



## OPEN ACCESS

## EDITED BY

Heather Michelle Wright,  
United States Geological Survey (USGS),  
United States

## REVIEWED BY

Federico Pasquaré Mariotto,  
University of Insubria, Italy  
Jan Marie Lindsay,  
The University of Auckland,  
New Zealand  
Supriyati Dwi Andreastuti,  
Center for Volcanology and Geological  
Hazard Mitigation (CVGHM), Indonesia

## \*CORRESPONDENCE

Omari Graham,  
omari.graham@sta.uwi.edu

## SPECIALTY SECTION

This article was submitted to  
Volcanology,  
a section of the journal  
Frontiers in Earth Science

RECEIVED 29 March 2022

ACCEPTED 27 June 2022

PUBLISHED 18 July 2022

## CITATION

Graham O, Edwards S and Robertson R  
(2022), More than a warning: Expanding  
the role of communication in Eastern  
Caribbean volcano science.  
*Front. Earth Sci.* 10:907559.  
doi: 10.3389/feart.2022.907559

## COPYRIGHT

© 2022 Graham, Edwards and  
Robertson. This is an open-access  
article distributed under the terms of the  
[Creative Commons Attribution License  
\(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or  
reproduction in other forums is  
permitted, provided the original  
author(s) and the copyright owner(s) are  
credited and that the original  
publication in this journal is cited, in  
accordance with accepted academic  
practice. No use, distribution or  
reproduction is permitted which does  
not comply with these terms.

# More than a warning: Expanding the role of communication in Eastern Caribbean volcano science

Omari Graham\*, Stacey Edwards and Richard Robertson

The University of the West Indies Seismic Research Centre, St. Augustine, Trinidad and Tobago

The infrequent nature of volcanic eruptions means that civil authorities and the public may often be unfamiliar with volcanic hazards and may not be fully prepared to deal with them. Many times volcano scientists are required to help governments and citizens understand the threat posed to their lives and property when volcanoes show signs of an imminent eruption. Effectively communicating the potential impact of these events can demand time and skills that these scientists may or may not have. Further, a lack of trusted scientific information can lead to public misinformation and hamper government responses. Although several risk reduction researchers and observatory scientists have advocated for the inclusion of communication specialists in scientific teams, communication resources at many observatories remain under utilised. Using the experience of The University of the West Indies Seismic Research Centre (UWI-SRC), this article explores the contribution of a specialist communication team to the work of a volcano monitoring agency. The Education and Outreach (E&O) team at the UWI-SRC manages all the agency's external communications. The team also works to raise public awareness of geological hazards in the UWI-SRC's Eastern Caribbean region of responsibility. Within the Caribbean region, most communication research related to disaster risk up until now has focused on communication during crises. Using semi-structured interviews and document review we investigated the impact of strategic communication in a long-term, multi-hazard monitoring programme. A qualitative analysis highlighted the equal importance of crisis communication during unrest and outreach work during quiescent periods. The UWI-SRC's communication programme has been effective in: 1) supporting scientists' public communication 2) sustaining stakeholder engagement 3) building physical and social science capacity and 4) strengthening organisational credibility. This article examines the contribution of specialist communication to advisory volcano science throughout the disaster management cycle in the English-speaking Eastern Caribbean. It argues that significant societal value can be added to the scientific work engaged in by advisory scientists by embracing a multi-level communication strategy.

## KEYWORDS

science communication, risk management, interdisciplinary research, volcano, Caribbean

## 1 Introduction

Populations near live volcanoes may be placed under significant threat when these volcanoes erupt. As volcanoes show signs of unrest, the risk to nearby settlements must be effectively communicated to the public and to those responsible for public safety in a timely manner. The growing complexity of successfully achieving these tasks has been receiving more attention from researchers and observatory scientists (Fearnley et al., 2018; Donovan, 2019; Pallister et al., 2019; Donovan, 2021) such that now, risk communication is accepted as an integral part of the risk management cycle. Once aware of the potential risk, civil authorities and private individuals can act to secure lives and livelihoods from potential loss or damage. Communication is needed throughout the cycle to ensure successful risk reduction and management. Risk management models (Chorus, 1999; Health Protection Network, 2008; Infanti et al., 2013) place risk communication at the center of a perpetual cycle of hazard identification, risk assessment, policy development, implementation and evaluation. At each point in this cycle, risk communication is required to achieve different objectives. Risk assessment, policy development and evaluation all require communication inputs. Successful risk management, therefore, is heavily dependent on effective communication.

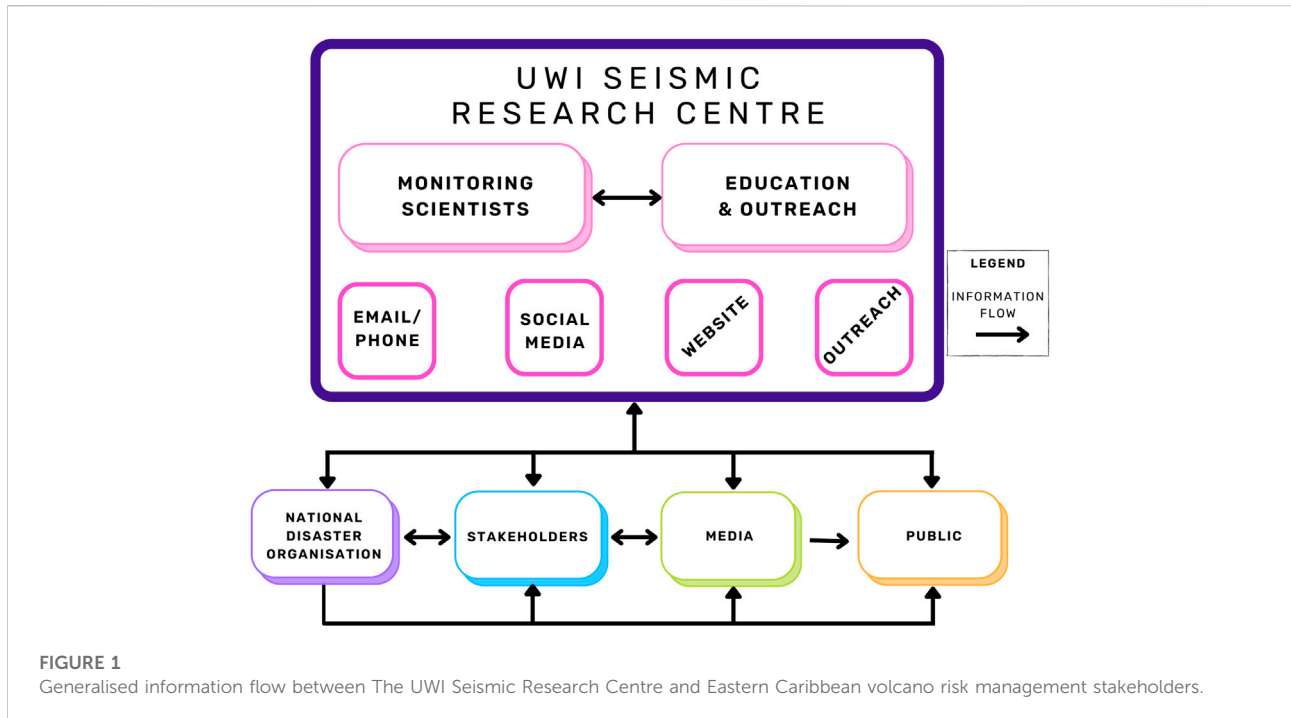
Deliberate communication should feature at each stage of the risk management cycle. Within disaster management, communication itself has over time become more accepted as its own discipline, particularly in the volcano surveillance community. Recommendations have been made to include communication professionals in scientific teams or to at least have a scientist able to communicate well with media and the public be a part of the team (Newhall et al., 1999; Pasquare and Pozzetti, 2007; IAVCEI Task Group on Crisis Protocols, 2016; Pallister et al., 2019). Efforts to engage vulnerable communities prior to the onset of natural hazards have the potential to save many lives. Outreach by scientists before the 2004 Indian Ocean earthquake and tsunami (Sieh, 2006) and during the 15 year eruptive episode at Tungurahua volcano, Ecuador (Stone et al., 2014; Mothes et al., 2015) demonstrate the importance of access to scientific information in disaster risk reduction. Community engagement is particularly important for developing countries (Andrestuti et al., 2018) where communal structures play an important role in daily life and consequently in people-centred early warning systems (UNISDR, 2006).

