Crisis Mapping Application of Google Maps Engine

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Abstract During crises, timely geospatial information is highly valued by victims, emergency managers, and the broader public. Web applications have revolutionized the speed and scale of crisis mapping. Adoption, usability, and data validation are critical, but for Google Maps Engine (GME), they remain untested.

This presentation describes quantitative analysis of 117 GME crisis maps measures adoption and validity, profiling the map data and its users. The map data profile includes the type of crisis, basemap selection, editability, type, quantity, source, format, and validation. The user profile examines the producer, software version, emergency phase, response speed, distribution, and audience. Additionally, verbal protocol analysis and cognitive interviews test usability among eight subjects.

The results show early adoption for GME Lite/Pro, but not for the enterprise platform nor API. Validation remains a serious concern for both static and crowd-sourced (57 percent of layers with little or no validation). The usability study exposes paths of least resistance (uploading data, adding features) and mental roadblocks (layer management, classification) among untrained users.

GME is an effective communication tool and will benefit from Google ubiquity and familiar interfaces. However, with technical and user limitations, GME will not and should not be the only tool in the toolbox.

Introduction When devastating events occur, geospatial information is a highly valued commodity. Such information can show victims of the crisis how to get to an evacuation route. An emergency manager can make life-and-death decisions about where to send rescue missions. Journalists often use visual maps to report on the current situation, while non-profit and on-governmental organizations (NGOs) may use maps to drum up resources from the international community.

This need for fast and digital spatial data has been the driving impetus in the development of crisis mapping, a new field drawing elements from information communication technology (ICT), geographic information systems (GIS), imagery analysis, social media, volunteered geographic information, software development, database management and journalism. The most effective map is one that can represent ground truth as close to real time as possible. Our ability to mine such "Big Data" from disparate sources and align them in space and time for humanitarian efforts is one of the great challenges and opportunities of the network age (UN OCHA, 2013).

Google Maps Engine (GME) is a young software-as-a-service that allows users to create and share maps. While many concerned citizens and organizations are now using the mapping platform to depict aspects of crises, it is still unclear how well it has been exercised in the context of a crisis. This project seeks to shed light on how it has and how it could be used to support crisis response efforts.

Background While maps pertaining to crises have been published on paper for many years, the current context of the crisis map is largely digital and online. One of the earliest digital crisis maps was developed during Hurricane Katrina. A group of Google engineers developed a Google Earth map that included various datasets and recent satellite imagery. The map was quickly adopted by various rescue workers and the United States Air Force (Google, 2006).

The next major milestone was the Ushahidi, a non-profit organization founded to solve a problem with scaling spatial data. During the violence that followed the 2007 elections in Kenya, activist Ory Okolloh initiated an effort to map the location of incidents (Tavaana). This led to the formation of Ushahidi, which continues to provide crisis mapping resources today.

Another key development by Ushahidi was its deployment of distant volunteers during the aftermath of the 2010 earthquake in Haiti. Teams of volunteers received Haitian Creole and French messages, translated them, geocoded any locations provided in the message, along with any addition processing. The maps helped inform decisions by the US Coast Guard, American Search and Rescue, Marine Corps. As a result, it is widely recognized that the crowd-sourced and crowd-processed map was integral in saving many lives in Haiti (Meier, 2012).

Literature review Due to these early successes, crisis mapping has quickly attracted the attention of numerous governments and organizations (Meier, 2012). There has also been an increase in the number of available platforms and software with which crisis maps may be developed. Industry and academic leaders have produced a new, but robust body of work that evaluates crisis mapping efforts. But despite widespread interest and adoption of crisis mapping, there is contested views on its implications at such a nascent stage. Some organizations are fully invested in crisis mapping, adopting impressive new methods on the fly, using small legions of volunteers to generate new maps (Meier, 2012; Mayer, 2013; Greenberg, 2013). On the other hand, different analysts seek to tempered the excitement and proceed cautiously toward crisis mapping (Raymond et al, 2012; Shanley, 2013; McDougall, 2012).

Authoritative data is sourced from an official authority; this could be a government agency, non-profit organization, or NGO. The benefits to including authoritative data in a crisis map is that these sources tend to be produced in advance by GIS professionals or surveyors and are more likely to have complete metadata and consistency across the dataset. However, there are also certain challenges in using authoritative data for crisis maps. First, agencies' can be slow to release information. For example, after the major floods that devastated Australia in 2010-2011, the Queensland Reconstruction Authority had not released its data publicly for weeks after the event (McDougall, 2012). Second, authoritative geospatial information can simply be hard to find (Baxter, 2012). Files may not be hosted on websites, but even when they are, the data may be tucked away in the depths of a sprawling website. Third, the datasets may have stringent licensing constraints or the jurisdiction may simply be "data-hugging", a reluctance to freely share data that may have had a high price tag. A less open government may also react defensively to requests to democratize spatial data as it may have more control over traditional media (Cavelty and Giroux, 2011). Finally, crisis maps have to contend with issues of data interoperability among jurisdictions. Many governments still rely heavily on paper maps and documents, or in rigid formats like pdf, so the crisis map author must spend the time and effort to bring layers together.

The are several significant benefits of crowdsourced data that fuel the growing interest. First, crowdsourced data has the potential to provide highly relevant data, nearly in real time. In the heat of a disaster, critical decisions are made with the best available data at the time, when even minutes matter. Second, crowdsourced maps provide a dimension of transparency. Victims can behave within the crisis using the same information available to authorities. Such information can improve horizontal flows of "bottom-to-bottom" communication or "crowdfeeding", for example, to help connect separated families (Cavelty and Giroux, 2011).

Albeit, there are also significant challenges inherent to crowdsourced data. The first, and most frequently recognized, is credibility. There are occasional cases of malevolent or useless reports, sometimes called "spam". But even when the intent is noble, it may still require additional processing - geocoding, translating, interpreting intent, and so on - either by volunteers or by paid labor (Meier, 2012; Gilbert-Knight, 2013). The enormity and complexity of those data points may make pattern detection very difficult to see through the noise (Shanley, 2013). It is also important to recognize the existence of the "digital divide" and that access to crisis maps - to participate in crowdsourcing or crowdfeeding - is limited to those with who own the hardware (Elwood, 2006). However, crisis mapping is quickly migrating to mobile devices which are rapidly saturating communities on a global scale.

One of the most alarming considerations is the security risk for individuals. In a human-made crisis, the individual reporting the information may be subject to retaliation, as was the case for Mexican citizens who tracked and published the movement of drug cartels in Nuevo Laredo (Chamales, 2013). The digital volunteer processing reports may also be subject to espionage laws in the foreign country (Wei, 2012).

Finally, privacy looms as another concern in the development of crisis maps (Raymond et al, 2012; OCHA, 2013; Shanley, 2013) . Those individuals submitting reports to a publicly-published map service must concede that anyone, any government, or any group can access that information. But even if the individual does no such thing, he/she may find that photographs or high resolution imagery have been published of their community without their knowledge or consent. Regardless of intent, crisis mappers must take every precaution to protect individual privacy rights (OCHA 2013). So clearly, the stakes are high with crisis mapping.

Both authoritative data and crowdsourced data offer substantial benefits for stakeholders, but also include an array of challenges and pitfalls, as summarized in Table 1. However, there is one theme which runs common throughout the existing literature on the topic: no single method method should replace the other. In fact, the most effective crisis map is one that uses both authoritative and crowdsourced data to provide rich context quickly and includes deliberate assessment of the potential risks.

Table 1: Data source trade-offs in crisis mapping.

