

Hawai'i residents' perceptions of Kīlauea's 2018 eruption information

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ABSTRACT

The 2018 eruption of Kīlauea Volcano was notable for its variety of large and spatially distinct hazards, simultaneously affecting three geographically disparate, culturally diverse regions in Hawai'i. We conducted a pilot study, consisting of 18 semi-structured interviews, two survey responses, and several informal conversations with Hawai'i residents to learn which sources/messengers of eruption information were deemed most trusted and credible. Participants' perceptions of the U.S. Geological Survey Hawaiian Volcano Observatory (HVO), community-based messengers, and traditional news media can be examined across four themes: relevance, expertise, sincerity, and pace. Among our interview participants, Lower East Rift Zone (LERZ) residents placed the highest trust in their community messengers, summit residents deemed HVO most trustworthy, and Ka'ū residents trusted information from both HVO and local news media. Our findings suggest that future official eruption communications would benefit from 1) designating communications personnel to act as community liaisons and 2) increasing pace and relevance of information delivery.

KEYWORDS: Kilauea; Hazard communication; Trust; Messenger; Social media.

1 INTRODUCTION

Residents and emergency responders living and working on active volcanoes depend on reliable and regularly communicated information regarding eruptive activity to make decisions that promote situational awareness and safety. Information can come from a variety of sources, including government science agencies, news organizations, and members of the impacted communities, as has been documented, for example, at Mount Agung, Indonesia [Syahbana et al. 2019] and Mount Pinatubo, Philippines [Newhall and Solidum 2017].

The 2018 eruption of Kīlauea Volcano on the Island of Hawai'i, USA (Figure 1), also known as the Big Island, was the largest of its kind in the last 200 years [Neal et al. 2019]. A broad and diverse communication strategy was required to minimize the impacts experienced by communities in each of the regions vulnerable to eruption hazards [Tsang and Lindsay 2019; Williams et al. 2020]. The three-month-long course of events was witnessed via a media landscape that greatly differs from past events at Kīlauea, such as the 1990 lava flow crisis in Kalapana, and even from other eruptions of U.S. volcanoes that have garnered substantial media attention, such as the 1980 eruption of Mount St. Helens [Perry and Greene 1983]. In addition to being covered by traditional media (newsprint, radio, television), the 2018 eruption was one of the first in the United States to be widely viewed on social media networks.

The U.S. Geological Survey Hawaiian Volcano Observatory (HVO) is the official volcano monitoring agency for the State of Hawai'i's active volcanoes, including Kīlauea. With their mandate to provide timely eruption information, HVO communicated 2018 eruption developments in a variety of ways, including through press briefings, media interviews,

community meetings, websites, and the U.S. Geological Survey (USGS) Volcano Hazard Program's social media pages (Facebook, Twitter, YouTube). In addition to HVO and traditional media outlets, there were several residents of Hawai'i's hazard-impacted communities who served as citizen journalists. These people are defined as community members unaffiliated with and unpaid by official media organizations who collected and posted eruption information and footage on their own websites or social media pages for other community members to read and view [Farinosi and Treré 2014].

In this study, we use semi-structured in-person interviews and printed surveys to gain a preliminary understanding of how residents on the Island of Hawai'i felt about eruption-related information provided by HVO, traditional news organizations, and citizen journalists. Specifically, we organize interview participants' perceptions into four themes (defined in Section 1.3) relating to trust and accessibility, which we use to evaluate each communicator's performance, and from there discuss considerations for future hazard communication efforts. Though exploratory, our results provide useful and actionable feedback to increase the reach and effectiveness of information dissemination and engagement with affected communities.

1.1 Eruptive hazards at Kīlauea Volcano

In the 35 years preceding the 2018 eruption, Kīlauea Volcano experienced near-continuous eruptive activity from Pu'u'ō'ō on the East Rift Zone (ERZ, 1983–2018 [Orr et al. 2012; Neal et al. 2019]), as well as a sustained lava lake in the summit crater Halema'uma'u for 10 years (2008–2018 [Gaddis and Kauahikaua 2021; Patrick et al. 2021]). Several historically recent eruptions have demonstrated that communities situated downslope of Pu'u'ō'ō are especially vulnerable to lava flows [Wright 1992]. In 1990, over 100 buildings in Kalapana were

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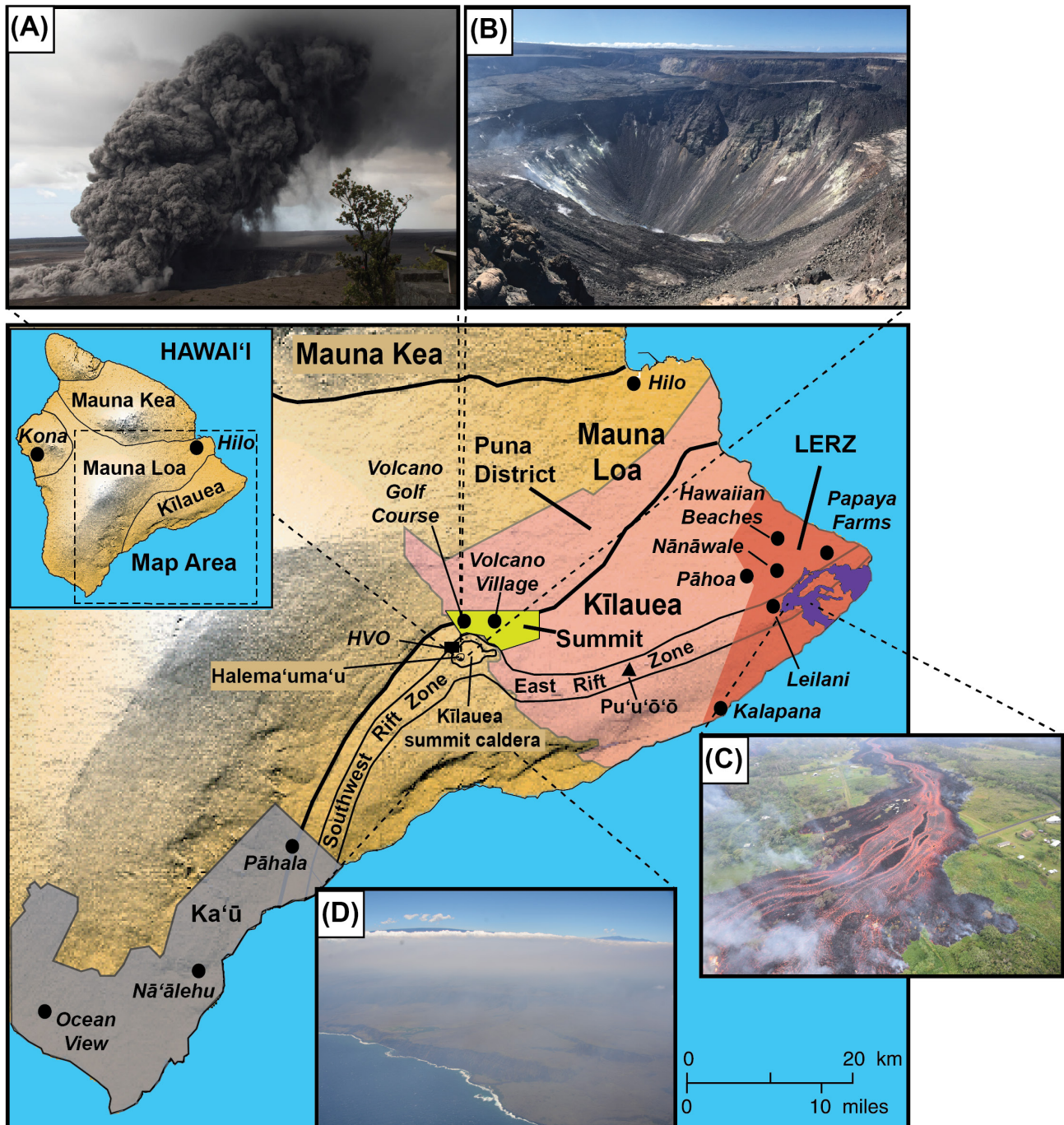


Figure 1: Map of the Island of Hawai'i and images of hazards produced by Kīlauea in 2018. Shaded polygons indicate the regions referred to in this manuscript as the Lower East Rift Zone, or LERZ (orange); summit (yellow); and Ka'ū (gray); as well as the Puna District (pink) that includes both the LERZ and summit. HVO = USGS Hawaiian Volcano Observatory. Hazards from the 2018 eruption included [A] eruptions of ash plumes from the summit that carried ash as far as the Hawaiian Ocean View Estates, or "Ocean View" (in southwestern Ka'ū); [B] the collapse of Kīlauea's summit caldera, producing earthquakes of M5.2 or larger once every ~30 hours and producing a large crater-like depression (photo taken in May 2019 by Matthew Patrick, USGS); [C] extensive lava flows that destroyed over 700 buildings in the LERZ; and [D] vog, which formed from atmospheric reactions with volcanic gas emitted from the LERZ and summit and degraded air quality throughout Hawai'i. (Adapted from [Tilling et al. \[2010\]](#)).

buried by 15–25 meters of lava [[Babb et al. 2011](#)]. From June 2014 to early 2015, a lava flow traveled 20 km from Pu'u'ō'ō and nearly cut off all existing roads into and out of the Puna

District [[Brantley et al. 2019](#)]. The risk posed by Kīlauea's eruptions in this region was exacerbated by rapid population growth in Pāhoā and Kalapana from 1970–80, which contin-

ued (albeit at a slower rate) through 2010 [Houghton et al. 2021] before decreasing between 2010 and 2020 [United States Census Bureau 2021].

The 2018 eruption of Kīlauea Volcano presented a suite of eruptive phenomena that posed risks to Hawaiʻi communities (Figure 1). Roughly 0.9–2.3 km³ dense-rock equivalent of lava (Figure 1A) erupted in the Lower East Rift Zone (LERZ) [Kern et al. 2020; Dietterich et al. 2021] and destroyed over 700 structures [Williams et al. 2020]. Evacuation of 0.8 km³ of stored summit magma that helped feed the LERZ flows caused the overlying caldera floor to repeatedly collapse [Anderson et al. 2019], eventually creating a crater over 500 m deep [Figure 1; Neal et al. 2019]. Caldera collapse events, each producing M5.2–5.4 earthquakes, recurred at 30-hour intervals from late May to early August, while over 700 earthquakes ≥ M4.0 occurred between each collapse [Neal et al. 2019]. These earthquakes rattled the summit area and contributed to structural damage of buildings within Hawaiʻi Volcanoes National Park, including HVO and the Jaggar Museum, and numerous other buildings and homes in the nearby Volcano Village and Volcano Golf Course communities. Eruptions of ash from the summit (Figure 1C) fell within those same neighboring communities and also traveled downwind to communities in the island’s southern Kaʻū district, presenting a novel hazard of ashfall to residents. Emission of an estimated 7.1–13.6 Mt of sulfur dioxide (SO₂) occurred from both the LERZ and summit [Kern et al. 2020], resulting in prevalent volcanic smog (“vog,” Figure 1E) and severely impacting local and downwind air quality in Puna and communities as far as Pāhala, Hawaiian Ocean View Estates, and Kailua-Kona [Figure 1; Whitty et al. 2020; Crawford et al. 2021].

1.2 Hazard communications during the 2018 Kīlauea eruption

Communications theory provides models for analyzing how people receive information during a natural hazard crisis with uncertain outcomes. Berlo [1960] developed a well-known model of communication in which a “source,” defined as the origin of a piece of information, delivers that piece of information (the “message”) through a mode of communication (a “channel”) to people (the “publics”) who receive the information. Broom [1977] suggested that communication is a social contract, and its effectiveness is defined by relationships between sources, messengers, and publics with a common theme (e.g. Kīlauea’s eruption) to which they are all cooriented [see also Broom and Dozier 1990]. Whereas the model of Berlo [1960] is unidirectional and best suited for broadcast media channels (e.g. print, radio, and television), Broom’s focus on relationships provides a multidirectional framework to analyze socially oriented communication media (e.g. community meetings, social media).

In the midst of the 2018 Kīlauea Volcano crisis, eruption and hazards information was variably sourced and prolifically messaged to publics on many channels. The following definitions of source, messenger, and channel are modeled after components defined by Berlo [1960], and we use them to interpret our findings (in Section 4) with the “coorientation measurement model” of Broom [1977]. Sources gathered first-hand accounts of eruption data and are originators of scientific ob-

servations and resultant interpretations, while messengers are individuals, groups, or organizations who conveyed Kīlauea-related information to publics. We consider HVO and their government partners to be official sources and messengers of eruption information. Citizen journalists acted as unofficial sources and messengers of eruption information by providing eyewitness accounts of the eruption and associated hazards to members of their community. We define news media organizations as messengers who provided officially sourced eruption information to publics. Channels are the vehicle through which eruption information was conveyed. Channels include social media (Facebook or YouTube), traditional news (radio, television, print newspapers, online or mobile news), government text or email alerts, official government websites (e.g. HVO), and community meetings.

We use the term publics, following the definition of Grunig [1992], to describe people who received, and had a vested interest in, information about the Kīlauea eruption. In this study, we define publics as residents from three regions of Hawaiʻi impacted by eruption hazards in 2018: the LERZ, the summit, and the Kaʻū district (in the Interview and survey methods section, we list the neighborhoods we define as being included in each region). We exclude citizen journalists from our definition of publics because, although they are members of communities in Hawaiʻi who interacted with HVO’s eruption-related information, the aim of our study is to understand how citizen journalists’ audiences interacted with and evaluated their communications compared with those of HVO and news media.

HVO has utilized a variety of channels to inform the public of eruptive activity over the last decade [Brantley et al. 2019], with social media playing its most significant role during Kīlauea’s 2018 eruption [Williams et al. 2020]. This eruption generated significant media attention, with professional reporters from across the world traveling to and reporting from the Island of Hawaiʻi about the eruption [Tsang and Lindsay 2019]. Despite this heightened media interest, Tsang and Lindsay [2019] reported that a number of LERZ residents expressed concern at either not receiving enough eruption coverage from news organizations or receiving sensationalized coverage of eruption events that provided no practical information for residents to use. Additionally, several LERZ residents interviewed by Tsang and Lindsay [2019] reported that government officials did not provide regularly scheduled press briefings to inform their community of eruption developments. Thus, some residents chose to voluntarily provide on-the-ground, locally relevant eruption coverage as citizen journalists [Tsang and Lindsay 2019].

