Modes and Existences in Citizen Science: Thoughts from Earthquake Country

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Abstract

In the Bay Area of San Francisco, the earthquake contours are not easy to define: seismology is still a relatively recent science, and controversies around methods to evaluate the earthquake risk are constant. In this context, the invitation to think about the modes of citizen science is an opportunity to reflect on the modality of hybridized scientific practices as well as the process by which the plurality and complexity of the earthquake characteristics can be articulated, and sometime reconciled.

Looking at different existences of the earthquake risk, the paper investigates different assemblages that question the clear-cut distinction between citizen science and science. I'll situate the question of the mode of citizen science within the larger framework of interdisciplinarity knowledge infrastructures and the work on 'mode of existence' initiated by Bruno Latour and Isabelle Stengers (2009).

Expanding our understanding with regard to how CS is performed opens the possibility of reconsidering the specific types of assemblages and infrastructures from which these modes emerge and on their distinct trajectories. It is also an invitation to make visible the integration processes, the communities, and the imaginations that "make" science.

Keywords: existence, earthquake, risk, knowledge, infrastructure, data

Introduction

On March 11, 2011, the Tōhoku earthquake and tsunami (also referred as the Great East Japan Earthquake) partially destroyed the Fukushima Daiichi Nuclear Power Plant, caused the death of 15,884 people, led to the evacuation of 300,000 others, and triggered a nuclear accident whose causes and long-term consequences are still under investigation (Ahn et al., 2015; Guarnieri and Travadel, 2018; Hasegawa, 2013; Kalmbach, 2015). The series of events constituting the earthquake, the tsunami and the ensuing nuclear disaster as well as its scale and amplitude were breathtaking and took the international community by surprise.

In Berkeley, California, the emotions aroused by the catastrophe and the threat of a nuclear disaster kept residents under alert. Like millions of others, I was glued to my computer, watching CNN live, trying to make sense of the information I had, and speculating on what was not yet known. Everywhere—in supermarkets, on playgrounds, at work—discussions swirled around the disaster, the sorrow, the pain, and the risk. On April 20, 2011, an interdisciplinary group of UC Berkeley faculty members gathered in an open discussion entitled "Coping with the Crisis: Implications for Japan's Future".[1] That evening, the panelists openly and genuinely shared their thoughts and their knowledge about what had happened, what it meant for the affected communities but also, for rest of us. The room was full, the faces were grave, and the discussion kept going for long hours, as people tried to sort out the information coming from divergent sources: the Japanese government, the news agencies, the citizen science network, the scientists (Shineha and Tanaka, 2017).

In the room, residents, other faculty members, and concerned citizens were wondering whom to trust and where to go from there.[2] This discussion was the first of many organized at UC Berkeley, stirred by a group of dedicated and concerned scholars[3] willing to use their knowledge and energy to limit the spectrum of the catastrophe unfolding under our eyes, informing the public and the policy makers. Relying on an international network of experts, citizen scientists, academics, friends, and family members, they translated and discussed information, weighing contributions from those who could take part in this large enterprise of interdisciplinary sense-making. As a graduate student working on risk in the San Francisco Bay Area, I was invited to participate in three of these workshops (Ahn et al., 2017; Akera, 2007; Amir, 2018), where scholars tried to find a common language to describe the complexity of the disaster that had been a deep emotional and intellectual shock. Building on what French philosopher Emilie Hache has described as a too-often disregarded competence of the Moderns—i.e., the capacity to use our emotional response to disaster as the trigger for constructive action to "collectively put words on a collective fear and draw energy to act" (quoted in Vincent, 2017), these scholars were joining forces to think through the multiple, intricate, complicated, and often contradictory dimensions of disasters at the scale of the Fukushima Daiichi event.

From modes of citizen science to disaster modes of existence.

The invitation to reflect on the modes of citizen science is an opportunity to reflect on the modality of hybridized scientific practices focusing on the modes of existence of the earthquake, such as I was able to experience them during my field work. In this paper, I'll situate the question of the mode of citizen science within the larger framework of interdisciplinarity knowledge infrastructures (Edwards et al., 2013; Fortun and Fortun, 2015; Lin et al., 2016; Pollock and Williams, 2010; Ribes and Lee, 2010) and work on "mode of existence" initiated by Bruno Latour and Isabelle Stengers (Latour, 2011; Stengers and Latour, 2009), and expanded by a large collaborative and exploratory project of co-construction "AiME project -An Inquiry into Modes of Existence" (Latour, 2013).[4]

In recent years, researchers have pointed out that what is often described as citizen science (CS) encompasses distinctive modes, often understood as differentiated sets of practices, purposes, and objectives (Eitzel et al., 2017. Kullenberg & Kasperowski, 2016; Selin et al., 2016; Traweek, 2013) Yet others, working on the role of data (and data science practices), have contributed to a better understanding of the processes by which heterogeneous data get integrated allowing for the emergence of interdisciplinary practices (Boix Mansilla et al., 2016; Borgman, 2013; Jirotka et al., 2013; Leonelli et al., 2017). This proliferation of digital tools, objects and practices has led to what Marres has described as a "redistribution of research" and a "redistribution of methods" which recognizes the contributions of various agents, "researchers, research subjects, funders, providers of research materials, infrastructure builders, interested amateurs, and so on," (Marres, 2012:140) and the modalities of enactments that are often hard to pin down.[5] Researchers have also noted that these data practices and modes of producing knowledge emerge from organizational settings, standards, and norms that define collaboration and interdisciplinarity in scientific arenas (Aronova, 2017; Landström, Whatmore, and Lane, 2011; Riesch and Nowotny, 2017) as well as by the virtues and political consequences attributed to what has often been thought of as – and criticized for being - a one-dimensional relationships between experts and non-experts (Allen, 2011; Kimura and Kinchy, 2016; Lidskog, 2008; Lynch, 2014; Wynne, 1996).

