COMMENT ON THE 2018 UPDATE TO THE USGS NATIONAL VOLCANIC THREAT ASSESSMENT

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This interesting paper by [1] contains rankings data pertaining to the critical issue of U.S. volcanic hazards. These data provide much-needed information for U.S. volcanoes. Results show that the Kīlauea volcano is ranked the #1 most hazardous U.S. volcano. This is a very important result, but the interpretations would be strengthened by further explanation of rankings. We understand that the paper's focus is volcanic hazards, but the authors raise several issues regarding the significance of their results, including casting doubt on some rankings' accuracy. With this comment, I hope to initiate a discussion on some of these issues. Volcanic hazard rankings are important because of volcanic threats to life and infrastructure. To test the idea of Kīlauea as the most hazardous volcano in the US, I monitored Yellowstone Caldera volcano from Nov. 1-Nov. 30, 2021. I considered this volcano to be worthy of a higher ranking than #21.

Yellowstone Caldera (a supervolcano located in Yellowstone National Park in Wyoming) shares both similarities and differences with Kīlauea (a shield volcano located in Hawai'i Volcanoes National Park in Hawaii) [2]. While Kīlauea and Yellowstone share the same type of hotspot plate tectonic setting, they differ in that the magma in Yellowstone Caldera's hotspot pushes through continental crust, while the magma in Kīlauea's hotspot pushes through oceanic crust [2]. This distinction is important as it results in Yellowstone Caldera being more associated with explosive eruptions and hazards while Kīlauea is more associated with effusive eruptions and hazards (though explosive eruptions have occurred) [2]. The volcanoes also have different activity levels with Kīlauea's most recent eruption beginning on Sep. 29, 2021 and this eruption's greatest hazard being higher emissions of volcanic gas as lava flows are mostly contained in a closed-off section of the park [3,4]. Yellowstone's most recent eruption was 70,000 years ago and resulted in thick lava flows along the Pitchstone Plateau [2,5]. While Kīlauea's worst eruption occurred in 1790 and resulted in the death of 5,405 people, Yellowstone's worst eruption occurred 2.1 million years ago when a massive and violent explosion resulted in the formation of a caldera 80 km long and 65 km wide [2,5].

To test Kīlauea and Yellowstone Caldera's rankings, I measured three indices once every weekday at approximately 2:00 PM throughout November of 2021. The first index I chose to measure was the number of earthquakes seen on a given day because more frequent earthquakes could be a sign of greater volcanic activity [6]. The second and third indices I chose to measure were the largest earthquake magnitude and the largest earthquake depth seen on a given day, as these indices are measures of how hazardous an earthquake is and could be a sign of more hazardous volcanic activity [6]. I considered these indices to be the best measurements to test the hypotheses as they all monitor earthquake activity which is often linked to volcanic activity and more dangerous earthquakes could be a sign of more dangerous volcanic activity [6]. I gathered this data from the USGS monitoring websites for Kīlauea and Yellowstone [3,5].

Due to its far higher levels of volcanic activity (as shown by its most recent eruption and data in Tables 1-2 and Figures 1-3) I can agree that Kīlauea should be ranked higher than Yellowstone Caldera in terms of volcanic hazardousness [1-3]. However, I believe that Yellowstone Caldera deserves to be ranked higher than #21 [1]. While unlikely, Yellowstone has the potential for an eruption that could devastate the U.S. and others around the globe with huge amounts of explosive force, volcanic ash, and lava [2,5]. Additionally, even smaller more likely eruptions, such as hydrothermal eruptions, lava flows, and rhyolitic lava eruptions could still have very dangerous effects [5]. Yellowstone National Park was the 2nd most visited national park in 2020 with 3.8 million visitors, meaning that even a smaller eruption could impact and endanger a large number of people, especially in busier seasons [7]. To conclude, while I can agree with Kīlauea's ranking, Yellowstone Caldera's potential for large and even smaller eruptions leads me to believe it deserves a higher threat ranking than #21 [1,2,5].

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Table 1. Kīlauea Hazard Measurements

Date	Time (CT)	Number of Earthquakes Kīlauea	Largest Earthquake Magnitude Kīlauea	Largest Earthquake Depth (Miles) Kīlauea
11/1/21	2:00 PM	43	3	22.7
11/2/21	2:00 PM	74	3	23.7
11/3/21	2:00 PM	26	3.4	22.6
11/4/21	2:00 PM	18	2.6	22.4
11/5/21	2:00 PM	16	2.8	21.9
11/8/21	2:00 PM	23	2.7	21.7
11/9/21	2:10 PM	30	3.2	22.8
11/10/21	2:00 PM	22	2.9	40.3
11/11/21	2:00 PM	12	2.4	20.8
11/12/21	2:00 PM	20	3	23.5
11/15/21	2:06 PM	15	2.6	21.1
11/16/21	2:00 PM	12	3.3	43.4
11/17/21	2:06 PM	14	2.5	21.3
11/18/21	2:00 PM	8	2.3	23.5
11/19/21	2:01 PM	7	2.3	22.7
11/22/21	2:00 PM	7	2.5	20.6
11/23/21	2:00 PM	16	2.4	22.2

11/24/21	2:00 PM	19	2.5	21.4
11/25/21	2:05 PM	14	3.1	22.6
11/26/21	2:00 PM	7	3.3	20.4
11/29/21	2:09 PM	16	3	22.9
11/30/21	2:00 PM	7	2.1	21.7

Table 2. Yellowstone Caldera Hazard Measurements.

Date	Time (CT)	Number of Earthquakes Yellowstone Caldera	Largest Earthquake Magnitude Yellowstone Caldera	Largest Earthquake Depth (Miles) Yellowstone Caldera
11/1/21	2:00 PM	4	2	9.3
11/2/21	2:00 PM	4	1.5	8.7
11/3/21	2:00 PM	0	0	0
11/4/21	2:00 PM	0	0	0
11/5/21	2:00 PM	3	1.2	9.6
11/8/21	2:00 PM	2	1.4	8.5
11/9/21	2:10 PM	2	2.3	4.8
11/10/21	2:00 PM	2	0.5	5
11/11/21	2:00 PM	4	1.6	5.7
11/12/21	2:00 PM	3	1.7	4.7
11/15/21	2:06 PM	0	0	0
11/16/21	2:00 PM	3	1.9	3.4
11/17/21	2:01 PM	2	1.3	2.8
11/18/21	2:00 PM	1	0.4	3.9
11/19/21	2:00 PM	1	1.2	2.7
11/22/21	2:00 PM	1	1.8	3.1
11/23/21	2:00 PM	3	1.5	5.2
11/24/21	2:00 PM	3	0.6	7.2
11/25/21	2:05 PM	0	0	0
11/26/21	2:00 PM	0	0	0
11/29/21	2:09 PM	2	2.4	4.8
11/30/21	2:00 PM	1	1	4.1

Figure 1. Graph of time versus number of earthquakes. Depicts the number of earthquakes measured at the various times it was recorded for each volcano.