1.3 Trusted and effective sources/messengers of hazard information

Substantive hazard communication research requires a synthesis of both natural and social sciences [Donovan et al. 2014]. In addition to understanding the causes of natural hazards and their potential impacts on human populations, hazard managers and communicators must also understand how or whether people develop trust in the messengers of volcanic hazard information [Haynes et al. 2008; Donovan et al. 2014].

The “trusted and credible messenger” [e.g. Furr-Holden 2021] is, perhaps, the most valuable component of persuasive communication, having appeared frequently in public discourse regarding COVID-19 vaccination campaigns [Oberman and Harris-Perry 2021]. Tumpey et al. [2019] described credible and trustworthy messengers (henceforth, “TCMs”) as people who communicate information to publics in a manner that is 1) empathic and caring, 2) honest and open, 3) dedicated and committed, and 4) competent and expertly. For our study, TCMs include both messengers and sources of 2018 eruption information. Similar qualities as those listed by Tumpey et al. [2019] are cited by hazard communication researchers as forming the basis of publics’ judgements of the trustworthiness of sources/messengers in complex or high-stress situations [Renn and Levine 1991; Earle and Cvetkovich 1995; Poortinga and Pidgeon 2003; Covello 2008]. In complex situations, people’s trust in a source/messenger is based less on “carefully reasoned arguments” than on “agreement and sympathy,” meaning that people in a crisis situation are more likely to trust a source/messenger that shares their values or “is seen as having the same understanding of a specific situation” [Earle and Cvetkovich 1995; Poortinga and Pidgeon 2003]. Therefore, it is vital for agencies responsible for eruption response and mitigation to understand how to effectively build trustworthiness with the communities they serve so that hazard-related information is understood and heeded during a natural crisis.

Another important component of successful hazard communication is providing clear messages that can be accessed and understood by vulnerable populations. Covello [2003] stated that successful crisis communication includes using “clear, non-technical language appropriate to the target audience,” and Sellnow et al. [2009] described the importance of effectively tailoring one’s messages to fit the needs of a particular group or population. McBride [2017] found that official earthquake preparedness documents in Christchurch, New Zealand, did not effectively prepare residents for the 2010–2011 Canterbury Sequence due to containing “overly long, jargon-laden text,” while vulnerable populations living on active volcanoes in Indonesia or Ecuador have been most resilient to hazards from these volcanoes when they have access to the relevant scientific information [Mei et al. 2013; Few et al. 2017; Naismith et al. 2020]. In fact, local people’s trust in scientists at Tungurahua Volcano, Ecuador, has resulted from the direct, sustained interactions (i.e. accessibility) of scientists with those communities [Stone et al. 2014; Mothes et al. 2015].

Given their demonstrated importance in hazard communication, we incorporate the concepts of accessibility and trust into our interpretation of the interview conversations we held with residents in Hawai'i. Specifically, we define four themes: *relevance*, *expertise*, *pace*, and *sincerity*. *Relevance* refers to how well a source or messenger delivered physically and cognitively accessible, locally relevant, and/or useful eruption information to various publics in Hawai'i [Covello 2003; Sellnow et al. 2009]. *Expertise* is the degree to which participants reported feeling that a source or messenger was knowledgeable about volcanic hazards and/or provided factual information about the 2018 eruption. This theme is derived from the “perceived competence” component of trust [Renn and Levine

1991] and the similarly phrased “competence and expertise” factor of TCMs [Tumpey et al. 2019]. *Pace* is the reported regularity and promptness with which a source or messenger delivered new information. We derive this theme from the “consistency” component of trust [Renn and Levine 1991] and the “dedication and commitment” factor of TCMs [Tumpey et al. 2019]. *Sincerity* describes whether participants reported feeling that a source or messenger acted honestly, transparently, or in good faith in communicating eruption hazards to them. This theme is derived from the “faith” component of trust [Renn and Levine 1991] and both the “empathy and caring” and “honesty and openness” factors of TCMs [Tumpey et al. 2019].

2 INTERVIEW AND SURVEY METHODS

During January 2020, we collected interview or survey responses from 20 residents of the Island of Hawai'i to address the following questions:

- How often did these residents turn to television, radio, print newspapers, websites of news and government organizations, and social media for eruption-related information?
- How frequently did people attend in-person community meetings facilitated or attended by HVO staff?
- What were respondents’ reported perceptions of information coming from
 - HVO,
 - the USGS Volcano Hazard Program’s social media handle @USGSVolcanoes (which provides information on behalf of HVO and the four other USGS volcano observatories), and/or
 - the USGS’s YouTube channel (which provided regularly updated video footage of the 2018 eruption)?
- What were respondents’ reported perceptions of information coming from traditional news media?
- On social media platforms, which accounts other than @USGSVolcanoes did respondents follow? What were respondents’ reported perceptions of information coming from these social media accounts?

2.1 Interview and survey participants

Recruitment of interview and survey participants followed three methods: (1) asking people in public venues to participate, (2) posting flyers at the University of Hawai'i Hilo’s campus with the lead author’s contact information, and (3) arranging interviews in advance over the phone or email. For the two participants whose interviews were arranged in advance, contact information for those participants was provided by either HVO contacts or one of our previous interview participants. We define interview participants as those with whom we held oral interviews, while survey participants are those who opted to fill out our survey questions entirely by hand. The survey format is described in Section 2.2.

The 20 interview and survey participants were from three distinct areas of the Island of Hawai'i. Ten people were

from the LERZ, residing in the neighborhoods of Leilani Estates (“Leilani”), Nānāwale Estates (“Nānāwale”), Hawaiian Beaches, and Kalapana during the 2018 eruption (Figure 1). We conducted oral interviews with eight of these residents, while the remaining two completed their surveys entirely by hand. Four interview conversations were conducted in Kīlauea Volcano’s summit region among residents of Volcano Village and Volcano Golf Course (Figure 1). The remaining six interviews were conducted in the Ka’ū district with residents of Pāhala, Na’ālehu, and Hawaiian Ocean View Estates (“Ocean View”; Figure 1). In terms of the local setting, 13 of the 20 interviews and surveys were held at farmer’s markets stands, outdoor dining tables, or on the University of Hawai’i Hilo’s campus. The remaining seven interviews were conducted in public parking lots, inside a locally owned shop, or over the phone. When possible, interviews were conducted in private, either at an empty table, in a participant’s car, or in an empty room. When complete privacy was not possible, interviews were conducted as far from crowded areas as possible.

Culture in Hawai’i includes time for storytelling as part of conversations. By honoring this “talk story,” individual interviews collected for this study sometimes lasted an hour or more. Digesting such conversations required additional time. This protracted time for individual interviews combined with conducting them only over the course of a few weeks, resulted in a sample size ($N = 20$) that is not representative of the entire impacted population on the Island of Hawai’i. For this reason, we frame this work as a pilot study in which the responses of our 20 interview and survey participants are considered informative, rather than indicative, of the attitudes of Hawai’i residents toward traditional and social media sources of eruption-related information during the 2018 crisis. We note, however, that qualitative methods require fewer respondents to determine relevant themes; anywhere from 5–50 may be sufficient to achieve this aim [Baker and Edwards 2012].

In addition to our 20 formal interviews and surveys, we conducted further conversations with numerous other individuals that were too casual or brief to be formally recorded in our survey documents; we refer to these conversations as “informal” interviews. Nonetheless, these conversations provided helpful information on eruption communications in harder-to-reach communities in the LERZ (via the Maku’u and Uncle Robert’s farmer’s markets) and Ka’ū (at the Na’ālehu and Ocean View “Malama” farmer’s markets). We also held formal interview conversations with two community messengers but do not report their quantitative responses in this study to avoid biasing those results in their favor (compared with other sources/messengers). We include quotes from both formal and informal interview conversations in Section 4 (Qualitative thematic insights from participants’ commentary) and the Discussion (Section 6).

Interview and survey participants were told that their participation was completely voluntary and that they could opt-out at any time during the conversation. Participants were not provided financial compensation for their time. While presented as structured questionnaires, our oral interviews were conducted in a semi-structured manner to facilitate organic

conversations with participants. These conversations lasted between 15 minutes and two hours, and we recorded contextual non-identifying information (cf. Supplementary Material 3). The two handwritten survey responses, by contrast, were completed in less than 15 minutes.

2.2 The survey

Our survey contained 30 questions, 26 of which are “Likert-type” questions that ask participants to rank their answers on a 5-point scale [Clason and Dormody 1994; Boone and Boone 2012]. We distinguish the mutually exclusive Likert-type questions posed in our survey from the official Likert scale, which is a summation of one or more responses made on a numerical scale into a composite score that quantifies an overarching trait “whose value characterizes the respondents’ attitudes and opinions” (Clason and Dormody [1994, p. 31]; see also Likert [1932]). We used Likert-type questions for determining the range of opinions in how our participants considered, thought, perceived, or felt about “mutually exclusive issues around phenomenon/s under study” [Joshi et al. 2015, p. 398], particularly the effectiveness of various channels, sources and messengers of eruption information in 2018.

Each of our 26 Likert-type questions were subdivided into two or more components, a technique known as waterfalling or follow-up questioning [Allen 2017]. For example, Q2 was phrased as follows: “To what extent did you feel that attending community-wide meetings during the eruption ... (a) improved your understanding of volcano hazards?, (b) answered your questions about the eruption and (caldera) collapse?, (c) confirmed your trust in HVO?,” and “(d) helped you feel better equipped to respond to the eruption?” Of the remaining four questions, one (Q1) was multiple-choice and three (Q26–27, 29) were open-ended. We also asked participants to report their sex and neighborhood of residence. Questions are ordered by the following topics: in-person community meeting attendance (Q1–2); traditional media and web sources of eruption information, excluding social media (Q3–10); social media sources (Q11–21); and participants’ opinions of various sources (Q22–30). Our complete survey is available in the Supplementary Material 1. We acknowledge that more inclusive language could have been provided to our participants regarding their gender [Malatino 2020], which we include in the Researcher reflections and research limitations section.

Several of our questions (Q14, 17–18, 21–25, 29–30) asked users to identify community organizations or social media groups other than @USGSVolcanoes that they relied on for eruption-related information in 2018. Although individual communicators were often named by interview and survey participants, we do not identify them in our results since we did not seek their permission to be named. We only directly name social media pages or physical organizations if they are not named after individual people. Our survey questionnaire and interview methodology were approved by the Institutional Review Board at the University of Illinois at Urbana-Champaign in December 2019.

2.3 Reporting survey responses

For our interviews and surveys, we recorded both quantitative (i.e. scores on a 5-point Likert-type scale) and qualitative (i.e. spoken dialogue or written commentary) responses. We rounded down Likert-type scores reported as half-integers or a combination of two consecutive integers to the lowest integer. In instances where participants provided distinct scores for multiple individuals or organizations within a single response, we report the median of all individual scores. We informed participants that on our Likert-type scale, 1 corresponds with the statement “not at all” and 5 corresponds with a “very great extent.” Although no statements were explicitly assigned to the intermediate three scores prior to collecting interview and survey responses, we assigned the following labels based on participants' commentary on their individual scores: 2 = “not much,” 3 = “fair,” and 4 = “great.”

We use the term HVO to describe communications from both the Hawaiian Volcano Observatory and the broader USGS since many residents of Hawai'i are more familiar with the staff and presence of HVO for volcano-related information than its parent federal agency headquartered in the continental United States. We also note that, while two of our survey questions (Q8b and 10) originally asked participants about the USGS's Volcano Notification System (VNS) alerts, we report this channel of communication as “Text/Email Alerts,” because participants associated VNS with text and email alerts provided by other government agencies, such as Hawai'i County Civil Defense (HCCD).

In addition to quantitative Likert-type scores, which are reported in [Section 3](#), we also recorded qualitative notes of our conversations with the 18 residents we interviewed, notes written in the margins of the two surveys completed by hand, and qualitative notes from our informal interview participants. As suggested in [Braun and Clarke \[2006\]](#), we analyzed these notes for recurring themes. Although we did not use a comprehensive codebook or computer-aided software to assist with more sophisticated analysis, we organized participants' qualitative comments into one or more of the four themes defined in [Section 1.3](#). Throughout this paper, we use *italics* to distinguish these four themes from ordinary text.

In [Section 4](#), we organize participants' comments regarding each source/messenger and their channels of communication according to our four themes. Then, in [Section 5](#) we present these interpretations visually as radar charts [e.g. [Barnes and Vidgen 2006](#)] whose axes or vertices correspond to each theme. After classifying each of the comments presented in [Section 4](#) as positive, neutral, or negative, we “calculated” each source/messenger's performance on a 5-point scale for each theme (i.e. radar chart axis) using the following rubric:

- Score of “1”: at least 75 % of comments are negative;
- Score of “2”: 60 % comments \leq negative comments < 75 % comments;
- Score of “3”: all other cases not satisfying the criteria for radar chart scores of 1–2 or 4–5;
- Score of “4”: 60 % comments \leq positive comments < 75 % comments;

- Score of “5”: at least 75 % of comments are positive.

An exception to this rubric is made for determining each source/messenger's overall scores in *expertise* and *pace*. In these cases, the radar chart score for expertise is the median value, rounded down if not a whole number, between the score determined from the qualitative rubric (above) and a quantitative counterpart to that rubric for participants' responses to Q22 and Q24 in our questionnaire survey, where Likert-type scores of 1–2 are assigned as “negative,” scores of 3 are assigned “neutral,” and scores of 4–5 are assigned “positive”:

- Score of “1”: at least 75 % of Q22 and Q24 responses have Likert-type scores of 1 or 2;
- Score of “2”: 60 % of Q22 and Q24 responses \leq (Likert-type scores of 1 or 2) < 75 % of responses;
- Score of “3”: all other cases not satisfying the criteria for radar chart scores of 1–2 or 4–5;
- Score of “4”: 60 % of Q22 and Q24 responses \leq (Likert-type scores of 4 or 5) < 75 % of responses;
- Score of “5”: at least 75 % of Q22 and Q24 responses have Likert-type scores of 4 or 5.

