# Crisis Mapping the 2010 Earthquake in OpenStreetMap Haiti

by

Chris Anderson-Tarver

B.A., Wheaton College, 2005

M.A., University of Colorado at Boulder, 2010

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirement for the degree of

Doctor of Philosophy

Department of Geography

2015

# Signatures

This Dissertation entitled:
Crisis Mapping the 2010 Earthquake in
OpenStreetMap Haiti
written by Chris Anderson-Tarver
has been approved for the Department of Geography

____________________________________
Barbara Buttenfield

____________________________________
Joe Bryan

Date_March 12, 2015

The final copy of this thesis has been examined by the signatories, and we
Find that both the content and the form meet acceptable presentation standards
Of scholarly work in the above mentioned discipline.

IRB protocol # ____14-0271___________

# Abstract

Anderson-Tarver, Chris (Ph.D., Geography, University of Colorado at Boulder Geography Department)

Crisis Mapping the 2010 Earthquake in OpenStreetMap Haiti

Thesis directed by Professor Barbara Buttenfield

OpenStreetMap (OSM), commonly described as the Wikipedia of maps, gained particular visibility in the wake of the January 12th 2010 earthquake in Haiti when approximately 503 OSM users who did not live in Haiti donated their time to map the country in a very short period of time. This dissertation documents at user and database levels the crisis mapping in OSM in response to the 2010 Haiti Earthquake. The mapping efforts in the OSM database for Haiti are worth investigating because volunteer mappers for the first time added information to a database at such a rate, in such quantities and with enough detail that it became the de-facto source of geographic information for most of the major relief agencies involved. The crisis mapping response to the Haiti earthquake demonstrates that VGI is rapidly becoming a viable, even necessary, option for communities that need help mapping their world. Given the socio/technical undercurrents of VGI, consequences exist within the context of crisis mapping of its use for social causes. A mixed-methods approach documents the crisis mapping, utilizing an online survey of the OSM Haiti crisis mappers, semi-structured interviews of OSM crisis mappers who went to Haiti, a Modified Content Analysis and a spatial analysis of the OSM Haiti database. For comparative purposes the analyses are performed starting one month before the earthquake and extending six months after. Results show that in the case of the OSM Haiti response, the term crisis mapping encompasses a varied and multi-layered process. For OSM Haiti, users not only crisis mapped as a humanitarian response but also because of a complex urge to map, driven by both membership in the OSM community and the need to fill in blank space in the OSM database. Consequences of employing a volunteer labor force for crisis mapping are discussed within the organizing rubric of the OSM Haiti users, the OSM database, and the affected Haitian population.

# Acknowledgments

In a project this size there are many people to thank, each having supported me in a myriad of ways. To start, I want to express my gratitude to my friends and family who put up with the many times of working intensely and my general unavailability during those times. I also want to thank my committee for taking the time to be involved with the many stages of this project. Your feedback has been invaluable to me.

Another person who deserves more than mere acknowledgement is Eric Wolf who first started the conversation I have here attempted to continue. Beyond this, Eric spent many hours downloading and splitting the OSM data for this dissertation. Without Eric's help in providing me these databases this dissertation would likely be ongoing.

I would also like to acknowledge the friends and family who provided myself and my family support through childcare, meals, transportation, and all the other various care you gave since I started grad school. You are my role models for selfless generosity.

To my advisor Babs, I would like to say that being under your mother hen wing is one of the best places to be in grad school. I am so thankful for all that you invested in me and for all the wisdom you brought to this project.

Finally to Jen. Your quiet gestures have shown me a selfless alterity that continually amazes me. This project would never have happened without the continual gift of your support. Thank you.

# Contents

# Figures

# Chapter 1
# A Collaborative Mapping Era

This dissertation addresses the problem that no documentation at a database level has been made of the crisis mapping in OpenStreetMap (OSM) in response to the 2010 Haiti Earthquake. The mapping efforts in the OSM database for Haiti are worth investigating because volunteer mappers for the first time added information to a database at such a rate, in such quantities and with enough accuracy that it became the de-facto source of geographic information for most of the major relief agencies involved (UNF 2011). To investigate crisis mapping for OSM Haiti, this dissertation studies several related topics. First, the process of mapping is examined within the context of historical and emerging technologies surrounding Volunteered Geographic Information (VGI) and the communities of mappers who participate in VGI. Second, the importance of VGI and its influence on changes in the mapping process is considered for crisis mapping especially in the example of the 2010 Haiti earthquake. As the crisis mapping response to the Haiti earthquake demonstrates, VGI is rapidly becoming a viable, even necessary, option for communities that need help mapping their world. Furthermore given the socio/technical undercurrents of VGI, consequences exist within the context of crisis mapping of its use for social causes. To better examine these topics, this dissertation discusses a mixed methods approach to inspecting changes to the OSM Haiti database as an example of what happens to a place recovering from a significant environmental disaster, and to understand more about volunteerism and crisis mapping.

**The Mapping Process**

The term mapping is difficult to define (Pickles 2004, p75). Often, it denotes the specific task of map-making in which a person manifests a map design; yet mapping can also be expanded to mean all the processes that go into producing geographic data and map products. Dent et al (2009) equate map-making with mapping and in the same breath claim that mapping encompasses "…all the processes of producing a map, whether the person is collecting data, performing the design of the map, or preparing the map for distribution in hardcopy or for the Web" (p.4). They note that a common historical distinction made in academia is between map-making and cartography. Here cartography is given a broader definition than map-making "for it requires the study of the philosophical and theoretical bases of the rules for map-making" (p.5). The distinction therefore is that someone can study maps and not be in the business of making maps. Critical cartographers have in turn pointed out that the distinction between cartography and map-making was made in part for the purposes of creating a scientific air for map-making: "… it was when cartography became formalized as a discipline that mapping was valorized as 'scientific'" (Crampton 2010 p.3; see also Pickles 2004, Wood et al. 2010). The problem with cartography understood as outside the context of map-making is that it obfuscates the reality that mapping is a social process and that therefore cartography cannot itself be understood as scientific or objective (Harley 2001, Pickles 2004, Crampton 2010, Wood et al. 2010). The study of maps is then itself a social process as maps are always interpreted within specific social contexts, something akin to the social sciences version of the observer effect in physics. Maps are made in social contexts and are interpreted in social contexts, therefore there is nothing objective about the nature of maps as they are always in motion. A more apt definition that will be used in this dissertation is that "… cartography is the practice of map making" (Dodge et al

2011 p.xix). If cartography is the *practice*, then returning to Dent et al (2009), mapping is the *process* of map-making. It is this process that will be explored in this project.

Mapping is a process with an endless variety of steps. This is true in part because of the impossibility of maps themselves: namely giving a snapshot of the world that appears ontologically secure yet is never so (Kitchin and Dodge 2007). Pickles 2004 adds that "The epistemological and ontological structure of the world in which we live and map … are complex assemblages of disparate, contradictory, and overlapping beliefs about the world, and their differences often give rise to quite different understandings of the map and the mapping process" (p.76). Likewise, mapping and maps are infinite processes due to the amazing complexity of the world, because of the difficulties of mapping subjects such as the complexity of humanity, objects such as fuzzy boundaries, or the ever changing temporality of culture. Mapping is an extremely diverse process judging from the myriad forms that maps can take. Many are familiar with paper maps produced through formalized cartography such as national topographic maps or their digital relatives produced with the realm of computer technologies. However if one is to expand maps to include "…schematic representations of a wide variety" (Pickles 2004 p.14) the notion of maps opens up to a wide world of forms and performances.

In this world of infinite mappings, academics have noted historical trends that characterize the manner in which mapping take place. Currently, the majority of maps are generated, viewed, and manipulated in digital computerized systems such as Google Maps (Dodge et al 2011b). This marks a historical break from the *de facto* paper medium of maps for centuries. Many other trends have been identified especially in the last five decades having largely to do with the advent of the "digital transition" (Goodchild 2000). Edney (1993: 57) characterizes technological developments leading to different types of cartography as distinct "cartographic modes". Examples of cartographic modes include early printing technologies in Western Europe during the Renaissance which gradually led to woodblock, copper engravings, lithography, and more recently photo-mechanical technologies (Dodge et al 2011b). Besides printing technologies, cartographic modes include shifts in data capture, innovations in geographic data processing, and cartographic representational media. Returning to the definition of mapping, the process of map-making, an easy assumption to make given the many digital and digitally enabled trends that are breaking historically normative processes, that mapping itself is quantitatively different than the mapping that took place 20, 50 or 100 years ago. While there is some debate on this point, some critical cartographers and academic geographers (Pickles 2004, Crampton 2010, Wood et al. 2010) have argued that while the process of mapping may have changed in terms of the tools and medium of mapping, the function of the maps produced from mappings has not essentially changed. In brief these cartographic theorists have pointed out that there should not be a separation from maps and the territories they represent, that maps form and inform the lands they contain. Again this focus on how maps work or have "agency" (Corner 1999) is itself under debate; as Kitchin and Dodge (2007: 343) have pointed out that maps don't make the world but rather the work they do is never done, "… they are always mapping".

Where this leads cartographic research then is towards a discussion of how mappings interact with the world. Crampton (2010: 184) states it well, "Maps operate within a whole nexus of relations, discourses, power relations and material circumstances … The task of critical cartography and GIS is [to] elucidate the nature of these circumstances of map practices". Likewise Dodge et al (2011b: 120) point to the present day by adding "the digital transition in cartography has made it more urgent to understand the wider social milieu in which maps are produced and disseminated". Methodologically speaking then, there is a need for research akin to ethnographies to discuss and probe how continually evolving mapping processes contribute to map narratives on one level, as well as cultural/political worlds on another level (Elwood 2008, Shuurman 2008, Ford 2014). Put another way, it is important for geographic research to look at the content of maps, technologies used in mapping, and the context in which maps create and recreate spatial narratives; all of which can possibly improve understanding of the process of mapping.

In trying to understand the process of mapping in a digital environment, an often overlooked step is the creation and use of spatial databases to manage data. Geographic Information System (GIS) databases in many ways are the organizing force of many mapping processes and as such deserve due attention to their influence. Since "… nowadays the majority of maps are digital and created only 'on demand' from geospatial databases for temporary display on screens" (Dodge et al 2011b:117), it is possible to say that often the database precedes the map. The influence database and GIS technology exerts is therefore not insignificant: "The freedom for people to make their own maps … is strongly inscribed in the design and functionality of the software itself" (Dodge et al 2011b:119). GIS databases are repositories which organize meaning from a mapping process and through a wide technological assemblage of digital encoding give context and power to data that for certain purposes is often less potent when isolated by itself. Since GIS databases aggregate mapping data of various degrees of separation from a mapping process, they are a form of mapping documentation.

Yet their purpose is not just to document, but to extend the spatial analysis of a mapping process to computations made possible through data assemblage, the implementation of topological rules, great computational efficiency, interoperability, and many other augmentations that computer databases bring to mapping data. Indeed GIS databases are so well designed to support complex tasks, that GIS and their databases are said to have fundamentally changed geography forever. If this is true, have GIS databases and their associated technologies led to "…new forms of line drawings; new cartographies for new worlds … new forms of mapping" (Pickles 2004: 161)? Writing at the beginning of the 21st century it seems undeniable that mapping technology has produced maps never thought possible 50 or 100 years ago. Advances in map technologies and their 'new forms of line drawings' are not just due to increased computing speeds or the plethora of complex and powerful software to manage geographic data, but from 'new worlds', themselves produced from new types of data stored in computer databases, possible through remote sensing technologies. Equally important in the glut of information from remote sensing is the ability to access, research and utilize collected geographic information. Spatial databases are again paramount in helping organize and search through spatial data. Even in mediums where much emphasis is placed on being able to link and search through data such as the Internet, databases often play vital, if background roles, as hidden digital libraries waiting for queries from across the world. Hiddenness here is framed by the following question: of all the maps a person has looked over, how many times has that same person explored the database that produced any of those maps? This hiddenness of databases only increases the importance of taking them into account in the mapping process.

If there were any place that 'new forms of mapping' are emerging as a result of the digital transition, it would be on the Internet. Consider for example, the User-Centered Design (UCD) for *The National Map* (TNM) project from the USGS Center of Excellence in Geospatial Information Science (CEGIS). CEGIS is the research branch of the USGS and is both developing TNM, and is in charge with delivering topographic information for the entire nation. The UCD project is concerned with the design of the TNM user interface (http://cegis.usgs.gov/UCD_projects.html). Perhaps the phrase user interface might conjure ideas of aesthetic design or the look and feel of a website, and as such it could be deduced that the UCD project researches how to properly display mapping projects in digital form especially through a website on the Internet. However, UCD itself is a term that means integrating user feedback into a production process of information system development (CEGIS 2012). Instead of focusing on a static package of information in map form, the UCD project researchers are trying to understand how recent developments in the mapping process might change the historical process TNM has typically used to deliver topographic information to the world. Specifically, the UCD project in its mission statement explains that it believes mapping has fundamentally changed specifically because of Internet socio/technologies. The UCD project website states that the Internet has fundamentally changed mapping in three areas: mapping now takes place through the web as a platform, users of geographic data are also quite often producers of geographic data, and mapping software on the Internet has an extremely social component often coupled with the creation of digital communities (CEGIS 2012). Given these changes the UCD project is trying to better implement a digital map environment to service its users; instead of what was previously a system-oriented paradigm, the project is also trying to harness the potential benefits of volunteered geographic information (VGI) through user participation. In this case this translates to research looking at how an entire mapping apparatus such as *The National Map* could incorporate collaborative data production as regards geospatial data among other research goals (CEGIS 2013). Returning for a moment to databases, according to the UCD project what is meant by trying to harness VGI, is having volunteers contribute information to the various databases behind TNM.

As noted by several critical cartography theorists and identified by the UCD project the change in mapping and therefore in database creation/updating has had a side-effect of a democratization of mapping (CEGIS 2013). Crampton (2010) has claimed that mapping traditionally produced maps created by an expert cartographer. However, recent technological changes have changed what was traditionally considered a top down map-creating process:

> "In other words, desktop mapping and geovisualization provided the beginnings of new forms of people's mapping. But the true democratization of cartography would only arrive with the advent of new advances in web technology, often referred to as Web 2.0 functionality such as massively distributed and hyperlinked datasets, mashups, and customizable open-source tools. These tools are profoundly different from their precursors because they allow *collaboratively linked* mappings" (Crampton 2010, p37; original emphasis).

**Proposal**

Given the context set forth so far, this dissertation broadly proposes to investigate what mapping means in a collaborative mapping era (or perhaps a participatory mapping era). Returning for a moment to the idea laid forth earlier that GIS databases document a mapping process, and looking at the form and content of a database that is considered a collaborative mapping creation, OSM will likely give insight into what has changed in today's mapping process. Currently, literature does exist on many aspects of mapping in a collaborative mappings era especially as it relates to OSM; however, few actually document the mapping process as it relates to the database itself (Soden et al 2015). Among some notable exceptions includes the work of Haklay (2010) who performed a comparative analysis of OSM data to Ordinance Survey data in England. In terms of documenting a mapping process, this comparative analysis of traditional national mapping agency (NMA) versus VGI mapping is framed in terms of spatial data quality and opens up many questions about what is truly different about VGI mapping. Therefore, the general focus of this dissertation is to investigate what "new forms of people's mapping" mean. As it has been laid out thus far in this document, the roles that GIS and database technologies have in volunteered information especially through the medium of the Internet are rich topics for discussion. The mapping process has been significantly altered by the advent of the digital era. Moreover the tools that have been developed in the digital mapping era which allow the mapping process to take place through the Internet are still poorly understood.

If a key difference noted by both the UCD project and Crampton is that mapping has been changed by the Internet especially in the possibility of collaboration, mapping starts then as a form of spatial practice used to organize a world. From this point mapping is contextually placed in an ebb and flow which negotiates the acceptance of multiple spatial perspectives within the constraints of the mediums chosen to display map-like products or to organize spatial data. As mentioned previously critical cartographers have taken a stand against the premise of a spatial practice some have termed the "cartographic ideal" whereby there is a single process (cartography) to document and illustrate the world (Edney 2011). By focusing on the spatial processes that create OSM, this project seeks to reiterate that maps (be they paper maps, digital basemaps, dynamic online map products such as Google Earth, or offline digital maps such as GeoPDFs etc.) as products of mappings have stories to tell and that by focusing on mapping technologies such as computer databases it is possible to discuss those stories and the concepts of the world intended by deploying those technologies.

Since this project seeks to document how OSM provides a particular way of looking at the world, it makes sense to focus on how OSM and its contributors sought to make meaning of a particular event. A contextual analysis of how OSM and its contributors reacted to a distinct historical event will open the possibility of asking questions such as what geographical features were edited into or out of the OSM database, when were they edited and by whom? Returning again to the collaborative process, questions such as what type of standardization or attribute schema was created, or how was collaboration reached are important contributions to what might be new in a VGI mapping process.

Crisis Mapping is the focus of this dissertation precisely because it currently represents a singularly collaborative process especially *vis-à-vis* OSM. Methodologically, this dissertation focuses on a temporal and spatial slice of OSM, analyzing changesets before and after a location has been affected by a particular natural disaster. Specifically, a Modified Content Analysis of the OSM database is proposed that focuses on the changesets stored for the country of Haiti. This Modified Content Analysis is combined with a spatial analysis of the changesets as well as with a survey and interviews with OSM users involved with mapping in OSM Haiti following the earthquake. Cases such as the response in the OSM database to the Haitian earthquake of 2010 have become notorious in large part because of the collaborative and decentralized nature of the OSM mapping community's efforts. Investigating the changes of the OSM database before and after a natural disaster through a Modified Content Analysis, spatial analysis, survey and interviews will help elucidate some of the process this bottom-up volunteered mapping entails.

**Research Questions**

Within the rubric of crisis mapping several research questions are posed. First, taking OSM as an example of VGI, do changes in the process of mapping exist when VGI is utilized for map-making, especially in the context of a humanitarian crisis? Second what does crisis mapping involving VGI look like at a database level and how does it change over time? Third, how are the varying experiences of individuals who contribute VGI to a database reflected in the database itself, and can these be teased out of the database, after the fact?

**Significance of the Research**

The significance of this dissertation is twofold. First, since research involving OSM has tended to investigate purely quantitative metrics such as spatial data quality, an analysis involving a mixed methods approach will help further an understanding of the OSM mapping process. Specifically, this dissertation wishes to answer the question how did the OSM database evolve after the earthquake in Haiti. Second, this dissertation seeks to contribute to ongoing dialogue over how VGI has changed the mapping process. To date there is very little empirical analysis at the database level to bolster the argument that mapping has fundamentally changed with recent techno/socio developments on the Internet coupled with computing technologies. Likewise, an analysis of crisis mapping allows for still open questions concerning the production and use of maps in an era where purportedly mapping has been democratized. It is expected that not only will mapping theorists benefit from this twofold agenda but also potentially OSM users involved in crisis mapping.

**Summary**

The mapping process is a difficult concept to define. A distinction found in academia for the mapping process is the division of map-making and cartography. Each term has a specific definition with map-making defined as the process of producing a map while cartography is the study of the theoretical underpinnings and rules for map-making. Critical cartographers have taken this distinction as obfuscating the social processes that continually contribute to the social nature of maps themselves. Given this nature of the mapping process an investigation into a current cartographic mode, VGI, needs to take into account the social context which forms and informs what the mapping production.

This dissertation therefore, acknowledges the complicated and evolving nature of the mapping process by exploring it through the specific example of the use of OSM after the Jan 12th 2010 earthquake in Haiti. Chapter 2 describes the techno/socio roots of the cartographic mode of VGI, OSM, and the related movement of Neogeography. Chapter 2 further explores these movements within the context of the Haiti mapping efforts and explores some of the ideologies of crisis mapping. Chapter 3 lists the steps taken to: preprocess the OSM database, perform interviews of a tier of OSM Haiti users, construct an online survey for another tier of OSM Haiti users, perform a Modified Content Analysis of the OSM Haiti database, and perform a Spatial Analysis of the OSM Haiti database

# Chapter 2
# Understanding Crisis Mapping and Web 2.0

**Introduction**

Volunteer mapping projects exist in many forms. For example, every year, the Audubon Society collects data surveyed by tens of thousands of volunteers on bird populations within certain geographic circles distributed across the entire North American continent (Audubon 2013). Another example is a website called SeeClickFix specializes in connecting volunteer citizens with local authorities to map problems in a community such as pot holes, broken street lamps, or blocked bike lanes (http://www.seeclickfix.com/). Another example can be seen in the ongoing support of the United States Geologic Survey (USGS) of The National Map Corps, a program that has historically utilized volunteer citizen cartographers to revise map data published by the USGS. Volunteered map data can also take shape through informal activities, by simply geotagging a picture on a photo sharing website like Flickr.

The previous chapter explained that currently, map-making is taking place in a collaborative era, and this collaboration occurs quite often through a digital mapping medium. Since the nature of volunteerism aims to promote participation of some type, volunteer mapping projects such as SeeClickFix are based in collaborative digital technologies often through Internet technologies that promote sharing of information through easy to use interfaces. Perhaps one the more interesting examples is mapping volunteerism done in response to a natural disaster or other crisis situations.

Currently, the term crisis mapping has specific connotations *vis-à-vis* volunteerism and digital technology. In 2011 Tufts University offered an experimental course called Tufts Crisis Mapping Class, which defines crisis mapping as "an emerging interdisciplinary field that uses technology to aid in response to humanitarian emergencies" (Tufts 2011). An international network of over 5000 crisis mappers have formed a humanitarian network called The International Network of Crisis Mappers, which are currently based on the website http://crisismappers.net/. This network defines those who volunteer in crisis mapping, crisis mappers, as individuals who:

> "…leverage mobile & web-based applications, participatory maps & crowdsourced event data, aerial & satellite imagery, geospatial platforms, advanced visualization, live simulation, and computational & statistical models to power effective early warning for rapid response to complex humanitarian emergencies. As information scientists we also attempt to extract meaning from mass volumes of real-time data exhaust." (Crisis Mappers 2013).

To understand collaborative mapping and crisis mapping, elements of its lineage are worth describing. This chapter investigates what technology and technological frameworks have made crisis mapping what it is today. The first section describes how each of the Web 1.0 and Web 2.0 shifts has contributed to changes in mapping. The second section describes this new collaborative mapping paradigm especially as it relates to VGI and the production of spatial data. The third section examines an example of crisis mapping in response to the earthquake in Haiti on January 12, 2010.

**Mapping and the Internet at the end of the 20th century (Web 1.0)**

At the beginning of the 6th edition of *Elements of Cartography* in their chapter describing the current state of cartography, Robinson et al. (1995) predict the future of mapping in regards to the introduction of the personal computer. Specifically the authors link the emergence of large digital map information databases, cost-efficient personal computers, and electronic networks linking map makers to map users. Robinson et al. identify several implications. First they note that map producers will likely become decentralized. Second, professional cartographers will lose authority over map-making. Third, the authors note that data sources will probably be more decentralized while central units will collect this disparate local data which will in turn share them with the greater public (Robinson et al. 1995 p. 6).

Markedly, these predictions were very astute, but perhaps even the authors in 1995 would not have imagined the rapidity and scale of the coming changes. With Internet technology rapidly changing the dynamics of map use and map creation the International Cartographic Association established a Maps and Internet Commission in 1999 to research what implications Internet technology held for GIScience (Peterson 2001). This was due in no small part to companies like MapQuest in 1997 reporting downloads from the Internet of 700,000 maps per day and in 2001 reporting 20 million downloads per day (Peterson 2001). Clearly since MapQuest started making maps available as a web service in 1996 the term cybercartography was needed to describe a phenomenon already in use (http://en.wikipedia.org/wiki/MapQuest).

This phenomenon is part of a much larger movement where computers started performing tasks previously reserved only for humans and their analog tools. This "digital transition" as Goodchild (2000) named it, has changed much of humanity in the last half century. Three major digital technology innovations that have perhaps most influenced mapping in the present day are computer, Internet, and mobile/wireless technologies. First, computer technologies and their associated products from digital monitors, to databases, to portable laptops, to expanding multimedia capabilities all have changed the tools of the trade for cartography. As a side note, digital technologies made possible through computers open up new possibilities for map-making, and at the same time are known to also restrict this process as for instance in the limitations of digital printing technologies (Cartwright 2008). Second, the Internet has not only transformed the delivery of map data and mapping products, it has also enabled a social dimension to map-making that is particular to the digital transition. Third, mobile technologies such as Global Positioning System (GPS), digital cameras, and other sensors such as accelerometers have allowed for the capture of space in ever increasing detail. These technologies are connected to networks such as the Internet through a vast array of cell phone towers or wireless networks covering major urban areas around the globe. This trifecta of computer, Internet, and mobile/wireless technologies not only changed the map-making process it also changed how maps and map data are delivered to map-users.

A common nomenclature used to describe the Internet is Web 1.0, that spans the period between 1991 as the release of the World Wide Web to the general public, and 2001~2003 when the dot-com bubble burst (http://en.wikipedia.org/wiki/Web_1.0). Common characteristics of Web 1.0 were the publication of products such as maps or personal websites. Web 1.0 deployed information, but mostly as a finished product that was controlled by companies and individuals who had the technological means to create content on the Internet. Common words used to describe Web 1.0 are static, proprietary, read-only, and content management systems.

The static nature of webpages on the Internet coincides with the use of GIS. Just at the time that Robinson et al (1995) predicted the loss of control of map-making by cartographers, there was a small window when professional cartographers enjoyed quite the opposite. This was due to the development of GIS as complicated software used to organize and sort digital geographic data. GIS were increasingly being used for centralized map production and the knowledge needed to manipulate GIS still lay in the hands of a few trained specialists (Gartner 2009). As evidence of this, the first symposium in 2000 organized by the Maps and Internet

Commission of the ICA envisioned map creation and the Internet largely as a means for map distribution or as a means by academics to get access to larger datasets (Peterson 2001).

This top-down approach to maps, the World Wide Web, and the technology of GIS can be linked to a goal to involve map users more closely in the map-making process. As Robinson et al (1995 p. 37) noted, "…rather than pursuing the goal of building up the stock of printed maps for potential future use, cartographers will increasingly need to concern themselves with making environmental data and mapping programs more accessible to non-professional mapmakers". Increasing the involvement of map-users in the map-making process might seem to weaken the position of those who at the time were professional or academic map-makers, but initially this was not the outcome. Involving map-users in map-making was really the fulfillment of the Map Communication Model whose groundwork was laid by Arthur Robinson. The Map Communication Model argues for mapping as "…a process of communicating information from the map expert or cartographer to the map reader" (Crampton 2010 p37, Gartner 2009). In other words the Map Communication Model ensures the salience of the guild of cartographers as protector of the craft of map-making.

Originally, Web 1.0 began involving users more actively in the map-making process, and marked an era of increased access to digital geographic information. Haklay et al (2008) note that in the first decade of Internet mapping the most popular form of map delivery was through public mapping sites such as MapQuest or Multimap. While these services tended to give limited interactive tools designed to allow a user to query and ultimately receive a map image, they are a milestone to delivering specific or even personalized map data via the Internet. Yet, perhaps an equally important development in map-making that began in the Web 1.0 era is the increasing ability of users to find and download geographic data to a computer. Internet sites where a user can find and access geographic data are commonly known as geoportals (Wikipedia: Geoportal 2013). Geoportals such as the Alexandria Digital Library (http://www.alexandria.ucsb.edu/), or the Geospatial One-Stop (http://geo.data.gov/geoportal/), are sometimes overlooked but nonetheless important elements to understanding what changes would later take place with map-making and the Internet. If mapping in the Web 1.0 era meant that users of map data on the Internet were limited to public mapping sites or even much more advanced Geographic Web Services (Haklay et al 2008), then Web 1.0 and ultimately the next chapter of Internet history (Web 2.0) would have been less about information sharing then each Internet generation were. To summarize, Web 1.0 increased the profile of maps by enabling access to static and eventually more dynamic map products, while at the same time laying the groundwork for users to have access to digital geographic information that they could use to their own means.

**Mapping and the Internet at the beginning of the 21st century (Web 2.0)**

Top-down approaches to map-making and the Internet in general changed with the advent of Web 2.0. After the bursting of the dot-com bubble in 2001~2003, Internet companies started to lean more heavily on already available technologies to generate Internet user content. Client-side web browser technologies like Ajax created more dynamic webpages that didn't need to be refreshed to communicate with servers (http://en.wikipedia.org/wiki/Web_2.0). This marked a shift from users just downloading information to their browsers, to users filling out forms for websites which compiled this information into an organized format (Goodchild 2007). Initially Web 2.0 did not describe the development of new technological specifications, rather it was a term coined to illustrate a new emphasis by software developers in deploying resources on the Internet (Gartner 2009). Importantly, quintessential Web 2.0 websites such as YouTube or Flickr are designed to encourage users to add content through interaction, blogs, tagging, and content aggregation. In essence this shift allowed for much of the labor of content generation to be done by those who used and contributed to the services provided instead of the companies originally providing the content.

Haklay et al (2008) also identify the availability of GPS and the adoption of eXtensible Markup Language (XML) as cornerstones to the change in mapping practices. GPS as a portable device to measure position was available during the Web 1.0 era but was not very accurate due to the U.S. military degrading its signal (Wikipedia: GPS 2013). After President Bill Clinton gave an Executive Order in 1996 to turn off this signal degradation, GPS units became a viable tool to produce high-quality vector GIS data by tracking a user's location (GPS.gov 2012). GPS devices became a cheap and easy technology that encode movements to a digital device. Yet this and other important technologies would not have been nearly as useful without XML as an interchange format for communicating data between applications (Wikipedia: XML 2013). For instance GPS data was difficult to exchange until the GPX interchange standard was first published allowing for a common language between applications (Hacklay et al 2008).

Returning to maps and map-making, the movement to Web 2.0 greatly altered who, what, and how maps were being made on the Internet. Several companies built platforms to gather as much content as possible from users of a web service, specifically in relation to map content. A titan in this endeavor is the Internet search giant Google with a host of products aimed at offering services to Internet users based on user-generated content (O'Reilly 2005). Google Maps and Google Earth are central strategies in the Google business model as platforms to encourage more user generated content while also building a geo-located advertisement network (Gurley 2009). Capitalizing on the great advantage that maps provide a business like Google, it is only logical to expect a sort of “Post-Fordist cartography” emerging to address user needs. (Crampton 2003, p34). A form of democratization of mapping was realized on a scale never before seen (Perkins 2009). While this democratization of maps had been noted in Morrison (1997) as relating to an opening of cartographic technology through desktop computers, a renewed interest in spatial data by Internet users wishing to express their ideas through maps, exponentially nurtured Web 2.0. In other words, map-making “…escaped from the dominant control of professional cartographers” (Perkins 2009 p168) (see also Crampton (2010).

So far what has been described in this dissertation is a substantial shift to the value of adding geographic information to data structures on the Internet. The democratization of data in Web 2.0 is something a little more political and ultimately cultural. U.S. laws require all federal agencies to share information for the cost of dissemination, not for other costs such as data production. This measure of openness of governmental data is by no means true in other nations across the world. Particularly noteworthy in its desire to maintain the financial benefits of stringent copyright laws is the national mapping agency of the U.K., the Ordinance Survey (OS). In an interview on the cultural blog Londonist, the founder of OSM, Steve Coast describes his reason for starting OSM.

> “OpenStreetMap exists because map data is very expensive in the UK. It's owned by a monopoly provider - the Ordnance Survey - who operate[s] in a quasi-commercial/public way. Even when you get your hands on that data you can't do much with it due to lots of license restrictions. In some places map data is public domain and in some it doesn't exist at all.” (Brown, 2007)

This dialogue reflects a frustration held by some Internet users of not having access to data for which they perceive as having some degree of ownership. While some have called this frustration a form of libertarianism (Keen 2007), for many the economics of having to buy spatial data every time a specifically local geographic query is needed is simply not feasible. Yet, for many the economics of volunteering to generate local geography was more feasible. While not every person involved in map-making on the Internet may need access to as much data as perhaps Steve Coast for a GIS project, the fact remained that developing Internet-based mapping applications was limited by the lack of free or open source data to use as basemaps. As the quote above illustrates, outside of the USA, data in the public domain was scarce until about 2005 (Haklay et al. 2008). Steve Coast in 2004 decided to create a website and host a database (OSM) which would act in a similar fashion to Wikipedia. Anyone could edit and contribute any information to a database, but in this case it would hold geographic data as opposed to encyclopedic entries. By allowing the labor of generating and maintaining content for a spatial database to be performed by anyone with an OSM account, Steve Coast brought crowdsourcing to an unprecedented level in terms of geographic data. This data generated by the crowd is currently licensed under an Open Data Commons Open Database License that dictates, "You are free to copy, distribute, transmit and adapt our data, as long as you credit OpenStreetMap and its contributors. If you alter or build upon our data, you may distribute the result only under the same license" (OSM 2013). The copyright logic espoused by OSM is therefore substantially different from map environments where the data is copyrighted such as Google Maps or Bing Maps. In other words the spatial data stored in the OSM database and often the software used to display it, is owned by the community (crowd) that contributes to the OSM project.

**OpenStreetMap**

At the time this dissertation is written OSM has ~2,000,000 registered users, with an average of ~1% of the total number of users contributing node edits in the last month (February

2015). This percent has been fairly constant since early 2013 (wiki.openstreetmap.org 2014), which is impressive considering that OSM contains over 21 million miles of road and 78 million buildings (Mapbox 2014). It should be noted that when this dissertation utilizes the word 'user' within the context of OSM, the reference is to persons who contribute to OSM and not simply those who use OSM data. This distinction is important because a person can use OSM data while not being part of the user community of OSM editors. Therefore, the total number of users means 2 million accounts are registered to add and edit content in the OSM database.

Initially in 2005 at the inception of OSM, Steve Coast and a small group of friends were mostly mapping road networks in the UK through handheld GPS units. GPS technology is still a major technological tool used by the OSM community. At the wiki webpage that describes OSM database statistics, GPX data is visualized in several graphs, again showing the importance of GPS data to OSM (http://wiki.openstreetmap.org/wiki/Stats). OSM is designed to easily let a user upload GPS traces that are collected while driving, walking, biking etc., to the main database where a user can label the type of feature just collected, give a name, and add any other attributes that person thinks are pertinent. The advantage is that many people are familiar with generating GPS traces and at the same time do not need to be familiar with the intricacies of online mapping thus facilitating the labor involved

In addition to logged GPS data, the managers of OSM also emphasize mapping local features of interest, from ski runs at a favorite resort to all the bars in a neighborhood, to the location of every tree in a city, in an effort to produce the most precise and up to date map possible. While there is a clear emphasis in OSM on mapping data related to transportation, according to the directions on what data to add to OSM, "…there is no 'one way' that it [mapping] should be done" (OSM 2010). Sometimes it is hard to remember when looking at images such as Figure 2.1, that 10 years ago this website was completely blank for major cities, let alone small villages such as Laufff, Germany.

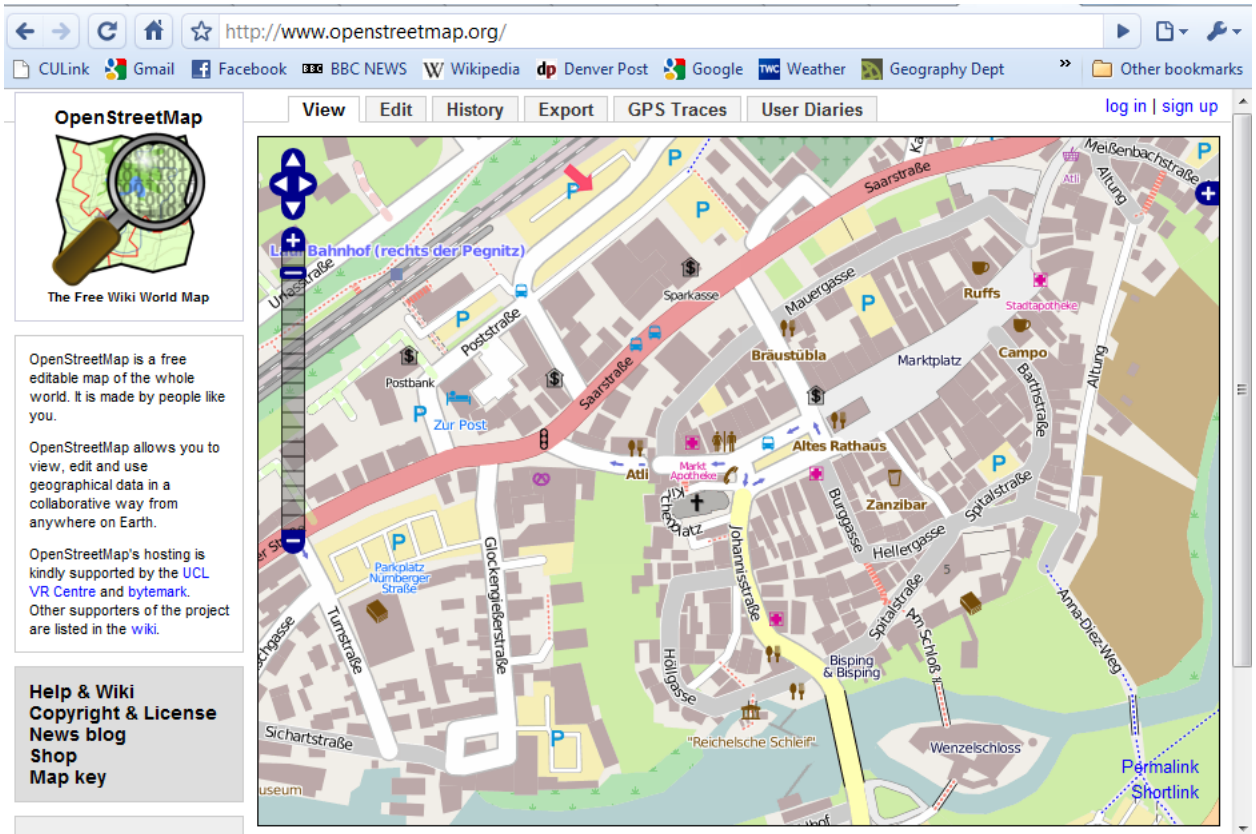



**Figure 2.1** Screenshot of Lauf, Germany in OSM (retrieved May 1st 2010)

OSM is synonymous not only with free data but also with open software. Open source software generally speaking means (Stallman 1999 p 56; cited in Crampton 2010):

- The freedom to run a program for any purpose
- The freedom to modify a program's source code
- The freedom to distribute, sell or donate copies
- The freedom to distribute modified copies of a software

These tenets are directly opposed to common practices by many major software companies who rely on international copyright laws to keep the inner workings of their software proprietary or at least keep it from being used without first paying a fee. The open source model as pertains to geographic data is therefore also about the tools needed to use this open data. Open and free software such as APIs, Apps, GIS packages, or public scripting libraries all exist for the OSM database and each have an important role in promoting the use of OSM in its openness and free-ness. These tools have often been developed in the classic open source culture of collaboration coupled at the same time with a fierce do it yourself attitude. Likely OSM would not be where it is today if geographic data were open source. It is the combined openness of data and the tools to use the data which make OSM what it is.

In the OSM community the openness of the mapping process is quite varied. It has translated into many collaborative efforts such as mapping parties where people get together and add to the OSM database, typically by going out and mapping locations with a GPS. Many software applications such as OSM database editors have also been collaboratively created and updated. However there is also often a do-it-yourself attitude to many problems. For example there exists popular OSM database editor called Java Open Street Map Editor (JOSM) that is largely the product of volunteered programming by Immanuel Sholz (wiki.openstreetmap.org 2013). Since OSM has adopted the wiki model of editing and feature creation it is possible to see what user has edited what feature(s) and when. The openness of who contributes to the database is also enlightening as it is often identified with civic engagement by providing local geographic data (Gilman 2012).

Civic engagement, openness, community, and collaboration are all some of the many reasons why people contribute to OSM. According to Budhathoki and Haythornthwaite (2012), Wikis (a collaborative website) such as OSM need both the breadth of a large crowds of users to generate content, and also temporal depth in terms of repeat users who can help steer the project through change. The distinction made by the authors is that the former group are simply members of a crowd while the latter group actually belong to a community, and that the distinction is better explained as the ends of a continuum rather than a binary process. One manner the authors use to explain the continuum is that users in a crowd typically don't have any interaction with each other while members of a community do.