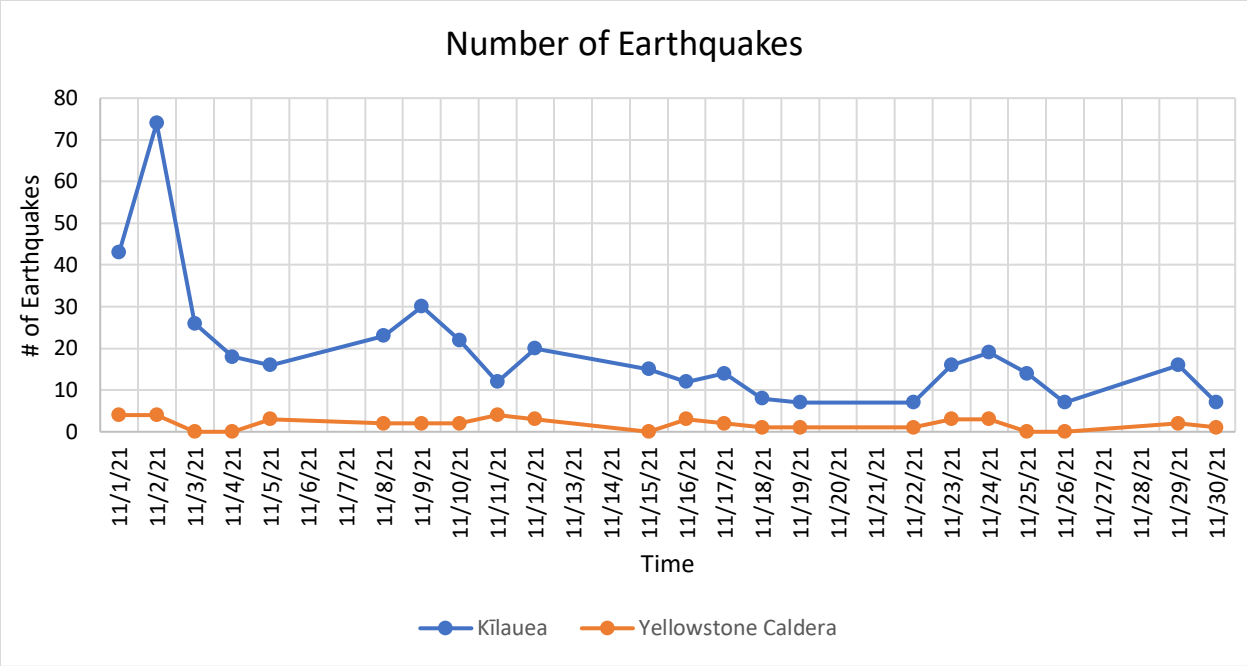


Figure 2. Graph of time versus largest earthquake magnitude. Depicts the largest earthquake magnitude measured at the various times it was recorded for each volcano.

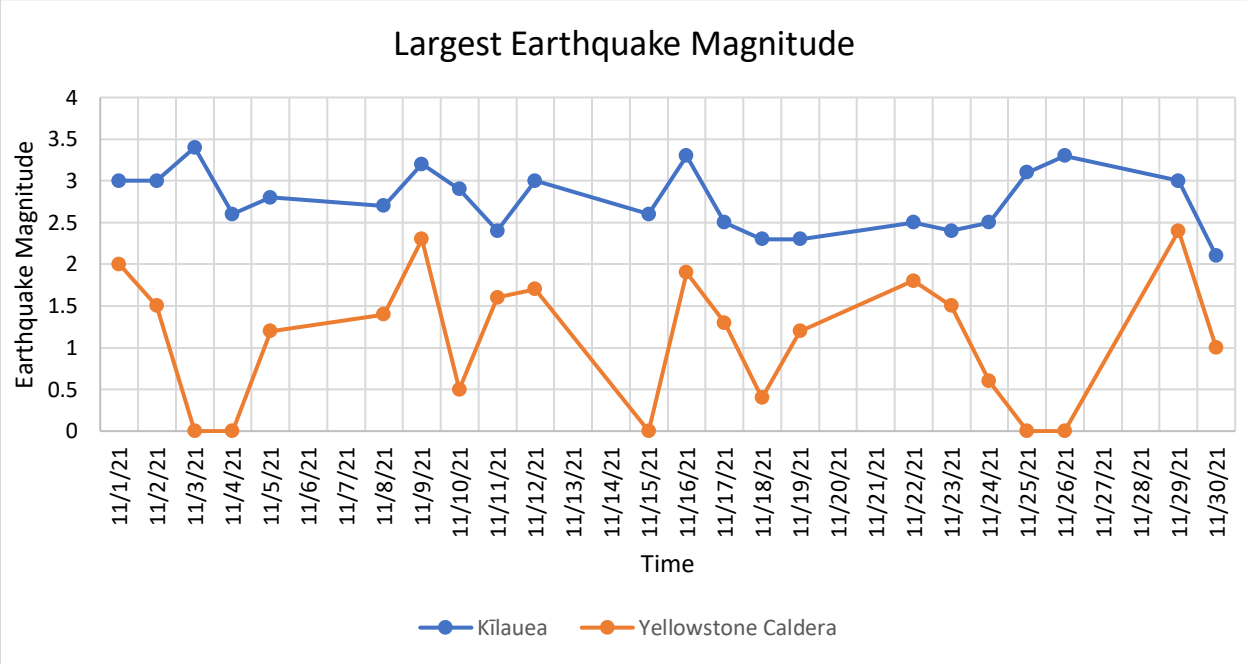
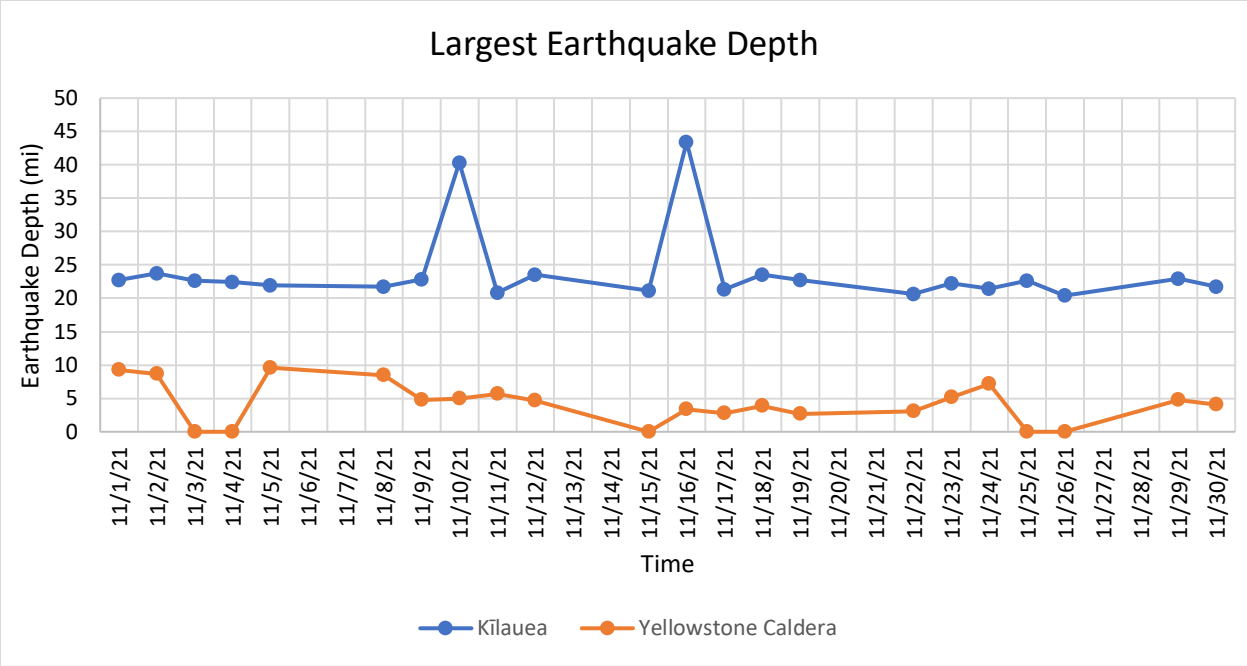


