RESEARCH ARTICLE

VOLCANICA

Social sensing the 2018 Kīlauea volcanic eruption through community Facebook use

Annie Matthews and James Hickey*

Department of Earth and Environmental Sciences, University of Exeter, UK.

Abstract

There is a lack of understanding around the impacts and responses of communities receiving hazard and risk information during volcanic crises, but social media posts may be able to provide valuable insights. Using 7434 posts in a local residents' Facebook group during the 2018 Kīlauea eruption, we track changes in social behaviour and emotional response. Eruption-related posts are dominated by information sharing and community observations. Sentiment and reaction analyses reveal an overall positive response, partly related to community support actions and local culture, despite the substantial detrimental eruption impacts. Temporal trends in the content of, and interactions with, posts can be linked to events during the eruption and actions taken by authorities, while the frequency of eruption posts decreases during hurricanes, indicating a shift in perceived risk in the community. Overall, results suggest social sensing with Facebook posts can provide insights on social actions and reactions during volcanic crises, but results differ from analyses of Twitter posts for the same event. More development of the techniques will be vital to gain full advantage of this promising approach.

Keywords: Social Sensing; Social Media; Kilauea; Volcano; Facebook.

Submitted: 2024-08-09 | Accepted: 2025-09-09 | Published: 2025-11-03

Editor: J. Barclay | Typesetter: A. Ryan

1 Introduction

Although there is considerable scientific understanding surrounding volcanic processes and hazards, volcanic risk cannot be reduced unless this information is communicated effectively. Effective crisis communication is a vital component of disaster risk reduction, management, and mitigation [Fearnley et al. 2017]. Effective risk communication is improved by understanding people's thoughts and feelings about risk, including their media consumption and who they trust [Fakhruddin et al. 2020]. During natural hazards, impacted individuals may share their feelings and actions with friends and followers on social media allowing for this information to be extracted and analysed with social sensing. Social sensing is defined as the observation of real-world events using unsolicited social media data [Arthur et al. 2018], and has previously been applied to natural hazards [e.g. Kirilenko et al. 2015; Steed et al. 2019; Spruce et al. 2020; Zhou et al. 2021]. Social sensing techniques have begun to make their way into volcanic applications, for example to supplement satellite data to map ashfall after an eruption [Yute et al. 2021], to analyse impacts on expressed emotions during an eruption [Ilyinskaya et al. 2024; Hickey et al. 2025], and to track community actions and responses to different volcanic events and interventions [Hickey et al. 2024]. Volcano social sensing may have the potential to be employed as a real-time syn-eruption monitoring tool to improve situational awareness [Hickey et al. 2024] but requires further development and testing to better understand the robustness of the techniques and the type of questions it can answer. Facebook is the world's most popular social media site with over 3 billion users [Statista 2024], making it a large source of potential data for social sensing. Applying social sensing to Facebook data from a volcanic eruption may help better understand perceptions of volcanic risk and improve future volcanic crisis communication. We use the 2018 Kīlauea lower East Rift Zone (LERZ) eruption as a case study to explore the feasibility of social sensing of volcanic eruptions using Facebook.

1.1 Eruption background and impacts

Kīlauea is an active basaltic shield volcano on the southeast coast of the island of Hawai'i (Figure 1). In early 2018, Kīlauea was erupting from two vents: the Pu'u 'Ō'ō cone and the lava lake at Halema'uma'u crater in the Kīlauea caldera [Neal et al. 2019]. In mid-March 2018, pressurisation of the magma system below Pu'u 'Ō'ō was inferred from inflation detected by tiltmeters [Neal et al. 2019]. On the 17th April the United States Geological Survey (USGS) Hawaiian Volcano Observatory (HVO) released a Volcano Activity Notice (VAN) stating that continued pressurisation of the magma system below Pu'u 'Ō'ō could form a new vent at any time [United States Geological Survey 2018] (Figure 2) . The continued pressure increase caused the lava lake at Halema'uma'u crater to rise, eventually overflowing on the 21st April [Neal et al. 2019]. In late April, continued ground deformation detected by GPS and the migration of earthquakes indicated a propagation of magma towards the LERZ [Patrick et al. 2020]. Just before 17:00 HST (Hawaiian Standard Time) on the 3rd May 2018 a fissure eruption began in the Leilani Estates subdivision of Puna (Figure 1B), with the HVO subsequently raising the Volcano Alert Level (VAL) from WATCH to WARNING.

Over the course of the LERZ eruption, 24 fissures opened producing extensive lava flows covering a total of 32.4 km^2; the draining of the magma system caused near-daily collapses of the Kīlauea caldera [Neal et al. 2019]. Other volcanic hazards included earthquakes, vog (volcanic fog), laze (lava haze from lava coming into contact with water), tephra fallout, Pele's hair, ash fall, and acid rain. On the 17th August 2018 after several days of reduced eruptive activity HVO lowered the VAL to WATCH, and on the 5th October after 30 days of no observed

* j.hickey@exeter.ac.uk

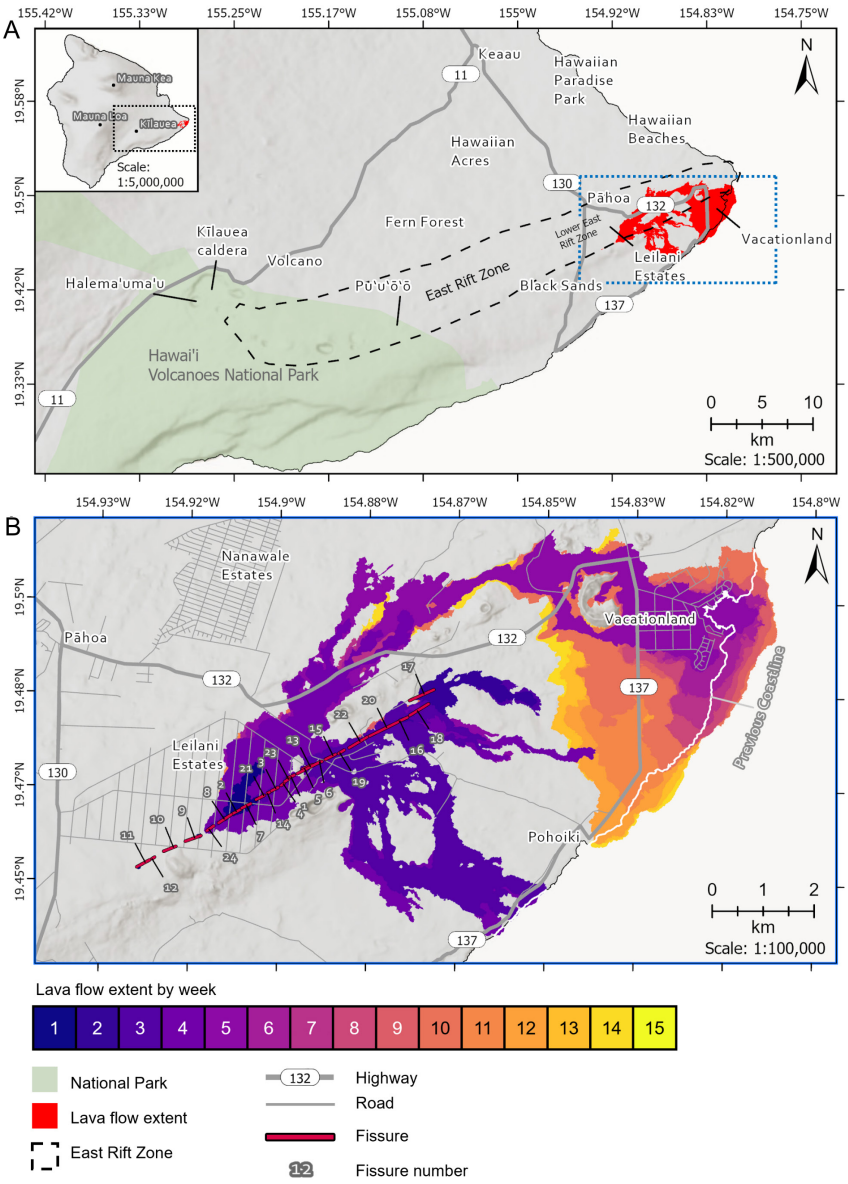

Figure 1: [A] Overview of the Puna district of Hawai'i including Kīlauea and its East Rift Zone, with the 2018 LERZ eruption lava flow in red. Dotted blue box showing location of (b). [B] The 2018 LERZ eruption fissure locations and extent of lava flows by week of the eruption, starting the 3rd May 2018. Lava flow data from Zoeller et al. [2020].

active lava at the surface the VAL was lowered to ADVISORY and the Aviation Color Code (ACC) was lowered to Yellow.

Although the eruption caused no recorded direct fatalities, several injuries were recorded, including 23 people injured when a lava bomb hit a tour boat that was viewing the lava ocean entry [Romo 2018]. Over 1800 structures were destroyed from exposure to volcanic hazards including lava flows, volcanic gases, and tephra [Meredith et al. 2022]. Many of the structures were homes, leading to 5563 people being temporarily or permanently displaced by the eruption. Of those 5563 individuals, 2668 were subject to mandatory evacuation orders [Kim et al. 2019; County of Hawai'i 2020]. The eruption also heavily disrupted the tourism industry, causing cruise ships to dock elsewhere, accommodation bookings to be cancelled, and the closure of the Hawai'i Volcanoes National Park. An estimated $415 million in revenue was lost across the island of Hawai'i because of the eruption [County of Hawai'i 2020].

1.2 Social media use during eruption

During the eruption, information was conveyed from the authorities to the public through multiple channels including traditional news outlets, community meetings, government text and email alerts, government websites, and social media [Goldman et al. 2023]. It was the first time the USGS employed social media as a significant channel for eruption information dissemination, using their Facebook and Twitter pages for public communication and outreach [Stovall et al. 2023]. The USGS found that social media allowed erup-

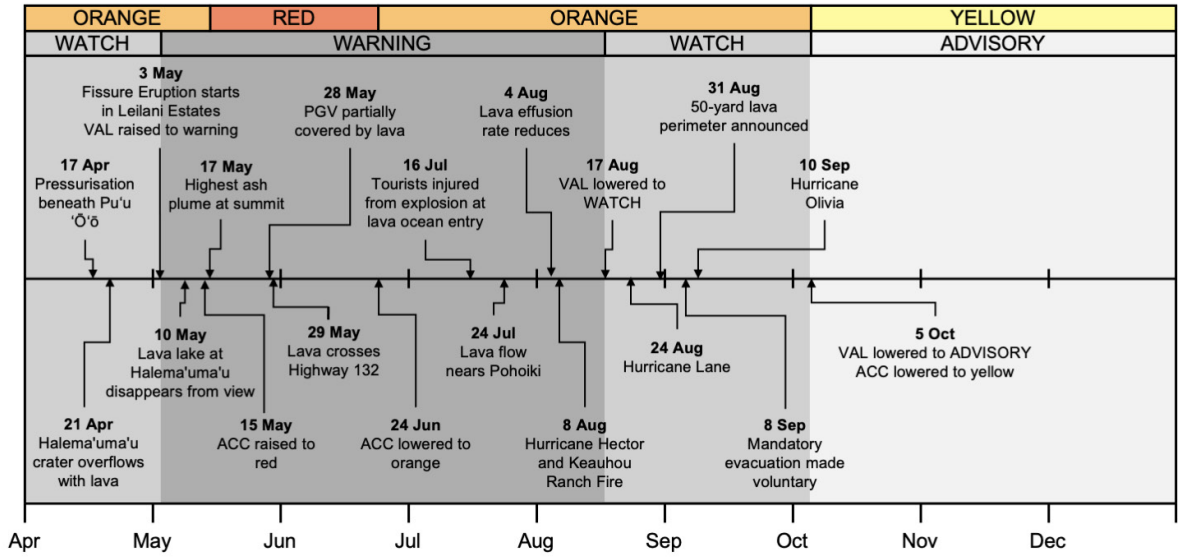

Figure 2: Timeline of selected events during the Kīlauea 2018 LERZ eruption from the 1st April to the 31st Dec 2018, with relevance for this study. Top bar indicates the Aviation Colour Code (ACC); the bar below indicates the ground-based Volcano Alert Level (VAL).

tion information to reach the public directly, helping to build community engagement and trust [Stovall et al. 2023]. Goldman et al. [2024] analysed community engagement with the USGS Facebook page 'USGS Volcanoes' during the eruption, including dialogue that provided information and corrected misinformation, and found mostly positive experiences and sentiment. Interestingly, however, residents of the heavily impacted LERZ placed their highest levels of trust in community messengers (community members unaffiliated with media outlets or authorities who voluntarily collected and distributed eruption information to the community) rather than the official authorities, and the Facebook pages of community messengers were their most common way of receiving eruption information from social media [Goldman et al. 2023]. Community messengers also scored highly in terms of improving residents' understanding of the eruption, answering questions, and being equipped to respond [Goldman et al. 2023]. Social sensing analysis of Twitter posts during the eruption revealed distinct temporal trends in sentiment, including showing a decrease in average sentiment during the eruption compared to the periods before and after, and shorter timescale stronger decreases in sentiment in response to specific eruption impacts [Hickey et al. 2025]. Geospatial assessment of the sentiment scores indicated that positive sentiment posts originating from Hawai'i contained numerous messages of hope and support while the negative sentiment posts detailed damaging impacts of the eruption [Hickey et al. 2025]. Content analysis of the Twitter posts highlighted differences in societal response actions that could be related to patterns in volcanic activity (e.g. the highest ash plume), civil protection actions (e.g. changes in alert levels), and socioeconomic pressures (e.g. National Park closure, destruction of homes) [Hickey et al. 2025]. However, the Twitter data used were extracted from a global data search, and despite using geospatial metadata to try to isolate data from within the State of Hawai'i, likely still contained data from the posts of people not directly affected by the eruption and posts sharing news articles rather than first-hand accounts of the eruption [Hickey et al. 2025]. Given their importance to the local community, and the likelihood of them mostly being used by residents impacted by the eruption, applying social sensing techniques to a community messenger Facebook page from the 2018 Kīlauea eruption could provide more detailed insights into social responses and behaviour during the eruption to better understand perceptions of volcanic risk.