In a survey of 444 OSM users performed by Budhathoki and Haythornthwaite (2012), OSM was found to be a somewhat uniform community. According to the results, 93% of the respondents were male, 65% were between ages 20 and 40, 80% were living in Europe, 95% were college educated, 61% were employed full time and 72% in the commercial sector, and 72% contributed from home. Another finding of interest is that these same users on average contributed to open source software projects (60%) and Wikipedia (72%). What is helpful with the Budhathoki and Haythornthwaite (2012) research is while the argument could be made that the OSM community has evolved from 120,000 users at the beginning of the project in 2009 to currently under 2 million, for the purposes of this dissertation the percentages quoted above are considered more or less accurate because the research project survey was conducted in December 2009.

### VGI, Neogeography and Web 2.0

As mentioned previously, examples of volunteered mapping are not new: geographic volunteerism has existed in many forms in the past. The examples of collaboration in the previous section are particularly interesting because of the grassroots nature of the volunteerism. This type of workforce is directly connected to the idea of crowdsourcing, a key concept in Web

2.0 circles. Crowdsourcing entails opening up a task to an undefined public or group of people instead of utilizing a controlled group of trained workers (Howe 2006). Essentially in an Internet crowdsourced paradigm, a task such as mapping the country of Haiti is opened up to any volunteer willing to spend time. Since it is assumed that volunteers in such tasks have a wide range of experience in any given skill set, there is usually a concerted effort on the part of those organizing a crowdsourcing project to make the task as simple as possible. VGI is the name used to describe all scales of mapping within a Web 2.0 paradigm that involve the voluntary production of map data as disseminated through the Internet (Goodchild 2007). VGI currently often involves the tools of Neogeography. According to Turner (2006 p.2-3) Neogeography means:

> "…'new geography' and consists of a set of techniques and tools that fall outside the realm of traditional GIS, Geographic Information Systems. Where historically a professional cartographer might use ArcGIS, talk of Mercator versus Mollweide projections, and resolve land area disputes, a neogeographer uses a mapping API like Google Maps, talks about GPX versus KML, and geotags his photos to make a map of his summer vacation. Essentially, Neogeography is about people using and creating their own maps, on their own terms and by combining elements of an existing toolset".

Mapping through applications on the Internet is known as mapping in the geospatial web (commonly known as geoweb) and can manifest itself in many levels (Haklay et al. 2008). Goodchild 2007b notes three basic levels of Web 2.0 sophistication which enable different levels of participation in the geoweb. First is what Goodchild (2007b) calls volunteered gazetteers, a geoweb service that collects places citizens find helpful or important to map. An example of a volunteered gazetteer is Wikimapia (http://wikimapia.org), which allows users to draw polygons overlaying satellite imagery to delineate buildings, parks, monuments etc. On a second, slightly higher level, there are Web 2.0 projects which source VGI for geographic data as well as for technical expertise to improve the mapping environment itself. Here for example, the type of license used by OSM is designed to improve the mapping environment by disseminating and encouraging the development of free and open source applications for the geoweb. OSM provides an example of this level of sophistication. The third level of sophistication describes users using APIs to publish their own layers, overlaying the virtual earth with their own symbology and with some individualized functionality. An example of this level of sophistication are mashups involving data of a person's choosing displayed together with a basemap application like Google Earth (Goodchild 2007b).

While these levels of sophistication are helpful to understand a user's level of involvement with software, the idea that Google Earth or OSM or Flickr belong in one level versus another is currently outdated. It is true that one can simply just store information such as placenames and location on a gazetteer such as Google's My Maps but the same programs have expanded to allow the third level of sophistication and above. OSM in particular allows users to not only download their entire database, but also the software used to host, update, and render it as well. This means that with minimal investment in a server and connection to the Internet, a person could host their own version of OSM to suit their particular purposes. The open-ness of these software platforms provide practically free options to an expert computer technician who five years ago would have had to purchase expensive software/licenses. A potential reason why the levels of sophistication exhibit intermingling could simply be that projects such as OSM are not simply a database or just the users contributing to it but are a "multi-faceted project", that encompass a database, a website, software tools, a community of mappers, and a set of shared values (Soden and Palen 2014, p315).

Another example of the intermingling of Goodchild's (2007b) levels of sophistication can be drawn from the source of the data within OSM. Goodchild's levels tend to separate data from

VGI and data from large governmental or corporate providers. While data in the OSM database is often contributed by users and their GPS tracks or by digitizing satellite imagery and is therefore considered VGI, large additions of public domain geographic data (gazetteers) come from large governmental or private organizations. These public domain datasets have been uploaded and incorporated into the OSM database of individually contributed data. Given the nuances of the source of the data in the OSM database, it is helpful to see Goodchild's 2007b levels as a soft framework for organizing VGI. One of the largest additions to the OSM database was the importing of the U.S. Census TIGER data into OSM at the end of 2007 (wiki.openstreetmap.org 2013b). Since that time, a large project has been undertaken by the OSM community to clean up this data to validate existence of roads, to correct geographic positional errors, and to update attributes. Figure 2.2 provides a visual inspection of the Front Range and area surrounding Denver that shows an interesting "data cleaning" divide between the large metropolitan areas and the rest of the Front Range. A majority of streets in Denver have been edited since the original TIGER database import, while in more rural areas have not.

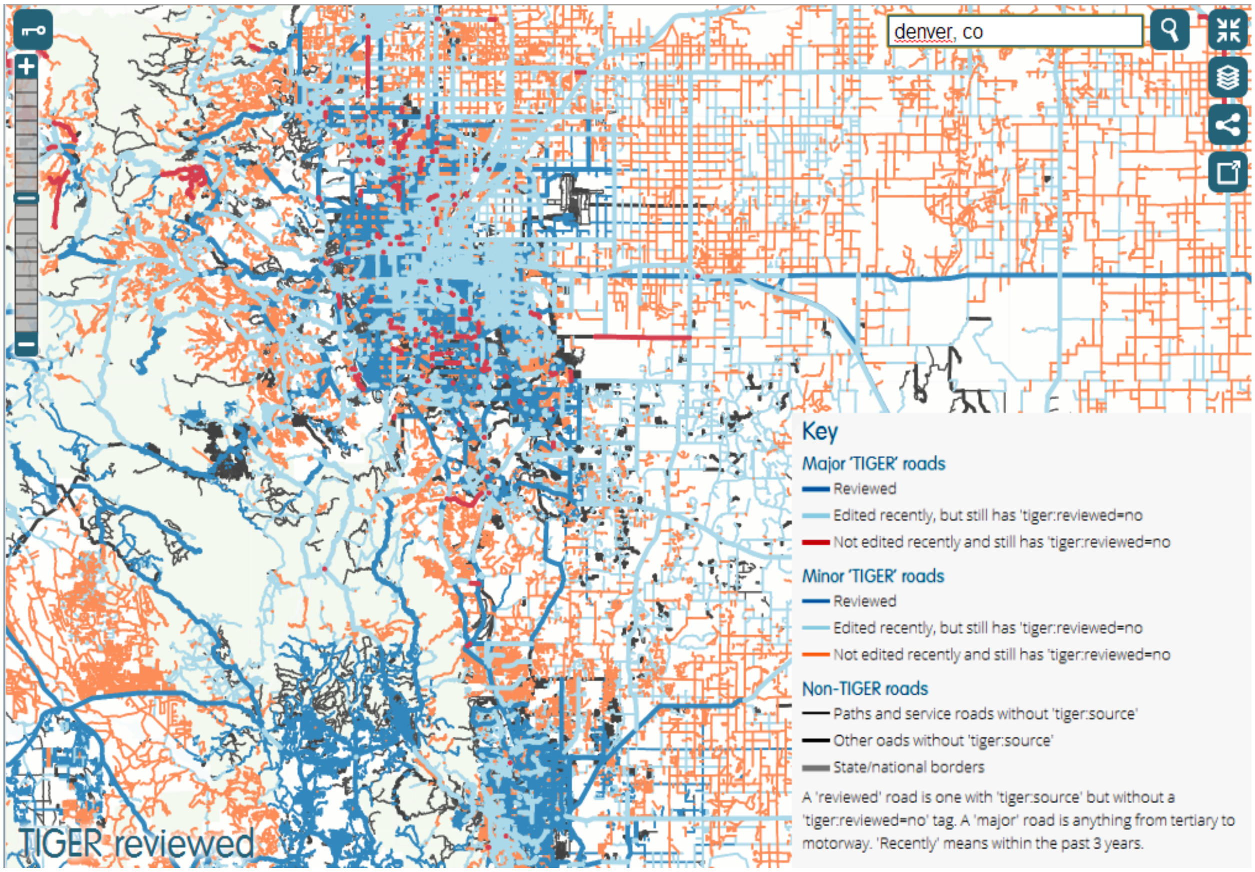



**Figure 2.2** Screenshot of Denver metro area road data from the OSM database. Denver is at the upper left of the image and the dense mass of blue lines in the bottom center is Colorado Springs (ITO! 2013).

There are many ways to map in the geoweb. Participants creating or utilizing VGI can choose to draw on top of base maps, use GPS units to digitally trace their movements, combine both GPS and graphic manipulation, or simply geotag a message posted to a micro-blogging website such as Twitter. All these options produce data which can be joined into a database of choice or simply used to overlay with an API. Likewise crowdsourcing can enrich attributes for places that have already been mapped. Some companies that produce navigation systems have incorporated user content to provide traffic data with more up- to-date directions within a road network. An example of this form of VGI is the mapping navigation company TomTom. A popular cellphone app called Waze currently offers free turn-by-turn GPS navigation data while also passively collecting data on current traffic patterns from all its users. Users of Waze can also choose to actively contribute road reports such as speed traps or accidents, and also edit the map data to have the most up to date information as possible.

What makes VGI mapping projects such as Waze and OSM fascinating is that they aim for the most personal of mappings by using the largest possible community of mappers. Often the size of the population of these communities of mappers directly correlates with the amount of geographic data generated. Since many web-based VGI map applications are designed using the Web 2.0 paradigm of generating as much user-content as possible, size of a participating user community matters. Yet the more disparate the community the more possibilities occur for disagreement and even conflict. Particularly in the case of OSM the database is enriched by users across the globe who map in localities for which they may have no physical experience. This point illustrates the idea that VGI ties the world perceived through all of the human senses, to a virtual, cartographic one. Often it is the existence of the personal connection to this mapping that makes a VGI community vibrant. In fact, Eckert (2010) describes results of interviews with OSM mappers who explain the importance of map gatekeepers in certain regions of the OSM world. Eckert (2010) shows there are places in the OSM database where users simply cannot make whatever changes they want. If a user makes changes that are controversial or that a self-appointed gatekeeper disagrees with or simply does not like, they remove the changes. The idea of database gatekeepers to a certain location on a map suggests many levels of VGI involvement. These gatekeepers offer an example of what likely happens intermittently in OSM: those who volunteer their time mapping can exhibit a certain kind of attachment within the OSM database. Moreover this example suggests that VGI is not only about increasing accuracy through number of contributors but also in its very reliance on volunteerism, is about emotive responses; perhaps in direct correlation to the amount of time spent actively mapping.

So far, this chapter has described the influence Web 1.0 and Web 2.0 technologies have had on mapping practices within the context of VGI. Web 2.0 technologies have particularly provided web functionality for open-sourced mapping software, and interested volunteers are contributing open-sourced map data of much of the globe. This context sets the framework for utilizing these data and functionalities to examine a specific case study, the 2010 Haiti earthquake.

**Mapping humanitarianism in Haiti through volunteer communities**

A year after the magnitude 7.0 earthquake devastated the small country of Haiti, a report titled Disaster Relief 2.0 (UNF 2011) was issued by a consortium of prominent humanitarian agencies praising the use of online technologies in promoting relief efforts immediately after the disaster. Particularly prominent in the report is the advent of crisis mappers in the production of basemap data used to meet the geospatial needs of the post-earthquake emergencies. Companies like Google, Digital Globe, GeoEye, online mapping collectives like OSM, and the San Diego State University Visualization Lab are praised for volunteering the central mechanisms for mapping activities in Haiti. It is worth noting that the authors of the report are arguably members of an old guard of humanitarian agencies: UN Foundation & Vodafone Foundation Partnership (a foundation in charge of connecting the UN with ‘you’-concerned citizens- to help solve global crises) along with the UN Office for the Coordination of Humanitarian Affairs (UN OCHA), and the Harvard Humanitarian Initiative. Since the Disaster Relief 2.0 report praises crisis mapping and claims it has changed the manner in which relief work is done, it is worth investigating what crisis mapping is and how it changed relief work. This section serves as an example of how Web

1.0, Web 2.0, and VGI production of spatial data have changed the process of map-making and often converge in crisis-mapping.

**Background on Haiti Mapping efforts**

The interrelation between mapping and humanitarian work is not a surprising one. As the Disaster Relief 2.0 report points out, natural disasters create rifts between what is known about a country by humanitarian organizations and local governments and the reality that faces relief efforts immediately after the destruction (UNF 2011). Mapping efforts *vis-à-vis* humanitarian crisis situations therefore initially involve a lot of fact-finding whose goal is to allow relief work to be coordinated and properly organized. In its report on the future of information sharing in regards to humanitarian emergencies, the UN Foundation (UNF) spends a lot of time explaining what was different about the crisis in Haiti. While, there existed virtually very little map data for Haiti (it was either buried by the earthquake or unavailable because persons in charge of the data were missing), humanitarian agencies faced a barrage of non-traditional forms of information. The UNF report states this over and over that even though information was flowing in at unprecedented rates, the information such as text messages, tweets, and raw unprocessed imagery was not standard information agencies were accustomed to. In terms of classic information management processing, such as emails and communications to and from agencies to their senior management, the agencies were doing better than ever. In fact in the UNF report, a member of the United Nations Disaster Assessment and Coordination team claimed;

> “everybody should realize, that we’ve … done very well by comparison to where [information management] was in the [2005] Pakistan earthquake, or during the [2004] tsunami, both in terms of the types of products that were outputted and the types of coordination we managed” (UNF 2011 p 18).

At the same time that relief workers were actually being more efficient, much of the infrastructure in place was unable to automatically extract relevant information from the multitude of non-traditional data sources. This necessitated human intervention – typically a grossly inefficient process- and therefore presented a serious challenge towards engaging local intelligence (Heinzelman and Waters 2010).

In the case of the 2010 earthquake in Haiti, mapping was the central mechanism used to "assess the damage and plan a response" (UNF 2011 p8). What was new in the case of the Haiti earthquake was the process used to collect large volumes of usable data related to the crisis. To compare situations with another catastrophic event, following the 2004 Indian Ocean Tsunami, an estimated $14 billion was donated in humanitarian aid, and yet it took 3 weeks for humanitarian agencies to have access to satellite imagery that could in turn be used to assess the damage, map internally displaced persons (IDP) camps, and locate viable routes to distribute aid (Johnson et al 2010). This is not to say that mapping was not taking place, or that existing GIS infrastructure was not available. In fact what was mapped in the interim (before satellite imagery was available to show the full spatial extent of the damage) were the movements of the global response community. Based on these initial reports, the UN OCHA released maps of areas believed to be most affected by the tsunami and therefore in most need of aid (Pisano 2005). Extensive GIS databases were subsequently created to gather vast amounts of information about the infrastructure of the affected areas before the disaster (ESRI 2005). At the time, the UN agency in charge of delivering satellite imagery for the Indian Ocean tsunami relief efforts, the United Nations Institute for Training and Research's Operational Satellite Applications Programme (UNOSAT) considered a turnaround time of 19 days (the time it took to make available the first image of the affected area) to be quite efficient (Pisano 2005). In comparison, satellite imagery of the initial effects of the Haiti earthquake was released in raw form 26 hours after the disaster. In the 19 days it took to release the first imagery for the Indian Ocean tsunami, 8cm resolution imagery and LiDAR data for Haiti was made available in the public domain courtesy of the World Bank (Johnson et al 2010).

The immediate availability of the satellite data was not the only innovation of humanitarian response to the Haiti earthquake. The two other technological shifts are equally significant, including, the use of cell phones and the farming out of mapping projects to volunteer cartographers. Paramount in crisis relief work is the need for immediate, ground information. From the point of view of relief workers, the two questions that are perhaps the most pressing in the hours/days following a disaster are, who needs help and where (Zook et al. 2010). Relief activities became more feasible with the use of a cell phone messaging system made available to the public immediately after the earthquake. This system set up a standard number for SMS messages requesting aid (Norheim-Hagtun and Meier 2010). The number known as a short code, is analogous to other standardize phone services such as 911. This particular short code was set up by a concerned citizen in Washington DC who thought that an SMS gateway might be helpful to relief efforts (Knowles 2010). As the short code, 4636, was made known through social media outlets, humanitarian agencies attempted to try and spread its existence through word of mouth and local radio stations letting those afflicted know that sending an SMS to 4636 could increase their chances of aid coming their way (Knowles 2010, UNF 2011).

It is estimated that even though only 11% of Haitians used Internet services before the earthquake, an estimated 35% of the 9 million Haitians had mobile phones allowing for a very distributed and decentralized form of personal communication (Rhoads 2010). It is safe to assume a greater concentration of cell phone users in the urban areas of Haiti such as Port au Prince, where the earthquake affected the most people. Another report claims that if taken on a household basis, 85% of people in Haiti had access to cell phones (Heinzelman and Waters 2010). As such, an organization specializing in immediate post-disaster response Internet technology Ushahidi, began to collect the SMS messages sent to 4636, translate them and map them whenever possible. Incredibly, some of the cell phone towers in the affected areas of Haiti were fully operational after the earthquake and the ones that were damaged were repaired within days. Once the short code SMS messages were sent, they were compiled to an online database and translated from Creole by a network of volunteers. In some cases the reports were mapped by another network of volunteers or were replied to in order to try and get more location information (Heinzelman and Waters 2010, Norheim-Hagtun and Meier 2010, Zook et al 2010). According to a report issued by Ushahidi, over 80,000 SMS messages were received in the days, weeks, and months following the earthquake with roughly 5% of these messages being mapped through a triage process assessing the most life and death messages (Norheim-Hagtun and Meier 2010, UNF 2011).

Even though an unprecedented wealth of information was made available in terms of up-to-date and on-the-ground information, another critical element to be noted was the lack of any reliable basemap of Haiti. Since as mentioned before, only an estimated 11% of Haitians used Internet technology before the earthquake, demand was minimal and digital maps for the country were sparse at best, especially in the popular online databases such as Google or MapQuest. As the need for a mapping system accessible to everyone became clear, a call was placed to the community of mappers who contribute to and maintain OSM for anyone willing to volunteer time and energy to map Haiti (OSM-Talk 2010). Several major satellite companies donated current imagery for Haiti within hours. Eventually, the World Bank flew over Haiti to provide aerial imagery. Thus anyone who had access to the Internet who was willing to donate time could help map roads and infrastructure by tracing lines, points, and polygons over the imagery and labeling them as best they could (Zook et al 2010). Naming features and tagging posed a significant challenge as names are not typically visible in imagery and the types of features are best assessed by local knowledge (e.g., school building, highway, church, dirt road). Fortunately, many features were able to be attributed through the release of semantically rich but geometrically sparse information compiled before the earthquake by MINUSTAH, the UN mission in Haiti, public domain CIA maps and various collections of digitized topographic maps (http://wiki.openstreetmap.org/wiki/WikiProject_Haiti/VectorAndMapData). As such what was for basemap purposes a sparse spot in the OSM database, became one of the best mapped countries in the world within a matter of weeks. As Figure 2.3 shows, the progress of the information is staggering considering that this was done by volunteers all over the world.

**Figure 2.3**. OSM basemap of Port-au-Prince from the day before the earthquake, the day after the earthquake and two weeks afterwards (modified from GeoFabrik 2013b)

While the rate of database content generation may have been a new phenomenon in the case of OSM Haiti, in many ways the volunteerism itself was not. An observed phenomenon in the wake of a crisis is the social convergence of persons to the physical location of the crisis area especially by those not associated with the official response who are looking to help or a simply curious (Hughes et al 2008). A variation of this phenomenon has also been observed in the form of a digital convergence where volunteers "mobilize via social computing platforms to report on events, search and distribute situational information, and articulate unspoken needs on behalf of victims" (Sodent et al 2015 p3). Furthermore, there is evidence that the digital convergence seen in Haiti was coordinated ad-hoc through existing listservs, IRC, and the Haiti wiki page (Soden and Palen 2014). This coordination served to motivate digital volunteers to map as well as to prioritize what was mapped to best help aid relief agencies working on the ground in Haiti (Soden et al 2015).

Another less understood mechanism used to generate up to date information for both the OSM basemap and the Ushahidi shortcode crisis map came from on-the-ground relief workers, who through the use of portable GPS units were able to load the latest OSM information onto their screens and contribute back to the VGI mapping efforts via email, social media and the Internet. The rich attribution that was possible through this ground truthing mechanism was dynamically created in OSM through a tagging procedure. Not only were roads or other types of infrastructure mapped but through the use of eyes on the ground, attributes such as road conditions, locations of IDP camps, the types of camps (organized or spontaneous), the type of material a building or road is made of, the type of damage caused by the earthquake (landslide, collapsed building etc.), the visible structural integrity of bridges and their estimated weight limit were all added to mapped features. While some individuals who were on the ground in Haiti added to the OSM Haiti database, aid organizations such as the International Organization for Migration supported the OSM project by paying surveyors to add to the database (Soden and Palen 2014).

It is particularly important that the use of these attribute tags was not based on some predetermined schema for disaster relevant attribution such as the United Nations Spatial Data Infrastructure for Transportation, but was determined through a cooperative and open effort throughout the OSM mapping community similar to how an entry in Wikipedia is edited and the headings are determined. As a result of a revision of possible tagging schemes mainly through the Humanitarian OSM Team (HOT), tags which were not previously part of the accepted/standardized attributes such as "impassable" were added for the benefit of humanitarian work (Neis et al 2010).

Given the relationship between mapping and humanitarianism set forth so far in the context of Haiti, a question that needs to be answered to better understand a background on the Haiti mapping efforts is: why did the context of a natural disaster in Haiti lend itself to VGI and humanitarianism? Another way to ask this question is, why did OSM become the de-facto map source for relief agencies? While this question is much too big to fully answer in this dissertation, a few points can be made. First, and this likely cannot be emphasized too much, the earthquake struck in one of the most populated urban areas of Haiti as well as its seat of government. The results of this from a logistical standpoint is that a high percentage of the people who could have helped coordinate and manage relief work from within the Haitian government were dead. Second, and perhaps equally as important, Haiti has a long and storied relationship with former colonial powers that has led to a legacy of poverty, a destabilized Haitian government and continual interference by foreign governments (Pinto 2010). These historic conditions and the current complicity of wealthy nations –especially the U.S.- in creating profound economic disparities in Haiti have very real effects tied to why Haiti became the poster child of crisis mapping. For instance, it stands to reason that if Haiti had been less institutionally poor, far fewer deaths would have resulted from substandard building practices. This is turn might have not only meant that more of Haiti's government would have been alive to aid and direct the relief efforts, but perhaps all of the map data that was buried under the ruble might have been readily available. This would have greatly reduced the use and acceptance by the relief agencies of OSM Haiti data.

**Crowdsourcing and the ideologies of crisis mapping**

In the crisis mapping response to the Haiti earthquake there are many examples of volunteer and technical communities (V&TCs). There are the already mentioned examples of OSM, Ushahidi, the 4636 alliance, as well as CrisisMappers –a community of participants involved in coordinating crowdsourced geospatial humanitarian tools with members from UNOSAT, Google, GeoEye, Digital Globe, OSM, and the San Diego State University Visualization Lab. What these and other V&TCs have in common is a basic approach to information gathering known as crowdsourcing. Based on the role that V&TCs have played in the Haiti disaster relief work with some humanitarians going so far as to say "what we did in Haiti changed disaster response forever; I don't know if I can overstate that" (Johnson et al 2010), it is important to investigate crowdsourcing in the context of a crisis situation.

The term crowdsourcing commonly has two parlances, one to describe the belief that a problem solved by a group of people is more effective than by one expert, the other is used in respect to the position that the more people contribute to an observation on a topic the more accurate the observation is. In relation to geographic information and humanitarian spatial data crowdsourcing can be defined as the leveraging of citizens as sensors for disaster relief

(Goodchild and Glennon 2010). In this humanitarian context, it is also about the stunted effectiveness of traditional state responsibility for gathering information where DIY efforts such as crowdsourcing fill the absence of an effective State and/or provide alternative accounts of disaster relief. Simply put crowdsourcing is the desire to solve a problem and sharing the problem with as large a number of persons as possible in order to get at a solution. Through digital technology a problem is shared across a global network –predominantly the Internet.

Crisis Mapping is a term used to denote the crowdsourcing of disaster mapping operations especially through web-based applications. Liu and Ziemke (2012 p71) say,

> "*Crisis mapping* is both a new field and an engaged network of people from the government, the technology industry, academia, humanitarian and human rights organizations, and news agencies. They are united by their common interest in leveraging ICTs [Information and Communication Technologies] to help visualize, understand and respond to crisis events of all kinds. Crisis Mappers create visual representations of the discrete, individual crisis events that, when aggregated together, make a Crisis Map. The best Crisis Maps are compelling, multi-layered interfaces that offer a window into the situation on the ground. End users have at their fingertips a wide range of analytic tools to help make sense of these Crisis Maps. Finally, Crisis Maps are used by the community and emergency responders to help save lives and coordinate relief efforts."

Crisis mapping is now a cross-disciplinary field that has three areas of focus: crisis mapping sourcing, crisis mapping analysis, and crisis mapping response (Liu and Palen 2010). Given the mapping implications of crowdsourcing, crisis mapping can also be said to possibly offer a differing point of view from traditional governmental relief agencies since crisis mapping involves opening up data generation to persons not directly affiliated with disaster relief.

Since much of the crisis mapping in Haiti took place through the efforts of V&TCs, it is helpful to examine what ideologies influence their use of VGI. VGI and Web 2.0 ideas have taken traction through a culture of participation, Web 2.0 advocates will simultaneously point to a democratization of knowledge and the extraction of voices that are not normally heard. Implicit in this rubric is an ideal that representative democracy is best served when the greatest number of citizens participate in the decisions of a community (Saco 2002). Simultaneously implicit is an individualistic beneficence for the users of Web 2.0, as the more one contributes, the more tailored to ones needs the knowledge garnished by a Web 2.0 application serves. It is therefore assumed that typically contributors to VGI benefit from any addition made in a database such as OSM. Often V&TCs involved in crisis mapping who use VGI and Web 2.0 technologies share these same ideals of democratization of knowledge production.

Furthermore Web 2.0 technologies and their production of the social space designed to mediate between the virtual and the material has promoted certain democratic ideals (i.e. participation, wisdom of the crowd, creativity though cognitive surplus, collaboration) and have specifically brought about ideal of openness. An open paradigm in relation to data means the level of accessibility to the source of the product. The Web 2.0 movement is closely associated with the free and open source software (FOSS), movement opposed to copyrighting (Crampton 2010). FOSS software is typically designed to grant a user full access to the source code and the right to use, change, or re-use the software as the user desires. Ushahidi is an example of a V&TC that espouses the philosophical ideals of crowdsourcing and open source through the adoption of "openness, transparency, collaboration, sharing, and a dynamic decision-making process" (Norheim-Hagtun and Meier 2010).

To better understand the ideological processes at work in crisis mapping, several questions can be asked within the context of OSM, Ushahidi and the 4636 project. First, did the use of crisis mapping in the already established humanitarian relief effort involve additional voices in the mapping process, especially those affected by the earthquake? Secondly, what did the addition of crisis mapping to the Haiti relief efforts change about humanitarian mapping?

*Does crisis mapping foster additional voices than traditional relief mapping?*

The first question's goal is to examine whether the Haitians themselves were involved in the participatory culture of crisis mapping. This is important given the democratic ideals mentioned previously as often important to VGI and Web 2.0. For the response to the earthquake in Haiti, it is clear from the narratives involving Ushahidi and the 4636 project, that had cell phone technology not been there, crowd of volunteers unable to translate or locate the position of those requesting aid, that a measure of voicelessness would have indeed taken place. Traditional humanitarian agencies such as the UN readily admit that they were not capable of transferring new forms of cries for help from social media outlets into action (UNF 2011). The UN likely had preferred formats of communication that it was prepared to listen to but cell phone technology was not one of them. In contrast, the group of volunteers who translated the SMS messages sent to the 4636 shortcode and other forms of communication likely had direct personal experience with living in Haiti. Indeed of the over 1000 estimated volunteers who translated the 1000-2000 daily text messages pouring in to project 4636, most of them were expatriate Haitians living in the U.S. and Canada (Heinzelman and Waters 2010).

Despite the clear increase in communication technology, there are several shortcomings that the crisis mapping model demonstrated. First of all, if the numbers for cell phone users are examined closely somewhere around 35% of the 3 million estimated persons affected by the earthquake had cell phones this possibly means that over a million cell phones were available to those in need of aid. While it is not a likely assumption to think that the 35% cell phone distribution was spread out evenly through the entire population of Haiti, and that of the more or less 1 million cell phones all of them were operational (charged, had a signal etc.), no number exists about the actual diffusion of the knowledge about the 4636 project amongst the affected

Haitian population. What is known is that somewhere around 80,000 SMS messages were received in total by the 4636 project following the months after the earthquake. A preliminary estimate would be that 13% of those affected by the earthquake who had cellphones each sent out a message communicating information to humanitarian agencies. However, what is more likely is that a much smaller number was communicating more frequently than others especially given the figure that 85% of households had access to cellphones. While this could mean that each message counts for the voice of two or three persons there is clearly a need to investigate the effectiveness surrounding the results of the Ushahidi and 4636 projects.

A second point to be made about the participatory culture of crisis mapping comes from the nature of humanitarian work as it is known today. Of the 25,186 text messages received by project 4636 within the first month of the earthquake, 3,596 reports were mapped and subsequently used by relief workers on the ground (Heinzelman and Waters 2010). This means 14% of the incoming communications were deemed important enough to place on a map for aid agencies to utilize. This second point leads to a logic of triage which needs to be further explored.

The technology offered by the Ushahidi process is perhaps a new manifestation of triage to be explored but it is still scripted by socially constructed narratives that manifest and interpret the body of the Haitian in need. As Redfield (2008) notes, triage represents, “a system of prioritization based on the facts of suffering themselves” (p197). What is problematic about triage is that humanitarian agencies make claims “resisting justifications for human suffering and insisting on the significance of life. At the same time, however, humanitarian practice involves a form of triage” (Redfield 2008, p 213). While this quote is referring to the practice of medical triage, triage by the Ushahidi and 4636 projects is clearly evident. Furthermore the VGI efforts by those contributing to the OSM database in Haiti post-earthquake participated in a form of triage by assessing what was important and what was not in terms of what to map to the OSM database.

That the dynamics of the triage in Haiti were different originate from the fact that is that it is not clear who was performing the triage. Unlike various forms of triage where persons in situations of need perform specific tasks in conjunction with medical experts to gain perceived benefits (Ticktin 2006), the Ushahidi approach seems to be different. Instead, as a special report from the United States Institute of Peace documents:

> "As messages were translated and tagged with preliminary coordinates by the diaspora, they were sent through the Internet to the Ushahidi-Haiti platform. There they were reviewed, clarified, and approved by more than 100 student volunteers who had participated in impromptu trainings. Urgent reports were often flagged by 4636 volunteers and triaged to a small team of volunteers at the Fletcher School who had a direct line of communication to the U.S. Coast Guard" (Heinzelman and Waters 2011 p 8).

However, this does not mean that the triage by the 100 volunteer students mappers was in any manner creating a new dynamic of participation which filters any less or any more than what is commonly constituted as an appropriate response towards "suffering bodies" (Ticktin 2006).

An interesting example of this dynamic of triage comes from a report that, "overall 70% of the information [SMS messages] that came in about people being trapped was unreliable. Many people fully understand that their family members are dead, but want us [USAR teams] to come to bring out the bodies" (UNF 2011 p 43). This example illustrates that while the voice that is enabled by crisis mapping technology (eg. harnessing SMS messages) is perhaps a "two-way communication [which] creates a different dynamic around accountability and responsiveness" (UNF 2011 p 13), the democracy of this context is no more different since dynamics of power between having a voice and having a say (on for example how the aid is distributed) may still be the same. If all the messages sent by the Haitians are published in real-time online (as an open-data paradigm would desire) the accountability for humanitarian aid would indeed be less 'in house'. However, caution must be followed in taking the next step of assuming that the digital voice of Haitians affected by the earthquake is being utilized in a matter to satisfy a democratic ideal of equal say.

If one looks at the some of the reports issued after the earthquake closely, the power dynamics of having a published account of the voice of Haitians are seemingly still the same (humanitarian agencies hold the power, those who suffer don't). For example despite the widely published accounts of suffering,

> "Attempts by civil society leaders to provide information in person were also thwarted. Standard protocols prevented community leaders, who could have been valuable key informants, from entering the UN Logbase where local conditions were discussed and decisions made. To enter, individuals needed to be affiliated with international organizations and/or response "clusters," or groupings of international organizations around a specific sector or service area, and carry an identification badge from organizations approved by the UN Office for the Coordination of Humanitarian Affairs (UNOCHA)" (Heinzelman and Waters 2011 p 3).

Likewise, well published accounts from the ground through Ushahidi were not able to dispel exaggerations on the part of journalists from the international media claiming violence and looting on the streets of Port au Prince (Heinzelman and Waters 2011). These misrepresentations caused delays in aid until accounts of violence were verified.

*What does crisis mapping change about the fundamentals of humanitarian mapping?*

This leads to the second question to be explored in the context of Haiti: what about humanitarianism changed with the addition of crisis mapping? It is helpful to think through what has probably not changed to then examine what is possibly different. To be clear, the example of the Ushahidi triage previously given is different from the crisis mapping that took place in OSM

Haiti. Yet, as is demonstrated in the following section the crisis mapping on the OSM Haiti database is no less subject to the triage seen in Ushahidi.

As stated previously, the involvement of V&TCs and the use of VGI in the humanitarian efforts of Haiti did not change some ethical dynamics with how the voices are gathered or what was done with the voices once they were gathered. In the case of crisis mapping many problems still exist. This is important to discuss since the OSM database has been praised as a triumph of VGI, creating a robust GIS basemap in days (Johnson et al 2010). Indeed the fact that all UN agencies in Haiti used OSM as their de facto spatial data is indeed an accomplishment in itself. However a distributed, less formal and more collaborative mapping effort is still an interpretive process especially when humanitarian aid is at stake.

For instance, the primacy of satellite imagery is important for understanding what can and cannot be mapped in the context of humanitarian efforts in Haiti. No matter how much interaction there could be between the estimated 640 mapping volunteers (UNF 2011) and the aid workers on the ground many structures seen from a bird's eye view are not easily understood without local knowledge. In fact there is clearly a dialogue in this dynamic where the drawing of geometry of structures informs its attribution and vice-versa. Members of OSM who formed H.O.T, acknowledged this disparity and therefore raised money to send people to Haiti to increase their humanitarian effectiveness and ultimately increase their community (Soden and Palen 2014). Even with the understanding that, "to get any information, you have to be on the ground. You have to walk around and ask people for it" (UNF 2011 p 39), it is important,

> "…to always recognize that user-generated [crowdsourced] content will provide only selective representations of any issue. While these representations may be highly useful to aid workers, it should not be forgotten that there will always be people and communities that are left off the map. Medical and health workers should therefore always be aware of the

> geographical inequalities in any crowdsourced data in order to ensure that the technologically disconnected are not denied crucial services that they may need" (Zook et al 2010).

The point made earlier that the Ushahidi crisis mapping triage was not performed by healthcare practitioners, or likely persons accustomed to triage in a crisis situation, has further implications. When a healthcare practitioner performs triage the process takes place typically in close proximity to the person being triaged with the health related repercussions generally known by the person performing the triage. The same cannot be said of those doing crisis mapping. The 'proximity' of map selection in database creation is likely to be the cartographic imagination of what constitutes the features to be captured given some goal of data capture (ie. all the roads of a certain size, all the primary schools etc.). While a bird's eye view of mapping coupled with a lack of local knowledge is interpretive enough, the Budhathoki and Haythornthwaite (2012) research showed a clear male dominance in the OSM community, creating a disparity in gendered knowledge as well (Cohen 2011). Prudence is therefore suggested when examining what type of voice is being enabled through crisis mapping.

While a critical analysis of crisis mapping may seem overly negative, there are many areas of unknowns where possible differences can exist in respect to traditional humanitarian practices. For example, even though there is a filtering of messages from the populations in need of aid, the culture of openness of crisis mapping does lend itself to a scrutiny by a large selection of actors in aid relief. This is a movement towards democratization. Humanitarianism performed in a culture of collaboration and transparency does perhaps promote the involvement of more diverse communities which in turn could change the way relief workers interact with those in need of aid as power is made more diffuse (Ticktin 2006). The beginnings of this is seen in reports that Ushahidi, project 4636 and OSM helped lives to be saved that would not otherwise have been, and aid to be diverted to unexpected areas which typical humanitarian data gathering metrics would have not identified (UNF 2011).

### Summary

When the earthquake in Haiti created a space where usable map information was needed, crisis mappers stepped in with VGI to fill the gap of geolocated data. The efforts of crisis mappers were made possible through technologies developed during both Web 1.0 and 2.0 eras. The volunteerism of crisis mappers has been argued to be a bottom up approach to mapping that relies heavily on collaborative communities. At the same time that V&TCs through the paradigms of openness and crowdsourcing changed the logistics of humanitarianism (this much is clear), it also entered a politics of life constituted through triage which manages populations in humanitarian crises. Therefore, the proposition that Ushahidi, project 4636, OSM and all the other V&TCs involved in aiding Haitians enabled volunteerism in amazing levels, spreading voices in ways that traditional relief agencies were not able to do logistically, with results that were life-saving does not guarantee that sacred human rights were always and equally upheld.

Taking a step back from humanitarianism, questions such as why Haiti's government, infrastructure, and population were so affected by an earthquake when other countries such as Chile suffered far fewer loses in the face of a natural disaster of similar strength begin to locate the needs of humanitarianism contextually but also globally. As such the relationship of crisis mapping to humanitarianism reveals itself to be full of processes in motion that constitute limiting factors when lives are at stake. The next chapter will therefore delineate an investigation of some of these processes through a mixed-methods approach involving a survey of OSM Haiti users, interviews with OSM Haiti users who went to Haiti as part of crisis mapping, and a Modified Content Analysis.

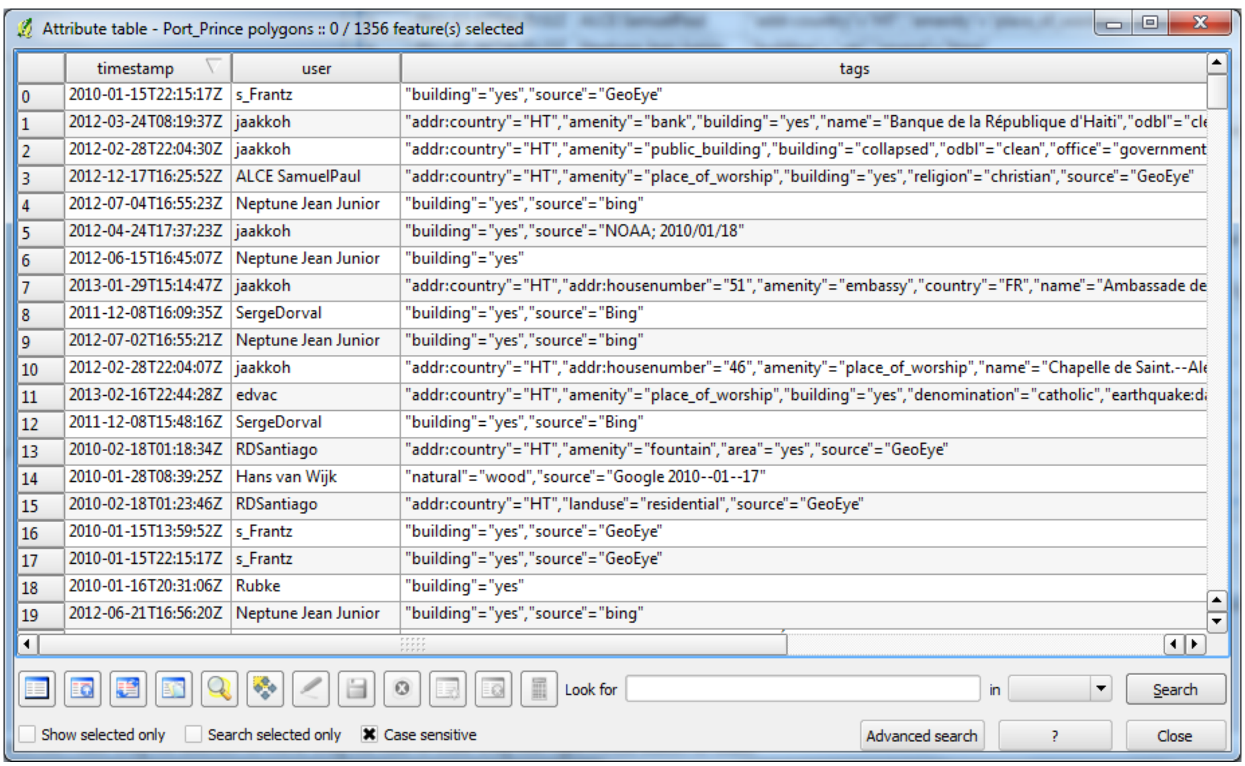
# Chapter 3
# Analyzing the OSM mapping process in pre- and post-earthquake Haiti

## Introduction

This dissertation employs a mixed methods approach to analyze the creation and editing of a portion of the OSM database. The OSM map-making process is considered to be a typical example of VGI mapping practices. Analyzing OSM's database helps describe what others have named as a new form of mapping practice, as discussed in earlier chapters. To analyze the content of a spatial database a researcher is faced with many options. Since the content of a spatial database often includes the collection of coordinates assembled into points, lines, and polygons, an analysis can be geographic in nature. Geographic databases also organize many types of attribute information that can be associated with coordinates. Attribute data can be qualitative or quantitative and therefore someone examining a spatial database has a variety of possible tools available depending on the category of the data organized by a spatial database.