	Authoritative	Crowd-Sourced
Advantages	More likely to have complete metadata More consistent data collection methods within a jurisdiction Validity, curated by GIS professionals	Large scale Capable of near real-time communication Transparency Crowd-feeding
Disadvantage	Slow release Data buried in sites or servers Licensing constraints "data hugging", defensive government reluctance to give up control Inconsistent data storage, structures among jurisdictions	Spam Additional processing required Difficult pattern detection Digital Divide

Problem Statement This project attempts to close an existing research gap. The current body of knowledge has not yet specifically investigated Google Maps Engine (GME) and the impact that it would have for emergency managers, victims, and the international community. The framework to study the suitability of Google Maps Engine is structured around four interconnected characteristics. Furthermore, any extensive comparison between Google Maps Engine and other crisis map platforms - for example, Crowdmap, GeoCommons, or CartoDB - are beyond the scope of this project, which aims to study Google Maps Engine in its own right.

Understanding the implications of crisis map data is essential to setting criteria and benchmarks for a successful crisis information platform. First, it must be discoverable and accessible. Some crisis maps are widely distributed because the software has been widely adopted. For example, Twitter maps have achieve success because there are over 230 million monthly active users (Edwards, 2013). However, this means little if a user in a crisis-torn or underdeveloped area lacks the internet bandwidth to transmit or receive information from the crisis map platform. Additionally, the system must empower its author to retain control the scope of the publication.

Second, the software must handle numerous forms of data with ease. Data interoperability is an issue that regularly plagues many sort of GIS, but the need is heightened during crises when resources and, especially, time are at a premium. Therefore, crisis mapping software is expected to have some degree of built-in flexibility, such that a GIS expert or data engineer is not needed to conduct the transformations and that they can be done quickly and accurately.

Third, usability for the amateur participant almost certainly requires a simple graphical interface. Much of the existing research has evaluated systems whose maps require significant GIS or software development skills, many of which are newly developed or rely upon other application programming interfaces (APIs) (Liu and Palen, 2010). Usability also relates to the cartographic styles chosen to represent data to the reader and is essential in quickly communicating information (Hakley et al, 2008; MacEachren et al, 2006).

Finally, crisis maps must be supported by a reliable cloud architecture that can handle enormous loads during and after the disaster event. The webmap may need to serve thousands of users simultaneously without crashing or lagging. The number of users may also jump suddenly, depending on events on the ground, but the map platform performance is expected to scale quickly to support the increased traffic. In the end, performance problems with a map platform inherently become accessibility problems as well. As such, the service level agreement is an important component in gauging the suitability of the software.

What is Google Maps Engine? Google Maps Engine is a platform designed, among other things, to address these criteria. It extends many of the functionalities that existed in its predecessors, Google My Maps and Google Earth Build. Google My Maps was developed to allow casual users to easily digitize features over the regular Google basemap. Now those tools are central to Maps Engine Lite and Maps Engine Pro. Earth Builder allows users to upload larger datasets as layers over Google Earth or Google Maps. These functions now exist in the full, platform-version of Maps Engine, known simply as *Google Maps Engine.*

So, in fact, there are three distinct Maps Engine products: Maps Engine Lite, Maps Engine Pro, and Google Maps Engine[1]. The technical distinctions, outlined in Table 2, merit some brief attention here, but will receive deeper discussion in the methodology and results of the project.

There are certain aspects of GME capability that are known outright already. The constraints and capabilities of each version corresponds with a target user audience. *Lite* is available for casual users who are unlikely to pay for any premium service, but also unlikely to map large quantities of data. *Pro* also offers a simple interface, but allows for more features and layers to be added, making it more suitable for small businesses. Finally, Google Maps Engine is designed for large and diverse datasets, including satellite imagery, kml, and shapefiles, and is thus more likely to be adopted by government agencies, corporations, and research institutions. While each has unique specifications, all three versions serve the purpose of hosting custom data in Google's data centers and enabling map authors to share those maps with their intended readers.

Table 2: Versions of Google Maps Engine and their specifications.

	Maps Engine Lite	**Maps Engine Pro**	**Maps Engine**
Commercial use		✔	✔
Map layers	3 per map	10 per map	100 per map
Features (points, lines, shapes)	500 per layer 1,500 per map 10,000 per user	2,000 per layer 10,000 per map 50,000 per user	Millions per layer
Attributes (values in info windows)	15 per feature	50 per feature	500 per feature
Import types	Spreadsheet or CSV	Spreadsheet or CSV	Spreadsheet, CSV, KML, Shape files, and images
Spreadsheet/CSV file import	100 rows, up to 20 MB	2,000 rows, up to 40 MB	1 GB
Geocoding on import (conversion of places to points on a map)	100 addresses per file	2,000 addresses per file	100,000 addresses per file

[1] On September 16, 2014, Google announce that Google Maps Engine Lite and Google Maps Engine Pro would be unified as Google My Maps. This announcement occurred before the presentations and write-up, but after the project study period.

Styling/icons	Basic	Basic styling, Pro icons, custom icons	Advanced styling, more icons, custom icons
Drawing tools	✓	✓	
Measurement tools Measure distance and area of lines and shapes	✓	✓	
Developer APIs			✓
Map publishing	Share or embed on web pages	Share or embed on web pages	Publish on web or use in your applications
Access to shared Pro maps	View only	View or edit	N/A
Map loads (views of your embedded/published maps by others)	2,500 views per day	5,000 views per day	Quota based

Methodology In light of this new geotechnology and the research gap evaluating it, this project sets out to investigate Google Maps Engine in a crisis response applications. Specifically, the goal is to answer the following questions.

- In what ways has Google Maps Engine been deployed for crisis mapping?
- How do such applications meet the aforementioned requirements of accessibility, interoperability, usability, and reliability?

To answer these questions, the methodology consists of two major components:

1. Quantitative analysis of existing GME crisis maps
2. Usability test of the GME interface
3. Synthesis of results from all components

The purpose of the quantitative analysis is to gather statistics on how the existing GME crisis mappers are using the software to communicate crisis-related information. First, 118 existing GME crisis maps are identified, using keyword searches in globally-popular social media websites, Twitter, Facebook, and Google Plus, along with similar searches with Google Advanced Search. The maps' publication dates spanned from January 2013 to May 2014. Characteristics of these maps are evaluated, recorded, summarized (Figure 1). The criteria are designed to shed light on questions pertaining to data validation, interoperability, and accessibility.

The usability testing examines the experience that users have while interacting with Google Maps Engine, both as a map author and map reader. A small sample of eight participants are recruited to perform a range of technical and mapping exercises. The participants have no prior knowledge of Google Maps Engine or GIS; their skills are limited to casual Google Maps use. A verbal protocol analysis exposes user behavior in the software , by (1) allowing the participant to roam freely through the software for 5 minutes, then (2) asking them to perform a series of small tasks (e.g., finding locations in the map, creating point and polygon features, sharing the map with a friend, uploading photos). The tasks will begin with simple actions but ramp up to the more complex action. Throughout the procedure, the participant will be asked to verbally indicate their strategy and behavior as she/he proceeds.