In this study we aim to explore if Facebook posts during the eruption can be used to track changes in social behaviour and emotional response during a volcanic crisis, and whether these changes correspond to events during the eruption and actions taken by authorities in response to the crisis.

2 Methods and materials

2.1 Data and filtering

The data used for our study consists of 7434 posts from the public Facebook group "Hawaii Tracker" between the 6th January 2018 and the 31st December 2018. Hawaii Tracker describes itself as "Lava, Storm and News Updates for the Big Island of Hawai'i" and was used extensively during the 2018 LERZ eruption, demonstrated by a large increase in the number of posts per day Figure 3 and significant growth in group membership. The group was first established in September 2014, coincident with the 2014-2015 Pāhoa lava flow crisis [Poland et al. 2016]; all current group administrators are based in Hawai'i. At the start of 2018 there were around 4000 group members, and this grew to ~30,000 by June 12th and to ~40,000 by September 17th. Despite being a public group, open to a global audience of Facebook account holders, manual reading of all 7434 posts qualitatively indicates that the

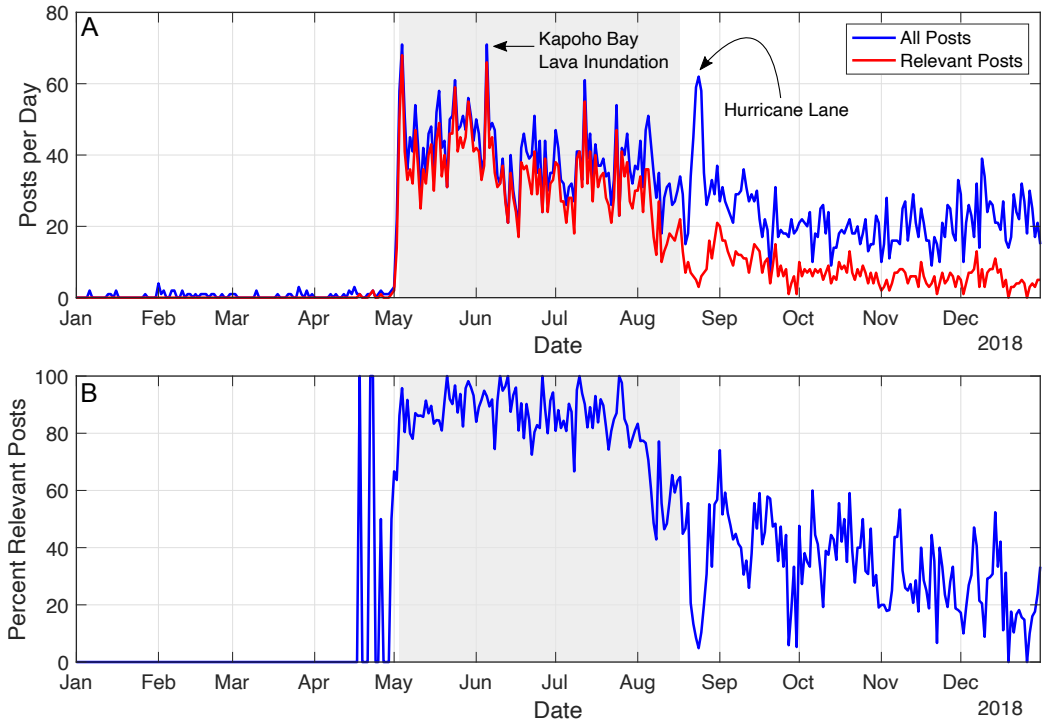

Figure 3: [A] Number of posts per day from the 1st January 2018 to the 31st December 2018. All posts (relevant and irrelevant) in blue, and relevant posts in red. [B] The proportion of posts that are relevant for the same time period. The grey background indicates the period of the eruption, defined when the VAL was at WARNING.

majority of users are local Hawai'i residents, and the majority of posts are related to local events. Unfortunately, public data does not exist to be able to accurately quantify this relationship. The predominantly local nature of these Facebook posts contrasts with the smaller proportion of local users in the Twitter posts analysed in a previous study of the same eruption [Hickey et al. 2025].

The data was scraped from Facebook on the 23rd March 2022 using the software `CrowdTangle` [Punziano et al. 2021] and includes a link to the post, the upload time and date, post content, the type of post media, and number and type of interactions. Each post contains the date and time of post upload in Greenwich Mean Time (GMT) and British Summer Time (BST). As most information surrounding the eruption is reported in Hawaiian Standard Time (HST), the date/time was converted from GMT and BST into HST. All dates/times reported here are in HST.

All data processing adheres to ethical guidelines established by the authors institution (University of Exeter), legal requirements such as the General Data Protection Regulation (GDPR), and the terms of service of Facebook. These guidelines indicate that research using publicly available data is ethically permissible, provided that researchers protect user privacy and manage the data responsibly. As Hawaii Tracker is a public Facebook group, anyone with or without a Facebook account can see what is posted in the group. The data used in this study does not include personal information on group users, their Facebook profiles, or location data. The data does include a link to the original post on Facebook, where the Facebook user who made the post may be visible and searchable; these data are not included in the analyses. The only personal information on users included in our analyses arises from situations where a post will mention a name, often where a user has been tagged in the text of a post. To mitigate ethical concerns all data analyses in this study ensure that posts and users are anonymised if a name is mentioned or profile picture shown, no raw post text is shared such that no user can be traced from its contents, and research outputs are only presented in summary or statistical form.

To improve the accuracy and applicability of our analyses, the data were filtered to only include posts that are relevant to the LERZ eruption. Posts were manually filtered for relevancy, considering post content and eruption context, into the categories:

- **Relevant**: Anything to do with the 2018 Kīlauea LERZ eruption, including but not limited to observations, information (both civilian and official), impacts, questions and requests, and community concern surrounding the eruption.

- **Irrelevant**: Not related to the 2018 Kīlauea LERZ eruption or its impacts, unclear whether they relate to the eruption, and posts that are empty or inaccessible (where posts may have been deleted or privacy settings have changed since being uploaded).

Additionally, relevant posts underwent a keyword search to identify posts mentioning the USGS or HVO. A range of names and acronyms used for the USGS and HVO were used as the keywords to identify as many posts as possible (Supplementary Material 1 Table S1).

2.2 Qualitative and quantitative analyses

The data were analysed to examine trends in post frequency, media type, and post interactions. In the raw data, post type was categorised as: Photo, Status, Native Video, Link, Live Video Complete, Video, YouTube, or Album (where a Native Video is a video that is uploaded directly to Facebook, and a Live Video Complete is a video that was originally broadcast live and is now available to watch on demand). These categories were simplified into the 'post media' types: Picture (Photo posts), Video (Video, Native Video, Live Video Complete, and Youtube posts), and Text (Status, Link, and Album posts). We analyse the number of Interactions for each post, which is defined as any Facebook user engaging with a post in the form of Comments, Shares, and Reactions. Reactions are a series of emojis that Facebook users can use to respond to a post, and as of 2018 were: Like, Love, Wow, Haha, Sad, and Angry. Comments are where subsequent users can reply to an original post with their response, and Shares are where Facebook users re-post the content of an original post. Data on post frequency, media, and interactions were counted, producing information on the total amount, proportion, and temporal changes.

Upon initial assessment of the data common post themes emerged. These themes were developed into six post categories to be used for content analysis to understand the topics being discussed during the eruption:

- **Observation:** Observations of the eruption and its effects, including both official and community observations (e.g. reporting earthquakes, and photos and videos of lava flows).
- **Information and Resources:** Information and resources about the eruption, both official and community, including official alert levels, warnings, and updates (e.g. daily eruption updates, information on community meetings, and links to websites offering help to those affected).
- **Damage and Disruption:** Physical impacts and disruption caused by the eruption (e.g. damaged buildings, evacuations, and road closures).
- **Requests:** Questions, requests, offers of help, and seeking information on the eruption.
- **Community Support and Concern:** Messages of community support, concern, and thanks. Community grief over destroyed or damaged places.
- **Other:** Posts which do not fall into any of the above categories but are still relevant to the eruption (e.g. artwork, political opinions, poetry).

Relevant posts were individually manually assigned a single category by the lead author, taking into consideration the post text, images, and context. Given the nature of the eruption and social media, posts often could have fallen into multiple categories so were assigned to the category that the majority of the post best aligned with. To reduce the potential for bias arising from the categorisation of posts by a single human coder the second author provided moderation of the categorisation to help ensure consistency; total removal of bias with this approach is, however, impossible. Nonetheless, given the large number of posts analysed the resultant influence of residual bias is likely small. Post categorisation was used to examine the total amount, proportion, and temporal changes of each category.

Text from relevant posts was analysed for sentiment using the MATLAB® Text Analytics Toolbox and VADER, a sentiment analysis model designed to understand sentiment expressed on social media [Hutto and Gilbert 2014; Spruce et al. 2020; Young et al. 2021; Hickey et al. 2025]. VADER analyses the sentiment of a string of text using words from the VADER sentiment lexicon. VADER also considers punctuation, capitalisation, and repetition. The sentiment determined by VADER is expressed as a number from +1 (most extreme positive) through 0 (neutral) to −1 (most extreme negative). The sentiment for each sentence in a post was determined, then a mean taken to provide an overall sentiment score for the post, as in our analyses VADER assigned erroneous scores to long texts consisting of multiple sentences.

To quantify observed trends between the different data products, statistical analyses were carried out using MATLAB®. Spearman's rank correlation coefficient was used to investigate the type and strength of relationship between results and was chosen because the data failed to meet the assumptions of Pearson's correlation coefficient as they are not normally distributed and contain outliers. Statistical hypothesis testing was carried out to confirm the relationship between results using a significance level of 0.05.

3 Results

3.1 Post frequency

In 2018 there were 7434 posts to Hawaii Tracker, with 4602 (61.9 %) of those being classed as relevant to the LERZ eruption. Post frequency is defined as the number of relevant posts per day. Post frequency stays at, or very close to, zero until the eruption started on the 3rd May. A small number of relevant posts are observed in April, related to the lava like overspill at Halemaʻumaʻu. The mean number of relevant posts per day increases from 0.18 before the eruption to 33.75 during the eruption. Post frequency increased dramatically after the start of the eruption, peaking on the 4th May, before steadily decreasing until October, where it remains constant and low (Figure 3A). The peak in post frequency on the 5th June is related to many homes being destroyed by lava around that time [e.g. Meredith et al. 2022]. The peak on the 12th July stems from reactions to the destruction of Ahalanui Park and Kua O Ka La School. The slight peak on the 17th August is in reaction to the VAL being lowered from WARNING to WATCH.