A common simplistic distinction between quantitative and qualitative research paradigms is that the former deals with numbers while the later does not. Pavlovskaya (2006) claims that geographers still hold the distinction that quantitative methods deal with advanced statistics and spatial analysis while qualitative methods deal with softer data such as informal semi-structured interviews. Likely, as Pavlovskaya (2006) claims, the distinction is really more of a continuum of tools available depending on the needed information. Furthermore, quantitative and qualitative "…approaches to knowledge production are not mutually exclusive but different ways to do research" (Pavlovskaya 2006, p2004).

The OSM database is designed to allow both qualitative and quantitative data capture. In Figure 3.1, a screenshot shows the attribute table for polygons in the OSM database for Haiti. As an example, the column “tags” stores the attributes added to a feature by the person creating it or updating it, and shows a majority of nominal data. Furthermore, in Figure 3.1 row 2 shows among other details that the polygon represents a public building that is collapsed, that it came from GeoEye (now Digital Globe) and that the building is collapsed and that it is a government office. Quantitative data is also stored in the form of timestamps, geometry such as coordinate pairs, and in the attribute table in the form of address marker, number of people in a refugee camp, the voltage going through a mapped power line etc.



Attribute table - Port_Prince polygons :: 0 / 1356 feature(s) selected

| | timestamp | user | tags |
|---|---|---|---|
| 0 | 2010-01-15T22:15:17Z | s_Frantz | "building"="yes","source"="GeoEye" |
| 1 | 2012-03-24T08:19:37Z | jaakkoh | "addr:country"="HT","amenity"="bank","building"="yes","name"="Banque de la République d'Haiti","odbl"="cle |
| 2 | 2012-02-28T22:04:30Z | jaakkoh | "addr:country"="HT","amenity"="public_building","building"="collapsed","odbl"="clean","office"="government |
| 3 | 2012-12-17T16:25:52Z | ALCE SamuelPaul | "addr:country"="HT","amenity"="place_of_worship","building"="yes","religion"="christian","source"="GeoEye" |
| 4 | 2012-07-04T16:55:23Z | Neptune Jean Junior | "building"="yes","source"="bing" |
| 5 | 2012-04-24T17:37:23Z | jaakkoh | "building"="yes","source"="NOAA; 2010/01/18" |
| 6 | 2012-06-15T16:45:07Z | Neptune Jean Junior | "building"="yes" |
| 7 | 2013-01-29T15:14:47Z | jaakkoh | "addr:country"="HT","addr:housenumber"="51","amenity"="embassy","country"="FR","name"="Ambassade de |
| 8 | 2011-12-08T16:09:35Z | SergeDorval | "building"="yes","source"="Bing" |
| 9 | 2012-07-02T16:55:21Z | Neptune Jean Junior | "building"="yes","source"="bing" |
| 10 | 2012-02-28T22:04:07Z | jaakkoh | "addr:country"="HT","addr:housenumber"="46","amenity"="place_of_worship","name"="Chapelle de Saint.--Ale |
| 11 | 2013-02-16T22:44:28Z | edvac | "addr:country"="HT","amenity"="place_of_worship","building"="yes","denomination"="catholic","earthquake:da |
| 12 | 2011-12-08T15:48:16Z | SergeDorval | "building"="yes","source"="Bing" |
| 13 | 2010-02-18T01:18:34Z | RDSantiago | "addr:country"="HT","amenity"="fountain","area"="yes","source"="GeoEye" |
| 14 | 2010-01-28T08:39:25Z | Hans van Wijk | "natural"="wood","source"="Google 2010--01--17" |
| 15 | 2010-02-18T01:23:46Z | RDSantiago | "addr:country"="HT","landuse"="residential","source"="GeoEye" |
| 16 | 2010-01-15T13:59:52Z | s_Frantz | "building"="yes","source"="GeoEye" |
| 17 | 2010-01-15T22:15:17Z | s_Frantz | "building"="yes","source"="GeoEye" |
| 18 | 2010-01-16T20:31:06Z | Rubke | "building"="yes" |
| 19 | 2012-06-21T16:56:20Z | Neptune Jean Junior | "building"="yes","source"="bing" |



**Figure 3.1**. Screenshot of a polygon feature class attribute table for Haiti in the QGIS software

## Methodology Overview

Since the OSM data stores and utilizes numeric and descriptive data it makes sense to employ a mixed methodology which blends both qualitative and quantitative approaches to analysis in trying to understand a mapping process at the database level (Cope and Elwood 2009). Mixed method approaches are often used sequentially and interactively at different stages of analysis. This dissertation first records some of the experience of crisis mapping on OSM Haiti through interviews and a survey of OSM users who were involved with the mapping process the. A second level of analysis is performed through a Modified Content Analysis as a means to analyzing crisis mapping in the OSM Haiti database. A third level analyzes the spatial distribution of the geographic objects in OSM Haiti especially as they progress through time. Before explaining the three levels of analysis, this chapter describes several; data pre-processing steps necessary to acquire, convert and dissect the data.

### Data Pre-Processing Steps

The main OSM database currently utilizes a PostgreSQL Open Source relational database system to store and manage all its data (http://wiki.openstreetmap.org/wiki/Database). While PostgreSQL has native data elements for geographic data, the OSM community elected to create their own data elements or primitives (http://wiki.openstreetmap.org/wiki/Data_Primitives). The three elements that organize the entirety of the OSM database include: Nodes, which define a point in space; Ways, which define linear and areal features; and Relations, which are ordered lists connecting nodes, ways, and other relations. In addition to the three elements, tags associated with each element describe what each element represents. For every data element several attributes are stored including but not limited to an ID number, a username of who last modified the element, a timestamp of the last modification, the version of the element, and the changeset in which the object was created. A full editing history of every element is stored in the database as well (http://wiki.openstreetmap.org/wiki/Data_Primitives).

Changesets are defined as a change or group of changes made to the OSM database by one particular user. The current version of the OSM editing application programming interface (API) limits the length of time that a changeset can take to 24 hours and also limits the number of features edited in a changeset to 50,000 (http://wiki.openstreetmap.org/wiki/API_v0.6). In particular, the Content Analysis and Spatial Analysis methodologies examine changesets one month before and six months after the Haiti earthquake of January 12th 2010. In Chaper 2, Figure 2.3 demonstrates three time slices spanning less than two weeks for OSM Haiti showing Port-au-Prince with all changesets loaded. Examining changesets before and after the Haiti earthquake provides a descriptive link between what is archived in the OSM database and the crisis mapping process.

Downloading the most current version of the OSM database for a given country is a simple task of going to a website (e.g., http://downloads.cloudmade.com/ or http://download.geofabrik.de/) which hosts that information, downloading it, and opening the data in a software package which supports the chosen data type. QGIS and ArcGIS each have an extension that can read OSM data formats such as .osm or .xml. GeoFabrik (2013) for instance has a free download service that extracts OSM data separated by continent and also further divided by region and country. What is much more difficult is to access changesets or the historical versions for a feature or area. Mooney and Corcoran (2011) describe an automated method for extracting changesets from the OSM API. The steps include: identifying the objects of interest in the most current version of the OSM database; for each object querying and downloading its history in an OSM-XML format; and finally joining both the objects' geometry and history into a PostGIS database. PostGIS contains a set of extensions that enable spatial objects for an object-relational database format called PostgreSQL (http://postgis.net/).

**Accessing, Reducing, and Converting the Data**

Since there does not exist ready to use software to simply download a portion of the OSM database that also contains historical edits from a certain timeframe, open source toolsets were explored. Stated differently, it was necessary to create personalized versions of the OSM database containing all the historical edits using scripting functions of various toolsets. This personalized version needed to contain a subset of the OSM database composed of changesets and data representing Haiti.

The OSM Planet contains all the OSM data in one file and is hosted by several ftp mirrors. Commonly the OSM Planet file contains only the latest revision of each element at the moment the OSM Planet file is generated. A reproduction of the OSM Planet File was created for each day during the study period. Several steps are therefore involved in recreating these reproductions. First, a copy of the OSM full history file (http://wiki.openstreetmap.org/wiki/Planet.osm/full) is downloaded. The OSM full history file is as the name implies a file which contains all the previous versions of every single item in OSM. At the time of this research, the Planet file containing data without the previous historical versions is over 500GB. To query the OSM full history file and retrieve changesets from the database, an open source toolset named osm-history-splitter is used (https://github.com/MaZderMind/osm-history-splitter). As the name suggests the tool is designed to split a full history planet file. While the tool has several options for how to split the database, the data is extracted within a rectangular footprint encompassing Haiti to produce a more manageable file. This process is surprisingly difficult and time-consuming as has been noted elsewhere (Mooney and Corcorran 2012). Each OSM Element (nodes, ways, relations) is assigned a unique identifier reflecting when it is first created. The OSM Full History File contains each revision of each object differentiated by a version number and timestamp field. A custom Python script was written that utilizes these timestamps to filter the reduced file, therefore reproducing an OSM Planet file for within the Haiti bounding box footprint for each specific date. The custom Python script read the history file and output only the latest revision of each element up to and including a specified date. This script was run for each date from December 12, 2009 to June 12, 2010 and produced 183 files in the native .osm file format. These 183 files are termed time slices for this dissertation. Time slices are defined as temporal partitions of the OSM history file.

A total of 183 versions of the OSM Haiti database were imported from native OSM file format .osm into ArcGIS Desktop. The file geodatabase format was chosen as the target file type since it preserves topology, can store feature datasets, themselves forcing all the feature classes they hold into a certain projection, and most importantly has no size limits in terms of storage and in terms of numbers of attributes in the attribute table. In order to convert the files into a file geodatabase format, ESRI released the ArcGIS Editor for OpenStreetMap as a toolbox to its software (http://www.esri.com/software/arcgis/extensions/openstreetmap) and was therefore be used in the geoprocessing environment.

The use of the ArcGIS Editor for OpenStreetMap to convert data from the XML (.osm) data format to the geodatabase (.gdb) format results in several translational difficulties. First, the .osm format does not store data in the traditional point, line, and polygon geometries utilized by ArcGIS. Rather, the OSM database stores data as nodes which are analogous to points, ways that are analogous to lines, and relations that are a description of a group of features that together form an entity and has no simple analogous data structure for ArcGIS. The closest analogous data structure for ArcGIS is a multipart feature that allows for multiple geometric objects per one set of attributes in a database. The difference however, is that relations are actual objects in and of themselves and can point to nodes, ways and relations all in the same relation. Multipart feature classes in ArcGIS are always comprised of the same geometry.

Second, another challenge that exists is converting OSM's tagging to a normalized relational database such a geodatabase. Since OSM features can have an unlimited number of tags per feature, the ArcGIS Editor for OpenStreetMap only auto generates an attribute table for the feature class it is converting based on a preset list of commonly used keys. The entire list of key/value pairs are currently stored in the attribute table as a binary large object or BLOB field. Therefore, while no tags are lost in the conversion process, unless the key/value pair are in the preset list of keys that will be explicitly added to the attribute table, a large portion of valuable data is not easily accessible. Fortunately, the toolbox has a tool to extract every single key/value pair in the BLOB field and explicitly display them in the attribute table. While this tool is helpful for making all the tagging data visible, it creates extremely large attribute tables because every key stored in the tagging schema is given its own unique column in the table. Therefore if a converted OSM feature class contains thousands of features and many have unique keys, the resulting attribute table can become unwieldy not because of the sheer number of rows representing each feature in the feature class, but also because of the hundreds of columns representing each unique key. A Python script iterates calling both the tool that converts the OSM data into a geodatabase and also the tool to extract all the tags into the attribute table.

Since the OSM data was now converted to a native ESRI data format, from here onward, this research utilizes GIS tools in the ArcGIS Desktop 10.1 suite and when a tool is mentioned it is almost always called from a Python 2.7 scripting environment. A task that is specific to this research is the removal of duplicate nodes in the converted geodatabase. When the ArcGIS Editor for OpenStreetMap converts a stand-alone .osm file it places all the converted data into one feature dataset itself a collection of features designed to organize feature classes into a common coordinate system. The conversion tool automatically generates five datasets: feature classes for points, lines, and polygons, and tables for relations and for revisions as is seen in Figure 3.2. Filenames that end in "revisions" contain a table that keeps track of edits within the feature dataset so that if a user wishes to convert the data back to an .osm format and upload it back to the OSM server, the ArcGIS Editor for OpenStreetMap uploading tool can know what changes were made (CodePlex 2012). The problem itself arises because of ways. Ways are actually an ordered list of nodes (http://wiki.openstreetmap.org/wiki/Way) that are translated into the feature dataset as either lines or polygons. If a way comprises a list of nodes where the first and last node are different then it is considered a line. If the first and last nodes of a way are the same, the way forms a loop and is considered a polygon.

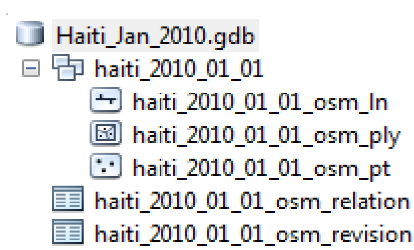



**Figure 3.2** ArcCatalog screenshot of a converted .osm file in its geodatabase format. The feature dataset holds the converted point, line, and polygon geometry of the original file

After the ArcGIS Editor for OpenStreetMap converts the OSM data into the feature dataset it places the nodes into a point feature class, open ways into a line feature class and closed ways into a polygon feature class. The difficulty with this method is that a large amount of redundancy exists in the point feature class since the tool doesn't take a node out of the point feature class if it is being used as a line or polygon elsewhere. The point feature class therefore essentially contains what would be analogous to all the vertices in the accompanying line and polygon feature classes, and therefore contains redundancy where those vertices intersect the point feature class. Since a later goal in this methodology is to count the edits made to the OSM Haiti database on a day by day basis, it is important to not count an edit in both the point feature class as well as the line or polygon feature classes when the point is a duplicate of the line or polygon vertice.

While the OSM data elements do indeed treat nodes/points as the basis for lines and polygons and therefore give nodes equal status to the line they are being used to represent, the actual mapping experience of the OSM database follows a similar experiential model as the point line and polygon view of vector geographic objects. For example, while adding to the OSM database by digitizing a satellite image, no version to date of the more popular OSM editors (JOSM, Potlach1/2, ID, Merkaartor, OSMAnd, etc.) asks a user when creating a way to first map the nodes and then to go back and re-categorize them as a way (although one can certainly do this). Rather the editors all have tools that draw lines and polygons where vertices are added, as the lines and polygon sides are being drawn. JOSM is perhaps the only exception to this rule as it contains one primary tool for mapping geometric objects, but as Figure 3.3 demonstrates, even this tool has a built-in interface that shows line or polygon objects when drawing more than one connected node. Given this, the conversion from the native nodes, ways, and relates format to the points, lines, and polygons geometry formats gains credence as reflecting a viable manner that OSM mappers are experiencing feature geometry.

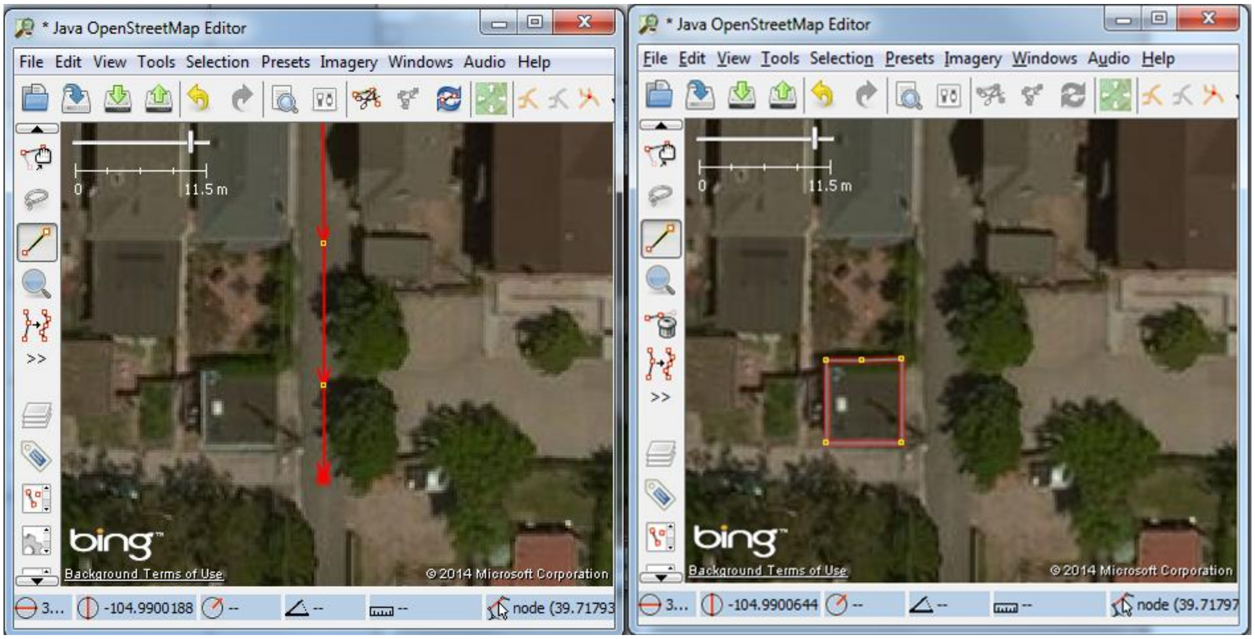



**Figure 3.3** Screenshot of JOSM editor using the Draw nodes tool. The left pane shows a way in the process of being drawn, while the right pane shows a polygon being drawn. While it is clear that both objects are comprised of nodes (small yellow squares), they also being displayed as lines and polygons.

To reduce the data volume as well as to make sure that the point feature class didn't contain duplicate data, a Python script was written to iteratively remove redundant point data. Redundancy in the point feature class is accounted for by using a spatial intersection with the lines feature class and another spatial intersection to check if the points touch the boundaries of the polygon feature class. If points meet either intersection criteria, the points are removed from the point file as redundant.

A final data reduction step is to select only features within a certain distance from the boundary of Haiti. As was stated previously, features from the OSM planet file were selected based on a rectangular footprint. To further reduce the amount of data the datasets were iteratively selected on location within a certain distance of the Haiti border. A visual inspection of several OSM datasets revealed that the large majority of features tagged as being in Haiti, were within 3 miles of the Haiti border. This is not unexpected as the previous OSM editors may have been using data with differing accuracies or didn't have access to a Haiti border polygon when they were mapping features and labeled them as being within Haiti even though the feature fall outside the border. As such a Python script was written to iteratively extract all features within three miles of the Haiti border.

**Identifying Database Differences**

In order to manage the 183 time slices efficiently for analysis, further pre-processing is necessary. When downloaded from the OSM database, a time-slice contains essentially all the cumulative features that are in the database for a defined timestamp and given footprint. In order to focus on the actual changes between the downloaded time-slices, files were created by subtracting each time-slice from the subsequent one. These diff files (abbreviation of difference) are defined as any feature that has been created, edited or deleted between two time-slices. In order to do this, a Python script was written to automate the creation of diffs. The basic process of diff creation is to find the time slice which directly follows the time slice being analyzed in order to analyze actual data differences and create the diff files. Since this research analyzes OSM Haiti on a day-by day basis, the Python script finds the day after and holds it in memory as a layer file. The script further iterates through each geometry type (point, line and polygon) creating spatial intersections to each of the corresponding original time slice feature classes. If for instance, a point exists in the original feature class but does not exist in the next day feature class, that feature is said to be deleted. If a point exists in the next day feature class but not in the original, that point has been added. However, if a point exists in the next day and not in the original there is a chance the feature is different from a spatial intersection perspective (does not have the same footprint) simply because the feature geometry has been modified or has moved locations as opposed to being a brand new feature.

The diff Python script identifies modified features first by joining features that were flagged as deleted to features flagged as additions based on the OSMID field. The OSMID field is a unique identifier for OSM features which lasts for the lifetime of the feature even if the feature is modified. If a feature is modified between days it will show up in both the delete and addition flagged features since it exists in the original but not in the next day feature class in a certain spatial footprint and exists in the next day but not in the original feature class as another spatial footprint. If these features share an OSMID then, they are necessarily the same feature but have been modified spatially. These features are classified as being modified and are removed from the list of additions and deletions.

The second method the Python diff script utilizes to identify whether a feature is modified is to look at a cumulative historical list of OSMIDs to see if features that have been tagged as additions are indeed new. Since the diff script up until now only compared a day and its following day, it is necessary to create a master list of all the OSMIDs as they are created to keep track of all the features in case a feature is modified over the period of several days or more. Technically, the modification of a feature spaced out over several days is not possible, since each database snapshot is made daily, each snapshot contains all previous edits, and once a feature is deleted it is not a simple task to add it back in to the database (http://wiki.openstreetmap.org/wiki/Undelete_node). Using this reasoning the modification of a feature can only happen between two successive days and since each database version carries all the features that have not been deleted, simply comparing the diffs between two days as was explained in the previous paragraph should capture all features that have modified geometry.

However, since the diff creation is taking place for data that has been translated out of the native .osm format, an artifact of this translation process is that features can be essentially modified several days after they appear to have been deleted. Figure 3.4 illustrates an example of this process. In Figure 3.4 between January 17 and 18, a series of points appear to have been deleted.

In actuality, if one looks closely at January 18, the points are identical to the vertices of a line. If the diff program did not take into account historical edits (edits done two days or more previously) then it would appear that the points in January 20 are new additions for the database, but as Figure 3.4 shows, the points have simply reappeared after the line has been deleted. If the

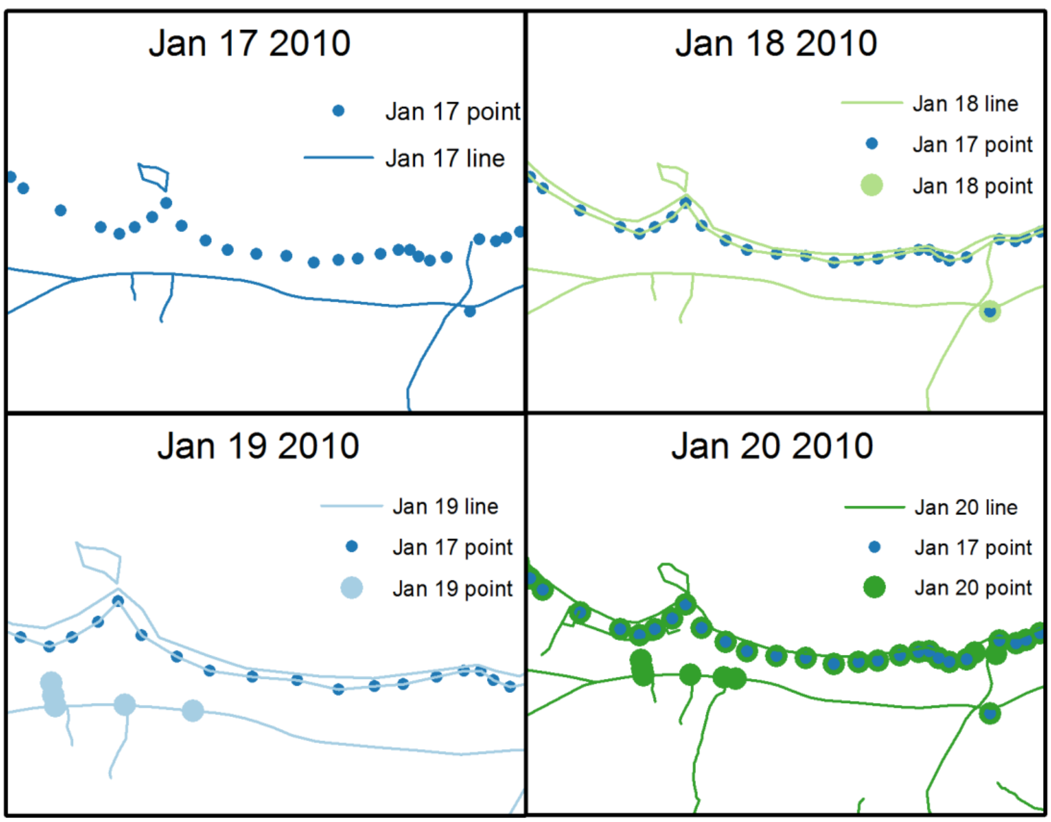



**Figure 3.4** An example of a historical modification. Between Jan 17 and 18 some lines have been added and all but one point in the lower right corner of the box have been deleted. Instead these points have been changed into the vertices of a line in Jan 18. This perseveres in the database until Jan 20 where the line has been removed and the points return from vertices to the point feature class.

diff program were written to function in the native .osm format, the only modification that would register would be that on January 18 a user added a way to the list of existing nodes and that on January 20 the way was deleted. However, as is mentioned previously, the ArcGIS Editor for OpenStreetMap places all the nodes in the point file regardless of if they are vertices for lines or polygons in the corresponding line and polygon feature classes of that same date. Since a previous step in this methodology is to essentially clean up points that are duplicates for vertices in the line and polygon files, this problem of points disappearing but not being truly deleted arises. As such, the Python diff script creates a cumulative list of all OSMIDs that have existed up to the day being queried. After features have been flagged specifically as additions and some are further flagged as actually being geometric modifications, the leftover additions are scanned against this cumulative list to ensure that they are actually true additions. If they are identified as being historically in previous versions of the database, they are not considered additions or modifications. For example Figure 3.4 the points that exist on January 17th, disappear on January 18th, and later reappear on January 20th should not be considered a deletion, addition or modification but rather a line was added and then deleted should be considered the correct difference.

So far the creation of diffs has been described as a process to identify day to day geometric additions, deletions and modifications. The changing of the tagging or attribute space is the last form of modification that constitutes an element of diff files. In this methodology if geometry is changed, it is assumed that tags were added or modified. Even if the tags are changed or if they are not, the geometry modification is recorded as the change of record in the database. If no geometry is changed or added between changesets, it is however entirely possible that a user simply changed or added the tags of a geometrically unchanged feature. Therefore the last stage in the diff files creation is to identify the features between changesets where the only change is the modification of the tags/attributes.

As is mentioned previously, the entire string of tags associated with an individual feature is stored in a BLOB field in the attribute table of the converted feature class. Within the diff Python script, a section of code was written to extract the contents of the BLOB field to compare them with the next changesets' corresponding individual feature. Since BLOB fields are data stored in a sequence of binary numbers, it is necessary to first translate the binary to a string. Fortunately Python has a built in function in the class of memoryview called .tobytes() which reads data in a memory buffer and returns the data as a bytestring, i.e. a string object(Python 2014). In this section of the diff script the cursor object in ArcGIS is used to retrieve information in a feature class attribute table row by row to compare to the corresponding feature in the next day timeslice. The cursor object itself returns a memory object which makes it simple for the .tobytes function to read the binary of the BLOB field as a string. Finally, if the strings are not exactly the same between the timeslices, then the feature of the day being queried is added to a list of features where only the tags are modified.

**OSM Haiti Human Subject Interviews and Surveys**

GIScientists have often utilized human subjects in their research. Leitner and Buttenfield (2000) utilized human subject testing to study how the inclusion of attribute certainty influenced decision making in a GIS. Mark et al. (1995) developed a series of subject testing protocols to refine computational models of spatial relations. Elwood (2009) used subject participatory research to explore how community organizations in Chicago utilize GIS. Kwan (1999) used human subjects as a direct source of geographic information by transcribing travel diaries into a

GIS to measure urban accessibility. Whether GIS academics explore how human subjects interact with spatial data models, how they utilize transportation networks in daily activities, or study human usage of GIS, human subject research is a widely accepted practice in the GIScience community.

There are many reasons for the involvement of human subjects in research on Volunteered Geographic Information (VGI). A common thread in VGI research is that individuals generate geographic information and often give that information over to another entity. Be it volunteers proactively adding data to the OSM database, to the passive collection of information via a smartphone app like Waze, volunteerism is a choice made by users. This choice is enabled through the design of Web 2.0 technologies to create an environment of "self-service" (Dodge and Kitchin 2013, p 22). It is therefore important when studying VGI to not only study the effects of this technology (in this case the "service" in self-service), but also to study the practices of mapping that propel it forward (the "self" in self-service).

The self-service that Dodge and Kitchin (2013) needs further elaboration for the process of map-making that takes place in OSM. Dodge and Kitchin (2013) describe self-service/egocentric map-making as essentially the process of creating and manipulating maps centered on a person's location with a certain amount of cartographic content choice (eg. Google Maps). In a scenario where two users create personalized maps, one using Google Maps, one using OSM, there is certainly an equivalent egocentrism involved. Both users want personalized results in a format that is easy to create. Furthermore, both users participate in the usage of a volunteered labor force within the paradigm of Web 2.0. The difference between OSM and Google Maps lies in the possibility of how individuals can interact with the data and in turn change it. While a Google Map user can define queries to search a map, the user cannot directly influence the database behind the map if one doesn't count the collection of user activity done by Google of people logged into their services (Kang 2012). Google Maps has a process to point out errors in its maps but Google staff determine what should be edited; and this is as far as it goes in allowing users to change its data.

The process of creating a map in OSM is not egocentric in the same manner. The personalization of OSM maps can be taken a step further. When using OSM data there is the possibility of changing the database to generate the map and therefore to change the map itself. Furthermore because of OSM's stated focus on local knowledge in data collection (OpenStreetMap 2014), there is an interesting interplay always in flux with both data production in OSM and the personalization of translating a user's geographic experience into a database. Every OSM user must perform this translation while at the same time being cognizant of the various communities that they are a part of (Eckert 2010). These communities could be local, ethnic, religious, or national –among many others. But always users are a part of the greater OSM community. How this affects the mapping process is a matter of some debate but at the least, how someone chooses to tag a feature in the OSM database (what language, alphabet, what tagging schema) will determine if and how that feature will be displayed by map renderers available to the user.

The geographic personalization of the OSM database in the form of local spatial knowledge is therefore always desirable but likewise in a form that can be used by the multiple communities. Not following the community tagging standards may result in an object not being rendered into a map; it is possible however for someone with advanced programming skills to create their own renderer and therefore display a database outside of accepted tagging norms. Local knowledge that falls outside the standard tagging schema can be captured and eventually rendered into a map. It is worth noting that the tagging schema is dynamic and changing as the community filters what it deems important to be placed on the acceptable tagging list after users make requests for certain geographic objects to be added. Despite the evolving tagging schema, there is reason to believe that local knowledge may still fall outside the standard tagging schema which can mandate the creation of a local ad-hoc tagging schema to be agreed upon by a local community of mappers (Deffner 2013).

What this exploration of tagging in OSM illustrates is the connection of self-service and community, and the complicated dynamics at play with VGI and OSM. If the exploration of tagging and self-service explains part of the complex VGI mapping process, involving the dynamics of mapping in Haiti after the 2010 earthquake complicates things even further. Initially, after the earthquake, the mapping for OSM Haiti was done by users with no local knowledge of Haiti in what amounts to mapping for presumably humanitarian purposes. Why users choose to take time to map in OSM Haiti is an important question to ask since it is currently unanswered and also explores the mapping process as it relates egocentric mapping (the self) to humanitarian crowdsourcing (helping the other). Therefore, in addition to a Content Analysis and a spatial analysis, the involvement of human research is beneficial to the methodological goal of this project: namely to better understand the mapping process behind post-earthquake OSM Haiti. If OSM Haiti can be considered as a digital library containing a history of mapping, learning about its authors is necessary to understand the process used to create the content. In this research project therefore, the human narrative is necessary for a more complete account of the mapping process used to create OSM Haiti. In order to achieve this, primary research data through mapper interviews and surveys allows for an analysis of motivation, impressions and a person's experience of this mapping practice.

Published estimates place the number of users who contributed to OSM Haiti at 600 (Chapman 2010, Soden and Palen 2014) a month after the earthquake. Johnson et al (2010) give the number of users to be 1,000. However it is unclear how Johnson et al (2010) arrive at the 1,000 number. In the Johnson et al (2010) presentation, an animation is shown of edits covering not only Haiti but also neighboring Dominican Republic. Perhaps the much larger number of 1,000 editors may be for OSM Haiti and surrounding areas; and as such, the number of 600 editors given by Chapman (2010) is assumed as a likely number of editors. While the number 600 only comes from the first month after the earthquake, Chapman's (2010) research also points to a rapid decline in OSM users contributing to OSM Haiti and therefore the initial assumption is made that this number will likely not increase much further as time goes on. In this research, a count of 503 users was discovered for the 7 month timeframe, and is therefore the number of users on which this research is based.

To conduct human subject research, a sampling of the OSM Haiti user population is taken and separated into two tiers. The first tier is comprised of individuals who mapped OSM Haiti during the temporal period of this study and who also travelled to Haiti during the same time period. This first tier contains a small group of key informants who were able to travel to Haiti for reasons to be explored in interviews. Tier 1 individuals are drawn from a list of people who have been identified as having been to Haiti in the OSM wiki (http://wiki.openstreetmap.org/wiki/Category:Users_in_Haiti). In this wiki roughly20 names are listed as OSM users who have visited or lived in Haiti. However after looking at OSM profiles of the usernames listed, it is anticipated that less than half of the 20 qualify for the research criteria of having edited in the database within the limit of 6 months after the earthquake. If approximately 10 users fit the criteria for Tier 1 and half are willing to be interviewed this would represent a 1% sample of the total population.

The second tier is comprised of individuals who contributed to OSM Haiti in the same temporal period but did not go to Haiti. The second tier is designed to sample the total population of the estimated 503 contributors to OSM Haiti within the timeframe of this study. For Tier 2 a target is made of a 10% sample size. A typical response rate for online surveys has been found to be ~40% (Hamilton 2009). However, in this research project it is assumed that OSM users may have a better than average response rate than the average person surveyed over the Internet since every OSM user has invested time into contributing to the OSM database. Moreover all the subjects in this research participated in a mapping project itself often credited with being an important disaster response tool, further increasing the chance of subjects having a personal stake in their work on the OSM database. However, the long period of time that has passed between the mapping event and this research may mitigate any possible increase in survey response rate. Given all this, it is anticipated that 125 surveys requests will need to be sent out for Tier 2 to achieve a target of 50 individual users who edited in the OSM Haiti database before and/or after the 2010 earthquake. This second tier will be chosen randomly from the entire list of users who contributed to the OSM database minus those who are in Tier 1.

Both tiers share operational procedures. First, for both tiers participant names, OSM usernames, or any other identifying identification is de-identified when reporting the results of the research. Secondly, initial contact for both tiers is made through the OSM messaging system. An account was set up for the purposes of this research in order to contact OSM users through the OSM messaging system. This is necessary since many users have not chosen to publicly display a personal email address on their username profile in the OSM wiki. However, the OSM messaging system is designed to forward messages to the email address that the user utilized to sign up for OSM in the first place.

Tier 1 involves semi structured interviews over Skype or in person if possible. An introductory message is first sent out via the OSM Messaging system and when a response is received, a follow-up message is sent, along with a copy of a list of potential questions to provide ideas for the interview. The questions are sent out ahead of time in order to give interviewees time to reflect on their involvement with OSM Haiti and also to give a sense of what the interview will focus on. A typical interview is expected to last between one to two hours. A copy of this list of questions appears in Appendix 1. Since it is expected that most people who went to Haiti after the earthquake in the timeframe of this research were going for humanitarian reasons, several questions ask about humanitarian involvement. Questions are intended to capture why a person went to Haiti, what was their background with OSM, and with humanitarian work. The questions further ask what the person's experience with mapping was while in Haiti and give space to reflect on their involvement with OSM Haiti.

Tier 2 utilizes surveys to capture in larger numbers the experience of those who mapped in OSM Haiti. Like Tier 1 an introductory message is first sent out via the OSM Messaging system. In this message a link to the survey is given, inviting the user to take the time to fill out the survey. The survey was created at www.surveymonkey.com and gave a total of 18 questions (Appendix 2). The questions were written to ask why users became involved with OSM, some of the details of their mapping such as frequency of mapping, which data sources were utilized, and their impressions in terms of whom the mapping benefited. The survey was left open for a month from July 30th 2014 to August 30th 2014.

**Content Analysis**

Content Analysis is a "…research methodology that utilizes a set of procedures to make valid inferences from text" (Weber 1985, p.9). Among other purposes, Content Analysis can reflect cultural patterns, reveal the focus of a group or individual, and describe trends in communication content (Weber 1985). Content Analysis is helpful to make inferences from text and also "inferences from data to their context" (Krippendorff 1980, p. 21 quoted in Rose 2001). Neuendorf (2002) explains that Content Analysis has its roots in the rhetorical analysis that early philosophers such as Aristotle applied to communication. Other early uses of classification systems similar to Content Analysis include concordances, which are collections of cross-linked terms typically arranged thematically to aid a reader in the retrieval or search for information from a large text such as the Bible (Neuendorf 2002).

Krippendorff (1980, 2004) itemizes six questions must be addressed in every Content Analysis:

- Which data are analyzed?
- How are they defined?
- What is the population from which they are drawn?
- What is the context relative to which the data are analyzed?
- What are the boundaries of the analysis?
- What is the target of the inferences?

Several methodological steps are commonly taken in order to perform a Content Analysis and answer Krippendorff's questions. Rose (2001) identifies four steps in a Content Analysis image analysis, which are applicable in this research as well. First, data should be chosen so that it is appropriate with the research question being asked. Often choosing the data can mean sampling for a dataset through random, stratified, and clustered sampling techniques. Second, categories are created to code the data. These codes connect the data to a broader social context and as such need to be exhaustive, exclusive, and informative to the research question. Third, the data coding should be based on the categories of step 2. A key objective in Content Analysis is the assessment of reliability in those coding the data. Intercoder reliability is a metric calculated to establish that the experiment is replicable and to determine if some codes are more contentious than others. Fourth, the results are analyzed through tabulation, frequency counts, or multivariate analyses. Neuendorf (2002) adds to this list the need for coder training to test reliability of each variable and to revise the codes based on the results.

**OSM Haiti and a Modified Content Analysis**

Methods from Content Analysis are utilized to understand the crisis mapping process in the OSM database pre- and post-earthquake Haiti. Strictly speaking this research follows a Modified Content Analysis protocol. This methodology approaches the analysis of the mapping process with the following assumptions:

- The Haiti OSM database was edited by a group of people who wanted to map in a consistent and thorough manner in order for their data to be reliable;
- Few if any people who initially edited the OSM database are Haitian residents or natives;
- Given the nature of the disaster, individuals mapping Haiti were doing so through heads-up digitizing of satellite and aerial imagery; and

- Coding of the satellite imagery to create features and tags was done through an interpretive process that was initially based on visual cues alone, by persons who had no direct physical experience with the local geography.

Tagging features in OSM in general is dictated by at least two motivations. First, to tag a feature in OSM gives it a purpose for a map form. For instance several map renderers are used to display the raw OSM data in map form. Renderers such as Mapnik are programmed to display certain types of features in certain visual templates at certain scales. For instance a way tagged as a footpath will not be displayed at small scales, while a way tagged as a highway will. Tagging is therefore extremely important for the usage of data in map form. Second, a tag provides a common language to communicate with others. The OSM community goes to great lengths to create an exhaustive list of categories that can be utilized to create a map of the world for everyone by anyone. Currently over 60 million unique tags are used in the OSM database (http://taginfo.openstreetmap.org/reports/database_statistics).