Figure 3. Graph of time versus largest earthquake depth. Depicts the largest earthquake depth measured at the various times it was recorded for each volcano.



COMMENT ON THE 2018 UPDATE TO THE USGS NATIONAL VOLCANIC THREAT ASSESSMENT

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This interesting paper by [1] contains hazard reporting data pertaining to the critical issue of the ranking of the most threatening American volcanoes. These data provide much-needed information for the decision toward which volcano is the top ranked. Results show that the Kilauea volcano is the most dangerous volcano in the U.S. This is a very important result, but the interpretations would be strengthened by comparison to Mt. Rainier. We understand that the paper's focus is on Kilauea's hazards but the authors raise several issues regarding the significance of their results, including casting doubt on the threat of frequent eruptions, population centers, & lack of lahars. With this comment, I hope to initiate a discussion on some of these issues. Volcanic hazard rankings are important because it is important to protect population centers from destruction & it is equally essential for scientists to know the makeup of the earth, including volcanoes humans live near. To test the idea of Kilauea as the most hazardous volcano in the US, I monitored it & the Mt. Rainier volcano from November 1 to December 6, 2021. I considered this volcano to be equally as dangerous.

Kilauea is a shield volcano formed from a hotspot tectonic setting, in contrast to Rainier, & located on the island of Hawaii in Hawaii Volcanoes National Park. Mt. Rainier is a stratovolcano formed from a subduction zone/convergent plate tectonic setting located in the Washington Cascades in Mt. Rainier National Park. Both volcanoes have similar hazards: the potential for large explosions, dust, ash, pyroclastic flow, earthquakes, & destruction of property. However, Kilauea has more frequent eruptions & lava flow [2], while Mt. Rainier has deadlier lahars [3]. In 1894 steam plumes were reported at Mt. Rainier & this is debated to be the time of the last eruption [4]. On September 21st 2021 Kilauea began erupting [5]; the current consequences are large amounts of volcanic gas in the air [6]. I believe the worst Rainier eruption was during the Osceola eruptive period (5,600-4,500 years ago) because there were huge lahars that flowed into the Puget Sound, a crater formed similar to Mt. St. Helens, & it altered the course of the White River [4]. The worst Kilauea eruption was in 1790 [7].

I measured earthquake frequency & depth because a larger number of earthquakes could indicate magma movement beneath the crust. I measured sulfur dioxide because this is a gas that is found in a volcanic eruption. I measured the volcanoes every day of November. I considered these the best measurements because I knew I could measure them frequently, they would look consistent on a linear graph, and they could provide hidden signals into what was going on beneath the surface. The sites I used to find data were the USGS [8,9] & NASA [10,11].

Mt. Rainier is as dangerous as Kilauea because of lahars, population centers, & the application of Kilauea's numbers. Lahars are the top reason Rainier is deadly. There are 80,000 people in Mt. Rainier lahar zones, meaning a major volcanic event could lead to the worst natural disaster in U.S. history [12]. Second, although Kilauea has people living on the volcano, these numbers don't compare to PNW towns in volcanic zones. The Seattle-Tacoma metropolis is one of the most populated areas. Several of these suburbs would be in the direct path of a lahar. Third, Kilauea experiences deep earthquakes & major eruptions with no significant damage to the surrounding area. If we applied the deep earthquakes/frequency & gas emissions to Mt. Rainier the entire area would need to be evacuated. Lastly, the subduction zone that Mt. Rainier sits on is a distinct hazard. Convergent plate boundaries are much more dangerous that Kilauea's hotspot because along these faults you have the potential for big earthquakes whenever plates collide [13]. In conclusion, volcanoes cannot be viewed in a vacuum. To accurately rank the most dangerous volcanoes there needs to be checks & balances between volcanologists to question what the USGS considers in their rankings. When we look at Mt. Rainier's lahars, population centers, potential for mass explosion, & the fault zone, it is imperative to note that it is just as dangerous & important to observe to protect the American population as on Kilauea.

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Table 1. Earthquake Frequency for Kilauea.

Date	Earthquake Frequency
11/1	58
11/2	53
11/3	18
11/4	23
11/5	20
11/6	19
11/7	28
11/8	24
11/9	24
11/10	16
11/11	20
11/12	14
11/13	20
11/14	28
11/15	32
11/16	17
11/17	33
11/18	16
11/19	13
11/20	20
11/21	15
11/22	17
11/23	22
11/24	21
11/25	21
11/26	21
11/27	25
11/28	18
11/29	21
11/30	12

Table 2. Earthquake Frequency for Mt. Rainier.