Similarly, the radar chart score for *pace* is the median value (rounded down if not a whole number) between the score determined from the qualitative rubric and the quantitative counterpart to that rubric (Q25). Participants often did not provide qualitative commentary on every single quantitative Likert-type question. Therefore, combining the quantitative scores and qualitative commentary, when available, for the themes of *expertise* and *pace* provides a more accurate picture of participants' perceptions of each source/messenger. We do not apply a combined qualitative and quantitative scoring system for participants' evaluations of each source/messenger's *relevance* or *sincerity*, since none of our survey questions directly address either of these themes. Complete comment tallies are provided in [Supplementary Material 2](#), as well as the spreadsheet ([Supplementary Material 3](#)).

2.4 Positionality statement

Qualitative inquiry requires researchers to examine their own positionality in relationship with the data they are analyzing. The questions researchers ask are directed by a researcher's perspectives, attitudes, education, social and cultural placement [[Creswell and Poth 2017](#)]. Our positionality, as researchers, are as volcanologists and a social scientist working for either an academic institution or federal agency. All researchers involved in this project have personal and/or professional connections with Hawai'i, with the first author being Native Hawaiian and having a familial connection to the Island of O'ahu. Three researchers are employees of the U.S. Geological Survey who were involved with either the response or after-action report for the 2018 eruption of Kīlauea. These “insider” positions to the research have led us to ask certain questions that an “outsider” researcher may not [[Phillips 2014](#);

McBride 2017]. This can also lead to certain types of “blindness”; our closeness to this topic colors the questions asked (i.e. those in our formal survey document, [Supplementary Material 1](#)), the choice of methods, as well as the interpretations and conclusions reached in this article. Other scholars may explore this research differently, and we welcome a robust discussion as a variety of perspectives can lead to enriching the literature on these critical topics. Researchers’ affiliation with the USGS may also have discouraged some interview participants from providing completely honest or transparent information regarding their perceptions of communications from HVO or @USGSVolcanoes. Thus, we acknowledge that some of the findings presented in this manuscript may have been different if the researchers who interacted with interview participants had no affiliation with USGS. However, since the first author is not a USGS employee, we were able to obtain perspectives from our interview conversations that may not have been possible if conducted primarily by USGS employees.

3 QUANTITATIVE INTERVIEW AND SURVEY FINDINGS

In this section, we report the quantitative responses provided by our formal interview and survey participants regarding the channels, sources and messengers of eruption information they followed.

Survey questions 1–2 asked participants to report on the frequency of meetings they attended and how helpful they found these meetings to be. During the eruption, 27 public community meetings were organized by various government agencies, including HVO. Of these, 16 were held in the LERZ (specifically, Pāhoa), three in Ka’ū ([Figure 1](#); two in Pāhala, one in Ocean View), and five in the summit region (Volcano Village). Twelve out of 20 participants reported attending one or more in-person community meetings ([Figure 2](#)). By region, seven out of 10 LERZ participants reported attending at least one meeting, with an eighth reporting not attending any meetings in-person but viewing recordings online; all four summit participants reported attending at least three meetings; and only one Ka’ū participant reported attending any ([Figure 2](#)). Almost all participants provided Likert-type scores of “3” or greater regarding the usefulness of these meetings, with summit participants providing the most consistently favorable evaluations.

Survey questions 3–7 asked participants to report how frequently they relied on traditional news channels and how helpful they found each channel to be. Of our 20 participants, the number who reported following traditional news channels to at least a “fair extent” were as follows: 10 for radio broadcasts ([Figure 3A](#)), 8 for television broadcasts ([Figure 3B](#)), 6 for print newspapers ([Figure 3C](#)), and 7 for the websites of any of the previous three channels ([Figure 3D](#)). Three participants reported viewing television broadcasts or videos on the website of local news stations. While all four traditional news media channels received mixed evaluations regarding their usefulness, the channels of local news stations all received Likert scores of “4” or “5.”

Survey questions 8–10 asked participants to report on how often they relied on HVO’s website and USGS or other government text/email alerts and how helpful they found those channels to be. HVO’s website is defined to include related

USGS webpages that monitored and reported about hazards on the Island of Hawai’i. HVO’s website was visited to at least a “fair” extent by 15 participants, with 12 reporting that they visited it to a “very great” extent ([Figure 4A](#)). HVO’s website also received overwhelmingly positive evaluations of its usefulness. Scores of “5” were provided by 11 participants for improving their understanding of the eruption, and by 10 participants for the website’s ability to answer their questions. Seven participants provided a score of “5” for HVO’s website equipping them to respond. By comparison, government text/email alerts were used to at least a “fair” extent by 11 participants, with 7 reporting using them to a “very great” extent ([Figure 4B](#)). Participants’ evaluations of the usefulness of these alerts were mixed.

Survey questions 11–13 asked participants to report on how often they received eruption information from various social media channels. Most participants reported following Facebook to at least a “fair” extent, while no participants reported using Twitter, Snapchat, or Pinterest—rendering questions 12 and 18–21 unnecessary. One participant from Nānāwale Estates reported following video blogs (i.e. “vlogs”) and YouTube channels of LERZ-based community messengers to a “very great” extent and provided Likert-type scores of at least “4” for the usefulness of these channels. Similarly, one participant from Ocean View reported following the YouTube channel of a local news media source to a “very great” extent and provided scores of at least “4” for the usefulness of this channel. Reported scores for all survey questions can be found in [Supplementary Material 3](#).

Survey questions 14–17 asked participants to report their frequency of reliance on and the usefulness of Facebook pages of community messengers, @USGSVolcanoes, and their friends, family, or neighbors. Participants identified a total of eight individuals (unnamed to preserve privacy) and five groups (Hawaii Tracker, Red Road Ohana, Kalapana Seaview Estates, Puna Weather Group, and Volcano Out and About) as community messengers. Community messengers served as both eyewitness sources of eruption status reports and messengers of HVO’s official eruption information [[Tsang and Lindsay 2019](#)].

Community messenger Facebook pages received the highest reported usage, with 13 participants visiting these pages to at least a “fair” extent and 11 visiting them to a “very great” extent ([Figure 5A](#)). Of these participants, 7 reported following one community messenger, in particular. These 7 participants, all LERZ residents, unanimously reported following this group’s page to a “very great” extent. Participants who reported following community messenger Facebook pages also provided overwhelmingly positive evaluations of those pages’ usefulness—scores of “5” were given by 10 participants for improving their understanding of the eruption and by nine for answering their questions ([Figure 5B](#)). As with HVO’s website, seven participants provided a score of “5” for community messengers’ social media presence for pages equipping them to respond to the eruption.

In contrast to the pages of community messengers, only 7 participants reported visiting the page of @USGSVolcanoes Facebook page to a “fair” or greater extent, and only 4 reported

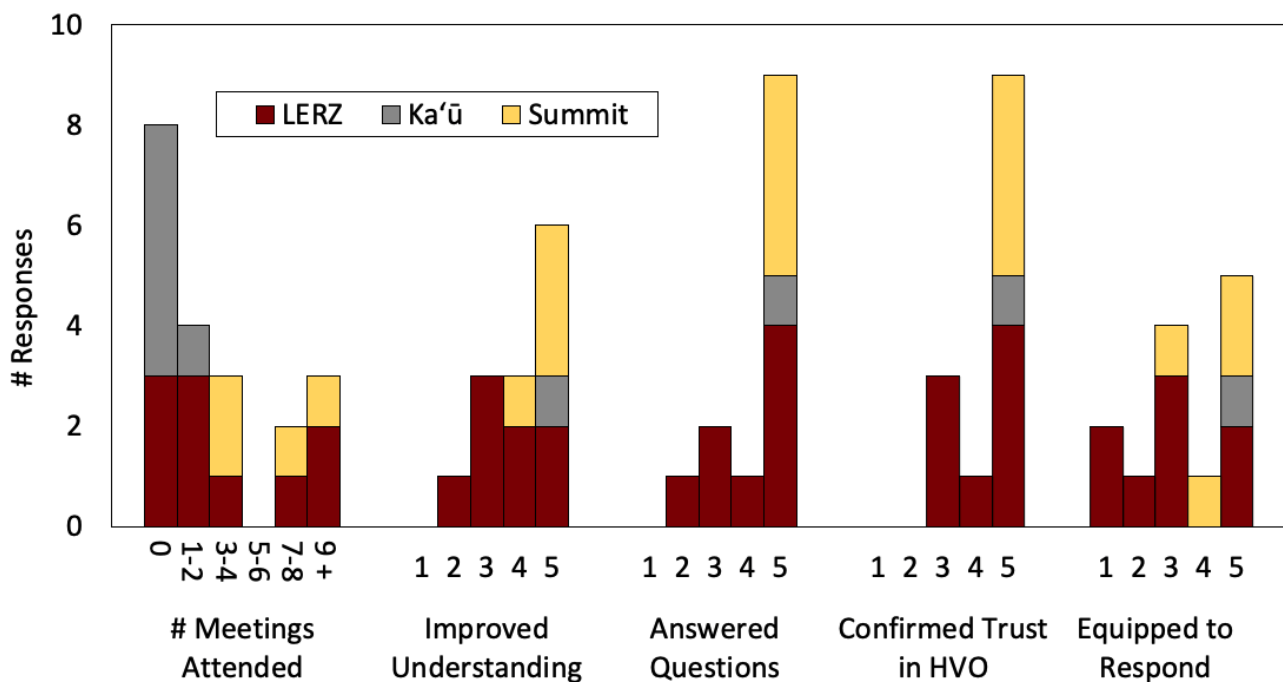


Figure 2: Responses from participants regarding in-person community meetings attended by the U.S. Geological Survey Hawaiian Volcano Observatory (HVO). The first cluster of bar graphs tallies how frequently participants reported attending community meetings, while the remaining four clusters plot participants' Likert-type scores in response to the following questions: "To what extent did you feel that attending community-wide meetings during the eruption ... (a) improved your understanding of volcano hazards?; (b) answered your questions about the eruption and [summit caldera] collapse?; (c) confirmed your trust in HVO?; and (d) helped you feel better equipped to respond to the eruption?" Our Likert-type scale corresponds with the following qualitative descriptions: 1: "not at all," 2: "not much," 3: "fair," 4: "great," 5: "very great."

visiting the pages of friends, family, or neighbors to this same extent (Figure 5A). Six participants said that @USGSVolcanoes did at least a "fair" job of improving their understanding of the eruption, while five of them said @USGSVolcanoes answered their questions and equipped them to respond to at least a "fair" extent (Figure 5C). Three participants reported that the posts by friends, family, or neighbors improved their understanding or answered their questions to at least a "fair" extent, with only two providing this assessment of these pages' ability to equip them to respond.

Survey questions 22–25 asked participants to evaluate how knowledgeable, responsible, factual, and prompt the three main groups of sources/messengers defined in Section 1—HVO, news media, and community messengers (termed "local groups" in the surveys)—were. Responses to questions 22, 24, and 25 are plotted in Figure 6. In conducting our interviews and surveys, we found that participants interpreted the word "responsible" in one of two competing senses: "acting responsibly by protecting" or "being liable/obligated to protect" participants "from eruptions, hazards, and impacts" (cf. Supplementary Material 1). Since we did not ask most participants to choose one definition over the other or clarify which definition they provided their Likert-type scores for, we do not include responses to this question in Figure 6 to avoid ambiguity.

The vast majority of participants provided Likert-type scores of "4" or "5" for the knowledge, accuracy, and promptness of HVO and community messengers. More LERZ participants provided scores of "5" for community messengers in terms of knowledge and promptness than for HVO, while an equal number of LERZ participants provided this score for both HVO and community messengers regarding their accuracy. Summit and Ka'ū participants' evaluations of HVO and community messengers are roughly similar, though we note that most participants from these regions did not provide evaluations of community messengers' performance. Participants provided mixed assessments of the knowledge, accuracy, and promptness of news media overall, while the four participants who emphasized or exclusively reported following local television news organizations gave scores of at least "3" in all three attributes.

Questions 26–27 asked participants to comment on information that they felt was either provided quickly or not quickly enough during the 2018 eruption. In Section 4, we incorporate participants' responses to these questions to interpret their evaluations of each source/messenger's *pace* (individual responses can be found in Supplementary Material 3). Question 28 asked participants to evaluate the usefulness of information provided by HVO regarding specific volcanic hazards (Figure 7A), and Questions 29–30 asked participants