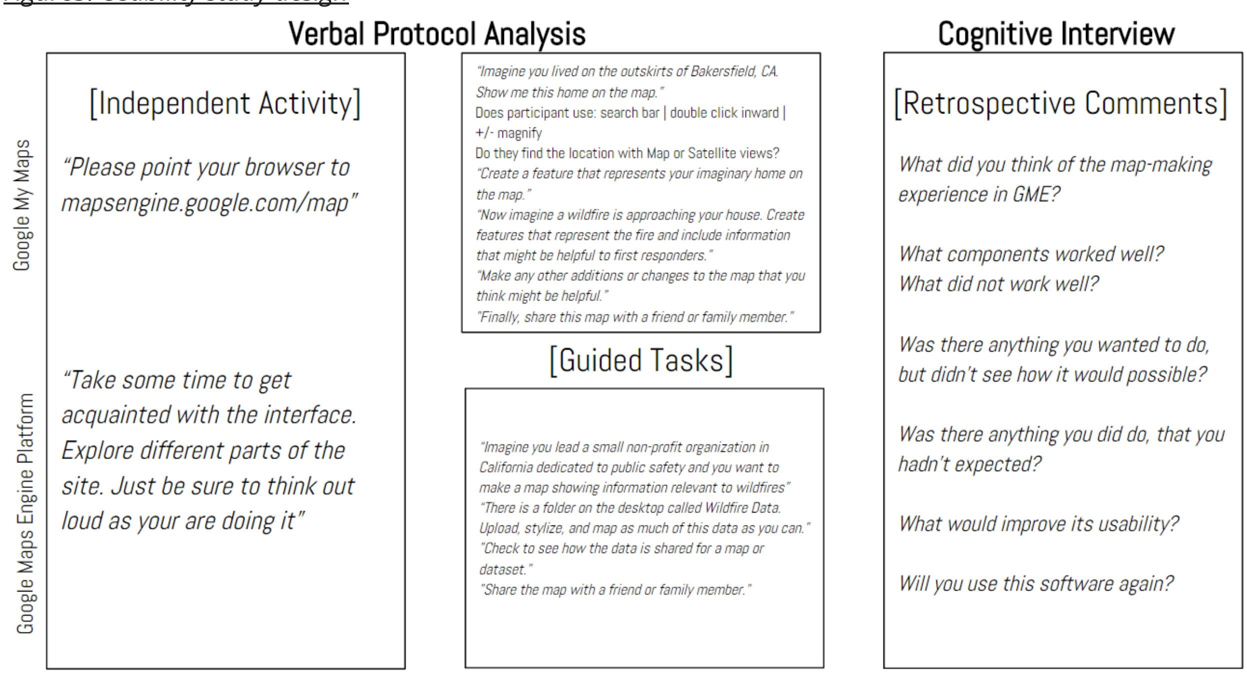
Google Maps Engine and Google Maps Engine Lite/Pro are two very different applications, so both are tested among the participants. The Google Maps Engine platform subjects are asked to explore the interface, then upload a shapefile, stylize the data, then publish and share their map. GME Lite/Pro subjects are asked to explore the interface, digitize some features, add attribute data, then share their map. Following the verbal protocol analysis, the researcher will conduct a short cognitive interview to understand the user's experience during the activity. Both the analysis and interviews will place heavy emphasis on themes of visual cartographic styling and usability.

The final step in this sequence is to summarize the results of the quantitative and qualitative analyses. It will be important during this phases to parse out the results according to differences in software versions (Lite, Pro, Google Maps Engine) and how well each would perform in a given type of crisis (natural disasters, humanitarian situations, warfare) and stage of the crisis (preparedness, response, recovery, mitigation). The final report may provide guidance to the crisis mapping community on which aspects of crisis response, if any, GME is suited to support.

Figure 2: Quantitative analysis fields of inquiry for existing GME crisis maps.

EVENT	MAP	AUTHOR	DATA / LAYERS
Location Type Subtype Start date End date	Title URL GME Version Basemap	Publish time and date Response time Type Proximity to event Product area Product relation to event Sharing Medium Share link # of reposts Intended audience Visibility Editability	Layer Names Type Feature count Metadata Source Source type Data format Validation

Figure3: Usability study design



Results In order the compile a meaningful profile of the 117 maps collected, numerous statistical summaries are performed against relevant attributes. This collection of metrics sheds light on who, what, where, when, why and how users are creating crisis maps with Google Maps Engine.

Map Producers This early in the development of GME, the analysis of map producers is important as it pertains to the adoption and validity of the maps. Each map is classified under a semantic category: corporate,government, individual, non-profit, public group, or research. This classification showed that individual authors, at 41 percent, have been more active in GME crisis mapping than any other group. There is also strong signs that these individual producers do not require direct personal or professional motivation to engage with the map-making. Nearly half of the individual mappers were doing so at locations distant from the area impacted by the given crisis. Additionally, 54 percent of the individual authors indicate no professional expertise relating to the crisis (geopolitical analyst, e.g.) nor to the software itself (GIS, computer science). On the other hand, mappers representing corporate, government and research institutions demonstrate strongly localized and professional motivations to produce GME crisis maps. In such cases, the release of such information by such institutions are likely motivated by jurisdictional responsibility (more stats supporting this here? %local? %professional relation).

Validation The clearer demographic picture of the map producers begins to shed light on the validity of each crisis map. The greatest data validation in the map population is seen from the government and research groups, where the agencies may employ professional trained geoscientists, collect first-hand data from the field, publish metadata, or include peer review. Emergency management agencies are arguably the most authoritative source of information in a crisis and account for 70 percent of government-produced GME crisis maps. Two thirds of the research maps are written from natural science fields. However, the other groups of map producers do not represent such authoritativeness, and thus validate the map data in other ways. Some individual authors included links to Youtube videos (Figure 2), National Weather Service reports, or geotagged photographs to validate the information on the map (Figure 3). One public group in Atlanta funneled crowdsourced reports through a Google Form (Figure 4). The form entries were then processed and geocoded to the GME crisis map. Unfortunately, 53 percent of the maps made by these groups include no evidence of any validation, making such maps hardly actionable during a crisis.

Figure 2: Map validated with YouTube videos: "[June 27th - Operation Al Kabune. Syria. Part 2. Armor]" by Brown Moses

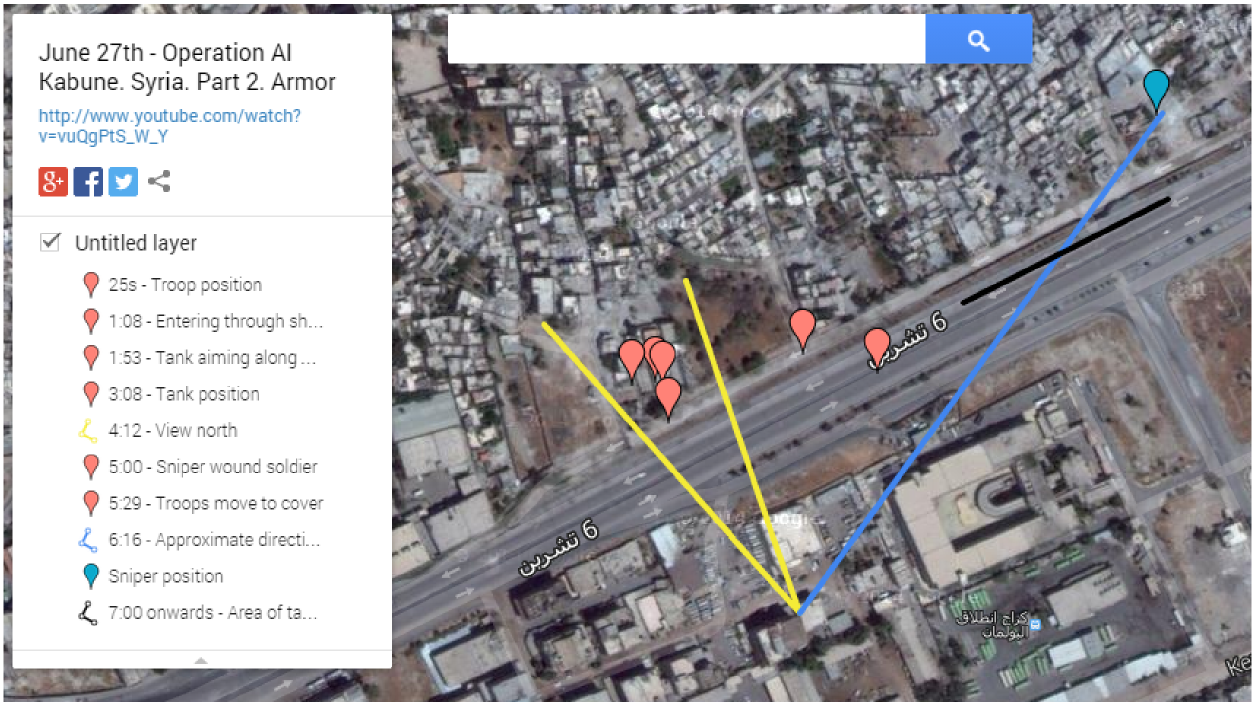


Figure 3: Map validated with National Weather Service reports: "[Fatal landslide, March 22, 2014]" by David McConnell

