2023 Alaska Seismicity Summary

Technical Report

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February, 2024

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Contents

1. Abstract

The Alaska Earthquake Center reported 45,546 seismic events in Alaska and neighboring regions in 2023. The largest earthquake was a magnitude 7.2 event that occurred on July 16 in the Alaska Peninsula region. It was a late aftershock of the 2020 M7.8 Simeonof Earthquake. Other strong earthquakes include the October 16 M6.4 and December 21 M6.1 earthquakes in the Andreanof Islands region of the Aleutian Islands. The largest earthquake in mainland Alaska, magnitude 5.4, occurred in the lower Cook Inlet region on March 19. We continued to monitor ongoing activity within the 2018 M7.1 Anchorage, 2018 M6.4 Kaktovik, 2018 M7.9 Offshore Kodiak, 2020 M7.8 Simeonof, and 2021 M8.2 Chignik aftershock sequences, the Purcell Mountains earthquake swarm, and the Wright Glacier cluster northeast of Juneau. All aftershock sequences continued to slow down compared to the previous years.

2. Introduction

The Earthquake Center reported 45,540 seismic events in Alaska and nearby regions in 2023 (Figure 2.1), which is ~1,500 less than last year (*Ruppert, February 2023*) and about 8,900 less than the record-breaking 2018 (about 55,000 seismic events) (Figure 2.2). AEC data analysts picked and cataloged 1,707,960 seismic phases, the second highest number after 2018 (Figure 2.3). The largest earthquake was a magnitude 7.2 event that occurred on July 16 in the Alaska Peninsula region. Two other earthquakes had magnitudes greater than 6: October 16 M6.4 and December 21 M6.1 earthquakes in the Andreanof Islands region of Aleutian Islands. The largest earthquake in mainland Alaska, magnitude 5.4, occurred in the lower Cook Inlet region on March 19. Overall, 34 earthquakes had magnitudes 5 or greater.

The seismicity rate did not vary significantly throughout the year, with all new aftershock and swarm sequences being rather short-lived (Figures 2.4-2.6). The largest spike in seismic activity came in early-to-mid March from the Tanaga-Takawangha volcanic complex in the central Aleutians (Ruppert et al., April 2023). Throughout the year we averaged 871 reported earthquakes per week, continuing the downward trend after the record-breaking year in 2018. The overall magnitude of completeness for this period was at Mc=1.4 (Figure 2.7), ranging from Mc=1.1 in the Interior and Southeast regions to Mc=2.0 in the Alaska Peninsula and the Aleutians (Figure 2.8). Most of the seismic events occurred at shallow depths, with the deepest events down to 254 km located in the central and western Aleutians (Figure 2.9).

We reported 4,094 seismic sources that were classified as something other than regional tectonic earthquakes (Figure 2.10). Of these, 444 were suspected quarry blasts (magnitudes M=0.3-2.6), the majority of which were located in the vicinity of Fort Knox and Healy mines in Interior Alaska. The reported events included 1,028 glacial quakes (magnitudes M=0.6-3.1), primarily located in the Prince William Sound, Icy Bay, and Yakutat Bay regions, and near Wright Glacier northeast of Juneau. We characterized 2,626 quakes as seismic events associated with volcanic activity (M=0.6-4.3). There were 34 events classified as “other” type (M=0.7-2.1). Ten events were classified as landslides (M1.1-3.0), some with visual confirmations.

A total of 225 earthquakes were reported felt in Alaska communities (Figure 2.11), with magnitudes of these events ranging from as small as 1.3 to as large as 7.2. The largest number of DYFI (Did You Feel It) responses, 2,191, came from the M4.5 earthquake that occurred July 3 at 14:47:29 UTC 1.8 miles southwest of Eagle River in the Cook Inlet region of Alaska (https://earthquake.usgs.gov/earthquakes/eventpage/ak0238gji26s/dyfi/intensity).

We continued monitoring several ongoing aftershock sequences such as the 2018 M7.9 Offshore Kodiak, 2018 M6.4 Kaktovik, 2018 M7.1 Anchorage, 2020 M7.8 Simeonof, and 2021 M8.2 Chignik earthquakes, as well as the earthquake swarm in the Purcell Mountains. See details on notable sequences in the following sections and in Table 1. Sequences that produced less than 1 event per day on average in 2023 are no longer tracked in detail.

Table 1. *Notable Alaska seismic sequences in 2023.**

Magnitude, Name (start date)	Total number of events	Magnitude of the largest event	Magnitude of completeness (Mc)	Rate of events per week
M7.8 Simeonof Earthquake (7/22/2020)	1,503	7.2	2.0	29
M7.1 Anchorage Earthquake (11/30/2018)	585	3.9	1.1	11
M8.2 Chignik Earthquake (7/29/2021)	213	5.0	2.6	4
Purcell Swarm (March 2019)	188	3.3	1.1	3

* The 2021 M8.2 Chignik Earthquake aftershock sequence and Purcell Mountains Swarm decreased to less than 1 event per day on average and will no longer be tracked in the summary table in future annual and quarterly reports.

3. Notable seismic events

3.1. October 16 M6.4 and December 21 M6.1 earthquakes in Andreanof Islands

On October 16, at 3:35 am AKDT (11:35 UTC), a magnitude 6.4 earthquake occurred under Adak Island at a depth of 205 km (Figure 3.1). No immediate aftershocks were recorded. This event was reported as felt on Adak. This was the second largest earthquake in 2023. Earthquakes as deep as 300 km may occur in the central Aleutian Islands. Such deep events are located inside the subducted Pacific Plate.

On December 20, at 20:35 AKST (December 21, 5:35 UTC), a magnitude 6.1 occurred 116 km southeast of Adak at a depth of 4 km (Figure 3.1). It was the third largest earthquake in 2023. AEC reported about 40 aftershocks through the end of the year, with magnitudes ranging between 2.0 and 4.9. A total of five aftershocks measured at magnitude 4 or greater. The source mechanism of the mainshock indicates that it ruptured the plate boundary along the Aleutian megathrust.

3.2. March 19 M5.4 earthquake in southern Cook Inlet

A magnitude 5.4 earthquake occurred on March 19 at 07:06 AM AKDT (15:06 UTC) in the Cook Inlet region of Alaska (Figure 3.2). It was the largest earthquake in mainland Alaska in

2023. It occurred at a depth of 65 km and was located 21 km west of Homer. This earthquake was felt widely in the Cook Inlet region and as far as Palmer in the north and Kodiak in the south. Maximum shaking, intensity IV - light, was reported in southern Kenai Peninsula communities. No damage was reported. According to its depth, this earthquake occurred in the down-going portion of the subducting Pacific plate. The Aleutian trench marks the boundary between the subducting Pacific and overriding North American plates in southern Alaska and the Aleutian islands. While the largest earthquakes occur on the interface between these two plates (like the 1964 magnitude 9.2 earthquake), the down-going portion of the Pacific plate keeps generating earthquakes down to 200 km in southern and central Alaska.

3.3. Landslides

Ten reported seismic events were classified as landslides (M1.1-3.0), most based on visual analysis of the waveforms, but some had ground confirmations. Landslides produce emergent P arrivals, have no S phase, and a long coda in the waveform.

On September 13 at 18:06 AKDT (September 14, 2:06 UTC), a large landslide occurred near Peters Dome, on the north side of Denali Peak in Denali National Park. This event was ground-truthed the following day by National Park Service officials during a flyover (Ruppert et al., December 2023). Preliminary estimates give a volume of approximately 4-6 million m³. The runout of this event was estimated during the flyover to be approximately 3 km. The estimated earthquake magnitude equivalent for this event is M=2.6. Smaller landslides occurred and were recorded in the next few days in the area of the initial large landslide.

