Alaska Earthquake Center Quarterly Technical Report October-December 2022

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Contents

1. Introduction

This series of technical quarterly reports from the Alaska Earthquake Center (AEC) includes detailed summaries and updates on Alaska seismicity, the AEC seismic network and stations, field work, our social media presence, and lists publications and presentations by AEC staff. Multiple AEC staff members contribute to this report. It is issued in the following month after the completion of each quarter Q1: January-March, Q2: April-June, Q3: July-September, and Q4: October-December. The first report was published for January-March, 2021.

2. Seismicity

Between October 1 and December 31, 2022 we reported 12,692 seismic events in the state and the neighboring regions (Figure 2.1), with depths ranging between 0 and 269 km and magnitudes between 0.3 and 6.3. The largest earthquake of Mw=6.3 occurred on December 14 at 18:40:27 UTC 28 km northwest of Amchitka in the Rat Islands region of Aleutian Islands. The next three largest earthquakes had magnitudes 5.1-5.5 and were all located in the Aleutian Islands. The largest earthquake in mainland Alaska was a M4.9 that occurred on November 18 at 00:03:09 UTC 22 km northwest of Anchorage. Overall, we reported about 138 events per day, or one event every 9.5 minutes on average. This is slightly more than in the previous quarter (Ruppert et al., November 2022).

The seismicity rate remained at a steady pace, with no notable increases (Figures 2.2, 2.3). The overall magnitude of completeness for this time period was at Mc=1.4 (Figure 2.4), ranging from Mc=1.0 in the Interior region to Mc=2.0 in the Alaska Peninsula and the Aleutians (Figure 2.5).

We reported 953 seismic sources that were classified as something other than regional tectonic earthquakes (Figure 2.6). Of these, 97 were suspected quarry blasts (magnitudes M=0.6-2.0), the majority of which were located in the vicinity of Fort Knox and Healy mines in Interior Alaska, with the exception of one blast located along the Richardson Highway north of Delta Junction. The reported events included 427 icequakes (magnitudes M=0.6-2.9), primarily located in the Prince William Sound, Icy Bay, and Yakutat Bay areas. Also, a glacial swarm near Wright Glacier northeast of Juneau continued some activity in early October. Glacial activity remained at a steady pace in October-November, finally reducing in December. We characterized 410 quakes as seismic events associated with volcanic activity (M=0.3-4.6). This is more than in previous quarters of 2022. Increased seismic activity was observed at several volcanoes, such as Redoubt, Katmai volcanic group, and Little Sitkin. The remaining 19 events were classified as “other” type (M=1.1-2.9).

AEC data analysts picked and cataloged 405,196 seismic phases, 265,620 of which were P-phase and 139,576 S-phase arrival picks. Fewer phase arrivals per event were cataloged for the Aleutian earthquakes due to sparser station coverage compared to mainland Alaska (Figure 2.7).

There were 60 earthquakes reported as felt (magnitudes M=2.0-5.1), four of which were located in Southeast Alaska, about six in the Interior, four in the Aleutian Islands and Alaska

Peninsula, one in the Kodiak Island region, and the remainder in the Southcentral region of Alaska. The largest number of DYFI (Did You Feel It) responses, 1,869, came from the M4.9 earthquake that occurred on November 18 at 00:03:09 UTC 22 km northwest of Anchorage (https://earthquake.usgs.gov/earthquakes/eventpage/ak022esj2eua/dyfi/intensity).

We continued recording aftershock activity for the following sequences: 2021 M8.2 Chignik, 2020 M7.8 Simeonof, 2018 M7.1 Anchorage, 2018 M6.4 Kaktovik, 2018 M7.9 Offshore Kodiak earthquakes, and the Purcell Mountains Swarm. See Table 2.1 for a summary.