If examined from a certain point of view, the mapping in the OSM database following the Haiti earthquake can be seen as performing a Modified Content Analysis. Many mappers involved in adding and modifying data to the OSM Haiti database were likely concerned with one primary objective: how to map Haiti in a manner that would help relief work on the ground. Given this context the mappers would likely answer Krippendorff's six questions in the following manner:

- Which data are analyzed? Answer: Satellite imagery, aerial photography, and scanned historical maps.

- How are they defined? Answer: The data is defined according to the rules of the OSM community and its database. The data has to fit into the data primitives of nodes, ways and relations. The data attributes follow a tagging schema encouraged for use by the OSM community (http://wiki.openstreetmap.org/wiki/Map_Features). Furthermore the tags are subject to the rules of the database storing them: they are case sensitive and must follow the syntactic structure of key=value. Keys describe an element such as a highway and value describes the accompanying key such as residential (e.g., highway=residential) (OSM 2013).
- What is the population from which they are drawn? Answer: OSM data is commonly drawn from imagery data, from GPS tracks, scanned historical maps, or from data imports given to OSM from various private, national and international data contributors. Regardless of the source of the mapping, OSM data has to by necessity be from data that itself has been released to the public domain. In the case of the response to the Haiti earthquake, satellite imagery was made available to the public domain and utilized by the OSM community for crisis mapping purposes.
- What is the context relative to which the data are analyzed? Answer: The context is post-disaster Haiti.
- What are the boundaries of the analysis? Answer: Haiti, or at least initially the areas most affected by the earthquake. The temporal boundary is a month before the earthquake and six months afterwards.
- What is the target of the inferences? Answer: Anyone who wishes to use the database and its resulting maps. Examples include NGOs and governmental agencies involved in relief work, Haitians themselves, news outlets wishing to depict Haiti, etc.

This research argues that with the OSM Haiti response, three of Rose's (2001) four Content Analysis steps have already been performed. The first step (choose the data) utilizes the aerial imagery and other sources of data donated after the earthquake. The second step (create coding categories) is accomplished by the tags taken from both recommended key = value combinations from the OSM wiki, as well as an ad-hoc process where tags were created by the community of mappers when the recommended schema was not enough. The third step of actually coding the data was performed in the database in the form of mapping and tagging through via the various OSM editors such as JOSM or Potlatch.

To continue the Modified Content Analysis, Intercoder Reliability typically needs to be measured. Intercoder reliability is defined as the "the extent to which independent coders evaluate a characteristic of a message or artifact and reach the same conclusion" (Lombard et al 2010). Intercoder reliability is therefore a measure of agreement. The reason that agreement is important for Content Analysis is that without it, the categorizing of an object cannot be assessed for validity. The idea here is that a certain level of agreement between independent judges denotes some sort of objective and consistent recording of data and that without this consistency any conclusion made in the analysis is 'useless' (Neuendorf 2002).

The concept of validity through Intercoder Reliability is quite interesting when placed within the context of the OSM mapping project at large as well as within the crisis mapping in OSM Haiti. OSM relies on crowdsourcing which relies heavily on the concept of the wisdom of the crowd espousing the idea that group knowledge is better than any individual expert. This shares a similarity with Intercoder Reliability in that both seek agreement from a group of persons as an argument for validity. As opposed to Content Analysis, the codes in question here are not set by a researcher, they are made by the OSM community. The distinction is an important one because the goal of Content Analysis, the ability to make inferences from a text, is dependent on the research question being answered. Moreover, the mechanism for assuring that Intercoder Reliability has an appropriate amount of agreement is to document any disagreements found in the coding of the data by two or more coders. Disagreements are conventionally taken to mean that the coding categories need refinement or that a discussion is needed among coders to reach an agreement (Rose 2001). This is a measure of difference from OSM where standard codes/tags are developed through a voting process and are essentially self-policed throughout the database. However, being an open database, anyone can use any tag they desire outside of the standard schema -itself continually evolving in OSM.

Assuming for a moment that OSM Haiti had a unifying question, something like ‘how does a community map Haiti in response to the earthquake?’, the truth is that there is no guarantee that any individual mapper will interpret the data of the various forms of imagery within the bounds of this question. The point is that even if a systematic coding schema was employed in OSM Haiti, the use of the coding may be non-uniform. Some coders may decide the best way to answer this hypothetical research question is to interpret imagery with roads; others may look for buildings; or others may choose to map waterways. There are simply too many options for what to map to necessarily satisfy a particular research question within the bounds of the context of this research. Furthermore, there is some evidence to suggest that a unifying coding schema was initially elusive as is evidenced by the development during the crisis mapping of the Humanitarian Data Model (HOT 2013) itself trying to standardize crisis mapping in OSM to blend standard OSM tagging conventions with the needs of interoperability with other datasets.

Further logistical problems with computing a metric for Intercoder Reliability exist. First, given a scenario where a feature is mapped by one user and then changed by another user, there is no way to know if the changes result in a difference in coding interpretation or if imagery was simply updated with higher resolution data equaling better data; and if the first coder had access to this would he or she have actually made the same decision. Moreover, the difference in coding could reflect simply a change on the ground, which is again not a difference in coding opinion. Second, when a change takes place simply on an attribute level such as a user changing a tagged object from "is_in =Haiti" to "is_in = Haïti" there is no clear understanding if the user does not want the tag to use the English spelling as a form of disagreement or if the user simply wants to create a French language basemap and does not hold any ideological differences with the way it was originally tagged. In either case there is no clear evidence of coding disagreement or agreement since the motivations for the change are not immediately clear. Thirdly, it is impossible to know that when a feature exhibits no changes that this stasis denotes coding agreement on the part of other mappers or simply that no one else has offered a difference of opinion. This is especially true initially when OSM users were simply trying to populate a blank map and may not have been mapping the same features. Therefore, the geographic coding likely didn't overlap in the initial mapping rush.

An Intercoder Reliability metric in the context of the Modified Content Analysis is therefore not feasible to formulate in this research project. However, there is reason to assume a significant level of Intercoder Reliability in terms of the modified methodology without a specific metric. Since the reason for measuring Intercoder Reliability is to make sure that inferences made from the coding in the Content Analysis are valid and this research project examines the mapping process for OSM Haiti, the question to ask is, was the coding valid as a mapping process? This is a difficult question to answer unequivocally since the answer will likely depend on who's asking, but for the purposes of this research the answer seems to be yes for several reasons. A major reason why this research project investigates this particular mapping project is that many outside the OSM community found the result of the mapping very useful and therefore valid as a mapping database (UNF 2011). Moreover, since OSM Haiti data was not used only by individuals outside of the OSM community but became the de facto map database of the humanitarian relief efforts, the validity of the coding at least on a large scale seems to have been recognized. Given these reasons, this research assumes without a quantified metric, but through anecdotal evidence that Intercoder Reliability was high enough to code imagery into map data that many people, especially persons on the ground in Haiti, found valid.

To conclude, it is argued that since the three basic steps of a Content Analysis have been performed by the mapping project of OSM Haiti (choose the data, choose the codes, and code the data) the fourth basic step of analyzing the coding is performed. While the third step of coding the data is often analyzed through an Intercoder Reliability metric before proceeding with the fourth step, in a crowdsourcing mapping project, an Intercoder Reliability metric is likely impossible to quantify. Because of the widespread acceptance of the coding on the part of those who utilized the OSM Haiti database, a valid Intercoder Reliability metric is inferred. Because the author of this dissertation did not dictate the first three steps of the Content Analysis and because Intercoder Reliability is inferred, this methodology is termed a Modified Content Analysis. For the fourth step, several tabulations are made on the diff files created from the 183 time slices. These tabulations include the number of features edited per day, the number of users editing per day, the tallied total number of users per day, the tallied number of edits to each OSMID, total edits per day by edit type (addition, deletion, geometry modification, or tag modification) among several others.

**OSM Haiti Spatial Analysis**

This research utilizes a spatial component at a geographic scale that covers the entire country of Haiti. Since this research performs a content analysis of the OSM database as well as human subject surveys and interviews, a spatial analysis will connects the semantic database story with human experiences. Furthermore, trends will likely arise as the spatial analysis takes the temporal element into account.

In order to visualize a spatial analysis of the OSM Haiti database the diff files are prepared to produce an appropriate method of data trend capture which also generalizes the edits. A Python script was written to iterate through the diff files to merge all the files representing edits in a time slice into one file. These edits are the additions, deletions, tag edits and geometric modification feature classes. Once merged, these final representations of all edits between time slices are used later in the methodology for a temporal depiction of changes. Another Python script was written in order to iteratively overlay a fishnet grid on the study area to tally the total edits within each cell. Each grid cell is approximately 8 $km^2$ and the entire fishnet covers the total rectangular extent of the study area.

The fishnet serves the purpose of generalizing the study area and as a means to summarize several days, a week, or a month worth of edits. The summarizing is done in the Python script by tallying all the edits for a given time period through the use of a spatial join, which joins attributes from one table to another based on a defined spatial relationship. The diff edit files were therefore spatially joined to a copy of the fishnet grid file via a spatial intersection for every single row in the diff edit files. The spatial join tool automatically generates a "Join_Count" field that tallies how many features intersected the grid feature class. This field is subsequently used to merge these fishnet grid feature classes into one fishnet grid summarizing a desired period of length. This was done separately for points, lines, and polygons.

In addition to creating fishnet grid summaries, one more metric was generated to give a spatial and temporal picture of the study area. The Standard Deviational Ellipse is computed for each day's worth of edits using the diff files and iterated in Python. Computing the Standard Deviational Ellipse using the Directional Distribution tool visualizes the central tendency, dispersion, and directional trends of feature edits (Esri 2014). The Standard Deviational Ellipse calculates the mean center of edits given a feature class and then measures both the standard deviation of the x and y coordinates from the mean center. These deviations are then used to delineate the axes of the ellipse (Esri 2014). The Ellipse is rotated in a certain direction if the features themselves exhibit a directional bias (Lee and Wong 2001). The Standard Deviational Ellipse was calculated using the tallied fishnet grids as an additional descriptor for the geographic progression of editing through time.

A note should be made about telling the story of the spatial dimension of the mapping in OSM Haiti as it relates to the release of information. As is noted earlier in this research, very little spatial information was available for the country of Haiti as much of it was buried under the rubble caused by the earthquake and there was little economic incentive among corporations to map Haiti. Therefore, much mapping in OSM Haiti relied on satellite and aerial imagery released to the public immediately after the earthquake. Figure 3.5 shows a compilation of all the high resolution imagery available to OSM mappers a week after the earthquake as they added information to the OSM Haiti database.

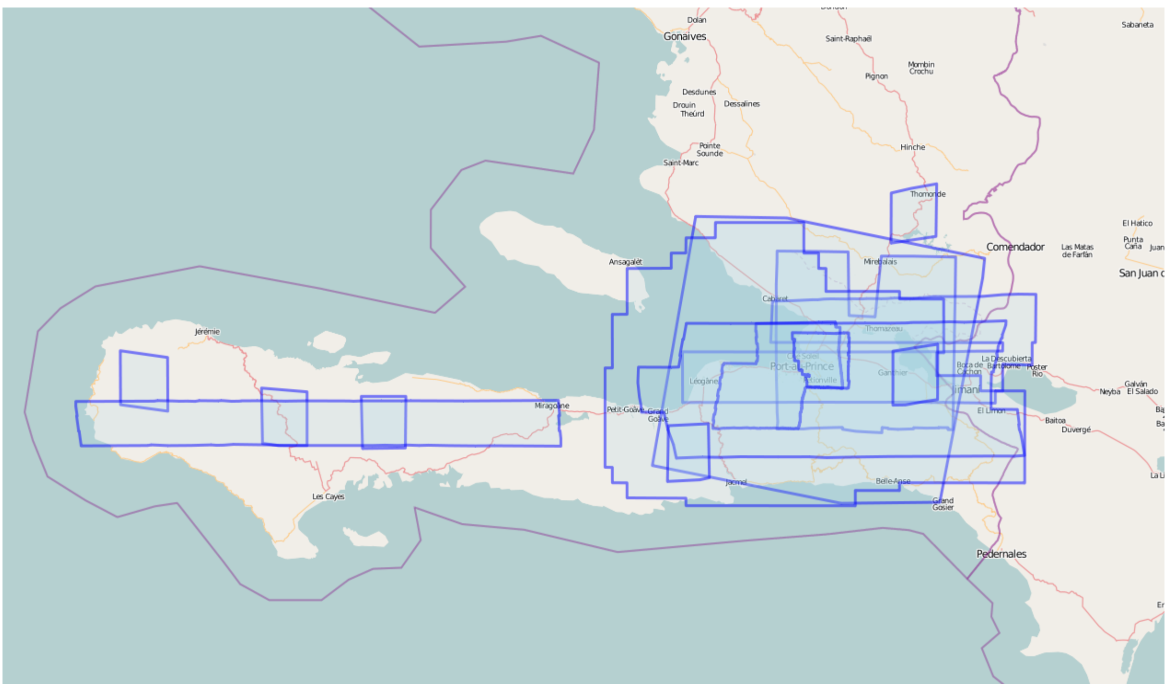



**Figure 3.5** Index of the fine resolution imagery footprints available in the public domain for Haiti as of January 19 2010 (wiki.openstreetmap.org 2010b).

There is likely a geographic bias in the mapping process for OSM Haiti which coincides with the footprint and timing of the release of imagery. Until imagery stopped being released in conjunction with the relief efforts, the spatial story of what was mapped is probably tied to what imagery was made available. It is also likely that the types of features being mapped associate with the quality and spatial resolution of each image dataset being released. Figure 3.6 shows the progress of the release of imagery for Haiti over a 12 day period. In the OSM community, best practice guides a user to tag any feature mapped through imagery released as part of the release work for Haiti, with the source of the dataset (e.g., source=Ikonos, GeoEye, 2010-01-17) (wiki.openstreetmap.org 2013d). A quick search through the OSM Haiti database reveals that a majority of tagged features do not denote the source of the data. Unless tagged as such, it is impossible to say for certain that any given feature comes from any specific data source, especially since lower resolution satellite imagery was available through Landsat satellites before and after the earthquake. Eventually post-earthquake high-resolution imagery was made available with coverage for the entire country (wiki.openstreetmap.org 2010c). The point is that initially during a period of time that extends past what is shown in Figure 3.6, a spatial description of editing patterns such as the tallied fishnet grids and the Standard Deviational Ellipse describe a combination of what

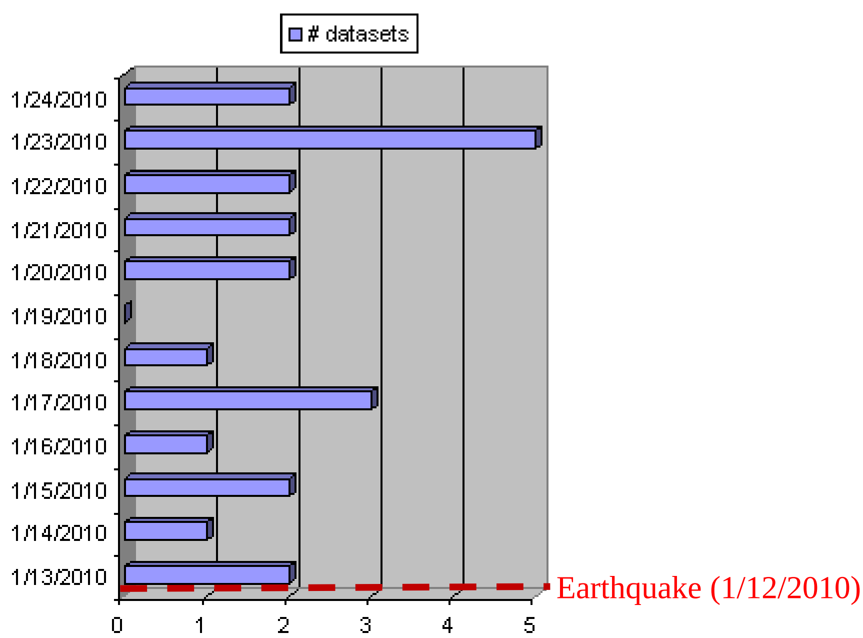



**Figure 3.6** Number of high-resolution imagery datasets available by date in the public domain for Haiti (wiki.openstreetmap.org 2010).

mappers thought was important to map, when imagery was released, the spatial footprint of the imagery being released, and the quality of the imagery (e.g., resolution and visibility).

**Summary**

This research utilizes a three-part mixed methods approach to describe the mapping process in OSM to the response of the Haiti 2010 earthquake. First, human subject testing is utilized to convey a part of the human element to the mapping process. Two tiers divide the estimated 600 OSM Haiti contributors into those who physically went to Haiti and those who did not. Tier 1, or those who went to Haiti are contacted for a semi-structured interview revolving around their experience in Haiti, their background with OSM and humanitarian work if any, and their reflections on the effects of what took place. Tier 2 randomly selects from the contributors to OSM Haiti approximately 200 participants in order to get a sample of responses to an online survey asking questions such as why they participated, how frequently they mapped and who they think benefited from their efforts as mappers.. Second, a Modified Content Analysis is outlined to describe how the mapping manifested in the OSM Haiti database at an attribute level. This research takes the position that the OSM Haiti crisis-mapping performed a Modified Content Analysis by coding various sources of imagery available to those mapping in OSM. To finish the Modified Content Analysis data points are tallied such as total users per day or feature creation per day. Third, a spatial analysis is performed to visualize and describe mapping edits for Haiti as they progress through one month before the earthquake to six months after. A fishnet grid is created to capture and generalize all edits every day for Haiti. Daily snapshots are tallied to provide compiled snapshots of an entire week or month of edits. These snapshots are combined with Standard

Deviational Ellipses of the snapshots to visualize the center, dispersion, and directional trends of feature edits. Taken together, the three parts allow for a multifaceted picture of the crisis mapping process as it took place within the database and how it involved volunteer mappers.

# Chapter 4
# OSM Haiti Crisis Mappers

## Introduction

In order to describe the human element of the mapping process of OSM Haiti, this research involved human subjects. The users who contributed to the OSM Haiti database from one month before to six months after the Jan 12 2010 earthquake are split into two tiers. Tier 1 users contributed to the OSM Haiti database and physically went to Haiti after the earthquake. Tier 2 users contributed to the OSM Haiti database and did not physically go to Haiti. Semi-structured interviews were utilized for Tier 1 due to the benefits that follow from communicating to someone directly involved with the mapping experience, and situated for some period of time in Haiti. For Tier 2 a representative sample is targeted for an online survey.

A total of 8 OSM users were contacted for Tier 1. This total was arrived at after cross-referencing the entire list of users who contributed to the OSM Haiti database within the timeframe of this research, to the list of users who had been identified as having been to Haiti (http://wiki.openstreetmap.org/wiki/Category:Users_in_Haiti). In particular, the initial estimate for Tier 1 had to be revised downward because 2 of the 10 users who had been to Haiti did not contribute to the OSM database during the timeframe of this research – a prerequisite for Tier 1. Out of the 8 users contacted, a total of 4 interviews were conducted. An additional user responded to the initial inquiry but did not schedule a time for an interview, because this user was in Malawi responding to the violent conflict in the Central African Republic. The template for interviewing the 4 users in Tier 1 is in Appendix 1. The results are reported through summaries of the pertinent responses by the interviewees lumped into broad categories. In addition, the questions and respective answers section is followed by a brief section with quotes that do not fit under any of the questions of the Tier 1 template but are pertinent to understanding the mapping process this research is investigating.

## Tier 1 Interview Responses

*Overview*

For the four OSM users who agreed to be interviewed for this dissertation, all four interviewees can be described as OSM advocates. In their responses all four not only demonstrate a belief in the project of OSM in general, they also spend time and energy to champion OSM to others while in Haiti. User2 and User4 went to Haiti on a short term basis while User1 and User3 actually moved to Haiti long term, with User3 currently residing in Haiti. User1, User2, and User3 championed OSM to both the humanitarian/development/ community in Haiti as well as to Haitians, while User4 mostly advocated involving OSM only to the humanitarian/development community in Haiti because that was who User4 was in contact with. All four users are also quite clear that their advocacy was not simply for adoption of OSM data by the humanitarian/development community in Haiti but also for the contribution to the OSM database. Even though all four users are OSM advocates, each have different takes of the effects short and long term that OSM had on Haiti and crisis mapping in Haiti. All four users describe the crisis mapping that took place in OSM Haiti as a watershed moment for OSM, the humanitarian branch of OSM, and the humanitarian community in Haiti and at large.

*User Background and involvement with OSM.*

The four interviewees that comprise Tier1 (for the rest of the dissertation referred to as User1, User2, User3, and User4) have different yet often connected backgrounds. When asked how they first got involved in OSM User1, User2, and User4 all claimed to have been mapping in OSM on and off for several years before the Haiti earthquake. User3 on the other hand had not heard of OSM at all until after the earthquake. At the time that User1 joined OSM, User1 was working for the World Bank on information management and was interested in ideas of collaboration and how to share information. User1 was drawn to the Open Source approach and was thinking about how to apply these principles to the development world. User1 joined OSM out of personal and professional curiosity and mapped completely for fun. User2 on the other hand had a stronger professional interest in OSM because User2 was working for a software company who had many clients in the development/humanitarian sector such as UNICEF. As their "map guy" User2 joined OSM in part because User2 wanted to explore its use for the software company.

User4 was very explicit that User4 joined OSM for humanitarian reasons. User4 had worked for Oxfam and during the Indian Ocean tsunami in 2004, managed the IT response for a certain province. During User4's experience at Oxfam, User4 realized that GIS was a useful tool for humanitarian application and that Oxfam was heavily underutilizing it at the time. User4 came across OSM and realized it was a perfect tool for humanitarian usage specifically because of its Open Source and Open Data culture. While the motivation for joining OSM was professionally driven, User4 also states that User4 contributed to OSM with a hobbyist mentality. As User4 states: "I've gone around the world and I've taken my

GPS with me. My kids would always shout at me when I would go around a roundabout twice: one for the inside lane, one for the outside lane”.

User3 on the other hand had no background in humanitarian or development work but did complete some courses in computer science. User3 started to practice mapping in OSM as a form of learning about the cultural heritage of a place. As User3 states, “After learning about OSM I immediately started mapping on weekends where I would go out and wander around the streets to map whatever features I would run into. This way you would learn about different aspects of the city, like for instance you run across a church and learn when it was built. For me it’s not just about mapping, it’s an ensemble of experiences”. All this wandering/mapping also helped User3 to learn how to use OSM. User3 immediately integrated OSM as a part of User3’s life because the ‘Open’ spirit made sense to User3 and also because User3 connected to OSM as a community project. Moreover, User3’s mother is Haitian and therefore according to User3, mapping in OSM Haiti was a form of helping Users3’s own community.

*Going to Haiti*

Both User2 and User4 went to Haiti for humanitarian projects. Before the Haiti earthquake User2 was involved in communities and conversations that were priming new uses of technology for humanitarian relief. Because of these personal connections User2 was asked to go to Haiti as part of the first HOT mission. User4 was asked by both Oxfam and a consortium on international NGOs called Net Hope to go to Haiti. The Net Hope project was to set up a wireless network to cover Port au Prince.

User1 and User3 moved to Haiti in part because of personal connections to Haiti. User1 moved to Haiti after tagging along as a tourist with User1’s spouse who had a World

Bank work project in Haiti. Before the earthquake, User1 and User1's spouse had supported an orphanage service organization in Haiti. After the earthquake User1 started receiving news of friends who had died or survived the earthquake. This led User1 to look for the orphanage service in OSM; and not finding it, User1 decided to map in OSM Haiti. Initially User1 was mapping without much communication with the rest of the OSM community. User1 cites a message posted online by Mikel Maron, a prominent member of the humanitarian OSM community, who, approximately 53 hours after the earthquake, first showed the enormous amount of mapping activity taking place in OSM Haiti. User1 points to this moment as an "ah-ha" moment realizing the enormous potential OSM held for humanitarianism as well as the projects User1 was working on for User1's job at the World Bank. This was particularly poignant because this was the first humanitarian project User1 had been involved with. Essentially, the connection that User1 felt from supporting the orphanage as well as the enormous amount of work needed to rebuild Haiti that User1 witnessed while first visiting Haiti greatly motivated User1 to move to Haiti,without concrete job plans set up. User3 on the other hand did not provide many details about moving to Haiti except that an uncle offered User1 a job and User1 wanted to be near family in Haiti.

*Roles in the OSM Haiti effort*

While in Haiti, all four users advocated for the use of and contribution to OSM Haiti data. However, the role that each user had in the actual Haiti crisis mapping effort varied greatly. User1 for instance initially mapped a lot from distance, eventually mapped as a hobbyist while living in Haiti, and focused mostly on mapping roads. User1 enjoyed taking an SUV out on the roads of Haiti and loosely using the ability or lack thereof of the SUV to drive the road as a criteria between classifying a road as a road or as a trek in OSM. This form of ground truthing is how User1 see User1's role in the OSM effort. User2 on the other hand did not map much in the OSM Haiti database prior to coming to Haiti but came to Haiti as part of the first HOT mission. This mission had three major components: to help those who had questions with how to use the OSM database, to grow a local OSM community, and to see what HOT could do as a future organization. User3 did not describe much of a role in the OSM Haiti effort as relates to crisis mapping. User3 went to a few OSM meetups in the Port-au-Prince area but mostly described being active on the OSM wiki. Specifically, User3 spends time translating the OSM Haiti wiki page from English to French. Initially since User4 spent a lot of time building a wireless infrastructure for Net Hope, User4 used OSM data to get around. Afterwards, User4's work focused on coordination among NGOs and at this point was actively promoting OSM data as a viable spatial database especially among the IT personnel User4 came in contact with at these NGOs.

*The Process of mapping in Haiti*

While some aspects of how each user mapped while in Haiti have been explored, a few more details are helpful to understand the mapping process they utilized. As was said previously User1 mapped many roads from an SUV using a GPS device. User1 described this as ground truthing. Later in the interview User1 added that ground truthing was not simply just updating the road geometry but was a lot of tagging updates. User1 gave the example that sometimes the conditions of the roads were not visible or well interpreted from the satellite imagery and that what looked like a road in poor satellite imagery was actually a long wall. Another task that User1 enjoyed was finding roads that had not been mapped because of cloud cover in the imagery available to the OSM community. User1 also described mapping points of interest while out and about in Haiti.

Since User2 went to Haiti with three specific goals and one of those was to grow a local OSM community in Haiti, much of the mapping process User2 describes is in the context of trying to grow this community. User2 describes being put in contact with the Cite Soleil Community Forum from a slum on the Northern end of Port-au-Prince, as a group willing to learn about OSM and to volunteer to map. User2 describes the group's motivation in this manner: "They said that they had seen a bunch of UN people come around and do mapping but they didn't really know what was going on. For them this was a chance to be in charge of that, they were the ones now doing the mapping. For a lot of people it was a way to make contributions at a time when most Haitians were fairly marginalized in the response". User2 further describes the use of donated GPS devices as well as Walking Papers to actually do the mapping. Walking Papers is a technology for street-level mapping where a user prints out a paper map using what is currently in the OSM database, draws on the paper map the footprints and location of items that the user wants to add to OSM, scans or takes a high quality picture of the paper, and then uploads the image to the Walking Papers website where the drawings are converted to objects and added to the OSM database through JOSM (http://walking-papers.org/).

The dynamics of mapping changed for User2 especially when the Cite Soleil Community Forum started getting paid by IOM (International Organization for Migration). Where the Cite Soleil group had volunteered to help train other Haitians to map in OSM, they now were paid to walk through the camps that IOM was managing to map them. After the mapping was complete, a paper map was printed and put up on information kiosks so that a map of the camp was viewable for those in the camp. While this was a job for this Haitian group, User2 is very clear that was something more as well: "I remember really clearly, even after mapping all day, they would be out at nights mapping Cite Soleil. I remember one night where a couple of them went around and mapped all the light posts in Cite Soleil. Why they picked light posts? I have no idea. So it was very clear, even when they were getting paid it was more than just a job to them".

Similarly to User1, User4 mapped as a hobby while out and about in Haiti. Since User4 utilized a Garmin loaded with OSM data to navigate in Haiti, often User4 would add data while moving around Port-au-Prince. User4 would often update the data in a similar ground-truthing fashion as did User1. However, User4 was often chauffeured around Port-au-Prince and so would also ask the driver about, for instance, what was a street name.

*Challenges of mapping in Haiti*

In addition to asking about the typical mapping process that each user utilized while in Haiti, each interviewee was asked about the challenges that being involved with the mapping process in Haiti posed. Each user had different answers dealing with not only the mapping itself but the social and cultural barriers that were experienced while in Haiti. User1 first explains that mapping using only satellite imagery was difficult simply because User1 often did not know how to interpret the imagery. User1 describes a learning curve when it came to humanitarian mapping as opposed to simply mapping as a hobbyist and often as a tourist before the Haiti earthquake. This often meant learning new tagging schemas and interacting with others involved in the crisis mapping from a distance. After moving to Haiti, User1 worked with several Haitians who actively map in OSM as hobbyists, but User1's overall impression of the sustainability of the OSM community were not optimistic. User1 explained that, "I'm not sure what the future of mapping in OSM Haiti will look like. The whole model is so clearly built around the idea that people have free time, they are passionate about mapping, and they are not paid… It's not clear that any of these are available for Haitians". In other words User1 expressed doubts that the mode of VGI which drives OSM can be transplanted into Haitian culture.

User3 follows a similar vein of expressing doubt over the future of OSM. After living in Haiti a while, User3 realized that a barrier to contributing to OSM was not necessarily technology or the lack thereof. User3 thinks that after the earthquake a lack of Internet or tools to map in OSM became less of an issue for Haitians as people rebuilt their lives. User3 states it this way: "I see all sorts of people who pay to have Internet in their homes or on their smartphones. To me this says where there's a will there's a way. I see people all over using Facebook or Twitter and looking at music videos. They are interested in those things". User3 describes a lack of interest in OSM on an institutional level as well: "I have talked to people who currently work for NGOs here in Haiti who haven't heard of OSM despite the fact that I know of people in the same agency who did contribute to OSM after the earthquake. There are some exceptions such IOM who to this day still use OSM. However, I think that here in Haiti, there was a lot of interest in OSM but that recently that interest if pretty much gone. I see a lot of data in the database that needs to be cleaned up and there are very few people willing to do it. One of the common things I see is that the people here who do use maps for whatever reason, they use Google. When I show the OSM they just 'oh that's nice' and keep using Google. I'm not anti-Google but I just know that the data in OSM is so much better". When asked why Haitians use Google, User3 replied that perhaps it's what people are used to especially because of the prevalence of smartphones who have Google built in. User3 also acknowledged that OSM is harder to use.

User2 also describes institutional resistance to the use of, or contribution to, OSM especially early after the earthquake but mixed in with people who had been using OSM quite early on and were very grateful. User2 states that as part of the HOT mission, the resistance often stemmed from a perceived lack of credibility: "We heard people say to us 'you guys are just a bunch of volunteers what do you know about mapping anyway'. There were individuals especially in certain UN GIS teams who were not interested. They were professional surveyors who were like, they know what they need, they don't need a bunch of volunteers telling them stuff." User2 further explains that some GIS professionals felt threatened by the free availability of OSM or would complain that they were already doing what OSM was doing. User2 believes that ultimately many GIS professionals felt threatened simply because in an environment where budgets are tight competition is not welcomed within the scope of job security.

In this vein User2 describes a specific example where the HOT team felt hostility from the Haitian national mapping agency. User2 describes it as,

> "The [Haitian] National Mapping Agency hated OSM in the beginning. They had created a business model whereby they were going to sell data. This was how they were going to cost recovery, and how someday they were going to become independent from donors. But then the earthquake happened. A lot their leadership was killed. It took months to recover the data. The data they did have was kind of old. So you had a young director who had lost a ton of his staff, and was personally traumatized, and then this international group comes out of nowhere saying hey look we have this amazing map. And I think it was threatening".

User1 also describes OSM in this context stating that OSM was "completely unstoppable". However despite this, User2 describes that fairly quickly in the HOT mission, the Haitian national mapping agency did end up meeting with the HOT group and eventually participated in some of the mapping parties. In the end the User2 said that the HOT group could not get the Haitian mapping agency to commit to a structured relationship with OSM. User3 also has personal experience with this dynamic: “I have contacts in the Haitian government branch that are in charge of mapping. Often they tell me that OSM was fun for a while but that they have real tools. OSM was good for the earthquake but now we don’t care –we have other tools. Or sometimes the argument is made that it’s better to try and go do mapping projects so that there’s the opportunity to get more financial backing. Everyone has data but very few are willing to share”.

User4 shared a similar experience but found less resistance to OSM as a data source:

> “… they’re busy as hell especially in an emergency. Getting them to learn new tools, that’s a step too far. Getting them to use it? No that wasn’t a big barrier. I was trying to get people to put hard data on OSM, but people have their concerns. They didn’t want to expose themselves –what’s the quality of the data- they didn’t want to look bad. They also had security concerns they didn’t want to map [on OSM] all their infrastructure, you know their warehouses and stuff. They could be targeted”.

User4 describes a dynamic not mentioned by other users, namely the perceived security repercussions of placing the locations of all an aid agency’s warehouses, where supplies are stored, on an online database. This point is interesting because it gives an example of some of the challenges an agency might face if it were to simply take its GIS data and make it available for anyone with access to the Internet. The security of mapping *vis-à-vis* OSM was later mentioned by User4 but in a different context: mapping while in Haiti. User4 explains: “Of course there’s the security constraints. When I changed agencies responsibilities, there were areas of town where I was walking around quite freely, which when I went back to working for Oxfam, they said do go to that area!” The implication here is that mapping in a ‘dangerous’ area of for example Port-au-Prince as part of a hobby/crisis mapping could expose oneself to theft or assault as a foreigner.

Another challenge described by several of the interviewees deals with crisis mapping at a distance. While none of the users stated that this was a challenge directly experienced while in Haiti, several offered their experience with respects to Haiti and crisis mapping in general. For instance User1 previously mentioned a learning curve associated with crisis mapping in OSM as opposed to everyday/tourist mapping in OSM. This is likely because User1 had no previous humanitarian mapping experience. User1 offers another explanation: "In terms of the Haiti mapping, the mapping process was a huge learning experience. The humanitarian OSM community was completely winging it and still managed to make a working basemap". In addition to this seat-of-the-pants process, User4 describes the bittersweet nature of blank spaces and newness with crisis mapping in OSM. User4 puts it this way, "People like to have fun when they map. It's about filling in a blank spot but it's also about what people think they are good at and enjoy…One of the problems with Haiti is that people were very quick to put the damage layer on but how does it get off? Where is the imagery to say there's no longer a broken building here? Who's got the interest to do that? Most of the hobbyists are gone there's no one to do to that. HOT is gone. It's more boring to go around in the database and update the disaster data to normal data. Part of that is that the high-res imagery itself didn't get updated to show the repairs".

One final set of challenges described by several interviewees relates to the interfacing with Haitian culture. In many ways, tension with Haitian culture has already been described with the example User3 gave expressing frustration that Haitians, despite having access to the Internet and to smartphones, have a lack of interest in giving back through volunteering efforts such as contributing to OSM. User4 provides another interesting example of the interaction of OSM with Haiti but with mapping street names. User4 recalls, "the street names proved to be rather a funny thing because OSM was putting up names of old military maps and I was looking at the street signs. The drivers were illiterate and they were saying the street is called this but I was saying I can read this. It turns out that the street names would often change with whoever came to power and the drivers would remember what it was called two or three names ago. What the sign says doesn't mean anything to them, they can't read the sign anyway, that's not what people call it anyway". When asked with what choice of name User4 would use, the response was: "I would go with the common usage name. I didn't have that much time to get involved with figuring out how to tag the names properly". User 2 also had an interesting anecdote with respect to Haitians and OSM. While mapping some of the Haitians were surprised that no standard existed for certain features. User2 describes, "A while into these mapping projects, one of the members of the team figured out that there was no way to tag a voodoo temple. There were all these other options for religious buildings but none for voodoo temples. So we had to sit down and as a group decide what was the proper way to do the tagging. They were really annoyed at first that there wasn't a preset already there. And then I told them, it's OSM you can put anything you want! So then it was just a matter of choosing what key/value to use".

*Outcomes:*

In spite of all the challenges previously mentioned, according to the interviewees, there were some real outcomes from the crisis mapping in OSM Haiti but some of the outcomes are not easy to quantify. One clear outcome was given by User1 who while living in Haiti witnessed the continued use of OSM data. User1 claims, "to this day if you go to Haiti and purchase a paper map, chances are good that the data is OSM data". Both User1 and User2 were proud that an outcome of the crisis mapping and subsequent OSM community building in Haiti resulted in local Haitian mappers. Both User1 and User2 said that to these Haitians, mapping in OSM is meaningful and believe that OSM technology can help them. User3 took a more negative point of view, “I think that here in Haiti, there was a lot of interest in OSM but that recently the interest if pretty much gone. I see a lot of data in the database that needs to be cleaned up and there are very few people willing to do it”. This point on the scale of the work needed to update the data is echoed when User4 made the comment about high-res imagery not being available to show a reconstructed Haiti. This task is clearly described by User1: “I believe after my involvement with Haiti, that to map a place thoroughly, there needs to be three rounds of mapping. First one maps a place roughly. Second, a round of ground-truthing takes place to verify and improve what exists in the database. Thirdly a final higher-level mapping is helpful. The third level of mapping mostly takes place in the ground to improve accuracy but it is also higher order mapping such as making sure that there are no bugs in the database. I think that in order for the Haiti data to be very high quality it would take many years. I don’t know if it would take 3 or 15 years -it is a very laborious process”.

According to all four users, the crisis mapping that took place in Haiti had outcomes that we not limited to Haiti. User1 said that despite the seat-of-the-pants newness of crisis mapping in the OSM community it was this an amazing beginning in terms of OSM crisis mapping and what was produced. User4 claims that, “it was wider than just mapping. The whole voluntary and technical community were really taken a bit more seriously by the UN/NGO community after this. A lot has now been formalized, we’ve got HOT, we’ve got the Digital Humanitarian Network, all that stuff. And also the value of social media in terms of humanitarian response”.

*Concluding quotes*

In this last section discussing the Tier1 interviews, several quotes are given that perhaps fit directly under the previous reporting categories but are also helpful as concluding comments to understand the crisis mapping process. User1 for instance shared that the mapping in OSM Haiti left a deep impression: “The enormous amount of mapping completely astonished me in terms of quantity, but also because I realized the potential OSM now had in terms of the development world. I was completely blown away! I thought: how dumb I was trying to build an Open Source framework for the development world when really all that I needed to do was map!” User1 also expressed what OSM Haiti likely meant to many who participated in the crisis mapping project: “How do you help in a humanitarian crisis? This is a very complicated question. You can always send your ten bucks. But then you also know in the field it’s this massively inefficient process just because of the nature of the catastrophe. And it feels really dumb: can’t we do anything else?”. User2 on the other hand, as part of the HOT mission, had this as a cautionary tale, “I took away from OSM Haiti how long it takes to build a community. Haiti is also a really difficult place to work”.

As someone who has spent many years working in the humanitarian sector, User4 has some interesting observations about the crisis mapping and relief work in general in response to the Haiti earthquake. In particular the following quote warns of the dangers of generalizing about crisis mapping from one example:

> Three things were special about Haiti. It was a relatively small area, there was the high-res imagery made available really quickly, and there was a lot of media coverage. There are many forgotten crises where the needs are comparable to Haiti, but it’s not as public so we don’t get as many volunteers. The Pakistan floods [which took place 7 months after the Haiti earthquake] for instance disproved all of the things from Haiti. There were no high-resolution images, it was over a much larger area, and it was very hard to engage volunteers to the same level…As with most things, no

> disaster is the same. It’s very unwise to extrapolate too many things from one disaster. Things change, the context is different, the technology is changed. Another difference with Haiti is that a lot of the government was wiped out. It was a weak government to start with but all their buildings were wiped out, all their data centers, all their records were gone, half their staff was gone. Haiti was quite unique in that sense. How often does that happen? …Also Haiti is on America’s doorstep so there’s easy access. For some reason it’s the quick onset, the tsunamis, the earthquakes that generate the public appeal. Direct aid really appeals to people.