Date	Earthquake Frequency
11/1	2
11/3	4
11/4	1
11/5	3

11/8	1
11/10	1
11/13	1
11/16	1
11/21	1
11/23	1
11/26	3
11/29	1
11/30	1
12/5	2
12/6	1

Table 3. Largest Earthquake Depth for Kilauea

Date	Earthquake Depth
11/1	22.7
11/2	23.7
11/3	21.9
11/4	23.7
11/5	23.9
11/6	23
11/7	20.9
11/8	22.8
11/9	40.3
11/10	20.8
11/11	23.7
11/12	22.3
11/13	23.5
11/14	22.2
11/15	22.7
11/16	43.3
11/17	23.5
11/18	22.9
11/19	22.7
11/20	25.7
11/21	23.5
11/22	23
11/23	22.5
11/24	21.5
11/25	22.9
11/26	27.9
11/27	23.2

11/28	22.9
11/29	21.9
11/30	21.9

Table 4. Largest Earthquake Depth for Mt. Rainier

Date	Earthquake Depth
11/1	-0.02
11/3	3.4
11/4	10
11/5	7.7
11/8	1.2
11/10	6.9
11/13	8.8
11/16	1.2
11/21	1.9
11/23	1.2
11/26	7.4
11/29	8.8
11/30	5
12/5	6.6
12/6	0.6

Table 5. Sulfur Dioxide Gas Emissions for Mt. Rainier

Date	Earthquake Depth
11/1	0
11/2	0
11/3	0.1
11/4	0
11/5	0
11/6	0.1
11/7	0
11/8	0
11/9	0
11/10	0
11/11	0
11/12	0.2
11/13	0
11/14	0
11/15	0
11/16	0
11/17	0

11/18	0
11/19	0
11/20	0
11/21	0
11/22	0.1
11/23	0
11/24	0.1
11/25	0
11/26	0
11/27	0
11/28	0.1
11/29	0

Table 6. Sulfur Dioxide Gas Emissions for Kilauea

Date	Earthquake Depth
11/1	0
11/2	1.5
11/3	2
11/4	0
11/5	0.5
11/6	0
11/7	0.1
11/8	0
11/9	0.9
11/10	0
11/11	0
11/12	0
11/13	0
11/14	0.1
11/15	0
11/16	0.3
11/17	0
11/18	0.6
11/19	3
11/20	2.1
11/21	0
11/22	0
11/23	1.2
11/24	0
11/25	0
11/26	0