A large landslide occurred on September 13, at 11:19 am AKDT (19:19 UTC), near Yakutat Bay/Lucia Glacier. The preliminary volume of this landslide is estimated to be approximately 10 million m³. The estimated earthquake magnitude equivalent is M=3.0. This event was ground-truthed on *Planet.com* imagery (Ruppert et al., December 2023).

3.4. Volcanic events

2023 saw an increase in seismic activity associated with volcanic processes. We characterized 2,626 quakes as seismic events associated with volcanic activity (M=0.6-4.3), which is 4 times as many as in 2022 (Figures 2.10, 3.3). The first and most energetic sequence began in February and continued into March under the Tanaga-Takawangha volcanic complex in the central Aleutians (Ruppert et al., April 2023). There were about 900 earthquakes reported in total, with six of them having magnitudes between M4.0-4.4. About 1,200 events were associated with the Katmai volcanic field, with magnitudes ranging up to 4.2 and activity continuing throughout the year. An unusual, but short-lived, swarm was associated with Bogoslof volcano in late October (Ruppert et al., February 2024), which erupted most recently in 2017. Most events were fairly small, with a few reaching M2.5-2.8 level. About a dozen earthquakes (M1.3-2.4) were recorded under Mt. Edgecumbe in Southeast Alaska in May and June. The Alaska Volcano Observatory installed a local monitoring network at this volcano in 2022, following observations of ground deformation consistent with an inflation of a magma body under the volcano. Seismic events were recorded at several other volcanoes as well.

4. Ongoing aftershock sequences and swarms

4.1. 2018 M7.1 Anchorage aftershock sequence

On November 30, 2023, we marked the fifth anniversary of the M7.1 Anchorage Earthquake. Aftershocks continued at an average pace of about 11 earthquakes per week, which is about 20% less than in 2022 (*Ruppert & Gardine, February 2023*). The largest aftershock, magnitude 3.9, occurred on April 3. Approximately 585 aftershocks were reported in 2023, with a magnitude of completeness of Mc=1.1, bringing the total count for the sequence to more than 14,000 aftershocks. About 17 of these aftershocks were reported as felt in 2023. While the original estimates for the duration of this aftershock sequence were on the order of 2-2.5 years (*Michaels et al*., 2019), the seismicity rate remains elevated compared to the background rate prior to the M7.1 earthquake (Figure 4.1). We expect this sequence to continue at a decreasing rate in 2024.

4.2. 2020 M7.8 Simeonof aftershock sequence

The Simeonof Earthquake continued to produce the most active ongoing aftershock sequence, with about 1,503 reported aftershocks between magnitude 1.1 and 7.2 (Figures 4.2, 4.3). The estimated magnitude of completeness was around 2.0, the same as in 2022. About 20 aftershocks had magnitudes greater than 4.0. The largest aftershock, magnitude 7.2, occurred on July 16.

While the rate of the aftershocks continued to decline in the first half of 2023, it picked up after the M7.2 event, which generated its own aftershock sequence (*Ruppert et al., April 2023, August 2023, December 2023*). The M7.2 earthquake was located within the western segment of the M7.8 aftershock region. It prompted tsunami evacuations, with an observed tsunami of 0.5 feet in both King Cove and Sand Point. It was felt throughout the Alaska Peninsula and the eastern Aleutian Islands. We recorded about 450 aftershocks, with a magnitude of completeness of 1.6. The largest aftershock was an M5.8, which occurred three minutes after the M7.2 (Figure 4.3). We expect the Simeonof aftershock sequence to continue in 2024.

5. Glacial seismicity and Wright Glacier cluster

Glacial seismicity is being recorded and studied globally; Alaska is no exception, due to its large expanse of glaciated areas. In 2023, we reported 1,028 glacial quakes, ranging in magnitudes up to M3.1. We normally record the majority of glacial activity near the termini of tidewater glaciers, such as in the Prince William Sound region, Icy Bay, and Yakutat Bay (Figure 5.1). This activity follows seasonal variability and peaks at different times in different areas (Figure 5.2). This year, glacial seismic activity in Prince William Sound peaked in October-November, later in the season than usual.

We continued to record events in a cluster under Wright Glacier, which is about 40 miles northeast of Juneau. A few of these events reached magnitudes between 2.9-3.0 and were felt in Juneau. The 2023 activity started in late May and had two different episodes of elevated rates: in July and October (Figure 5.3). This year activity continued much later into the season

than observed in 2020 or 2021, but similar to 2022 (*Ruppert & Gardine, February 2021, February 2022; Ruppert, February 2023*). Overall, seismic activity in this cluster was only half the rate of those observed in 2022 or 2021. Periodic seismicity in this area has been observed since the 1970s, with event rates usually peaking in summer and early fall. These quakes tend to cluster near the Speel River, where it drains glaciated areas of Mt. Ogden. The levels of activity, however, are not the same every year. Seismicity rates observed in 2020-2022, for example, have not been observed since 2011-2012.

6. Acknowledgments

We would like to acknowledge the center's seismic data analysts who analyzed and cataloged thousands of events and seismic phases in 2023: Ayumi Bakken, Kenneth Becker, Shila Cotton, Shah Khan, Natalia Kozyreva, Heather McFarlin, Sarah Noel, and Ronald Wilkes.

This material is based upon work supported by the U.S. Geological Survey under Grants No. G15AC00047, Modification No. 0005 to award G15AC00047, and G19AC00008. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Geological Survey. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Geological Survey.

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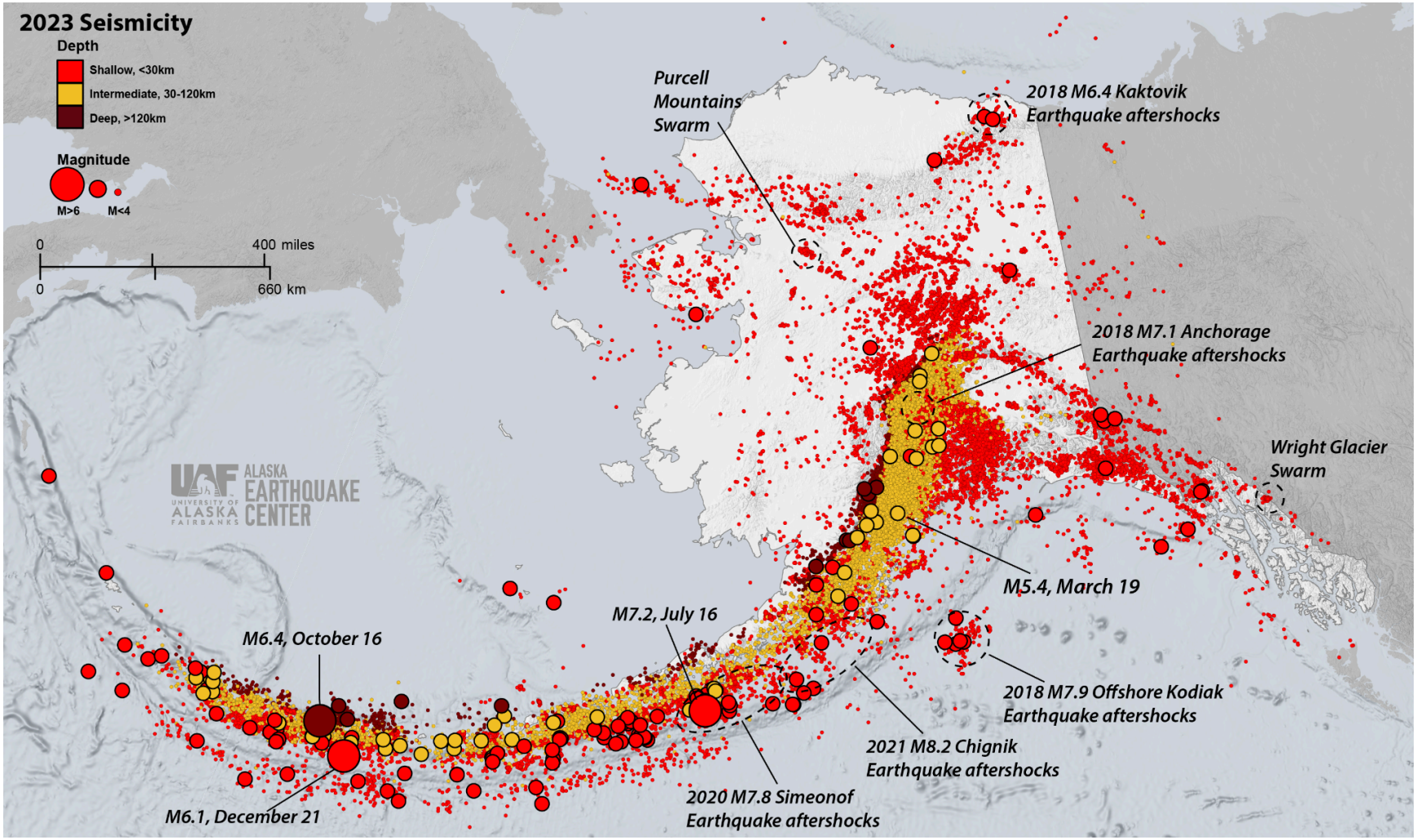