As the scientific agency responsible for monitoring volcanoes on the English-speaking islands of the Eastern Caribbean, The University of the West Indies Seismic Research Centre (UWI-SRC) has been providing information on Caribbean volcanoes since 1953 (Latchman et al., 2012). Scientists at the Centre advise nine (9) governments on the volcanic hazard within their territories. These governments then are responsible for deciding and executing mitigation actions when necessary. The Centre's Education and Outreach (E&O) programme has

over the last 20 years worked to improve the communication surrounding volcanic and other geologic hazards in the Eastern Caribbean. A major part of this work involved supporting scientists' communication during crises, but more significantly, also included using science communication outside of crisis periods to increase public awareness of the geological hazards common to the region. The UWI-SRC regularly interacts with National Disaster Organisations (NDOs), the media and the public, providing general advice and information to all levels of society (Figure 1). Developing communication as one of the agency's core competences was an attempt by the UWI-SRC to increase the societal impact of its work. Specifically, it was intended to help the Centre actively serve the public beyond its routine monitoring and advisory role during crisis response. Despite a traditional focus on physical science, the Centre sought to broaden its impact and improve its accessibility by strategically deploying its communication resources throughout risk management cycle. UWI-SRC scientists' role as communicators during volcanic crises and their relationships with stakeholders at the science-management interface were explored in Graham et al. (2022). The authors argued that user-focused communication products and routine stakeholder interaction had the potential to reduce managerial risks at the regional science-management boundary. This article focuses on the impact of the E&O section's science communication programme on the UWI-SRC's work and the Centre's contribution to civil society outside of crises.

Traditional approaches to conveying risk information in the region and around the world were often based on a deficit model of science communication. This model of communication, which focused on moving information primarily in one direction from experts to those "in need of information", frequently did not motivate the desired action. This one-directional flow of information generally ignored important social and economic factors considered by those making personal decisions about risk. As a result, risk managers often had difficulty convincing the public to take the most appropriate mitigation action (Paton et al., 2008). One example being during the Soufrière Hills eruption on Montserrat when nineteen people who remained in the exclusion zone were killed by a pyroclastic flow in 1997. Survivors' reasons for visiting the area identified to be unsafe by officials included tending to farms and escaping unpleasant conditions in evacuation shelters (Loughlin et al., 2002). A more contemporary approach to science communication utilises a relational/transactional communication model that facilitates multi-directional information flow (Bretton et al., 2018a; Doyle and Paton, 2018; Graham et al., 2022). In this approach information moves between experts, the public and risk managers in all directions and over extended periods of time.

The UWI-SRC has pursued a relational risk communication strategy led by its Education and Outreach team since 2001. Beginning then and with funding from the Office for Foreign Disaster Assistance of the United States Agency for International



Development (USAID-OFDA), the UWI-SRC took its first steps toward a systematic programme of public education and science/risk communication. The initial “Mitigation of Geologic Hazards in the Lesser Antilles and Adjacent Islands: Public Education and Awareness Project” sought to produce indigenous information material for distribution throughout the Eastern Caribbean (UWI Seismic Research Centre, 2003). The first phase of the project also involved training regional National Disaster Organisations in the science of Earthquake, Tsunami and Volcano related hazards.

Significantly, this project enabled the hiring of a communication professional to work along with UWI-SRC scientists to produce customised public education and awareness products (Latchman et al., 2012). This was the beginning of what became the UWI-SRC E&O section. The E&O section is now primarily responsible for raising public awareness of geologic hazards across the Eastern Caribbean through its various products, tools and events. Its work program focuses on maintaining information pathways between stakeholders, executing interdisciplinary projects, building scientific capacity through promotion of earth-science education and strengthening the UWI Seismic Research Centre brand between crises. During crises, the E&O team manages UWI-SRC crisis communication, including supporting scientists’ media appearances and backing risk management partners’ communication efforts. Ultimately, by applying a sustained, multi-directional communication strategy, the UWI-SRC aims to reduce vulnerability in at-risk communities through involvement, cooperation and synergy.

After two decades of routine science communication, the Centre continues to work to expand public access to information on geologic hazards in the Eastern Caribbean and create a model for sustainable community engagement. It also remains a strong advocate for policy action to strengthen resilience within the region. The impact of strategic communication on operations at an observatory type agency is considered here in brief. The E&O team’s efforts to improve inter-agency collaboration, research project diversity, technical capacity and organisational credibility are specifically highlighted. This article explores the largely positive effect of a specialist communication team on the work of a multi-national volcano monitoring agency.

## 2 Materials and Methods

A qualitative methodology was used to explore the impact of specialist communication skillsets on operations at the UWI-SRC, an organisation traditionally engaged in physical science, natural hazard monitoring and research. Semi-structured interviews were used to gather UWI-SRC scientists’ opinions on communication’s role in the Centre’s scientific advisory work and the value it added to these efforts. A parallel review of UWI-SRC annual reports and project documents was used to track the activities of the Education and Outreach section at the UWI-SRC. The qualitative research process allowed for careful consideration of the unique issues surrounding the UWI-SRC experience and was able to utilise participants’ recollections to validate or refute pre-existing notions (Creswell, 2003). The qualitative depth of

this study was enhanced by participants' "war" stories; experiences that may be considered peripheral in other research settings. A qualitative approach was able to capture the type of contextual information often lost in the effort to publish material more closely aligned with the positivist tradition (Patton, 2002). The integration of the physical (geological) and the social sciences at the Centre was captured by considering grey literature, mainly annual and project reports produced in house. Social constructionism (Burr, 2015) underpins much of the previous work done in this area of research and serves as a theoretical guide for this study.

## 2.1 Semi-structured interviews

Seven semi-structured interviews were conducted face-to-face at the UWI-SRC office in St. Augustine, Trinidad between 9th June and 9th July 2016. Participants included all scientists employed at the UWI-SRC and based at their St. Augustine office at the time that data collection was undertaken. The small scientific team comprised one specialist per monitoring discipline and consisted of a geologist, geophysicist, geochemist, engineer, seismologist, volcano seismologist and communication specialist. Two authors formed part of the participant group. These authors were not involved in any analysis of interview data. With participants' permission, interviews were recorded using a digital voice recorder. Researcher notes were also made during the interviews. The interviews were manually transcribed, and the transcripts coded using the qualitative analysis software NVivo (2018). Interview transcripts were put through a single round of descriptive coding followed by a single round of pattern coding. The initial round of descriptive coding identified recurring topics within interview transcripts. The second round of coding established patterns of thought across the data set. A thematic analysis (Braun and Clarke, 2006) was used to expose the themes discussed in this article.

## 2.2 Document review

A document review was used to catalogue communication/outreach driven activities and projects at the UWI-SRC. Objectives and outcomes for projects in which the E&O section played a significant role were compiled from bi-annual UWI-SRC reports from 2000 to 2018 and *via* project-specific reports. Descriptions of the circumstances surrounding the creation of several major standalone outreach products and initiatives were also gathered from these reports. The examination focused on identifying sources of the value added by the UWI-SRC's communication/social science work.