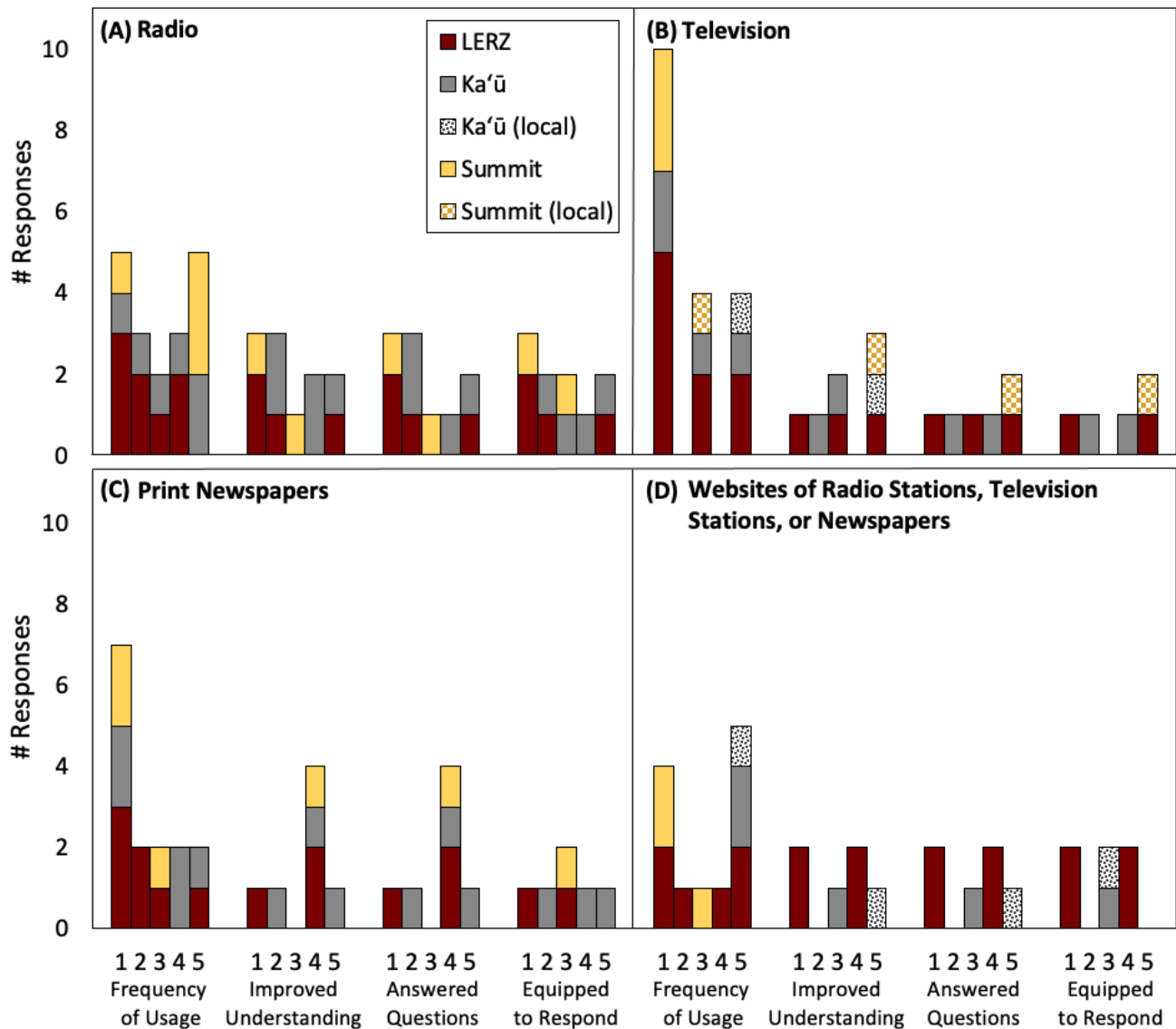


Figure 3: Participants' responses regarding eruption information communicated through [A] radio broadcasts, [B] television broadcasts, [C] print newspapers, and [D] websites of radio stations, television stations, or newspapers. In each panel, the first cluster of bar graphs tallies participants' Likert-type score responses for how often they viewed each channel, while the remaining three clusters plot participants' Likert-type score responses to the following questions: "During the eruption, to what extent did you feel that [each channel] ... (a) improved your understanding of volcano hazards?; (b) answered your questions about the eruption and [summit caldera] collapse?; and (c) helped you feel better equipped to respond to the eruption?" Our Likert-type scale corresponds with the following qualitative descriptions: 1: "not at all," 2: "not much," 3: "fair," 4: "great," 5: "very great." Follow-up questions were not asked of people who reported viewing a channel "not much" or "not at all." Gray-speckled and yellow-checked bars are responses from Ka'ū and summit participants, respectively, pertaining to the local news organizations.

to identify and evaluate the usefulness of information on those same hazards from other sources/messengers ("organizations, news/social media, or online resources") if their information was deemed "just as useful as, or more useful than, the information provided by HVO" (Figure 7B).

Overall, participants provided consistently positive evaluations of the information HVO provided for most types of volcanic hazards, with earthquakes receiving the most scores of "5," and pyroclastic flows receiving the lowest overall scores

(while still receiving a score of "5" from half of respondents for that hazard). Among LERZ participants, however, HVO received lower overall scores relative to the total interview and survey population, and only received one score of "5" for their vog communications. For all hazards except pyroclastic flows, LERZ participants provided more scores of "5" for the information provided by community messengers than by HVO. Scores provided by the pair of Ka'ū and summit participants for local news media organizations are no better, and mostly

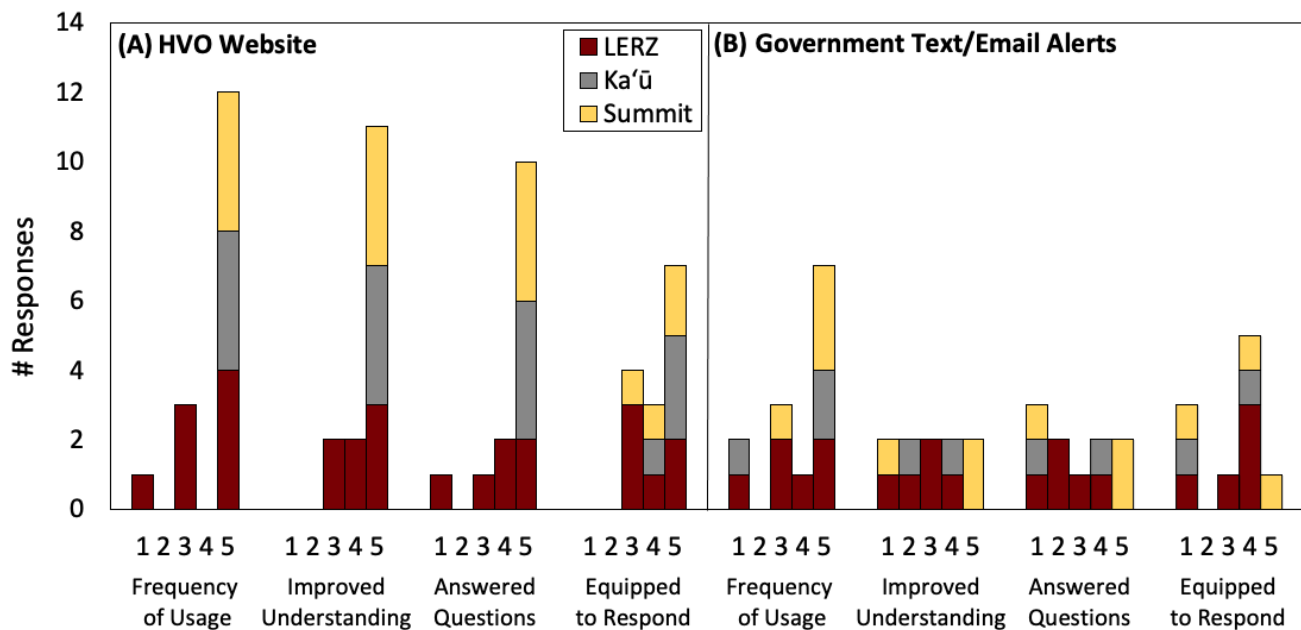


Figure 4: Participants' responses regarding eruption information communicated from [A] the the U.S. Geological Survey Hawaiian Volcano Observatory (HVO), and [B] government text/email alerts. In each panel, the first cluster of graphs tallies how frequently participants reported using each channel, while the remaining three clusters plot participants' Likert-type scores in response to the following questions: "During the eruption, to what extent did you feel that [each channel] ... (a) improved your understanding of volcano hazards?; (b) answered your questions about the eruption and [summit caldera] collapse?; (c) helped you feel better equipped to respond to the eruption?" Our Likert-type scale corresponds with the following qualitative descriptions: 1: "not at all," 2: "not much," 3: "fair" 4: "great," 5: "very great." Follow-up questions were not asked of people who reported viewing a channel "not much" or "not at all."

worse, than the corresponding hazard information scores provided for HVO by a majority of participants from either the Ka'ū or summit regions.

4 QUALITATIVE THEMATIC INSIGHTS FROM PARTICIPANTS' COMMENTARY

In this section, we report interview and survey participants' qualitative comments for each source/messenger and interpret them in the context of the four themes (*relevance*, *expertise*, *pace*, and *sincerity*) defined in Section 1.3.

4.1 USGS Hawaiian Volcano Observatory (and government partners)

Most participants reported that HVO was a knowledgeable, accurate, and timely source of eruption information (Figure 6); in other words, they had strong *expertise* and *pacing*. A Volcano Golf Course resident said that "nobody knows more" about eruption information than HVO, while an Ocean View resident stated that HVO scientists "were the only ones to count on" to provide factual information. This same Ocean View resident also said that HVO provided new information "at least every few hours," even as "things were changing very fast," illustrating that HVO's rapid *pacing* also showed they were acting in good faith (i.e. high *sincerity*) by following through on their obligations to keep residents informed despite the challenge of rapidly changing eruption developments. Another Ocean View resident said that instead of using "cue

cards or monitors," at press briefings, HVO staff contributed their "first-hand knowledge," illustrating HVO's ability to be transparent (i.e. *sincere*) in its delivery of information.

Participants shared additional comments illustrating the *sincerity* of HVO and USGS staff and how well they provided accessible (i.e. *relevant*) information. One Hawaiian Beaches participant also noted the frequent presence of USGS staff at the *Pu'u Honua O Puna* evacuation facility (colloquially known as "The Hub"). Similarly, a Volcano Village resident said that USGS staff made themselves available at farmer's markets to answer people's questions. One Pāhala participant said that HVO scientists "knocked themselves out" to provide information on a variety of volcanic hazards "all the time." In a similar vein, an Ocean View participant said that HVO staff were "good at providing information and did as good a job as they could."

In contrast to the positive feedback provided by most participants, several participants criticized HVO for not providing *relevant* messaging. One Leilani participant said that HVO "gave the science but not on-the-ground information" about potential hazards and impacts, while a Nānāwale participant said that HVO's responses to residents' questions were "very analytical and less response-oriented," leaving people unsure of how to act (particularly, whether or not to evacuate). We clarify here that HVO's purview is to provide hazards information but not response actions or guidance, which in most places in Hawai'i County is the responsibility of Hawai'i

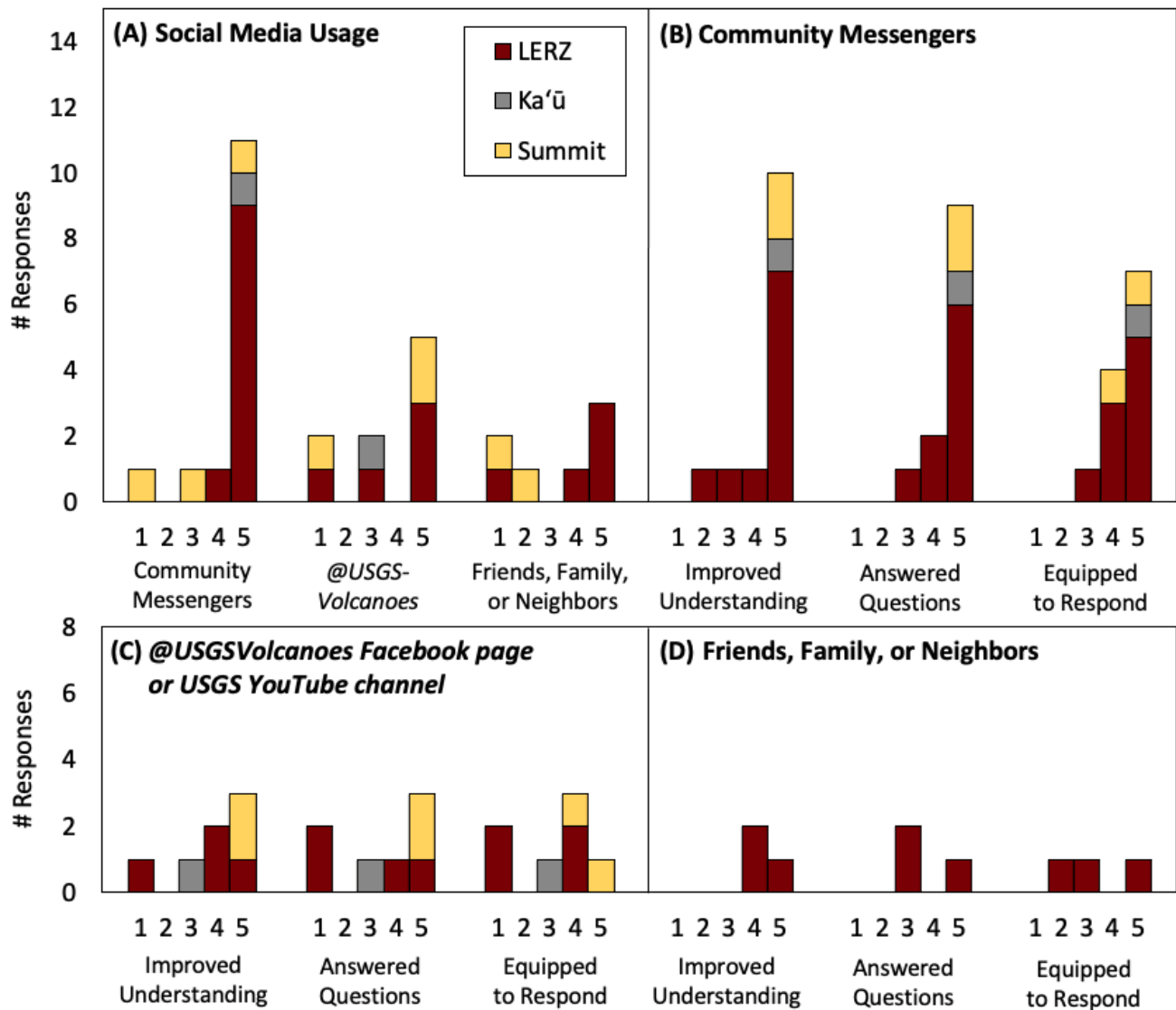


Figure 5: Participants' responses regarding eruption information communicated through social media. Panel [A] shows participants' reported frequency in following the Facebook pages of community messengers, @USGSVolcanoes, or friends, family, or neighbors. Panels [B]–[D] plot participants' Likert-type scores for each of the three groups of messengers in response to the following questions: "During the eruption, to what extent did you feel that [each channel] ... (a) improved your understanding of volcano hazards?; (b) answered your questions about the eruption and [summit caldera] collapse?; and (c) helped you feel better equipped to respond to the eruption?" Our Likert-type scale corresponds with the following qualitative descriptions: 1: "not at all," 2: "not much," 3: "fair," 4: "great," 5: "very great." Follow-up questions were not asked of people who reported viewing a channel "not much" or "not at all."

County Civil Defense. In 2018, HVO used its channels to guide residents toward the official response guidance provided by the relevant partner agencies such as Hawai'i County Civil Defense, the National Park Service, or Hawai'i State Department of Health. Another Nānāwale resident criticized HVO for lacking *expertise*, writing on their survey sheet that "HVO had numerous new personnel who knew less than people who lived in lower Puna prior to [the] 1983–2018 Kilauea eruption," referring to eruptive activity at Pu'u'ō'ō prior to the 2018 eruption.