***Figure 2.1**. 2023 seismicity map for Alaska and the neighboring regions.*

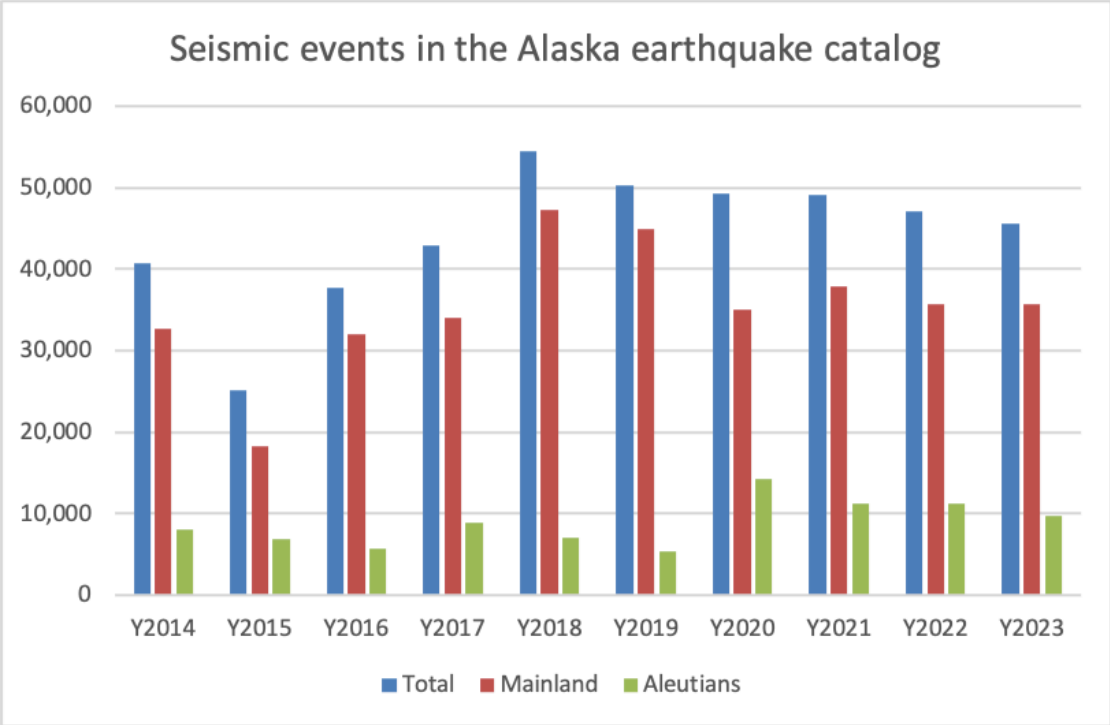

Figure 2.2. *Earthquakes reported in the Alaska earthquake catalog for the past 10 years. The total number of events, as well as the number of events in the Aleutians and mainland Alaska, are shown. 2018 was the highest year, with about 55,000 events.*

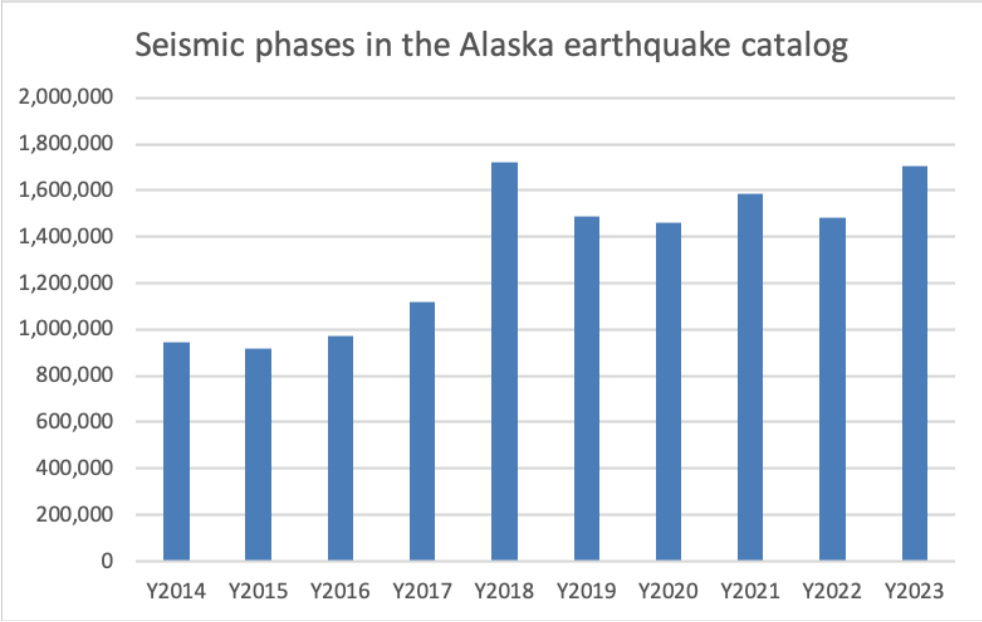

Figure 2.3. *Seismic phases reported in the Alaska earthquake catalog for the past 10 years. 2018 was the highest year.*