## 3 Results

### 3.1 Thematic analysis

Two major themes emerged from the thematic analysis: science communication practice and stakeholder relationships. The influence of stakeholder relationships on communication at the science-management interface is discussed in Graham et al. (2022). Four sub-themes stemming from science communication's contribution to various operations at the UWI-SRC are explored below.

#### 3.1.1 Communication support

Participants pointed to the value of the Education and Outreach team in supporting scientists' communication with stakeholders. As the UWI-SRC's communication arm, scientists see the E&O team's main responsibility as facilitating timely information dissemination during both crisis and inter-eruptive periods. In each case, the E&O team works alongside scientists to share and receive information.

"I think the communications professional is very, very important. First of all, they know which audience they are going to talk to. They know the sort of thing that audience expects, the way in which we communicate, whether it is written or oral or interviews and they basically do all the setting up. . . This is why you have a communications officer. I was very impressed when I came here that SRC had [an outreach officer]. [The outreach officer] was here on her own at the time, but she did the communications. Many [organisations] I've been to in Europe and in the US, did not have a dedicated outreach officer. And it was very obvious working with [the outreach officer] how much she brings to the whole thing. And so, I could never do this without a communications professional. It's something if I went somewhere else, I would make sure we had someone in that sort of post because it is very, very important."—UWI-SRC Scientist A.

"And we have discovered here at seismic, we should have the communication specialist, the Education and Outreach department/section in our case to guide us because as scientists we don't always say it in the language that the people best understand."—UWI-SRC Scientist D.

While participants recognised the need for professional communication intermediaries between scientists and civil interests, they believed scientists still played a key role in public communication. They felt that scientists' ability to communicate uncertainty and diverging scientific views in appropriate ways made them valuable communicators.

“One of the things that’s really important that I’ve learnt is the uncertainty in what we’re talking about, especially in volcanoes. It’s not a black/white thing, there is so much uncertainty in trying to forecast what is going to happen. And trying to explain that to the public is incredibly difficult. It really is, but it’s something that we have to make an effort to do.”—UWI-SRC Scientist A.

The E&O team’s role is seen as there to complement scientists’ work, providing guidance and communication training where necessary.

### 3.1.2 Sustained engagement

The Centre’s efforts to continuously engage the public during quiescent periods were also raised by participants. Proactively educating the public on volcanic hazards and ways to mitigate these hazards was considered a part of the UWI-SRC’s responsibility.

“I see one component that deals with educating the public. Which is really the primary component. Ensuring that they understand which geologic hazards they are vulnerable to and they understand ways in which they can mitigate against the effects of these hazards. And that information is sent out in an attractive and timely and engaging manner. And then also that’s a kind of proactive thing. That’s something that we would be doing during quiet periods.”—UWI-SRC Scientist C.

The scientists interviewed also explained that the UWI-SRC through the E&O had taken up the responsibility of keeping the realities of volcanic eruptions in focus at a governmental and individual level. The outreach programme at the UWI-SRC aims to improve crisis response, strengthen governments’ long-term risk management capacity and instill a sense of personal responsibility in citizens.

“It means therefore that ideally we would have them developing their society, developing their economy in such a way that if they get a large magnitude earthquake or they have an eruption of the volcano in their territory that the impact would not be such that people get killed or that their economy is set back to an extent that they can’t, you know, immediately recover. That kind of thing. We [are] light years from that. I think for most of the hazards we are only at the stage of saving life. We haven’t really reached the stage of, kind of development in a sustainable way. I mean, that’s a struggle. So, I think a lot of that communication that goes on when there is no activity is geared towards that.”—UWI-SRC Scientist B.

According to participants, the UWI-SRC communications during quiet periods focuses on encouraging government and other civil stakeholders to place greater focus on loss mitigation ahead of impact.

In the past, the emphasis had largely been on recovery after suffering losses from any one of several natural hazards common to the region. Events like the annual Earth Science Week, Volcano Awareness Week and more recent development projects are opportunities for both formal and informal knowledge exchange.

### 3.1.3 Building scientific capacity

Maintaining and ultimately increasing the geoscience capacity in the Eastern Caribbean region was also important to participants. This stance appeared to be in response to a need for more regional scientists but also represented a step away from less progressive policies inherited from a colonial past.

“So being exposed to the field and recognising that it’s a real hazard in our region, the field is not saturated, we did not have many local scientists in this area and it looked like a good prospect, so I accepted the challenge when I was offered. Unfortunately, after I graduated the administration at Seismic had changed and the interest in having someone on the technical staff being involved in research had also changed.”—UWI-SRC Scientist D.

“...even though the head of department was not favourable to my doing post-graduate work, he then showed me an advert for a job at [an international scientific agency]. . . So, he showed it to me, and I applied. Normally you would have post-grads, doctorals, post-docs or that sort of qualification for this post, but I still applied and was successful in getting the job. So that now expanded my perspective.”—UWI-SRC Scientist D.

The current crop of scientists at the centre have adopted a different approach to previous managers. There is now a focus on creating and nurturing new regional experts.

“You have to have people that will be there to take over when the senior people retire. And the only way you can do that is by involving them in what you are doing.”—UWI-SRC Scientist B.

“Which is why I think in the territories where you have these hazards, I think, you really need to have. . . the agencies that monitor [the hazards], really need to be from the place where the people are.”—UWI-SRC Scientist B.

Participants consider maintaining the UWI-SRC’s Caribbean identity key to any future organisational success. A competent scientific agency based in the Caribbean, staffed by Caribbean scientists is viewed as symbolic of a region capable of achieving a fundamental level of self-sufficiency.

### 3.1.4 Institutional credibility

The credibility enjoyed by the UWI-SRC in the territories it monitors is not lost on its scientists. This credibility has



TABLE 1 Roles for physical and communication/social science at The UWI Seismic Research Centre throughout the risk management cycle.

Stage of risk management cycle	UWI Seismic Research Centre (physical science) role	Education and outreach team (communication/social science) role
Identify hazard	Data collection/scientific monitoring of 16 live volcanic centres Publish quarterly bulletins and annual reports	Raise public understanding and awareness of volcanic hazard through strategic science communication
Assess risk	Provide hazard inputs (scientific advisories) for risk assessment by civil authorities	Supply locally specific risk perception perspectives to assessment exercise Contextualise hazard information for risk assessment by territorial civil authorities
Develop policy	Provide consultancy during development of territorial land use and volcanic emergency response plans	Contribute insights on public knowledge and behaviour gained from outreach work and interdisciplinary research Facilitate stakeholder training in volcanic hazard and impact Provide information material to support policy development
Implement policy	Participate in simulations and preparedness exercises during quiescence Provide expert advice during crises to support emergency management decisions making	Maintain public awareness through targeted outreach  Facilitate/support efficient emergency management communications during crises
Evaluate policy	Technical contributions to policy document updates and reviews Participate in post unrest/eruption reviews	Participate in post unrest/eruption reviews Develop and administer data collection instruments during evaluation Collect formal and informal public feedback on scientific/emergency management performance during crises <i>via</i> social media and outreach interactions

allowed scientists to offer advice that is received with a degree of trust.

“But I think SRC does have a good reputation in all of the islands. So, I think if you’re introduced as “This is the SRC” that’s a good way to being sort of [respected]. The word isn’t respected. There’s another word, which I can’t find. But you know, giving you the authority, people sort of recognizing your authority.”—UWI-SRC Scientist A.

The Education and Outreach section is described as actively working to shape public perception of the Centre and also being responsible for the Centre’s public relations.

“A secondary objective of the Education and Outreach section is to promote or strengthen the image of the Centre. So that’s where the public relations part of it would come in.”—UWI-SRC Scientist C.

Maintaining the UWI-SRC’s image and by extension its credibility is one the major responsibilities held by the E&O team.