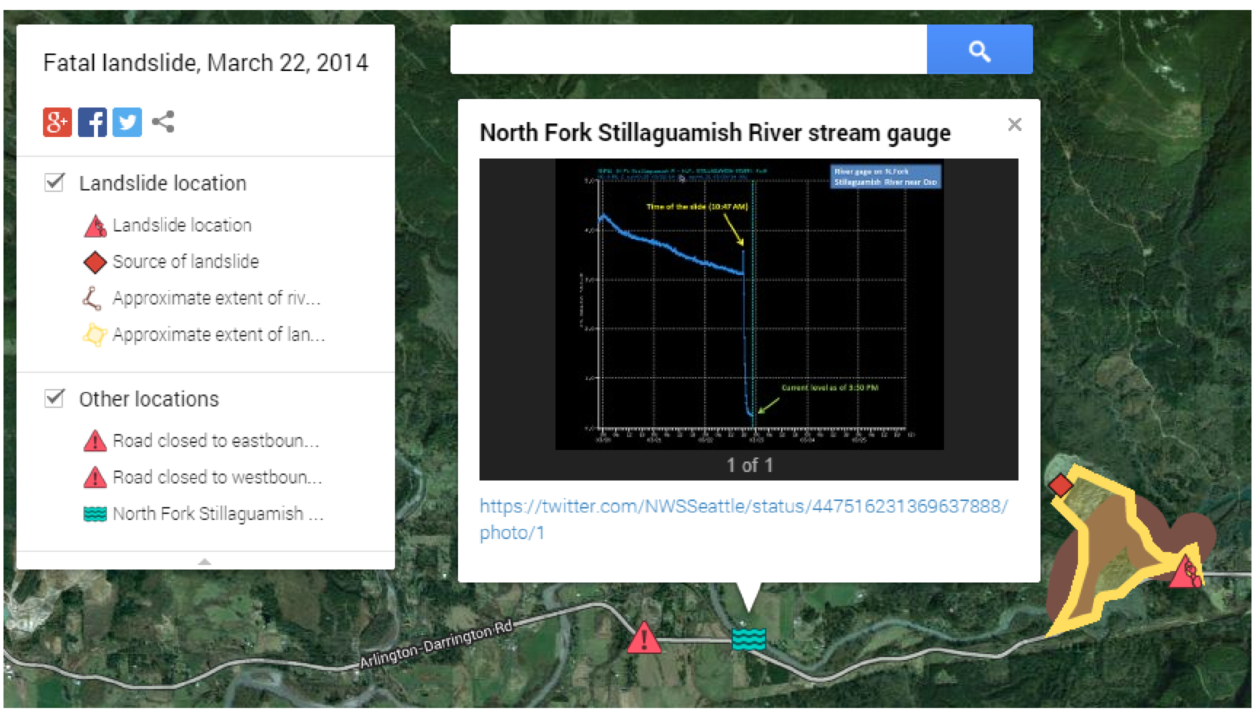
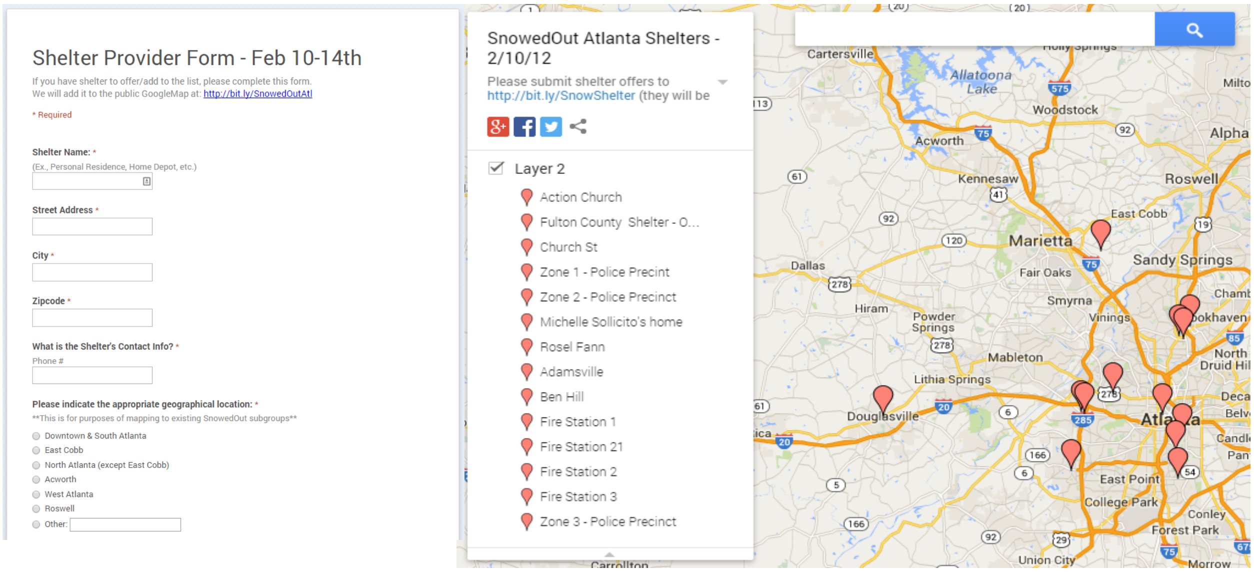


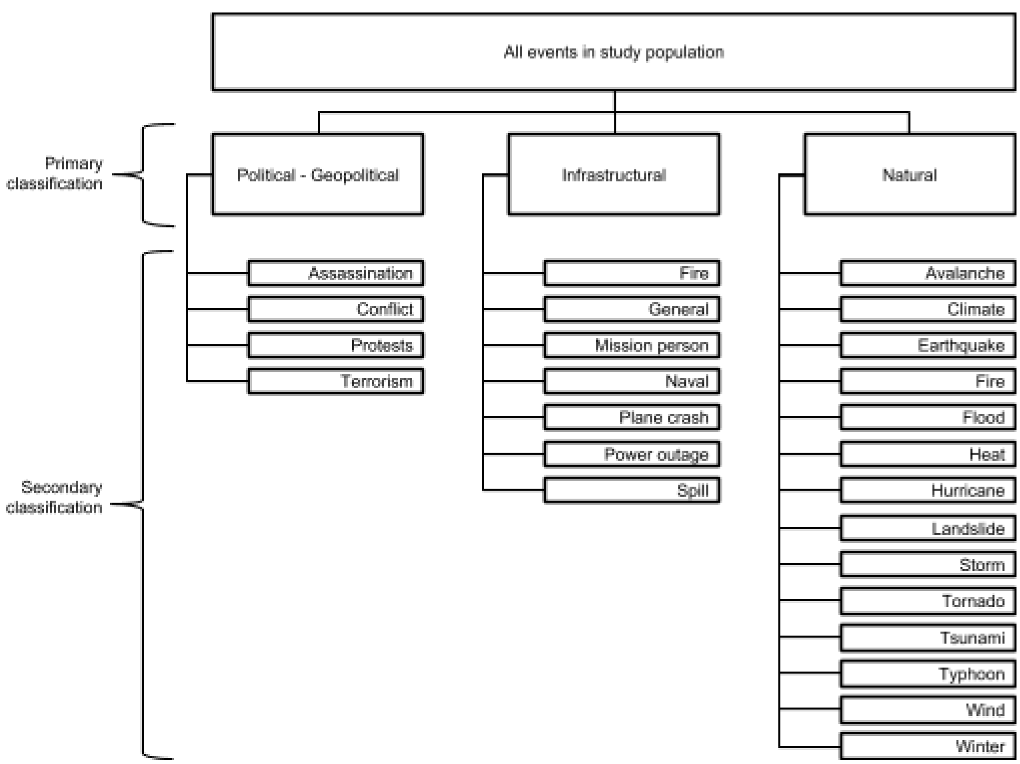
Figure 4: Map made from processed entries on Google Forms: "[Shelter Provider Form - Feb 10-14th]" by Cassandra Beyer.