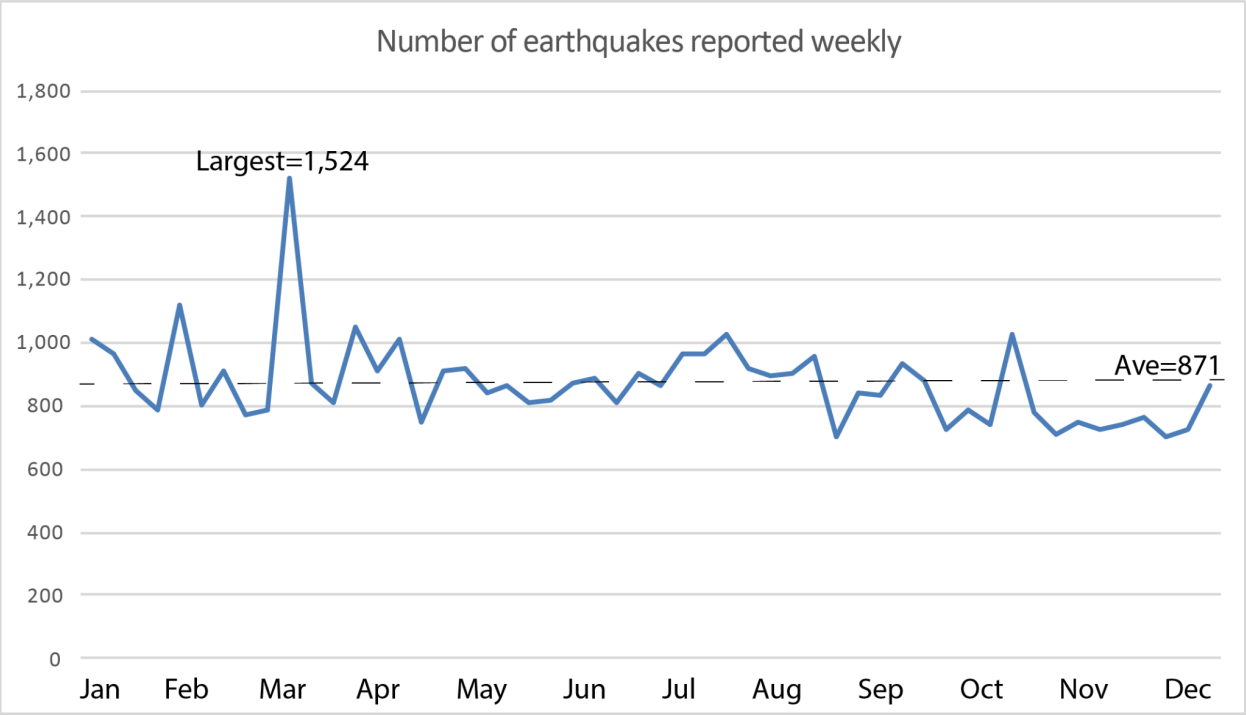

Figure 2.4. *Weekly earthquake reporting in 2023. The largest spike in seismic activity came in early-to-mid March from the Tanaga-Takawangha volcanic complex in the central Aleutians.*

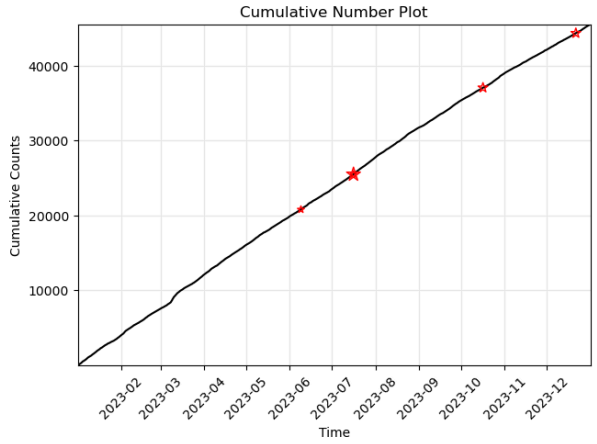

Figure 2.5. *Cumulative number of seismic events in the 2023 Alaska earthquake catalog. Red stars indicate the five largest earthquakes.*

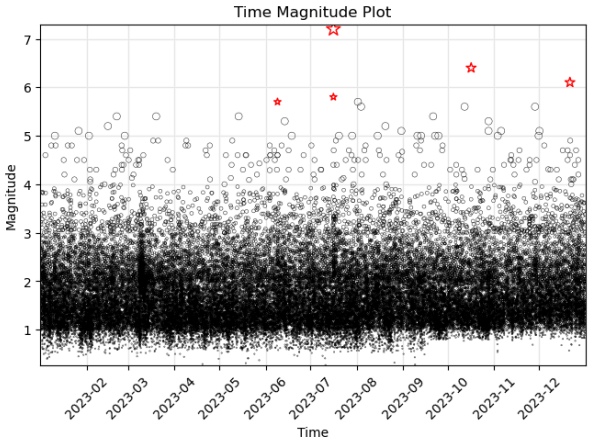

Figure 2.6*. A time-magnitude plot of seismic events in the 2023 Alaska earthquake catalog. Red stars indicate the five largest earthquakes.*

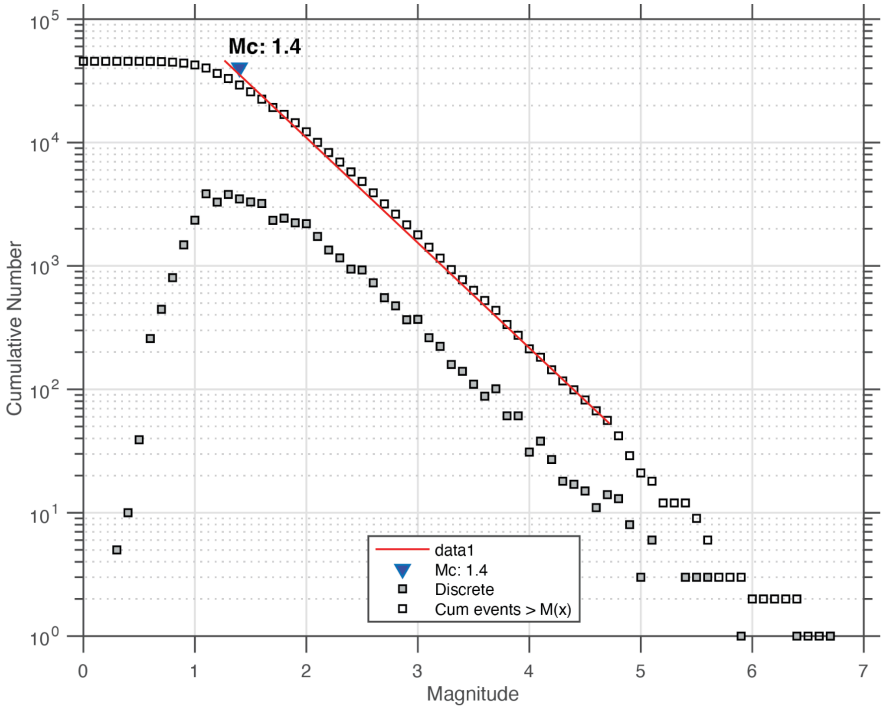

***Figure 2.7**. Frequency-magnitude distribution of events for the 2023 Alaska earthquake catalog (glacial, other, landslides, and quarry blast types are not included).*