11/27	1.5
11/28	0.6
11/29	0

Figure 1. Graph of time versus earthquake frequency for Kilauea

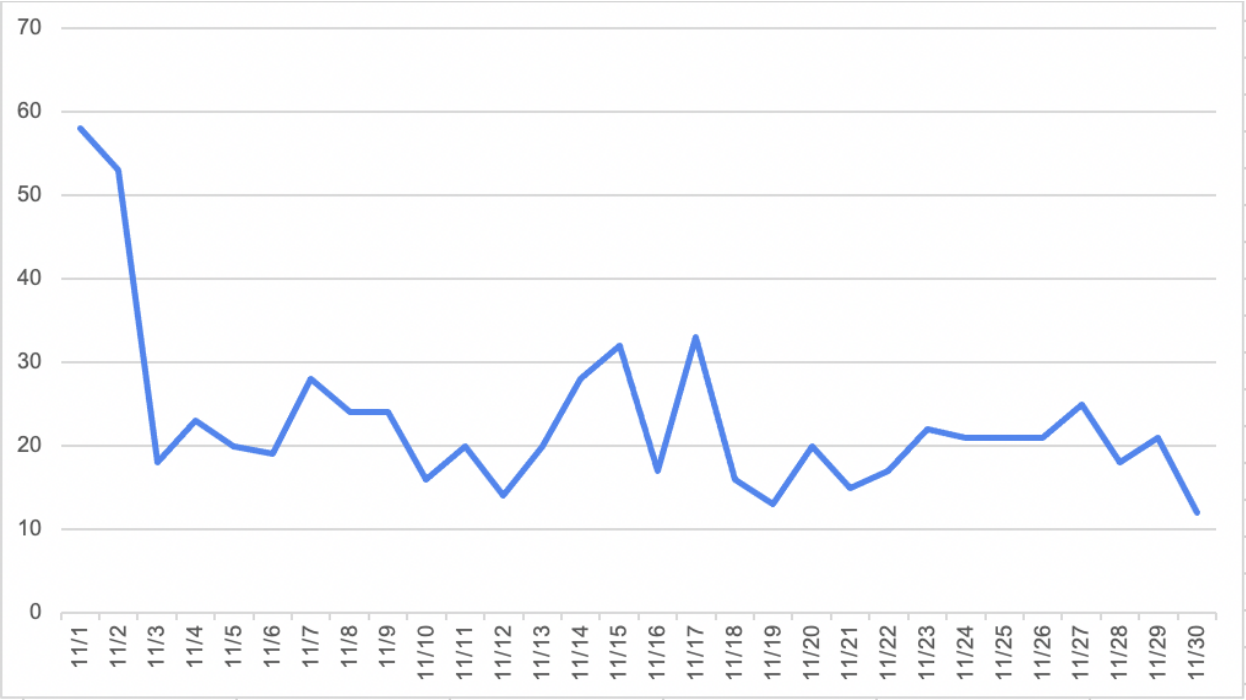


Figure 2. Graph of time versus earthquake frequency for Mt. Rainier

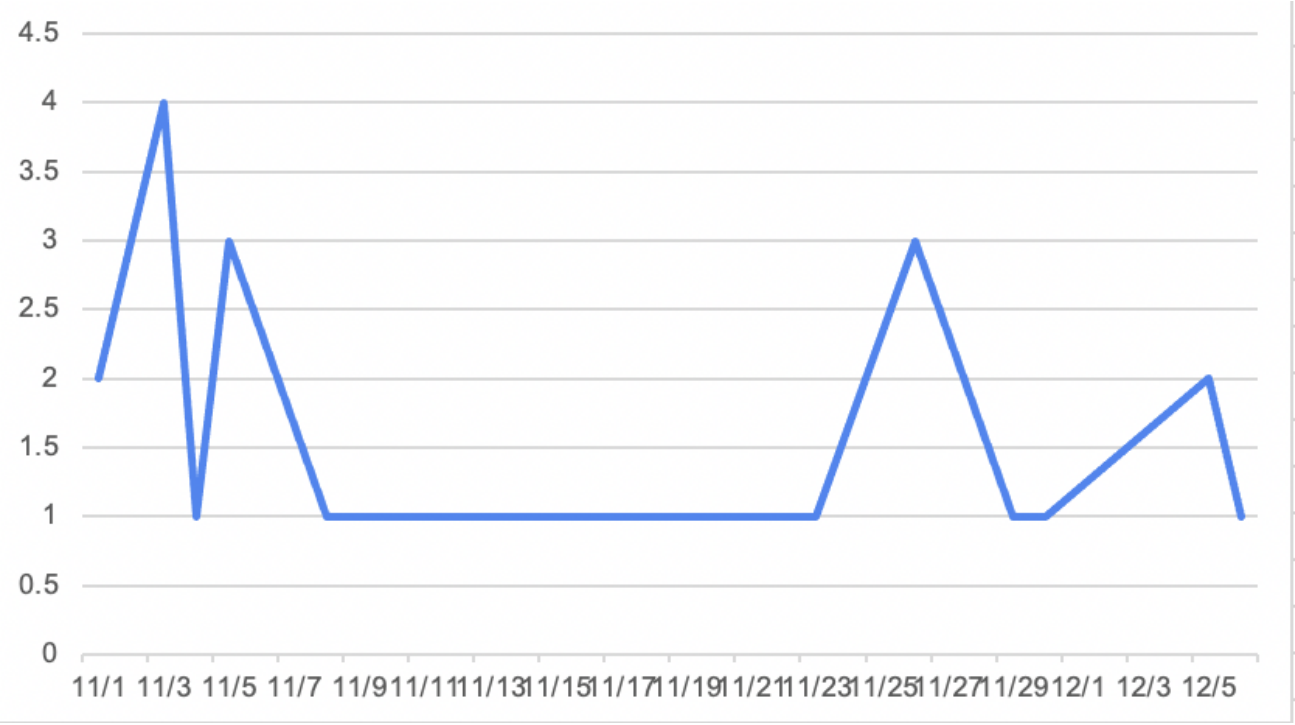


Figure 3. Graph of time versus earthquake depth for Kilauea

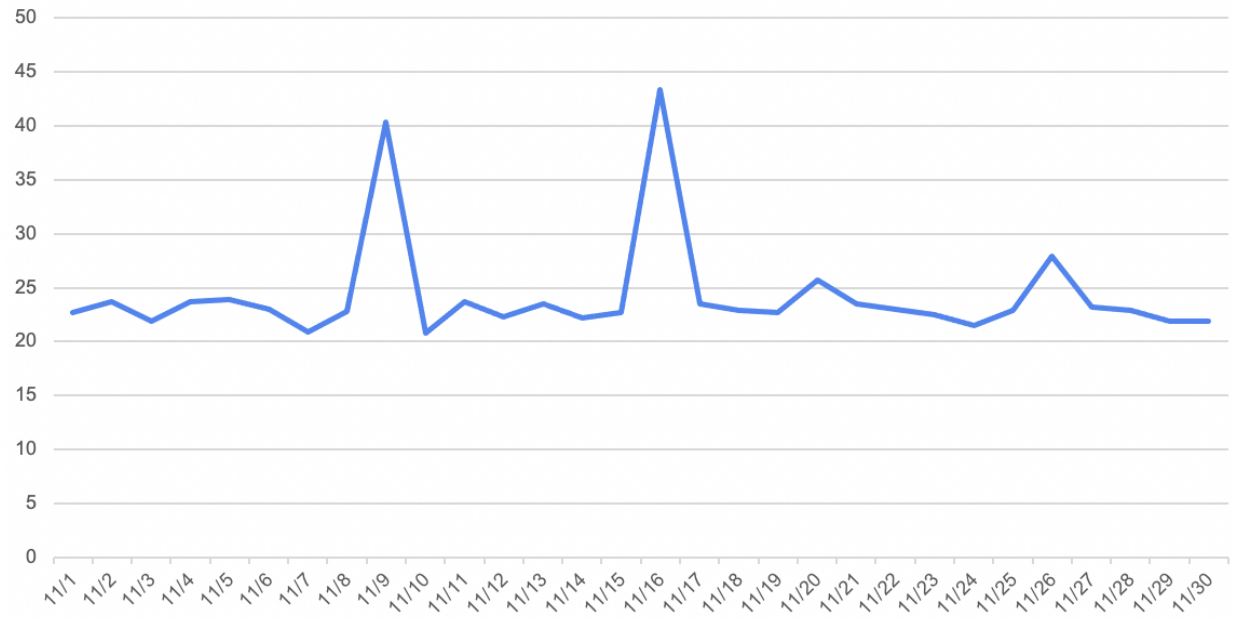


Figure 4. Graph of time versus earthquake depth for Mt. Rainier

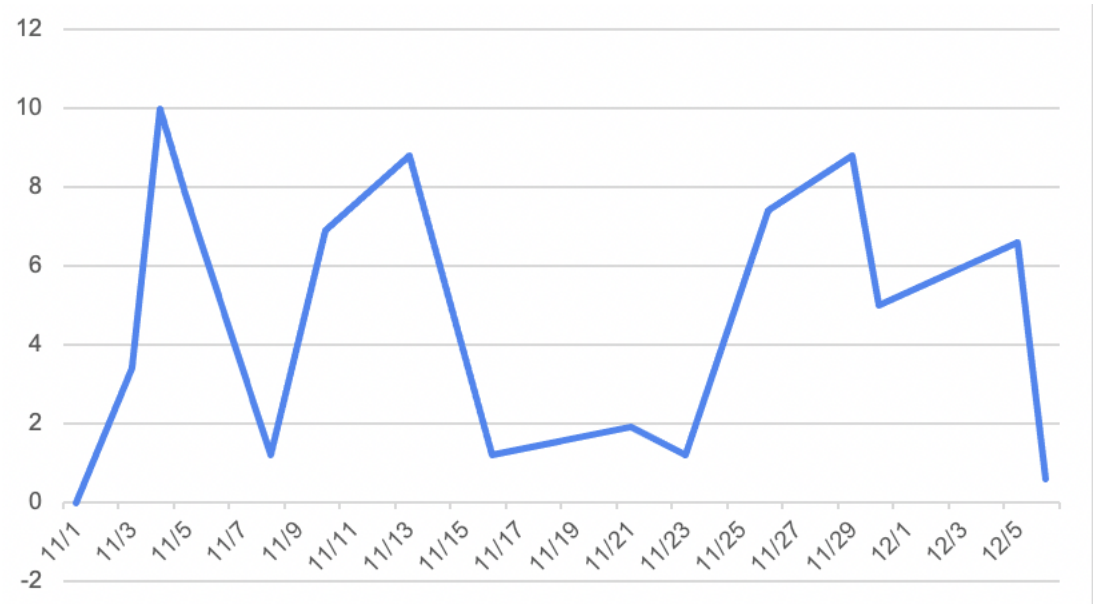


Figure 5. Graph of time versus sulfur dioxide emissions for Kilauea

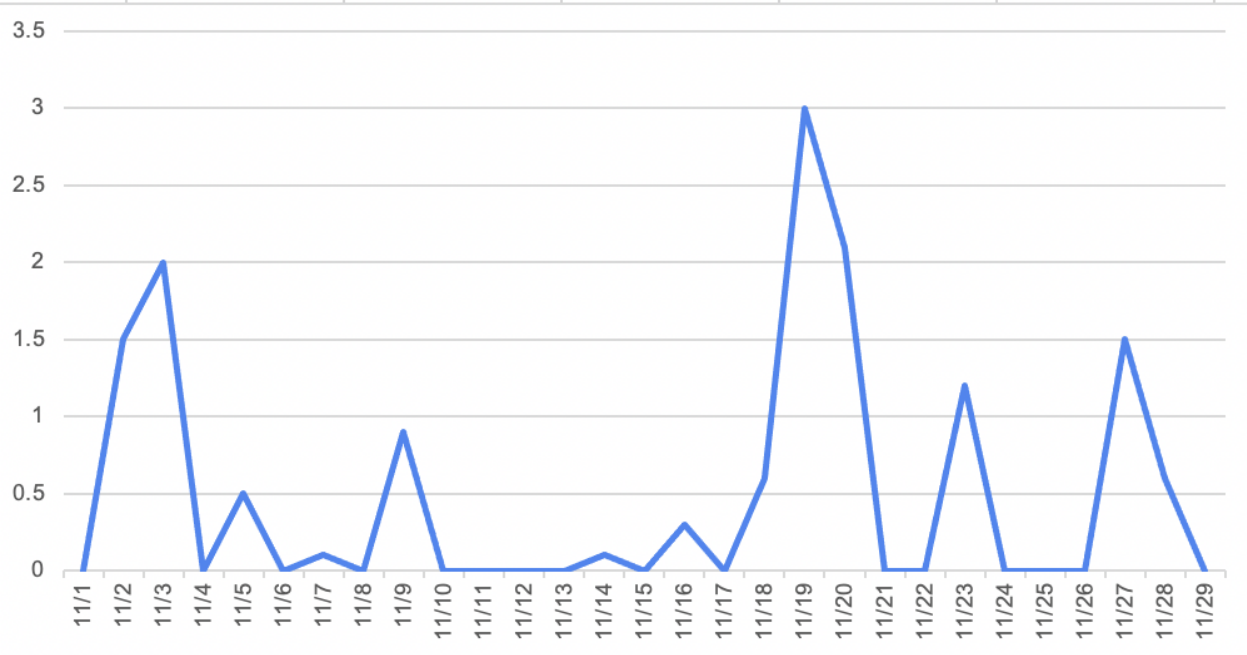
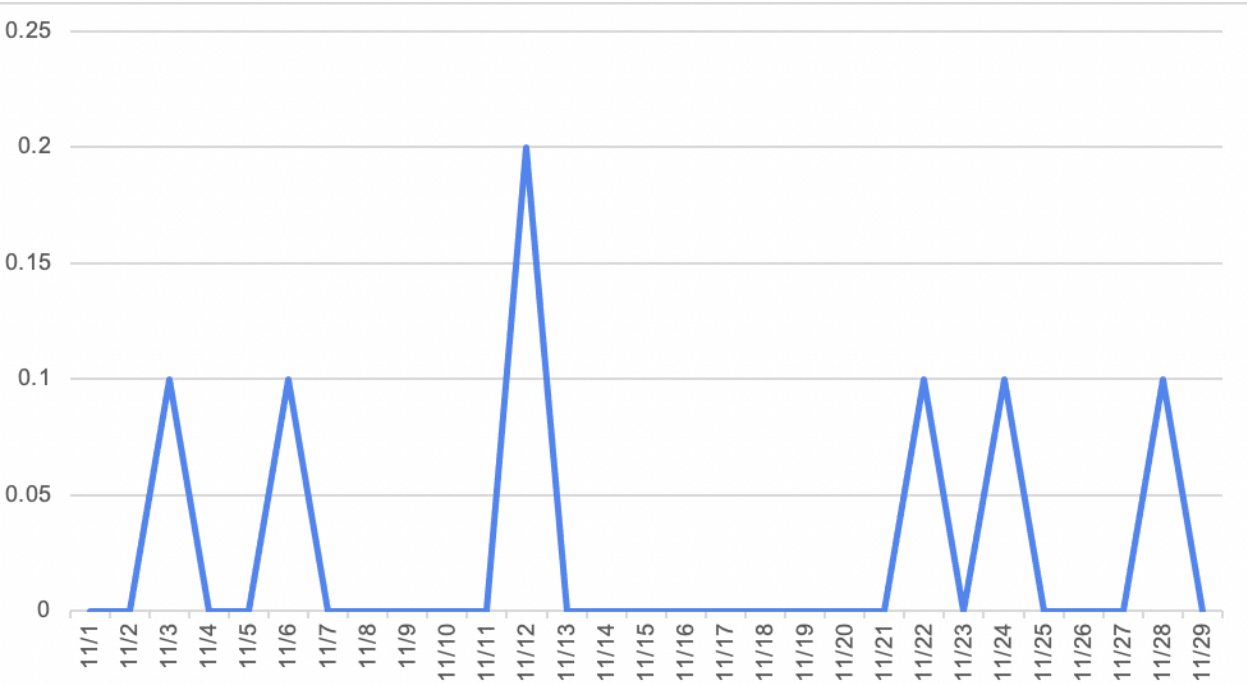


Figure 6. Graph of time versus sulfur dioxide emissions for Mt. Rainier



COMMENT ON THE 2018 UPDATE TO THE USGS NATIONAL VOLCANIC THREAT ASSESSMENT

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This interesting paper by the U.S. Geological Survey contains hazard and exposure data pertaining to the critical issue of the relative threats of different U.S. volcanoes. These data provide much-needed information for researchers and citizens alike to gauge how much of a threat different volcanoes in the U.S. pose. Results show that the Kīlauea volcano poses the highest threat. This is a very important result, but the interpretations would be strengthened by considering a broader range of factors. We understand that the paper's focus is accessing the unmitigated threats of U.S. volcanoes based on fifteen factors, but the authors raise several issues regarding the significance of their results, including recognizing that the report omitted