One Leilani participant reported that HVO's *pacing* was insufficient, stating that they "weren't on the front lines or [at] nightly conferences" even though "daily updates" were needed, especially for lava flows. We note, however, that HVO conducted a 24-hour watch of LERZ volcanic activity starting May 4th, 2018, and also provided daily media briefings from its emergency operation center in Hilo starting on May 8th. Two participants provided more nuanced commentary regarding HVO's *pacing*. One of them, an informal interview participant who reported having family in Leilani, said that HVO's hazard communications were "slow to begin with,"

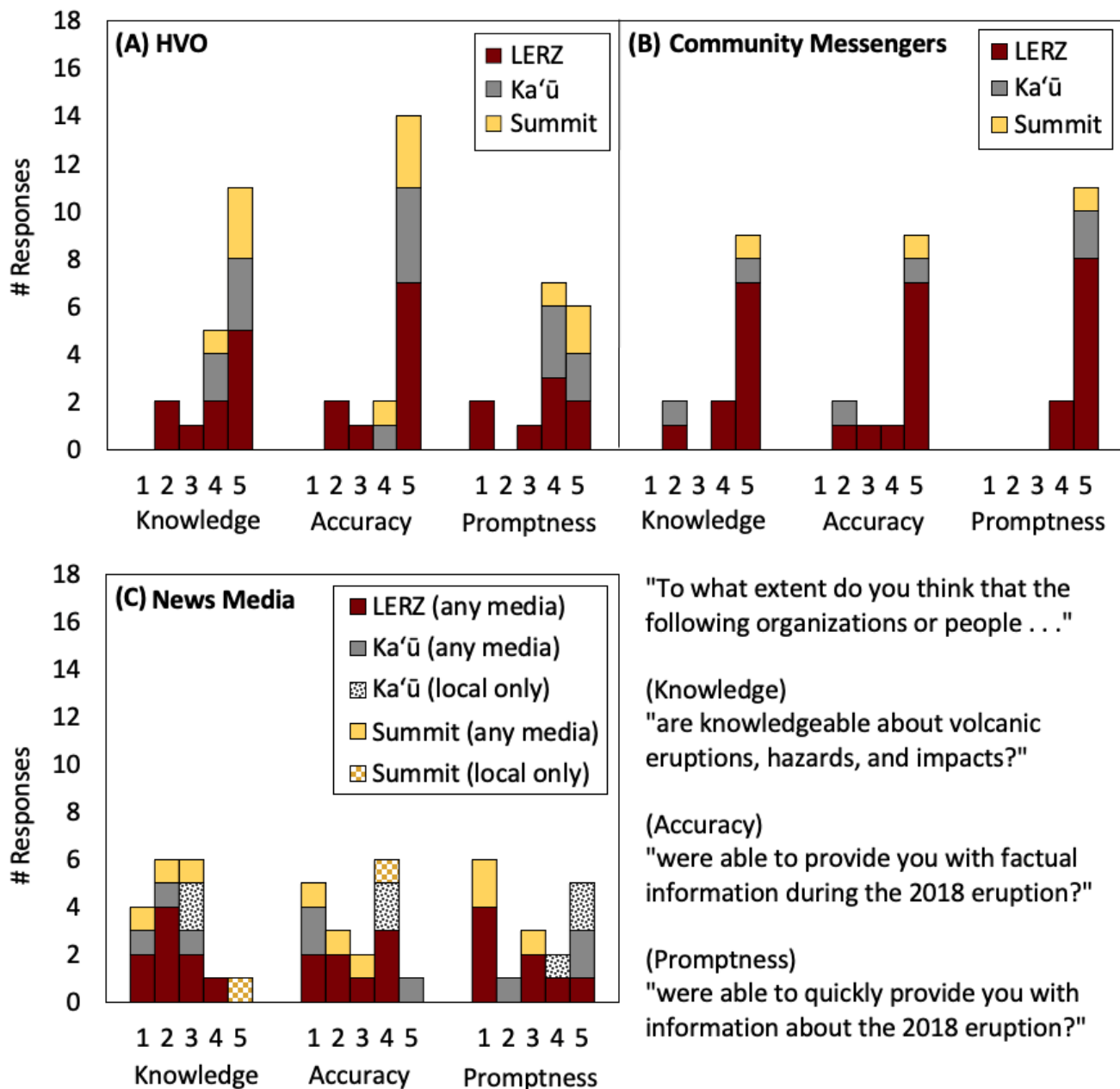


Figure 6: Participants' stated opinions of each major source or messenger of eruption information: [A] U.S. Geological Survey Hawaiian Volcano Observatory (HVO), [B] community messengers, and [C] news media organizations. Each cluster of graphs plots participants' Likert-type responses to the questions shown in the bottom right quadrant of the figure. Our Likert-type scale corresponds with the following qualitative descriptions: 1: "not at all," 2: "not much," 3: "fair," 4: "great," 5: "very great." Gray-speckled and yellow-checked bars in [C] are responses from Ka'ū and summit participants, respectively, who emphasized local news media throughout their interview conversations.

but that "once they got into a rhythm" the participant found HVO's lava flow information to be helpful to a "very great" extent. The other participant, a Kalapana resident, wrote that "in the moment it felt like nothing was happening fast enough ... Looking back, I think we were getting all the info we needed, in good timing."

4.1.1 Community meetings

Participants' positive feedback of HVO at community meetings focused on HVO's *sincerity*, *relevance*, and *expertise*. A

Volcano Village participant emphasized how HVO scientists made themselves available at community meetings to answer residents' individual questions, while a Volcano Golf Course resident said that HVO did an "impeccable" job across the board. Two LERZ participants and one Ka'ū participant emphasized that HVO scientists and staff were the most *relevant* and *expertly* messengers at the community meetings they attended.

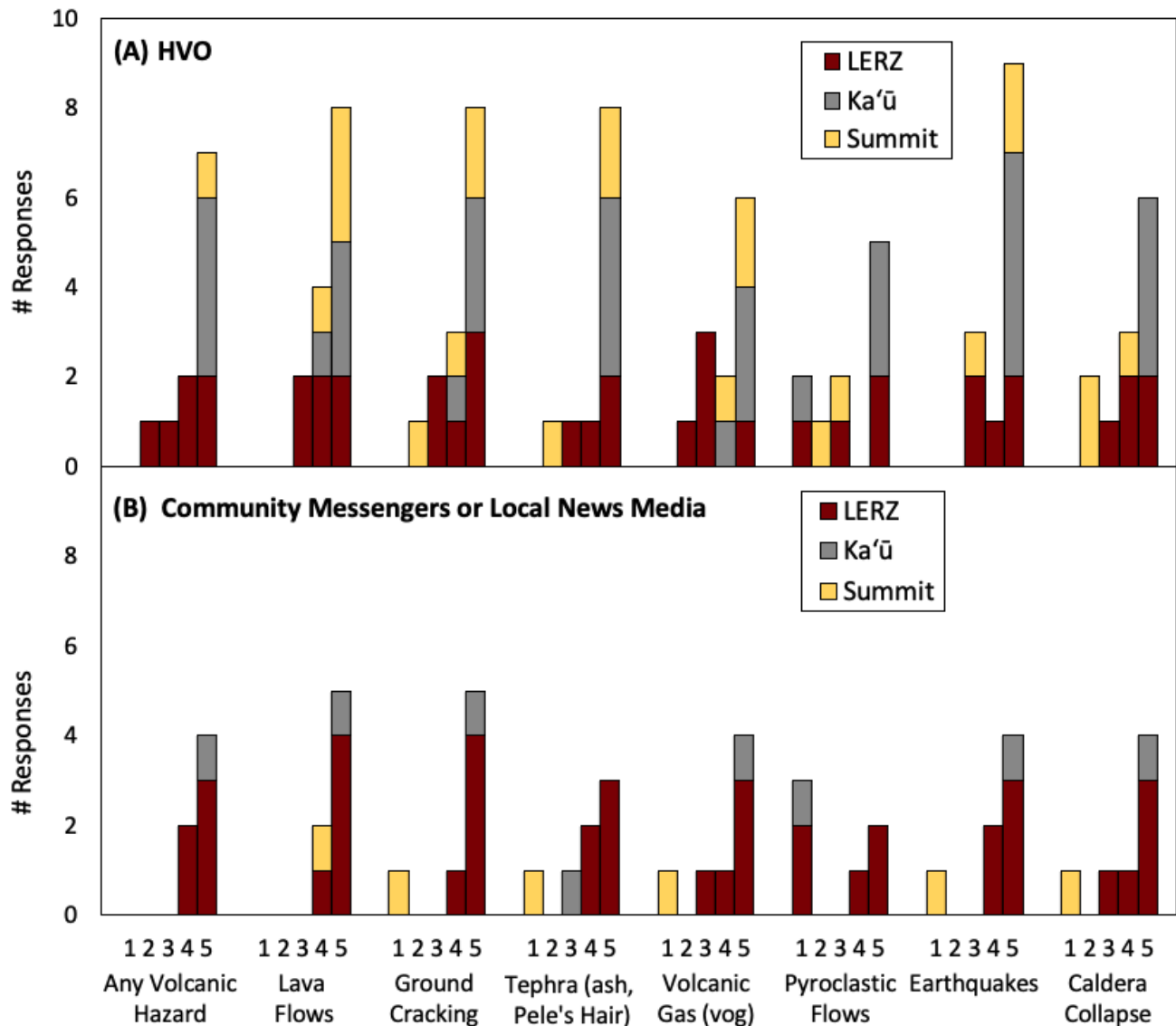


Figure 7: Participants' responses regarding the communication of specific hazards from [A] U.S. Geological Survey Hawaiian Volcano Observatory (HVO) and [B] community messengers (LERZ participants only) or local news media (Ka'ū and summit participants). For each source/messenger, Likert-type scores address the following question: "How helpful do you think information about the eruption was with respect to ..." each of the hazards labeled at the bottom of the plot. Our Likert-type scale corresponds with the following qualitative descriptions: 1: "not at all (helpful)," 2: "not much (help)," 3: "fair(ly) (helpful)," 4: "great (help)," 5: "very great (help)."

By contrast, one Nānāwale participant provided several critical comments regarding HVO's delivery of information at community meetings. First, this participant stated that there was "not enough certainty" from HVO "on what would happen next," and was frustrated about "constantly [being] told that [HVO] didn't know what was going to happen," indicating that HVO had insufficient *expertise* to provide *relevant* messaging. Moreover, this participant said that community messengers "would be the first to detect hazards and then tell HVO," and that while HVO's community meeting updates were "informative," they were "behind the curve" (i.e. poorly *paced*). Furthermore, this participant mentioned a "feeling of secrecy" (i.e. *insincerity*) from HVO and their government

partners since the participant and other community members were "not privy to drone and helicopter information" that could answer their questions of "which areas [are the hazards located] today?"

4.1.2 HVO's Website, government text/email alerts, and vog hazard messaging

HVO's website was the single most popular channel reported by our interview and survey participants overall (Figure 4), and the second most popular channel reported by LERZ participants (after the social media of community messengers, Figure 5). Most participants provided positive feedback regarding HVO's website, highlighting the satisfactory *pace* and

expertise demonstrated by HVO on this channel. One Ocean View resident stated that the website “kept up with new developments,” giving it a 5 for helping them feel better equipped to respond. A resident from Leilani also said that HVO’s website provided hazard information “quickly.” Another Leilani participant commended HVO’s website for providing “fantastic data” of current lava flow locations and projected pathways, with a third Leilani participant saying the website allowed them to “see exactly where flows were going.” A participant living outside of Hawai'i who had a family member in Leilani reported using HVO’s website to fact-check information provided by community messengers. Another Ocean View resident stated that HVO’s website answered “all and more” of their questions, including those they “had no inkling to ask.” This same participant added that he thought that the website’s content was “almost too much, but informative.” In addition to HVO’s main website, participants from all three regions (LERZ, summit and Ka’ū) commended HVO’s earthquakes data webpage for its *expertise* and *pacing*. One Ocean View resident said that the USGS’s earthquake coverage “really stood out,” and a Volcano Village participant said that earthquake information was provided “quickly.”

Several participants criticized HVO’s website for providing *irrelevant* information. One Leilani resident said it was “too informative,” similar to the (less critical) sentiment of the Ocean View resident who said it provided “almost too much” information. A Kalapana resident said it was “hard to understand everything” on HVO’s website, and the Leilani participant who had praised HVO’s “fantastic” lava flow data stated that you still had to “know how to mine” their website for useful information. Conversely, one Nānāwale resident stated that HVO’s website was “lacking in sophistication and immediacy for lava flow tracking,” suggesting that it provided inadequate *expertise* and *pacing*. Participants did not provide comments regarding the *sincerity* of HVO’s website messaging.

Participants provided mixed evaluations of government text/email alerts, as well as vog hazard information provided by either HVO or other government agencies. Several people reported a lack of *relevant* information from automated government text or email alerts (Figure 4B), with one Volcano Golf Course resident saying that the USGS’s VNS alerts were “redundant,” while a Kalapana resident said these same alerts were “hard to understand.” Other interview and survey participants reported not receiving enough vog hazard information from HVO. One Leilani participant said HVO’s communication of vog information was limited (i.e. lacking *relevance*), while the informal interview participant with family in Leilani (who had mentioned using HVO’s website to fact-check community messengers’ information) said HVO provided vog updates slowly (i.e. with poor *pacing*) at the beginning of the eruption. By contrast, one Ocean View participant mentioned finding a vog website (which we postulate as the Hawai'i Interagency Vog Information Dashboard*) that provided “useful pictorial maps” (i.e. *relevant* information) of where air quality was degraded.

* <https://vog.ivhnn.org/>

4.1.3 USGS social media communications

The few participants who reported receiving information from social media groups affiliated with HVO provided mixed commentary on their communications. One Ocean View resident said that, while USGS’s YouTube channel was “not the main source” of eruption information they sought (suggesting their information was not particularly *relevant*), they nevertheless provided “more in depth” information (i.e. *expertise*) than other sources. A Nānāwale participant, meanwhile, criticized the Facebook presence of @USGSVolcanoes for their slow *pacing* and lack of *relevance*, saying that they only provided lava fissure updates “once every couple of days,” since they did “more summit than [lava] flow coverage.” This same participant found the “lag” in lava flow coverage “a bit shocking,” indicating a negative perception of @USGSVolcanoes’ *sincerity*. Although we did not ask this participant to specify whether their comments on @USGSVolcanoes’ pacing referred to a specific phase of the eruption, we note that that, during the entire first month of the eruption, @USGSVolcanoes posted multiple comments each day regarding LERZ fissure eruptions or lava flows, in addition to posts on summit activity.