### 3.2 Document review

Since the creation of the Education and Outreach officer post at the UWI-SRC, the responsibilities of the current E&O team have expanded to include duties beyond the initial focus on raising public awareness on geological hazards. Table 1 outlines the E&O team’s contributions to the UWI-SRC’s work throughout the risk management cycle. These duties support

tasks generally led by physical scientists but requiring communication and social science input.

During inter-eruptive periods the UWI-SRC is regularly involved in projects aimed at reducing public vulnerability to volcanic hazards. Other E&O involved projects focus on improving the Centre’s understanding of the social impact of these hazards. Table 2 lists the inter-disciplinary projects undertaken by the UWI-SRC since the formalisation of the E&O section.

## 4 Discussion

Integrating specialist communication into the UWI-SRC’s core functions has added essential capacity to the organisation. Over the last 20 years the UWI-SRC’s E&O section has provided a framework for sustained stakeholder collaboration and information exchange. It has created research opportunities in emerging fields and nurtured new researchers. It continues to deliver hazard information in accessible, culturally sensitive ways and has worked hard to improve the centre’s overall credibility. The E&O section’s work has contributed to reducing vulnerability to volcanic hazards across the Eastern Caribbean. The timely evacuation of ~20,000 persons from northern St. Vincent during the explosive phase of the 2020–2021 eruption at La Soufrière, is a testament to the Centre’s ability to engage, support and finally warn communities threatened by live volcanoes. These efforts have not always been fully understood or appreciated but have contributed to the Centre’s continued growth. The Centre *via* its E&O section routinely pursues strategies comparable to those executed by much larger agencies with similar responsibilities (Doyle et al., 2015; Mothes et al., 2015; Andreastuti et al., 2018). During

TABLE 2 Interdisciplinary projects involving The UWI Seismic Research Centre since 2001.

Period	Project	Description	Selected UWI-SRC involved products/publications
20 months (January 2001–August 2002)	Mitigation of Geologic Hazards in the Lesser Antilles and Adjacent Islands: Public Awareness Project	This project was developed to raise public awareness on geologic hazards in the Eastern Caribbean. Project activities included training workshops, awareness campaigns and information material	“Volcanoes, Earthquakes and Tsunamis in the Eastern Caribbean” (booklet) Island specific volcano brochures Geologic hazards poster The Volcanic Hazard Atlas of the Lesser Antilles* <a href="#">Lindsay et al. (2005)</a> *Produced on recommendation received during project
1 year (March 2009–March 2010)	Tsunami and Other Coastal Hazards Warning System Project	Branded “Tsunami Smart” public awareness and teaching resources produced and disseminated as part of the Public Awareness and Education component of the larger regional project	Tsunami Smart Teacher Resource Kit Tsunami Smart Student Workbook Tsunami Warning! Caribbean (book)
48 months (October 2011–September 2015)	Volcanic Unrest in Europe and Latin America (VUELCO)	A collaboration between ten (10) institutions aimed at improving the understanding of volcanic unrest processes and outcome forecasting to aid decision making and risk management	<a href="https://doi.org/10.1002/grl.51003">https://doi.org/10.1002/grl.51003</a>
14 months (January 2017–March 2018)	VolFilm: Multilingual and multi-platform films for resilience to risks from volcanic hazards	The project created a suite of videos to help decision makers and people in communities threatened by volcanic activity to understand the risks they face from the major kinds of volcanic hazard	Experience: Pyroclastic flows “A glowing cloud” (film) Experience: Ashfall “An eclipse” (film) Explosive eruptions: the hazard (film) Explosive eruptions: the impact (film)
7 years (2012–2019)	Strengthening Resilience in Volcanic Areas (STREVA) Project	An interdisciplinary project focused on developing a practical and adaptable volcanic risk assessment framework able to reduce the negative impact of volcanoes on people and physical assets	<a href="https://doi.org/10.1016/j.jvolgeores.2019.01.002">https://doi.org/10.1016/j.jvolgeores.2019.01.002</a> <a href="https://doi.org/10.3389/feart.2019.00205">https://doi.org/10.3389/feart.2019.00205</a> <a href="https://doi.org/10.1016/j.ijdr.2017.04.015">https://doi.org/10.1016/j.ijdr.2017.04.015</a> Soufrière erupt! (film) Living with the volcano (film)
20 months (November 2018–June 2020)	Volcano Ready Communities Project (VCRP) in St. Vincent and the Grenadines	This project sought to improve response capability in twelve (12) high-risk communities near the La Soufrière volcano St. Vincent through first responder training, risk assessment and information material production	The 1979 La Soufrière Eruption (film) Understanding Volcanic Hazard Maps (film) Volcano Monitoring in the Eastern Caribbean (film) Earthquakes and Volcanoes in the Eastern Caribbean (film) Living with La Soufrière (poster) Community multi-hazard maps (9 communities)

quiescent periods, yearly week-long outreach campaigns executed as “Earth Science Week” (various territories) and “Volcano Awareness Week” (St. Vincent and the Grenadines) celebrations aim to reach those most likely to be impacted by an eruption. School workshops, community meetings and stakeholder consultations during the week aim to raise awareness and reduce potential risk. The quality of the Centre’s outreach work has been demonstrated in its ability to attract funding through collaborations with regional and international partners interested in executing impactful projects. Sustained stakeholder outreach and participation in people-centred projects like STREVA and VRCP have raised the profile of the UWI-SRC above that of comparable agencies in the Caribbean region. The work of the centre has moved past only supplying scientific opinions on volcanic and other geologic disturbances. The modern UWI-SRC is increasingly being

operated as an institution interested in and involved throughout the entire disaster risk management cycle.

## 4.1 Embracing the science of communication

The perception of science’s role in reducing risk to volcanic hazards has been changing in recent years ([Fearnley et al., 2018](#); [Nakada et al., 2019](#); [Donovan, 2021](#)). Although specific arrangements may still vary, scientists are increasingly expected to play a greater role in disaster risk reduction ([UNISDR, 2015](#)). However, the extent to which these expectations influence standard operating procedures in observatory settings remains difficult to quantify. Participants in this study have recognised the value of professional science

communication and have taken steps to ensure that the discipline assumes a prominent position in the UWI-SRC's operations as the Centre assumes more disaster risk reduction responsibility. Figure 1 demonstrates the extent to which this scientific agency chooses to engage its partners. This position though, may not be typical in volcanology and science in general. Pallister et al. (2019) note that while representatives at a 2013 Volcano Observatory Best Practice workshop gathered to consider hazard communication, discussions centered mainly on observatories' role in issuing hazard alerts and warnings with media relations/outreach receiving little attention. The need for greater communication capacity had to be confronted by the UWI-SRC in the past and perhaps is the reason why science communication enjoys the appreciation it now does at the Centre. Historical crises in the region had highlighted the need for professional communication intermediaries between scientists and civil interests during volcanic eruptions.

During the 1971–1972 eruption of the La Soufrière volcano in St. Vincent “*scientists learned through hard experience that direct communication between scientists and news media... in a fluid emergency situation was unwise*” (Shepherd et al., 1988). Later, a disputed evacuation before the eruption of La Grande Soufrière on the French-speaking island of Guadeloupe in 1975–1976 (Feuillard et al., 1983; Fiske, 1984) further demonstrated the importance of scientific teams having the ability to communicate uncertainty and diverging views to the public. In 1979 when La Soufrière, St. Vincent erupted again, regional scientists applied lessons from previous experiences, choosing on this occasion to present a consensus view to government officials who would then communicate to the public (Shepherd et al., 1979; Shepherd et al., 1988). While there is significant value in learning from experience (McGuire et al., 2009), there is also much to be gained from retaining the appropriate expertise. Formalising science communication roles in observatory settings frees monitoring scientists to focus mainly on their hazard assessment duties, while the science of communication is handled by an equally qualified specialist. Advisory science by its very nature, does not function well without high quality communication. This truth should be reflected in the personnel involved. Despite its acknowledged value, science communicators worldwide often report that their work is underappreciated, particularly in developing countries (Navarro and McKinnon, 2020). These situations persist although science communication typically becomes more critical when there are fewer expert sources of information. The increasing frequency with which observatories and their scientists are required to face the public should motivate agencies large and small to elevate science communication to a position where it can fully contribute to their operations. As growing populations expose more people to volcanic hazards and civil responses become more complex, the benefits of expert science communication will only become more apparent.

