Journal of Environmental Radioactivity 190–191 (2018) 51–65

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Calibration of Safecast dose rate measurements

Guido Cervone[a,b,*], Carolynne Hultquist[a]

[a] Geoinformatics and Earth Observation Laboratory, Dept. of Geography and Institute for CyberScience, The Pennsylvania State University, University Park, PA, United States

[b] Research Application Laboratory, National Center for Atmospheric Research, Boulder, CO, United States

ARTICLE INFO

Keywords:
Safecast data
Data calibration
Volunteered geographic information
Citizen science
Fukushima Daiichi

ABSTRACT

A methodology is presented to calibrate contributed Safecast dose rate measurements acquired between 2011 and 2016 in the Fukushima prefecture of Japan. The Safecast data are calibrated using observations acquired by the U.S. Department of Energy at the time of the 2011 Fukushima Daiichi power plant nuclear accident.

The methodology performs a series of interpolations between the U.S. government and contributed datasets at specific temporal windows and at corresponding spatial locations. The coefficients found for all the different temporal windows are aggregated and interpolated using quadratic regressions to generate a time dependent calibration function. Normal background radiation, decay rates, and missing values are taken into account during the analysis.

Results show that the standard Safecast static transformation function overestimates the official measurements because it fails to capture the presence of two different Cesium isotopes and their changing magnitudes with time. A model is created to predict the ratio of the isotopes from the time of the accident through 2020. The proposed time dependent calibration takes into account this Cesium isotopes ratio, and it is shown to reduce the error between U.S. government and contributed data. The proposed calibration is needed through 2020, after which date the errors introduced by ignoring the presence of different isotopes will become negligible.

1. Introduction

Safecast is a widespread Volunteered Geographic Information (VGI) project started in the immediate aftermath of the 2011 Japanese nuclear emergency to collect spatio-temporal radiation dose rate measurements (Safecast, 2016). It relies on “citizens as sensors” (Goodchild, 2007) to collect distributed data and upload them to a central open access repository. VGI refers to datasets which are voluntarily contributed, and contain temporal and spatial information (Fast and Rinner, 2014). Because of the massive amount of real-time, on-the-ground data generated and distributed daily, the utilization of VGI during emergencies is a new and growing area of research (Cervone et al., 2016a).

Citizen-led movements aimed at measuring environmental variables could generate actionable data for situational awareness during emergencies (Sprake and Rogers, 2014). Sensors for environmental data collection are being built using inexpensive off-the-shelf components (Hemmi and Graham, 2014). The widespread use of mobile devices, paired with the increased reliability and speed of wireless networks, enable citizens to share data reliably and in real-time (Cervone et al., 2016b). However, despite the availability of massive contributed geospatial ‘big data’, they are often not validated in a rigorous setting and by an independent set of researchers. Because of this lack of verification, crowdsourced data are usually not considered reliable for use during emergencies despite their suitability (Fairbairn and Al-Bakri, 2013; Fowler et al., 2013). If properly validated, citizen science projects could provide actionable data during emergencies (Sprake and Rogers, 2014).

1.1. Prior research using Safecast data

Despite the large number of active users and massive quantity of observations collected, Safecast data received limited external scientific validation from researchers. An initial study by Coletti et al. (2017) performed statistical tests to compare about five weeks of Safecast data (2011-04-23 to 2011-05-30) with U.S. government measurements over an area of approximately 100 km^2 in the Fukushima prefecture. They concluded that Safecast data are correlated with the government measurements, but that the distributions of the two datasets are different. They showed that the DOE/NNSA observations were generally

* Corresponding author. Geoinformatics and Earth Observation Laboratory, Dept. of Geography and Institute for CyberScience, The Pennsylvania State University, University Park, PA, United States.

E-mail addresses: cervone@psu.edu (G. Cervone), hultquist@psu.edu (C. Hultquist).

https://doi.org/10.1016/j.jenvrad.2018.04.018
Received 17 August 2017; Received in revised form 18 April 2018; Accepted 19 April 2018
Available online 15 May 2018
0265-931X/ © 2018 Elsevier Ltd. All rights reserved.

higher than the corresponding Safecast values, but this result is true only on a rather small subset of the data used in their study. Successive studies using additional data showed that Safecast tend to over-estimate the DOE dose rate measurements.

A study by Hultquist and Cervone (2017) compared 5 years of Safecast data with official measurements. Both DOE and Safecast data were decay corrected to allow for comparison at specific dates and then spatially standardized after data was aggregated to a common grid. Decay corrected DOE data were compared to raw Safecast data collected within a fixed temporal window. The results showed a high correlation between the two datasets, but also a systematic bias (overestimation) in the Safecast data. Spatio-temporal maps were created to compare Safecast data collected within a month long temporal window with U.S. government measurements that were corrected for decay for the middle of the same month. The maps in this study showed an overall good correlation. However, no tests were performed specifically to characterize or try removing this bias from the Safecast data.

This research presents a methodology to characterize the bias, and proposes a time dependent mathematical function to remove this bias from the Safecast data. The calibration method described is applicable both to previously collected data, as well as to data that will be collected in the future. Calibrated Safecast data could be used during emergencies to complement government measurements or provide an assessment when other sources of data are not available.