*Tier1 Summary*

Tier 1 reflects several themes that characterize each interview and also threads that weave between the four users. In terms of common threads, all four users agree that what took place in OSM Haiti after the earthquake was indeed a watershed moment for OSM and humanitarian mapping. Not only did the crisis community on the ground adopt OSM data as the data to use, the OSM community has itself been changed by its own realized potential, which has led to the existence of formal organizations within OSM for humanitarian purposes such as the creation of HOT. Interestingly, while it appears that all four users did various quantities of mapping while in Haiti, all participated in a form of OSM advocacy towards the existing humanitarian community and Haitian nationals. Even though only User2 went with the formal purpose of training in and advocating for OSM, the other three users demonstrate through their jobs or their hobbies an OSM and Open Source/Open Data activism. In other words, all four users actively promoted OSM as a source for map data to individuals and organizations in Haiti.

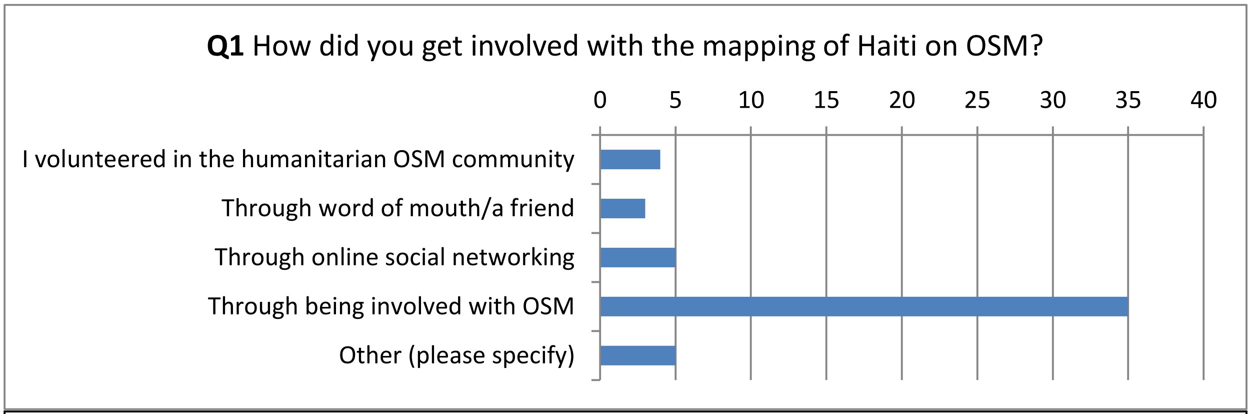
All four users describe different forms of resistance or antagonism to OSM and its approach to mapping. User1 and User2 describe a resistance immediately after the earthquake to OSM on the part of both the NGOs on the ground and the Haitian national mapping agency. Specifically User2 recounts NGOs and professional mappers who did not think that OSM could have quality data because of its volunteerism. User3 also describes resistance to OSM but in a later context when much of the Haitian government had a chance to start rebuilding itself. Instead of adopting OSM in a full manner for day to day operations, some of User3’s contact explain for a need for better tools and that it is easier to get funding if OSM is not utilized. User4 did not feel like there were any problems with adopting OSM data but rather it was difficult to get anyone to in turn contribute data.

Of the four interviewees, three describe their mapping in OSM Haiti as type of hobby. Only User2 who came to Haiti as a job directly relating to OSM did not use this rubric. User1 states that mapping was a form of ground truthing, a fun challenge, and a way to fill in blank spots. User4 also talks about being a tourist mapper and a sort of multitasker mapper when User4 would map while around the Port-au-Prince area for jobs. User4 also describes the general feeling that OSM mappers prefer filling in blank spots and ties this with having fun as opposed to mapping as a chore when simply updating the mapping data. User2 talks about mapping in OSM as giving a voice to Haitians while both User2 and User3 describes mapping as a job to Haitians. User3 says that mapping is a form of learning about a place especially in a cultural heritage sense. User3 also closely ties mapping with contributing to a community.

The content and style of the mapping in OSM Haiti also varied for each user. Both User1 and User4 mapped roads and points of interest while in Haiti. User4 recounted the difficulty of figuring out names for the roads as there was a choice between what the road sign said and what the common usage was. User1 took the time to make sure that the attributes that User1 added to the database were as accurate as possible through extensive ground truthing. User2 did not describe User2’s own mapping but rather what others were mapping. This is in part due to an emphasis of User2 on OSM training and community building rather than personally mapping. User3 describes an emphasis on cultural heritage and the environmental landscape. Interestingly none of the interviewees explicitly claimed that their personal mapping contributions while in Haiti were humanitarian mapping. Indeed User3 states that it is difficult to know what constitutes humanitarian mapping and what doesn't.

**Tier2 Survey Responses**

` Tier 2 surveys were conducted through Survey Monkey. A total of 208 survey invitations were went sent out and 52 responses were received. This represents a 25% success rate and a 10% sample of the total population of users who contributed to the OSM Haiti within the study timeframe. A list of the survey questions are found in Appendix 2. After the survey was closed, the results were downloaded and organized as an Excel file. The results from the survey are in Appendix 3 and organized in the same order in which they were given in the survey. Each question is given the label Q with the question number (i.e. Q1, Q2, Q3 etc.). The survey results for Tier 2 show some interesting trends for the respondents. For instance Q1 shown in Figure 4.1, overwhelmingly shows that those who




**Q1** Answers: 52
**Q1** Total Respondents: 45

**Figure 4.1**. Question #1 from the online survey

started mapping in OSM Haiti did so through already being a part of the OSM community. Likewise Q2, which asks how much mapping experience users had before the earthquake, shows a clear trend that users had previous mapping experience but had never mapped in a humanitarian situation before. A related question Q4, shows that respondents when asked if they regularly contributed to OSM before the earthquake answered in a majority as yes.

Figure 4.2 shows a sample of the countries from which OSM users contributed to the OSM Haiti crisis mapping effort. Figure 4.2 is compiled from answers to Q17 where respondents were asked to identify where they were when they contributed to OSM Haiti. Since Figure 4.2 shows a total of 37 respondents, the map represents a 7% sample of the

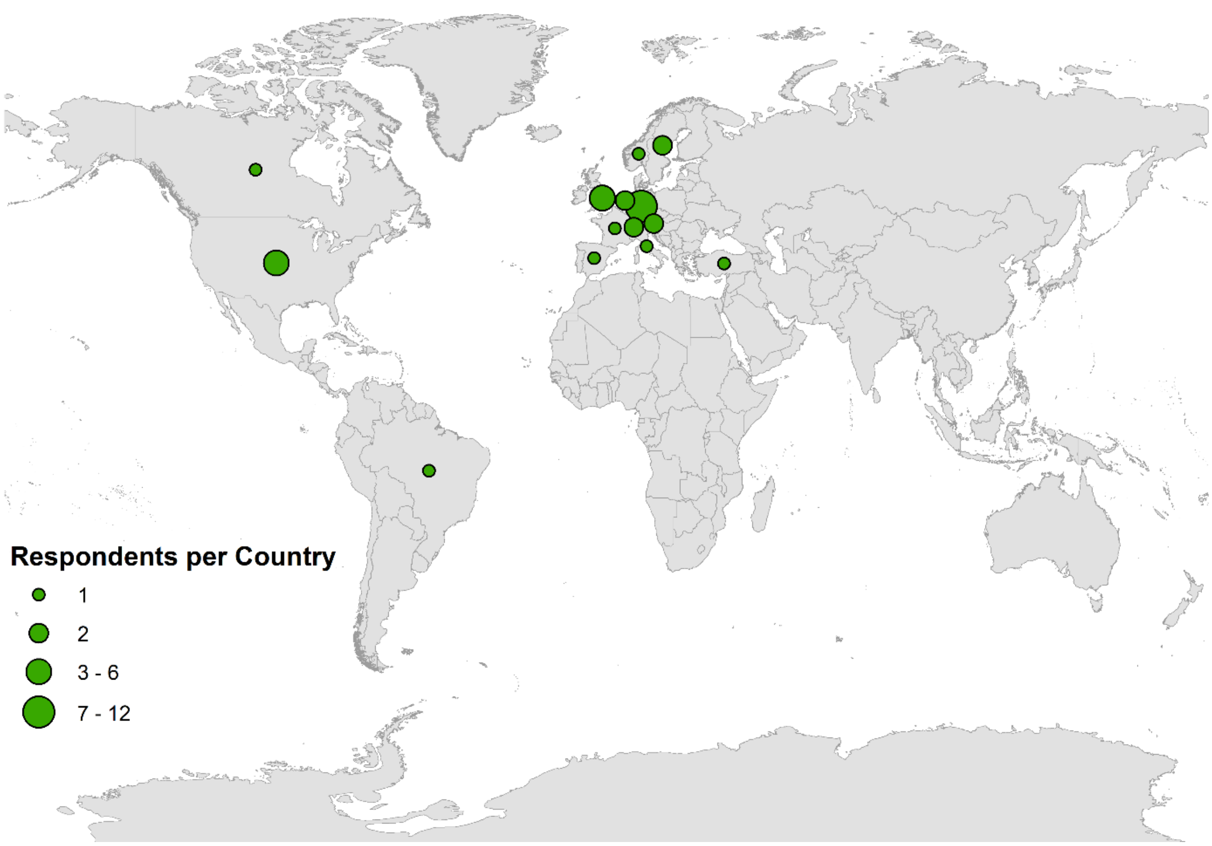
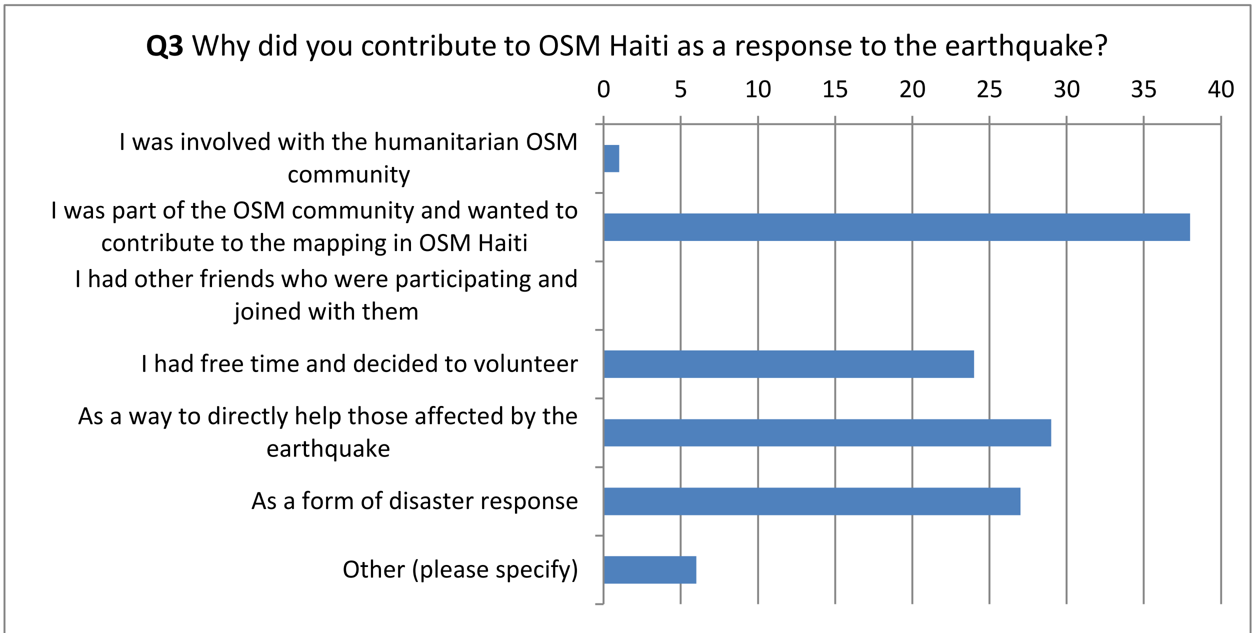



**Figure 4.2**. Countries from where users contributed to the OSM Haiti crisis mapping effort. 37 respondents identified the country from which they contributed. This represents a 7% sample of the total OSM population who contributed during the research timeframe.

OSM population for this study. As Figure 4.2 shows, according to the answers to Q7, the majority of OSM Haiti contributors were from the European Union. Germany had the greatest number of contributors followed by both the United Kingdom and the United States.

Q3, shown in Figure 4.3, inquires why people mapped in OSM Haiti, and demonstrates that there were various reasons to map. While a large majority declared that they mapped in OSM Haiti because they were a part of OSM, three other popular answers describe the group as volunteers, humanitarian, and crisis responders. Some of the Q3 fill-in responses given under the choice of "Other (please specify)" are particularly telltale. First, one user answered, "it was also a way to increase the coverage of OSM in general, since suddenly high quality satellite images were available". This answer is fascinating especially given a comment made by User4 in Tier 1 that some users simply find it fun to fill in blank spaces on a map even in a crisis situation. A second "Other" response is, "I needed information and then saw it was having mistakes", which is interesting because of the personal draw that this user felt to create or edit data so that it is more accurate. A third quote, "Practical help, feels Vetter than just give money" is also helpful to understand the mapping process because it shows that mapping in a database feels for this user like a direct way to provide aid for those affected by the earthquake.

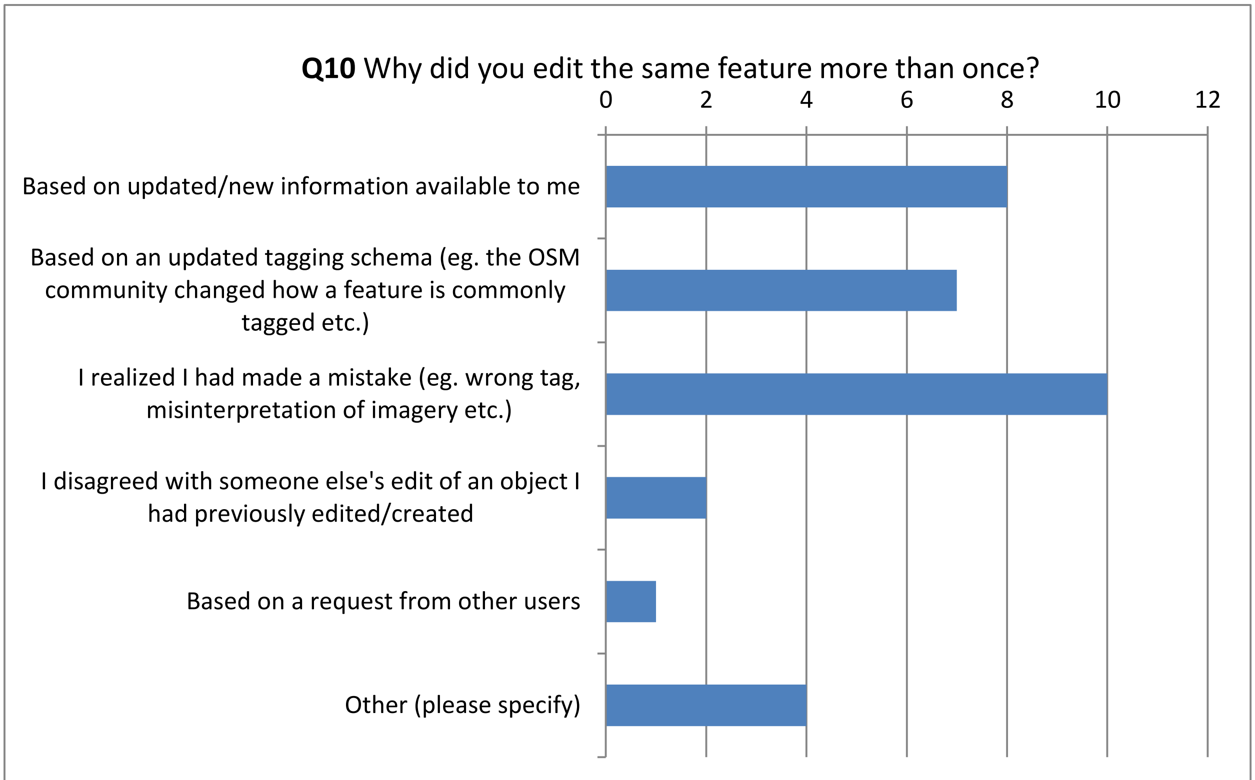
Q5 asks if users had a sense of the impact of the mapping in Haiti. A little less than half said that yes they did know that people in Haiti were using OSM data. Q6 asks how often users tried to map. A majority answered that they mapped as often as they could and immediately felt a sense of urgency to map.




**Q3** Other:
-"it was also a way to increase the coverage of OSM in general, since suddenly high quality satellite images were available"
-"i needed information and then saw it was having mistakes"
-"Practical help, feels better than just give money"
**Q3** Answers: 125
**Q3** Total Respondents: 45

**Figure 4.3**. Question #3 from the online survey

Q8 through Q12 ask the users about their editing patterns. Q8 asks what was the source of a user's edits and most said satellite data released after the earthquake. Q9 asks if users edited a feature more than once. This question got a mixed answer with 17 saying yes and 27 saying no. The answer to this question denotes that users were perhaps more concerned with content creation than with changing existing data. Q10 follows up Q9 by asking why they edited features more than once. The answers shown in Figure 4.4 are also mixed with most saying they had realized they had made a mistake, and some saying they had simply updated data based on new information. Finally several users answered that they changed data based on changes made by the OSM community to the agreed upon tagging schema. Q11 asked respondents if they had edited a feature they themselves had not created.

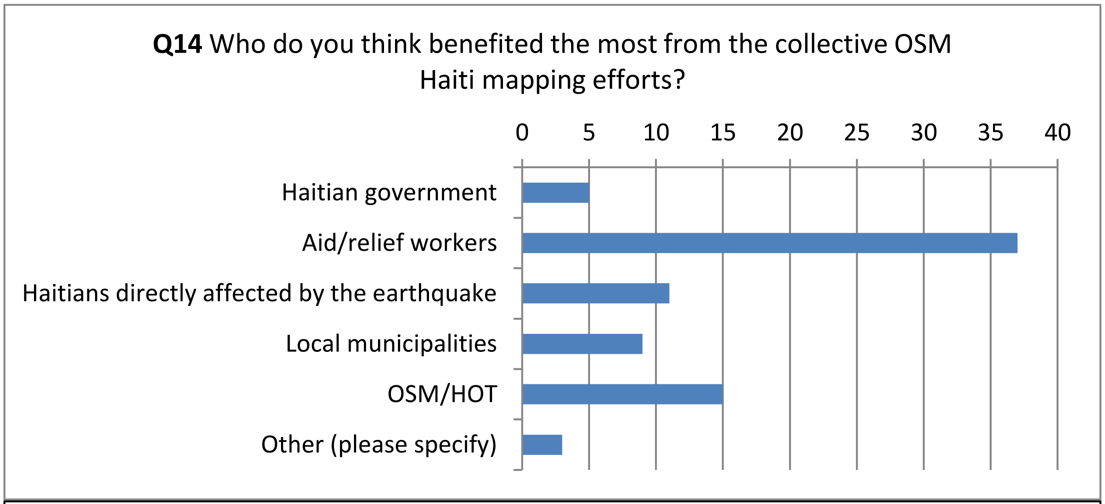



**Q10** Other:
-"Extending a previously edited object that was not completely mapped"
-"I added streetnames to places I had already mapped"
-"The boundary import took a lot of sorting out..."
**Q10** Answers: 32
**Q10** Total Respondents: 17

**Figure 4.4**. Question # 10 from the online survey

Here at 34, the overwhelming majority answered that they had indeed edited a feature they hadn't created. This number is confusing since only 17 users said they had edited a feature more than once in Q9. Perhaps many users confusedly answered they had not edited a feature more than once in Q9 thinking the question inferred that it was a feature they had created themselves. Q12 follows up Q11 and asks why users edited a feature they had not created. Here most users answered that they edited another user's content because they believed the user had made a mistake. The next biggest answer for Q12 is that edits of other's data was based on updated information. Interestingly, Q12's answer patterns are consistent with Q10 which asked the same question regardless of authorship. Therefore, editing one's own or someone else's feature is most often done because of a perceived mistake. Q12 also had one helpful write-in response from a user who said, "The boundary import needed a lot of sorting out..." This answer points out a possibility not asked in the survey that edits could be made to GIS data that was imported into the database by another user as opposed to data created by hand from scratch.

Q13 and Q14 ask users about the perceived impact of their contributions. Q13 asked if users thought their edits had helped the relief work in Haiti with the majority saying yes and a smaller group saying they weren't sure. Q14, shown in Figure 4.5, asks specifically who users thought directly benefited from the OSM Haiti data. As is seen in Figure 4.4, the large majority said that the aid/relief workers were the ones who benefited most from the mapping.




**Q14** Other
-"I sure hope my efforts helped rescue at least a single creature"
-"Everyone who lives and work in Port-au-Prince"
-"I don't know."
**Q14** Answers: 80
**Q14** Total Respondents: 43

**Figure 4.5**. Question #14 from the online survey

Q15 and Q16 revolved around asking users if they would map again in OSM if there was another natural disaster in the world. Most answered that they would map in OSM no matter if the country was poor or wealthy. The next most popular answer was a tie with two similar answers that users would map in OSM if the region affected by the natural disaster was itself poorly mapped in OSM. The difference in these two answers was that one question stipulated that the region was poorly mapped in OSM while the other answer stipulated that the region was poorly mapped in OSM and other spatial databases. Q16 was a follow up question to Q15 and asked if a user choose to answer that they would not map in OSM, why not? No one responded to Q16.

Q17 and Q18 were both open-ended questions designed to allow users a chance to reflect on their experience. Q17 specifically asked how users felt about their experience of mapping in OSM Haiti. Responses were quite interesting and varied. Many stated that the experience was quite rewarding, while several stated that while the experience was rewarding it was also frustrating because of a lack of feedback, a lack or organization, and the difficulty of using the mapping tools. Several respondents reported feeling much more connected to Haiti after mapping in OSM while others stated that they were troubled because they could see dead bodies in the high-resolution imagery. Several users also cited their excitement at filling in blank spots in the database. Q18 allowed for completely open-ended answers because it simply asked if users had anything to add. Here the answers were varied with one user stating that they felt there was a discrepancy between what they were seeing through the media in terms of reports of mass graves and what they could see in the imagery and another answer stated that Haiti was their first humanitarian mapping project but that the thrill of crisis mapping wore off afterwards.

# Chapter 5
# The Evolution of the OSM Haiti Database

**Introduction**

In addition to describing how human subjects were involved with the crisis mapping process for OSM Haiti after the earthquake, the evolution of the database needs to be described. Through the design and functionality of a spatial database is inscribed the possibility of what can and cannot be mapped in a crisis situation. Furthermore, in studying the crisis mapping process of OSM Haiti, the OSM database acts as a repository that contains a documentation of the mapping process to be explored. This research proposes two approaches for this description: first, the results of a Modified Content Analysis and second, a spatial description of the database. The multiple approaches are necessary to highlight two of the several forms of geographic knowledge being captured in the database: attribute and geometric. The results of this research are given not simply as just a static snapshot of the OSM database but also to show the evolution of the database through time as the mapping process takes place.

**Modified Content Analysis Results**

Content Analysis is a method of summarizing large amounts of data, through valid inferences (Weber 1995). The results given here facilitate a summarizing answer for the question: what was the crisis mapping process in OSM after the 2010 earthquake? Furthermore, since an assumption is that the OSM mappers mimicked the beginning steps of a Content Analysis, these steps are synthesized into a Modified Content Analysis resulting in a means to understand the coding (i.e. mapping) process. The Content Analysis is termed Modified because the first three steps of a Content Analysis, choose the data, select categories to code the data, and code the data were performed by the OSM community who participated in the OSM Haiti crisis mapping and not through the methodological directive of this dissertation. Moreover, the term Modified is utilized because a common metric to evaluate the third step of coding the data, Intercoder Reliability, is applied in a variation on the conventional format, and this modification is assumed to be valid for the OSM Haiti coding due to the widespread acceptance of the database by the humanitarian and relief community in Haiti. It might be tempting to think of coding as resulting in written text, however as an interpretive process, coding may result in geometric/spatial data as well. To perform the fourth step of the Modified Content Analysis, summarizing and analyzing the coding process the results are given as a series of tables that describe mapping activity through various lenses. The lenses include geometric activity, editing activity, and user activity. These are not mutually exclusive categories but are rather organizing rubrics to analyze the coding. Finally, the context for exploring an alternative to Intercoder Reliability is given.

Geometric activity is here defined as a description of the mapping process through the feature types used in the OSM database: nodes, ways, and relations. Chapter 3 points out that while the OSM data elements are nodes, ways, and relations they are utilized as points, lines, polygons (a way that ends and begins at the same node) and relations for the purposes of this research. In the case of these four geometry types, there is a clear trend evident in the mapping process. For instance, in Figure 5.1 the daily total features by point, line, polygon, and relate, all but the relates show a clear trend of adding a large number of features immediately after the earthquake for a period of about 2 months. After approximately 2 months the points, lines, and polygons all plateau in terms of adding to the database. Interestingly, while points eventually have the most number of features in the database, the graph shows that about a week after the earthquake, lines features formed the largest number of features for about two weeks. Polygons showed a slower increase in numbers than points and lines. Lastly, points showed three brief instances where the total number of features actually decreased from day to day in the database (January 13, February 3, and March 2). It is important to remember however, that Figure 5.1 does not show the complete editing story since even if the total number of features changes little after two month post-earthquake, users could still be actively modifying the features that exist.

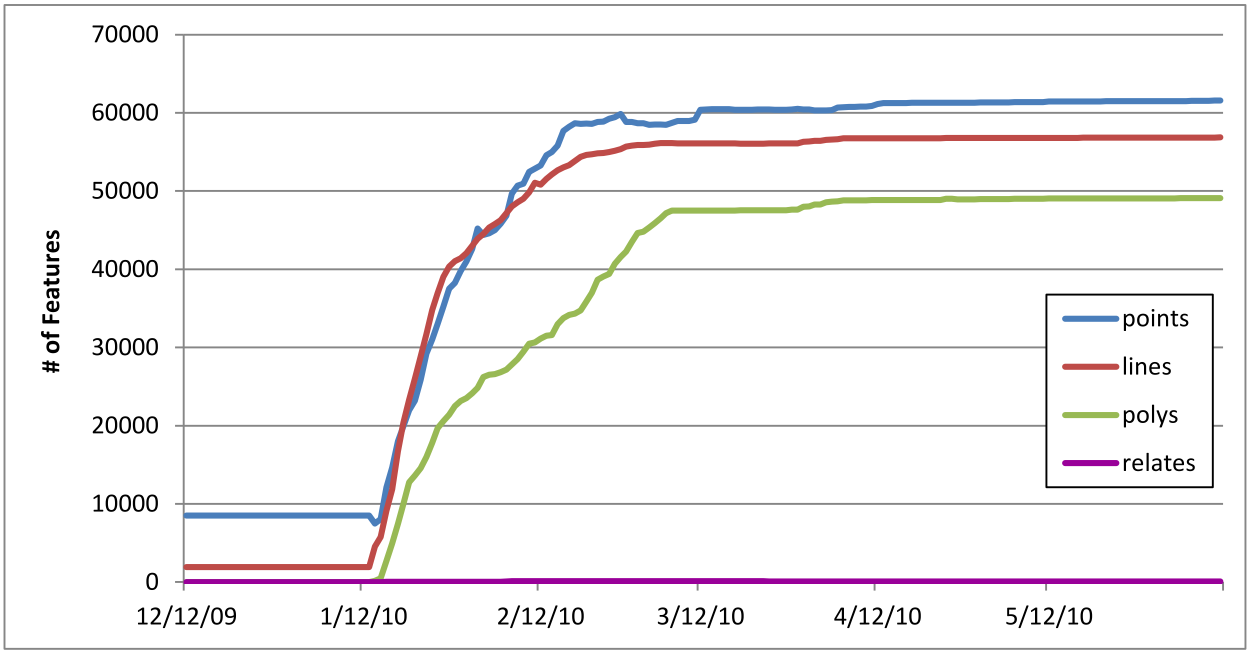



**Figure 5.1**. Daily total number of features in the OSM Haiti database by geometry

Another view of geometric activity is provided by Figure 5.2. This chart provides a lens where geometric activity is also blended with editing activity. Here again points, lines and polygons have the highest daily activity. Points peak early on the 16th of Jan in terms of highest number of features (~10,000) edited in one day. If one takes the high editing window to be the two month period from Jan 13th to Mar 13th, the average number of point edits is 2103 every day. Lines peak the day after points on the 17th of Jan with ~9000 features edited that day. Lines exhibit smaller day to day oscillations than points with the exception of Feb 18th. Taking the same 2 month high activity editing window, lines average 2,488 features per day. Polygons show much less average editing with 1,390 average edits in the high editing window.

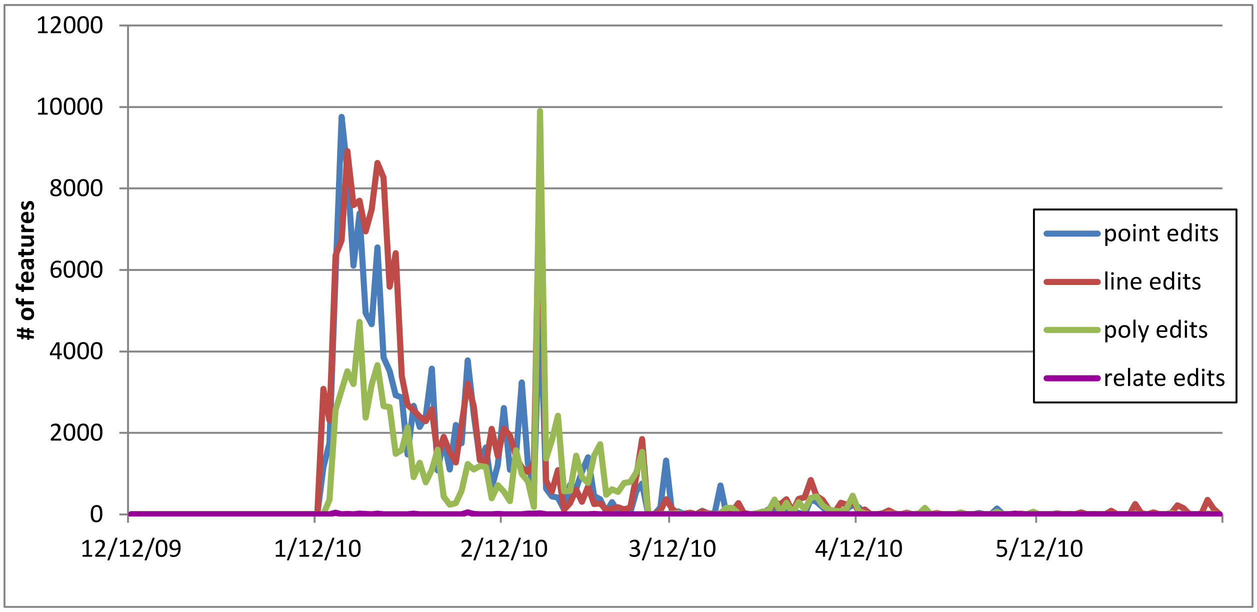



**Figure 5.2** OSM Haiti database daily activity by feature geometry

The most polygons edited in one day are ~10,000 on Feb 18th. Upon closer inspection of the unusual Feb 18th spike, the vast majority of edits appear to be performed by an automated "bot" (a program written by a user to automate editing) designed to change large numbers of features with a predetermined parameter or set of parameters. What is not visible in Figure 5.2 is that lines have an almost identical spike on Feb18th. Given that in the OSM data model, polygons are simply lines (ways) that start and end at the same point, one can conclude that the bot affected mostly ways. Another manner to think about this is if Figure 5.2 were divided by nodes, ways, and relates, the spike on the 18th would be twice as high and almost completely constituted as ways.

Within the lens of editing activity, Figure 5.3 displays a trend of a two month high-activity editing period after the earthquake as very similar to what is seen in Figures 5.1 and 5.2, but is viewed in different terms. Editing patterns in Figure5.3 are displayed under different editing types such as database additions, deletions, geometric modification, and tagging edits. While additions and deletions are self-explanatory, geometric modifications are edits to an already existing feature in the geometric/spatial domain. For example simply moving an existing point from one coordinate location to another would be considered a geometric modification. Tagging edits modify the tagging of the feature. Tagging edits are technically not exhaustive since often when a user changes the geometric qualities of a feature such as in a geometric modification, they will also change the tags as well.

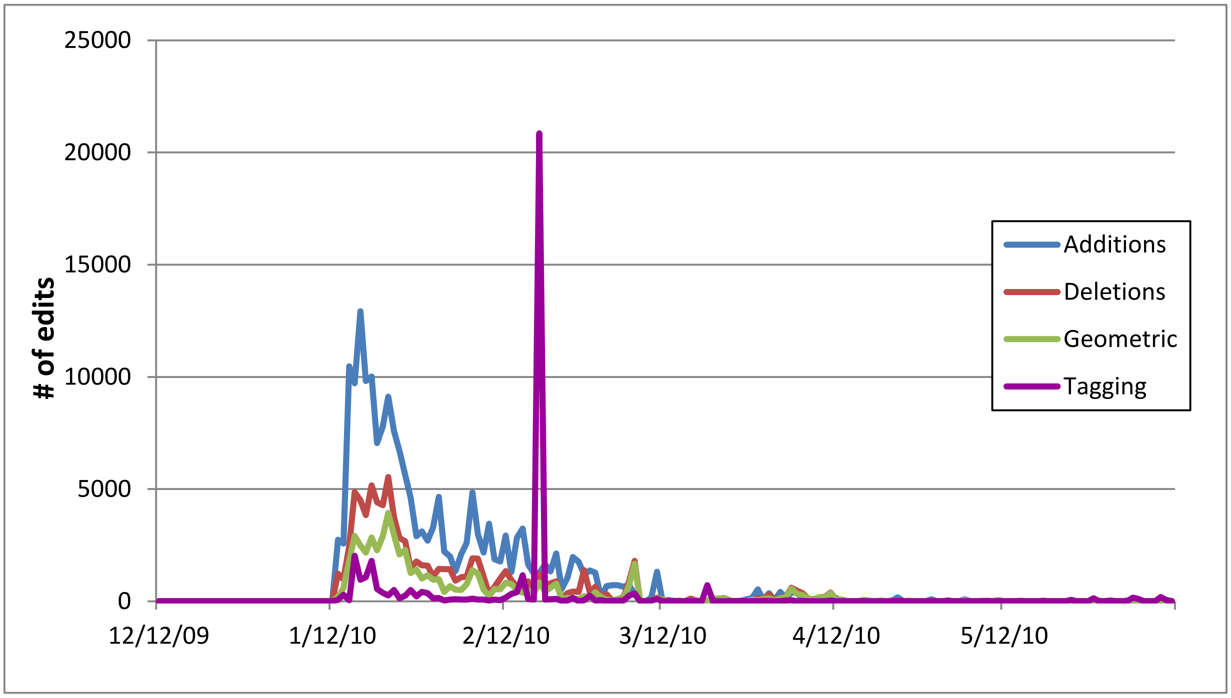



**Figure 5.3** OSM Haiti Database daily activity by editing type

In Figure 5.3, for several days after the earthquake additions, deletions, and geometric changes were increasing at similarly steep rates. Additions form the majority of edits for most of the two month high-activity window, peaking on the 17th of Jan with 12,927 additions. Deletions plateau close to their highest rate of 5,532 deletions in a single day for a week after the 16th of

Jan and then steadily decline for the rest of the two month activity window. Interestingly, geometric modifications follow a daily pattern similar to deletions but with less number of edits. This opens the question as to why users were deleting and modifying the database at similar daily rates. These two editing patterns may be in actuality two forms of the same mapping process. It is conceivable for instance that users who are deleting features are in the mindset of performing quality control and/or updating the content. Modification of existing features could be categorized as another form of quality control or content update. Closer inspection of this pattern reveals that both activities are driven almost entirely by line and polygon modification/deletions. Another pattern that is evident is that the same spike in activity seen in the feature geometry lens on the 18$^{th}$ of Feb is evident here but is entirely devoted to tag edits. Therefore, the bot that scanned the OSM database made changes only to the tagging schema that already existed in the database.

While a further exploration of the tagging activity would likely help expand the Modified Content Analysis, it is beyond the scope of this dissertation. However, an initial exploration of tagging for feature edits was undertaken to give a sense of the scale of change before and after the earthquake. Two results can be reported. First, there were 102 unique tag keys (in OSM tags are structured as key=value eg: "name=Toussaint Louverture International Airport" or "building=collapsed") before the earthquake in the OSM Haiti database and this number jumped up to 581 by the end of the research study period. Second, there were 1,872 unique key=value pairs in the OSM Haiti database before the earthquake and this number jumped up to 21,972 six months after the earthquake.

In Figure 5.4, the lens of user activity also shows a pronounced high-activity window. However, as opposed to the previous figures, Figure 5.4 shows high-activity for three months after the earthquake instead of two months. In addition to showing a longer high-activity period, Figure 5.4 shows two different perspectives on user activity. First it shows the tallied number of OSM Haiti users for the study period. There is a rapid increase in new users (new to editing in OSM Haiti beginning the tally one month before the earthquake, not necessarily new to OSM in general) editing in the database with new users plateauing approximately a month after the earthquake. A total of 503 users contributed to the OSM Haiti database within the study period of 1 month before to 6 months after the earthquake. The second perspective on user activity is

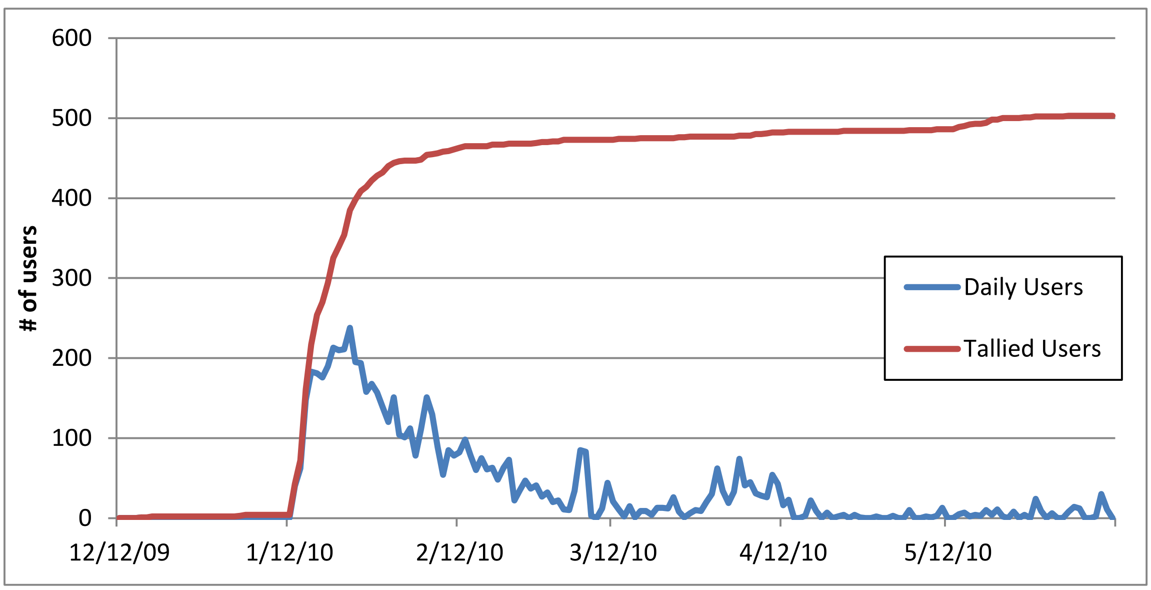



**Figure 5.4** User activity in the OSM Haiti Database by daily number of users and tallied (cumulative) total users.

seen in the daily users plotline. Here the most users editing the OSM Haiti database in one day is 238 on the 23rd of Jan. One last point about Figure 5.4 is that since the large majority of users newly editing in OSM Haiti edited the OSM Haiti database within two weeks after the earthquake, it can be safely said that after January, most of the editing in the OSM Haiti database was performed by users who had already contributed to the database in that previous month and therefore could be considered as experienced OSM Haiti mappers, so to speak.