## 4.2 Benefits of inter-eruptive co-operation

Despite repeated calls for physical scientists to play a greater role in risk management frameworks, scientists remain concerned about the impact of this shift (Papale, 2017; Bretton et al., 2018a; Donovan, 2019; Papale, 2021). References to “keeping science free from political interference” reflect a feeling among many scientists that their roles should remain limited to providing scientific information which civil authorities then use to develop policy and inform their decision-making during crises. Chief among scientists' concerns are liability for injury, death and property damage during hazard events (Bretton et al., 2015; Scolobig, 2015). While acknowledging the range of science-management arrangements in place around the world, the findings presented here indicate that there are several additional areas where hazard specialists can make valuable contributions to civil risk management efforts while maintaining a separation of roles. The UWI-SRC's effort to maintain stakeholder relationships via its participation in risk reduction projects, policy development and performance evaluation identifies areas for possible cooperation. Increased scientific involvement throughout the risk management cycle positions the advisors to better understand the nuances of volcano risk management in local settings, enabling them to provide better service during crises. This approach has proven successful in disaster management settings around the world (Mercer et al., 2009; Kelman et al., 2012; Gottsmann et al., 2014; Kenney and Phibbs, 2015). At its various non-crisis events, UWI-SRC scientists are exposed to stakeholders' priorities, administrative processes and cultural norms. Information exchanged during these interactions help align mental models and provide important context for future planning and crisis time interventions. These benefits stand to be lost if scientists remain inaccessible.

Long repose between eruptions can reduce public awareness of volcanic hazards in at-risk communities (Paton et al., 2008), but they also present opportunities for cooperation. Time between crises can and should be used to prepare both civil authorities and the public for future eruptions. Increased involvement in non-crisis activities with other stakeholders, offer scientific agencies “safer” opportunities to contribute to national/regional risk management goals. In resource constrained environments, maximising expertise for public good is especially important. Any one of the Eastern Caribbean small island developing states (SIDS) which have live volcanoes can ill afford being set back by a significant eruption. Governments aiming to secure citizens should benefit from what scientific input they can as risk reduction strategies become more comprehensive. Scientific agencies disposed to providing these necessary services will be considered that much more valuable to their societies.

The UWI-SRC's movement toward more interdisciplinary and transdisciplinary work approaches during “peace time” (Table 2) is in line with efforts in the broader scientific community to provide more impactful and usable research results. Stakeholders have



welcomed this type of research as a more practical option aimed at addressing the “usability gap,” having a greater focus on real-world issues (Lemos et al., 2012; Kirchoff et al., 2013; Mauser et al., 2013; Pearman and Cravens, 2022). Despite still lacking some of the methodological structure of some more established research traditions (Felt et al., 2016; Woiwode and Froese, 2021), transdisciplinarity is quickly being embraced as a practical means to understanding complex societal problems requiring input from physical science, social science and indigenous ways of knowing. Several methods have been trialed in the UWI-SRC’s efforts to involve stakeholders in research projects with varying degrees of success. Additional demands on participants’ time remain a significant hurdle in early attempts to co-create research as also noted by Thompson et al. (2017). However, if more research-derived solutions prove promising in practice, stakeholders should be more willing to devote time to research activities. Developing transdisciplinary fixes and methods that can be applied in similar resource-limited contexts will likely encourage more organisations to take up the challenge. More projects aimed at solving real-world problems can provide extra incentive for governments being asked to devote scarce resources to support research. Practical solutions developed in this way are more likely to deliver value for money. Pursuing more research jointly conceptualised by scientists (physical and social) and management practitioners in more diverse settings will also over-time widen the methodological pool available to researchers.