Two LERZ community messengers reported that @USGSVolcanoes’ comment threads were among the “most useful” sources of locally *relevant* eruption updates they found. It is important to note, however, that the @USGSVolcanoes social media team answered very specific questions within their comments sections, meaning their *relevance* may have been limited to specific residents whose questions were directly answered on these threads. Moreover, it is possible that the two LERZ community messengers we interviewed were also referring to comments posted by other community members on the comment threads of @USGSVolcanoes, rather than exclusively referring to comments posted by the @USGSVolcanoes team.

4.2 Community messengers

Individuals and groups from local communities (i.e. community messengers) in the LERZ and summit communicated 2018 eruption hazards through social media and/or in-person interactions with other community members. Specifically, these messengers provided on-the-ground eyewitness coverage that residents felt was missing from other sources or messengers [Tsang and Lindsay 2019] and translated technical information provided by HVO into understandable terminology. Community messengers’ posts and videos were extremely popular with LERZ participants compared with those of @USGSVolcanoes or interview and survey participants’ friends, family, or neighbors (Figure 5). On the other hand, none of our Ka’ū interview participants mentioned relying on community messengers from their region for eruption updates, though one participant from Ocean View mentioned following to a “very great” extent the social media page of a helicopter pilot who regularly filmed Kīlauea’s summit caldera. One summit participant mentioned following the page of a community messenger group based in their region and benefitting from these messengers to the same extent as from @USGSVolcanoes (Figure 5).

LERZ interview and survey participants reported that community messengers from their region provided the most *relevant* eruption information, often through *sincere* in-person community outreach efforts. Many of these participants also reported that community messengers provided eruption information at a desirable *pace* (Figure 6). In fact, LERZ participants often linked *pacing* with *sincerity* in describing communications from their community messengers. Three Nānāwale participants said that eyewitness sources quickly recorded and shared their observations of hazards, with one saying that active community member comment threads on YouTube allowed them to efficiently find answers to questions on eruption hazards and appropriate actions to take. Another one of these Nānāwale participants wrote on their survey that it was “comforting to have people out there” providing updates for the LERZ community and claimed that social media network “members sharing info and videos le[d] to [the] establishment” of the most frequently mentioned community messenger group, which they stated was their community’s “best resource for real time info.” In addition to praising *pacing*, one Leilani participant said that members of this particular community messenger group demonstrated *sincerity* by providing in-person explanations of eruption hazards at The Hub, consistent with findings from interviews conducted by Tsang and Lindsay [2019]. A different community messenger was also considered highly *paced* by one Kalapana participant, while a passerby who briefly visited our interview table at the University of Hawai‘i at Hilo stated that this other community messenger “had a direct pulse on how people were feeling,” highlighting their *sincerity*. Similarly, the Ocean View participant who reported regularly following a helicopter pilot’s social media postings said the pilot’s footage gave them “peace of mind.”

Most LERZ participants reported that a local community messenger group was an *expert* and *relevant* messenger of eruption information. A Hawaiian Beaches participant said that this community messenger provided more accurate information than news media (consistent with the relative performance of these two messenger groups in Figure 6) and also translated HVO’s website information into terms they could understand. This same participant claimed that this community messenger correctly predicted the trajectory of the main “Fissure 8” lava flow as it progressed around Kapoho Cone and toward the ocean. We note that this comment belies the fact that the HVO provided comprehensive and state-of-the-art modeling of lava flow projections during Kilauea’s 2018 eruption to emergency management partners, which were made available online [Dietterich et al. 2021]. A Nānāwale participant said that one community messenger group provided more personal and immediate eruption information than HVO. Another Nānāwale participant said that, although this same community messenger’s commentary could be “narrowly focused” or “pigeonholed,” its messengers listened to residents’ concerns “with knowledge and compassion” (i.e. *expertise* and *sincerity*). One Leilani resident even reported that one community messenger group had more *expertise* than HVO, wanting to assign this particular messenger group Likert-type scores of “10” for both their knowledge of volcano

hazards and the accuracy of their information, compared with scores of 2 in both attributes for HVO. However, we note that this Leilani participant reported not visiting or viewing HVO’s channels.

Participants provided mostly negative commentary regarding the *expertise* of community messenger groups different than those highlighted above, individual eyewitness sources and messengers, and any other messengers communicating through social media. One Nānāwale participant stated that several video bloggers (i.e. vloggers) drew “alarmist or false conclusions” from earthquake data (implying both low *expertise* and *sincerity*). The prevalence of misinformation on one social media platform led one Papaya Farms participant (for whom we did not collect formal survey responses) to consider the entire platform “a joke,” dissuading them from seeking any information through that channel. Similarly, an Ocean View participant said that a local community messenger social media page did not contain posts from knowledgeable messengers. However, several participants emphasized that community messengers still demonstrated *sincerity* and provided messages with high *relevance* and *pacing* despite lacking *expertise*. One Nānāwale participant said that while most LERZ community groups provided less factual eruption information (and thus, *expertise*) than HVO, their social media content was useful for residents to gather on-the-ground information at a rapid *pace*. This participant also stated that several individual eyewitness vloggers covered changes in Kilauea’s earthquake activity “better than official sources,” implying higher *relevance* and *pace* compared with sources like HVO. Additionally, this Nānāwale participant described two individual messengers as possessing complementary sets of *expertise*: one had “scientific knowledge” while the other had “cultural knowledge” despite being “a bit alarmist.”

4.3 Traditional news media organizations

Most participants reported that traditional news media organizations were poor messengers of eruption information, citing limited *expertise*, *relevance*, and *sincerity*. Participants’ most common criticism of news media, particularly state and national media, was that they reported “sensational” rather than factual or practical information that residents could act on, consistent with Tsang and Lindsay [2019]. One Volcano Village participant said they “had to be cautious with what [news media] put out,” while a Kalapana resident said that television news broadcasts in particular were “very misleading.” Another Kalapana participant said that national news media’s eruption coverage was “an explosion” of hyperbole. A Hawaiian Beaches resident said that national news media “had no clue about the (geographic) extent of the eruption,” referring to a common misconception that the eruption was occurring over large areas of the Big Island rather than several very specific regions. One Volcano Golf Course participant even said that news media treated the eruption like “the next Pompeii,” referring to the well-known 79 CE Plinian eruption of Mount Vesuvius.

In contrast to state and national news media, participants provided mostly positive commentary for the *relevance*, *expertise*, and *sincerity* of local news media organizations. One

Ocean View participant, who reported following online video updates from a local news media organization to a “very great” extent, said local news media would “try to report accurately” on eruption information. This participant also said that the videos from this source on social media provided the most useful information on a variety of hazards. Similarly, a Nā'ālehu participant said that they frequently used the mobile app of a local news media organization, which had an “entire tab devoted to the volcanic eruption” that they found very informative. The Kalapana participant who described national news coverage as an “explosion” still said that “local news” coverage was “sensational” (without naming specific news organizations). This divergence in sentiment is captured in the breadth of quantitative responses depicted in Figure 3, though we note that participants who reported primarily or exclusively following local news organizations (as indicated by the patterned bars in Figure 3) gave higher Likert-type scores than the general interview and survey population did for news media as a whole.

Participants provided mixed feedback on the *pacing* of eruption information from non-local news media. One Ocean View participant, who reported regularly viewing “footage of road cracking and evacuations” on a social media video platform and visiting the website of a national broadcast media source said that news media provided information “within 10–15 minutes” of a new event. Similarly, a Leilani participant who reported following state news organizations said that news media “were there that night” the eruption began. By contrast, a Volcano Golf Course participant said that “nine times out of 10,” news media “did not quickly provide information.” On the other hand, participants provided consistently positive feedback for the *pacing* of local news media organizations. One Ocean View participant said that a local broadcast news organization provided the “most recent newscasts” on its mobile app, while another Ocean View participant stated that a separate local news media source provided “daily updates.” A third Ocean View participant said that this second news media source provided aerial footage quickly.

We also report on participants' commentary regarding print newspapers and radio, which often provided information sourced from HVO. Participants provided mostly negative commentary on the *sincerity* of information from print newspapers, and mixed evaluations of their *relevance*, *expertise*, and *pacing*. A Leilani participant criticized newspapers for providing eruption updates “several days late” (i.e. poorly paced) with “heavily edited” wording (lacking *sincerity* and *relevance*). Similarly, a Hawaiian Beaches participant emphasized that “newspapers were incorrect” (lacking *expertise*) about the details of eruption-related events. Conversely, an Ocean View participant said that they read HVO's “Volcano Watch” column in the local newspaper and found the articles on summit inflation/deflation and gas emissions to be very informative (thus providing *expertly* and *relevant* messaging). This Ocean View participant also said that print newspapers provided eruption information “every day” (i.e. at a good *pace*). However, one Volcano Village participant who reported relying on print newspapers to a “fair” extent said that their information was “nothing different from HVO,” im-

plying that this information was redundant and thus not as *relevant* as messages provided by HVO themselves. While most participants did not provide additional commentary on the *pacing* of newspapers, they provided mixed quantitative evaluations of newspapers' promptness (Figure 3C).

Participants provided mixed commentary on the *relevance*, but mostly positive commentary on the *pacing*, of radio news stations. An Ocean View participant said that (local) radio broadcasts featuring HVO staff improved their understanding of eruption hazards to a “very great” extent. This participant also referenced the value of “hourly updates” provided by a local radio station. Similarly, a Kalapana resident found local radio broadcasts helpful, particularly when they featured HVO scientist Dr. James Kauahikaua or members of a well-regarded community messenger group. Conversely, one Volcano Golf Course participant said that radio broadcasts from a “Honolulu-based” station were irrelevant to audiences within the Island of Hawai'i, and a Leilani participant said that most radio stations were limited to the western “Kona side” of the island rather than the eastern side where the LERZ is located.

5 EVALUATING THE PERFORMANCE OF EACH SOURCE/MESSENGER

In this section, we combine participants' quantitative survey responses (Section 3) with our thematic interpretations of their qualitative commentary (Section 4) to evaluate their overall perceptions of each source/messenger's communication of 2018 eruption information.

5.1 HVO

Overall, HVO was described as providing mixed *relevance*, consistently positive *expertise* and *sincerity*, and mostly positive *pacing*. However, considerable variation existed in participants' qualitative feedback of everything but HVO's *expertise* among its individual channels (Figure 8). We note that HVO's *sincerity* is ranked higher overall than for any individual channel, since most of the positive commentary that participants provided for this attribute apply to HVO's communication efforts as a whole (including press briefings and news media broadcasts) rather than any one particular channel.

HVO's *relevance* was deemed most positive at community meetings, where participants had their most direct and personal access to HVO messengers. Conversely, HVO's website received the most positive *pace* evaluation, while their website and the @USGSVolcanoes page received mixed *relevance* evaluations. Participants did not provide commentary on the *sincerity* of HVO's website or the @USGSVolcanoes page, which may be due to the fact that participants had more in-person interactions with, and thus more opportunities to judge HVO messengers' *sincerity*, at in-person community meetings, press briefings, or news media broadcasts. This interpretation is supported by Broom's coorientation model, which in this context posits that the more connection and interaction residents have with messengers of eruption information, the more likely they are to relate to and trust those messengers [Broom 1977].

The paucity of evaluations of the *relevance* and *sincerity* of HVO's website and @USGSVolcanoes' social media may

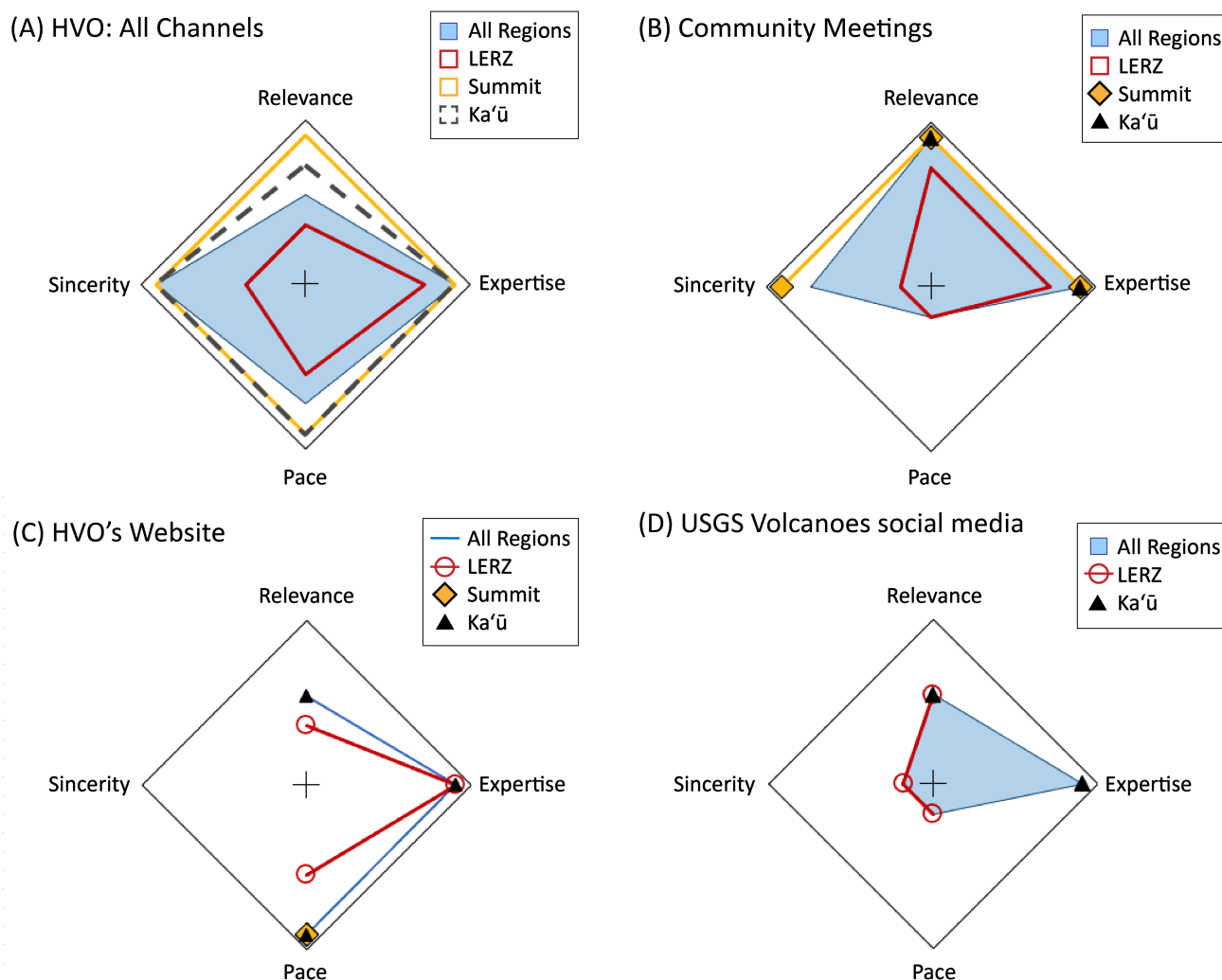


Figure 8: Radar charts illustrating participants' perceptions of U.S. Geological Survey Hawaiian Volcano Observatory (HVO)'s performance communicating through [A] all channels (including press briefings and news media broadcasts), [B] community meetings, [C] HVO's website, and [D] USGS social media channels identified by study participants. Plots include total and regionally distinct feedback. Themes are plotted on a five-point scale: 1 = "consistently negative," 2 = "mostly negative," 3 = "mixed," 4 = "mostly positive," 5 = "consistently positive." In lieu of axis tick marks (to avoid cluttering), the center of each chart is indicated with a +. Plots are left blank for themes lacking qualitative commentary; markers or open outlines plot the scores for the remaining themes. For specific scores, the reader is referred to [Supplementary Material 2](#). No summit participants provided qualitative commentary for @USGSVolcanoes.

