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Validating Safecast data by comparisons to a U. S. Department of Energy Fukushima Prefecture aerial survey

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ABSTRACT

Safecast is a volunteered geographic information (VGI) project where the lay public uses hand-held sensors to collect radiation measurements that are then made freely available under the Creative Commons CC0 license. However, Safecast data fidelity is uncertain given the sensor kits are hand assembled with various levels of technical proficiency, and the sensors may not be properly deployed. Our objective was to validate Safecast data by comparing Safecast data with authoritative data collected by the U. S. Department of Energy (DOE) and the U. S. National Nuclear Security Administration (NNSA) gathered in the Fukushima Prefecture shortly after the Daiichi nuclear power plant catastrophe. We found that the two data sets were highly correlated, though the DOE/NNSA observations were generally higher than the Safecast measurements. We concluded that this high correlation alone makes Safecast a viable data source for detecting and monitoring radiation.

1. Introduction

Volunteered Geographic Information (VGI) provides alternatives to government and corporate sponsored sources for determining the impact of natural or man-made disasters via crowd-sourced measurements (Goodchild, 2007). Ordinary citizens persons with smartphones or handheld sensors can make observations of disaster related phenomena that can supplement data gathered from traditional remotely sensed sources and ground-based equipment. However, sensing platforms are expensive to deploy, operate, and maintain, whereas VGI equipment is typically owned and operated by volunteers for comparatively little cost. Also, these citizen-based observations can cover areas from perspectives difficult to achieve with official sources, and with a very high spatial and temporal resolutions, especially in urban areas.

In fact, while space- and air-borne remote sensing can achieve a very high spatial resolution, in the order of a few centimeters in different parts of the electromagnetic spectrum, and vehicles can be deployed to capture data from the ground, satellites are not always overhead and are limited by atmospheric opacity (clouds and pollution), planes cannot remain airborne indefinitely, and ground vehicles have limited operating ranges and times.

Moreover, individuals intelligently evaluate their surroundings to focus their equipment on interesting scenes, whereas government or corporate managed sensors mechanically scan the environment without consideration to what is being observed, which means that these government and corporate sources may require more post-processing and analysis to mine useful information.

The Safecast VGI project uses "citizens as sensors" (Goodchild, 2007) to produce publicly available collection of radiation levels by time and location. Safecast participants collect these radiation measurements as a public service as well as for awareness of their own radiation exposure, and can be used as a citizen-led early warning system to detect radioactive leaks and hot spots. On March of 2015 there were over 27 million logged observations from around the globe. About 75% of the observations originated in Japan, primarily in Fukushima, surrounding prefectures, and in

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major Japanese cities. Up until 2013, virtually all measurements were confined to Japan (Bonner and Brown, 2015).

Unfortunately VGI fidelity can be questionable because of possible operator reporting bias, poor data quality (such as the inclusion of generated test data), and equipment reliability and accuracy (Flanagin and Metzger, 2008). Though the Safecast organization has taken steps to ensure that the hardware is properly tested and calibrated before shipping (Safecast, 2015a), it is possible for the volunteer to make mistakes in assembling the sensor, particularly if they are inexperienced with putting together complicated electronic equipment. Moreover, the user may ignore equipment operating instructions (Safecast, 2015c), which may reduce observation quality. Though Safecast employs moderators to vet newly uploaded data (Brown et al., 2016), it is still theoretically possible for low quality data to be added to the publicly available database.

To address this open issue, we compared Safecast radiation observations with a similar set of observations made by the U. S. Department of Energy jointly with the U. S. National Nuclear Security Administration (DOE/NNSA) (Lyons and Colton, 2012). We found that the two datasets were strongly correlated, but that the DOE/NNSA observations were generally higher than the corresponding Safecast values. Later, we explore possible explanations for these differences. However, given the high correlation between the two datasets, we conclude that the Safecast data has utility for measuring environmental radiation.

1.1. The 2011 Tohoku earthquake and tsunami

On March 11, 2011 at 5:46:24UTC a 9.0 magnitude earthquake occurred 130 km east of Sendai, Honshu, Japan at a depth of approximately 30 km near the Pacific and North American plate subduction zone (U. S. Geological Survey, 2011). Earthquake models showed that the fault moved upwards by 30 m–40 m over a 300 km by 150 km area with effects that were felt as far away as Korea, southeastern Russia, and China (U. S. Geological Survey, 2011). The plate shift was extreme enough to move the Earth's axis 25 cm and speed up its rotation by 1.8 μs per year (Chai, 2011). Moreover, the earthquake slid Honshu, the main island of Japan, 3.6 m to the east, while part of the Oshika Peninsula moved about 5.3 m towards the earthquake's epicenter (Norio et al., 2011).