The percentage of posts that were relevant per day increases sharply at the start of the eruption, and generally remains above 80 % until August where it starts to decrease steadily until the end of the year (Figure 3B). The decline in relevant posts from August coincides with a reduction of the lava effusion rate prior to the eruption being declared over. Other natural hazards on Hawai'i cause reductions in the percentage of relevant posts. For example, the decrease around

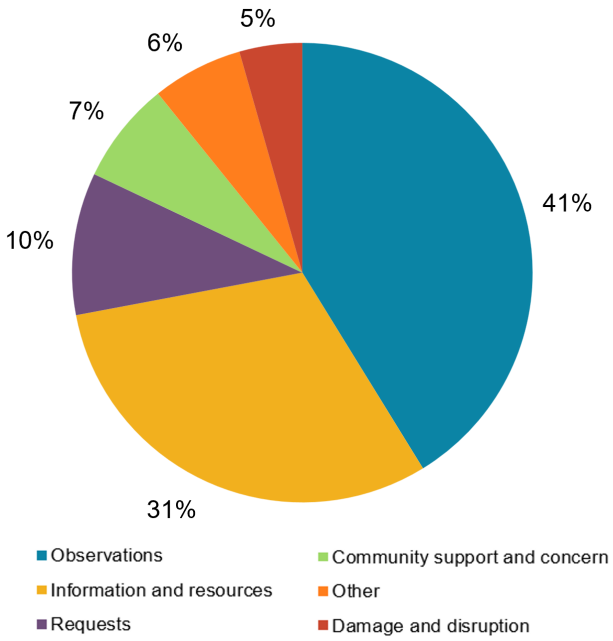

Figure 4: Proportions of content categories of relevant posts.

the 5th–8th August is related to the Keauhou Ranch Fire on Mauna Loa, Hawai'i Volcanoes National Park, which was discussed on Hawaii Tracker at the time.

Hurricanes have a large impact on the percentage of relevant posts, with hurricane season in Hawai'i running from early June to late November. 'Hurricane' is mentioned in 250 posts on Hawaii Tracker in 2018, with the group describing itself as 'Lava, Storm and News Updates for the Big Island of Hawai'i. Hurricane Hector (31st July–13th August), which produced a 10–20 foot high surf but no landfall or reported damage or casualties [Berg et al. 2018], is discussed on Hawaii Tracker in 56 posts, with the frequency peaking on the 8th August with 11 posts. Hurricane Lane was a Pacific tropical cyclone between the 15th and 29th August 2018. Lane became a category 5 hurricane on the 22nd August and on the 24th and 25th August Lane's centre passed within 130 miles of the State of Hawai'i, causing record breaking rainfall. Lane caused one death on Hawai'i , severe flooding affecting more than 100 structures, and $20 million in damage to public infrastructure [Beven and Wroe 2018]. 'Lane' is mentioned in 218 posts on Hawaii Tracker, peaking at 62 posts on the 24th August, while posts relevant to the LERZ eruption reached their lowest level since the eruption onset (post frequency of 3). Only 5 % of posts on the 24th August were relevant to the eruption (Figure 3B). Hurricane Olivia (1st–14th September) was responsible for heavy rainfall and some flooding in the State of Hawai'i [Cangialosi and Jelsema 2018]. 'Olivia' is mentioned in 46 posts, peaking at 12 posts on the 10th September. Posts mentioning 'Olivia' occur between the 5th and 16th September, where there is a short-term drop in the percentage of posts relevant to the LERZ eruption (from ~70 % to ~30 %) superimposed on the background longer-term decrease in relevant posts owing to the eruption having ended (Figure 3B).

3.2 Content analysis

Content analysis revealed that Observation was the most common post category, followed by Information and Resources, Requests, Community Support and Concern, Other, then Damage and Disruption (Figure 4). The frequency of Observation posts remained high during the eruption, peaking on the 18th May and coinciding with the caldera explosion producing the largest ash plume [Neal et al. 2019], then slowly decreased until the VAL was lowered to WATCH, after which it remained low for the rest of the year (Figure 5A). The peak around the 16th September was derived from people exploring the newly formed lava flows and Pohoiki, a much-loved beach with great community importance that was originally feared to be destroyed in the eruption but survived.

Information and Resources posts rapidly increased in frequency at the start of eruption then slowly decreased until the VAL was lowered to WATCH, after which the frequency remained low (Figure 5B). The highest Information and Resources posts frequency was on the 4th May, related to information sharing at the start of the eruption. A peak on the 29th May was related to information on evacuations, lava affecting the Puna Geothermal Venture (PGV, a geothermal power plant) and lava crossing Highway 132. In the Requests category, post frequency peaked on the 3rd May relating to information seeking as the eruption started (Figure 5C). Over the course of the eruption the Requests post frequency gradually decreased; after the VAL was lowered to WATCH it remained very low.

Community Support and Concern post frequency remained relatively low throughout the eruption, and decreased after the VAL was lowered to WATCH (Figure 5D). The highest Community Support and Concern post frequency was on the 12th July, stemming from community reactions to the destruction of Ahalanui Park and Kua O Ka La School; the text of these

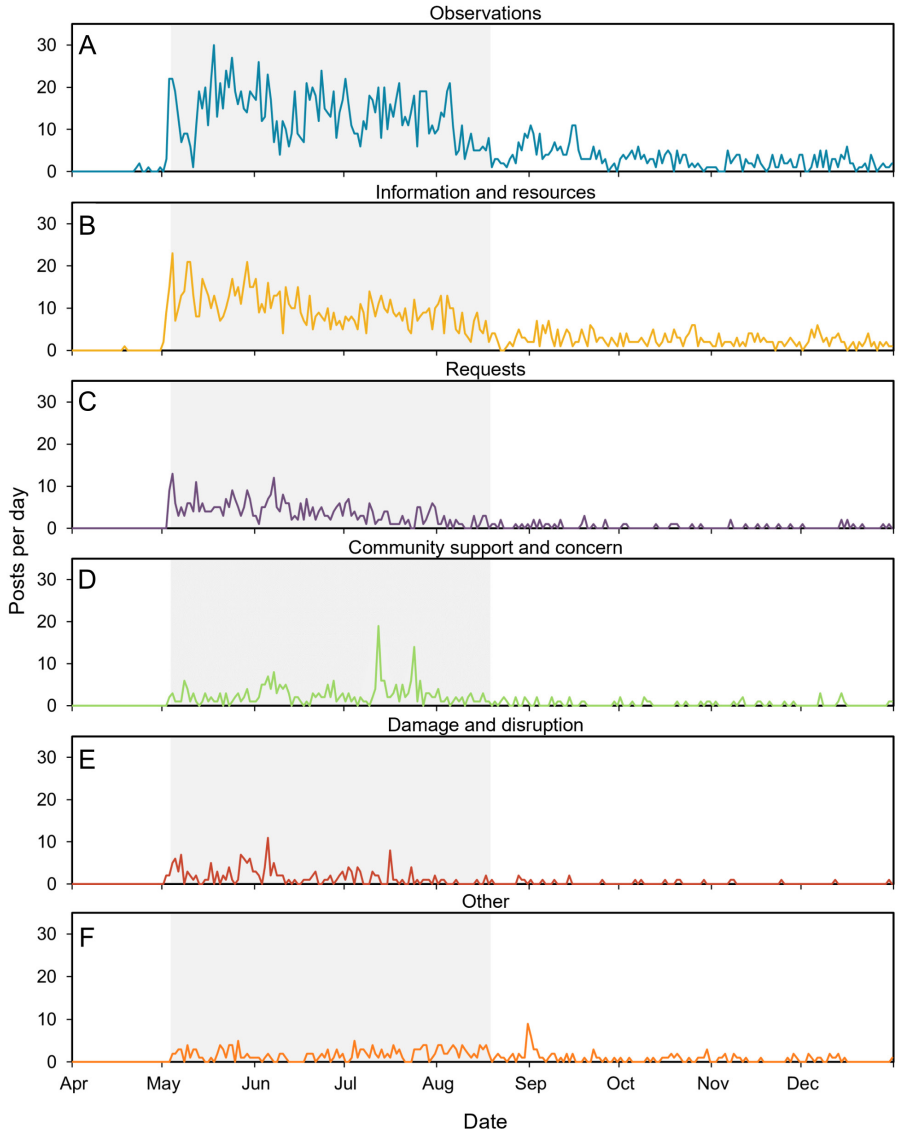

Figure 5: Relevant posts per day from the 1st April 2018 to 31st December 2018 in the content categories: [A] Observation; [B] Information and Resources; [C] Requests; [D] Community Support and Concern; [E] Damage and Disruption; and [F] Other. The grey background indicates the period when the VAL was at WARNING.

posts indicated both were beloved community locations. A second peak on the 24th July relates to the lava flow nearing Pohoiki; group members discussed their heartbreak and posted memories of Pohoiki in response to the prospect of the beach being destroyed.

Damage and Disruption posts were most frequent in May and June, then declined in frequency until the VAL was lowered to WATCH, after which the frequency stayed very low (Figure 5E). Damage and Disruption posts at the start of May relate to reporting of cracks in roads caused by the ground deformation from the magma intrusion. The high frequency of Damage and Disruption posts at the end of May is related to the PGV being partially covered by lava, which was of great concern to residents due to perceived uncertainties of the possibility of lava mixing with chemicals used at the PGV. The high frequency at the end of May also coincides with the destruction of homes by lava flows and evacuation orders for Kapoho and Vacationland. A peak on the 5th June relates to a number of homes being destroyed by lava flows, with many photos and videos of the destruction being posted to confirm which homes were lost. A peak on the 16th July relates to a littoral explosion at the lava ocean entry that threw a lava bomb into a tourist boat, injuring 23 people [Romo 2018].

Posts in the Other category remained steady and low throughout the eruption (Figure 5F), and are generally a mixture of political opinions, jokes, and expressions of frustration. The peak on the 31st August is caused by mainly negative reactions to the introduction of a 50 yard perimeter around the lava flow by Hawai'i County Civil Defense [County of Hawai'i 2018].

3.3 Post media type analysis

Picture posts make up the largest proportion of relevant posts (49 %), followed by Text posts (26 %) and Video posts (25 %)

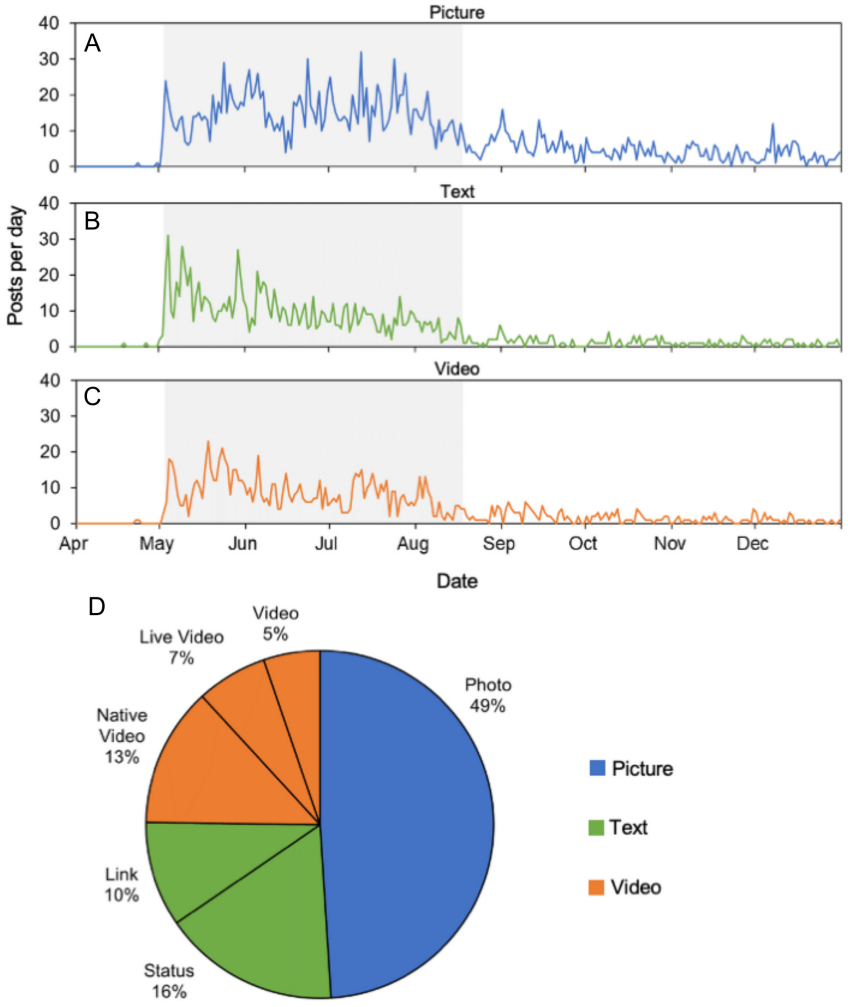

Figure 6: Post media type. Timeseries of media type of relevant posts from the 1st April 2018 to the 31st December 2018 for the categories: [A] Picture; [B] Text; and [C] Video. VAL at WARNING indicated by grey background. [D] Proportions of different post media categories for relevant posts.