how mitigation efforts can reduce the threats of volcanoes. With this comment, I hope to initiate a discussion on some of these issues. Volcanic hazard rankings are important because they help guide long-term hazard assessment and response planning decisions. To test if Kīlauea is the most hazardous volcano in the US, I monitored the Yellowstone volcano from November 7 to December 5. I considered this volcano to be of approximate danger to the Kīlauea volcano.

Kīlauea volcano is a shield volcano located on the eastern slope of Mauna Loa Volcano in Hawai'i Volcanoes National Park while Yellowstone volcano is a supervolcano located in the Yellowstone Caldera of Yellowstone National Park [1, 2]. Both are hotspot volcanoes, although Yellowstone volcano is an explosive volcano while Kīlauea volcano is an effusive volcano [1, 2]. Both that can cause earthquakes, hydrothermal explosions, lava flows, and ash falls [1,2]. The Kīlauea volcanoes' worst eruption is thought by researchers to have occurred between 850 and 950 CE, with the most recent eruptive period lasting 300 years and ending in the 1970s. During the most recent period of eruption, significant amounts of ash blanketed the areas around the volcano to create the Keanakāko‘i tephra and several hundred people were killed due to hot, ash-rich surges [1]. The Yellowstone volcano last erupted around 174,000 years ago, which is considered the worst eruption of the volcano. Since then, researchers have recorded over 60 small scale eruptions that have resulted in earthquakes and rock falls [2].