Following what has been referred to as the ontological turn of in Science and Technology Studies (Law and Lien, 2013; Lynch, 2013; Mol, 2013), researchers have acknowledged that there may be different ways to understand ontological questions that are "in actuality decided through specific, historical, cultural, technological, scientific interventions" (Marres, 2013: 423). Expanding our understanding with regard to how CS is performed, opens the possibility of reflecting on the specific types of assemblages from which these modes emerge and on their specific existences. It is also an invitation to reflect on the integration processes (Akera and Mohsin, 2016; Gerson, 2012; Star and Griesemer, 1989), the communities (Knorr-Cetina, 1999), and the imaginations (Jasanoff and Kim, 2015) that "make" science. Questioning the modality of citizen science therefore requires thinking about the ways in which science is conducted: the modi operandi (Whatmore, 2009) according to which the order of things is determined. It also requires a description of how the work of sense-making and knowledge-building is accomplished, recognizing the co-existence of multiple methods, epistemologies but also existences of the object under investigation. Doing so, I would like to argue for a displacement from the question of the mode of citizen science to the possibly larger question of the mode of existence of the objects of citizen science. I hope that framing the contours of these modes of existence will allow the emergence of coherent pragmatic and epistemic assemblages, precise and labeled modalities of existence, that will help, in return, clarify the need of extending the articulations of modes of citizen science.

As the discussions in the aftermath of the Tōhoku earthquake and tsunami and Fukushima Daiichi Nuclear disaster made explicit, studying disasters with the tools of academic knowledge is a humbling experience. Not a single discipline or method can describe or explain the entire chain of reactions leading to a catastrophe of the scope of the 2011 events (Fortun et al., 2016; Mazel-Cabasse, 2017, 2018). Rather, the catastrophic event can be approached as an association of distinctive modalities, or modes of knowing, that crosses traditional division of academic disciplines and methods: "[D]isasters come into existence in both the material and the social world and perhaps, in some hybrid space between them" (Oliver-Smith and Hoffman, 1999: 24). What seems coherent and valid from the perspective of the event is sometimes hard to articulate and prone to debate from the perspective of well-defined academic disciplines.

To account for this complexity, anthropologists have argued that disasters "are both socially constructed and experienced differently by different groups and individuals, generating multiple interpretations of an event/process. A single disaster can fragment into different and conflicting sets of circumstances and interpretations according to the experience and identity of those affected" (Oliver-Smith, 1999: 26). In the second half of the 20th century, the French philosopher Etienne Souriau (1892-1979) had explored the possibility of this *existential pluralism* and proposed to think about existences as multiples and co-existing modes, allowing us to describe associations or phenomena that are situated without being ethno- or geo-centered.[6] Before him, and focusing this time on earthquakes, the American philosopher William James writing about his experience of the 1906 earthquake and fire that partially destroyed San Francisco, was aware of the articulations that define - for scientists, residents, and himself - the multiple but simultaneous existences of the earthquake. In a piece published under the title *"On Some Mental Effects of the Earthquake"* he reflected on the definition of the earthquake: "For '*science*,' when the tensions in the earth's crust reach the breaking point, and strata fall into an altered equilibrium, earthquake is simply the collective name of all the cracks and shakings and disturbances that happen. They are the earthquakes. But for me the earthquake was the cause of the disturbances, and the perception of it as a living agent was irresistible" (James, 1906: 1216-1217).

In the next sections, I will look at the constant re-organization of specific assemblages that have been necessary to grasp the complexity of the modes of existence of the earthquake in the Bay

Area of San Francisco. Using William James's own words as a red thread, I will show how each of these specific configurations is necessary to bring the earthquake it's full existence.

The mode of existence of the earthquake in the Bay Area

I will first explore what happens when the "tensions in the earth's crust reach the breaking point" and look at the history of Seismology as a scientific discipline as an important moment of definition of the earthquake as an object of science. Next, I will look at the risk of earthquake or what James has described as the "altered equilibrium": in this case, I'll use the hazard map, which requires the mobilization of various tool sets to both solidify and transport what has been previously defined as the earthquake. Finally, I'll investigate the possibility for the earthquake to be considered as a "living agent," a phenomenon in the Souriau's sense, that needs to be experienced to be known.

Mode of existence 1. When the "tensions in the earth's crust reach the breaking point"

When James write about his experience of the 1906 earthquake, Seismology is a very different discipline than it is today. Some of the earliest-known scientific comments regarding earthquakes occurred in the mid-1600s, but most historiography on seismology starts soon after the Lisbon Earthquake in 1755 and rely on the detailed descriptions of "Earthquake Observers" (Coen, 2013, but also Quenet, 2005). For centuries, discoveries have been driven by observations of large earthquakes: the solidification of the discipline can be described as the co-production (Jasanoff, 1999, 2004) of the tools and methods needed to comprehend the trigger mechanisms and the risk it represents. In Northern California, the first earthquake known as the "Big One" happened in 1868 in the still very rural State; despite little damages the event prompted the installation of the first seismometers at the University of California, Berkeley. When instrumentation was scarce and theory still in formation, science continue to rely on the descriptions of trained observers who were not always scientists or experts. No detail was too small and no nuance in the experience of a felt earthquake too trivial to be left undocumented. To define earthquakes, seismologists and local earthquakes observers used their own perceptions of the event ("How did the earthquake feel?") as well as their sense of observation ("What did it produce?") (Coen, 2013).