(Figure 6). The frequency of Picture posts remains high throughout the eruption, and experienced an initial rapid increase as the eruption started. The frequency of Picture posts decreases from late July onwards (Figure 6A). The frequency of Text posts also peaks as the eruption starts, then decreases over the course of the eruption (Figure 6B). A peak in Text post frequency on the 29th May is related to information on evacuations, and lava affecting the PGV and Highway 132. The frequency of Video posts increases from the start of the eruption to mid-May and then starts to steadily decrease (Figure 6C).

3.4 Interaction analysis

The total interactions per day includes Comments, Shares, and Reactions on relevant posts. From the start of the eruption the number of total interactions per day increases, peaking in June, then drops slightly to a roughly constant value through to August, after which it steadily decreases (Figure 7). The highest number of total interactions per day is on the 14th June, at 29,388, which comes from two video posts of the lava which received 10,500 and 6700 Shares. The high number of Shares increased the volume of people who saw the posts, subsequently generating significantly more interactions. Combined, these two posts generated 21,956 interactions, almost double the average total interactions per day during the period when the VAL was at WARNING.

The number of Shares per day increases from when the eruption starts until June; it then very slowly decreases (Figure 7). Peaks in Shares often relate to images or videos of the eruption that are visually stunning or shocking. On the 16th June a video from Hawai'i Volcanoes National Park detailing all the information of the eruption so far was shared widely. The peak on the 17th July comes from videos of the littoral explosion that caused injuries on the tourist boat, and the peak on the 12th August relates to a post sharing and celebrating the new black sand beach at Pohoiki.

The number of Comments per day on relevant posts fluctuates during the eruption (Figure 7). The peak in Comments on the 24th May stemmed from a post with an update of eruption information in Leilani, and a post discussing the rescue of pets from the evacuated area, while the peak on the 16th July came from posts reacting to the injuries of tourists on the

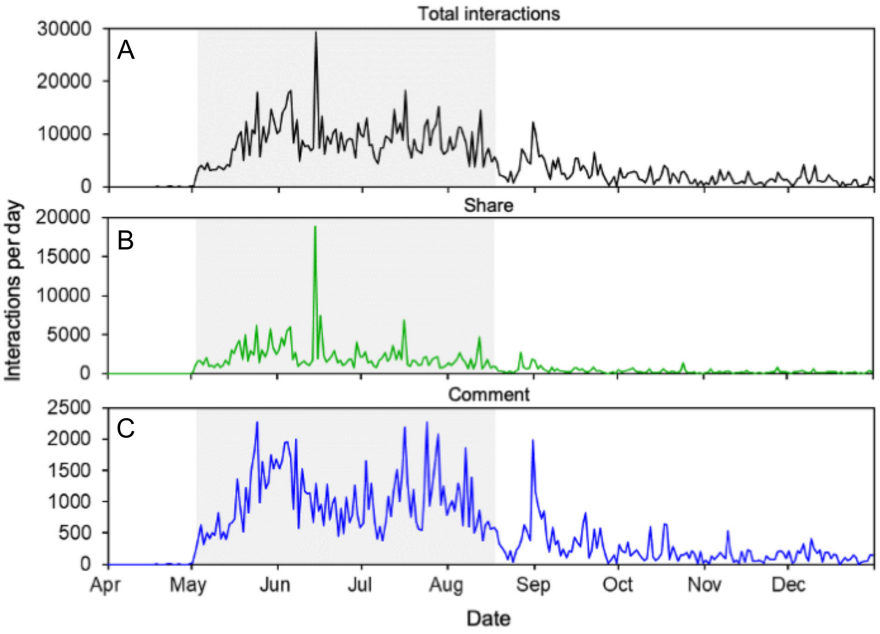

Figure 7: Post interactions. [A] Total interactions (Comments, Shares, and Reactions), [B] Shares, and [C] Comments of relevant posts from the 1st April 2018 to the 31st December 2018. VAL at WARNING indicated by grey background.

boat affected by the littoral explosion. Anger over the Department for Land and Natural Resources' (DLNR) perceived lack of action to save turtles from the eruption caused the peak in Comments on the 24th July. Posts discussing the loss felt from the eruption caused the peak in Comments on 28th July. The peak on the 7th August relates to posts expressing frustration at Hawai'i Civil Defense and the Mayor over the lava viewing area plans, and the fining of people by DLNR for being near the lava. The peak on the 31st August stemmed from reactions to the introduction of the 50 yard perimeter around the lava.

From all Reactions to relevant posts, Like was the most common, followed by Wow, Love, Sad, Haha, and Angry (Supplementary Material 1 Figure S1); they also show variable temporal evolutions during the eruption with peaks reflecting different events (Figure 8). The highest peak of Likes on the 28th July comes from artwork, posts about loss, and some observations of the eruption. The peaks in Likes around the 12th August, and 31st August to 3rd September, all relate to posts about the new black sand beach at Pohoiki (Figure 8A). The highest peak in Wow reactions on the 16th July (Figure 8B) related to information on, and videos of, the littoral explosion at the ocean entry that caused injuries on a nearby tour boat. The Wow peak on the 14th June was from videos of the lava flow and fissure 8 which were widely shared.

The frequency of Sad Reactions is highest during the eruption with several clear spikes related to specific events (Figure 8C). Peaks in Sad Reactions commonly relate to the destruction of homes by lava flows (e.g. 24th May and 2nd July). The highest peak from the 1st–6th June related to expressions of sorrow at evacuations, the destruction houses, and in particular the destruction of Kapoho Bay tidepools. High frequencies of Sad Reactions also relate to the destruction of locations with great importance to the community, such as the Ahalanui Park and Kua O Ka La School on the 12th July, and the destruction of part of Pohoiki beach and the prospect of the whole beach being lost to the lava on the 23rd July. However, posts celebrating that Pohoiki beach was not destroyed by the lava cause peaks in Love reactions in late August and early September (Figure 8D). Other peaks in Love reactions relate to community reactions to micro houses being built for evacuees (5th to 7th June), a post describing the loss felt because of the eruption (28th July), and a late peak on the 6th December in reaction to a resident being reunited with their cat which was assumed lost in the eruption.

The amount of Haha Reactions per day generally stays very low or at zero during and after the eruption (Figure 8E). Posts with high amounts of Haha Reactions at the start of the eruption tend to be light-hearted jokes and memes (typically humorous images that are copied and spread rapidly by internet users) about eruption events. For example, a spider being on the USGS webcam of Halema'uma'u crater (11th May), jokes about the stress of the eruption and animals in the disaster area refusing to be caught (20th–26th May), and a piece of lava that looked like a crocodile (13th July). As the eruption progressed, posts with high numbers of Haha Reactions shifted towards mocking the authorities' responses to the eruption. For example, from the 7th–10th August there were multiple posts making fun of the discussion over a lava viewing area, which residents felt, at ~3 months into the eruption, was not discussed soon enough by the authorities. The highest peak in Haha Reaction frequency on the 9th September related to a meme making fun of Civil Defense's road barriers, as did a post on the 11th November.

The number of Angry Reactions per day generally stays at zero during and after the eruption (Figure 8F), but clear peaks are seen relating to specific events during the eruption. The peak in Angry Reactions on the 24th May related to a reported scam targeting people affected by the eruption, and

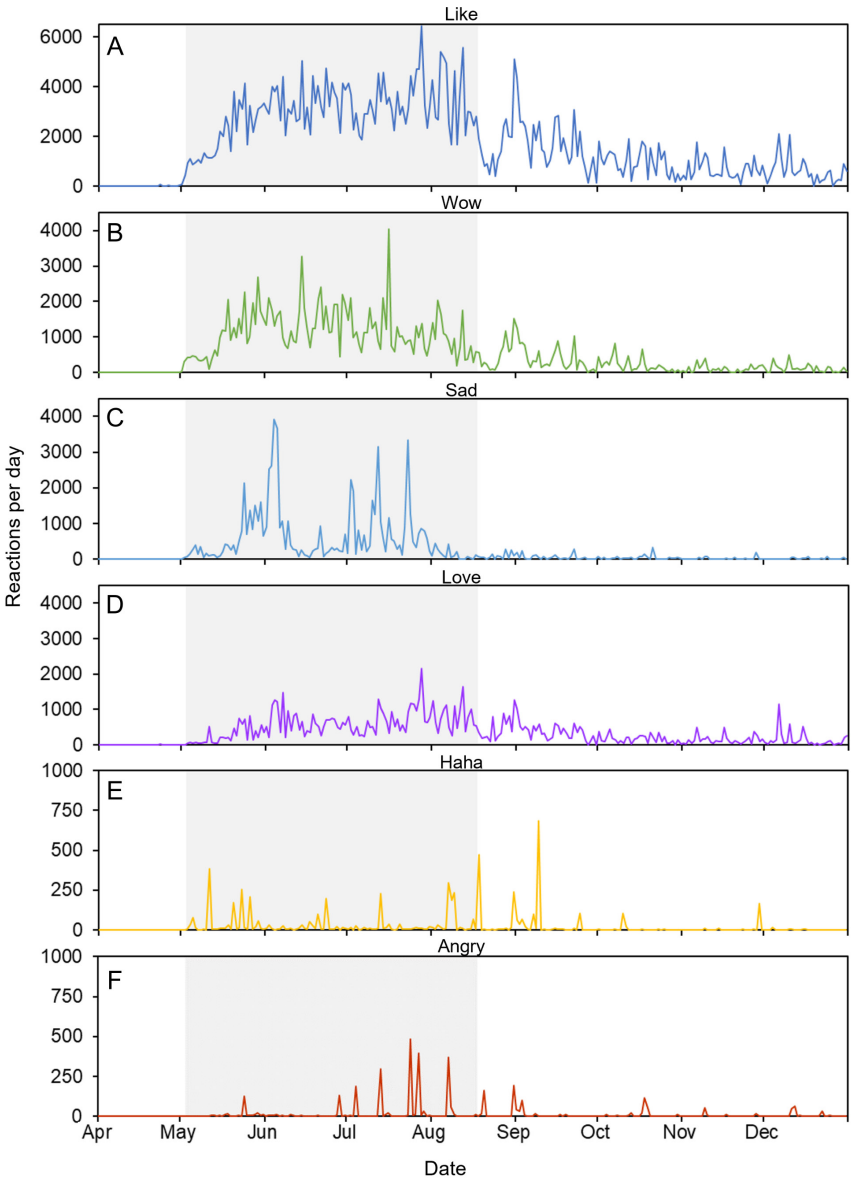

Figure 8: Reactions per day to relevant posts from the 1st April 2018 to the 31st December 2018. [A] Like, [B] Wow, [C] Sad, [D] Love, [E] Haha, [F] Angry. Note the differing scales on the y axes. VAL at WARNING indicated by grey background.

the peak on the 28th June stemmed from insurance companies not wanting to pay out on claims for homes destroyed by lava. Peaks in July were all related to anger towards the DLNR. There are several instances of DLNR fining residents for being in the disaster area, and anger from residents at the perceived failure of DLNR to save turtles from the eruption. The peak from the 31st August to 3rd September comes from reactions to the introduction of the 50-yard lava perimeter. The peak on the 18th October relates to anger at the Hawai'i County and Mayor for not establishing a lava viewing area and some areas (such as Pohoiki) still being closed.