There are many maps with crowdsourced data, however, very few map authors create open sandbox layers for anonymous users to make edits and additions (just six percent). More often. the map authors funnel social media posts with a designated hashtag or within a discussion thread. Those posts are then georeferenced onto the crisis map. These reports usually go in in without due validations, however some authors maintained quality requirements by validating posts with photo or video evidence.

Event classification There is a broad range of events which may be characterized as crises, from plane crashes, to roadside bombings, to heatwaves. In order to gain a deeper understanding of GME crisis mapping *as a phenomenon*, each event is classified according to a primary and second category.

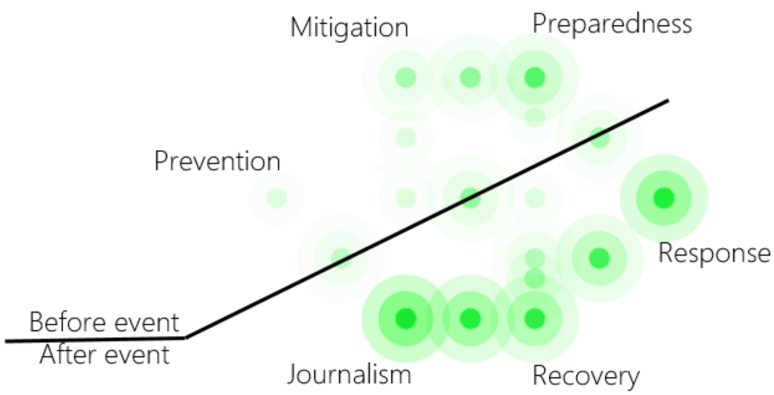
Figure 5: Primary and secondary classification of crisis map events.



The study population shows that most GME crisis maps are built in response to natural disasters.

Temporality The actionability of a map during a crisis is largely a factor of its temporal character. One way to characterize crisis maps is by examining its place within the sequential phases of a crisis. As such, the population of maps was first classified according to its purpose, that is, the emergency management phase it serves.

Figure 6: Distribution of crisis map, by phase.

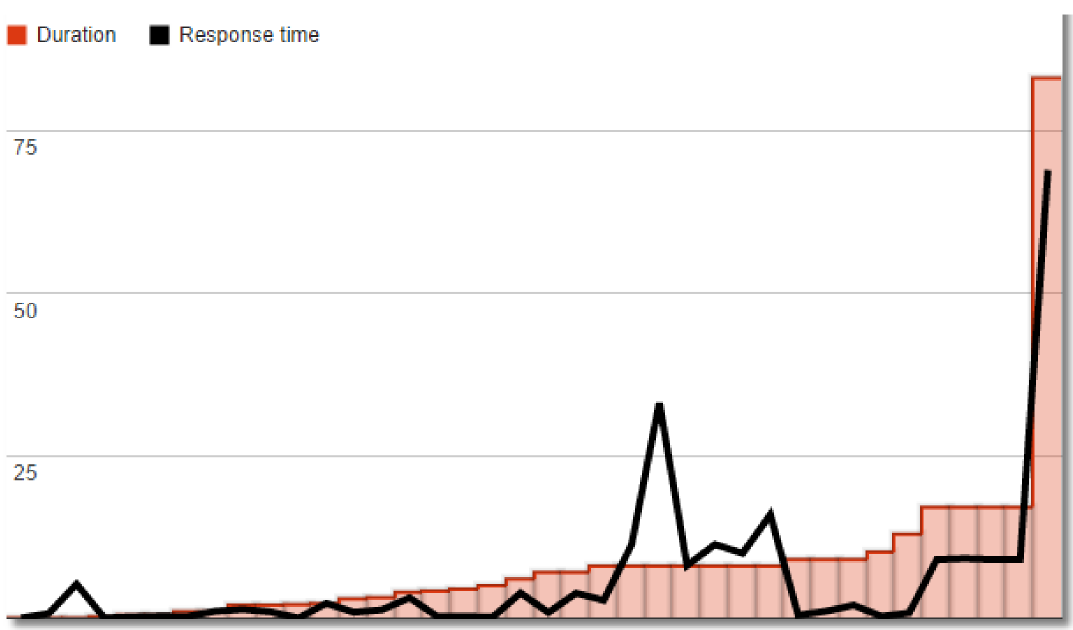


The maps designed to aid in the response efforts, in particular, are effective as a factor of time. The response maps are thus analyzed by the duration of the crisis and the time at which the GME crisis map is initially shared. On average, the response maps are found to be published when the crisis is 74 percent though its duration:

$$Responsiveness = (\beta - \alpha)/(\Omega - \alpha)$$

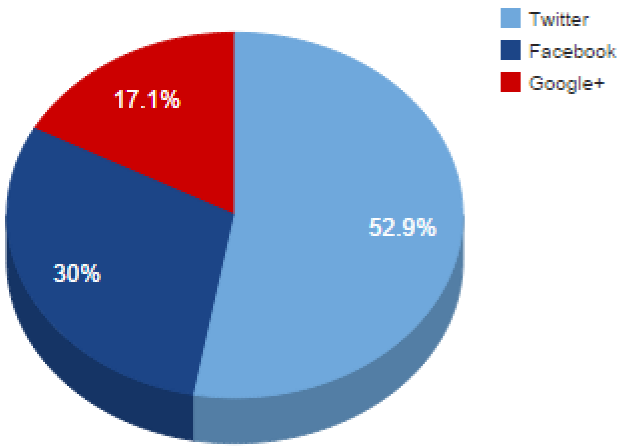
where β represents the time at which the map was initially published, α represents the starting time of the crisis, Ω is the ending time of the crisis. On a case-by-case basis, most GME crisis maps in the population were published while the crisis event was still underway.

Figure 7: User responsiveness to event duration.



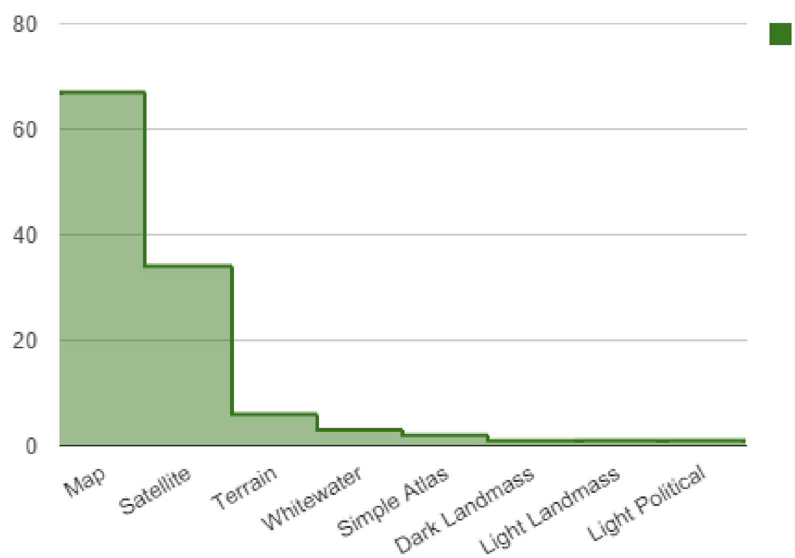
Social media channels There are likely to be many factors which affect the speed at which these maps are shared. One factor includes the media used to share the maps, in these cases, the social media sites, Twitter, Facebook and Google Plus. The study reveals that a slim majority of map producers are sharing their maps on Twitter, despite having 256 million fewer monthly active users than Google Plus and Facebook and 1.1 billion fewer than Facebook (Social Media Hat, 2014)!