The field went through a first important transformation after the 1906 earthquake, when data collection became more systematic and organized: the Lawson Commission's report was the first full-scale attempt to comprehensively document an earthquake. Rupturing 296 miles of the San Andreas fault, the magnitude 7.9 earthquake "afforded an exceptional opportunity for adding to our knowledge of earthquakes" noted geologist Andrew Lawson, head of the commission and chair of the Department of Geology at the University of California, Berkeley (in Lewis, 2008). To accomplished this prodigious task, he dispatched teams of observers on foot and horseback to explore the fault, from Humboldt County in Northern California to the Coachella Valley, south of Los Angeles. By 1908, he had mapped the entire San Andreas Fault and went on completing a report which included the elastic–rebound theory, another important step in understanding of the earthquake mechanism.[7]

From that moment, interest for earthquake as phenomena kept growing in California. In the first part of the twentieth century, Harry O. Wood, Franck Neumann and Charles Richter, defined intensity and magnitude scales conceived as interpretive frameworks for earthquakes: translation tools that were aimed to describe particular earthquakes into words and situate them on a scale. In 1931, Harry O. Wood, who had been working for decades with eyewitness earthquake observation reports (the "felt reports"), published the "Modified Mercalli Scales" with Franck Neumann. This new scale was designed to make reporting easier by defining the earthquake with degrees and thresholds, thus eliminating ambiguities, but also to "insert explicit statement[s] about the mental states conducive to certain reported effects" (Coen, 2013: 258).[8] At the time of publication of this scale, Seismology was still very much considered an imperfect science. Wood and Neumann noted that, "though the importance of the factor of acceleration is recognized, we have as yet no satisfactory definition of intensity, no formula expressing earthquake violence in term of ground movement" (Wood and Neumann as cited in Coen, 2013: 259). For this reason, Wood encouraged the young Charles Richter to focus on this particular problem: creating a mechanical equivalent of intensity: the Richter's magnitude scale, which measures the strength of earthquake was introduced in 1935.[9] What made this scientific breakthrough possible is the translation of the earthquake experience - how it felt, where it had occurred, and what damage it caused – to a fact that science could take for granted.

In the last decades of the twentieth-century, scales describing the earthquake as perceived by human have continued to be very successful in Seismology. In the US,[10] the "Did You Feel It?" program (DYFI) administered by the US Geological Survey (USGS) collects real-time information and measurements from earthquake witnesses. "The idea of the DYFI program is that citizens use an Internet Web site[11] to report their experiences and observations for any earthquakes that they have felt (or not felt) by answering a simple multiple-choice questionnaire." (Atkinson and Wald, 2007) Respondents' answers are used as a diagnostic of Modified Mercalli Intensity at the observers' locations and are later visualized into a map. With the help of the "distance versus intensity" calculation, these personal testimonies are translated into a Community Internet Intensity Map (CIIM). The CIIM records perceptions of earthquake, organizes them, and helps scientists to visualize experiences derived from collective perceptions, and observations of the event. Still called "felt maps," these community-generated maps are found to be "surprisingly" (Atkinson and Wald, 2007: 362) valuable for the scientific community, "especially when considering the limited efforts required for implementation" (Bossu et al., 2008: 224).

The qualitative and quantitative approaches of the earthquake have never ceased to co-exist, generating and translating different forms of socio-technical assemblages that pursue the same objective: getting a more precise representation of the earthquake signals and a better understanding of the mechanism that trigger tectonic plates movement. During that period, the development of seismology has brought together a number of disciplines that have joined forces to get into the details of the unfolding nature of earthquakes. In 1998, the National Science Foundation (NSF) established the collaborative Network for Earthquake Engineering Simulation (NEES) with 14 research centers that share a centralized data repository and earthquake simulation software.[12] To guarantee progress, this research consortium relies heavily on networks of seismographs, GPS devices and broader range of geophysical monitoring devices, which have been used continuously since the 1960s. Today's felts reports, witeness testimonies and data collections from devices combined with the portability of mobiles application continue to be a key element to the identification and decription of seimologcal events (Bossu et al., 2015). Whether interpreting their own observations or relying on the traces of a seismograph,[13] seismologists and observers make connections in order to establish relations between experience and science. Through this heterogeneous dataset, they've learned how to "read" important signals, to organize sensations, observations and recollections into the coherent form of a particular seismic event (November et al., 2009).

Mode of existence 2. Scenario and map: navigating the "altered equilibrium"

Until today, these programs continue to gather an impressive amount of data—shared across laboratories and universities. Focusing on the infrastructure for data collection, the first mode of existence described the materialization of the earthquake as an object of scientific enquiry. Progressively emerging as objects of science starting from the exploration of its traces to the collection and synthetization of digitalized data, the "tensions in the earth's crust reach the breaking point" are still being discovered through a system of "circulating references" (Latour, 2000). In this section, we'll see how, from the contested and unstable definition of the earthquake, emerges an elusive but performative existence of the risk. To do so will look at the USGS Seismic Hazard Map which is at the same time a document with transformative capacities (Asdal, 2015) and a navigation system (November et al., 2010) which opens a window of continuity between the realm of everyday and the realm of possible events. The production Seismic Hazard Map brings together a long chain of facts and figures, tools, funding agencies, political will, and organizational cooperation that illustrates the familiar path of major scientific research (Lynch, 2012) and make the traces of the earthquake visible and transportable.