1.2. Fukushima Daiichi nuclear accident

On 2011-03-11 at 05:46 UTC (14:46 local time, UTC +9) a massive Mw 9.0 underwater earthquake occurred 70 km offshore of the eastern coast of Japan, with the epicenter at 38.322N and 142.369E. The earthquake generated a tsunami that rapidly hit the eastern coast of Japan, and propagated across the Pacific Ocean. A tsunami wave hit the Fukushima Daiichi Nuclear Power Plant (FDNPP) about 40 min after the earthquake which led to a cooling system dysfunction.

Several radioactive releases ensued as a result of an increase of pressure and temperature in the nuclear reactor buildings. Some releases were the result of both controlled and uncontrolled venting, while others were the result of explosions that compromised the containment structures. The explosions were most likely caused by ignited hydrogen, generated by reaction between zirconium and water occurring after the reactor core damage. Several radioactive isotopes were released into the environment, and of particular importance for this research are the releases of Cesium, and more specifically ^{137}Cs and ^{134}Cs isotopes with a half-life of approximately 30 and 2 years respectively. Other radioactive elements released have a much shorter half-life (e.g. Iodine or Zirconium; in the order of hours to days), that quickly decay and thus can be omitted from the computations (Morino et al., 2011).

The largest radioactive emissions occurred between the 2011-03-12 and 2011-03-21. Radioactive particles were quickly transported regionally which contaminated several areas of Japan and traces of the release reached North America and Europe (Bowyer et al., 2011; Potiriadis et al., 2011; Masson et al., 2011). Elevated levels of radiation were recorded at different locations throughout Japan on the ground, in the water, and in the air. The individual radionuclide distributions assessed by Kinoshita et al. (2011) over central-east Japan and starting at the FDNPP nuclear power plant indicate that the prefectures of Fukushima, Ibaraki, Tochigi, Saitama, and Chiba and the city of Tokyo had higher than normal radiation dose rates due to the dispersed radioactive elements.

Estimating the fate of the contaminants and predicting their health impact quickly became an issue of great importance (Calabrese, 2011). Transport and dispersion (T&D) models were used to compute radioactivity levels and ground deposition, as well as to estimate the non-steady source release for the accident (Yasunari et al., 2011; Stohl et al., 2012; Terada et al., 2012; Katata et al., 2012; Cervone and Franzese, 2014). At the same time, the Safecast project was started to monitor radiation levels on the ground, and to provide an independent assessment of the emergency.

2. Data

This study is based on radiation data from a U.S. Department of Energy (DOE) survey, contributed volunteered measurements (Safecast), nine deposition studies from the Japan Atomic Energy Agency (JAEA), and a background radiation survey from the Japanese National Institute of Advanced Industrial Science and Technology (AIST). Additionally, elevation data from the Advanced Spaceborne Thermal Emission and Reflection (ASTER) satellite were also used, mainly for plotting purposes.

2.1. Background radiation

The AIST completed a 2007 survey of natural background radiation. The data covers the majority of Japan at a resolution of about half a kilometer and captures the natural variation in the background radiation, which for the most part, is dependent on the local topography and geology. In this research, the term anomaly is used to refer to the transformed radiation observations (both U.S. government and Safecast), where the spatially corresponding natural occurring background radiation has been subtracted from each measurement. The resulting anomaly is assumed to represent the increase in radiation caused by the Fukushima nuclear accident.

Fig. 1 (a) shows the background radiation for most of Japan, with values ranging from between 0.05 and 0.30 μSv/h. The study area, defined by the convex hull that encompasses the available DOE radiation data, is shown in hashed red. Fig. 1 (b) shows the background radiation for the study area, with values ranging between 0.06 and 0.16 μSv/h. The extent of the DOE measurements (shown in red) corresponds to the edge of the polygon, and is used in all maps to mask the study area. The figure also shows the location of the FDNPP which is indicated with a red diamond at 37.4213N, 141.0331E. Additionally, concentric arcs are plotted at 20, 40, and 60 km from the power plant. The locations of the power plant and the arcs are included in all maps for reference and to ease the visual comparisons.

2.2. JAEA surveys

The JAEA took surveys of the energy spectrum of gamma-ray emitting radioactive nuclides (Saito et al., 2015). The Cesium deposition density surveys during the period ranging from 2011-04-29 to 2013-03-11 are interpolated and distributed as raster datasets with a spatial cell resolution of 500 m^2 (Japan Atomic Energy Agency, 2014). Fig. 2 shows the ratio of ^{134}Cs over (^{137}Cs + ^{134}Cs) for the nine surveys performed. Note that the extents of the surveys are not consistent but there is a significant overlap. The color scale is identical for all figures, and shown in the last panel. The ratio monotonically decreases as a function of time because of the shorter half-life of ^{134}Cs with respect to ^{137}Cs. While there are spatial variations over the domain, the range of values is small and overall consistent, regardless of the domain extent. The figure shows an average starting ratio of approximately 0.5 in 2011, which is consistent with the published source term parameters of the nuclear release, and an average ratio of approximately 0.3 in 2013.

2.3. DOE data

The DOE in conjunction with the U.S. National Nuclear Security Administration (NNSA) responded to the accident by running a number of missions to acquire airborne remote sensing radiation levels in the Fukushima prefecture between 2011-03-14 and 2011-05-28 (Lyons and Colton, 2012). The data provide a broad footprint of the radiological release over land, and are assumed to be the 'ground truth' for this

Download English Version:

https://daneshyari.com/en/article/8080403

Download Persian Version:

https://daneshyari.com/article/8080403

Daneshyari.com