Figure 8: GME crisis maps shared through major social media channels.



Basemap Finally, the basemap itself can shed light on the efforts made by map producers to optimize the context with which the reader may digest the information. The vast majority of GME users were content to use the typical “Map” and “Satellite” layers, commonly seen on Google Maps and other web mapping sites (Figure 9). These layers do provide the greatest context for crisis maps, while the others (e.g., “Dark Landmass”) are mostly designed for stylistic applications. Based on these results alone, however, it is unclear whether users choices concerning base map visualization were motivated by the familiarity with “Map” and “Satellite” layers, or if it they were chosen for the purpose of contextualization.

Figure 9: Base maps used in GME crisis maps.



Usability Study The first set of participants in the usability study were first asked to explore the interface. Using GME Lite/Pro, there are no fewer than 39 possible actions that one can take when starting with a new map project. During the sandbox exercise, the five participants performed 21 of the 39 actions with a period of about five minutes, as charted in Figure 5. These results indicate which actions are most self-evident to a new user (e.g., titling the map) and which actions are largely missed or misunderstood by a new user (setting default view).

Table 3: How many participants were able to perform the given actions in GME Lite/Pro?

3	2	1	0
map title add point measure add polygon add layer	map description route basemap stylize feature (individual)	delete layer name route import share data table label polygon address search feature description (from info window) add photo help	Learn more Folder new map open map delete map set default view embed export KML toggle layer "+/- zoom" settings black bar delete feature stylize feature (by data column) stylize feature (sequence) stylize feature (uniform) find in table feature description (from table)

The next phase of the GME Lite/Pro testing had participants representing their imaginary homes on the map. In order to find a location near "Bakersfield, CA", four of the five used the search bar as their first strategy to finding the map location. Two participants used the panning function to find a suitable location. Just one used the scroll wheel on his mouse and no one used the +/- buttons to zoom in or out. All but one participant used point features to represent their hypothetical property on the map and every participant was able to successfully name their feature. Statistically, the choice of basemap showed a near even split between the regular map view and satellite view. However, the comments from participants suggested that this relates more to the obscurity of the basemap selection in GME Lite/Pro, rather than any particular affinity for the regular map view. One user stated that he wanted to show satellite view but did not see how it could be done.

The next set of participants were asked to perform a similar initial task in GME Platform. They were allotted the same amount of time, but accomplished much less than the participants on GME Lite/Pro. Rather than test various functions, the three participants clearly spent more time and energy struggling to understand much of the terminology found commonly in GIS metadata (attribute count, bounds, data formats, etc). For the second section of this test, the users were provided a shapefile of all US wildfires. Remarkably, all three participants were able to quickly upload the data, but then require significant direction to understand data must be added to a layer. Some components of stylizing the layer were understood by the user (fill, border), but others components went escaped their comprehension (filter rules). Throughout these steps, it was clear that GME Platform users were more hesitant and less adventurous than the participants using GME Lite/Pro.

The GME Platform tests also concluded with a cognitive interview. The participants claimed that the interface was "user friendly" despite experiencing several obstacles during the exercises. One participant felt the platform would be a terrific learning tool for students. All three participants found the finished maps were easy to publish and share, far more achievable than the map creation steps leading up to it. These challenges were related to the layout not being intuitive and containing numerous buttons and links with unclear functions, such as layer zoom levels.

Discussion In the few years that crisis maps have emerged, both the challenges and benefits have come under increasing recognition. As the applications continue to expand to new users and to the new platforms, it is critical that ethical and pragmatic standards be developed as quickly as the technology. The methods and results of profiling GME crisis mapping applications are directed at the goal of understanding how it is used, as a tool and as a phenomenon, so that future GME crisis maps do more good and no harm. By adopting the same framework of criteria - temporality, accuracy, completeness, context, and accessibility - this sections considers the degree to which GME and its users have met or fallen short of the criteria.

The results of the quantitative analysis revealed early adopters of GME that are capable of drafting and deploying crisis response maps very quickly. The rapidness of response is extremely important for jurisdictions managing a crisis. Additionally, GME benefits emergency managers by avoiding down time. The service level agreement for GME is 99.9% by month, but it has actually operated at 100% reliability since its launch. On the matter of temporality, this means stakeholders using GME applications have not, and very likely, would not have to wait for the site to be back online since it is highly reliable.

However, the GME software has two major shortcomings that allow temporal uncertainty the map. First, GME maps provide very little time-stamping. The administrator of a map map see the time that a file was uploaded in the back end of the GME dashboard. But none of this information is shown on a published map, so users or other jurisdictions will be unable to quickly align the timing of the map with their own. Furthermore, crowdsourced maps do not natively timestamp the creation, edits, or deletion of features in a map. Second, unlike other Google document types, GME maps have no versioning support. Versions are especially useful for crowdsourced maps, allowing the map producer to validate and release multiple versions of the map, or to roll back to a prior map when necessary.

Inaccurate maps are useless at best, but can also be very harmful, by causing misallocation of human, physical, and financial resources. The GME maps in the population showed significant government and academic adoption, suggesting there is interest in GME as a platform for authoritative providers. Some users have pro-actively included their own metadata in feature info windows or the map description to document the validity of its geodata. Others have relied on Google's massive geodatabase to accurately locate places involved in the crisis, by searching the entities with the built in geocoder. Google also optimizes accuracy by reprojecting data on-the-fly and by enforcing topological rules upon the datasets during upload. While this may be effective in catching systematic errors, it will not prevent human errors. Neither GME platform nor Lite/Pro require even the most basic metadata, which means there will always be GME maps of dubious accuracy.

The completeness of a crisis map also factors into questions about resource allocation and other stakeholders' decision-making abilities before, during, and after a crisis event. Lite/Pro map producers have been able to generate more complete maps by creating crowd-sourced layers. The GME platform can host a more complete map as well, through its support of many different file types. This type of interoperability means multiple jurisdictions could upload to a common operational map. To make this easier, Safe Software has partnered with Google to write the GME Data Loader utility. This workbench software provides a graphical user interface to create workflows that transform various data types and write the results directly into a GME account.

Yet the GME ecosystem is still nascent; this is made evident especially by the few numbers of prevention, mitigation, and preparedness maps. The GME platform will need to have far greater buy-in at all levels. To do so, Google will need show that the benefits of GME outweigh the potential cost and learning curve involved in sophisticated GME maps. In the meantime, others may adopt Lite/Pro, but there are still limitation in the variety and volume of data that can be uploaded to Lite/Pro. This means Lite/Pro may be relegated to mostly casual individual users, leaving out the larger data providers holding the most complete datasets.

Contextual geodata is necessary for the sort of "dominant battlefield awareness" that is so crucial in geospatial intelligence. One of great strength of GME products is that the user's data will be served as layers over a very complete and recognizable basemap. Features in the basemap and the user's layers are searchable and highly interactive. Victims and relief workers can view their own GPS location and its spatial relationship to important locations (evacuation routes, hospitals, shelters, etc) by viewing the crisis map in the GME mobile application. Even better, when users enroll in Google Maps Engine Pro, they are also given access to Coordinate (Google, 2014). Coordinate allows teams to simultaneously view their respective real-time GPS positions on a map, improving coordinated efforts during a crisis.

One drawback that remains in both Lite/Pro and the platform is the ability to perform any types of spatial analysis. If an emergency coordinator wants to produce a map of low-lying, flood prone areas during a storm, this analysis would have to be performed in other software programs. The results of the analysis can then be exported back to GME, but the GME products are not going to provide off-the-shelf support of spatial analysis.