Another view of user activity is seen in Figure 5.5. Here the graph is produced by taking the total number of edits and dividing by total users on a day by day basis. This chart is helpful as a summary but it has some known accuracy errors. For instance the day that has the most edits per user Feb 18th is the day where the bot performed thousands of line and polygon tagging edits. The number of edits for Feb 18th in Figure 5.5 is therefore an outlier and produces a vastly inflated edits per user value since it is known that one user produced all those edits. However, assuming there are not many other bot edits in the OSM database, Figure 5.5 is informative because there appear to be 3 phases of editing activity. Immediately after the earthquake (assuming the Feb 18th value is inflated) editing activity is its highest. Again ignoring the Feb 18 value, the 17th of Jan has the highest value with 115 edits per user. This first phase of very high activity is highlighted by a red color block in Figure 5.5, and is sustained for approximately two weeks. The second (green) phase of more moderate but still sustained edits per user lasts for approximately 5 weeks. The third (blue) phase starts on 9th of March, on the first day no one edited the OSM Haiti database post-earthquake. This third phase lasts the rest of study period timeframe and is marked by spurts of moderate activity intermingled with no mapping activity at all.

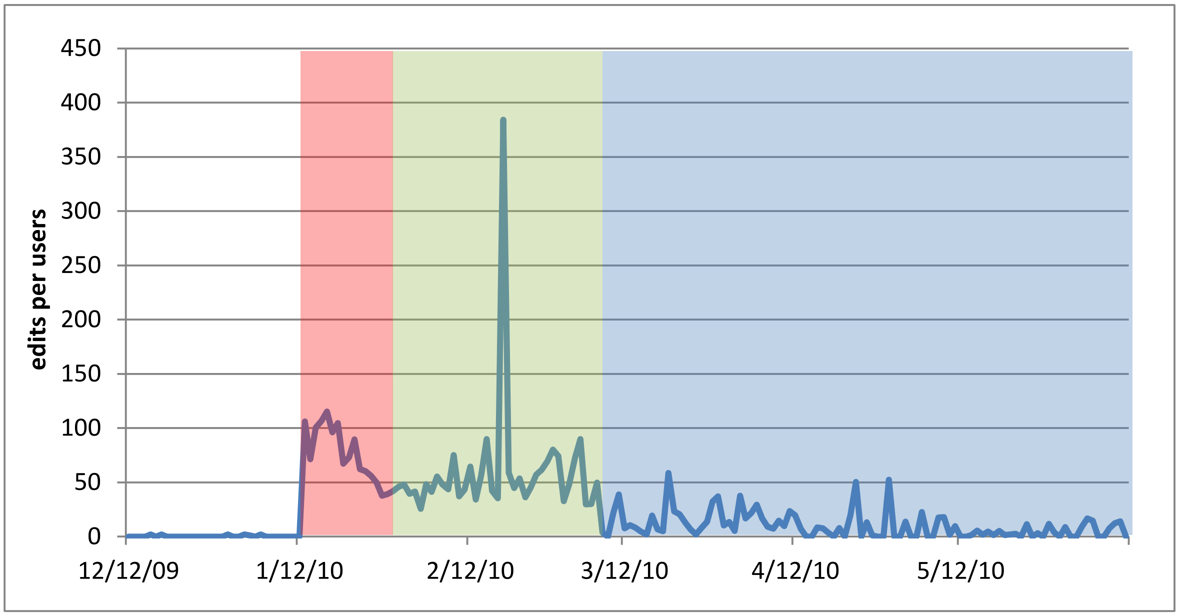



**Figure 5.5** Daily activity in the OSM Haiti Database by edits per user. Edits per user is found by dividing the total number of edits by total users on the same day. Color blocks are added to suggest three editing phases and described in the text.

So far the results of the Modified Content Analysis have shown that the mapping process for the OSM database had a concentrated high-activity period for two months after the earthquake, that the majority of users who contributed started within two weeks after the earthquake, that not all the edits were done in person (but also by bots), and that deletions and geometric edits follow a similar pattern. In order to evaluate the validity of the results of a Content Analysis, traditionally, an Intercoder Reliability metric would be computed. However, and as stated in Chapter 3, for many reasons an Intercoder Reliability metric is impossible to evaluate within the rubric of this research, due to the nature of crowdsourced data. As described below however, a substitution for Intercoder Reliability is considered trough database coding change. Database coding change is first given as the number of times each OSMID (individual OSM feature) is edited, and second by how many users edited the same OSMID. It is proposed that these two descriptions will provide a context for understanding an Intercoder Reliability alternative, or rather extending Intercoder Reliability to better understand the mapping process being described in this project.

**Extending Intercoder Reliability**

Intercoder Reliability is essentially a measurement of agreement. Agreement in a traditional Content Analysis would likely be evaluated by a scenario of whether several users code the same feature in the same manner. Again as was pointed out at the beginning of this chapter, Content Analysis coding applied to the context of OSM Haiti can mean the creation, deletion, manipulation of geometry, and the editing of feature tags. Agreement on a database scale should therefore be assessed through the study of these types of coding. Since the OSM Haiti database is not a static coding process, coding change is an appropriate rubric to explore agreement. As mentioned in Chapter 3 coding change can happen for many reasons, and following one feature's coding change will not result in a measure of agreement as updates or lack thereof do not denote either agreement or disagreement without further data on the user's motivations.

However, looking at the aggregate coding change can elucidate patterns for the entire database to give a sense of how editing activity behaves. Looking at this behavior within the context of crisis mapping might for instance describe whether the aggregate group of OSM users tacitly agree that the OSM Haiti database was sufficiently hydrated or whether features that already existed in the database needed to be updated. This idea of sufficiency is complex but has the basic metric of whether it allows an individual or group of individuals to operate (spatially) within a certain environment (Lynch 1960). As an aside, the term "hydrate" originated in database science to refer to adding content to a database whose schema (organizational structure) is defined, but for which items (records, objects, features or attributes, depending on the schema) have not yet been added. Fortunately, coding change has been explored in Figures 5.2, 5.3, 5.4, and 5.5 all of which show various angles of editing encompassing both geometric and tagging activity. Two more coding change points of view are given to explore editing behavior. First, Figure 5.6 shows a sorted count of all edits performed in the OSM Haiti database within the study period of this research project. Each feature OSMID is tabulated by how many edits were performed on a given feature. What is interesting in Figure 5.6 is that less than half the features in the OSM-Haiti database actually changed at all. For those that did change, the large majority

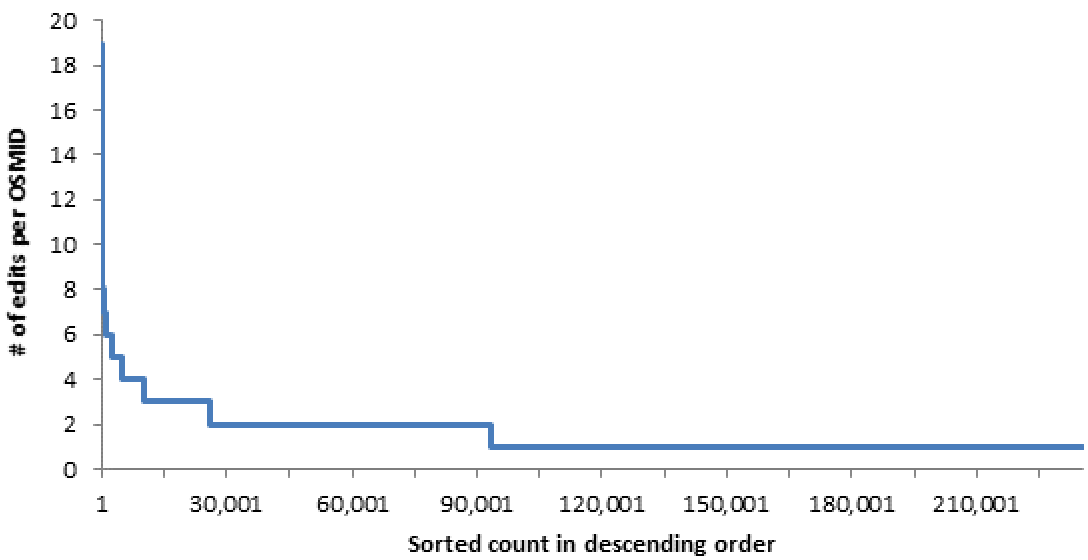



**Figure 5.6** Sorted count of edits showing number of edits per feature OSMID for the research study period.

were only edited twice (i.e. one edit to the database to create the feature plus one more edit to change the feature). The feature with the highest number of edits has 19 edits. Again, Figure 5.6 is not a chart to infer agreement yet the mapping behavior suggested here is one that is not concerned with modifying the content. Within the context of the OSM Haiti crisis mapping, many mappers were likely trying to simply add data as fast as possible and were perhaps not concerning themselves with evaluating existing data.

Another manner to look at database wide coding change is seen in Figure 5.7. Here instead of how many changes were made to each feature, Figure 5.7 tabulates how many users contributed to each feature. This table displays an even more drastic decline in terms of users per feature with approximately 20% of features having more than one user in their edit history. Both Figures 5.6 and 5.7 are likely skewed not because of agreement or disagreement, but rather are simply by-products of what is seen if Figures 5.1, 5.2, and 5.3: the OSM Haiti database was hydrated quite rapidly. After the majority of features were added, editing activity tapered off.

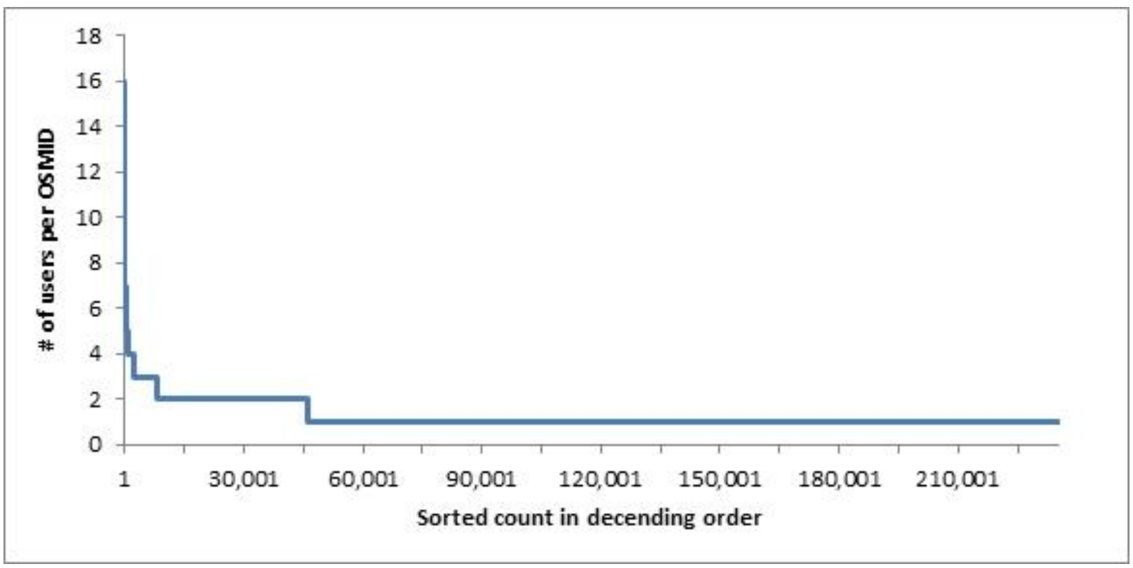



**Figure 5.7** Sorted count of edits showing number of users per feature OSMID for the research study period.

To conclude, Intercoder Reliability while not possible as a metric within this Modified Content Analysis, can be extended if a certain level of sufficiency and agreement was reached by the OSM Haiti mappers. Results from Figures 5.2, 5.3, 5.4, and 5.5 point to a temporal stabilization in terms of editing activity. Figures 5.6 and 5.7 point to an editing pattern of very few features being edited more than once and those that were edited more than once were edited by very few mappers. While database hydration appears to be a motivating force, simply comparing Figures 5.6 and 5.7 also shows that of the features that were edited, half were edited by the same user, and half were edited by more than one OSM user (~90,000 features were edited more than once, and ~45,000 were edited by more than one OSM user). Taking some of the results from the online survey, Q10, Q11, and Q12 allow for a better understanding of why users edited features and why users edited features specifically created by other users. The answers to Q10 which asked why a user edited the same feature more than once, show that the top two reasons for editing a feature were because the user realized they themselves had made a mistake and simply because there was new information for that feature. Disagreement of another user's edits of a feature that the original user had created or edited was quite low. Q11 shows that most of the respondents did edit other user's features and this was because they believed the feature had a mistake. While this appears to be in contradiction with the results of Q10, the difference here is that OSM users do indeed edit each other's features and when they do, the original editor does not tend to dispute this edit. Therefore, given the low activity level of multiple users editing the same feature, results from the survey which indicate very little overall disagreement when a feature is edited, and the widespread acceptance of OSM as a basemap by relief workers Intercoder Reliability is extended to assume both sufficiency for the task at hand and agreement between coders.

**Spatial Analysis Results**

The final series of results for this research provides a spatially explicit analysis of the crisis mapping process of OSM Haiti. This is important in part because OSM is designed to be a spatial database, because all those who contributed to OSM did so as spatial mappers, and because the earthquake itself had a spatial impact (Figure 5.8). The 2010 earthquake was devastating to Haiti because it happened in a location that was close to populated urban centers. Figure 5.8 illustrates the areas where the most people who were affected would likely benefit from mapping information. In other words, those interested in helping the relief efforts after the earthquake through mapping could concentrate their efforts on the areas that would most benefit from up to date fine-resolution map data and in the areas where relief work was under way. The expectation would be that mapping would largely be concentrated in the more severe damage intensity zones shown in Figure 5.8. Conversely, mapping outside the damage zones is not directly related to crisis-mapping and edits to OSM-Haiti in these areas could be considered more as development work or as is mentioned previously simply as a form of database hydration.

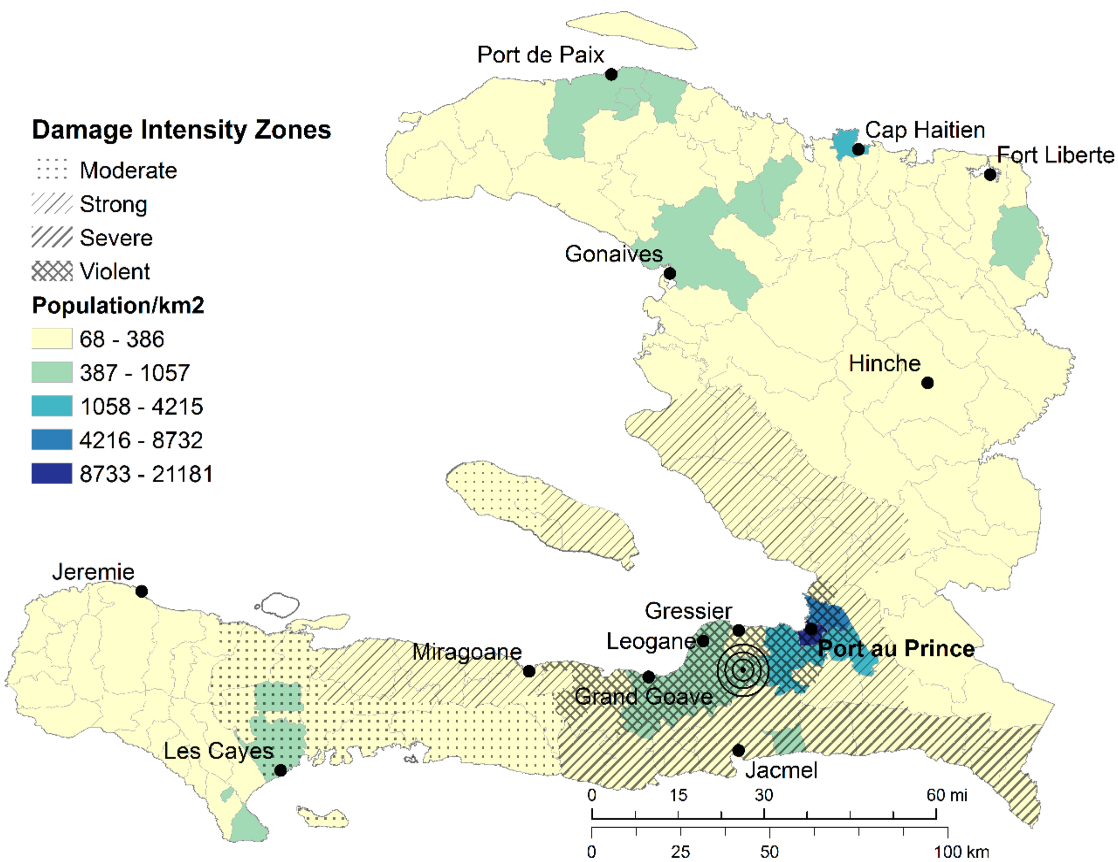



**Figure 5.8**. Population density vs earthquake damage assessment. Population estimates from 2009 released by US Census Bureau (2013). Population data is divided into Level 2 administrative communes. Damage assessment data released Feb 17 2010 by Minustah (2010).

As shown in the results from the Content Analysis, immediately after the earthquake a large number of edits were made to the database. The pattern of these edits varies by geometry type in terms of editing rates and it varies spatially as well. Figure 5.9 gives a comparative display of fishnet grids whose cells contain tallies of all the edits that occurred within each grid cell for the range of dates specified. Grid cells are 8 $km^2$ and after counting how many edits occurred within each cell, the results are color coded with a 5 class quantile breaks stratification. Also displayed within each fishnet grid is the standard deviational ellipse for the entirety of the edits for that date range.

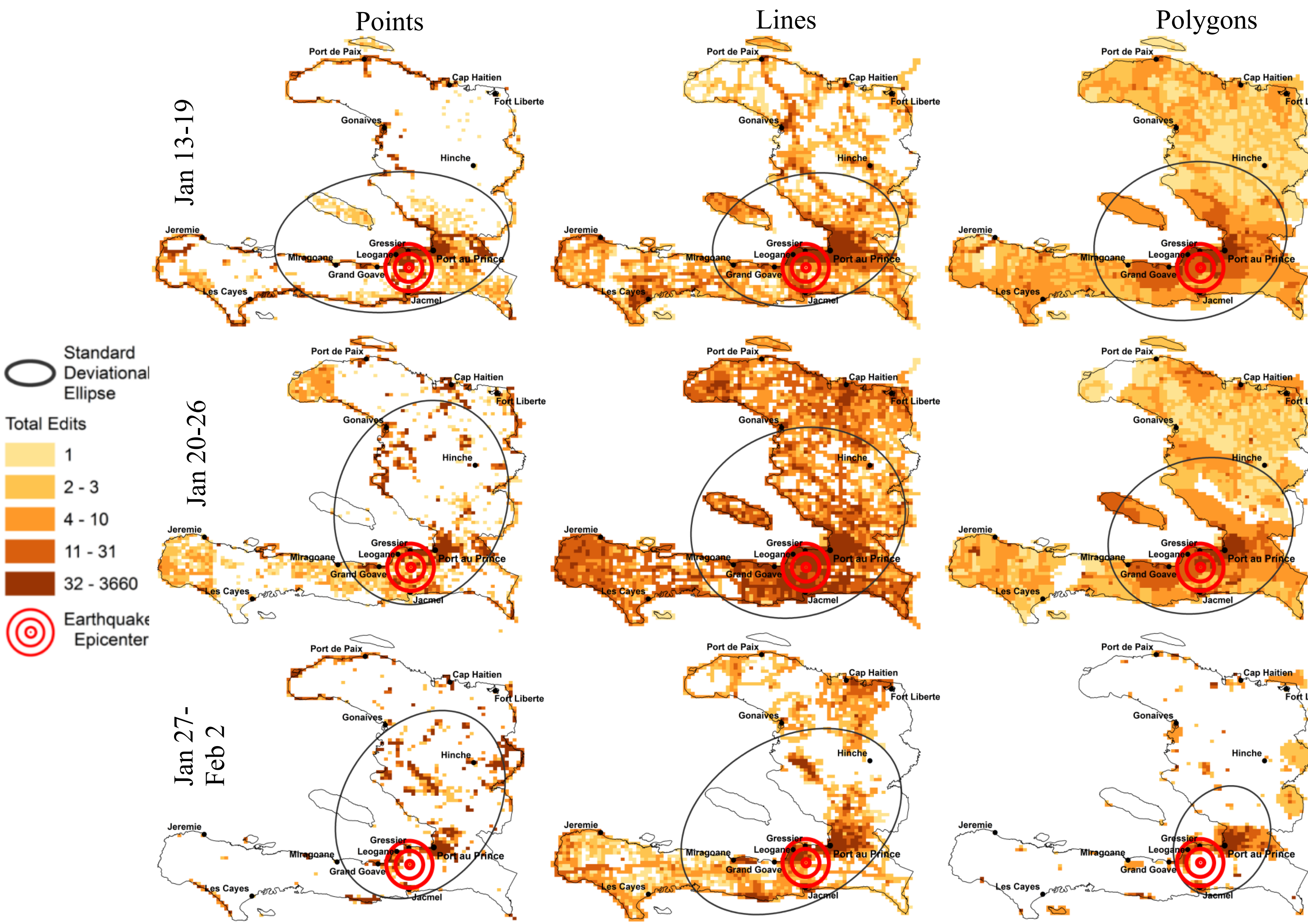



**Figure 5.9** Fishnet grids for Haiti displaying the three weeks of edits after the earthquake for points, lines, and polygons. Each grid cell contains the tallied edits for that location for the range of dates specified.

Figure 5.9 show some clear differences in terms of the geometry type but also in terms of the timescale of the editing. As one might expect, point edits tended to cluster, the line feature classes are more dendritic, and the polygon edits blanket the country in a nearly uniform manner. Through the use of the 8 $km^2$ cells, in Figure 5.9 points are displayed either as clusters or as representing single point edits. For the first week of point edits, many of the edits that appear to follow the coast are part of an effort by OSM Haiti users to clean up the dataset by converting the demarcation of the coastline from points to lines. Line edits on the other hand visually appear to show editing patterns that represent lines. These are likely roads that span Haiti. However, given the 8 $km^2$ size of the grids, it is also possible that clustering occurred for locations such as urbans areas where line segments might be smaller than ~2km. Polygons on the other hand show widespread coverage of Haiti for the first two weeks of Figure 5.9. In many cases, this coverage is entirely due to the addition of administrative boundaries such as Departments and Arrondissements. What is most interesting is how there seems to be a trend manifested in all three geometry types, namely an initial concentration of edits around the area most damaged by the earthquake, followed by edits expanding outward to the rest of the country, and then finally retracting.

Even though there is a clear spatial/temporal editing trend in Figure 5.9, there are variations between the geometry types. For instance if the standard deviational ellipses of the point fishnet maps are scrutinized, the first week of edits are clearly centered around the damage area of the earthquake; whereas in the following two weeks the center of edits shifts towards the rest of the country, moving further north. The third week for point edits shows a large widespread standard deviational ellipse but the edits are clearly more clustered and less widespread than the second week. While it appears that lines start off less widespread than points in the first week because of the smaller standard deviational ellipse, this is likely due to a higher concentration of edits in the damage area. In terms of filling in Haiti or being more distributed, lines are but are clearly more widespread than points. The second week of line edits shows the same shift north to editing the rest of the country and less on the damage area while at the same time the ellipse itself grows in size because the edits are distributed more evenly across the country. While it is not as evident as the points, the line edits do step back slightly in the third week to be less dense and widespread as week two. Polygon edits do not appear to exhibit the same second week Haiti-wide expansion but do show the clearest retraction of edits in the third week.

One aspect of Figure 5.9 which is striking with all three geometry types is that the first week of edits is not simply focused in the damage area. The context for this phenomenon might be found in referring back to both Figure 5.1 where the point features initially had a slight dip in total number of features, and Figure 5.3 where deletions and geometric edits were seen to be somewhat high initially. What this might suggest and was discovered upon further inspection, is that rather than assuming that the first week of Figure 5.9 is simply the record of lots of feature additions, there was a fair number of initial database cleaning up and updating. In addition, mapping outside of the damage area is part of an effort by OSM Haiti mappers to hydrate the OSM Haiti database. For example, the second week of edits for the points show some interesting clusters of edits near the peninsular edges of Haiti in the south near Jeremie and in the north, west of Port de Paix. Inspection of these edits showed that a large majority of the edits in both clusters were the addition of the location of peaks in these mountainous regions. These along with many other edits were likely not directly benefiting crisis mapping efforts.

Figure 5.10 continues the temporal story started in Figure 5.9 by displaying the rest of the fishnet line edit tallies for the study period. First is displayed the fourth week (Feb3-9) after the earthquake followed by the rest of the study period in months. The line edits for both Feb 3-9 and Feb10 – March 11 are centered north of the damage area and show large ellipses that show edits across the country. The Feb 10 – March 11 map has many more edits in it which are slightly more distributed across Haiti as it has a bigger standard deviational ellipse. This is expected since that month long tally is as the tail end of the high-activity trend identified in the Content Analysis results. The March 12- April 11 map displays the significant slowdown of edits even compared to the fourth week map. Its ellipse while still centered north of the damage area is oriented in a north-south direction likely because there are fewer edits on the western peninsula of Haiti. The April 12- May 11 map shows very few edits and those that exist are concentrated in the damage area. The last map of May 12 – June 11 shows an ellipse that apart from a circle of edits to the North, is centered on Port au Prince and not on the entirety of the damage area. That the ellipse is so influenced by the edits north shows how few edits happened this month.

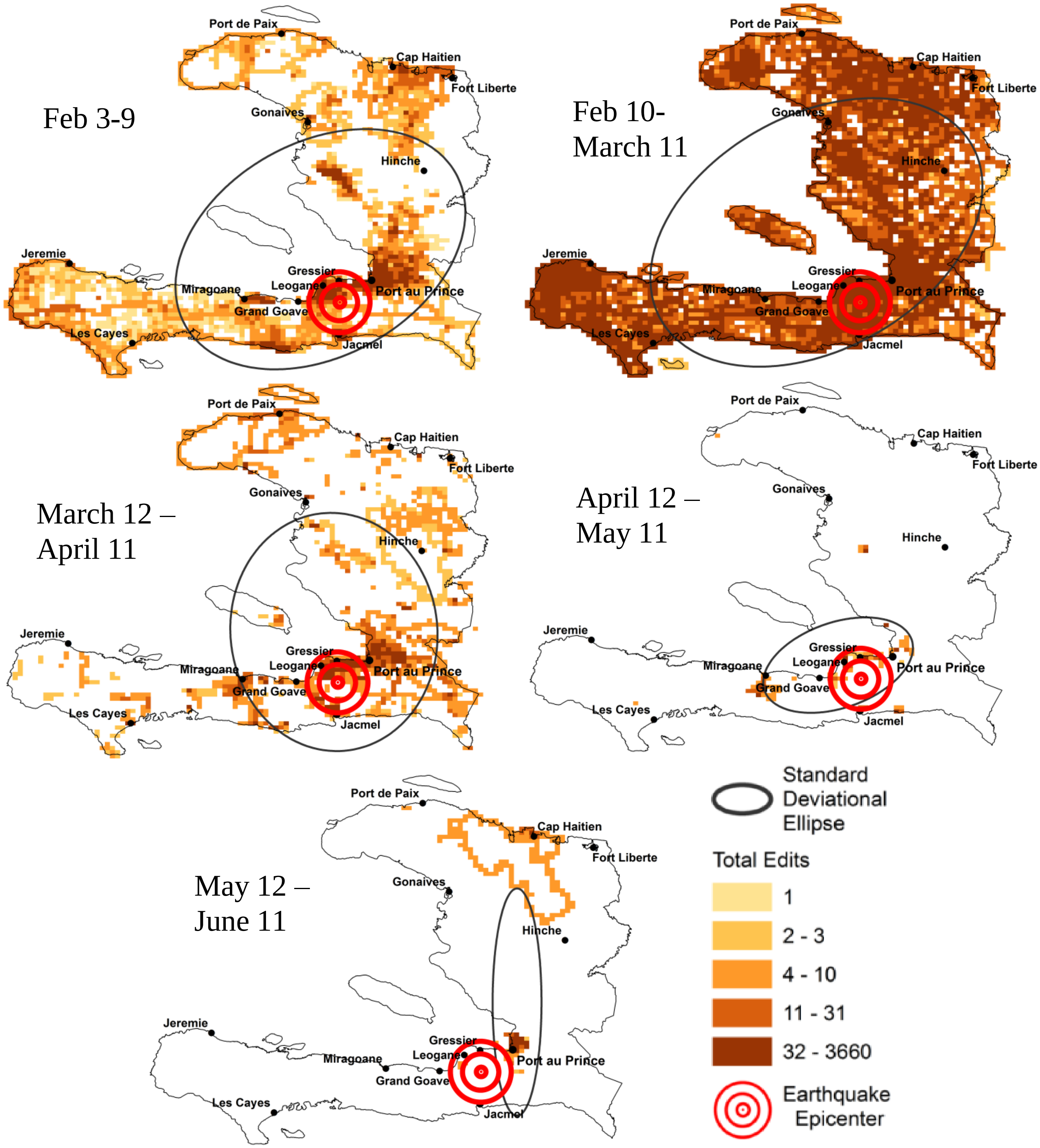



**Figure 5.10** Fishnet grids for Haiti displaying the fourth week of line edits after the earthquake with the following four months of the study period. Each fishnet grid cell contains the tallied edits for that location for the range of dates specified.

**Summary**

The Content Analysis and spatial analysis results of this research project show several trends. First, mapping activity for OSM Haiti happened at the highest rates immediately after the earthquake and gradually diminished over a period of two months. A total of 503 OSM users mapped within the study period with the vast majority of those mapping in OSM Haiti mapping within two weeks after the earthquake. At peak activity 238 users edited the OSM database in one day. Despite a clear spike in activity especially in the first two weeks, the number of edits per number of users did not fluctuate nearly as much as the number of editors themselves or the number of edits. Also of interest is the evidence that bots or automated mapping scripts influenced the database. Features tended to have very few users modify them once they were created. Likewise features in the OSM Haiti database tended to have very few edits to modify them after they were created. Spatially, no matter if the features were divided up by points, lines, or polygons, edits were centered the first week on the damage area of Haiti. The second week of edits showed a migration to editing the rest of the country -except for polygon features which were already fairly widespread to begin with. The third week of edits displays a noticeable lessening of edits often coupled with a contraction in the spatial breadth of the edits. When the spatial editing pattern is observed for the rest of the study period, the two month high mapping activity is initially clearly observed and then a subsiding of edits is quite evident.

# Chapter 6
# The Practice of Crisis Mapping

This research explores the response in OSM to the 2010 earthquake in Haiti as a case-study for crisis-mapping. Chapter1 introduces this research by arguing that currently, a majority of mapping happens through computerized systems. Moreover, this new cartographic mode often utilizes GIS and GIS databases to analyze, store, and display map data. Their influence is therefore quite important when it comes to organizing spatial meaning, and in the case of GIS databases, often overlooked. Often when critically examining the mapping process, the role of data is overlooked for the sake of its symbology. The technology of GIS and GIS databases are also currently joined with the social and technological world of the Internet to such an extent that it is suggested that mapping currently exists in the context of a collaborative mapping era. In particular, OSM through a labor force provided by VGI has created a map database that provides a viable alternative to many other GIS databases across the world. The mapping behind OSM is particularly interesting since it gives insight into a collaborative mapping process but also since it simultaneously proposes a multitude of mappings of the world. While the concept of crisis-mapping itself is not new, the crisis mapping efforts in the OSM database for Haiti are particularly worth investigating because volunteer mappers for the first time added information to a database at such a rate, in such quantities and with enough accuracy that it became the de-facto source of geographic information for most of the major relief agencies involved.

Several research questions are given at the beginning of this dissertation and answered in the following paragraphs. First, taking OSM as an example of VGI, do changes in the process of mapping exist when VGI is utilized for map-making, especially in the context of a humanitarian crisis? Second, what does crisis mapping involving VGI look like at a database level, and how does it change over time? Third, how are the varying experiences of individuals who contribute VGI to a database reflected in the database itself, and can these be teased out of the database, after the fact?

To answer the first question (does VGI change the process of mapping within the context of humanitarian mapping), a brief review of what is meant in this dissertation by the process of mapping is necessary. Broadly speaking mapping is the process of map-making, and in a humanitarian crisis mapping context, spatial databases fill a major map-making need to organize meaning from a chaotic situation. This first research question can therefore also be re-worded as: did VGI change the ways that meaning was generated, organized, and utilized spatially within the Haiti earthquake? The results of this dissertation in part answer this question through two types of analysis of the OSM database and by an analysis of the volunteers themselves.

From the point of who does the mapping, VGI does change the mapping process in a crisis situation in several points and does not in others. Given the results of the Modified Content Analysis, VGI provides an unprecedented large labor force to address the problem generating spatial data quickly post-disaster. These crisis mappers are also a different maping labor force than in previous crisis situations because they are volunteering at a global distance from the actual site of the crisis. The survey results further show that VGI changes the mapping process by providing a labor force that is mostly not trained in humanitarian work or in interpreting disaster imagery. The spatial analysis of the database shows through the example of database hydration, that VGI changes the mapping process by providing a labor force not solely focused on humanitarian work. On the other hand, from both the survey and interview results, VGI does not appear to change the mapping process in terms of who used the mapping and for what purpose. Namely, the relief agencies in Haiti were still the recipients of the mapping process. Moreover, the example given by User4 in the Tier 1 interviews that relief agencies did not put sensitive map data into OSM for security concerns shows that the ‘open’ data paradigm that informs OSM’s use of VGI did little to change the power dynamics of who controls certain types of spatial information.

The second research question of what VGI crisis mapping looks like in OSM Haiti, is directly answered by both types of database analysis. From the Modified Content Analysis, VGI crisis mapping in OSM Haiti follows clear trends of a high level of activity that lasts approximately two months after the earthquake. Furthermore, the actual editing of the database is not only done by individuals but is also done by bots. By and large, features added to the OSM database remained largely untouched within the study period, and when a feature was edited it was edited by two or fewer users. The spatial analysis shows that VGI crisis mapping was not confined to the damage zones of the earthquake. This mapping in the areas outside damage zones is explained as database hydration. The spatial analysis similarly shows that VGI crisis mapping also exhibits a high-mapping activity footprint which spans the whole of Haiti. Taking the results of the Modified Content Analysis in terms of when the high-activity editing took place, the spatial footprint of these edits cover the entire country, showing that even at the beginning of the crisis mapping, database hydration was taking place. Finally, the spatial analysis also clearly shows that while much of the mapping took place around the most populated areas (the same areas also most damaged by the earthquake) a lot of the database hydration took place in quite low population density areas.

The third research question, of how individual experiences of those who participated in VGI crisis mapping are reflected in the OSM database, is the least well answered in this dissertation. This is due in large part to the lack of an in-depth analysis of the tags used to provide the geometric features meaning. Another reason why the results do not answer this third question is that the spatial analysis does not follow individual users' editing patterns to see what spatial behavior they exhibit. Outside of the database, the results of the survey and interviews do provide answers of what individual experiences were in this crisis mapping process some of which are explored in the discussion in the following paragraphs.

**The many facets of crisis mapping**

The crisis mapping process that built the OSM Haiti database was not a simple one. Indeed it would be a mistake to reify crisis mapping into a singular process. For instance, the spatial analysis, interviews, and surveys of this dissertation show at least two clear mapping patterns immediately after the earthquake: database hydration and mapping to aid humanitarian efforts in the zones affected by the earthquake. Since both patterns exist (and there are undoubtedly more) within the rubric of crisis mapping a description of this process must acknowledge the many ways crisis mappers used crisis mapping to bring meaning to a humanitarian tragedy. As an organizing rubric, three points of access to the crisis mapping process are utilized. First, the mapping process is described through the metric of the OSM users who contributed to the database. Second, the OSM Haiti database itself is explored. Lastly, the context of this crisis mapping is discussed with an emphasis on Haiti itself and the humanitarian cause which bookends the whole project.

**The user and OSM Haiti**

Chapter 4 discussed the surveys, which greatly aid to understand the population of persons who participated in this crisis mapping project. To facilitate discussion of survey contributors, the discussion here (unless otherwise specified) is meant to limit the population of OSM Haiti users to the study period of the research project. As stated previously in the dissertation, the term "users" is intended to refer to those who added or edited content in OSM. The reader should keep in mind that mappers form the studied population, not people who visited the OSM portal but did not contribute to it. From the survey results, the OSM Haiti user on average was not new to the OSM community (although many did indeed join OSM for the first time after the earthquake), but was new to crisis mapping. While the survey further suggests that OSM Haiti users became involved because of already being part of the OSM community, there seems to be no single motivation for mapping.

In the survey results, Q3 shows that a mix of reasons were given when asked why users contributed to OSM in response to the earthquake. Q3 shows the highest ratio of answers to respondents given (125 answers from 45 respondents). It is easy to imagine that in a crisis mapping situation, the explicit reason for contributing to a mapping effort would simply be to aid relief work in some fashion. While it is important to note that respondents to Q3 were given the choice to select multiple answers, the choice with the most selections was one that does not have any explicit humanitarian language (for example, "I was part of the OSM community and wanted to contribute to the mapping in OSM Haiti"). According to the survey users on average mapped in response to the earthquake as a community response. The implication here is that while OSM users in the entire community are an international conglomeration of persons (there appears to be some dispersion in Figure 4.1), there is seemingly still a sense of 'this is what we do as a community'. Therefore, for the roughly 500 OSM users who performed crisis mapping, most were regular contributors and mapping was not simply a driving moral imperative. It appears to be a habit (the term often utilized in the interviews is 'hobby') and a belief in the greater project of OSM as well. That said, there is clearly seen in Q3 that OSM Haiti contributors acted as a show of empathy from a distance.

User1 from the interviews gives an example of the notion of mapping as habit. In User1's description of becoming involved in the crisis mapping for OSM Haiti, the reason given was a show of emotion at the loss of friends in Haiti, User1 started mapping in OSM because of being unable to find the location that was a personal connection to Haiti on a map. For User1, there was no clear notion of the potency of OSM in terms of creating a basemap. User1 explained that it was only after a day of mapping, and after someone else pointed it out, that the concept of crisis mapping *vis-à-vis* crowdsourcing became apparent.

The urge to map is helpful also because of another pattern seen in OSM crisis-mapping, namely that of database hydration. Database hydration will be explored further below in the discussion on the OSM database, but suffice it to say that the motivations for hydrating a database are inherently tied to the user community. Figures 5.8, 5.9 and 5.10 show the spatial pattern of database hydration quite clearly given that a sizeable portion of the mapping took place outside of the damage zone. In Q3 again, there is a comment that a user wrote in under the "Other" choice stating that "It was also a way to increase the coverage of OSM in general, when suddenly, high quality satellite images became available". This statement is important for several reasons. First, it shows the urge to map being described in the previous paragraphs can be viewed as part of the OSM project writ large, to hydrate the database. Second, there is an implication that the quality of the data was a draw for mapping carefully. In response, a question could be

“What is the resolution that imagery needs to be available for OSM users to want to add to the OSM database, especially in the absence of the possibility of collecting the data in person (i.e., going to Haiti)”? More pointedly, since ‘low’ quality satellite data (e.g., Landsat) was available for Haiti before the earthquake, this is suggestive of an imagery resolution threshold that motivates users to map within the metric of database hydration.

A scan of the list of imagery provided after the earthquake shows a large range from 2.5m to 15cm resolution (http://wiki.openstreetmap.org/wiki/WikiProject_Haiti/Imagery_and_data_sources/Old#Quality). The implication is that the features of interest to OSM users likely starts within this range of imagery resolution. This range has implications for further crisis mapping efforts since the question to ask is “At what geographic level of detail does a humanitarian crisis become ideally mappable for the OSM community? Does the level of detail for crisis mapping differ for database hydration? These questions are going to become increasingly important as data for crisis mapping is going to be made available at much finer resolutions in the near future. At the time of writing, Patrick Meier, a key persons responsible for the Ushahidi Haiti efforts, has helped to form a group of crisis mappers known as the Humanitarian UAV Network (http://uaviators.org/) who are developing tools for deploying small unmanned aircraft systems immediately following a humanitarian crisis situation. Patrick Meier is also involved in a project called MicroMappers (http://micromappers.org/) which combines crowdsourcing and artificial intelligence to automate the process of sifting through the large amounts of data that these drones will undoubtedly generate. Therefore, in the near future crisis mapping will potentially be able to automate the mapping process so that with fine-detail images (2cm or less) damage assessments can be quite rapid, consistent, and powered in part by volunteers.