also have been influenced by individual users' technological access or fluency. The summit region consists mostly of older residents who are likely not frequent social media users [Bell et al. 2013], providing a plausible explanation for why the @USGSVolcanoes Facebook page was viewed by fewer participants than HVO's website. In the LERZ, a Papaya Farms resident (from whom we did not collect formal survey responses) stated that they had limited access to high-quality internet and telecommunications infrastructure and only received three automated text alerts for the entire eruption. This individual instead reported relying on word-of-mouth information from another resident, whom the participant said checked HVO's website regularly during the eruption. Similarly, at a public

meeting held in the Ocean View Community Center in January 2020 as part of HVO's Volcano Awareness Month, one resident raised a concern about not being able to check vog forecasts due to having limited internet access.

5.2 News media and community messengers

News media were described as the least competent messengers, receiving mixed evaluations of *relevance* and *pace*, and low evaluations of *expertise* and *sincerity* (Figure 9). State and national news media (which we term "non-local" in Figure 9) were considered particularly poor messengers, receiving the lowest evaluations of all news media messengers or channels. By contrast, local news media organizations received mostly

positive feedback from participants who reported following them, and entirely positive feedback from Ka'ū participants. Participants' commentary regarding messengers communicating through print newspapers or radio was similar to news media overall, with the exception of having higher *expertise* due to participants' positive evaluations of information that these channels sourced from HVO. As with HVO and community messengers, participants' perceptions of news media messengers also varied by region, with LERZ and summit participants giving news media more negative evaluations than the overall interview and survey population, while Ka'ū participants gave news media overwhelmingly positive evaluations (Figure 9). We consider newspaper and radio independently from televised local and non-local (i.e. state and national) media since our surveys did not ask participants to specify whether the radio stations or newspapers they received eruption information from were broadcast or published in the Island of Hawai'i (i.e. locally).

Community messengers as a whole were perceived by LERZ participants as having positive *relevance*, *sincerity*, and *pace* (Figure 10B). This is explained by the fact that these community messengers not only provided on-the-ground eruption information quickly and consistently for LERZ residents on widely accessible social media pages, but also had an intuition for how to make their communications relatable to their fellow community members. This is consistent with observations from the field of risk communication that the most successful and trusted communicators are those whose messaging is tailored to the needs of specific audiences [Covello 2003; Sellnow et al. 2009]. The most frequently mentioned community group also received consistently positive feedback in *expertise*, while other community messengers were given mixed evaluations for this attribute. The most frequently mentioned community messenger's high ranking in *expertise* may result, in part, from acknowledging one of their members as a formally trained geoscientist in public communications, as well as the group's perception by several LERZ participants as having the best ability to track and forecast lava flow hazards. Another possible factor contributing to LERZ participants' positive perceptions of this particular community messenger group's *sincerity*, *relevance*, and *expertise* is that this group's members gathered eyewitness lava flow hazard information from other LERZ residents at venues like The Hub [Tsang and Lindsay 2019].

Summit and Ka'ū participants provided very few qualitative remarks regarding community messengers, likely due to 1) the concentration of those messengers in the LERZ and 2) the absence of similarly well-regarded community messengers within their own residential regions. However, even the LERZ-based groups and individuals reported by our formal interview and survey participants did not have universal visibility within their own region. Based on the commentary from one of our informal LERZ participants (from Papaya Farms), the pervasiveness of misinformation on social media, the most common channel for LERZ community messengers, made this platform an untrustworthy channel of information for certain residents. The Papaya Farms resident, as well as the LERZ community messengers we held informal conversations with,

also mentioned challenges with providing adequate internet access to various regions of the LERZ, a concern also reported by Tsang and Lindsay [2019].

6 DISCUSSION

6.1 Explaining regional differences in participants' perceptions of each source/messenger

Participants' qualitative and quantitative responses suggest that each region had distinct "trusted and credible" sources/messengers [Figure 10; Furr-Holden 2021]. These regional differences can be explained by the base location of those sources and messengers. LERZ participants most frequently reported receiving eruption information from a community messenger group, whose members are part of the LERZ community and interacted with LERZ residents both online and in-person. LERZ participants also reported receiving information from one or more other locally based community groups or individuals. Volcano Village and Volcano Golf Course, on the other hand, are located near Hawai'i Volcanoes National Park and HVO (prior to their relocation to Hilo following the 2018 caldera collapse). Those residents were in regular contact with HVO scientists, many of whom were living near Kīlauea's summit and thus also members of that same community, which could explain summit residents' preference for HVO's website. Neither HVO nor the most widely followed community messengers were located in the Ka'ū region; therefore, news media may have been the most visible messengers of eruption information there. Moreover, half of the six Ka'ū residents we interviewed reported relying primarily or solely on local news organizations rather than state or national media. We thus see that the presence (or absence) of messengers within a given community played a fundamental role in how positively those messengers' communications were received and thus how trusted and credible those messengers were deemed to be.

The success of community messengers in the LERZ and HVO in the summit can be explained by Broom's [1977] "coorientation measurement model." This model provides a qualitative assessment of a) how closely the views of a source/messenger and the publics they're communicating with are aligned concerning a matter (in the case of our study, the type of information that should be communicated to residents concerning Kīlauea's 2018 eruption), b) how closely each group's views of that matter align with their *perception* of the *other* group's views (or "cognitions") of that same matter, and c) how accurate each group's views of the other's cognitions actually are. Broom's coorientation measurement model is consistent with observations from previous survey-based studies of volcano hazard communications between scientists and community members that these communications are most successful when a source/messenger and the publics they are communicating with have a shared understanding of the risk posed by a given volcano [Haynes et al. 2008; Gaillard and Mercer 2012; Donovan et al. 2014]. The benefit of having a source/messenger that resides in the same region as the publics they are communicating with is this relationship inherently strengthens their understanding or agree-

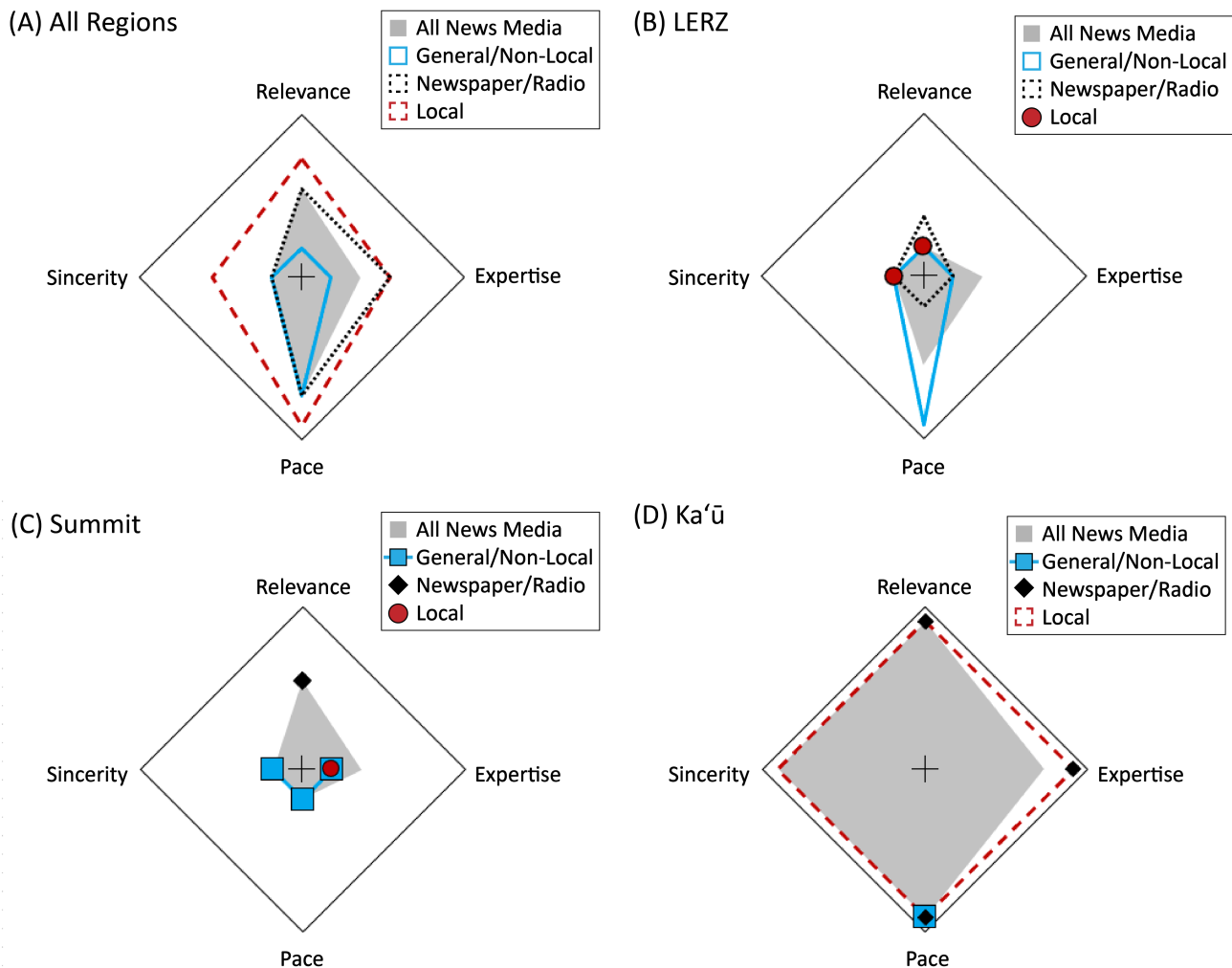


Figure 9: Radar charts illustrating participants' perceptions of various news media organizations or channels. Gray shaded areas include commentary on all news media, while line plots provide comments regarding specific televised news organizations (i.e. non-local or local) or non-televvised channels (i.e., newspaper or radio). Themes are plotted on a five-point scale: 1 = "consistently negative," 2 = "mostly negative," 3 = "mixed," 4 = "mostly positive," 5 = "consistently positive." In lieu of axis tick marks (to avoid cluttering), the center of each chart is indicated with a +. Plots are left blank for themes lacking qualitative commentary; markers or open outlines plot the scores for the remaining themes. For specific scores, the reader is referred to [Supplementary Material 2](#).

ment about Kīlauea's 2018 eruption, which means that both source/messenger and residents from the same region have a higher congruency of each others' perceptions about the eruption. This congruence, in turn, facilitates the accuracy of each party's perceptions of the other's cognitions.

Unlike the other two regions, Ka'ū participants identified two equally trusted and credible sources/messengers: HVO and local news media (Figure 10), neither of whom are from that specific region of Hawai'i. In fact, Ka'ū participants who did mention eruption communications from other Ka'ū community members stated that those messengers had low credibility, even if some were well-meaning. Thus, in the absence of trusted and credible community-based messengers, Ka'ū residents relied on official and traditional sources of eruption information. However, not all Ka'ū residents viewed HVO or local news media as trusted or credible sources or messengers

of eruption information. Among our informal conversations at Ocean View's Malama farmer's market, one Ka'ū resident stated that "Filipino News was more helpful than local news," while several others indicated that they did not feel a strong need to follow any information, either from HVO or news media, regarding the eruption. These responses further highlight how a source or messengers' *relevance* is a crucial determinant in whether residents of a hazard-impacted region deem that source or messenger's information as worthy of seeking out or following on a regular basis.