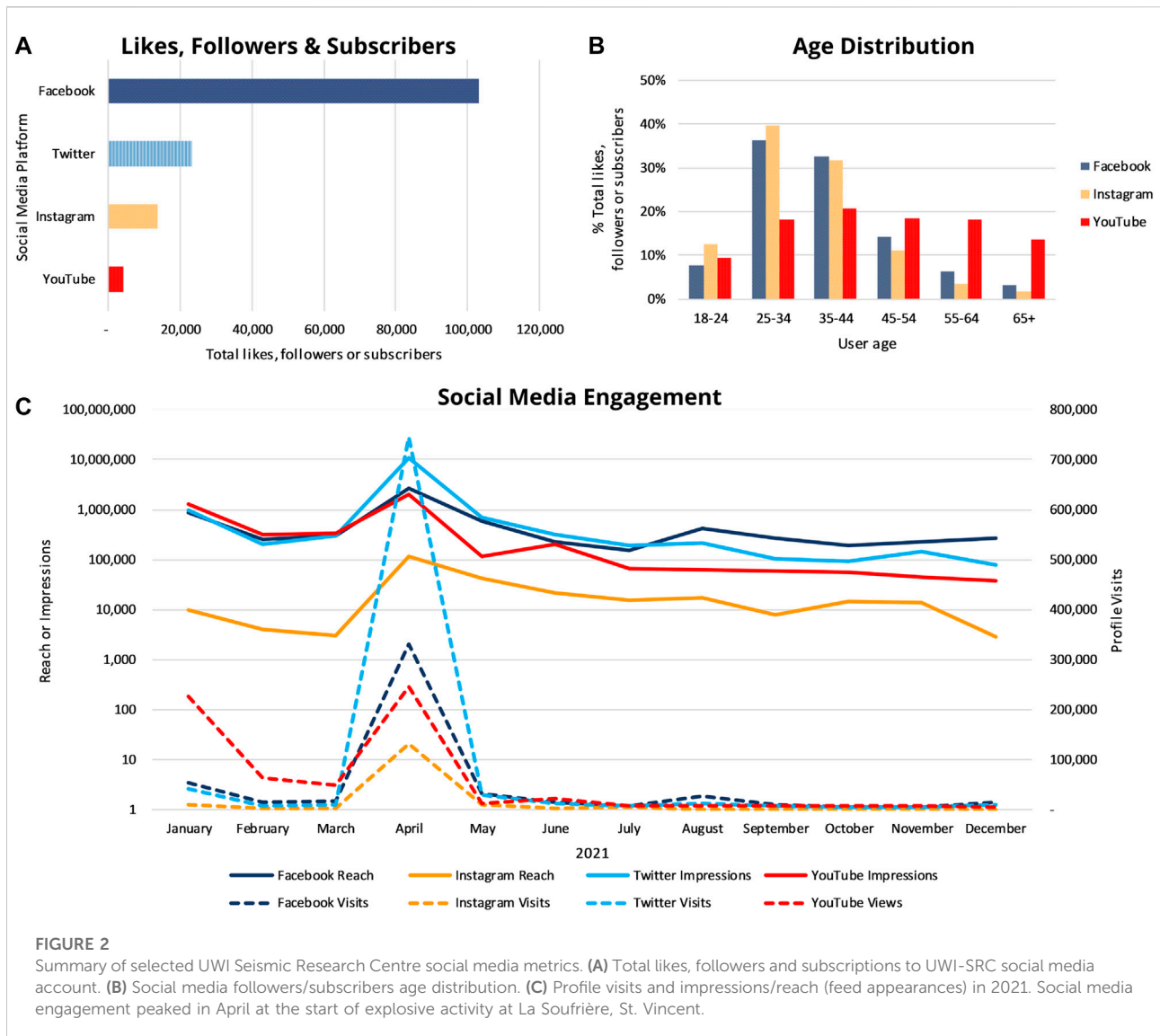
### 4.3 Capacity for growth

The UWI-SRC’s programme to increase physical and social science capacity demonstrates an understanding of the critical importance of subject matter experts to society (Jasanoff, 1990; Guston, 2001; Donovan et al., 2012; Donovan, 2021). Through its Creating Opportunity from Research Experience (C.O.R.E.) internship (UWI Seismic Research Centre, 2021) and post-graduate programme, a nursery of sorts, the Centre is now able to produce new Caribbean specialists available to join an existing pool of experts preparing for and responding to regional crises. The Centre capably advised civil authorities throughout the 2020–2021 eruption at La Soufrière, St. Vincent and the Grenadines, receiving international support in areas where the region lacked resources. Acting on information from a regional agency, political decision makers were able to take timely mitigation action, avoiding loss of life. This type of cooperation underscores the positive impact of resident scientific capacity on disaster risk reduction frameworks. In this instance the UWI-SRC and its disaster management partners have demonstrated what can be achieved as the intentions of Sendai framework (UNISDR, 2015) begin to materialise. These indications should motivate increased efforts to sustain and improve technical capacity.

Caribbean universities are well positioned to develop the multi-disciplinary talent pool needed to understand and manage volcanic risk in the region. The Seismic Research Centre’s experience within The University of the West Indies (The UWI) demonstrates many of the benefits to be had from close observatory-university partnerships advocated for in the literature (IAVCEI Task Group on Crisis Protocols, 2016; Pallister et al., 2019; Lowenstern et al., 2021). Having come into existence almost simultaneously, both regional institutions have made worthy contributions to post-colonial Caribbean society. Potential remains for increased collaboration between the geology/geography program at The UWI and The Seismic Research Centre. With increased support from the university more students can be involved in the UWI-SRC’s work at sixteen (16) volcanoes and may choose to specialise in volcanology. Researchers and students in the social sciences should be invited and encouraged to collaborate with colleagues at the UWI-SRC as interdisciplinary approaches become more refined. Resources at the university’s Disaster Risk Reduction Centre can also be harnessed to improve the region’s preparedness for future volcanic events. Creating hazard and risk assessment expertise should remain a regional priority. To ignore the need to produce its own experts, would be to accept that the region can only exist in a perpetual state of dependence. Even in constrained circumstances, the best use must be made of existing knowledge resources if volcanic regions are to be self-sufficient. Well-trained, well-resourced, homegrown and suitably experienced experts operating in an integrated risk-management framework are critical to achieving more resilient societies.

### 4.4 Accessible science, trusted scientists

Finally, the contributions of specialist communication and outreach to strengthening the Centre’s overall accessibility must be noted. The need to integrate communication strategies at observatories and other scientific organisations involved in managing public risk is well documented; their implementation is strongly encouraged (Newhall et al., 1999; IAVCEI Task Group on Crisis Protocols, 2016; Donovan, 2019; Pallister et al., 2019). In this regard, the advent of the internet and more recently social media has presented scientists with both opportunity and challenge (Sennert et al., 2018). While modern communication technology allows early warning messages to reach vast amounts of people quickly, it also raises the prospect of misinformation on the same scale. The ability to share information easily also raises public expectation of an almost constant flow of information. Having a dedicated and knowledgeable team to satisfy these demands, on a routine basis and during dynamic crisis events, is fundamental in modern risk management. The UWI-SRC’s effective use of social media in the volcano risk-management space presents a workable template for official agencies that has been lacking (Disaster Management SoFS Working Group, 2014; Dufty, 2015; Sennert



et al., 2018). It has also demonstrated the immense benefit of utilising social media as part of a modern, well-executed risk communication strategy. Social media provides a useful platform to continuously engage large numbers of people, across different demographics (Figure 2). At the time of writing the UWI-SRC's Facebook page had over 103,000 likes, its Twitter and Instagram accounts over 23,000 and 13,600 followers respectively. Online visibility invariably increases during crises. At height of the 2020–2021 La Soufrière eruption the Centre's tweets reached 11 million twitter users, while its Facebook posts appeared on 2.6 million users' feeds. Videos on the UWI-SRC's YouTube channel explaining various volcanic phenomena and monitoring techniques amassed 246,000 views in April alone. Scientific agencies and civil protection must use the platform provided by social media to their advantage.

Transactional communication facilitated by social media and other outreach can be a key asset when earning and maintaining public trust. Open, multidirectional communication gives the public opportunities to question methods and interpretations that scientists can defend in a public forum. Information gaps identified by the public can also be highlighted and addressed improving the overall service offered by the agency. This communication approach can over time raise organisational credibility. High levels of credibility can help agencies withstand the negative fallout that can arise when dealing with uncertain natural processes, a concern harboured by many scientists (Marrero et al., 2015; Bretton et al., 2018b). Robust science, culturally sensitive messaging and appealing presentation can be combined to close gaps between scientific understanding

and public perceptions of hazard and risk. Failure to strategically address these “disconnects with society” could result in the type of communication breakdowns observed during the height of COVID-19 pandemic (Flores and Asuncion, 2020; Metcalfe et al., 2020; Dudley et al., 2021). With the appropriate human and physical resources in place, agencies can be publicly perceived as credible sources of scientific information who also understand the common man. This, even when dealing with the uncertainty of natural hazards, increasing sources of misinformation and at times disinformation. Both state and non-governmental organisations involved in risk-management can derive substantial benefit from having communication and social science disciplines assume their rightful place in the disaster risk reduction framework. Investing in these skillsets should be a top priority for any agency involved in protecting the public good.

## 5 Conclusion

The UWI Seismic Research Centre plays an important role in protecting the people of the Eastern Caribbean against the volcanic hazards that exist in the region. This role is not limited to issuing warnings before the onset of these hazards but also includes helping residents learn to live with them sustainably. All UWI-SRC outreach is motivated by a desire to reduce vulnerability in the territories under its care. Sustained investment in science communication and social science capability should position this Caribbean institution to make valuable contributions to regional risk management into the future. Even as scientists work with civil authorities, conduct impactful research and support capacity building, the UWI-SRC's outreach work will remain crucial to reducing the impact of volcanic unrest and eruptions in the Eastern Caribbean. With organisational support, science communication at the Centre can continue to meaningfully contribute to the sustainable development of the region.

## Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by Campus Research Ethics Committee, The University of the West Indies, St. Augustine Campus. The

patients/participants provided their written informed consent to participate in this study.

## Author contributions

OG was the primary researcher and was responsible for preparing the manuscript, including tables and figures. SE and RR provided review/editorial support in the preparation of this work.

## Funding

The support for payment of open access publication fees provided by The UWI Seismic Research Centre and The University of the West Indies, St. Augustine Campus Research and Publication Fund.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## Acknowledgments

The authors wish to recognize the contributions of all the staff at The University of the West Indies Seismic Research Centre to the work of the Education and Outreach section over the years. We also wish to thank all regional and international stakeholders that have partnered with the UWI-SRC E&O on various occasions.

## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feart.2022.907559/full#supplementary-material>

## References

- Andreastuti, S., Budianto, A., and Paripurno, E. T. (2018). "Integrating social and physical perspectives of mitigation policy and practice in Indonesia," in *Observing the volcano world: Volcano crisis communication*. Editors C. J. Fearnley, D. K. Bird, K. Haynes, W. J. McGuire, and G. Jolly (Cham: Springer International Publishing), 307–320.
- Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.* 3 (2), 77–101. doi:10.1191/1478088706qp063oa
- Bretton, R. J., Gottsmann, J., Aspinall, W. P., and Christie, R. (2015). Implications of legal scrutiny processes (including the L'Aquila trial and other recent court cases) for future volcanic risk governance. *J. Appl. Volcanol.* 4 (1), 18. doi:10.1186/s13617-015-0034-x
- Bretton, R. J., Gottsmann, J., and Christie, R. (2018a). Hazard communication by volcanologists: Part 1 - framing the case for contextualisation and related quality standards in volcanic hazard assessments. *J. Appl. Volcanol.* 7 (1), 9. doi:10.1186/s13617-018-0077-x
- Bretton, R. J., Gottsmann, J., and Christie, R. (2018b). Hazard communication by volcanologists: Part 2 - Quality standards for volcanic hazard assessments. *J. Appl. Volcanol.* 7 (1), 10. doi:10.1186/s13617-018-0079-8
- Burr, V. (2015). *Social constructionism*. Oxfordshire, England, UK: Routledge.
- Chorus, I. (1999). *Toxic Cyanobacteria in Water - a guide to their public health consequences, monitoring and management*. Geneva, Switzerland: World Health Organization.
- Creswell, J. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage Publications.
- Disaster Management SoFS Working Group (2014). *Building a system of systems for disaster management workshop: Joint issues statement*. Canberra, Australia: CSIRO.
- Donovan, A. (2019). Critical volcanology? Thinking holistically about risk and uncertainty. *Bull. Volcanol.* 81 (4), 20. doi:10.1007/s00445-019-1279-8
- Donovan, A., Oppenheimer, C., and Bravo, M. (2012). Social studies of volcanology: Knowledge generation and expert advice on active volcanoes. *Bull. Volcanol.* 74 (3), 677–689. doi:10.1007/s00445-011-0547-z
- Donovan, D. A. (2021). Experts in emergencies: A framework for understanding scientific advice in crisis contexts. *Int. J. Disaster Risk Reduct.* 56, 102064. doi:10.1016/j.ijdrr.2021.102064
- Doyle, E. E. H., and Paton, D. (2018). "Decision-Making: Preventing miscommunication and creating shared meaning between stakeholders," in *Observing the volcano world: Volcano crisis communication*. Editors C. J. Fearnley, D. K. Bird, K. Haynes, W. J. McGuire, and G. Jolly (Cham: Springer International Publishing), 549–570.
- Doyle, E. E. H., Paton, D., and Johnston, D. M. (2015). Enhancing scientific response in a crisis: Evidence-based approaches from emergency management in New Zealand. *J. Appl. Volcanol.* 4 (1), 1. doi:10.1186/s13617-014-0020-8
- Dudley, M. Z., Bernier, R., Brewer, J., and Salmon, D. A. (2021). Walking the Tightrope: Reevaluating science communication in the era of COVID-19 vaccines. *Vaccine* 39 (39), 5453–5455. doi:10.1016/j.vaccine.2021.08.037
- Dufty, N. (2015). The use of social media in countrywide disaster risk reduction public awareness strategies. *Aust. J. Emerg. Manag.* 30, 12–16.
- Fearnley, C., Winson, A. E. G., Pallister, J., and Tilling, R. (2018). "Volcano crisis communication: Challenges and solutions in the 21st century," in *Observing the volcano world: Volcano crisis communication*. Editors C. J. Fearnley, D. K. Bird, K. Haynes, W. J. McGuire, and G. Jolly (Cham: Springer International Publishing), 3–21.
- Felt, U., Igelsböck, J., Schikowitz, A., and Völker, T. (2016). Transdisciplinary sustainability research in practice. *Sci. Technol. Hum. Values* 41 (4), 732–761. doi:10.1177/0162243915626989
- Feuillard, M., Allègre, C. J., Brandeis, G., Gaulon, R., Le Mouel, J.-L., Mercier, J., et al. (1983). The 1975–1977 crisis of La Soufrière de Guadeloupe (F.W.I.): A still born magmatic eruption. *J. Volcanol. Geotherm. Res.* 6, 295–304.
- Fiske, R. Geophysics Study Committee; National Research Council (1984). "Volcanologists, journalists, and the concerned local public: A tale of two crises in the eastern caribbean," in *Explosive volcanism: Inception, evolution and hazards* (Washington: National Academy Press), 170–176.
- Flores, R., and Asuncion, X. V. (2020). Toward an improved risk/crisis communication in this time of COVID-19 pandemic: A baseline study for philippine local government units. *Jcom* 19 (07), A09. doi:10.22323/2.19070209
- Gottsmann, J., Christie, R., and Bretton, R. (2014). *Inside the volcanic boiler room: Knowledge exchange among stakeholders of volcanic unrest*. Vienna, Austria: EGU General Assembly.
- Graham, O., Edwards, S., and Robertson, R. (2022). Managing stakeholder relationships for improved situation awareness during volcanic emergencies: An Eastern Caribbean case study. *Int. J. Disaster Risk Reduct.* 67, 102656. doi:10.1016/j.ijdrr.2021.102656
- Guston, D. H. (2001). Boundary organizations in environmental policy and science: An introduction. *Sci. Technol. Hum. Values* 26 (4), 399–408. doi:10.1177/016224390102600401
- Health Protection Network (2008). *Communicating with the public about health risks*. Glasgow, Scotland: Health Protection Network Guidance.
- Iavcei Subcommittee for Crisis Prot, C., Newhall, C., Barberi, F., Blong, R., Calvache, M., Cheminee, J.-L., et al. (1999). Professional conduct of scientists during volcanic crises. *Bull. Volcanol.* 60 (5), 323–334. doi:10.1007/PL00008908
- IAVCEI Task Group on Crisis Protocols (2016). Toward IAVCEI guidelines on the roles and responsibilities of scientists involved in volcanic hazard evaluation, risk mitigation, and crisis response. *Bull. Volcanol.* 78 (4), 31. doi:10.1007/s00445-016-1021-8
- Infanti, J., Sixsmith, J., Barry, M. M., Núñez-Córdoba, J., Oroviogicochea-Ortega, C., and Guillén-Grima, F. (2013). *A literature review on effective risk communication for the prevention and control of communicable diseases in Europe*. Stockholm: ECDC.
- Jasanoff, S. (1990). *The fifth branch: Science advisers as policymakers*. Massachusetts, United States: Harvard University Press.
- Kelman, I., Mercer, J., and Gaillard, J. (2012). Indigenous knowledge and disaster risk reduction. *Geography* 97 (1), 12–21. doi:10.1080/00167487.2012.12094332
- Kenney, C. M., and Phibbs, S. (2015). A Māori love story: Community-led disaster management in response to the Ōtautahi (Christchurch) earthquakes as a framework for action. *Int. J. Disaster Risk Reduct.* 14, 46–55. doi:10.1016/j.ijdrr.2014.12.010
- Kirchhoff, C. J., Carmen Lemos, M., and Dessai, S. (2013). Actionable knowledge for environmental decision making: Broadening the usability of climate science. *Annu. Rev. Environ. Resour.* 38 (1), 393–414. doi:10.1146/annurev-environ-022112-112828
- Latchman, J., Lynch, L., and Edwards, S. (2012). 60 years of monitoring volcanic and earthquake activity in the English-speaking Eastern Caribbean. *Caribb. Geogr.* 17 (1&2).
- Lemos, M. C., Kirchhoff, C. J., and Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nat. Clim. Change* 2 (11), 789–794. doi:10.1038/nclimate1614
- Lindsay, J. M., Robertson, R. E. A., Shepherd, J., and Ali, S. (2005). Volcanic hazard Atlas of the lesser Antilles. *Trinidad and tobago, W.I.: Seismic research unit*. Kingston, Jamaica: The University of the West Indies.
- Loughlin, S. C., Baxter, P. J., Aspinall, W. P., Darroux, B., Harford, C. L., and Miller, A. D. (2002). Eyewitness accounts of the 25 June 1997 pyroclastic flows and surges at Soufrière Hills Volcano, Montserrat, and implications for disaster mitigation. *Geol. Soc. Lond. Memoirs* 21 (1), 211–230. doi:10.1144/gsl.mem.2002.021.01.10
- Lowenstern, J. B., Ewert, J. W., and Lockhart, A. B. (2021). Strengthening local volcano observatories through global collaborations. *Bull. Volcanol.* 84 (1), 10. doi:10.1007/s00445-021-01512-w
- Marrero, J. M., García, A., Llinares, Á., Berrococo, M., and Ortiz, R. (2015). Legal framework and scientific responsibilities during volcanic crises: The case of the el hierro eruption (2011–2014). *J. Appl. Volcanol.* 4 (1), 13. doi:10.1186/s13617-015-0028-8
- Mausser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., et al. (2013). Transdisciplinary global change research: The co-creation of knowledge for sustainability. *Curr. Opin. Environ. Sustain.* 5 (3), 420–431. doi:10.1016/j.cosust.2013.07.001
- McGuire, W. J., Solana, M. C., Kilburn, C. R. J., and Sanderson, D. (2009). Improving communication during volcanic crises on small, vulnerable islands. *J. Volcanol. Geotherm. Res.* 183 (1–2), 63–75. doi:10.1016/j.jvolgeores.2009.02.019
- Mercer, J., Kelman, I., Suchet-pearson, S., and Lloyd, K. (2009). Integrating indigenous and scientific knowledge bases for disaster risk reduction in Papua New Guinea. *Geogr. Ann. Ser. B, Hum. Geogr.* 91 (2), 157–183. doi:10.1111/j.1468-0467.2009.00312.x
- Metcalfe, J., Riedlinger, M., Bauer, M. W., Chakraborty, A., Gascoigne, T., Guenther, L., et al. (2020). The COVID-19 mirror: Reflecting science-society relationships across 11 countries. *J. Sci. Commun.* 19 (07). doi:10.22323/2.19070205
- Mothes, P. A., Yepes, H. A., Hall, M. L., Ramón, P. A., Steele, A. L., and Ruiz, M. C. (2015). The scientific-community interface over the fifteen-year eruptive episode of