It is largely acknowledged that “another large earthquake in the San Francisco Bay Area is inevitable and imminent in geologic time” (Stark and Freedman, 2009: 126). As the popular saying goes, “the question is not *if*, the question is *when*.” But despite recurring - and alarming - predictions, large disasters are rare. Not totally forgotten but not totally present, their existences seem incomplete or partial - that is, until they become destructive and their multidimensionality breathtaking. As we’ve seen, earthquakes, before they happen, are never completely predefined; instead, they have changing characteristics resulting from their complex trajectory: from the moment of recognition, to being identified as a quantifiable risk. To narrow down the characteristics of the “ altered equilibrium,” scientists and experts have developed earthquake scenarios which rely on an assemblage that some have described as a “mixture of geological maps, rules of thumb, expert opinion, physical models, stochastic models, numerical simulations, as well as geodetic, seismic, and paleo seismic data” (Stark and Freedman, 2009: 116).

Earthquake-risk scenarios focus mainly on calculations, whether they concern the probability of a fault rupture or the insured or uninsured costs incurred for a particular rupture in a given place. They investigate the interactions of tectonic-plate movement (Modified Mercalli Intensity, magnitude, liquefaction) and their consequences (fire-related damage, floods, landslides); the potentially aggravating factors (wind conditions and other adverse meteorological conditions) and their effects on buildings (retrofitted, not retrofitted, soft-story, unreinforced, masonry), public facilities (schools, hospitals, state and federal buildings), infrastructure (water, sewer, gas, transportation, bridges, piers, tunnels), population (prepared or not, injured, dead, displaced, or traumatized), and economic situation (sales, taxes, revenue, insurance, mortgage defaults), to name just a few. They also analyze and study the consequences of past events: the 1906 Earthquake and the subsequent San Francisco Fire (Perkins et al., 2006; Tobriner, 2006), the Loma Prieta Earthquake (Bourque and Russell, 1994; Nigg and Mileti, 1998), the Oakland Fire (FEMA, 1991b; Hoffman, 1998; Schiewe, 2011), and the Northridge Earthquake (Bolin and Stanford, 1998; Comfort, 1994; Tierney,

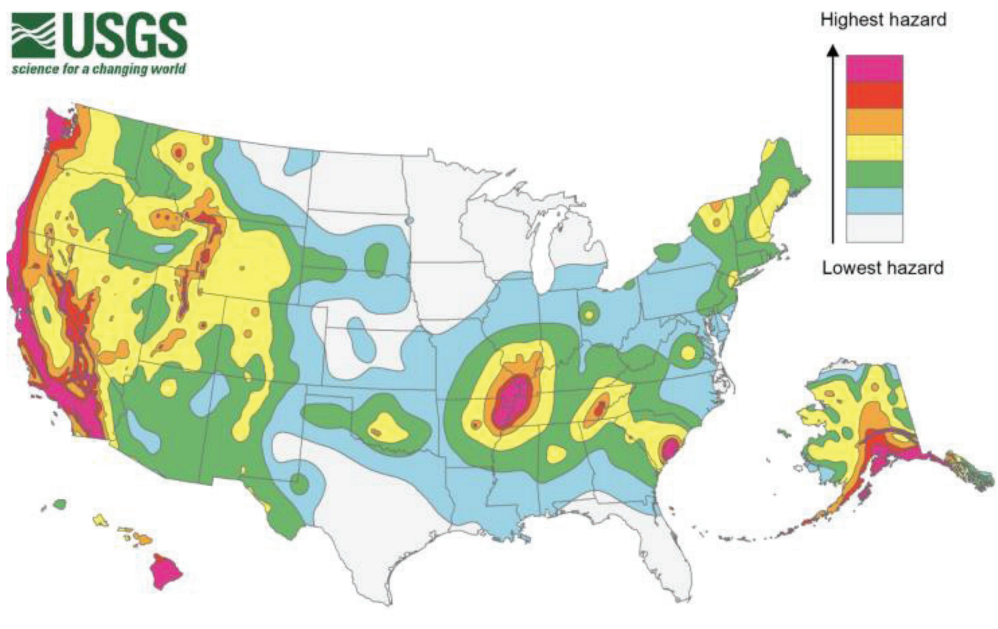

Figure 1. Simplified 2014 Hazard Map (PGA, 2% in 50 years). Source: USGS.

1995), making critical assessments of disaster responses at the time.