3.5 Sentiment analysis

Sentiment is expressed as a number from +1 (most extreme positive) through 0 (neutral) to −1 (most extreme negative). Using illustrative posts that mirror some of the real data would generate a positive sentiment of 0.91 for the text "*oh wow, what an amazing sight – the pure beauty of mother nature*!", and a negative sentiment of −0.59 for "*Lava has spilled onto the highway, cutting off road access after already destroying a number of homes this morning*.". Days with a low number of posts produce noisy sentiment results, for example in April before the eruption begins. The sentiment of relevant posts generally ranges from 0.45 to −0.29, with an overall mean of 0.09 (Figure 9A) and most posts (~52%) evaluated as positive (Figure 9B). The daily average sentiment gradually increases over the VAL at WARNING period, with a mean across that period of 0.08 (Figure 9C). After the VAL was lowered to WATCH the sentiment becomes noisier and roughly constant, with a mean of 0.09. Several peaks in the sentiment timeseries can be related to events during the eruption. A negative peak on the 2nd May relates to reporting of eruption

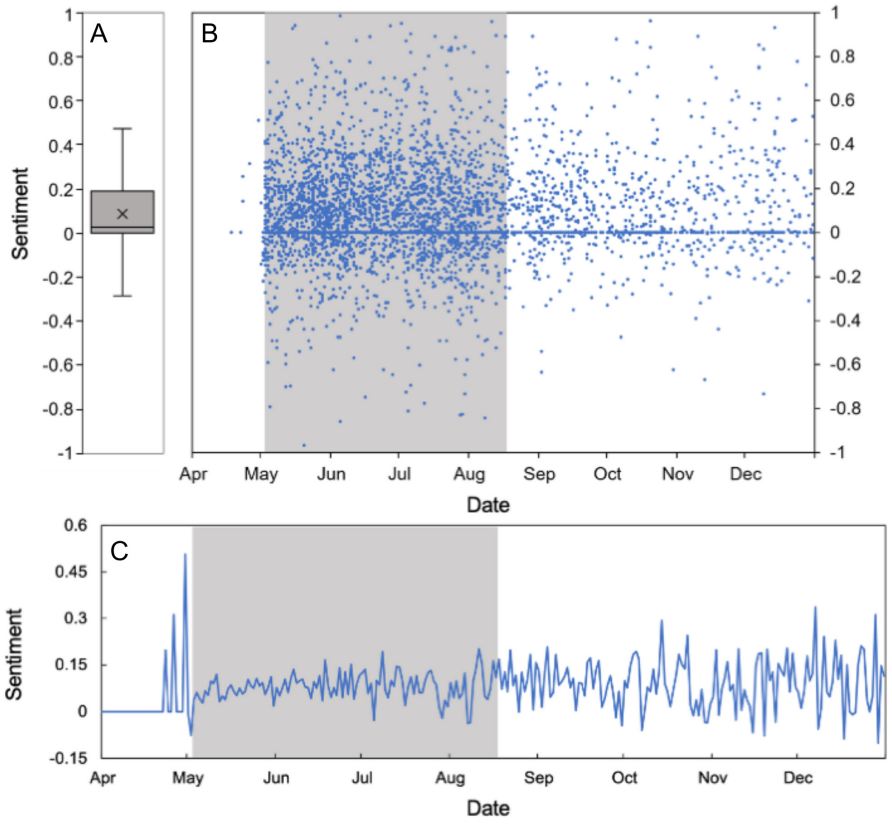

Figure 9: Sentiment analysis results of all relevant posts from the 1st April 2018 to the 31st December 2018. [A] Mean (cross), median (middle line) and interquartile range of sentiment from relevant posts. [B] Daily sentiment distribution. Each point marks a single post, thereby also indicating days with relative higher or lower post frequency. [C] Mean daily sentiment timeseries. VAL at WARNING indicated by grey background.

precursors (earthquakes, ground deformation, and cracks in the ground), although a relatively low number of posts that day (14) may introduce noise into the sentiment analysis. The negative peak on the 7th August relates to community frustration at Hawai'i Civil Defense, the Mayor, and Hawai'i County over the potential lava viewing area, as well as responses to DLNR fining people for being in the lava area. A positive peak on the 11th August comes from reactions to the waning of the eruption and positive observations of Pohoiki beach. Several peaks cannot be attributed to specific events during the eruption (18th June, 5th July, 8th July, 30th September, 7th October), which could be due to low post frequency introducing noise into the sentiment analysis, or simply no standout events causing the spikes in the sentiment timeseries. Interestingly, none of the negative peaks appear to correlate with destructive events (e.g. lava engulfing residential areas, or the threat to Pohoiki beach).

Sentiment analysis was also separately carried out on 689 relevant posts that mention the USGS or HVO. Of these posts, the sentiment generally ranges from 0.32 to −0.27, with a mean of 0.02 and most posts having a positive sentiment (Supplementary Material 1 Figure S2). The low volume of data produces noisy results, but a positive spike in sentiment can be seen on the 18th August when the VAL was lowered to WATCH, and on the 8th September when the lava inside Fissure 8 was diminishing and evacuation orders were lowered from mandatory to voluntary (Supplementary Material 1 Figure S3).

3.6 Statistical correlation analyses

To investigate the type and strength of relationship between results, the Spearman's rank correlation coefficient (r_s) was calculated for the content, interaction, and media analysis, and sentiment results using the daily frequencies (Figure 10). Statistical hypothesis testing was carried out to confirm the relationship between results using a significance level of 0.05; results that were statistically non-significant are omitted from display and further analysis. Positive r_s results indicate that as one variable increases, so does the other. Negative r_s results indicate that as one variable increases, the other decreases. As the r_s value approaches 1 or −1, the strength of the relationship increases. In our analyses, almost all statistically significant correlations are positive (i.e. values greater than zero); for example, the correlation between the number of Observation posts per day and the number of Photo posts per day is 0.91. A statistically significant negative correlation is only recorded between the sentiment analysis trend and the daily frequency of posts categorised as Information (Figure 10). The strongest correlation (0.93) recorded is between the daily number of Wow reactions, and the daily number of post Shares.

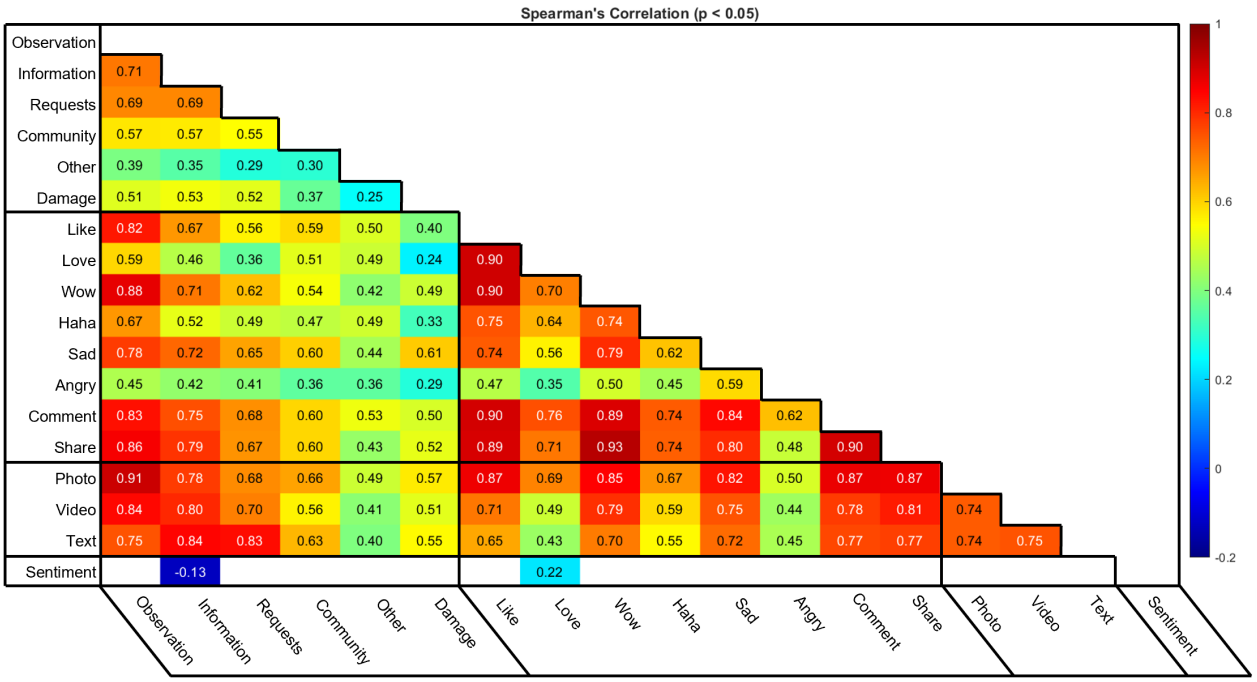

Figure 10: Spearman's rank correlation coefficient matrix showing type and strength of relationship between results. Correlation is calculated using daily frequencies (e.g. the correlation between number of Observation posts per day and the number of Text posts per day is 0.75). Duplicate and statistically non-significant results (significance level 0.05) are omitted from the figure and replaced with empty white boxes..

4 Discussion

4.1 Facebook usage during the eruption

The majority of posts were found to be in the categories 'Observation' and 'Information and Resources' (72 %), indicating that Hawaii Tracker was primarily used as a form of distributing eruption information. Posts in the category Observation are most strongly positively correlated to Photo (r_s = 0.91, Figure 10) and Video (r_s = 0.84) posts, indicating that eruption observations are most commonly posted visually, perhaps due to the large amount of information that can be conveyed by an image or the visually stunning nature of the eruption. The Information and Resources category is most strongly positively correlated to Text posts (r_s = 0.84), indicating that eruption information is mostly conveyed in written form. The categories Observation, and Information and Resources, also have strong positive correlations with Comments (r_s = 0.83 and r_s = 0.75, respectively) and Shares (r_s = 0.86 and r_s = 0.79, respectively), suggesting that posting of eruption information sparked discussion on Facebook, and posts were commonly shared to reach a wider audience. Goldman et al. [2023] found that residents frequently turned to community messenger Facebook pages to find eruption information; our results demonstrate high levels of Facebook engagement through high levels of interactions with posts on Hawaii Tracker and support their conclusion.

The high number of Observation posts supports suggestions that social media could be an untapped resource for eruption monitoring [Hickey et al. 2025]. It should be possible to use eruption observations posted to social media as a crowd sourced real time eruption/crisis monitoring technique; the instant nature of social media could provide rapid situational awareness for scientists and civil protection officials working on the eruption. Such a process would be similar to, but a technological update on, the *vigías* network that undertook community-based monitoring of Tungurahua volcano, Ecuador, during the early 2000's [Stone et al. 2014], and whose work was greatly appreciated by the Instituto Geofísico (the local volcano observatory) [Mothes et al. 2015]. Also, a potentially wide spatial distribution of social media users (dependent on internet connection, and social media usage) could facilitate observations to be reported in places where scientific monitoring is not installed, as was partially explored by Yute et al. [2021] who supplemented satellite imagery with social media data to map ash fall after the January 2020 Taal eruption in the Philippines.

The content categories Information and Resources, and Requests, both peak at the start of the eruption and decrease over time, indicating that information dissemination, information seeking, and offers of help were highest at the start of the eruption and decreased with time. The two categories have a moderate positive correlation in their daily number of posts (r_s = 0.69, Figure 10). As the Requests category covers both questions *and* offers of help, the positive correlation could suggest that even when lots of eruption information was being shared users still had questions, or, that there were many offers to help during the start of the eruption. Splitting the Requests category into 'questions' and 'offers of help' could determine the

cause of this relationship but was beyond the scope of our current study. These broad-scale patterns, as well as the specifics of the requests being made, could be monitored during future eruptions to provide information to emergency management practitioners. After the VAL was lowered to WATCH, both categories remained at low levels, indicating a reduced need to for eruption information and support.

The majority of posts relevant to the eruption on Hawaii Tracker in 2018 were visual (75 % were either Photos or Videos). A high proportion of image-based content could reflect the visual nature of social media, where photos and videos are more likely to gain interactions. Photo and Video posts are strongly positively correlated to the number of Like, Wow, Sad, Comment, and Share interactions per day (Figure 10). The high proportion of image-based posts also highlights the importance of taking visual attachments into account when conducting content or thematic analyses, as the meaning of a post can depend on the images and/or videos accompanying it.

Our results also allow examination of what people post on Facebook after a volcanic eruption. The frequency of relevant posts remaining above zero after the VAL was lowered to WATCH indicates Facebook users are still thinking about the eruption after it had waned, which is likely partially driven by the eruption being classed as still ongoing and the VAL not being lowered to NORMAL until March 2019. Alternatively, the frequency of relevant posts remaining above zero after the VAL was lowered to WATCH may be due to impacts of the eruption still being felt by the community. Long-lasting impacts are supported by Gissurardóttir et al. [2018] who found that residents that were highly exposed to the 2010 Eyjafjallajökull volcanic eruption in Iceland were at an increased risk of mental distress and more likely to exhibit symptoms of post-traumatic stress disorder in the 6-9 months following the eruption. The most commonly posted categories after the VAL was lowered to WATCH are Observation, and Information and Resources, suggesting that users still desired, and felt the need to share, eruption information even after the eruption had quietened.