- Tungurahua Volcano, Ecuador. *J. Appl. Volcanol.* 4 (1), 9. doi:10.1186/s13617-015-0025-y
- Nakada, S., Miyagi, Y., Miyagi, Y., Kubo, T., and Fujita, E. (2019). Conveying volcano information effectively to stakeholders - a new project for promotion of next generation volcano research. *J. Disaster Res.* 14 (4), 623–629. doi:10.20965/jdr.2019.p0623
- Navarro, K., and McKinnon, M. (2020). Challenges of communicating science: Perspectives from the Philippines. *Jcom* 19 (01), A03. doi:10.22323/2.19010203
- NVivo, QSR international pty ltd. (2018). "(Version 12)".
- Pallister, J., Papale, P., Eichelberger, J., Newhall, C., Mandeville, C., Nakada, S., et al. (2019). Volcano observatory best practices (VOBP) workshops - A summary of findings and best-practice recommendations. *J. Appl. Volcanol.* 8 (1), 1–33. doi:10.1186/s13617-019-0082-8
- Papale, P. (2017). Rational volcanic hazard forecasts and the use of volcanic alert levels. *J. Appl. Volcanol.* 6 (1), 13. doi:10.1186/s13617-017-0064-7
- Papale, P. (2021). "Some relevant issues in volcanic hazard forecasts and management of volcanic crisis," in *Forecasting and planning for volcanic hazards, risks, and disasters*. Editor P. Papale (Amsterdam, Netherlands: Elsevier), 1–24. doi:10.1016/b978-0-12-818082-2.00001-9
- Pasquarè, F., and Pozzetti, M. (2007). Geological hazards, disasters and the media: The Italian case study. *Quat. Int.* 173–174, 166–171. doi:10.1016/j.quaint.2007.03.002
- Paton, D., Smith, L., Daly, M., and Johnston, D. (2008). Risk perception and volcanic hazard mitigation: Individual and social perspectives. *J. Volcanol. Geotherm. Res.* 172 (3), 179–188. doi:10.1016/j.jvolgeores.2007.12.026
- Patton, M. (2002). *Qualitative research and evaluation methods*. Thousand Oaks, CA: Sage.
- Pearman, O., and Cravens, A. E. (2022). Institutional barriers to actionable science: Perspectives from decision support tool creators. *Environ. Sci. Policy* 128, 317–325. doi:10.1016/j.envsci.2021.12.004
- Scolobig, A. (2015). The dark side of risk and crisis communication: Legal conflicts and responsibility allocation. *Nat. Hazards Earth Syst. Sci. Discuss.* 3 (4), 2739–2756. doi:10.5194/nhessd-3-2739-2015
- Sennert, S. S. K., Klemetti, E. W., and Bird, D. K. (2018). "Role of social media and networking in volcanic crises and communication," in *Observing the volcano world: Volcano crisis communication*. Editors C. J. Fearnley, D. K. Bird, K. Haynes, W. J. McGuire, and G. Jolly (Cham: Springer International Publishing), 733–743.
- Shepherd, J. B., Aspinall, W. P., Rowley, K. C., Pereira, J., Sigurdsson, H., Fiske, R. S., et al. (1979). The eruption of Soufrière volcano, st vincent april-june 1979. *Nature* 282 (5734), 24–28. doi:10.1038/282024a0
- Shepherd, J., Rowley, K., Lynch, L., Beckles, D., and Suite, W. (1988). "Summary proceedings of lesser Antilles volcanic assessment seminar," in Lesser Antilles Volcanic Assessment Seminar, St. Augustine, Trinidad, Apr. 1988 (UWI Seismic Research Unit).
- Sieh, K. (2006). Sumatran megathrust earthquakes: From science to saving lives. *Phil. Trans. R. Soc. A* 364(1845), 1947–1963. doi:10.1098/rsta.2006.1807
- Stone, J., Barclay, J., Simmons, P., Cole, P. D., Loughlin, S. C., Ramón, P., et al. (2014). Risk reduction through community-based monitoring: The vigias of Tungurahua, Ecuador. *J. Appl. Volcanol.* 3 (1), 11. doi:10.1186/s13617-014-0011-9
- Thompson, M. A., Owen, S., Lindsay, J. M., Leonard, G. S., and Cronin, S. J. (2017). Scientist and stakeholder perspectives of transdisciplinary research: Early attitudes, expectations, and tensions. *Environ. Sci. Policy* 74, 30–39. doi:10.1016/j.envsci.2017.04.006
- UNISDR (2006). "Developing early warning systems: A checklist," in Third International Conference on Early Warning, Bonn, Germany (United Nations International Strategy for Disaster Reduction).
- UNISDR (2015). "Sendai framework for disaster risk reduction 2015–2030," in Proceedings of the 3rd United Nations World Conference on DRR, Sendai, Japan, 18 March 2015.
- UWI Seismic Research Centre (2021). *CORE internship* [online]. Trinidad: The UWI seismic research centre. Available: <https://uwiseismic.com/education-outreach/core-internship/> (Accessed 316, 2022).
- UWI Seismic Research Centre (2003). *Mitigation of geologic hazards in the lesser Antilles and adjacent islands: Public education and awareness - final report*. St. Augustine.
- Woiwode, H., and Froese, A. (2021). Two hearts beating in a research centers' chest: How scholars in interdisciplinary research settings cope with monodisciplinary deep structures. *Stud. High. Educ.* 46 (11), 2230–2244. doi:10.1080/03075079.2020.1716321