Interdisciplinary working groups are the always-moving forms of organizations producing earthquake data for broader earthquake communities. They are responsible for the production of reports, fact sheets, and maps. The work of data compilation needed to evaluate earthquake risks is colossal: during the last few decades, each Working Group has gathered together about 100 scientists (USGS, 1999, 2003). In California, the USGS and its local branch, the California Geological Survey (CGS); FEMA and its local branch, Cal-EMA; the Seismological Laboratory at the University of California, Berkeley; and the Lawrence Livermore National Laboratory (LLNL) were among the first to produce fact sheets and earthquake probabilities. The following diagram introduces the agencies present in 2008 and the process of data validation of the National *Earthquake* Hazards Reduction *Program* (NEHRP) program.[14]

As the diagram shows, individual California scientists, engineers, and policy makers, coming from a wide number of academic institutions, private-sector and government agencies, together with the Working Group on California Earthquake Probabilities (WGCEP), the California Geological Survey (CGS), and the Southern California Earthquake Center (SCEC), work together to determine the most accurate methodology for developing an earthquake forecasting model. Together, they contribute to the creation of the establishment of the USGS National Seismic Hazard Map, which continues to be updated through the years. These working groups rely on public funding, which for several decades has provided grants and cooperative financial agreements to support creation and analysis of their data.

Despite this impressive amount of work, experts and scientists have noted that large earthquakes more often happened where they are not expected: "We think we understand where all the faults are, so we know where they're going to occur, but both the Northridge and Loma Prieta earthquakes occurred on unknown faults. That was a surprise to me professionally" recalled an earthquake expert and Bay Area resident. Corroborating this statement, statisticians have determined that the earthquake "probability estimate (is) shaky, as is the uncertainty estimate." They also noted that the characteristics earthquake model (which include the elastic rebound paradigm mentioned earlier) fails "to provide any mechanism for producing the vastly larger number of smaller earthquakes" (Geller et al., 2016: 126). Finally, they've pointed out that the forecasting of hazards through probabilistic seismic hazard analysis (PSHA) often conflict with

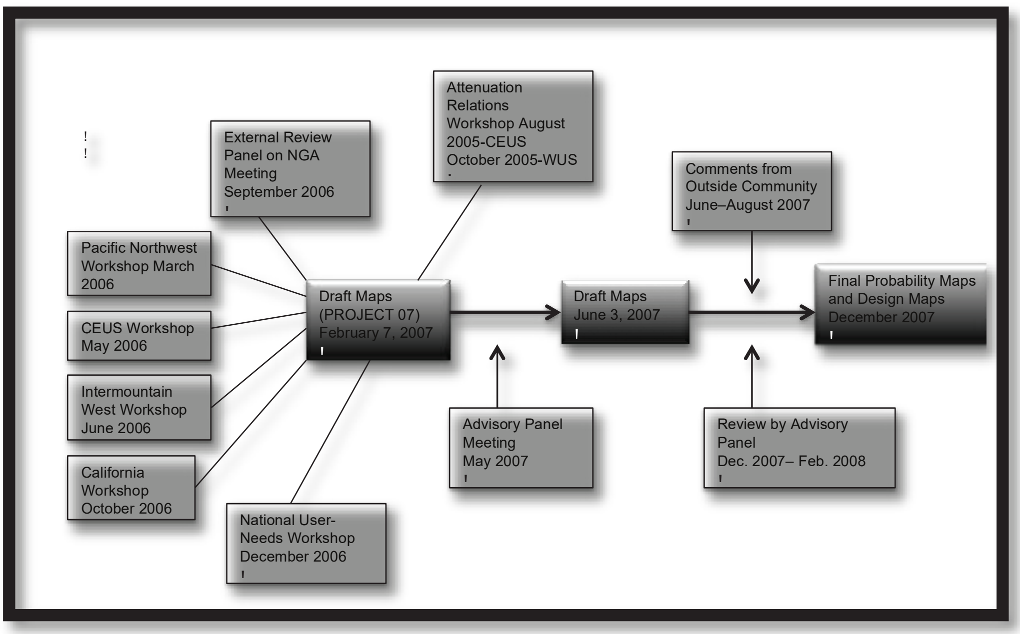

Figure 2. Process for developing the 2008 USGS National Seismic Hazard Map. CEUS, Central United States (Petersen et al., 2008).

observational data in such way that it does not "make it possible to produce reliable hazard maps" (Stark, 2017). As a consequence, they recommended that Bay Area residents should "largely ignore the USGS probability forecast," but rather" take reasonable precautions, including bracing and bolting their homes as well as securing water heaters, bookcases, and other heavy objects. They should keep first aid supplies, water, and food on hand" (Stark and Freedman, 2009: 126).

Contested scenarios, and the map that represent them, are not the final step of construction of earthquake risks; instead, they are just a starting point. Despite its weaknesses, the Seismic Hazard Map has performative capacities: it "does not simply describe an external reality 'out there': (it) also take(s) part in working upon, modifying, and transforming that reality" (Asdal, 2015). As researchers in Geography and STS have noted, a map is a space of conflict and negotiation: the visualization of the risk (however imperfect it is) and the geographical space that it represents co-construct each other: "risks transform spaces and (…) spaces subsequently lead to changes in the nature of risks themselves" (November, 2008: 1523). In practice, the Seismic Hazard Map operates as a major instrument of risk prevention that feeds policy planning at the federal level: it is included in recommendations by the National Earthquake Hazard Reduction Program[15] (NEHRP), and plays a significant part in the creation of buildings codes[16] by the Building Seismic Safety Council[17] (BSSC) and in the retrofitting guidelines designated by the Federal Emergency Management Agency (FEMA). The map is also an important source of information for the financial sector: the California Earthquake Authority (CEA) uses it to define premiums for state insurance program and financial companies, such as the pension funds who take earthquake risk very seriously in portfolio construction.