From the results of this research, database hydration has at least two motivating factors besides simply adding to the OSM database. First, database hydration as it took place in Haiti is about the urge to fill blank spaces. In the transcript of the interview, User4 mentions that filling in blank spots in OSM was a motivation and that this filling-in is a fun and enjoyable task. This view is bolstered by two respondents to the survey who in Q17-10 and Q17-16 directly equate fun with mapping in poorly mapped or blank areas. Another comment which points to the importance of blankness in a database is made in the survey results from Q15 where the survey question asks if OSM users would map again if another natural disaster occurred in Haiti or elsewhere. One user wrote in the “Other” field that they would map again if there were no previous map. Since the context of the question is crisis-mapping, this particular user is connecting the blankness of a database to crisis-mapping. Actually, this user is not alone. Looking at the rest of Q15, 20 users checked that they would likely perform crisis-mapping if OSM itself was poorly mapped in the affected area; and 20 users also checked that they would perform crisis mapping if no spatial data existed in any database. Blankness is clearly an important element of crisis-mapping within the OSM community.

Besides blankness, database hydration secondly appears to be a sort of gift to the Haitian people. This gift might best be understood as a form of nation-building, or within the rubric of contributions to a community. Within the survey results, one comment that alludes to this is in Q14 where respondents are asked who benefited most from the collective OSM Haiti mapping efforts. One user wrote “Everybody who live[s] and work[s] in Port-au-Prince until now”. This filled-in answer does indeed differ from the options given in Q14, namely that aid/relief workers benefited, Haitians directly affected by the earthquake benefited, OSM/HOT benefited etc… This particular user was also the only person in the previous question Q13 to answer that volunteering to map in OSM Haiti did not help with earthquake relief work in Haiti. Looking further at this user's answer in Q18 reveals that when asked if there was anything else they would like to add, stated: "…I don't know a major humanitarian organisation that used [OSM] during the first weeks of the rescue efforts in Haiti. It was useful during the months after that, above all during the cholera crisis, since October 2010". Returning to Q13, and given the answer to Q18, perhaps this user interpreted the term relief work in Q13 as a very specific time period and answered with a no due to a lack of knowledge about OSM usage in the immediate post-earthquake time period. Regardless of the users' answers to Q14, an insight is that several of the interviewees describe crisis mapping in Haiti beginning a form of long term work for Haitians themselves.

The motivation described here implies a nation-building view of database hydration in OSM Haiti, especially in User2 and User3's interviews. User2 for instance went to Haiti with the purpose of growing an OSM community, and states, "There's a value in OSM that people who live in an area are the ones who lead that mapping effort. The goal was to take the resource that had been created by all these volunteers and pass it on to those who were there who saw value in it and were interested in maintaining it". User2 further describes the training, hurdles, and changes that took place in efforts to grow the Haitian OSM community. User3 shows this concern for Haitians themselves as well. User3 not only contributes to OSM Haiti while in Haiti, but maps cultural locations above and beyond simply humanitarian mapping. User3 tried to act as an ambassador for OSM while living in Haiti, by wanting to teach Haitians about the valuable resource that OSM Haiti is to the local community. User3 also comments on working to convince the Haitian government to use OSM Haiti. Further on, User3 clearly states that these efforts are seen as a way to make Haiti better.

Given these observations about OSM Haiti users, it is clear that for users ethical and economic components are intertwined. User1 for instance started performing crisis mapping as a form of mourning the loss of friends in Haiti, as a way to help those friends who were still there, and for the off-chance that map data would become useful. As part of a community of mappers, all the interviewees and likely most of the survey respondents became involved in this crisis mapping because they were a part of a community that shared a similar belief, and those who joined quickly after the earthquake (as shown in Figure 5.4) also shared this belief, that mapping is a helpful response to natural disasters. In economic terms these OSM users constituted a labor force within the rubric of VGI; but the actual motivational ideology of each user clearly has some variance. As mentioned previously regards to Q3, it is surprising that an explicitly humanitarian reason was not chosen as the predominant answer but rather a broader cultural one of being part of the OSM community.

One final point to be made continues the discussion begun in Chapter 2 concerning the ethics of triage and the implications for the question, "What is chosen to fill a crisis mapping database?" As mentioned earlier, the imagery that will be used by volunteers in the future will be of increasingly fine detail. Several consequences are envisioned. First, the effect of triage inherent to humanitarian work will only be more pronounced within the realms of crisis mapping as more social media, imagery, or other data details will be filtered to remove the unwanted noise from the data. Furthermore, as the case of the use of bots in OSM Haiti shows, who or what is doing the filtering will likely evolve into more automated means.

A second point concerning crisis mapping triage is that those performing the triage will have to emotionally handle the side effects of being involved with humanitarian work. For instance, given the several comments made in the survey results about being able to see dead bodies in the imagery released to the public domain that was used for tracing into OSM, a form of crisis mapping Post-Traumatic Stress Disorder is likely to occur. Again the increase of fine-detailed imagery will only increase this probability.

**The database and OSM Haiti**

The role of the database in the OSM Haiti crisis mapping process is extremely important. In Chapter 1 the idea is posited that within the context of a digital mapping environment the database often precedes the map. In keeping with this idea, this dissertation has attempted to focus the conversation on the data as opposed to the symbology used to display the data. To push this idea further one should also consider that what is possible to map and by whom is inscribed in the design of the database along with the data in the database. Both these statements help to understand the power of a GIS database. Since the OSM database organized meaning spatially for over 500 volunteers in the context of the 2010 earthquake, its role within the crisis mapping context needs to be explored.

As previously mentioned, OSM as an example of an open VGI database designed to allow anyone with an OSM account to add content. After a user has added geometric content the OSM database is also designed to allow any entry within the key=value form to be added. The quote from User2 about how Haitian mappers resolved that no official tagging standard existed for voodoo temples illustrates this freedom: “It’s OSM you can put anything you want!” In Chapter 5 an initial exploration of the evolution of the tagging data for the study period revealed a 6 fold increase in keys and an almost 12 fold increase in key=value pairs in the OSM Haiti database. While no analysis is made in this dissertation of the effectiveness of the tagging schema for OSM Haiti, anecdotal evidence suggests that the post-earthquake development of the Humanitarian Data Model mentioned in Chapter 3 was necessary to unify the OSM crisis mapping coding schema. The user freedom to use any tag is therefore a double edged sword. On the one hand, had OSM's tagging flexibility not been there, and had for instance only allowed a narrow classification of standard features centered on transportation, it is clear that the crisis mapping for OSM Haiti would not have been as useful for storing data of use for the humanitarian/relief community on the ground in Haiti. At the same time, the large increase in unique tags shows a 'too many cooks in the kitchen' problem that was clearly in mind when members of HOT later took the time to develop the Humanitarian Data Model.

The example of the Humanitarian Data Model leads to another point about the structure of the OSM database, namely that its effectiveness was at the time diminished by its lack of a standardized data model. An explicit reason given for the creation of the Humanitarian Data Model was that it "…seeks to reconcile schemas from many humanitarian response agencies, all of which are based on field requirements" (wiki.openstreetmap.org 2015). Since the classification of humanitarian features was an ad-hoc process at the beginning stages of the OSM Haiti effort, integrating the OSM database ontology with other datasets in existence was likely a challenging task and a barrier for the adoption of OSM data into other institutions' databases. User2 states that one of the goals of the first HOT mission was to answer questions about how to interact with the OSM database from those persons who wanted to use OSM data. There were therefore some clear concerns about the OSM learning curve for those on the ground in Haiti. User2 and User4 also point out that some agencies on the ground in Haiti were hesitant about the quality of the volunteered geographic data, again demonstrating how the structure of the OSM database influenced its use and effectiveness.

One final point to be made about how the database structure influenced the crisis mapping process comes from the geographic extent of the database. First, several comments made in the surveys point to a frustration on the part of some of the crisis mappers that there was no sense of where they should focus their mapping efforts. The point to be made here is that the global extent of OSM creates a conundrum of where a crisis mapper should map to be efficacious. The answer not easily solved when one can essentially map anywhere. Since the Haiti earthquake, a tool was developed called the OSM Tasking Manager (http://tasks.hotosm.org/) to specifically deal with this problem of how to direct crisis mapping volunteers.

**Haitians and OSM Haiti**

Throughout the interviews and the surveys very few examples are given of Haitians using OSM data while several examples exist of Haitians contributing to the OSM community, as evidenced by the descriptions of Cite Soleil mapping and the description of paid mapping work for Haitians. User1 does cite personal knowledge of several Haitians using and contributing to OSM and also that the data is still likely what is used as a basemap for navigating Haiti. Yet from the survey results Q14 shows that the OSM crisis mapping users did not on average think of their collective efforts as benefiting Haitians. User3 who currently lives in Port-au-Prince speaks to the lack of usage of OSM data especially in terms of little desire to contribute to the OSM database.

As mentioned in several of the interviews, it is not clear that the VGI model espoused by OSM gives a voice to Haitians. User1's quote perfectly sums up this point: "The whole model is so clearly built around the idea that people have free time, they are passionate about mapping, and they are not paid… It's not clear that any of these are available for Haitians". While User3 claims that the lack of access to Internet/GPS technologies is not the problem, and that a lack of motivation is the problem, a lack of means was undoubtedly the case in the wake of the earthquake. And yet a supposed lack of motivation to contribute to OSM is contradicted by both User1 and User2, who claim that Haitians were very motivated to map in OSM, with User2 describing mapping in OSM as a means to shift the balance of power back to Haitians in a time where Haitians had very little say in the humanitarian/relief process (UNF 2011). Returning to the previous quote what is at stake here appears to be a longer term view of mapping. For OSM to be sustainable in Haiti two models are given: that of the hobbyist mapper and the mapper who is monetarily paid for mapping. Several Users expressed doubts that the hobbyist model is possible for Haitians and the paid model does not allow for a community generated map as the organization paying the wages dictates what gets mapped.

Database hydration as it relates to Haitians is a particularly interesting point of discussion. As was pointed out, while the initial swell of crisis mapping was ultimately intended to help the affected Haitian community, the survey is clear that the initial intended audience were the aid/relief workers. What is not clear, is who the mapping shown in the spatial analysis outside of the earthquake disaster area was intended to benefit. Already mentioned is that the general OSM community benefits from a more complete database in terms of coverage. This database hydration should likely be thought of as a gift to the Haitian people as well. Given the opportunity to map Haiti, mapping in a disaster zone was not enough. With the release of high-resolution imagery the draw of a blank space was impetus enough to map in very rural parts of Haiti.

While the ‘fun’ nature of filing in a blank space clearly has importance, other motivations were at play. The interviews hint at the OSM ideology espoused by many OSM users of subversive data openness and mapping practice transparency driven by what can be seen as a particular form of activism (activism against proprietary, top down, and centralized mapping institutions). Here, this same subversiveness is applied to humanitarianism, namely that there is a better model for a labor force, data production, and data sharing. While the UNF (2011) report states that the VT&C community proved itself to the humanitarian community it is not clear that these ideologies proved themselves to Haitians themselves. Indeed in the interviews User3 seems to point to a long term lack of interest on the part of Haitians for these values. This leads to a final question to be asked in relation to database hydration, namely why did it need to happen to begin with? In other words, why was the OSM database just as blank as other popular spatial databases such as Google Maps before the earthquake? While it is beyond the scope of this dissertation to answer this question, the fact that the database was quite clearly not being updated by Haitians before the earthquake leads to the logical question of why should it be expected that a gift of a large spatial database containing enough data to serve as a routing basemap would be maintained by Haitians? To the credit of the first and successive HOT missions, this conundrum was attempted to be addressed by the supplying of the materials necessary to map and also the building of a community.

**Limitations and Future Work**

There are several limitations to the study completed for this dissertation. First, to comprehensively describe the crisis mapping process which generated the OSM database, a thorough description would need to be integrated of the listserv dialogues, blogposts, and other general communication archived on the Internet relating to the OSM Haiti mapping process. It is assumed that an analysis of these conversations would further elucidate how decisions were made and what difficulties were encountered while in the process of an ad-hoc humanitarian mapping effort.

Secondly, a more thorough analysis of the OSM Haiti database in the attribute domain would further inform and describe this crisis mapping process. While the term crisis mapping is defined, it is clear that the OSM Haiti crisis was a very specific event that may never be replicated in a similar fashion. As User4 pointed out, other natural disasters of somewhat similar scales have occurred since the earthquake with different outcomes. Also, the term crisis mapping can easily be extended in other disaster situations such as socio/political conflicts (genocide, civil war, infectious disease spread etc.). Therefore, the results given in this dissertation form only initial description of transformations in humanitarian work resulting from the use of a volunteer labor force for tasks such as crisis mapping.

A final criticism of this dissertation is that it presents a limited account of what took place on the ground in Haiti. The use of ancillary spatial data for instance is limited. The account of what took place in Haiti is constrained temporally as well. A more thorough analysis of crisis mapping would look at the long term effects of this activity, analyzing more than six months post-earthquake. A more thorough investigation of Haiti's past in terms of how its status as a failed and monetarily poor nation-state contributed to the form of crisis mapping that took place would also greatly add to the understanding of the practices that built the OSM Haiti database.

The work begun in this dissertation can be extended in several directions. One such direction directly addresses a limitation of this dissertation, the focus on a single crisis mapping event. The findings of this dissertation may be broadly generalizable to other crisis mapping events, possibly taking some of the methodological approaches of this dissertation to other crisis mapping events to provide fruitful comparative analyses. Soden et al. (2015) recently follows such a comparative approach within OSM. What is suggested here is to take the methodology to a much larger scale, analyzing every HOT activation to date. Such a meta-analysis would likely generate results that would enlighten more patterns and descriptions of the term crisis mapping, and tell contributors and user communities more about mapping practice generally.

## Summary

This dissertation seeks to document at a database level the crisis mapping process for OSM Haiti. Results reflect a large number of volunteers in the case of OSM Haiti. One might surmise from the results of interviews and surveys that VGI crisis mapping is a process that is simultaneously diverse and complicated. OSM Haiti marks the beginning of HOT; and its inception annotates the realization by many of the potential of OSM for humanitarian work. Much has changed since 2010. The conclusions given in this discussion should be understood in the context of the Haiti earthquake, and may not be uniformly generalizable to other uses of VGI crisis mapping. However, one conclusion seems likely to translate to other crises is that VGI generation and database editing has a short window of high activity immediately after the crisis onset (here, the Haiti earthquake). Another conclusion which likely translates to other VGI crisis mapping uses is that while VGI is becoming a necessary labor force for crisis mapping, it does not necessarily change the power dynamics of those affected by the disaster. Here, the pattern that those in need of aid often have little to say with how the aid is managed is still present in the case of OSM Haiti. The point is that while VGI changed the dynamics of the database production, it is unclear that the resulting basemaps changed the practices of the relief agencies in terms of humanitarianism or the lives of Haitians themselves.

# Appendix 1

**Tier 1 Questions**

- How did you first get involved with OSM?
- Had you ever been involved in relief work prior to Haiti?
- Briefly describe how you became involved with mapping in OSM Haiti.
- What was your role in the OSM Haiti relief effort?
- Why did you decide to go to Haiti?
- How was your work flow organized when it came to mapping? (team or individual, all US, mixed Haitian/US, etc.). Alternate: walk me through a typical day's work in your role with OSM Haiti.
- What kinds of data did you enter? Where did it come from? What kinds of editing did you do?
- What were some of the challenges you encountered doing that work? How did you deal with those challenges?
- If there were anything you could change about the mapping that took place in OSM Haiti what would it have been?
- What were the most important things that you learned from your involvement?
- How does your experience with OSM Haiti compare with other mapping and disaster relief projects that you have worked on or are familiar with?
- What long-term benefits do you see in the post-earthquake mapping that took place in OSM Haiti for Haitians? For others?
- What long-term changes have you seen in OSM as a result of the work in Haiti? Any new applications of technology, changes in workflow, volunteer involvement, etc.

# Appendix 2

**Tier 2 Questions**

<u>How did you get involved with the mapping of Haiti on OSM?</u>
_I volunteered in the humanitarian OSM community
_Through word of mouth/a friend
_Through online social networking
_Through being involved with OSM
_Other:

<u>Did you have any mapping experience before contributing to OSM Haiti post earthquake?</u>
_This was my first volunteer mapping experience
_I had mapped in OSM before but not as part of a humanitarian effort
_I have experience with GIS software and/or Internet mapping APIs
_I use common mapping websites such as Google Maps but had never used OSM before
_Other:

<u>If you were an OSM user before the 2010 Haiti earthquake how often did you contribute?</u>
_I contribute regularly (more than once a month)
_I contribute irregularly (less than once a month)
_I was not a user before the earthquake

<u>Why did you contribute to OSM Haiti as a response to the earthquake?</u>
_I was involved with the humanitarian OSM community
_I was part of the OSM community and wanted to contribute to the mapping in OSM Haiti
_I had other friends who were participating and joined with them
_I had free time and decided to volunteer
_As a way to directly help those affected by the earthquake
_As a form of disaster response
_Other:

<u>When you were mapping did you know about any effects the OSM data/map had on the ground in Haiti (i.e. that it was an important resource for aid workers)</u>
_I was aware of persons in Haiti who were using OSM
_I found out about how OSM Haiti was used after a period of time (several days) of mapping without knowing
_I did not know at all or knew very little during the time I was mapping in OSM Haiti.
_Other:

<u>What was your sense of the temporal nature of mapping in OSM Haiti after the earthquake?</u>
_I did not feel a sense of urgency to map after the earthquake. I mapped as I normally do with any other location in OSM.
_I did not feel a sense of urgency at first but as I heard about the need for map data I felt the need to map as quickly and/or as often as I could.
_I immediately felt a sense of urgency to map after the earthquake. I mapped as quickly and or as often as I could.
_I joined the mapping efforts in OSM Haiti a month or more after the earthquake and did not feel any urgency to map.
_I joined the mapping efforts in OSM Haiti a month or more after the earthquake and felt there was still an urgency to map in OSM Haiti.

Where did you contribute from? (ie. city and/or country). If you want you can be more specific and add details such as: coffee shop, Internet café, place of residence, work, dorm, OSM group meetup…

What data source did you primarily use?
_Satellite data made available to the public after the earthquake
_Satellite data that was already available to the public before the earthquake
_Scanned historical maps
_Aerial imagery such as from airplane flyovers
_Information obtained from communications to someone in Haiti
_Digital vector datasets made publicly available before or after the earthquake
_Other:

Did you edit the same feature more than once?
_Yes
_No

If yes why did you edit the same feature more than once?
_Based on updated/new information available to me
_Based on an updated tagging schema (eg. the OSM community changed how a feature is commonly tagged etc.)
_I realized I had made a mistake (eg. wrong tag, misinterpretation of imagery etc.)
_Based on a request from other users
_Other:

Did you edit a feature that you did not originally create?
_Yes
_No

If yes why did you edit a feature you did not create?
_I edited a feature I did not create based on updated information
_I edited a feature I did not create based on an updated tagging schema (eg. the OSM community changed how a feature is commonly tagged etc.)
_I edited a feature I did not create because I believed that someone else had made a mistake (eg. wrong tag, misinterpretation of imagery etc.)
_I edited a feature I did not create base on a request from other users
_Other:

Do you feel that by volunteering to map in OSM Haiti you helped in some manner with the earthquake relief work in Haiti?
_Yes
_No
_Not Sure
_Other:

Who do you think benefited the most from the collective OSM Haiti mapping efforts?
_Haitian government
_Aid/relief workers
_Haitians directly affected by the earthquake
_Local municipalities
_OSM/HOT

_Other:

Would you map in OSM again if another large natural disaster occurred in Haiti or elsewhere?
_Yes, but I would be drawn to map in OSM only if there was a great humanitarian need especially in an impoverished country
_Yes, I would map in OSM again as a form humanitarian work no matter if the country is poor or wealthy
_Yes, but I would be drawn to map in OSM especially if the location affected by a large natural disaster was itself poorly mapped in OSM
_No (if you choose this answer you can explain why in the next question)
_Other:

If no, why would you not map in OSM again if another large natural disaster occurred in Haiti or elsewhere?

How do you feel about the overall experience of mapping in OSM Haiti after the earthquake? (was it rewarding? frustrating? exciting? etc.)

Is there anything else you would like to add?

# Appendix 3

**Tier 2 Survey Responses**

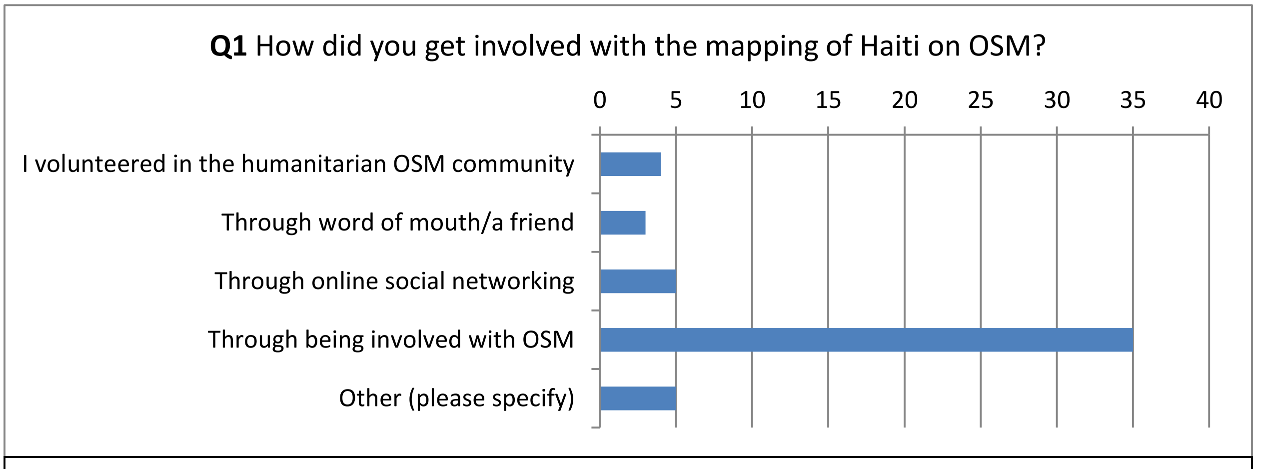
Appendix 3 summarizes in chart and table form the results from a Survey Monkey Survey held between July 30th 2014 and August 30th 2014. A total of 204 invitations were sent out with 52 responses received. The survey had a 25% success rate and represents a 10% sample of the total number of OSM Haiti users within the 7 month timeframe of this study. The total number of answers and total number of respondents who answered a question are given under each question where the respondent was allowed to select multiple options.

Notes:

-Some questions have responses given under “Other (please specify)” quoted explicitly under the question’s chart. These quotes are not the total of all filled-in answers for each question but are chosen as individual responses of interest for this research.

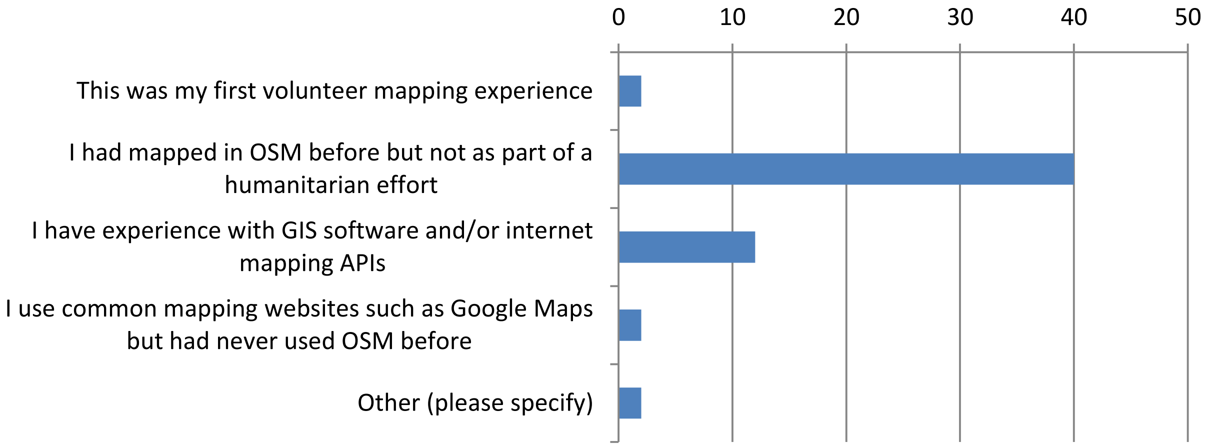
-Some filled in answers have been modified to de-identify personal information about the user.

-Spelling and grammatical mistakes have been corrected in some filled-in responses for ease of comprehension



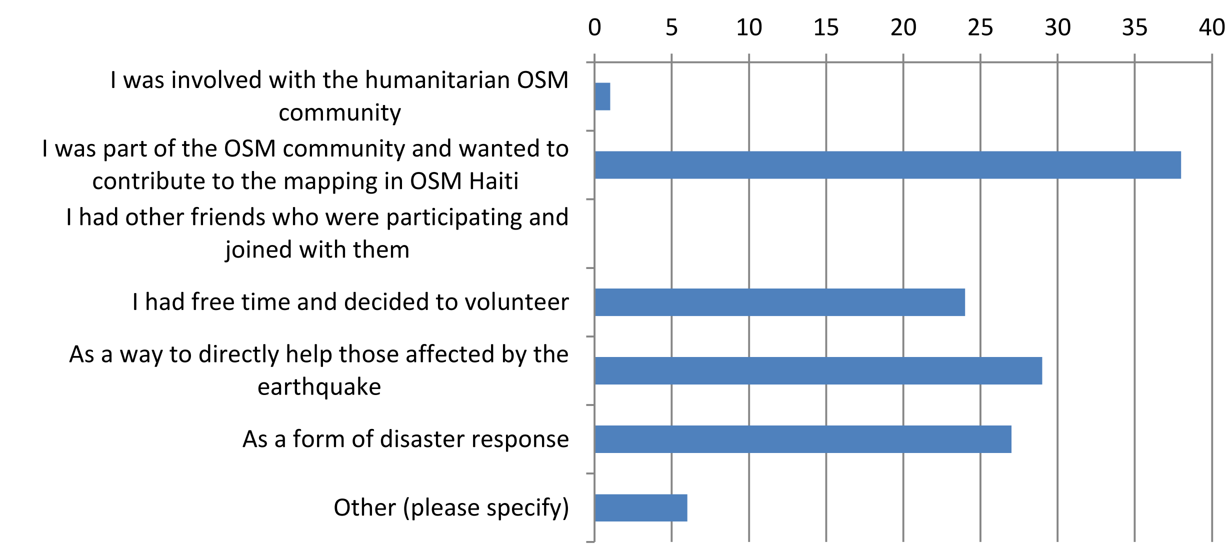

**Q1** Answers: 52
**Q1** Total Respondents: 45

**Q2** Did you have any mapping experience before contributing to OSM Haiti post earthquake?

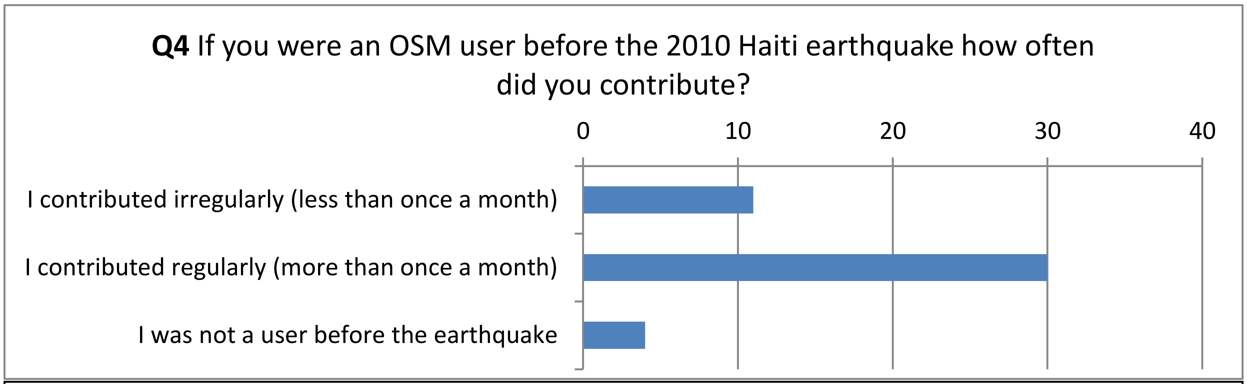



**Q2** Answers: 58
**Q2** Total Respondents: 46

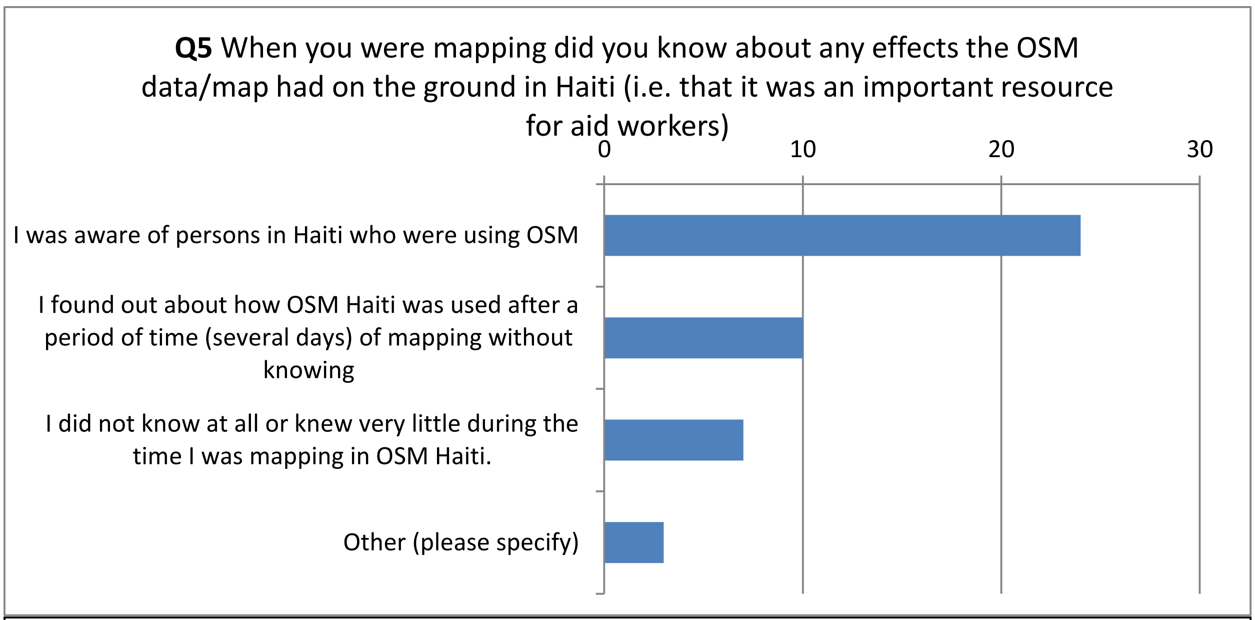
**Q3** Why did you contribute to OSM Haiti as a response to the earthquake?



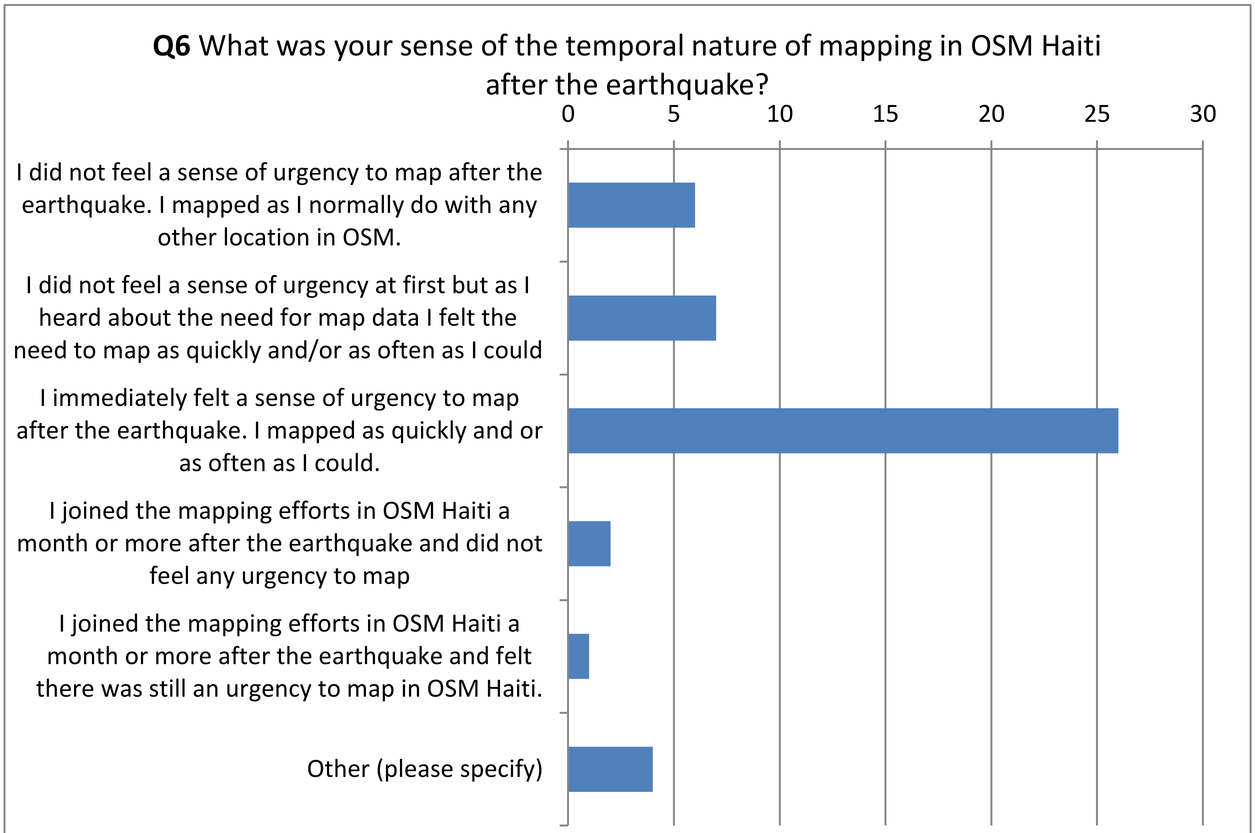

**Q3** Other:
-"it was also a way to increase the coverage of OSM in general, since suddenly high quality satellite images were available"
-"i needed information and then saw it was having mistakes"
-"Practical help, feels better than just give money"
**Q3** Answers: 125
**Q3** Total Respondents: 45




**Q4** Answers: 45

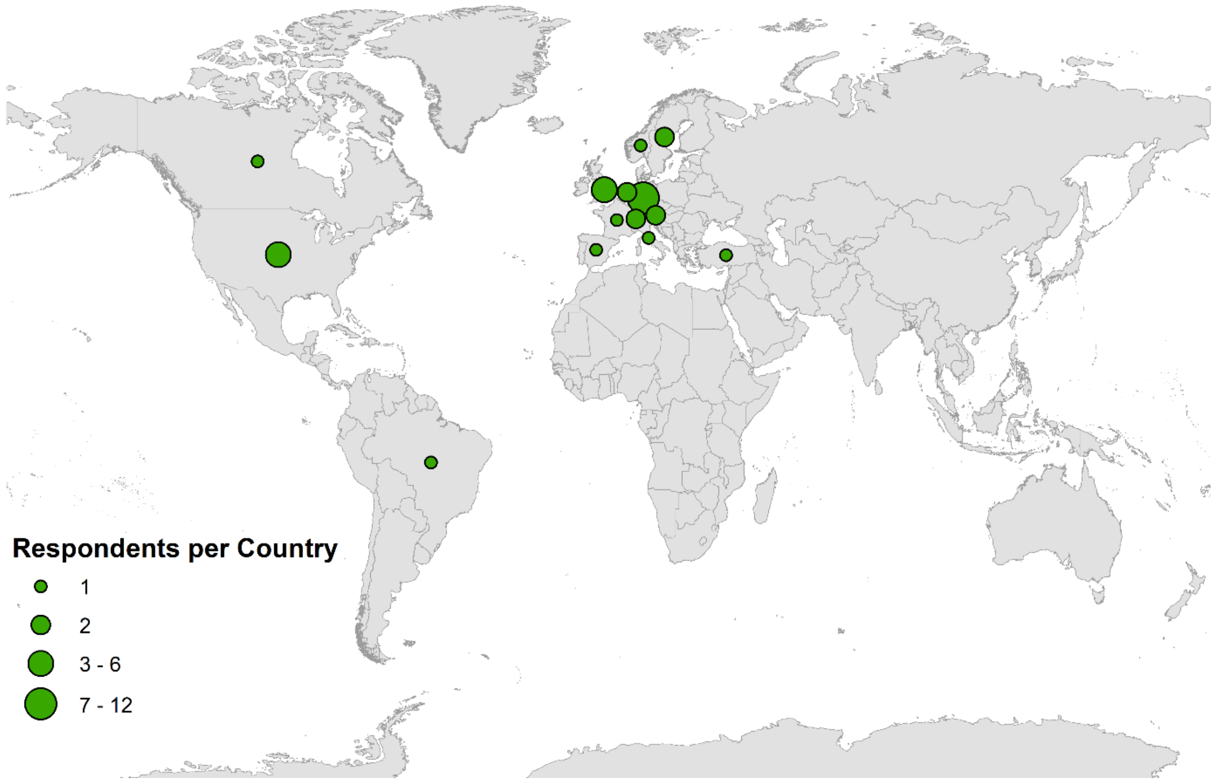



**Q5** Other:
-"my understanding was that personnel on ground were using OSM to find collapsed houses to send rescue workers."
-"I was informed by the Crisis Camp OSM team about people on the ground in Haiti using OSM"
**Q5** Answers: 44
**Q5** Total Respondents: 44

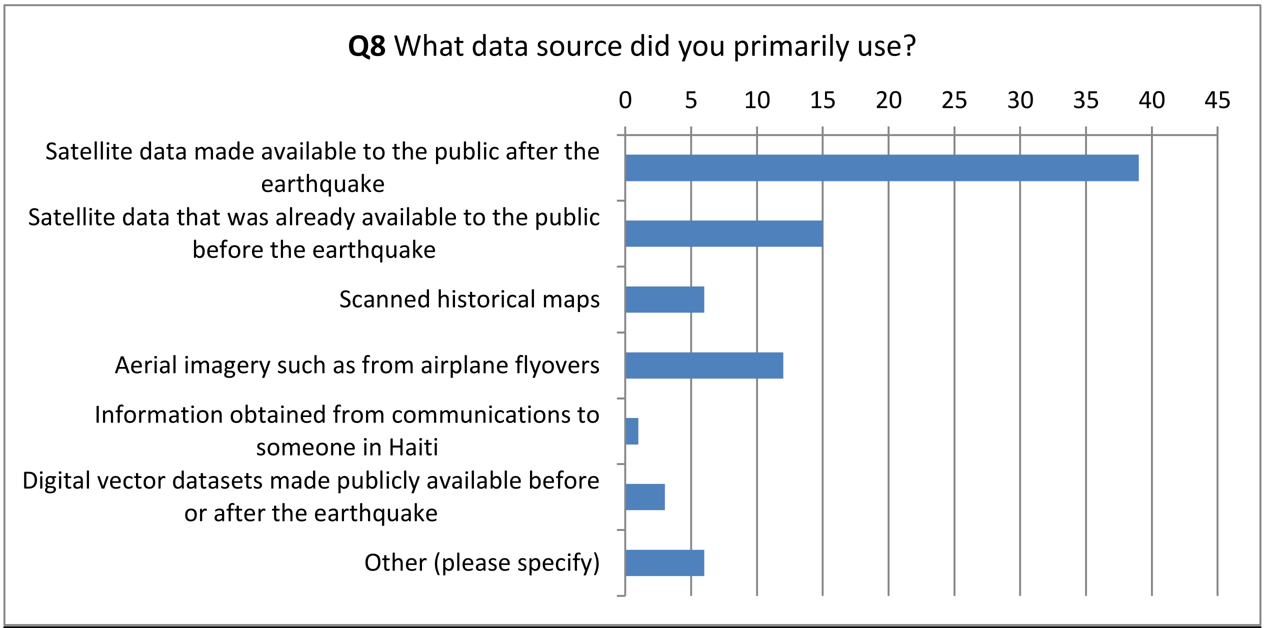



**Q6** Other:
"I immediately felt a sense of urgency, but I only participated in mapping during the Crisis Camp"
**Q6** Answers: 46
**Q6** Total Respondents: 44

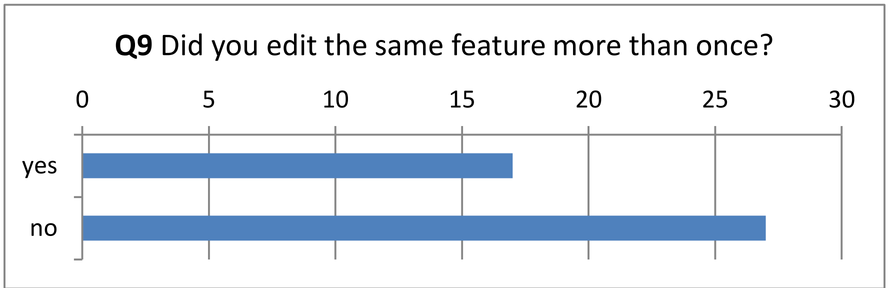
**Q7** Where did you contribute from? (ie. city and/or country). If you want you can be more specific and add details such as: coffee shop, Internet cafe, place of residence, work, dorm, OSM group meetup...