This paper compares data on the magnitude of the most recent earthquakes, the depth of the most recent earthquakes, and the distance of the most recent earthquakes from the nearest settlement between the two volcanoes. These indices were chosen since they best approximate the threat earthquakes, the most measurable and presently destructive hazards occurring from volcanic activity in the two regions, pose to the nearby communities. Measurements were recorded every other day starting November 7 and ending December 5 at 1:00 PM CT and were taken using the U.S. Geological Survey's Observatory pages for the Kīlauea and Yellowstone volcanoes [3,4].

My research builds on the U.S. Geological Survey's (USGS) findings to assert that Yellowstone volcano is as hazardous as the Kīlauea volcano. Although the Kīlauea volcano consistently displayed earthquakes with higher magnitudes that were located closer to settlements, the Yellowstone volcanoes' earthquakes were consistently shallower, and shallower earthquakes tend to be more damaging to humans. Figures 1 and 3 reinforce this conclusion. This data, displayed fully in Table 1, indicates that the USGS National Volcanic Threat Assessment was somewhat accurate but lacked nuance in its assessment of volcanic threats. Although the Kīlauea volcano is dangerous due to its frequent, high magnitude earthquakes near settlements, the Yellowstone volcano poses a comparable hazard to nearby settlements because its earthquakes, though of lesser magnitude, are shallower. It should be noted, however, that the deeper earthquakes of the Kīlauea volcano indicate that is may be more dangerous in the long term. Recognition of this nuance—that hazards associated with volcanoes must be determined by a holistic set of measurements—will help future researchers develop tools that not only accurately rank the threats volcanoes pose but will also advise on what resources are necessary to aid different communities affected by different volcanoes.

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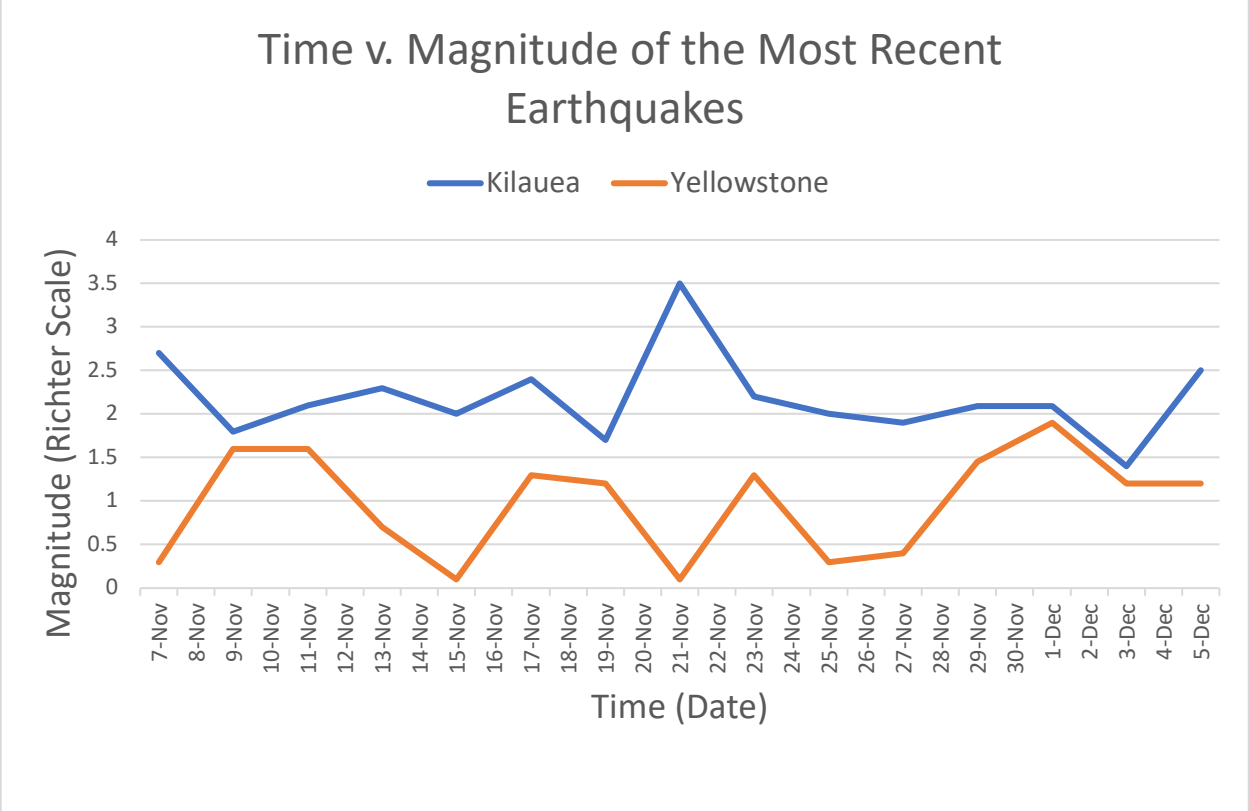
Table 1. Hazard measurement comparisons.

Date	Time	Magnitude of Most Recent Earthquake Kīlauea/Yellowstone	Depth of Most Recent Earthquake (Miles) Kīlauea/Yellowstone	Distance of Most Recent Earthquake from Nearest Settlement (Kilometers) Kīlauea/Yellowstone
11/7	1:00 PM	2.7/0.3	20.3/2.7	10/27
11/9	1:00 PM	1.8/1.6	20.7/4.7	5/21
11/11	1:00 PM	2.1/1.6	18.6/5.6	7/0
11/13	1:00 PM	2.3/0.7	20.3/2.9	6/34
11/15	1:00 PM	2/0.1	19.8/1.6	9/25
11/17	1:00 PM	2.4/1.3	20.6/2.8	6/28
11/19	1:00 PM	1.7/1.2	1.7/2.4	3/28
11/21	1:00 PM	3.5/0.1	20.4/2.6	6/24
11/23	1:00 PM	2.2/1.3	21.1/4.7	5/17
11/25	1:00 PM	2/0.3	20.7/2.9	5/33
11/27	1:00 PM	1.9/0.4	20/4.2	7/26
11/29	1:00 PM	2.09/1.45	30.87/2.21	11/49
12/1	1:00 PM	2.08/1.9	33.15/2.8	6/22
12/3	1:00 PM	1.4/1.2	19/12.7	0.1/34