4.2 Assessing emotional response to the eruption with Facebook data

First-order emotional responses to the eruption can be tracked, via proxy, using sentiment analysis of the text from posts relevant to the eruption. Interestingly, an overall positive sentiment throughout the eruption (Figure 9) suggests that the general community feeling remained mostly positive even during a time of disaster. Similar positive sentiment results were found during the 2021 Fagradalsfjall fissure eruption on the Reykjanes peninsula, Iceland, in sentiment analysis of Twitter (X) posts [Ilyinskaya et al. 2024]. However, the Fagradalsfjall eruption produced negligible social or economic impacts on the local people or community, with no properties destroyed or livelihoods affected, compared to the more impactful 2018 LERZ Kīlauea eruption, where over 1800 structures were destroyed, including many homes, and 5563 individuals were displaced [Kim et al. 2019; County of Hawai'i 2020; Meredith et al. 2022].

A common theme throughout the relevant posts on Hawaii Tracker is a sense of awe towards the eruption, which is often considered to be Pele herself. Pele is the Hawaiian volcano deity (sometimes called Madame Pele, or simply 'she'), who is believed to live within Halema'uma'u at the summit of Kīlauea. Pele is revered by many Hawaiians, especially by people in Puna where she is considered *'aumakua* (family or deified ancestor). Leathers [2014] found that residents of Puna perceive Kīlauea as worthy of respect, and "*live in the wake of Pele's will, by choice*". The overall positive sentiment observed during the 2018 LERZ Kīlauea eruption seems likely to be linked to the strong connection to volcanoes in Hawaiian culture. Pele is respected and users do not perceive the destruction caused by Pele negatively, rather it as Pele reclaiming the land. For example, one Facebook post exclaimed that there is no better way to lose one's home than by the Earth reclaiming it and expressed their awe at the show Pele provided. Further interdisciplinary social science exploration of cultural beliefs expressed on Hawaii Tracker during the eruption could provide more insight into the reasoning behind the overall positive sentiment value, and help guide future hazard and risk information communication, but was beyond the scope of our current study. An additional factor that could have also contributed towards an overall positive sentiment are the posts that expressed messages of hope and support, as captured by our Community Support and Concern category. These posts would have likely produced relatively highly positive sentiment scores, thus pulling up averages. Similar positive sentiment posts reflecting messages of hope and support were also found in Twitter analysis [Hickey et al. 2025].

A recent study conducted a sentiment analysis of Twitter posts relating to the 2018 Kīlauea LERZ eruption and found that during the eruption the mean sentiment expressed in a global data set was 0.00 [Hickey et al. 2025]. When only looking at Twitter posts originating in the State of Hawai'i, Hickey et al. [2025] found a marginally higher overall sentiment during the eruption of 0.02. Similarly, Ilyinskaya et al. [2024] observed an overall positive sentiment in Twitter posts written in Icelandic (which is predominantly only used by residents of Iceland) during the Fagradalsfjall fissure eruption on the Reykjanes peninsula in 2021. Our study focuses on a Hawaiian community Facebook group, where all group administrators are residents of Hawai'i and it is likely that the majority of group members are too (see Section 2), and we observe a slightly positive mean sentiment value of 0.08 during the eruption as well as a positive interquartile range between 0.00 and 0.19 (Figure 9). Together, these three studies suggest that social media users living near to volcanic eruptions express an overall positive sentiment, even during a disaster. However, it is currently difficult to establish a baseline for sentiment as there is a low volume of relevant posts when an eruption is not taking place; it is also difficult to assess how representative of the public the sentiment analysis results are given they are restricted to social media users as a subset of a full demographic. Interestingly, the Twitter-based sentiment analysis results for Kīlauea highlight sharp decreases in sentiment during the destruction of Vacationland in June and the injuries on the tourist boat on the 16th July [Hickey et al. 2025], however,

our Facebook results do not show such trends. Therefore, it is possible that the two sentiment analyses are based on different subsets of Hawaiian people, with Twitter users more likely to react and post in a more negative manner than Facebook users in a local community group. Both Twitter and Facebook sentiment values decrease at the start of May, perhaps in response to eruption precursors such as frequent earthquakes. A similar result was found prior to the 2021 Fagradalsfjall eruption, where expressed sentiment during intense pre-eruptive seismicity was more negative than during the subsequent eruption [Ilyinskaya et al. 2024].

Our positive sentiment analysis results (Figure 9) are supported by the proportion of positive Reactions to posts (32.06 % for Wow, Love, and Haha) compared to the proportion of negative Reactions (9.5 % for Sad and Angry). Like is not included as it can be used on Facebook as an acknowledgement of seeing a post, not necessarily that a user 'likes' the content. Love was the third most used Reaction and has a moderately positive correlation with Community Support and Concern posts (r_s = 0.51), which reinforces how the community was supporting itself during the eruption. Wow was the second most common Reaction, which may speak to the visually stunning nature of this eruption as the number of Wow Reactions and Observation posts per day are strongly positively correlated (r_s = 0.88). The high proportion of Wow Reactions may also be due to the nature of social media where impressive posts are more likely to be shared further and reach a wider audience, driving further interactions, which is evidenced by a strong positive correlation between Wow reactions and post Shares (r_s = 0.93). The wider audience reach means it is also important to consider the large international media attention the eruption received, drawing in more social media users to react to the eruption online. Hickey et al. [2025] investigated differences in sentiment expressed in Tweets about the eruption originating from within and outside the State of Hawai'i and found a weak negative correlation between sentiment and distance from the eruption, with Tweets from Hawai'i being the most positive. There is no location data for the posts used in our present study so we cannot provide certainty that the overall positive sentiment in the Facebook posts is originating from Hawaiian locals rather than users further afield who may have joined a local Hawaiian community Facebook group. The difference in emotional responses between local and international social media users could provide insight into the perceptions of residents versus non-residents to volcanic eruptions and inform local versus international media statements for hazard and risk communication. However, assessing this difference will require careful ethical, equity, diversity, and inclusivity considerations over how to collect, use, and store the user and location information required. Despite not being able to exactly quantify the proportion of residents versus non-residents posting in our Hawaii Tracker Facebook group dataset, our reading of the posts and interpretations of their meanings, plus the fact that all group administrators are based in Hawai'i, suggests to us that the majority of people using the group were residents. We also acknowledge that the group demographics could have changed during the eruption, as its usage grew and the popularity of the group could have attracted members from outside Hawai'i.

4.3 Correlating social reactions to events during the volcanic eruption

Volcanic eruptions produce a variety of hazards and events, each of which can elicit different social responses. Our analysis of posts from Hawaii Tracker can be linked to several events during the eruption and allow social reactions to these events to be investigated. For example, the destruction of, and damage to, houses caused by the lava flow can be related to increases in post frequency (Figure 3), Damage and Disruption posts (Figure 5), and Sad Reactions (Figure 8) in May and June. These relationships are supported by independent, field-based damage data that recorded a large increase in the number of buildings damaged by lava during this time period [Meredith et al. 2022]. Damage and Disruption posts are moderately positively correlated to Sad Reactions (r_s = 0.61, Figure 10), indicating that the users of Hawaii Tracker reacted negatively to the destruction of buildings. Comparing results of our social sensing analyses alongside independent data tracking the evolution and impact of the eruption also highlights correlations. Posts categorised as Support and Concern, and Damage and Destruction, have similar cumulative temporal evolutions to the cumulative number of buildings in contact with lava, and the area of the lava flow (Figure 11). The variations in these trends are non-linear, reflecting the dynamic evolution of the eruption and lava effusion, which are then recorded in social media posts detailing the damage caused by the lava and/or requesting or offering support. Similar results were also observed in Twitter-based analyses of the same eruption [Hickey et al. 2025]. However, posts categorised as Observations, Information and Resources, and Requests, have a more linear cumulative evolution through time, similar to that recorded in the cumulative number of earthquakes per day though it is more difficult to attach a causative relationship between these parameters (Figure 11).

The eruption caused no fatalities but a few injuries, mostly stemming from a littoral explosion (caused by the meeting of lava and water) at the lava ocean entry, which threw a lava bomb onto a nearby tourist boat on the 16th July. Twenty-three people were injured and reactions to this event can be seen in Hawaii Tracker data as an increase in Damage and Disruption posts, Shares, Comments, and Wow Reactions. This event is not linked to an observable change in mean daily post sentiment (Figure 9), suggesting that the balance in text of posts of users of Hawaii Tracker was neutral for this day/event. Videos of the explosion were widely shared and reacted to, seen in the spike in daily Shares (Figure 7) and Wow Reactions (Figure 8). On social media, it is common for a post that is shocking or visually stunning to be more likely to be shared by users, thus generating more interactions and more shares (colloquially known as 'going viral').

Our results can be used to inform what is important to the community. Peaks in Comments and Love Reactions can be linked to the recovery of pets, and many posts tell stories of animal rescues during the eruption, reinforcing that the community considers pets and animals to be of importance and

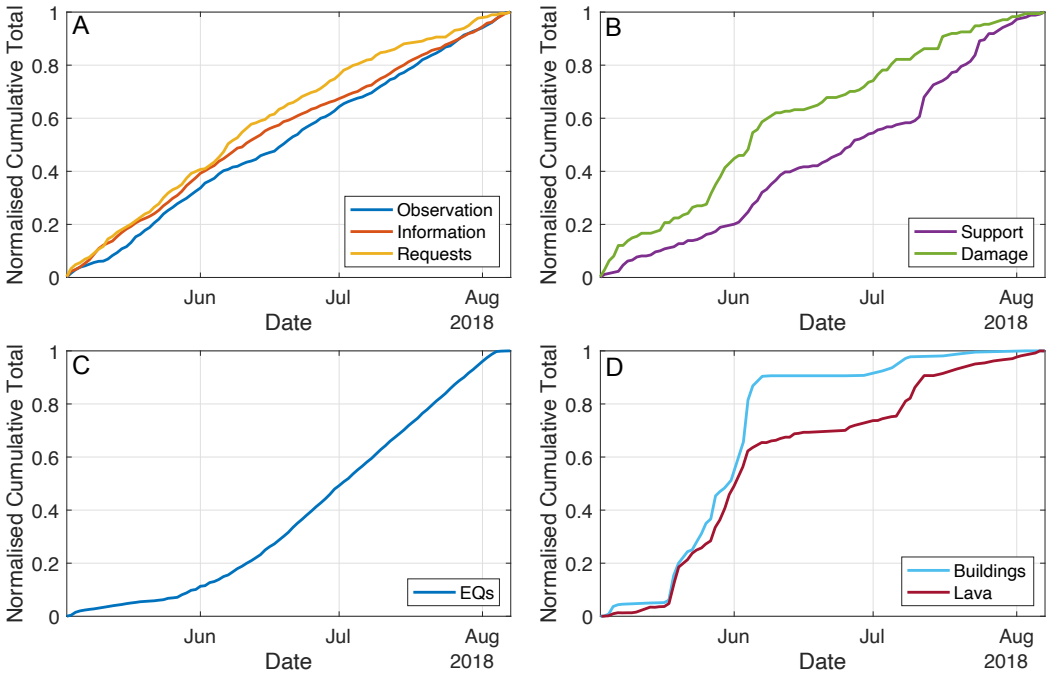

Figure 11: Cumulative evolution of social sensing results and eruption data. [A] Normalised cumulative totals of Facebook posts categorised as Observations, Information and Resources, or Requests. [B] Normalised cumulative totals of Facebook posts categorised as Support and Concern, or Damage and Destruction. [C] Normalised cumulative number of earthquakes. [D] Normalised cumulative number of buildings in contact with the lava and the area of lava flow inundation [Meredith et al. 2022]. All datasets are normalised to the same time period (3rd May–7th August).

was concerned for their welfare during the eruption. The data can also be used to gain insight into what locations are important to the community. The destruction of Ahalanui Park and Kua O Ka La School on the 12th July produced a high number of Sad Reactions, and the highest number of Community Support and Concern posts. Another important community location is Pohoiki, a beach in Puna used for fishing and surfing, and much beloved by the community [Timboy 2019]. Lava flows threatened to destroy the beach, eliciting an increase in Community Support and Concern posts and Sad Reactions, with users expressing heartbreak and posting memories of time spent at Pohoiki. The lava flow stopped just short of Pohoiki, which was celebrated on Hawaii Tracker as can be seen by an increase in Like and Love Reactions. In the weeks and months that followed, Pohoiki developed a new black sand beach which was explored and celebrated online, causing an increase in Shares and Likes. The community's frustration at Pohoiki remaining closed in October can be seen as a peak in Angry Reactions, showing the residents' desire to get back to this important community location. The discussion of Pohoiki, Ahalanui Park, and Kua O Ka La School on Hawaii Tracker highlight that it is possible to track social responses to events during an eruption, especially when the events concern things important to the community.