Maps such the Seismic Hazard Map should therefore be considered has "navigation platform" that are not true representation of the world, but establish a system of "correspondences" (November et al., 2010) indicating salient makers, the "altered equilibrium" that need to be operationalized in practice. As a performative object, the Seismic Hazard Map imposes its reality on others by deploying, in a single moment, the complexity of its composition, its own existence. This capacity of data translation and communication is pivotal in the risk definition: an only partially 'immutable mobile' (Latour, 1990).

Mode of existence 3: The transformative experience of the earthquake as "a living agent"

Direct experience of earthquakes is one way of knowing what it is to live in a seismic zone.[18] Experience of the intensity of an earthquake depends not only on the observer distance to the epicenter but also on the crustal material that seismic waves must travel through. For the observer, the feeling of the earthquake also depends on the type of building he may be standing in and the quality of the observer's attention to the phenomenon.[19]

The perception of the floor, walls, and other surroundings—all moving, and the ground falling away under one's feet—along with a definite feeling of spatial disorientation: an earthquake is happening. The feeling of "solid ground" now in motion is deeply unsettling. While droping, covering, and holding, the idea that of an earthquake slowly makes its way through the nervous system. "Earthquake!"—but then, "How big?" In his post-earthquake account, the philosopher William James described his own experience, recalling a California friend's warning about the possibility of a seismic event:

> Accordingly, when, lying awake at about half past five on the morning of April 18 in my little "flat" on the campus of Stanford, I felt the bed begin to waggle, my first consciousness was one of gleeful recognition of the nature of the movement. "By Jove," I said to myself, "here's B's old earthquake after all"; and then, as it went crescendo, "and a jolly good one it is too!" I said. Sitting up involuntarily, and taking a kneeling position, I was thrown down on my face as it went fortior shaking the room exactly as a terrier shakes a rat. Then everything that was on anything else slid off to the floor, over went bureau and chiffonier with a crash, as the fortissimo was reached; plaster cracked, an awful roaring noise seemed to fill the outer air, and in an instant all was still again, save the soft babble of human voices from far and near that soon began to make itself heard, as the inhabitants in costumes négligés in various degrees sought the greater safety of the street and yielded to the passionate

> desire for sympathetic communication. The thing was over, as I understand the Lick Observatory to have declared, in forty-eight seconds. To me it felt as if about that length of time, although I have heard others say that it seemed to them longer. In my case, sensation and emotion were so strong that little thought, and no reflection or volition, were possible in the short time consumed by the phenomenon. (James, 1906: 1215 -1216)

Taking a broad view, earthquakes are what happen when familiar categories lose their everyday, common properties; when they are moved suddenly and without warning. It is a moment where the "Order of Things" (Foucault, 1970), the well-established ordinance of the world as we know it, is transformed. Objects, time, values, space, thinking, and emotion: everything changes substance. Every "thing" becomes a mass, moved by gravity, and the human body is one of them. Of course, the process of a rumbling earthquake is, in fact, usually very quick, often not lasting more than a couple of seconds.[20] But these few seconds can be life-changing. Writing to his brother Henry after the earthquake, James declared: "[It is] impossible not to feel it as animated by a will, so vicious was the expression of the temper displayed, and I see now how absolutely inevitable was the primitive theological interpretation of such disturbance" (Livingston, 2012) —a disturbance so large that it also impacts the categories of human and non-human, physical and meta-physical.

For residents of seismic zones, the contour and intensity of earthquake risk are partly defined by the spatial and emotional traces that past disasters leave behind them, creating an invisible map of dangers, memories, and emotions. In After the Quake (Murakami, 2002), Murakami's characters live through what psychologists call a "post-traumatic experience," which unfolds in several steps. Here, the description of the effects of an earthquake on the characters portrays the "mysterious and profound way" in which those changes operate (Rosbrow, 2012). Psychoanalyst T. Rosbrow, reflecting on the Murakami pieces, describes its development as "first, strangeness—the loss of the familiar; second, the past intruding into the present with the physical/emotional sense of being 'shoved'; and third, most importantly, the sense of randomness that follows in the wake of traumatic events, which wipe out our needed sense of predictability and order" (Rosbrow, 2012). After the Loma Prieta Earthquake in 1989, many in the Bay Area were deeply shocked in a way similar to Rosbrow's description. As one expert in post-earthquake evaluations observed during our discussions, "After the 1989 Loma Prieta Earthquake, about three days after, I woke up in a sweat. Like, 'Oh my God, I have to get out of here!" Another scientist confirmed:

> I don't know if [the experience of the earthquake] basically changed me, but I know that I had been in number of damaged areas caused by earthquake shortly afterward. I find that those trips had a major effect on me, in terms of considering how serious earthquake risks are, and their consequences. I think it caused me to look at what the consequences are in society and the value that society has.

Connecting science and experience, the past and the future, the collective and individual, direct or indirect experiences of earthquakes have a strong impact on the human soul. "If an earthquake is what happens beneath the ground, beyond our sight and immediate comprehension, then so too are our individual lives shaped by psychological and emotional tremors that we find hard to grasp, and subject to numerous unpredictable and violent aftershocks." (Clark, 2002). Living with the risk of earthquakes—waiting, as well as planning, for the next "Big One"—allows earthquake experts and scientists to add a layer of lived experience to their scientific knowledge. As one of the persons interviewed recalled:

> As a seismologist, I individually think of earthquakes from a purely scientific perspective. That obviously builds into understanding what the likely effects of earthquakes are. As an individual and regular person living in the Bay Area, I am interested to know the kind of very real impact an earthquake would mean for me. I think that's an important combination; a lot of seismologists are spread around the world working on earthquake hazards wherever they are, but actually living in an earthquake zone forces you to combine the scientific aspect [with] the personal and societal aspects.