The tsunami caused by this earthquake affected 20 different Pacific Rim countries with most of the damage occurring in Japan. It is estimated that the tsunami reached a peak of 38 m above mean sea level while penetrating up to 10 km inland (Norio et al., 2011). Over 300,000 buildings, 2000 roads, and 50 bridges were damaged or destroyed. There were also approximately 15,000 casualties, 5300 injured, and 4600 missing people due to the tsnunami (U. S. Geological Survey, 2011). The combined earthquake and tsunami had an estimated initial overall economic impact of up to 183 billion US Dollars (Norio et al., 2011).

1.2. The Fukushima Daiichi nuclear disaster

The 11 nuclear power plants in northeastern Japan automatically shutdown when the earthquake struck (Norio et al., 2011). In spite of these automatic safety procedures, the Fukushima Daiichi power plant suffered a level 7 catastrophic nuclear incident, the highest level on the International Nuclear and Radiological Event Scale (INES), due to earthquake and tsunami damage (Norio et al., 2011). The 5.7 m seawall at the Daiichi power plant was overcome by a 15 m high tsunami that flooded backup diesel generators and washed their fuel tanks into the ocean (Funabashi and Kitazawa, 2012), which meant that the power plant had no diesel generators to power the cooling systems (Nakamura and Kikuchi, 2011). In turn, this resulted in the partial meltdown of the reactor cores, which led to significant releases of radiation into the atmosphere and the ocean (Funabashi and Kitazawa, 2012; Nakamura and Kikuchi, 2011; Chino et al., 2011).

1.3. The advent of the Safecast project

Motivated by the lack of reliable and publicly available information regarding the ongoing Fukushima Daiichi nuclear power plant disaster, that same month a group of hobbyists organized the Safecast project, which focused on providing the means for citizens to collect and share radiation observations. The Safecast project logged their first observations with handbuilt radiation detectors in April, 2011, just one month after the tsunami struck Japan (Brown et al., 2016). The Safecast project is internationally crowdfunded and crowdsourced with over 650 handheld units and several stationary sensors that have contributed more than 27 million radiation measurements as of March 2015 (Bonner and Brown, 2015). In May 2014 there were over 14 million Safecast observations within Japan, though there were also millions of observations from Korea, Iraq, the United States, and other locations.

Fig. 1 shows log-adjusted Safecast radiation observations for Japan, and depicts the radiation plume from the Fukushima Daiichi Nuclear Power Plant (FDNPP) spreading to the northwest about 50 km before turning and fading to the southwest. Most of the data follows the roadways because the hand held units are typically attached to car windows during observations, though there are also data gathered from ships off the east coast of the main island. The green circles indicate several permanent stationary sensors that also contribute observations to the Safecast database.

Safecast's current handheld radiation detector, the bGeigie Nano, is shown in Fig. 2, and is the fifth generation of their open source hardware design. It uses the LND 7317 radiation sensor, which is a 5.08 cm diameter pancake style radiation sensor that can detect alpha, beta, and gamma radiation using a Geiger-Müller tube filled with a mixture of neon and halogen gases (LND, Inc, 2011). The device also has a Global Positioning System (GPS) receiver to record the location of radiation readings. The Safecast detector records only the sensor output in counts per minute with time and location information and does not do any other manipulation of the saved data. For the display on the device, the counts per minute can be converted to either micro Sieverts per hour (μSv/h) or Becquerel per meter squared (Bq/m^2), both based on ^{137}Cs. Radiation observations are logged to a Secure Digital (SD) memory card, which can then be uploaded to the Safecast site; the data is freely available to the public via the Creative Commons CC0 license (Creative Commons, 2015). bGeigie Nano kits can be purchased online for roughly $450, and then assembled by users within a few hours (Safecast, 2015b; Brown et al., 2016). The device is typically deployed by attaching it to the outside of a vehicle's window and driving through areas of interest, though users can also collect observations from their bGeigie Nano while walking (Brown et al., 2016).

1.4. Safecast data Validity

The Safecast team has implemented quality control measures to ensure equipment accuracy. First, all the electronic components are factory tested before being shipped (Safecast, 2015a). Second, units are randomly selected, assembled, and undergo calibration tests at the Jülich Research Centre in Germany, QualTek in the US, and the International Atomic Energy Agency (IAEA) testing laboratory in Seibersdorf, Austria. The tested units have demonstrated ±10% accuracy, which is the typical Safecast performance (±15% is their maximum), which compares well to the normal industry