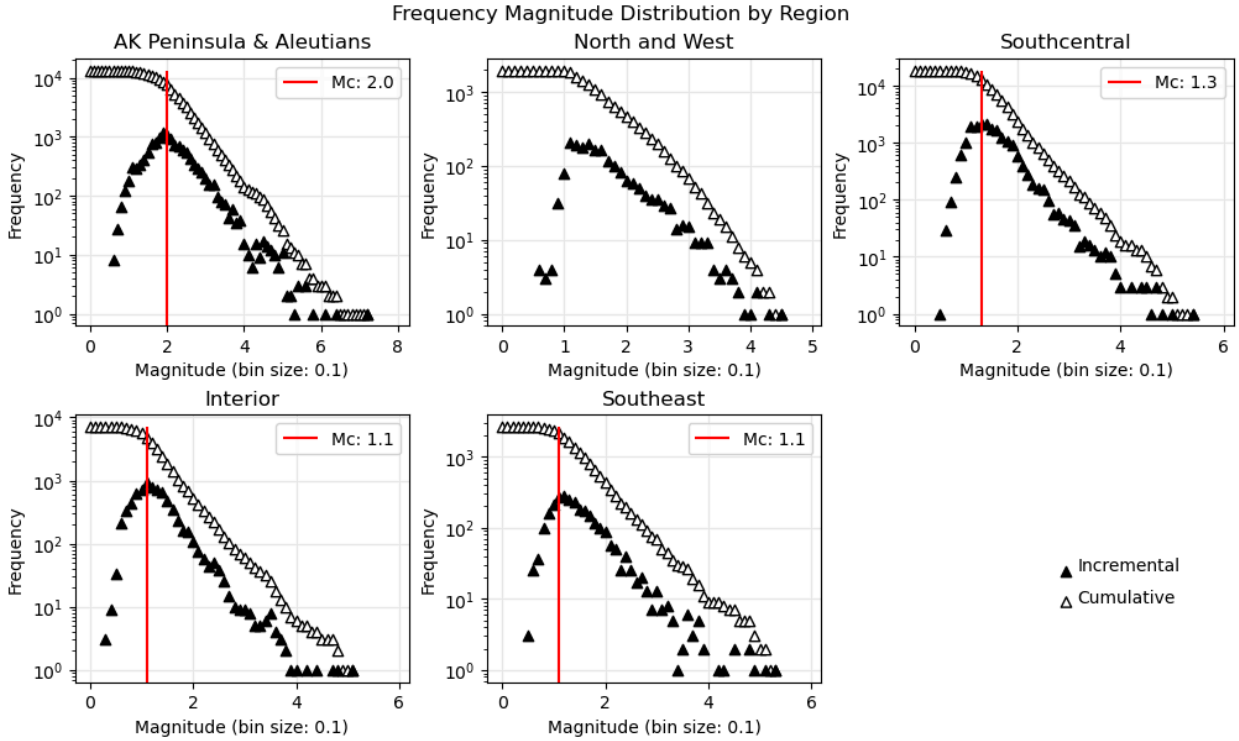

***Figure 2.8**. Cumulative distribution of events for the 2023 Alaska earthquake catalog grouped by geographic region (glacial, other, landslides, and quarry blast types are not included).*

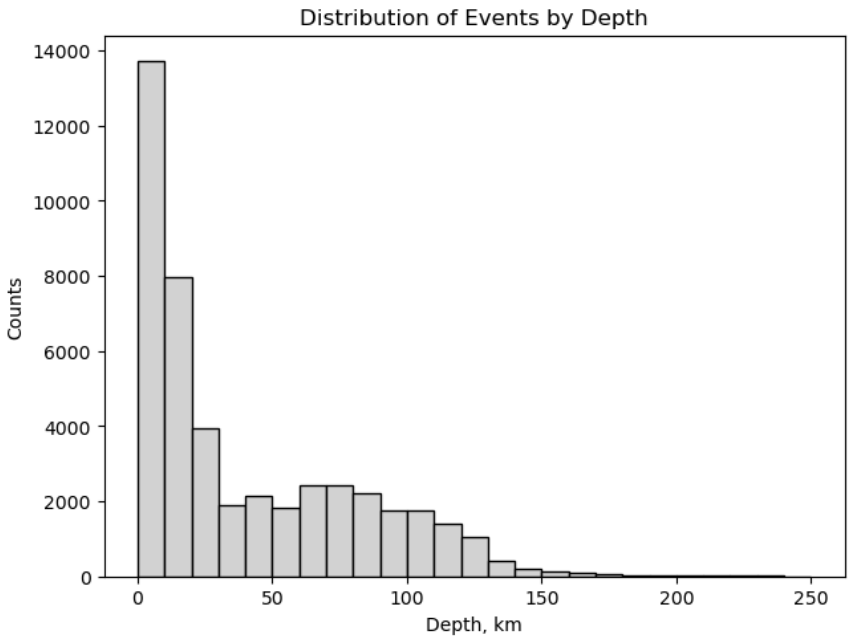

***Figure 2.9**. Depth distribution of events for the 2023 Alaska earthquake catalog. The majority of the events occurred in the 0-50 km depth range. The deepest earthquake occurred at 255 km in the central Aleutians.*

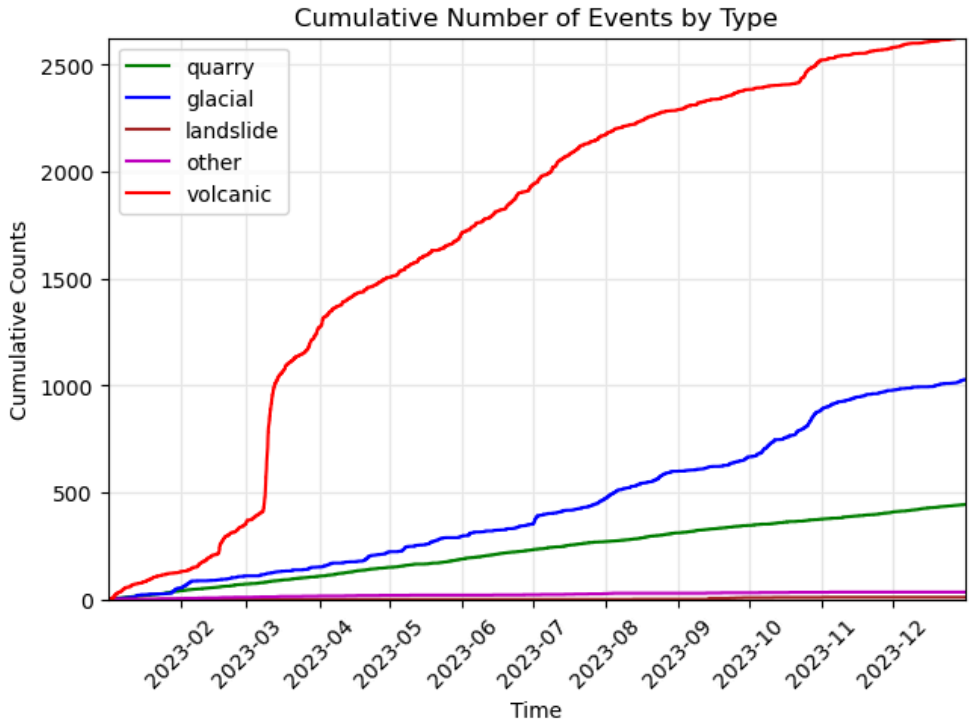

***Figure 2.10.** Cumulative number of non-tectonic seismic events for the 2023 Alaska earthquake catalog (volcanic, glacial, quarry blast, and "other" types).*