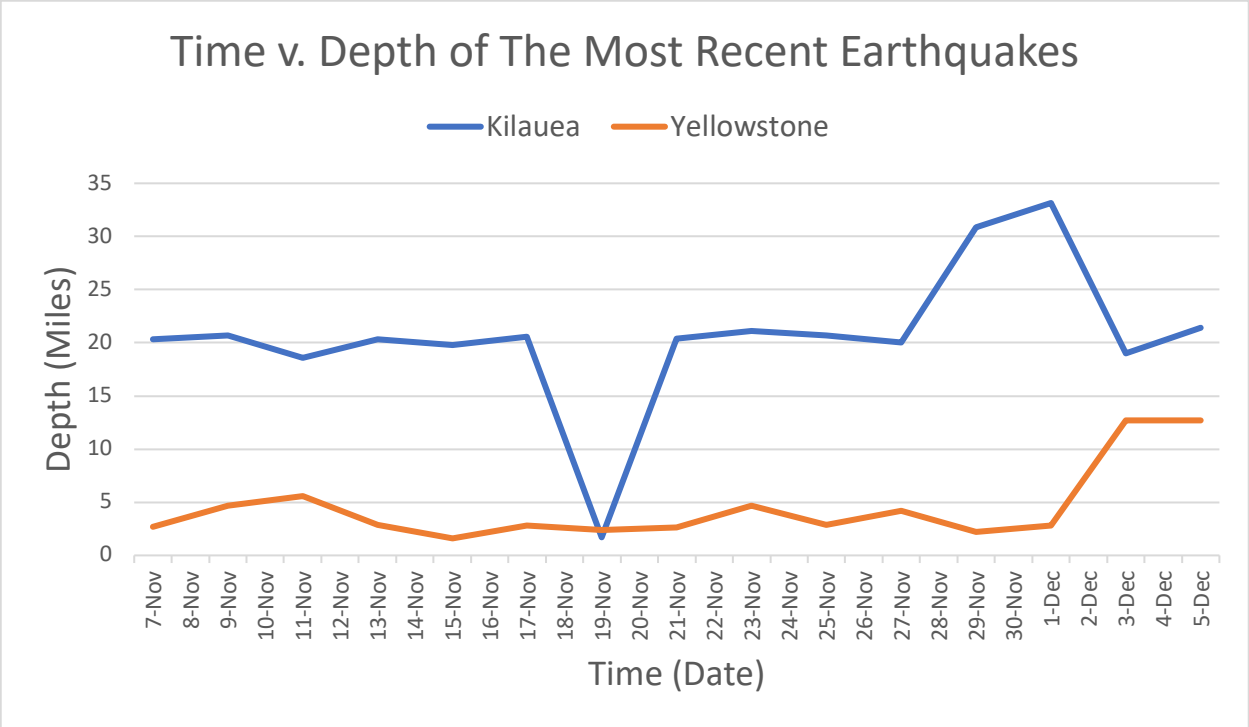
12/5	1:00 pM	2.5/1.2	21.4/12.7	7/34

Figure 1. Graph of time versus magnitude of the most recent earthquakes (Kīlauea and Yellowstone).



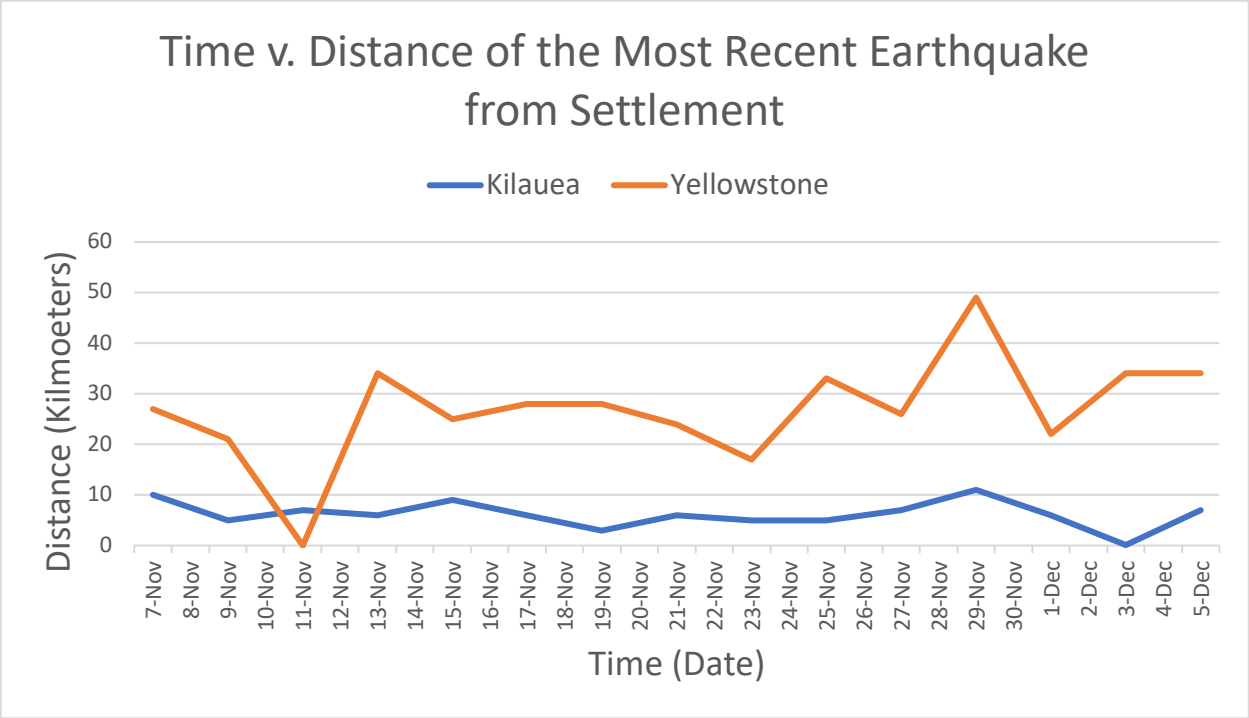
This line graph displays the varying magnitudes, as measured by the Richter scale magnitude of the most recent earthquake as of 1:00 PM on the date measured, of earthquakes associated with the Kīlauea and Yellowstone volcanoes. Kīlauea volcano's measurements appear in blue while Yellowstone volcano's measurements are red. The measurements were taken every two days from November 7 to December 5, totaling 15 measurements.

Figure 2. Graph of time versus depth of most recent earthquakes (Kīlauea and Yellowstone).



This line graph displays the varying depths, as measured by miles of the most recent earthquake as of 1:00 PM on the date measured, of earthquakes associated with the Kīlauea and Yellowstone volcanoes. Kīlauea volcano's measurements appear in blue while Yellowstone volcano's measurements are red. The measurements were taken every two days from November 7 to December 5, totaling 15 measurements.

Figure 3. Graph of time versus distance of the most recent earthquake from settlement (Kīlauea and Yellowstone).



This line graph displays the varying distances from nearest settlements, as measured in kilometers of the most recent earthquake as of 1:00 PM on the date measured, of earthquakes associated with the Kīlauea and Yellowstone volcanoes. Kīlauea volcano's measurements appear in blue while Yellowstone volcano's measurements are red. The measurements were taken every two days from November 7 to December 5, totaling 15 measurements. Settlement is defined as a location inhabited by a community of people.