have within a project. These typologies can be used when developing citizen science projects to help these projects clarify and achieve their aims and when considering existing work to identify particular strengths and limitations (for more information on these typologies and their use, please see the HIWeather Citizen Science Guidance Note; WMO, 2021).

The papers included in this special issue present different types of citizen science on the two main continuums describing how much influence the scientists have over the project (from instructing to co-creating) and

Figure 1
Typologies of Citizen Science



Note. From McLaren et al. (in prep).

the citizens' role in the project as sensors, interpreters, engagers, or collaborators. The projects presented by Kempf (2021) and Goded et al. (2021), which crowdsource data online, exemplify citizen science projects where scientists lead and citizens have a relatively passive role. These projects are effective ways for scientists to collect large amounts of data but are less effective at increasing interest, awareness, and understanding of science among citizens. The project presented by Kox et al. (2021), where high school students built and operated weather monitoring stations, is more collaborative; as such, quantity of data is lower but the citizens who participated likely gained more benefit.

Citizen science in schools. In this special issue, a range of citizen science methods are presented as tools to understand weather impacts. Kox et al. (2021) provide an update on the Klimawandelanpassung auf regionaler Ebene citizen science project (KARE-CS) which works with two schools in the Bavarian Prealps region of Germany. These schools were supported to build micro weather stations which were low-cost, independent, comparable to professional stations, appealed to youth, and were simple to set up and use. The school students were able to use these stations to produce valid weather data and carry out detailed analyses; this data approach was combined with observations of weather phenomena and impacts. It is useful when undertaking a citizen science project to understand what was liked and disliked about the project as well as why people were motivated to take part (Raddick et al., 2013). In their work, Kox et al. carried out a survey with the school children to assess their views and motivations. Overall, the pupils had positive views of the project and particularly the self-building aspect of the monitoring station. Most reported that they took part due to a general interest in science and to contribute to research efforts.

Working with specific groups, especially within schools, is an effective way to increase understanding of weather and hazard phenomena and impacts as well as interest in science. While effective, these projects also tend to be relatively intensive and therefore have limited reach.

Crowdsourcing Online

Another common citizen science method to engage populations more broadly is through crowdsourcing with tools such as smartphone apps. Further work in Germany utilised an existing weather smartphone app to crowdsource weather data. Kempf (2021) reports on the rollout and early observations of this initiative, which saw the public provide more than 600,000 observations over 5 months from approximately 125,000 active users. Key considerations in this project included ensuring the system was understandable by lay audiences, privacy concerns such as geolocating observations, copyright of images shared by users to supplement their observations, and false observations. These considerations demonstrate the complexity of such projects but measures were able to limit the impacts of challenges to citizen-provided data, such as automatic plausibility checks to identify false reports and adapting response scales to meet user expectations. Overall, citizens rarely misused the system. This citizen science project offers insights and support for similar other projects using smartphone apps to crowdsource data.

Beyond the domain of high-impact weather, crowdsourced data has a long history in earthquake research. One key way to involve citizens in earthquake science is to provide the opportunity for them to report their experiences of earthquake shaking. The United States Geological Survey offers an online platform for citizens who feel earthquake shaking to report their location, intensity of shaking, and damage in “Did You Feel It?” reports (Wald & Dewey, 2005).

In this special issue, Goded et al. (2021) present an overview of “Rapid” and “Detailed” Felt Reports collected from people across Aotearoa New Zealand since 2004, totalling nearly one million long-form reports from over 30,000 earthquakes. These reports can be submitted online or via an app to GeoNet, New Zealand’s geological hazards monitoring service run by GNS Science. In “Felt Rapid” reports, citizens report the intensity of shaking they experienced from one of six cartoons demonstrating effects on people, buildings, and contents. For “Felt Detailed” reports, people complete a survey on a range of factors including what they did in response to the shaking, building damage, impacts on their neighbourhood, tsunami-related behaviour, and demographic factors. This information is used by scientists for a number of purposes, including assigning Modified Mercalli Index intensities to specific earthquake events and feeding data into strong motion maps to help understand ground shaking. In this paper, Goded et al. summarize these reports as well as current and planned research to use this citizen science-collected data and discuss the broader role of citizen science in improving earthquake understanding and resilience.

Citizen seismology projects can backfire if information is incomplete or missing, with reduced trust in the science organizations, as was seen during an earthquake sequence in Mayotte in 2018 (Fallou et al., 2020). In response to some earthquakes not being presented in the local earthquake information app, which uses crowdsourced information similar to USGS’s “Did You Feel It” reports, over 10,000 people spontaneously formed their own information-sharing group on social media; due to a lack of seismologists in this group, however, misinformation and conspiracy theories arose. This example demonstrates the importance of ensuring alignment between scientific communication and audience needs, as well as the important role that scientists play in citizen projects to ensure accurate, useful information is being produced and shared. For example, members of the public tend to have more confidence in findings of citizen science projects which include professional scientists in some capacity (Lewandowski et al., 2017). The roles which both citizens and scientists play in particular projects is therefore important to consider reflexively at the beginning, throughout, and after the project.

Conclusion

High-impact weather events cause considerable social and economic harm globally, with these effects likely to increase as climate change drives extremes and population growth leads to commensurate growth in exposure. Citizen science is increasingly used internationally as a way of both gathering large amounts of data and to engage and educate the public about natural hazards such as high-impact weather events as well as scientific processes generally. The papers in this special issue demonstrate different ways in which citizens can contribute to developing our understanding of hazard impacts and improving warnings. Kox et al. (2021) describe a project involving schools, encouraging youth to learn more about hazard monitoring and to engage in science and research. Kempf (2021) and Goded et al. (2021) demonstrate how advances in technology over the last decades, such as the rise of smartphones, can be used to obtain large amounts of data about impacts of hazard events including severe weather and earthquakes. This data can help researchers understand these hazards better, such as how earthquake shaking is experienced and how people respond (Goded et al., 2021), and improve forecasts and warnings as citizens report on-the-ground impacts of severe weather. Across these projects, it is clear that citizen science is diverse, demonstrated by the typologies described in this editorial, and that it can be beneficial for both research and society.

This editorial introduced the HIWeather Citizen Science Project, summarizing the papers in this issue and presenting the research in the broader context of high-impact weather and citizen science. The editorial team would like to thank those involved in the production of this special issue, including the wider HIWeather team, the contributing authors, and the peer reviewers.

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