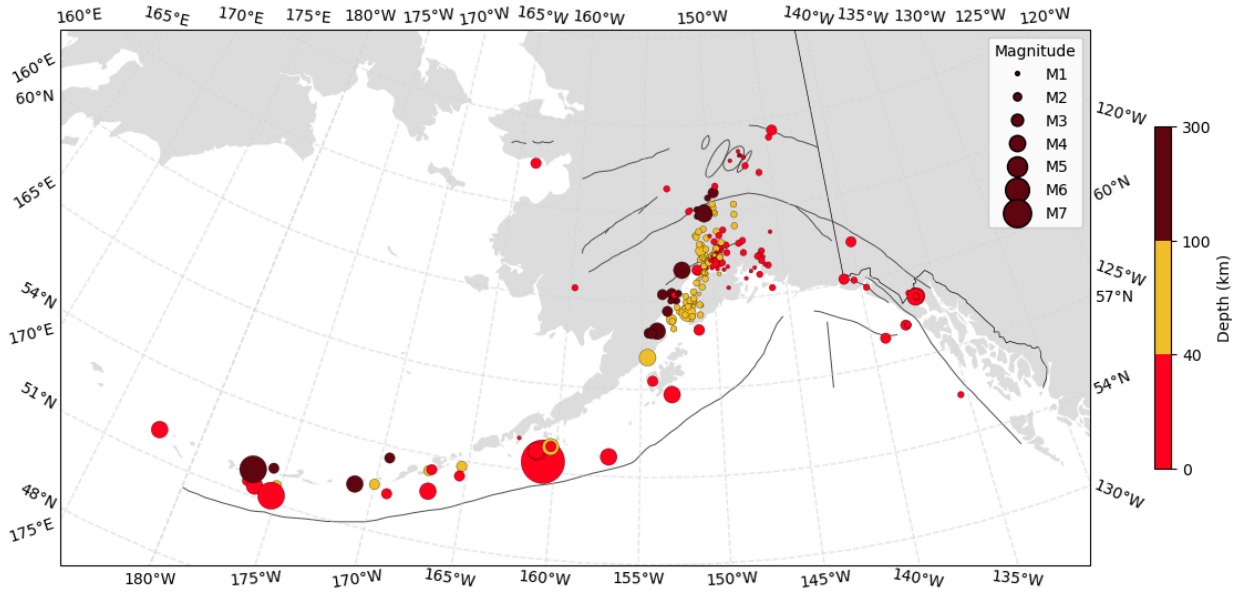

Figure 2.11. *Map of felt events in 2023.*

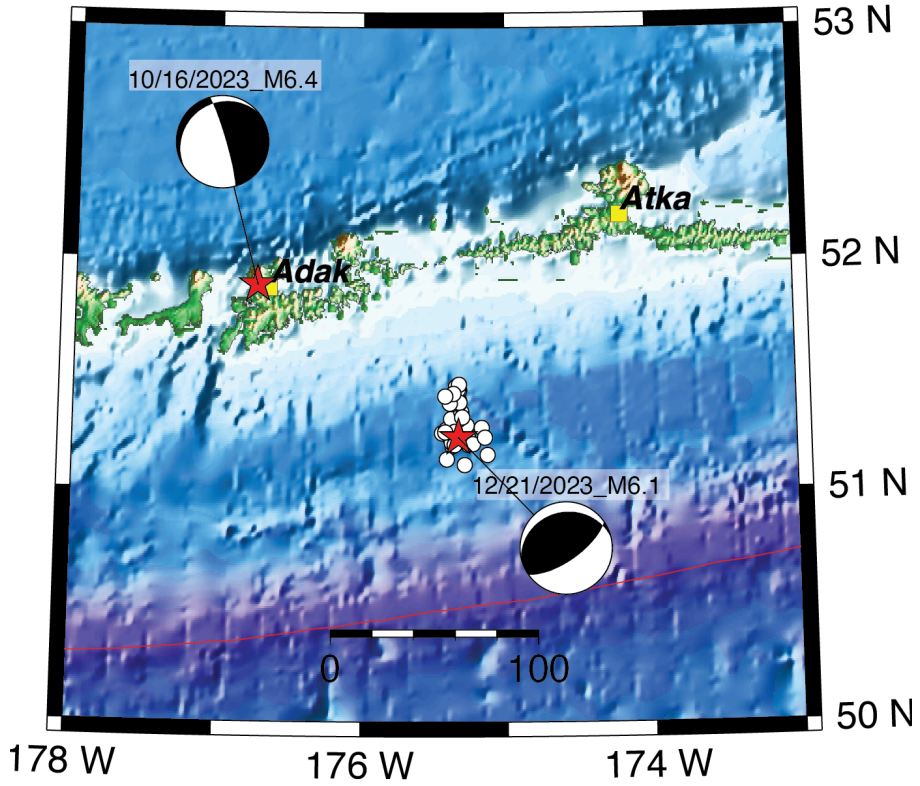

Figure 3.1*. Location map for the second and third largest earthquakes recorded in 2023 in Alaska. Red stars are epicenters of the October 16 M6.4 and December 21 M6.1 earthquakes. White circles are M6.1 aftershocks reported through December 31. Focal mechanisms are from the ANSS combined earthquake catalog.*

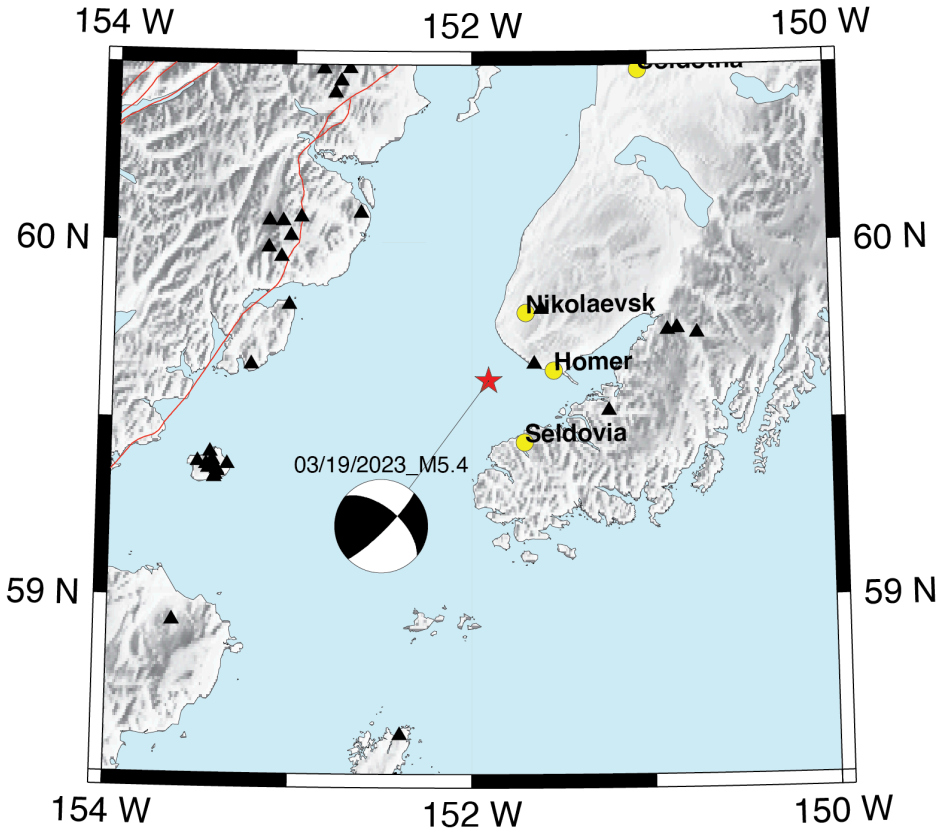

Figure 3.2. *Earthquake location map for the M5.4 March 19, 2023 earthquake (red star). This was the largest earthquake reported in mainland Alaska in 2023. Black triangles show seismic stations. The focal mechanism is from the ANSS combined earthquake catalog.*

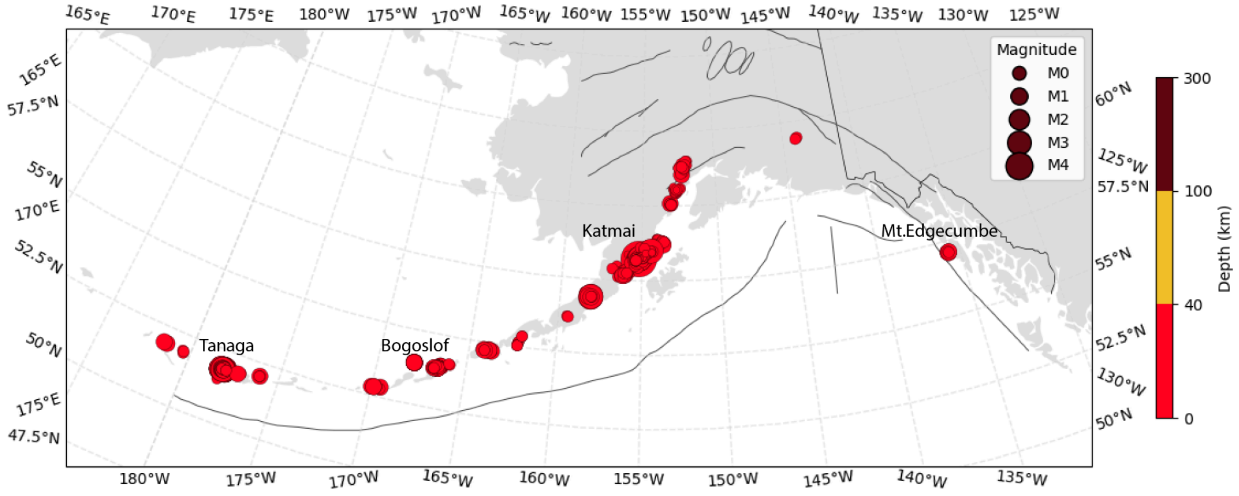

Figure 3.3. *Map of volcanic events for 2023. Volcanic areas mentioned in the text are labeled.*