The potential for, but eventual partial, inundation of the Puna Geothermal Venture (PGV, a geothermal power plant) by lava in May was of concern to Hawaii Tracker users, being linked to an increase in text posts, and posts classified as Information and Resources, and Damage and Disruption. Users expressed concerns over the interaction between the lava and chemicals stored at the site, and the potential release of harmful gases. These discussions could be linked to the (unfounded) rumours that the eruption was caused by geothermal energy production and that blue flames in the LERZ were caused by sulphur gas from the PGV [Stovall et al. 2023]. The occurrence of these rumours in the USGS Volcanoes' Facebook page comments are tracked by Goldman et al. [2024] who found an increase in misinformation surrounding the PGV during May. However, the majority of posts on Hawaii Tracker mentioning the PGV appear factual, although our analysis does not take into account the subsequent comments and discussions in response to an original post. By further analysing posts mentioning the PGV, and the comments in reply, it may be possible track the amount of information versus misinformation, gaining insight into rumours and misinformation on community Facebook pages during a volcanic eruption with benefits for future hazard and risk communication protocols.

Our results also show how community perceptions of risk can change when faced with multiple (and differing) hazards. The dips in frequency of posts relevant to the eruption seen around the times of Hurricanes Hector, Lane, and Olivia (Figure 3) suggest that these events were considered as posing more risk than the ongoing eruption, prompting the community to pay less attention to the eruption and focus on the perceived more immediate threat posed by the hurricanes. Consecutive disasters can increase vulnerability, making the effects of a disaster more pronounced [de Ruiter et al. 2020].

The first hazard can deplete resources and increase the vulnerability for the second hazard. Therefore, knowledge of how a community responds to multiple hazards, and how their perception of risk may evolve, is useful information for risk managers and civil protection officials and could be inferred from analysis of social media posts. Furthermore, our findings might suggest that when faced with more than one type of hazard, such as volcanic and meteorological, non-critical communications related to the hazard deemed to pose lower risk may not be as effective as they would be without the additional simultaneous (higher risk) hazard. Consequently, if possible (e.g. when the hazards have differing timescales), those communications could be postponed until the hazard perceived as posing more risk has passed.

4.4 Correlating social reactions to the authorities' responses during the volcanic eruption

Some actions taken by the authorities during the eruption are met with negative reactions on Hawaii Tracker. For example, fines issued to people for being too close to the lava by the Department for Land and Natural Resources (DLNR), DLNR's perceived failure to save turtles from the eruption, the introduction of a 50 yard perimeter around the lava, and the lack of decision on establishing a lava viewing area by Hawai'i Civil Defense and the Mayor all elicited increases in the number of Angry Reactions (Figure 8). Furthermore, users sometimes make fun of the authorities which can be seen, for example, in an increase in Haha Reactions in response to Civil Defense's road barriers (Figure 8). The aforementioned authorities may be able to learn from the community responses to their actions in order to improve upon their implementation, and timing, in the future.

The USGS (including the HVO) played an essential part in the eruption response, not only monitoring the eruption, but also providing public outreach and communications to the news media [Stovall et al. 2023]. Two clear positive spikes in the sentiment of posts mentioning either the USGS or HVO are observed, relating to the lowering of the VAL to WATCH, and the reduction in lava at Fissure 8 with the mandatory evacuation becoming voluntary (Supplementary Material 1 Figure S3). Of those posts mentioning either the USGS or HVO, they elicited ~89,000 Reactions, of which just 0.48 % were Angry and 63.58 % were Like. In comparison, of all the Reactions to all relevant posts, 0.46 % were Angry and 58.44 % were Like, which may suggest there was no extra anger directed towards the USGS or HVO during and after the eruption, and that their work had a greater level of appreciation than posts not mentioning them. We note, however, that we did not analyse the text of comments written in response to posts, which is often where anger (and other emotions) may be more likely to be expressed.

The average sentiment of posts mentioning the USGS (0.02) is neutral-minorly positive, compared to a more positive 0.09 as the mean sentiment of all relevant posts in the dataset. In contrast, Goldman et al. [2024] analysed sentiment of comments on posts on the USGS Volcanoes' Facebook page (which was used to share information from the USGS) during the eruption; they found a more positive sentiment (0.1–0.2) in the comments during the time the VAL was at WARNING. The higher sentiment observed by Goldman et al. [2024] may be due to the different aspects of Facebook that were analysed. The posts mentioning the USGS in our study were often factual reporting of eruption events either by users of Hawaii Tracker or the USGS (shared posts from the USGS Volcanoes' Facebook page), which may explain why the sentiment is close to neutral. Goldman et al. [2024] observed the sentiment of comments, which are written in response to posts so often convey more emotion, perhaps explaining the more positive sentiment; they also noted a moderate positive correlation between the sentiment expressed in comments and the frequency of the words "thank" and "mahalo" ("thank you" in Hawaiian). Themes of gratitude within the comments of USGS Volcanoes' Facebook comments may also be the reason for the positive sentiment values.

5 Limitations and future opportunities

The manual relevancy filtering and content categorising methods used allowed for human judgement to evaluate both the text and attachments (e.g. photos, videos, links) of posts in their context, but this subjective approach may introduce biases. Future evaluations of similar datasets may benefit from training and utilising machine learning (ML) methods to filter and/or categorise posts, as has been applied in previous social sensing studies [e.g. Arthur et al. 2018; Spruce et al. 2020; Young et al. 2022; Hickey et al. 2025]. The use of ML methods may also facilitate the potential for real-time social sensing applications during ongoing volcanic eruptions by more rapidly being able to process and analyse data [Hickey et al. 2025].

For simplicity the content analysis only assigned one category per post, but posts often discussed multiple themes, so the categorisation was focussed on the theme which was considered to be dominant. Therefore, the true breadth and extent of post categories and themes may not have been fully captured through our content analysis. Future works should explore assigning multiple content categories to posts. Individual assessments on a post-by-post basis could also reveal what type of posts, related to specific events, drove different types of engagement, for example by calculating ratios between comments, likes, and shares.

The sentiment analysis we employed only used the text within the posts and did not consider any accompanying visual content. Sentiment analysis of disaster images using machine learning has been explored, but is still a developing technique requiring further research [Hassan et al. 2022]. Automated visual sentiment analysis may allow for a deeper understanding of the overall sentiment of each post and be more time efficient than attempting to analyse visual sentiment manually. The `VADER` algorithm we used for sentiment analysis does not take emojis into consideration, which are important indicators of tone and emotion in social media. In its `Python` version `VADER` does have additional support for emojis. Integrating this code into `MATLAB`® or running the sentiment analysis in `Python` could produce slightly different sentiment analysis results and could be explored as a comparison.

Although a useful insight into community perceptions, the data used in this study only takes into consideration the ex-

pressed perceptions of the users of the Hawaii Tracker Facebook group, and not the whole community. It is also important to note that Hawaii Tracker was not the only social media page to be used by residents during the eruption [Goldman et al. 2023]. Residents who did not use Hawaii Tracker will not have their perceptions captured by this study; data suggests that 68 % of US adults used Facebook in 2018, and that it is more popular with adults aged 18–29 than those aged 65+ [Smith and Anderson 2018]. Other social media platforms may more robustly capture different demographic groups and produce differing social sensing results [e.g. Ruan et al. 2022]. Additionally, social media user demographics and platforms continue to evolve, with features frequently added or removed. Consequently, the social media landscape now is likely very different from that of the 2018 eruption, seven years ago. These shifts should be considered if planning similar analyses for future eruptions; the 2022 Mauna Loa eruption [Lynn et al. 2024] and the recent 2025 Kīlauea eruptions might be good targets to assess using similar techniques and datasets.

Our study is predominantly observationally driven work; we do not develop, explore, or support any social science theory. Investigating the extent to which our results can be explained with, or develop, social science theory around usage of social media in a crisis context, or around risk communication and disaster research, could be a fruitful avenue for future study. Our evidence for social media posts mocking the authorities' responses to the eruption may also suggest that future work could explore perceived behaviour towards authority figures and organizations through social sensing during eruptive crises.

6 Conclusions

Our study shows promising results for the use of Facebook to socially sense volcanic eruptions in regions where Facebook is widely used, and outlines key areas of improvement for further refinement. Posts categorised as Observation or Information and Resources were the most common on the community Facebook page Hawaii Tracker during the Kīlauea 2018 LERZ eruption, indicating that social media could be an untapped resource for syn-eruption monitoring of visual eruption dynamics and variations in eruptive activity that could be otherwise missed by resource-constrained volcano monitoring agencies. Eruption observations were most commonly conveyed visually, while eruption information was mostly shared in written form. Destruction of, and damage to, houses caused by the lava flow can be related to increases in post frequency, Damage and Disruption posts, and Sad Reactions in May and June, while information dissemination, information seeking, and offers of help were highest at the start of the eruption and decreased with time. Together, these two findings suggest the community was actively supporting itself throughout the course of the eruption, and the specifics of the relationships uncovered could be of use to volcano observatories, civil protection, emergency managers responding to similar future eruptions. An overall positive sentiment was expressed in the text of, and Reactions to, posts, showing that the community remained positive even in a time of disaster, and could be linked to the strong connection to volcanoes in Hawaiian culture and community support. Sentiment expressed in our analyses of Facebook posts during the eruption was higher than the sentiment observed in Twitter posts, highlighting a difference between the two social media platforms for the same eruption. Variations in a number of social sensing metrics (e.g. number of shares, overall post frequency, frequency of different post categories, changes in types of post Interactions) can be used to infer what is deemed most important to the community. In particular, animal rescues and threats to (and recoveries of) popular community locations (Ahalanui Park, Pohoiki beach, and Kua O Ka La School) elicit strong reactions in our analyses. Similarly, we also identify periods when alternative natural hazards (namely, hurricanes, but also a forest fire) seemingly pose a greater perceived threat to the community, with posts relevant the eruption decreasing in response to the presence of hurricanes; such findings may be used to influence future hazard and risk communication strategies. In general, our work helps to better understand the perceptions of volcanic risk, with the hope that such information can be used to improve future volcanic crisis communication. Further study may enable movement towards a future of using social sensing as an eruption monitoring technique in real time during volcanic crises.

Author Contributions

Annie Matthews: Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing - original draft, Writing - review & editing. **James Hickey**: Conceptualization, Methodology, Project administration, Supervision, Writing - original draft, Writing - review & editing.

Acknowledgements

This study received no external funding and is based on an undergraduate research project dissertation. We thank James Young for extracting the Facebook post data from the Hawaii Tracker Facebook group using `CrowdTangle`. For the purpose of open access, the author has applied a Creative Commons Attribution (CC BY) licence to any Author Accepted Manuscript version arising. Earthquake data were accessed from the NSF SAGE data archive operated by EarthScope Consortium (NSF award 1724509). The authors thank two anonymous reviewers, and the editor Jenni Barclay, for their time and thoughtful comments that helped to improve the manuscript.

Data Availability

The raw Facebook data that support the findings are available from Zenodo (https://doi.org/10.5281/zenodo.17084528).

Copyright Notice

References

Arthur, R., C. A. Boulton, H. Shotton, and H. T. P. Williams (2018). "Social sensing of floods in the UK". *PLOS ONE* 13(1), e0189327. DOI: 10.1371/journal.pone.0189327.

Berg, R., S. Houston, and T. Birchard (2018). *National Hurricane Center Tropical Cyclone Report: Hurricane Hector (EP102018)*. URL: https://www.nhc.noaa.gov/data/tcr/EP102018_Hector.pdf.

Beven, J. and D. Wroe (2018). *National Hurricane Center Tropical Cyclone Report: Hurricane Lane (EP142018)*. URL: https://www.nhc.noaa.gov/data/tcr/EP142018_Lane.pdf.

Cangialosi, J. and J. Jelsema (2018). *National Hurricane Center Tropical Cyclone Report: Hurricane Olivia (EP172018)*. URL: https://www.nhc.noaa.gov/data/tcr/EP172018_Olivia.pdf.