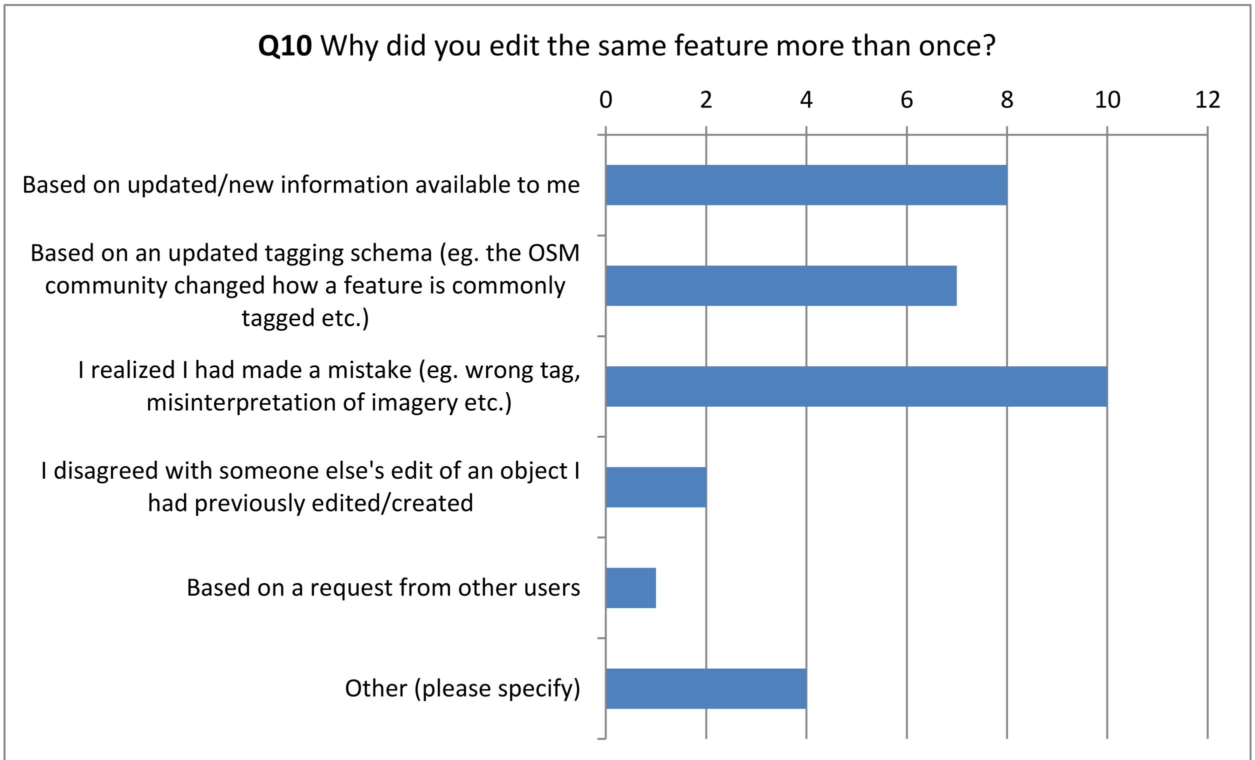

**Q7** Answers: 42
**Q7** Mappable Answers: 37



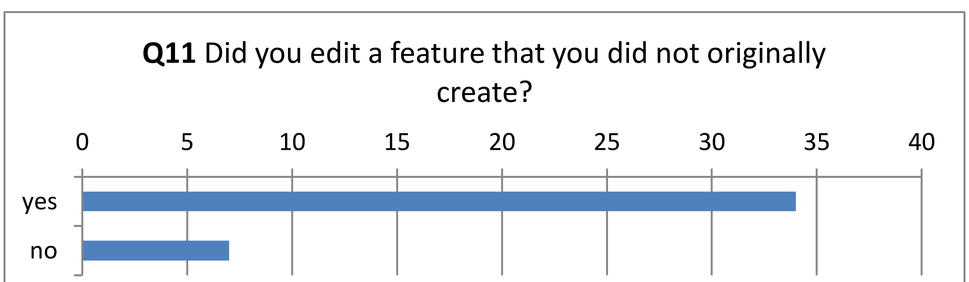

**Q8** Answers: 82
**Q8** Total Respondents: 44



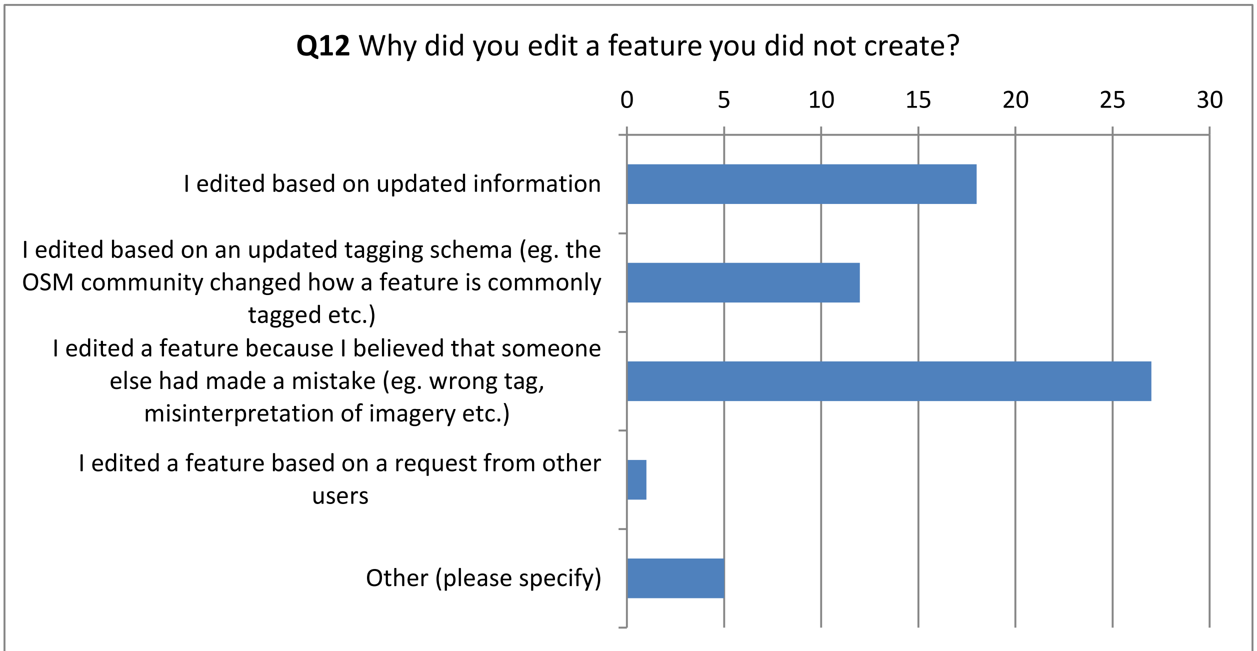

**Q9** Answers: 44



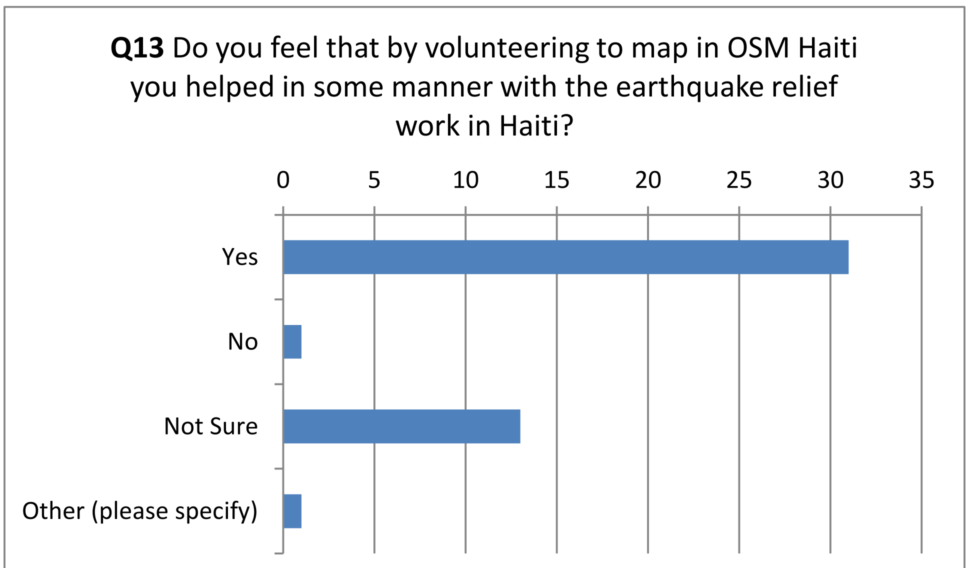

**Q10** Other:
-"Extending a previously edited object that was not completely mapped"
-"I added streetnames to places I had already mapped"
-"The boundary import took a lot of sorting out..."
**Q10** Answers: 32
**Q10** Total Respondents: 17



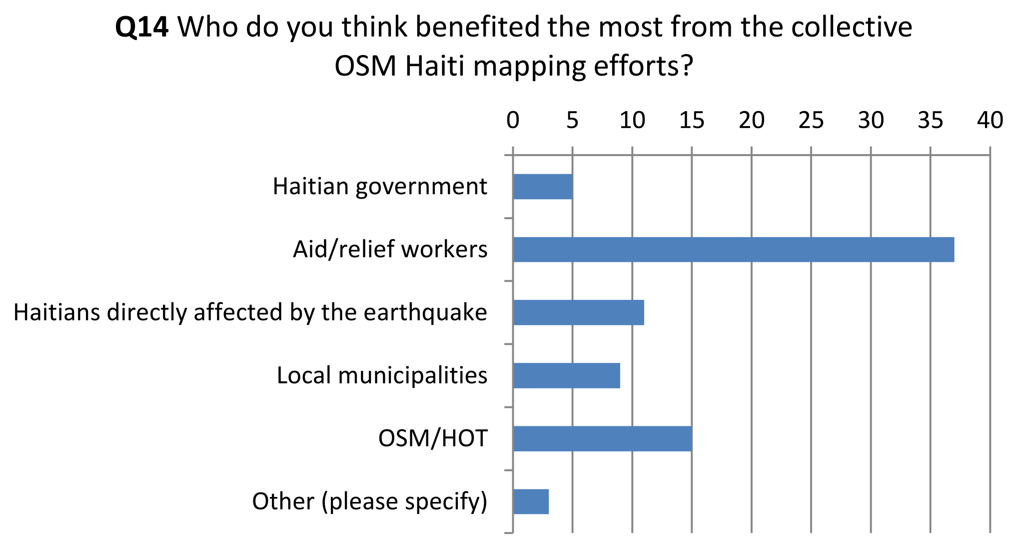

**Q11** Answers: 41



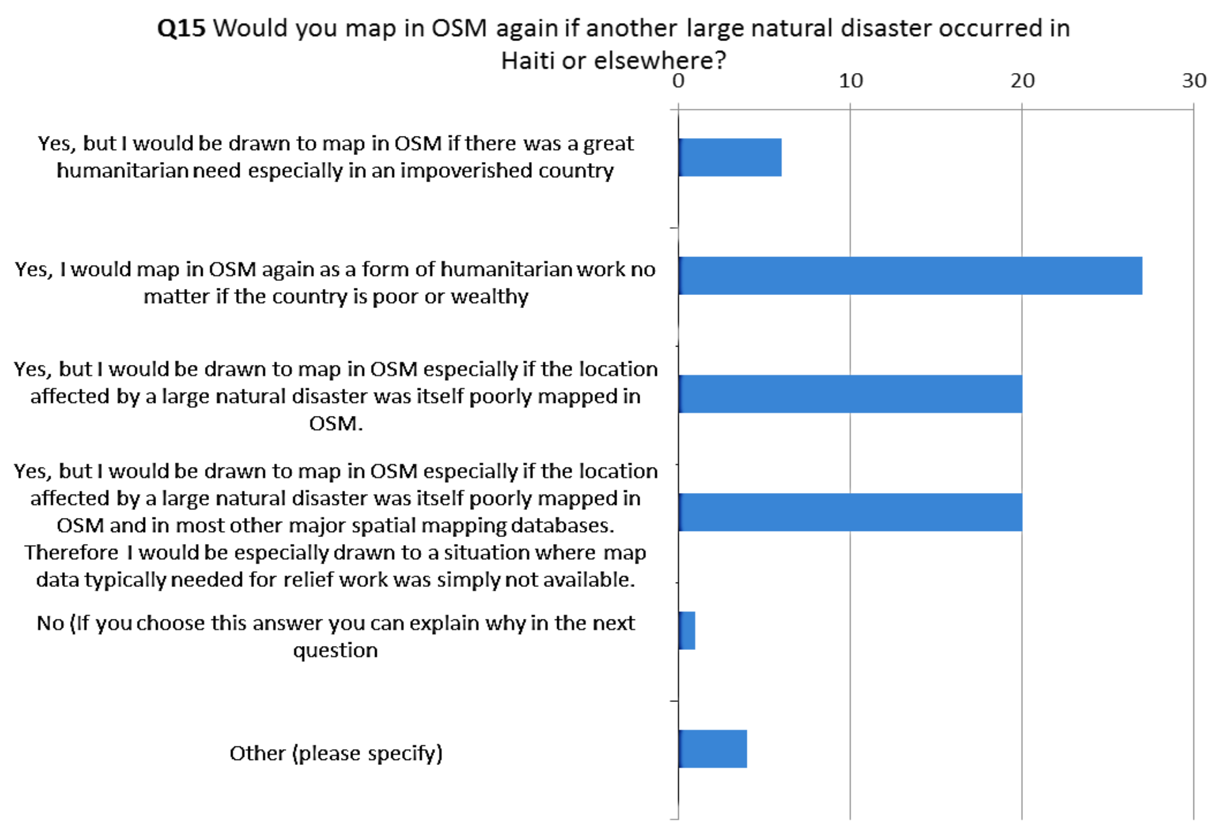

**Q12** Other:
-“Mapping "correct" is a very inexact definition. The map data is always an approximation of what's on the ground. You have to decide detail level yourself when you are mapping. No matter how good the data in the database is, there is ALWAYS ways to improve it. For example by making the geometry more exact.”
-“..because I felt I could improve/better integrate the data”
-“Mainly corrections to others edits (tags, rationalisation of boundaries, street names)”
-“The boundary import needed a lot of sorting out...”
**Q12** Answers: 63
**Q12** Total Respondents: 35




**Q13** Other:
-“I sure hope my efforts helped rescue at least a single person”
**Q13** Answers: 46
**Q13** Total Respondents: 44




**Q14** Other
-"I sure hope my efforts helped rescue at least a single creature"
-"Everyone who lives and work in Port-au-Prince"
-"I don't know."
**Q14** Answers: 80
**Q14** Total Respondents: 43




**Q15** Answers: 78
**Q15** Total Respondents: 44

**Q16** Why would you not map in OSM again if another large natural disaster occurred in Haiti or elsewhere?

No responses

**Q17** How do you feel about the overall experience of mapping in OSM Haiti after the earthquake? (was it rewarding? frustrating? exciting? etc.)

| | |
|---|---|
| 1 | Very rewarding and exciting. But also heartbreaking seeing in minute detail what a wreck the country was (before as well as after the earthquake). Also illuminated the difference in what was reported in the media, as I more than once had in front of me up to date photographic evidence that what the media was saying was simply untrue. |
| 2 | Very rewarding, but frustrating; my team had to split up and I ended up working on identifying features and dead bodies in photos, on a different computer program. |
| 3 | Quite exciting to feel part of an effort moving towards helping people directly, and from a distance. However, I felt there was a lack of feedback on what was needed to be mapped (and where), and absolutely no information about the priorities of which areas needed mapping the most. A closer sense of (mapping) community would also have been welcomed. This lead to me feeling slightly disappointed about the result, wondering if the tracks I had mapped were ever actually needed by anyone. And a little frustrated as the potential for positive results is enormous- but it relies on the infrastructure and systems (ie. User Experience/useability) being in place to support the mapping work. |
| 4 | exiting and dramatic |
| 5 | Rewarding. I felt that contributing to the effort in a practical way was more rewarding that just making a donation to the relief fund (though I did do that, and still contribute to the Red Cross today to support their ongoing effort in Haiti). I have also felt more connected with Haiti since contributing map data, although I was already very interested in the Caribbean, and Haiti to an extent. I nearly always contribute to relief efforts when disasters strike but never before have I felt so connected afterwards, as with Haiti. I think this is due to contributing map data which may have had some utility to the emergency workers on the ground. |
| 6 | I felt to do the "right" thing, though without any real feedback of the effects. |
| 7 | Amazement on how quickly contributors had already mapped most areas by the time I had a chance to join. |
| 8 | It felt relevant. Even more so since the experiences from Haiti has led to a more organized and systematic way of providing mapping to aid and disaster response. |
| 9 | It was very exciting to see mapping tools appear and rewarding once the first mails from the ground workers (red cross) came in. |
| 10 | It's more fun to map a place where existing maps are very poor, and OSM database is (nearly) blank. You will get a lot of result quick, since you start with a "blank" paper. However, before really good post-disaster high-res imagery became available, the progress were very slow and difficult and/or with a sense of inaccuracy. |
| 11 | rewarding and exciting.  doing what I loved *and* helping people help people |
| 12 | rewarding. |
| 13 | rewarding |
| 14 | rewarding, and very special to help out directly in this way. |
| 15 | Exciting to be part of an urgent effort. Challenging since the satellite imagery was different from what I was used to, and hard to interpret. |

| | |
|---|---|
| 16 | For me it was "fun", I didn't map so much earthquake related stuff in Port au Prince (as there was already so much mapped), I continued for months to map the rural, and poor areas of the western peninsula, that were very sparsly mapped in OSM. And that was quite rewarding, as I felt it could help aid-workers, locals, or whoever, to better navigate there.(if they ever use OSM) |
| 17 | I just did my "job"; sometimes it was shattering, e.g. when you realized that you could see people piling up bodies on the sat images. |
| 18 | a bit of all |
| 19 | surprised about the cooperation with the satellite imaginary companies (during this time only a few countries had good coverage with good satellite photos...) |
| 20 | the most rewarding crisis mapping experience I have had. Nothing since was as directly useful, and I have been involved with everything from 2010 to present as a member of OSM |
| 21 | It made me feel like I could make a difference even though I am sitting half the world away. |
| 22 | neutral |
| 23 | work must be done |
| 24 | Some kind of exiting, because it was the first time that this kind of disaster relief happened. |
| 25 | A lot exciting. |
| 26 | Feels like a good thing to do. Easy, and worthwhile. |
| 27 | Rewarding because one knew it was in use (via contacts in FEMA, first responders etc) and later with people who had been there. |
| 28 | Rewarding to find out it was being used by aid workers and made a difference. Perhaps a little exciting before then to watch the OSM community come together and work so hard doing what they could to help. |
| 29 | Interesting |
| 30 | Very rewarding though the editor at the time (I think it was Potlatch or maybe I used QGIS) was very frustrating. Working with iD for HOTOSM has been much nicer |
| 31 | Exciting, rewarding. It felt like directly helping instead of give money to big organizations. |
| 32 | It was exciting and sort of rewarding too, but also exhausting at times (one or two times I worked throughout the night). |
| 33 | it was rewarding |

**Q18** Is there anything else you would like to add?

| | |
|---|---|
| 1 | What was the real population of Haiti before the earthquake? The OSM forum asked "Where is everybody?" as one of the surveys (World Bank flyover?) was so detailed and clear it was not at all obvious where the millions were, or had lived. The PAHO was not able to get logons for non-US people because of their absolute assumption that the whole world's population had a valid zip code! I love America but sometimes they are so uuurrgh! A calculation of the volume of the bodies of those officially killed showed that the mass graves were where? That volume should have been easily visible and filmable by the media - I didn't find either. This effort was one of the best things I've ever done, in a fairly long and interesting life. |
| 4 | I got more actively involved in HOT since Haiti, and now maintain the website http://hot.openstreetmap.org for HOT on a voluntarily basis. |
| 6 | My humble hope is that my as well as so many other's efforts on that day helped some if not all of those effected by the earthquake. I now enjoy a neighbor who is Haitian. How cool is that!! |
| 9 | hmm, no |
| 10 | No |
| 11 | No |
| 12 | No at the moment. |

| | |
|---|---|
| 13 | no, ta. |
| 14 | You have to understand that there was no updated map of Port-au-Prince available before the earthquake. Posted there in august 2008 as the french deputy head of diplomatic mission, I was in charge of crisis readiness for most of the european communities (among a lot of others tasks), which was pretty difficult without good maps... I started to update the 1986 map myself, but it was a huge work (and I had a lot of work...). Suddenly, after the earthquake, all the highdef photographs were available and everybody started to map Port-au-Prince. Let's be clear : I don't know a major humanitarian organisation that used it during the first weeks of the rescue efforts in Haiti. It was useful during the months after that, above all during the cholera crisis, since october 2010 - as it is useful in everywhere in the world. We finally had maps of Port-au-Prince... A shame we had to wait a earthquake for that... |
| 15 | No. |
| 16 | For me, Haiti was by far the time when I spent the most effort into crisis mapping, maybe due to the "thrill" of doing it for the first time ever. In later disasters, e.g. Japan or the Philippines, I did a few things, but didn't feel the urgency that much (for which I'm afraid I don't know the reasons very well). |

# References


Audubon (2013). Christmas Bird Count. http://birds.audubon.org/christmas-bird-count. Accessed April 12, 2013

BBC News (2005). Wikipedia Survives Research Test. http://news.bbc.co.uk/2/hi/technology/4530930.stm Accessed April 13, 2013.

BeyoNav (2011). Geo-Analytics on OpenStreetMap Road Data. http://www.beyonav.com/openstreetmap. Accessed April 13, 2013.

Budhathoki, N. and C. Haythornthwaite. (2012). Motivation for Open Collaboration: Crowd and Community Models and the Case of OpenStreetMap. American Behavioral Scientist: 57(5), pp 548-575.

Brown, M (2007). Londonist Interviews OpenStreetMap Guru Steve Coast. Londonist. http://londonist.com/2007/04/londonist_inter_11.php. Accessed April 30th 2010.

Cartwright, W. (2008). Delivering Geospatial Information with Web 2.0. In: International Perspectives on Maps and the Internet. Ed. M. Peterson. Berlin, Springer-Verlag, pp. 11-28.

CEGIS. (2012). http://cegis.usgs.gov/UCD_projects.html. Accessed March 12, 2012.

Chapman, K. (2010). "OpenStreetMap in the First Month After the Haiti Quake". http://web.archive.org/web/20101204051518/http://www.maploser.com/2010/09/06/openstreetmap-in-the-first-month-after-the-haiti-quake/. Accessed November 20, 2014.

Cohen, N. (2011). Define Gender Gap? Look up Wikipedia's Contributor List. The New York Times. http://www.nytimes.com/2011/01/31/business/media/31link.html. Accessed April 14, 2013.

Codeplex. (2012). ArcGIS Editor for OpenStreetMap: Documentation: Details on the OSM Feature Dataset. http://esriosmeditor.codeplex.com/wikipage?title=Details%20on%20the%20OSM%20Feature%20Dataset&referringTitle=Download%20Data%20from%20OSM. Accessed November 12, 2014.

Cope, M., and S. Elwood (2009). Ch1 Introduction: Qualitative GIS. In*: Qualitative GIS a Mixed Methods Approach.* M. Cope and S. Elwood eds. Thousand Oaks, CA: Sage Publications.

Corner, J. (1999). The Agency of Mapping: Speculation, Critique and Invention. In: *Mappings*. Ed. D. Cosgrove. Reaktion Books, London: 213-252.

Crampton, J (2003). *The Political Mapping of Cyberspace*. Chicago, IL: University of Chicago Press.

Crampton, J (2010). *Mapping: A Critical Introduction to Cartography and GIS*. Chichester, UK: Wiley-Blackwell.

Crisis Mappers (2013). Crisis Mappers: the Humanitarian Technology Network. http://crisismappers.net/. Accessed April 12, 2013.

Deffner, R. (2013). Keep from Crumbling –Ulaanbaatar Project Week 3. http://hot.openstreetmap.org/updates/2013-10-20_keep_from_crumbling_ulaanbaatar_project_week_3. Accessed March 5, 2014.

Dent, B. D., Torguson, J.S., and T.W. Hodler. (2009). *Cartography: Thematic Map Design.* 6th ed. MacGraw-Hill, New York.

Dodge, M., Kitchin, R., and C. Perkins. (2011). Preface: Introducing *The Map Reader.* In: The Map Reader: Theories of Mapping Practice and Cartographic Representation. Eds: M. Dodge, R. Kitchin, and C. Perkins. Wiley-Blackwell, Chichester West Sussex: xix-xxiii.

Dodge, M., Kitchin, R., and C. Perkins. (2011b). Introductory Essay: Technologies of Mapping. In: The Map Reader: Theories of Mapping Practice and Cartographic Representation. Eds: M. Dodge, R. Kitchin, and C. Perkins. Wiley-Blackwell, Chichester West Sussex. pp. 116-121.

Eckert, J (2010) "Tropes 2.0: Mobilization in OpenStreetMap". Association of American Geographers Conference. Talk. Washington D.C.

Edney, M. (1993). Cartography Without 'Progress': Reinterpreting the Nature and Historical Development of Mapmaking. Cartographica, 30 (2/3), pp 53-68.

Edney M. (2011). Foreword. *Mapping Latin America: A Cartographic Reader*. Dym, J. and K. Offen (eds). University of Chicago Press, Chicago.

Elwood, S. (2008). "Volunteered geographic information: future research directions motivated by critical, participatory, and feminist GIS". GeoJournal, 72: pp. 173-183.

Elwood, S. (2009). Multiple Representations, Significations and Epistemologies in Community-Based GIS. *Qualitative GIS: A Mixed Methods Approach*. Ed. Cope, M. and S. Elwood. Thousand Oaks, California: SAGE Publications, pp 57-74.

ESRI. (2005). GIS Supports Indian Ocean Tsunami Disaster Relief. ArcNews Online. http://www.esri.com/news/arcnews/spring05articles/gis-supports.html

ESRI. (2014). "Directional Distribution (Standard Deviational Ellipse) (Spatial Statistics)" ArcGIS 10.1 Help.

Ford, H. (2014). Big Data and Small: Collaborations between ethnographers and data scientists. Big Data and Society, 1 (2), pp 1-3.

Gartner, G (2009). Web Mapping 2.0. *Rethinking Maps: New Frontiers in Cartographic Theory*. Ed. M. Dodge, R. Kitchin, and C. Perkins. New York, NY: Routledge pp. 68-82.

GeoFabrik (2013) OpenStreetMap Data Extracts. http://download.geofabrik.de/. Accessed March 29, 2013.

GeoFabrik (2013b) Port-au-Prince Animation. http://labs.geofabrik.de/haiti/old-png-images-documenting-mapping-effort/port-au-prince-animation.gif. Accessed March 29, 2013.

GPS.gov (2012). Selective Availability. http://www.gps.gov/systems/gps/modernization/sa/. Accessed April 23, 2013.

Goodchild, M. (2000). Cartographic Futures On a Digital Earth. Cartographic Perspectives. 36, pp 3-11.

Goodchild, M (2007). "Citizens as sensors: the world of volunteered geography". GeoJournal, 69: pp. 211-221.

__________(2007b). “Citizens as Voluntary Sensors: Spatial Data Infrastructure in the World of Web 2.0”. International Journal of Spatial Data Infrastructure Research. Editorial. Vol 2, pp24-32.

Goodchild M., and J.A. Glennon. (2010). Crowdsourcing geographic information for disaster response: a research frontier. International Journal of Digital Earth vol. 9 (1) pp. 1-11.

Haiti Data. (2014). Haiti Landcover (Occupation du Sol), SPOT-CNIGS [04.1998] - polygon. http://haitidata.org/layers/cnigs.spatialdata:hti_biota_landcover_spot_cnigs_041998_polygon. Accessed April 1 2014.

Haklay, M. (2010). How good is OpenStreetMap information? A comparative study of OpenStreetMap and Ordnance Survey datasets for London and the rest of England. Environment and Planning B, 37(4) 682 – 703

Haklay, M., Singleton, A., and C. Parker. (2008). “Web Mapping 2.0: The Neogeography of the GeoWeb”. Geography Compass, Vol 2(6): pp. 2011-2039.

Hamilton, M. 2009. Online Survey Response Rates and Times: Background and Guidance for Industry. http://www.supersurvey.com/papers/supersurvey_white_paper_response_rates.pdf. Accessed January 21, 2014.

Harley, J. B. (2001). The New Nature of Maps: Essays in the History of Cartography. Baltimore, MD: Johns Hopkins University Press.

HOT. (2013). Humanitarian Data Model - REDUX. http://hot.openstreetmap.org/updates/2013-06-07_humanitarian_data_model_redux. Accessed Nov 24 2014.

Howe, J. (2006). The rise of crowdsourcing. *Wired Magazine*, June. http://www.wired.com/wired/archive/14.06/crowds.html. Accessed April 13, 2013.

Hughes, A., Palen, L., Sutton, J., Liu, S., and S. Vieweg. (2008). “Site-Seeing” in Disaster: An Examination of On-Line Social Convergence. In F. Fiedrich and B. Van de Walle (eds): *Proceedings of the 5th International ISCRAM Conference*.

Humanitarian OSM Tags. (2013). Humanitarian OSM Tags/Humanitarian Data Model OLD. http://wiki.openstreetmap.org/wiki/Humanitarian_OSM_Tags/Humanitarian_Data_Model_OLD

ITO! (2013). ITO! Map: TIGER Reviewed. http://www.itoworld.com/map/162?lon=-105.03447&lat=39.73797&zoom=8. Accessed April 13, 2013.

Johnson, J., J. Crowley, and S. Erle. (2010). Haiti: CrisisMapping the Earthquake. O’Reilly Media. http://www.youtube.com/watch?v=fJvR84UX5RI. Accessed April 13, 2013.

Kang, C (2012). Google announces privacy changes across products; users can’t opt out”. Washington Post. http://www.washingtonpost.com/business/economy/google-tracks-consumers-across-products-users-cant-opt-out/2012/01/24/gIQArgJHOQ_story.html. Accessed April 25, 2014.

Keen, A (2007). *The Cult of the Amateur: How today’s Internet is Killing our Culture*. New York, NY: Broadway Publishing Group.

Kitchin, R. and M. Dodge. (2007). “Rethinking Maps”. Progress in Human Geography, Vol 31(3): pp. 331-344.

Knowles, D. (2010). Twitter Message Sparks Big Rescue Effort. Aol News. http://www.aolnews.com/2010/01/29/twitter-message-sparks-big-rescue-effort/

Krippendorff, K. (1980). *Content Analysis: an Introduction to its Methodology*. Thousand Oaks, CA: Sage Publications.

Krippendorff, K. (2004) *Content Analysis: an Introduction to its Methodology.* 2nd ed. Thousand Oaks, CA: Sage Publications

Lee, L. and W.S. Wong. (2001). Statistical Analysis with ArcView GIS. New York, NY: John Wiley & Sons Inc.

Leitner, M. and B. Buttenfield. (2000). Guidelines for the Display of Attribute Certainty. Cartography and Geographic Information Science, 27(1): pp. 3-14

Liu, S. B. and L. Palen. (2010). The New Cartographers: Crisis Map Mashups and the Emergence of Neogeographic Practice. *Cartography and Geographic Information Science Special Issue: New Directions in Hazards and Disaster Research*, 37 (1): pp. 69-90.

Liu, S. B. and J. Ziemke. (2012). From Cultures of Participation to the Rise of Crisis Mapping in a Networked World. In A. Delwiche and J. Henderson (eds.): *Routledge Handbook of Participatory Cultures***.** New York: Routledge.

Lynch, K. (1960). *The Image of the City.* Cambridge, MA. MIT Press.

Mark, D., Comas, D., Egenhofer, M., Freundschuh, S., Gould, M., and J. Nunes. (1995). Evaluating and Refining Computational Models of Spatial Relations Through Cross-Linguistic Human-Subjects Testing. In A. Frank and W. Kuhn (eds): *Spatial Information Theory: A Theoretical Basis for GIS.* Lecture Notes in Computer Science No. 988. Berlin, Springer: pp. 553–68.

Mapbox (2014). OpenStreetMap Data Report. https://www.mapbox.com/osm-data-report/2013/. Accessed Feb 6th 2015.

Minustah (2010). République d'Haiti Damage Assessment Maps (17 FEB 2010). Haiti Earthquake Data Portal. http://cegrp.cga.harvard.edu/files/haiti/RepDHaiti_Damage_17FEB2010.zip. Accessed Jan 5 2015.

Mooney, P. and Corcoran, P (2011). Accessing the history of objects in OpenStreetMap. In *Proceedings of the Fourteenth AGILE International Conference on Geographic Information Science,* Utrecht, The Netherlands.

Mooney, P. and Corcoran, P (2012). The Annotation Process in OpenStreetMap. Transactions in GIS, 16(4): p561-579

Neis, P., P. Singler, and A. Zipf. (2010) "Collaborative mapping and Emergency Routing for Disaster Logistics - Case studies from the Haiti earthquake and the UN portal for Afrika." In: Car, A., Griesebner, G., Strobl, J. (Eds.): Geospatial Crossroads @ GI_Forum '10. Proceedings of the Geoinformatics Forum Salzburg.

Neuendorf, K. (2002). *The Content Analysis Guidebook.* Thousand Oaks, CA: Sage Publications.

Norheim-Hagtun, I. and P. Meier. (2010). Crowdsourcing for Crisis Mapping in Haiti. Innovations: 5(4), pp. 81-89.

O'Reilly, T (2005). What is Web 2.0: Design Patterns and Business Models for the Next Generation of Software. http://oreilly.com/web2/archive/what-is-web-20.html. Accessed April 30th 2010.

OpenStreetMap (2014). Beginners Guide 1.1. http://wiki.openstreetmap.org/wiki/Beginners_Guide_1.1. Accessed Feb 11, 2014.

Ord, J. and A. Getis. (1995). Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. Geographical Analysis, 27(4): p. 286-306.

OSM-Talk (2010). Haiti Earthquake mapping response. Posted by Mikel Maron Jan 13 2010. http://lists.openstreetmap.org/pipermail/talk/2010-January/046811.html. Accessed April 24 2013.

Pavlovskaya, M. (2006). Theorizing with GIS: a tool for critical geographers? Environment and Planning A, 38: pp2003-2020.

Perkins, C. (2009). Playing with Maps. *Rethinking Maps: New Frontiers in Cartographic Theory*. Ed. M. Dodge, R. Kitchin, and C. Perkins. New York, NY: Routledge pp 167-188.

Peterson, M (2001). The Development of Research in Maps and the Internet. *Proceedings of the 21st International Cartographic Conference*. pp. 1134-1143.

Pickles, J. (2004). A History of Spaces: Cartographic reason, mapping and the geo-coded world. Routlege.

Pinto, A. (2010). Denaturalizing "natural" disasters: Haiti's earthquake and the humanitarian impulse. Open Medicine, 4(4), p193-196.

Pisano, F. (2005). Using satellite imagery to improve emergency relief. Humanitarian Exchange Magazine. 32. http://www.odihpn.org/report.asp?id=2770.

Python (2014). Built-in types. Documentation: The Python Standard Library. Section 5. https://docs.python.org/2/library/stdtypes.html?highlight=tobytes#memoryview.tobytes. Accessed November 15 2014.

Redfield, P. (2008). Sacrifice, Triage, and Global Humanitarianism. In: Humanitarianism in Question: Politics, Power, Ethics. Ithaca: Cornell University Press.

Robinson, R. and B. Petchenik (1976). *The Nature of Maps: Essays Toward Understanding Maps and Mapping.* Chicago, IL: University of Chicago Press.

Robinson, A., J. Morrison, P. Muehrcke, J. Kimerling, and S. Guptill (1995). *Elements of Cartography*. 6th ed. New York, NY: Wiley and Sons.

Rose, G. (2001) *Visual Methodologies*. Thousand Oaks, CA: Sage Publications.

Shuurman, N. (2008). Database Ethnographies Using Social Science Methodologies to Enhance Data Analysis. Geography Compass, 2(5), pp 1529-1548.

Soden, R. and L. Palen. (2014) From Crowdsourced Mapping to Community Mapping: The Post-Earthquake Work of OpenStreetMap Haiti. COOP 2014 - Proceedings of the 11th International Conference on the Design of Cooperative Systems. pp 311-326.

Soden, R., Anderson, T. J., Palen, L., and M. Barrenechea. (2015). Open Data Dreams in a Time-Critical Reality: The Evolution of OpenStreetMap in Response to Humanitarian Events. In proceedings of the

SIGCHI conference on human factors in computing systems (CHI). Under Review.

Ticktin, M. (2006). Where Ethics and Politics Meet: The Violence of Humanitarianism in France. American Ethnologist, 33**,** pp33-49.

Tufts. (2011). Tufts Crisis Mapping Class. Experimental College. http://tuftscrisismappingclass.com/. Accessed: April 12, 2013.

Turner, A. (2006). *Introduction to Neogeography* (O'Reilly Short Cuts series). O'Reilly Media.

UNF. (2011). Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies. Washington D.C.: UN Foundation & Vodafone Foundation Technology Partnership. http://issuu.com/unfoundation/docs/disaster_relief20_report.

US Census Bureau (2013). International Programs: Demobase - Gridded Mapping. Demobase Haiti. https://www.census.gov/population/international/data/mapping/demobase.html. Accessed Jan 5 2015.

Weber, R. (1985). *Basic Content Analysis*. Beverly Hills , CA: Sage Publication.

wiki.openstreetmap.org (2010). File:Haiti Imagery Dataset count by date.png http://wiki.openstreetmap.org/wiki/File:Haiti_Imagery_Dataset_count_by_date.png. Accessed April 3, 2014.

___________________(2010b). File:Haiti High Resolution Imagery as of 2010-01-19.png. http://wiki.openstreetmap.org/wiki/File:Haiti_High_Resolution_Imagery_as_of_2010-01-19.png. Accessed April 3, 2014.

___________________(2010c). WikiProject Haiti/Imagery and data sources/Haiti Imagery Coverage by Department. http://wiki.openstreetmap.org/wiki/WikiProject_Haiti/Imagery_and_data_sources/Haiti_Imagery_Coverage_by_Department. Accessed April 3, 2014.

___________________(2013) JOSM. http://wiki.openstreetmap.org/wiki/JOSM. Accessed April 13, 2013.

___________________(2013b) TIGER. http://wiki.openstreetmap.org/wiki/TIGER. Accessed April 14, 2013.

___________________(2013c) WikiProject Haiti/Imagery and data sources/Old: Best Practices.

___________________(2014) Stats. http://wiki.openstreetmap.org/wiki/Stats. Accessed February 5, 2015.

___________________(2015) Humanitarian OSM Tags. http://wiki.openstreetmap.org/wiki/Humanitarian_OSM_Tags. Accessed February 5, 2015.

http://wiki.openstreetmap.org/wiki/WikiProject_Haiti/Imagery_and_data_sources/Old#Imagery_commentary. Accessed April 3, 2014.

Wikipedia: Geoportal (2013). http://en.wikipedia.org/wiki/Geoportal. Accessed April 12, 2013.

Wikipedia: GPS. (2013). http://en.wikipedia.org/wiki/Global_Positioning_System. Accessed April 13, 2013.

Wikipedia: XML. (2013). http://en.wikipedia.org/wiki/XML. Accessed April 13, 2013.

Wood, D., Fels, J. and J. Krygier. (2010). Rethinking the Power of Maps. New York: Guilford Press.

Zook, M., Graham M., Shelton T., and S. Gorman. (2010). Volunteered Geographic Information and Crowdsourcing Disaster Relief: A Case Study of the Haitian Earthquake. World Medical & Health Policy: 2(2) pp. 7-33.