GME was always designed to to improve the discoverability of geodata, so it should score highly against the accessibility criteria. The usability tests in this study clearly showed that Maps Engine Lite/Pro do provide a sufficiently simple interface, such that a novice user can begin to produce a functional map in only a few minutes. But the usability dropped off significantly for GME platform. This software includes more advanced functions, but also contains less-intuitive functions as compared with its Lite/Pro counterpart. One the positive side, both the usability test participants, as well as the map producers in the study population, indicate that sharing GME maps is a very simple task, particularly due to the ubiquity of major social media channels, like Facebook and Twitter. Until Google integrates GME maps as organic search results or map search results, social media will continue to be the most prominent conduit to access the crisis maps. Google could also improve sharing by surfacing the number of "views" that a map receives (like Youtube views or Facebook "likes"). Showing this may have the effect of enhancing a viral maps and their global reach.

Conclusion The past several years have seen an extraordinary emergence of online crisis maps. As a tool, crisis maps are benefitting from all of the hallmarks of Web 2.0: highly dynamic content, crowdsourced data, and APIs within vibrant cyber-social ecosystem. As a phenomenon, the users within that ecosystem are demonstrating that they can both consume and produce geodata in disastrous scenarios. But still, the field of study highlights concerns that the technology and participants in crisis mapping are evolving faster than our ability or willingness to understand and control the impact of such mapping.

In the spirit of this concern, this study explored Google Maps Engine, as a tool and as a phenomenon, to understand who, what, where, when, why, and how the crisis maps are made. These questions were answered within a framework of criteria: temporality, accuracy, completeness, context, and accessibility.

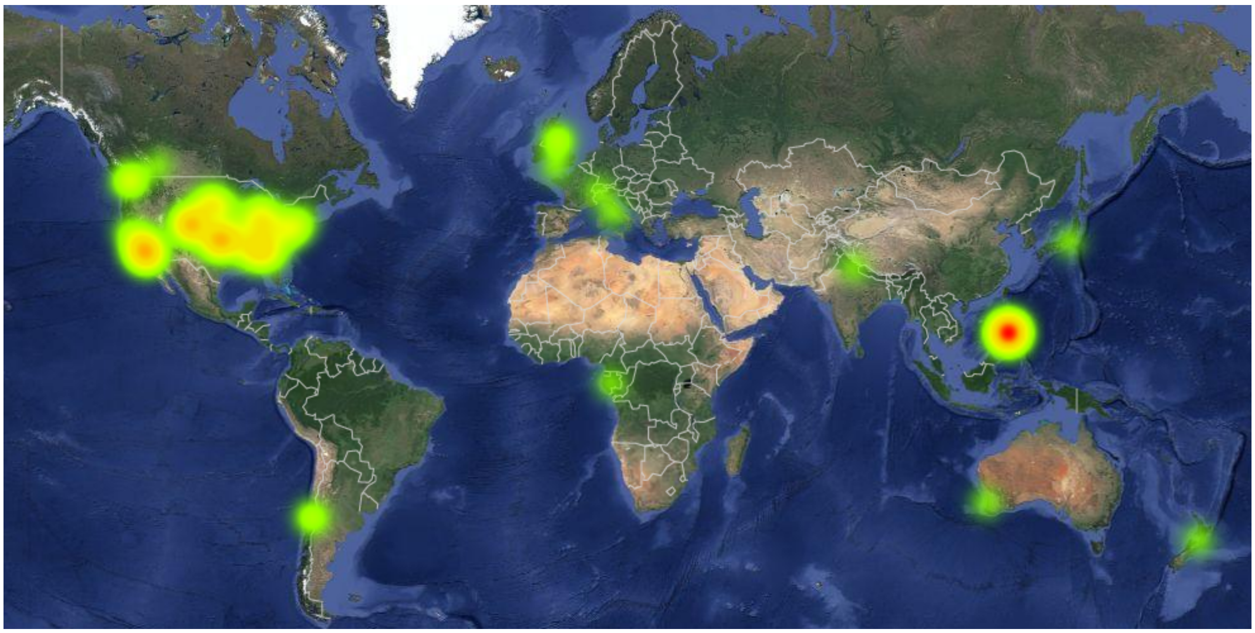
The results from the quantitative analysis profile and the usability testing have shown mixed results. One one hand, GME and its users have convincingly demonstrated a prodigious ability to produce, develop, and share maps quickly. GME platform has successfully hosted authoritative datasets generated by emergency agencies and other government and research institutions. And GME Lite/Pro maps have been deployed to collect crowdsourced data, using a variety of methods (social media posts, form submissions, direct edits to the map). On the other hand, GME and its users have also been ineffective in certain ways. The most usable version of GME (Lite/Pro) has data storage limits and the platform version (which has much higher limits) is far less accessible, due to its cost and/or its learning curve. Additionally, the lack of in-tool analysis, versioning, and metadata enforcement diminish GME and its users' ability to meet the framework criteria.

Even with these new findings, there remain several outstanding question that need further research. For example, time will tell how GME is further developed. Namely, will it make changes that improve the usability of GME platform and drive greater buy-in from authoritative providers?   The pace at which crisis mapping has evolved suggests that answers to these may be just around the corner. Even so, there are still shortcomings within the GME technology, as well as with its users, that indicate GME will and should be just one tool in the crisis mapper's toolbox.

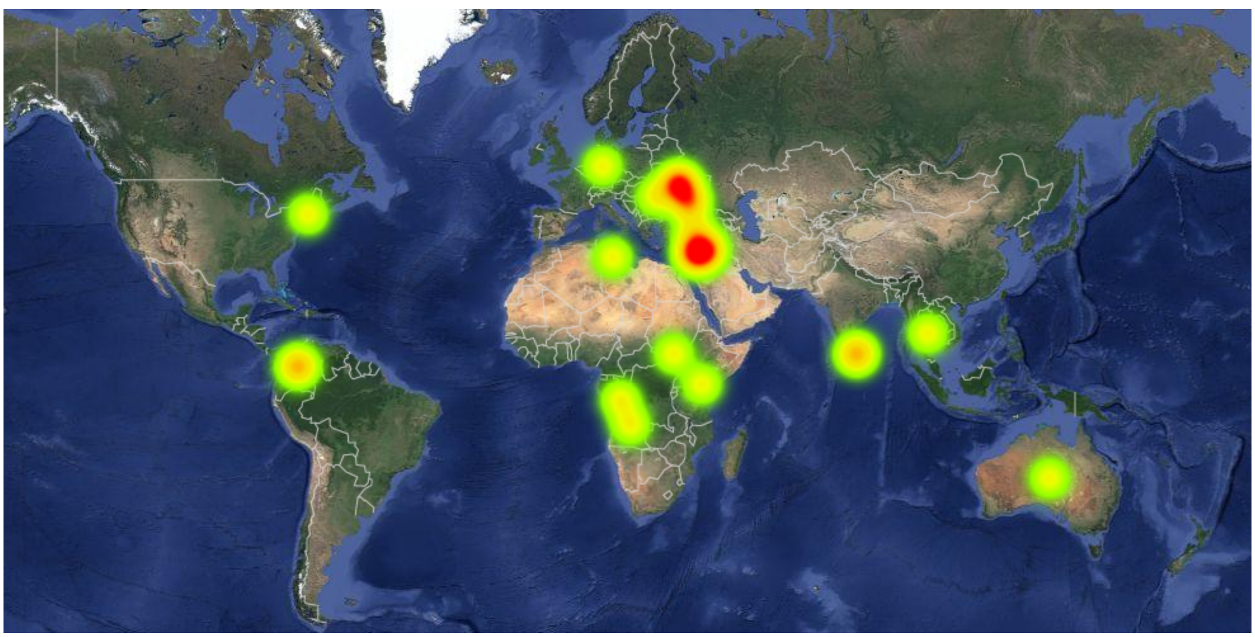
Appendix

Editable map examples.
"*Tacloban City Yolanda Damage*"
"*Haiyan Severity Estimates*"
"*#WaldoFlood Map*"
"*Storm Victims Resource Map*"
"*Stranded in Atlanta? Pin your last location on this map!*"
"*Strongest Earthquakes in PH*"
"*Frost Quakes / Ice Quakes*"