During my fieldwork, I have observed that, building on years of expertise and experience, experts and scientists interested in understanding, mitigating and preparing for disaster have used their intimate and multidimensional knowledge of the phenomenon—how it felt, how it displaced things, how it changed the landscape—as a basis for scientific inquiry. The introduction of these non-rational dimensions ultimately opens up new perspectives in the definition and organization of our worlds: it allows existences—or ontologies—of actants that were not previously visible to come into being. With time, these experts and scientists whom I have interviewed and those who participated the post Fukushima workshops have come to recognise that their knowledge and their experience are interwoven, giving them some responsibilities toward their fellow residents. While observing the consequences of catastrophe unfolding and imagining the ones to come, they have defined the contours of an hybrid form of sense- and knowledge-making.

Facing the complexity, the messiness, and the unknown existence of the earthquake as a "living agent", trying to answer difficult questions that for most do not have any clear answer, they to be became scientists-citizen, or amateurs with "passionate interests"(Latour and Lepinay, 2009) who learn to be affected and care about technicalities (Mol, 2010) and, as Emilie Hache suggested, are able to tap into the reservoir of our collective emotions to describe the world and take action. For this community of experts, living through the routine moments of everyday life in a seismic zone, sharing the common fate of a potential threat and building infrastructures that can help mitigate the risk, has been a transformative experience.

Conclusion

Earthquakes produce movement: the movement generated by tectonic plates, but also the movement provoked by the response to the earthquake. During the workshops that I attended in the aftermath of the Tōhoku earthquake and tsunami and the Fukushima Daiichi disaster, and while speakers were presenting their work, it became clear to me that the event we were discussing had multiple existences, multiple ways of "being into the world," which were hard to reconcile. This apparent diversity of experiences is reinforced by the many ways in which the narration, the stories, and the analyses of the event were performed across disciplinary fields and epistemologies. As is often the case in risk and disaster studies, much of the work presented was built on what can be described as the "fifty shades" (Strasser and al., this issue) of citizen science: a variety of research programs and methods sometime relying on nonscientists to collect and analyze data, and often sharing their data in order to increase public understanding of science and to impact public policies. Each contribution looked at distinct existences of the disaster that, far from being antithetical to each other, showed kaleidoscopic facets, imagination, and epistemologies of the same event.

Science and Technology scholars have noted that nineteenth-century scientists have "take(en) out the human element from the research, to make the research processes and products objective" (Strong, 2008), thus making the multiple agency, the actants, the mode of existence, that "interfere" with the scientific process invisible and, in the same movement, taken away the complexity of the subjectivity of the scientist as a knowing subject (Houdart, 2008; Mialet, 2012a). In my research I have observed that the everyday company of earthquakes, even those yet to be, is an experience strong enough to hybridize knowledge and change the nature of expertise. A century after the 1906 earthquake, this interpretive move is still a work in progress as contemporary seismologists continue to revisit past events and engage with scientific communities and the public. In this paper, I have tried to show how the distinct existences of the earthquake require distinct assemblages of collaboration between scientists and nonscientists, using different type of data and infrastructures to emerge.

The first mode of existence focuses on the observation and translation of multiple mechanism that are responsible of the earthquake: if the contours of the "tensions in the earth's crust reach the breaking point" are hard to delimitate and multiple methods are still needed to comprehend the complexity of the phenomenon, collaboration between non-scientists and scientists is part of the solution. The second mode of existence addresses another iteration of the existence of the earthquake, its visualization and translation into a quantifiable risk. In this section, I have showed that, in that form, the earthquake was gaining another existence with performative abilities, able to stabilized a contested snapshot of the definition of the "altered equilibrium". The third mode of existence is addressing the more personal and affective dimension of the earthquake as a "living object". This existence is certainly the most difficult to grasp, but it is also the mode where emerge the non-rational dimension of knowledge and where intersection of citizen a non-citizen science is the most interesting, offering the opportunity to imagine a continuum of knowledge that include academic practices as one important but certainly not unique way of sense-making.

In recent years, as scientific infrastructure evolves, data used by earthquake scientists, observers and concerned citizens have come from disparate systems of measurements: each system allows us to look at the movement of tectonic plates from particular angles and perspectives. Quantification by means of instrumentation has often taken precedence over eyewitnesses' perceptions, but despite this considerable progress, earthquakes remain hard to grasp, and are calling for other modes of existence, other assemblages. In a world that has become increasingly datafied, where the conditions of knowledge-making are transformed to the point where researchers start evoking a change of paradigm for their discipline (Hey et al., 2009), the questions of the modes of sciences, redistribution of research and methods become crucial articulation to observe, analyze and in cases critic. In the context of disasters, the focus on the collective good (for the preparedness and preservation of the multiple cities of the Bay Area) has (in some places) brought about a shifting of hierarchies of knowledge: scientists now allow themselves to become amateurs, paying attention to several modes of existence—several ontologies—of the earthquake and the earthquake risk as they emerge in a situated manner. More research needs to be conducted to understand how the interaction between data structures, infrastructures, institutions on one side and workflow and repertoires on this other, enables or constrains the emergence of new modes of existence. In this context, datafication, often thought of as a quantitative approach, must be integrated to clarify the messiness of heterogeneous data, or whatever else might be given by experience.