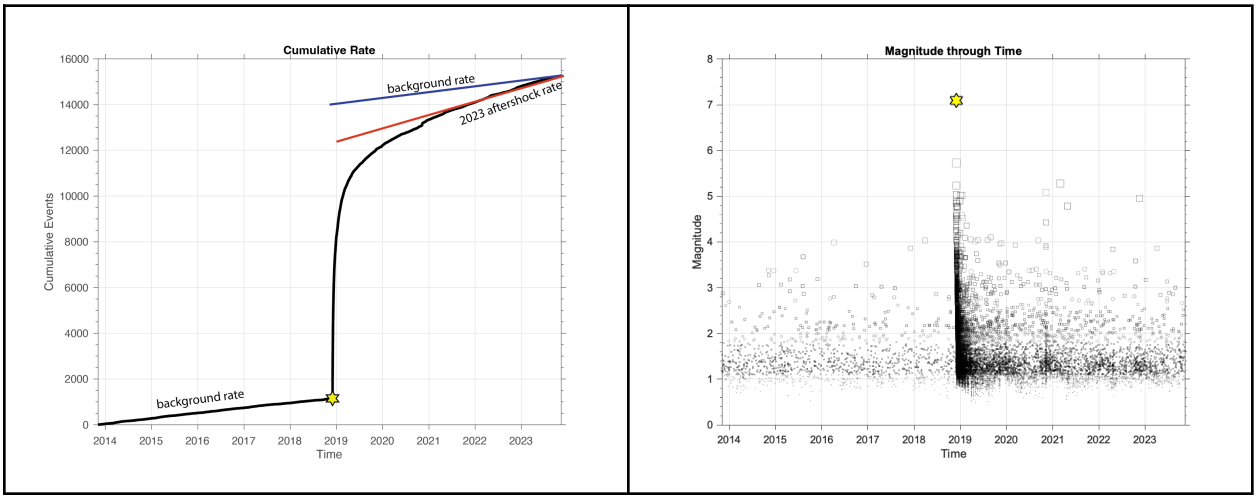

Figure 4.1. *Cumulative number (left) and time-magnitude (right) plots for the M7.1 2018 Anchorage Earthquake aftershock sequence through 2023, including 5 years of background seismicity before the mainshock. The M7.1 mainshock is shown by yellow stars.*

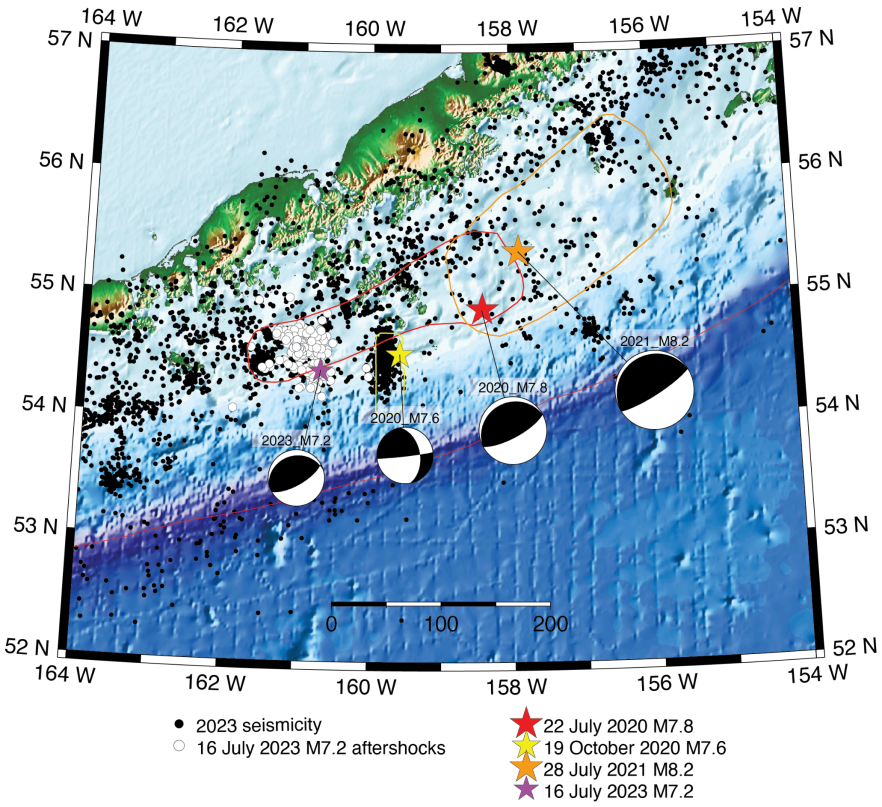

Figure 4.2*. Offshore Alaska Peninsula and Shumagin Islands regional map. Black circles are earthquakes recorded in 2023. White circles are the M7.2 aftershocks recorded within the first week. Stars indicate the four largest earthquakes that occurred in the region since July 2020. The approximate extent of rupture zones is shown for the 2020-2021 earthquakes. Focal mechanisms are from the ANSS combined earthquake catalog.*

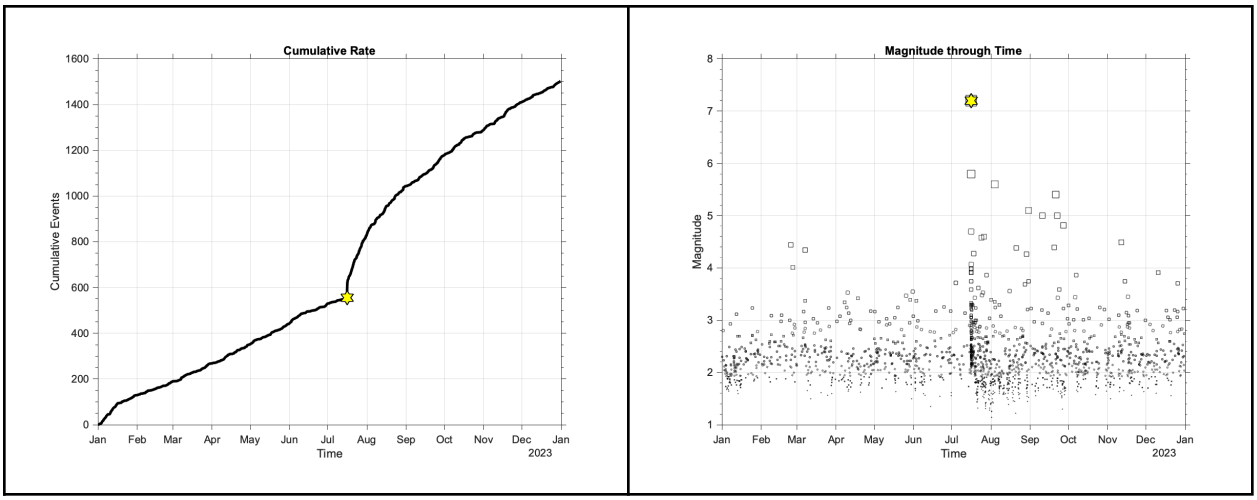

Figure 4.3. *Cumulative number (left) and time-magnitude (right) plots for 2020 M7.8 Simeonof Earthquake aftershock sequence in 2023. The yellow star indicates the June 16, 2023, M7.2 Sand Point earthquake.*