Finally, the fact that different volcanic hazards affected each hazard-impacted community in unique ways may have contributed to different perceptions of risk among interview and survey participants. For example, while the lava and gas hazards impacting the LERZ and earthquakes affecting the summit were rapidly evolving and continuous [Neal et al. 2019],

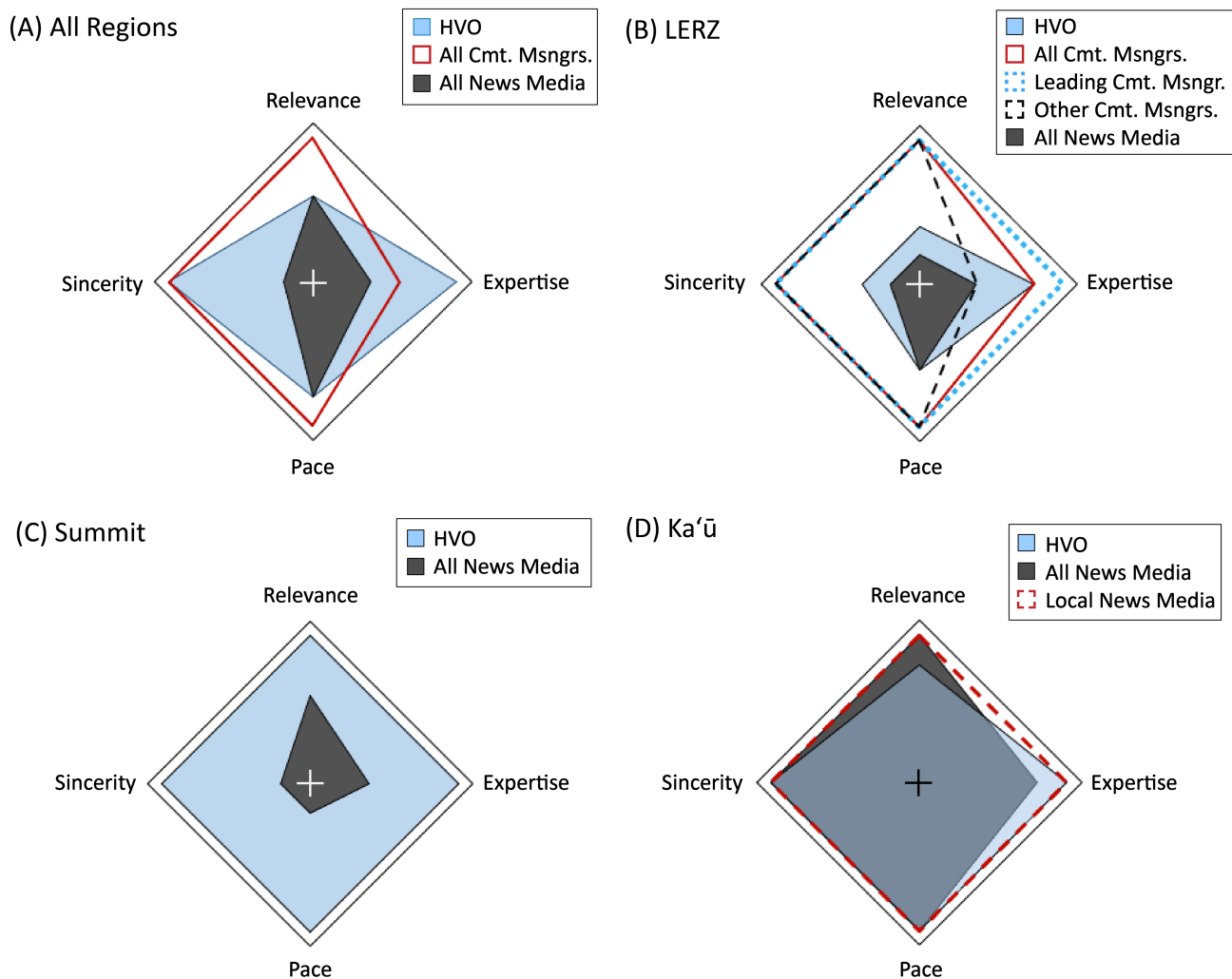


Figure 10: Radar charts comparing how participants' perceptions of the three main sources/messengers of eruption information differed by participants' region of residence. Panel [A] provides cumulative evaluations from all three hazard-impacted regions, while panels [B]–[D] provide evaluations from each region. In Panel [A], "All Cmt. Msngers." includes all groups and individuals considered to be community messengers. In Panel [B], "All Cmt. Msngers." includes all LERZ-based community messengers, while "Other Cmt. Msngers." includes all LERZ-based community messengers except for the community messenger group mentioned most frequently ("Leading Cmt. Msngr.") by our interview and survey participants. Summit and Ka'ū participants provided too few comments regarding community messengers for radar charts to be plotted for those regions. Themes are plotted on a five-point scale: 1 = "consistently negative," 2 = "mostly negative," 3 = "mixed," 4 = "mostly positive," 5 = "consistently positive." In lieu of axis tick marks (to avoid cluttering), the center of each chart is indicated with a +. Plots are left blank for themes lacking qualitative commentary; markers or open outlines plot the scores for the remaining themes. For specific scores, the reader is referred to [Supplementary Material 2](#).

ashfall presented a less urgent, though long-term, hazard in Ka'ū that, combined with the smaller number of in-person communications between HVO and members of Ka'ū communities, may have influenced Ka'ū participants' perceptions that news media had better pacing compared with the perceptions of summit and LERZ participants, and that HVO had better pacing than several LERZ participants reported.

6.2 Lessons for future eruption hazard communications

Our findings suggest that the most meaningful area of improvement for future eruption communications both in

Hawai'i and other volcanically active regions include 1) making official eruption information easier for residents to access and interpret and 2) continuing to strengthen the trust and credibility of official sources/messengers of this information among the impacted communities. These lessons, which apply most readily to the LERZ due to the high proportion of negative perceptions from LERZ participants regarding HVO's eruption communications, are consistent with those provided by [Williams et al. \[2020\]](#) and [Tsang and Lindsay \[2019\]](#), as well as the conclusions drawn by researchers studying hazard communications on other active volcanoes

[Haynes et al. 2008; Donovan et al. 2014; Naismith et al. 2020]. In the case of Hawai'i, the continuation of partnerships between local media and HVO, as well as the presence of “local moderators” at community meetings [Williams et al. 2020], can address the concerns expressed by some LERZ interview and survey participants regarding HVO's *relevance*, *pace*, and *sincerity*. These partnerships may also close the gaps in cognition [Broom 1977] between HVO scientists and LERZ residents who view their own community messengers as the most trusted and credible communicators of eruption information. Increasing the presence of official messengers, as liaisons, at community venues such as “The Hub” could therefore increase the perceived credibility of and trust in those messengers while also increasing residents' access to official eruption information. Successful examples of situational awareness being enhanced by coordination of community messengers and official messengers include the “vigías” volunteer volcano watchers living on Tungurahua volcano, Ecuador [Stone et al. 2014; Mothes et al. 2015; Lavigne et al. 2018], and the “JalinMerapi” volunteer network based on Merapi volcano in Indonesia [Mei et al. 2013; Lavigne et al. 2018].

Social media was reported by LERZ participants as their most frequent channel for 2018 eruption information, with LERZ-based community messengers' posts and videos being followed most frequently (Figure 5). Although the social media channels of @USGSVolcanoes provided a virtual and remote means for Hawai'i residents to engage in two-way dialogues with HVO scientists (providing the potential for high perceived *relevance* and *sincerity* compared with their website), few of our interview and survey participants reported following the @USGSVolcanoes page regularly (Figure 5), and none reported following the @USGSVolcanoes Twitter account. As reported by Tsang and Lindsay [2019], a number of residents in Hawai'i may intentionally avoid organizations with the name “United States” in its title (such as the U.S. Geological Survey) due to feelings of mistrust in the federal government. In fact, this is a sentiment shared by volcano-based communities in other parts of the world toward their own national governments [Haynes et al. 2008; Donovan et al. 2014]. By contrast, HVO, even though it is a federal government entity, has invested in decades of community outreach, and is thus a well-known and mostly trusted authority in Hawai'i [Brantley et al. 2019], which helps explain why most residents we interviewed or surveyed reported using HVO's website to a “very great” extent in 2018. Thus, we conclude that Hawai'i residents' usage of @USGSVolcanoes' social media might increase if a greater emphasis were placed on that social media group's connection with HVO.

7 RESEARCHER REFLECTIONS AND RESEARCH LIMITATIONS

This study has several limitations. As mentioned throughout the article, we collected data from a fairly small sample size of 20 interview and survey participants, meaning that their responses are informative, but not indicative of the broader perceptions held by Hawai'i's residents toward 2018 eruption communication. Moreover, we did not employ a formal strategy for gathering representative interview and survey popu-

lations from each of the three hazard-impacted communities, suggesting that the regional patterns we identified in participants' responses do not completely reflect the overarching perceptions of their respective communities. These interviews and surveys were also conducted 16 months after the 2018 events had ceased; thus, participants' reported opinions and recollection of eruption communications may not have been the same as they were immediately following the eruption. However, given that our results are largely consistent with the findings of Tsang and Lindsay [2019], who conducted their interview study shortly after the eruption ended, we are confident that our own findings accurately represent what participants may have reported during the eruption.

We also note that no field testing of the questions was conducted before arrival on the Island of Hawai'i. Field testing may have improved our ability to sustain natural, semi-structured interview conversations while ensuring that all relevant questions were answered by the end of our conversations. Aside from two demographic questions, only the 11 “top-level” questions (Q1, Q3, Q8, Q11, Q22–28) were intended to be asked of all interview participants. However, top-level questions were not answered by all interview participants since some conversations had to be cut short before all questions could be addressed. “Follow-up” questions were usually not asked if the preceding top-level question received a Likert score below “4,” meaning very few participants answered all survey questions, and the number of responses collected for each follow-up question was lower than for the corresponding top-level questions. We note that further questions could have been asked, particularly regarding how participants distinguished between local, regional, and national media outlets and levels of trust. Moreover, we did not explore whether participants used or interacted with YouTube videos specifically (Q11), or which apps they may have used for information seeking or sharing.

Given the above limitations, we suggest this work be considered a pilot study; the development of survey instruments like this are recommended to be piloted first before being applied to a larger quantitative study, and these studies can include participant numbers from 12–30 [Johanson and Brooks 2010]. Our learnings from this research may inform development of surveys like this in the future, as was done by Haynes et al. [2008], whose research consisted of an initial exploratory phase of qualitative research followed by a second quantitative phase that was informed by the themes obtained from the first. Holistic quantitative assessment would require an additional several months dedicated to interviews, and the survey instrument could be improved by 1) implementing a robust method for sampling a more objectively random population of participants and 2) tailoring survey questions to each hazard-impacted region in Hawai'i to reflect nuances within participants' responses suggested by the results of our pilot interviews.

We also acknowledge that our survey contained two limitations regarding demographic information. First, we did not ask participants whether they were Native Hawaiian. Given Native Hawaiian's centuries-long history of living with and understanding Hawaiian volcanic hazards [Varez and Kana-

hele 1991; Swanson 2008], we may have received different perceptions of messengers' expertise and relevance from Native Hawaiian participants compared with other Hawai'i residents. Second, we could have used more inclusive language around participants' gender; for future surveys, we recommend using the term "gender" rather than "sex," and allowing participants to provide their own self-identified gender [Malatino 2020] rather than asking them to choose between "Male," "Female," and "Other/Prefer not to answer," which implies a negative connotation toward transgender, non-binary and other gender identities [Human Rights Campaign Foundation 2020; Wyrick 2021].

One further consideration is that the eruption of 2018 and our interviews and surveys conducted in January 2020 pre-date the COVID-19 outbreak in Hawai'i. Thus, participants' views of what constitutes effective and credible messaging may have evolved in ways this study cannot capture, and a similar study conducted today may lead to different conclusions. Moreover, the pacing of HVO's social media communications have increased since the 2018 response, with the @USGSVolcanoes group providing nearly 50 unique posts during the first three days of Kīlauea's 2020–2021 summit eruption and multiple daily updates during the first month of that eruption. (At the time of writing, Kīlauea's summit is still actively erupting.) Thus, it is possible that Hawai'i residents' awareness and perceptions of @USGSVolcanoes' social media have changed since our interviews and surveys were conducted, and current sentiments may be more accurately captured through the analysis of social media communications between Hawai'i residents and sources/messengers of eruption information within the last two years.

8 CONCLUSIONS

This work presents an improved understanding of the perceptions that residents in Hawai'i had regarding hazard communications by USGS Hawaiian Volcano Observatory (HVO), traditional news media, and community messengers during the 2018 eruption of Kīlauea Volcano. We also provide increased resolution of how these perceptions varied between three of the regions (Lower East Rift Zone, summit, and Ka'ū) impacted by the 2018 eruption. Respondents living in areas impacted by the eruptions preferred information channels managed by or featuring the sources or messengers they viewed as being most trusted and credible according to definitions provided by Tumpey et al. [2019] and Renn and Levine [1991]. Specifically, HVO was viewed as the most trusted and credible source and messenger among summit participants, community messengers were most trusted and credible among Lower East Rift Zone (LERZ) participants, and both HVO and local news media were the most trusted and credible communicators among Ka'ū participants. Although HVO was considered an expert source and messenger by LERZ participants, their communications were criticized by some of those participants as overly technical and not provided quickly or regularly enough. These same participants praised their own community messengers for providing timely and easy-to-understand eruption information.

News media organizations were reported by most participants as the least trusted messengers of eruption information. However, half of Ka'ū participants reported viewing local news media organizations' broadcasts regularly and regarded them as equally trusted and credible messengers compared with HVO. Participants commonly reported that news media, particularly national and state organizations, used sensationalized images and stories that rarely or never provided residents in eruption-impacted areas with information they needed to make informed decisions. This sense that the media were exaggerating hazards appears to have reduced community members' trust in accurate reporting. Also, the focus of state- and national-media coverage on non-local audiences was a reason that interview and survey participants did not rely on those sources. The absence of trusted and credible Ka'ū community messengers may explain local news media's strong performance there compared with the summit and LERZ, though we note that several Ka'ū residents we spoke with reported not following any sources or messengers of 2018 eruption information. Similarly, at least one LERZ resident did not report following any of the main sources or messengers of information, relying instead on HVO-sourced updates translated by a community member that this resident knew.

AUTHOR CONTRIBUTIONS

RTG co-designed the survey instrument, conducted interviews, analyzed data, and led co-writing of the manuscript. WKS co-designed the survey, assumed the role of primary advisor for RTG's NSF GRIP at the USGS Cascades Volcano Observatory, and provided perspectives on state-of-the-art volcanology literature as well as USGS response during the 2018 eruption. DED provided survey feedback, guidance on conducting in-person interviews on Hawai'i, and perspectives on state-of-the-art volcanology literature as well as the 2018 eruption and response. SKM provided perspectives on prevailing social science concepts necessary for interpreting the results of interviews and surveys, and guidance on how to write this paper for an interdisciplinary audience. All authors read and approved the final manuscript.

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tor and soliciting reviews for this manuscript and Jamie Farquharson, Ph.D., for supervising and guiding the editorial process. We thank our two anonymous reviewers for providing helpful, constructive feedback, which we have incorporated into the final manuscript. Our survey questionnaire was approved by IRB #20430 from the University of Illinois Urbana-Champaign. This research is directly supported by NSF GRFP Grant No. DGE-1746047. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Any use of or discussion surrounding unofficial (i.e. “community”) sources or messengers of Kilauea eruption communications does not imply endorsement of these communications by the U.S. Government.

DATA AVAILABILITY

Survey questionnaire design, interview participants’ qualitative and quantitative responses, example calculations for radar chart scores, and complete radar chart scores are included as Supplementary Materials alongside the online version of this article.

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