County of Hawai'i (2018). *Puna Lava Zone Policy Changes – Involving Checkpoints (31 August 2018)*. URL: https://www.hawaiicounty.gov/Home/Components/News/News/1395/.

– (2020). *Kīlauea Recovery and Resilience Plan*. URL: https://recovery.hawaiicounty.gov/home/showpublisheddocument?id=302781.

De Ruiter, M. C., A. Couasnon, M. J. C. van den Homberg, J. E. Daniell, J. C. Gill, and P. J. Ward (2020). "Why We Can No Longer Ignore Consecutive Disasters". *Earth's Future* 8(3), e2019EF001425. DOI: 10.1029/2019ef001425.

Fakhruddin, B., H. Clark, L. Robinson, and L. Hieber-Girardet (2020). "Should I stay or should I go now? Why risk communication is the critical component in disaster risk reduction". *Progress in Disaster Science* 8, page 100139. DOI: 10.1016/j.pdisas.2020.100139.

Fearnley, C., A. E. G. Winson, J. Pallister, and R. Tilling (2017). "Volcano Crisis Communication: Challenges and Solutions in the 21st Century". *Observing the Volcano World*. Edited by C. Fearnley, D. Bird, K. Haynes, W. McGuire, and G. Jolly. Springer International Publishing, pages 3–21. DOI: 10.1007/11157_2017_28.

Gissurardóttir, Ó. S., H. Hlodversdóttir, E. B. Thordardóttir, G. Pétursdóttir, and A. Hauksdóttir (2018). "Mental health effects following the eruption in Eyjafjallajökull volcano in Iceland: A population-based study". *Scandinavian Journal of Public Health* 47(2), pages 251–259. DOI: 10.1177/1403494817751327.

Goldman, R., W. Stovall, D. Damby, and S. McBride (2023). "Hawai'i residents' perceptions of Kīlauea's 2018 eruption information". *Volcanica* 6(1), pages 19–43. DOI: 10.30909/vol.06.01.1943.

Goldman, R. T., S. K. McBride, W. K. Stovall, and D. E. Damby (2024). "USGS and social media user dialogue and sentiment during the 2018 eruption of Kīlauea Volcano, Hawai'i". *Frontiers in Communication* 9, page 986974. DOI: 10.3389/fcomm.2024.986974.

Hassan, S. Z., K. Ahmad, S. Hicks, P. Halvorsen, A. Al-Fuqaha, N. Conci, and M. Riegler (2022). "Visual Sentiment Analysis from Disaster Images in Social Media". *Sensors* 22(10), page 3628. DOI: 10.3390/s22103628.

Hickey, J., J. Young, M. Spruce, R. Pandit, H. Williams, R. Arthur, W. Stovall, and M. Head (2024). "Social sensing a volcanic eruption: application to Kīlauea 2018". *Natural Hazards and Earth System Sciences* 25(5), pages 1681–1696. DOI: 10.5194/nhess-2024-3.

– (2025). "Social sensing a volcanic eruption: application to Kīlauea, 2018". *Natural Hazards and Earth System Sciences* 25(5), pages 1681–1696. DOI: 10.5194/nhess-25-1681-2025.

Hutto, C. and E. Gilbert (2014). "VADER: A Parsimonious Rule-Based Model for Sentiment Analysis of Social Media Text". *Proceedings of the International AAAI Conference on Web and Social Media*. Volume 8. Association for the Advancement of Artificial Intelligence (AAAI), pages 216–225. DOI: 10.1609/icwsm.v8i1.14550.

Ilyinskaya, E., V. Snæbjarnarson, H. K. Carlsen, and B. Oddsson (2024). "Brief communication: Small-scale geohazards cause significant and highly variable impacts on emotions". *Natural Hazards and Earth System Sciences* 24(9), pages 3115–3128. DOI: 10.5194/nhess-24-3115-2024.

Kim, K., P. Pant, E. Yamashita, and J. Ghimire (2019). "Analysis of Transportation Disruptions from Recent Flooding and Volcanic Disasters in Hawai'i". *Transportation Research Record: Journal of the Transportation Research Board* 2673(2), pages 194–208. DOI: 10.1177/0361198118825460.

Kirilenko, A. P., T. Molodtsova, and S. O. Stepchenkova (2015). "People as sensors: Mass media and local temperature influence climate change discussion on Twitter". *Global Environmental Change* 30, pages 92–100. DOI: 10.1016/j.gloenvcha.2014.11.003.

Leathers, M. (2014). "Risk Perception and Beliefs about Volcanic Hazards: A Comparative Study of Puna District Residents". M.S. Thesis. University of South Florida Tampa.

Lynn, K. J., D. T. Downs, F. A. Trusdell, P. E. Wieser, B. Rangel, B. McDade, A. J. Hotovec-Ellis, N. Bennington, K. R. Anderson, D. C. S. Ruth, C. L. DeVitre, A. P. Ellis, P. A. Nadeau, L. Clor, P. Kelly, P. J. Dotray, and J. C. Chang (2024). "Triggering the 2022 eruption of Mauna Loa". *Nature Communications* 15(1), page 9451. DOI: 10.1038/s41467-024-52881-7.

Meredith, E. S., S. F. Jenkins, J. L. Hayes, N. I. Deligne, D. Lallemant, M. Patrick, and C. Neal (2022). "Damage assessment for the 2018 lower East Rift Zone lava flows of Kīlauea volcano, Hawai'i". *Bulletin of Volcanology* 84(7), page 65. DOI: 10.1007/s00445-022-01568-2.

Mothes, P. A., H. A. Yepes, M. L. Hall, P. A. Ramón, A. L. Steele, and M. C. Ruiz (2015). "The scientific–community interface over the fifteen-year eruptive episode of Tungurahua Volcano, Ecuador". *Journal of Applied Volcanology* 4(1), page 9. DOI: 10.1186/s13617-015-0025-y.

Neal, C. A., S. R. Brantley, L. Antolik, J. L. Babb, M. Burgess, K. Calles, M. Cappos, J. C. Chang, S. Conway, L. Desmither, P. Dotray, T. Elias, P. Fukunaga, S. Fuke, I. A. Johanson, K. Kamibayashi, J. Kauahikaua, R. L. Lee, S. Pekalib, A. Miklius, W. Million, C. J. Moniz, P. A. Nadeau, P. Okubo, C. Parcheta, M. R. Patrick, B. Shiro, D. A. Swanson, W. Tollett, F. Trusdell, E. F. Younger, M. H. Zoeller, E. K. Montgomery-Brown, K. R. Anderson, M. P. Poland, J. L. Ball, J. Bard,

M. Coombs, H. R. Dietterich, C. Kern, W. A. Thelen, P. F. Cervelli, T. Orr, B. F. Houghton, C. Gansecki, R. Hazlett, P. Lundgren, A. K. Diefenbach, A. H. Lerner, G. Waite, P. Kelly, L. Clor, C. Werner, K. Mulliken, G. Fisher, and D. Damby (2019). "The 2018 rift eruption and summit collapse of Kīlauea Volcano". *Science* 363(6425), pages 367–374. DOI: 10.1126/science.aav7046.

Patrick, M. R., B. F. Houghton, K. R. Anderson, M. P. Poland, E. Montgomery-Brown, I. Johanson, W. Thelen, and T. Elias (2020). "The cascading origin of the 2018 Kīlauea eruption and implications for future forecasting". *Nature Communications* 11(1), page 5646. DOI: 10.1038/s41467-020-19190-1.

Poland, M., T. Orr, J. Kauahikaua, S. Brantley, J. Babb, M. Patrick, C. Neal, K. Anderson, L. Antolik, M. Burgess, T. Elias, S. Fuke, P. Fukunaga, I. Johanson, M. Kagimoto, K. Kamibayahi, L. Lee, A. Miklius, W. Million, C. Moniz, P. Okubo, A. Sutton, T. Takahashi, W. Thelen, W. Tollett, and F. Trusdell (2016). "The 2014–2015 Pāhoa lava flow crisis at Kīlauea Volcano, Hawai'i: Disaster avoided and lessons learned". *GSA Today*, pages 4–10. DOI: 10.1130/gsatg262a.1.

Punziano, G., F. Marrazzo, and S. Acampa (2021). "An Application of Content Analysis to Crowdtangle Data: The 2020 Constitutional Referendum Campaign on Facebook". *Current Politics and Economics of Europe* 32(4), pages 371–397.

Romo, V. (2018). *Kīlauea 'Lava Bomb' Hits Tour Boat; Explosion Injures 23 (16 July 2018)*. URL: https://www.npr.org/2018/07/16/629613564/kilauea-lava-explosion-injures-23-tourists.

Ruan, T., Q. Kong, S. K. McBride, A. Sethjiwala, and Q. Lv (2022). "Cross-platform analysis of public responses to the 2019 Ridgecrest earthquake sequence on Twitter and Reddit". *Scientific Reports* 12(1), page 1634. DOI: 10.1038/s41598-022-05359-9.

Smith, A. and M. Anderson (2018). *Social Media Use in 2018 (1 March 2018)*. URL: https://www.pewresearch.org/internet/2018/03/01/social-media-use-in-2018/.

Spruce, M., R. Arthur, and H. T. P. Williams (2020). "Using social media to measure impacts of named storm events in the United Kingdom and Ireland". *Meteorological Applications* 27(1), e1887. DOI: 10.1002/met.1887.

Statista (2024). *Most popular social networks worldwide as of January 2024, ranked by number of monthly active users (2 February 2024)*. URL: https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/.

Steed, R. J., A. Fuenzalida, R. Bossu, I. Bondár, A. Heinloo, A. Dupont, J. Saul, and A. Strollo (2019). "Crowdsourcing triggers rapid, reliable earthquake locations". *Science Advances* 5(4), eaau9824. DOI: 10.1126/sciadv.aau9824.

Stone, J., J. Barclay, P. Simmons, P. D. Cole, S. C. Loughlin, P. Ramón, and P. Mothes (2014). "Risk reduction through community-based monitoring: the *vigías* of Tungurahua, Ecuador". *Journal of Applied Volcanology* 3(1), page 11. DOI: 10.1186/s13617-014-0011-9.

Stovall, W. K., J. L. Ball, E. G. Westby, M. P. Poland, A. Wilkins, and K. M. Mulliken (2023). "Officially social: Developing a social media crisis communication strategy for USGS Volcanoes during the 2018 Kīlauea eruption". *Frontiers in Communication* 8, page 976041. DOI: 10.3389/fcomm.2023.976041.

Timboy, M. (2019). *Beloved & Humble Puna Stronghold – o Pohoiki (1 July 2019)*. URL: https://keolamagazine.com/land/o-pohoiki/.

United States Geological Survey (2018). *USGS Hazard Notification System (HANS) for Volcanoes: Volcano Notice - DOI-USGS-HVO-2018-10-04T19:15:27-07:00*. URL: https://volcanoes.usgs.gov/hans-public/notice/DOI-USGS-HVO-2018-10-04T19:15:27-07:00.

Young, J. C., R. Arthur, M. Spruce, and H. T. P. Williams (2021). "Social Sensing of Heatwaves". *Sensors* 21(11), page 3717. DOI: 10.3390/s21113717.

– (2022). "Social sensing of flood impacts in India: A case study of Kerala 2018". *International Journal of Disaster Risk Reduction* 74, page 102908. DOI: 10.1016/j.ijdrr.2022.102908.

Yute, A. L. F., E. J. G. Merin, C. J. S. Sarmiento, and E. E. Elazagui (2021). "Supplementing satellite imagery with social media data for remote reconnaissance: A case study of the 2020 Taal volcano eruption". *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLVI-4/W6-2021, pages 329–335. DOI: 10.5194/isprs-archives-xlvi-4-w6-2021-329-2021.

Zhou, S., P. Kan, Q. Huang, and J. Silbernagel (2021). "A guided latent Dirichlet allocation approach to investigate real-time latent topics of Twitter data during Hurricane Laura". *Journal of Information Science* 49(2), pages 465–479. DOI: 10.1177/0165551511007724.

Zoeller, M. H., R. L. Perroy, R. Wessels, G. B. Fisher, J. E. Robinson, J. A. Bard, J. Peters, A. Mosbrucker, and C. E. Parcheta (2020). "Geospatial database of the 2018 lower East Rift Zone eruption of Kīlauea Volcano, Hawai'i". *U.S. Geological Survey data release*. DOI: 10.5066/P9S7UQKQ. [Dataset].