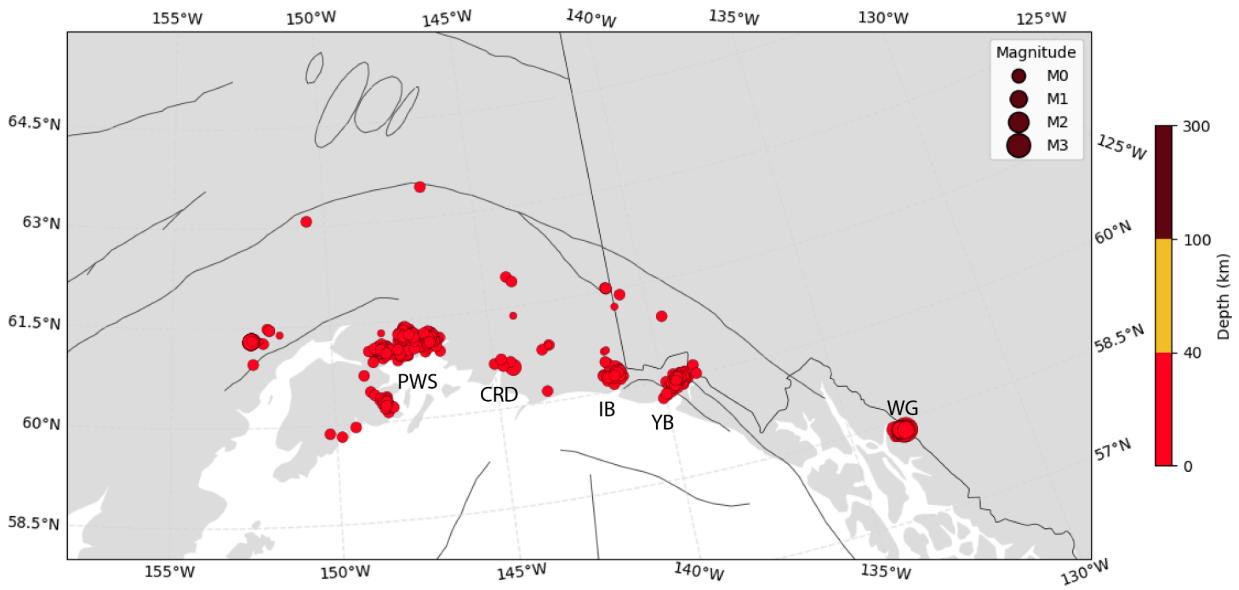

Figure 5.1. *Glacial events reported in 2022, with the most active areas labeled. PWS - Prince William Sound; CRD - Copper River Delta; IB - Icy Bay; YB - Yakutat Bay; WG - Wright Glacier.*

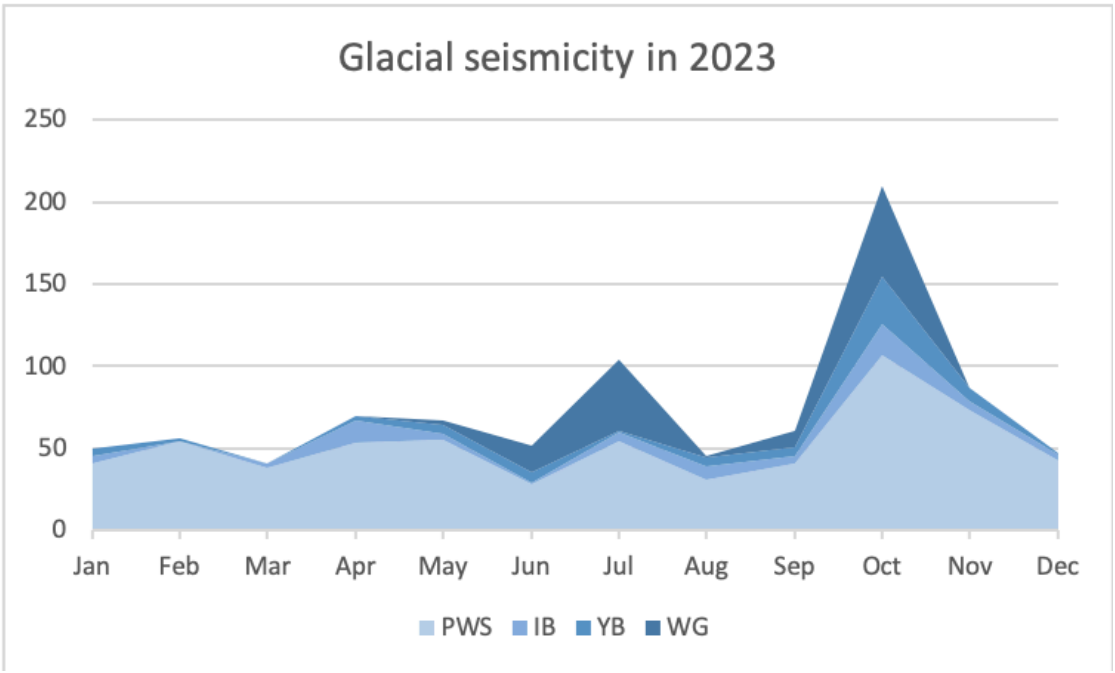

Figure 5.2. *Monthly counts of reported glacial events separated into the four main regions of activity. The highest peaks of activity were recorded in July and October. PWS - Prince William Sound; IB - Icy Bay; YB - Yakutat Bay; WG - Wright Glacier in Southeast Alaska.*

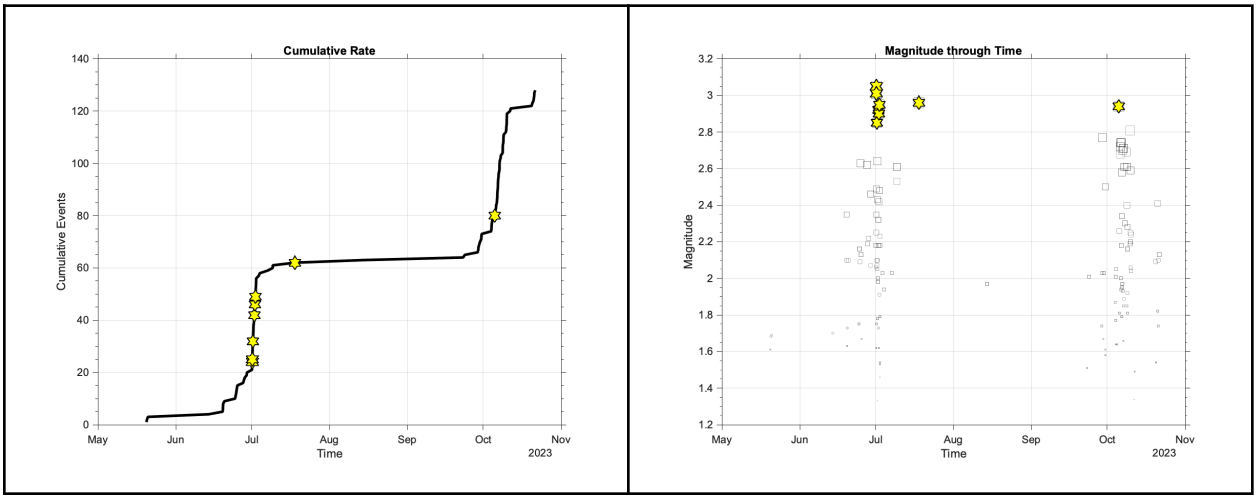

Figure 5.3. *Cumulative number (left) and time-magnitude (right) plots for the Wright Glacier cluster for 2023. Note two different episodes of increased activity. Yellow stars indicate earthquakes with a magnitude of 2.8 and greater.*