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Notes

1 That day, the panel discussion included among others Peter Hayes, Nautilus Institute, USF; Joonhong Ahn, Nuclear Engineering, UC Berkeley; Mary Comerio, Architecture, UC Berkeley; Cathryn Carson, Professor, History and then–Associate Dean of Social Sciences, UC Berkeley.

2 While experts in conference rooms were pleading for democracy, the case for science was far from being settled in other public spaces. Debates raged about the scientific assertions and assumptions of the possible impact of radioactivity on the Bay Area. Pieces of information were collected by residents from all around the globe. Social media provided a platform for the dissemination of alternative information and independent research (Abe, 2013) at a time when official information was substantially lacking. (Slater et al., 2012)

3 This panel had been put together with the precious support of Prof. Joonhong Ahn (1958 –2016), member of the Nuclear Engineering Department, and Faculty Member of the Center for Japanese Studies within the Institute of East Asian Studies. Professor Ahn's dedication to the question of resilience and to STS approaches made his contribution to the field unique.

4 Which was, it itself a form of citizen science project, built around book and an interactive platform on which Mediators, Collaborators and Co-researchers were collaborating to define different modes of existence.

5 As Star and Griesemer noted almost three decades ago, "[M]ost scientific work is conducted by extremely diverse groups of actors—researchers from various disciplines, amateurs and professionals, humans and animals, functionaries and visionaries. Simply put, scientific work is heterogeneous." (Star and Griesemer, 1989: 391-392)

6 The concepts were developed by French philosopher Etienne Souriau in the 1940s and rediscovered by Bruno Latour and Isabelle Stengers in recent years (2009). Souriau, a philosopher of aesthetics interested in the emergence of the work of art, developed concepts of "instauration" which, more than being simply the transformation of raw material into an artistic object, described the progressive institution and discovery of multimodal interactions during the laboring process of creation.

7 "According to these theories, earthquakes were due to the sudden release of strain that had been gradually built up by the constant creeping of the earth's surface near a fault. In his contribution to the commission's final report, Harry Fielding Reid had argued that there has indeed been a gradual distortion of the earth's surface near the San Andreas Fault during the late nineteen century, just as the elastic rebound theory called for (Geschwind, 2001: 60-61)."

8 The Modified Mercalli Intensity Scale is still used today in the Shake Map, also known as the "Did You Feel It?" map.

9 Only after tectonic plate theory was largely accepted by the scientific community in the 1960s were seismologists able—and even today only partially - to describe and explain the mechanisms that trigger an earthquake.

10 The Japan Meteorological Agency seismic intensity scale measuring seismic coefficient known as *shindo,* which measure strength of earthquake ground motion, is still the wildly used in Japan.

11 http://earthquake.usgs.gov/dyfi

12 Cornell University; Lehigh University; Oregon State University; Rensselaer Polytechnic Institute; SUNY, Buffalo; University of California, Berkeley; University of California, Davis; University of California, Los Angeles; University of California, San Diego; University of California, Santa Barbara; University of Illinois, Urbana-Champaign; University of Minnesota; University of Nevada, Reno; and University of Texas, Austin.

13 Both the Lick Observatory and the Student's Observatory in Berkeley were equipped with two Ewing and one Gray-Milne seismographs.

14 To reiterate, the NSF is the National Science Foundation, and the NIST is the National Institute of Standards and Technology.

15 "The activities of the Program shall be designed to: (A)[…] research and develop effective methods, tools, and technologies to reduce the risk posed by earthquakes to the built environment, especially to lessen the risk to existing structures and lifelines; (B) improve the understanding of earthquakes and their effects on households, businesses, communities, buildings, structures, and lifelines, through interdisciplinary and multi-disciplinary research that involves engineering, natural sciences, and social sciences; and (C) facilitate the adoption of earthquake risk reduction measures by households, businesses, communities, local, state, and federal governments, national standards and model building code organizations, architects and engineers, building owners, and others with a role in planning for disasters and planning, constructing, retrofitting, and insuring buildings, structures, and lifelines through: (i) grants, contracts, cooperative agreements, and technical assistance; (ii) development of standards, guidelines, voluntary consensus standards, and other design guidance for earthquake hazards risk reduction for buildings, structures, and lifelines; (iii) outreach and information dissemination to communities on location-specific earthquake hazards and methods to reduce the risks from those hazards; and (iv) development and maintenance of a repository of information, including technical data, on seismic risk and hazards reduction"(112th Congress 1st Session, S.646 To reauthorize Federal Natural Hazards Reduction Programs and for others purposes, In the Senate of the United States, March 17, 2011).

16 The building code has been adopted by 37 states, including California.

17 The BSSC, established by the National Institute of Building Sciences, develops and promotes building earthquake mitigation regulatory provisions for the whole nation.

18 Of course, the human body does not perceive all earthquakes, and the experience of an earthquake can be indirect. But very small earthquakes, such as those at M2.5 and less, that might not be perceived by the human body are recorded and are visible on the Real Time USGS maps. Therefore, tremors that are neither humanly perceived nor recorded through instruments do not "exist" as earthquakes.

19 Comparing experiences can fuel conversations for a while. For many, it is often interesting to think about and discuss what they experienced: the growing rumble of the P waves or the shock of the S waves.

20 Very occasionally, however, they can be surprisingly long; the Tōhoku earthquake, for example, lasted approximately six minutes.