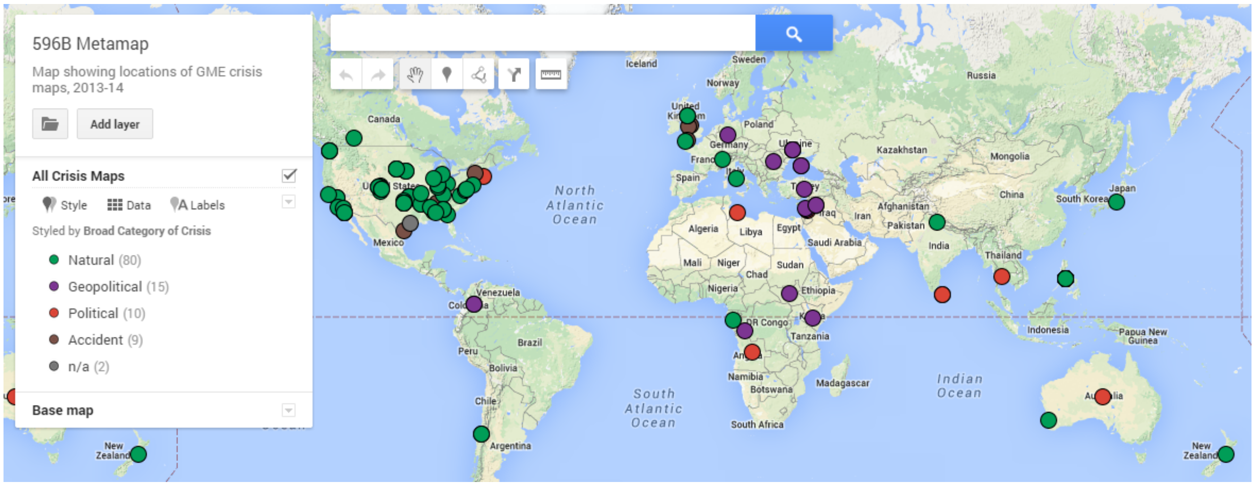
Natural disaster event locations among GME crisis maps (Fusion table link).



Humanmade disaster event locations among GME crisis maps (Fusion table link).



Phase distribution globally (link).



Example maps for each crisis phase.

Prevention	Mitigation	Preparedness
Response	Recovery	Journalism

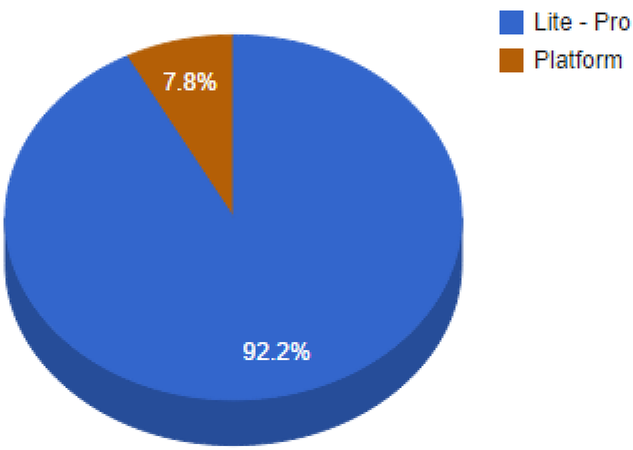
Producers

		Corporate	Government	Individual	Non-Profit	Public Group	Research	Total
Is the map producer within the place impacted by the crisis?	distant	4	1	22	5	3	3	38
	local	16	16	26	4	8	9	79
	Total	20	17	48	9	11	12	117
What is the map producer's professional identity?	Activism	1		1	3	2		7
	Amateur			28	1			29
	Analyst			6				6
	Computer Science			6		1		7
	Design			2	1			3
	Education						1	1
	Emergency Mgt	1	12		2	1	1	17
	GIS	1	1	2			1	5
	Humanitarian				2		1	3
	Insurance	2						2
	Law Enforcement		1					1
	Media	12		1		7		20
	Natural Science						8	8
	Politician		1	1				2
	Public Services	1	2					3
	Sales/Marketing/Ads	2						2
	Transportation			1				1
	Total	20	17	48	9	11	12	117
Does it pertain to the nature of the crisis?	no	5		38	1	2	1	47
	yes	15	17	10	8	9	11	70
	Total	23	22	49	11	10	2	117

Data validation

All Phases		Map Authors						
		Corporate	**Government**	**Individual**	**Non-Profit**	**Public Group**	**Research**	**Total**
Data Source / Validation	Business	2		1				3
	Crowd	6		7	2	7		22
	Government	4	17	7	2	2		32
	Media	3		6				9
	Photo	1		1	2			4
	Research	1		5	3		12	21
	Unknown	3		17		1		21
	Video			3		1		4
	Total	20	17	47	9	11	12	116
Response Phase								
Data Source Validity	Crowd	**3**		3		4		10
	Government	1	**7**	2	2	1		13
	Media	1		2				3
	Photo				1			1
	Research	1		2			1	4
	Unknown	1		**6**				7
	Total	7	7	15	3	5	1	38
Distance from Source	First hand	2	**6**	5	2		1	16
	Second hand	**5**	1	**10**	1	**5**		22
	Total	7	7	15	3	5	1	38

Software versions used in study population.



Participants' maps from the usability study.

Lite/Pro maps: 01, 02, 03, 04, 05

Platform maps: 06, 07, 08

Usability Study participation videos

Video 01

Video 02

Video 03

Video 04

Usability Study participation consent form (link)

Letter of Information and Consent Form

LETTER OF INFORMATION ABOUT THE RESEARCH STUDY:
Using Verbal Protocol Analysis and Cognitivie Interviewing to Assess
Usability of Google Maps Engine for Crisis Responses.

You are asked to participate in a research study conducted by Joel Irish of MGIS Penn Statue University. If you have any questions or concerns about the research, or would like to know the results of the research, please feel free to contact Joel Irish at jdi116@psu.edu.

PURPOSE OF THE STUDY
The goal of this study is to explore how individuals interact with Google Maps Engine to the usability of the software, the interpretation of functions and cartography, to assess the suitability of GME as a crisis response tool.

PROCEDURES
If you volunteer to participate in this study, we would ask you to do the following things:
1. sign and date a consent form
2. schedule a time slot for the session
3. participate in the protocols (approximately 20 minutes)

POTENTIAL RISKS AND DISCOMFORTS
If you feel uncomfortable you may withdraw at any time and for any reason without penalty. You do not have to answer any question that makes you feel uncomfortable, and all information is kept completely confidential.

PAYMENT FOR PARTICIPATION
You will not receive payment for participating in this study. However, you will be given a $10 gift card to Starbucks after completion, as a thank-you gift.

CONFIDENTIALITY
Every effort will be made to ensure confidentiality of any identifying information that is obtained in connection with this study. Digital recordings will be transcripted and then erased; transcriptions will be shredded.

RIGHTS OF RESEARCH PARTICIPANTS
You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study.

SIGNATURE OF RESEARCH PARTICIPANT
I have read the information provided for the study "Using Verbal Protocol Analysis and Cognitivie Interviewing to Assess Usability of Google Maps Engine for Crisis Responses." as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____ I agree to have my voice, actions, and upper body videotaped.
____ I do not agree to have my voice, actions, and upper body videotaped.

________________________________ ______________
Name of Participant (please print) Date

____
Signature of Participant

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