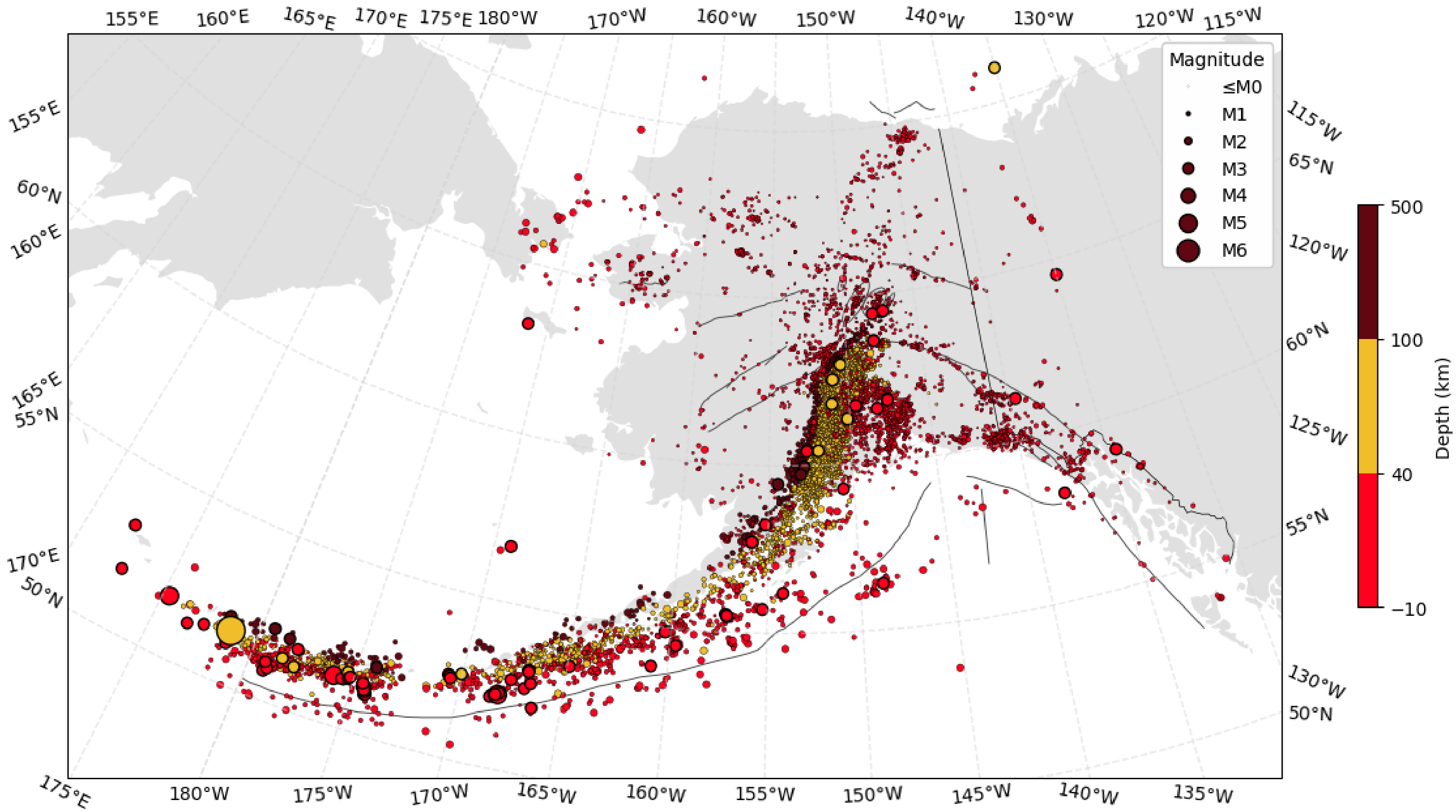
We continued to follow several processing changes that were implemented in January 2022 to accommodate staffing shortages and to decrease processing time lag. Beginning with mid-December 2021 data, only earthquakes with magnitude about 0.8 and greater were analyzed and cataloged; smaller events detected by the automatic system were discarded. Also, analysts picked additional phase arrivals only up to 2 degrees distance; only automatic picks were reviewed beyond this distance, no new phase picks were added.

Table 2.1. *Notable Alaska seismic sequences in October-December, 2022. **

Earthquake	**Number of events**	**Magnitude range**	**Magnitude of completeness (Mc)**	**Number of events per week**
New sequences this quarter				
December 14 M6.3 Rat Islands	80	1.9-3.6	2.2	N/A
Continuing sequences (in order of decreasing activity)				
2020 M7.8 Simeonof	267	1.2-4.8	2.0	20
2018 M7.1 Anchorage	262	0.8-4.9	1.2	20
Purcell Mountains Swarm	206	0.8-2.7	1.1	16
2021 M8.2 Chignik	63	1.6-3.9	2.4	5

* The 2018 M6.4 Kaktovik and 2018 M7.9 Offshore Kodiak earthquake aftershock sequences decreased to less than 1 event per day on average and are no longer being tracked in the summary table. Also, this is the last time activity in the Chignik aftershock zone is being tracked in this table.

Figure 2.1. *Earthquake map for Alaska and neighboring regions for October-December, 2022.*



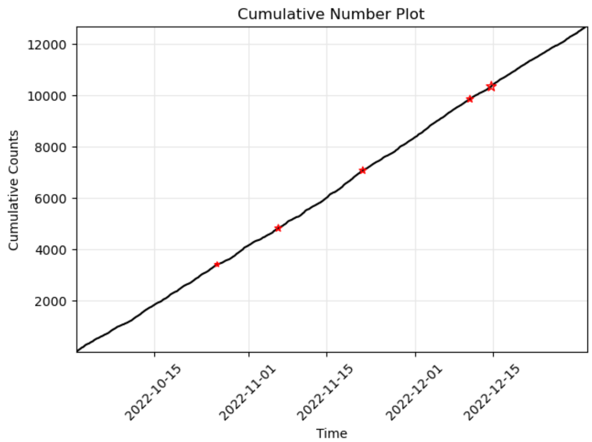


Figure 2.2. *Cumulative number of events for October-December, 2022. Red stars indicate the five largest earthquakes.*

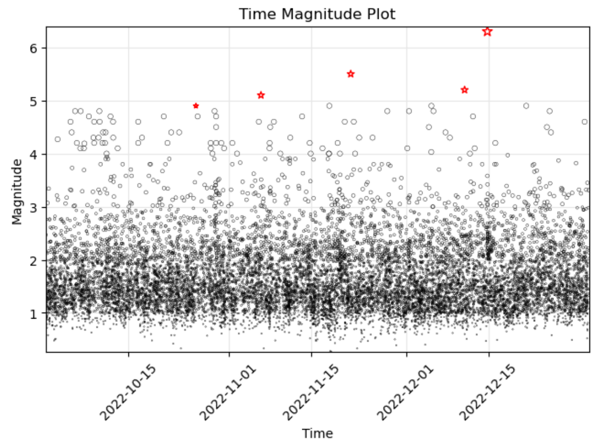


Figure 2.3*. Time-magnitude plot of events for October-December, 2022. Red stars indicate the five largest earthquakes.*

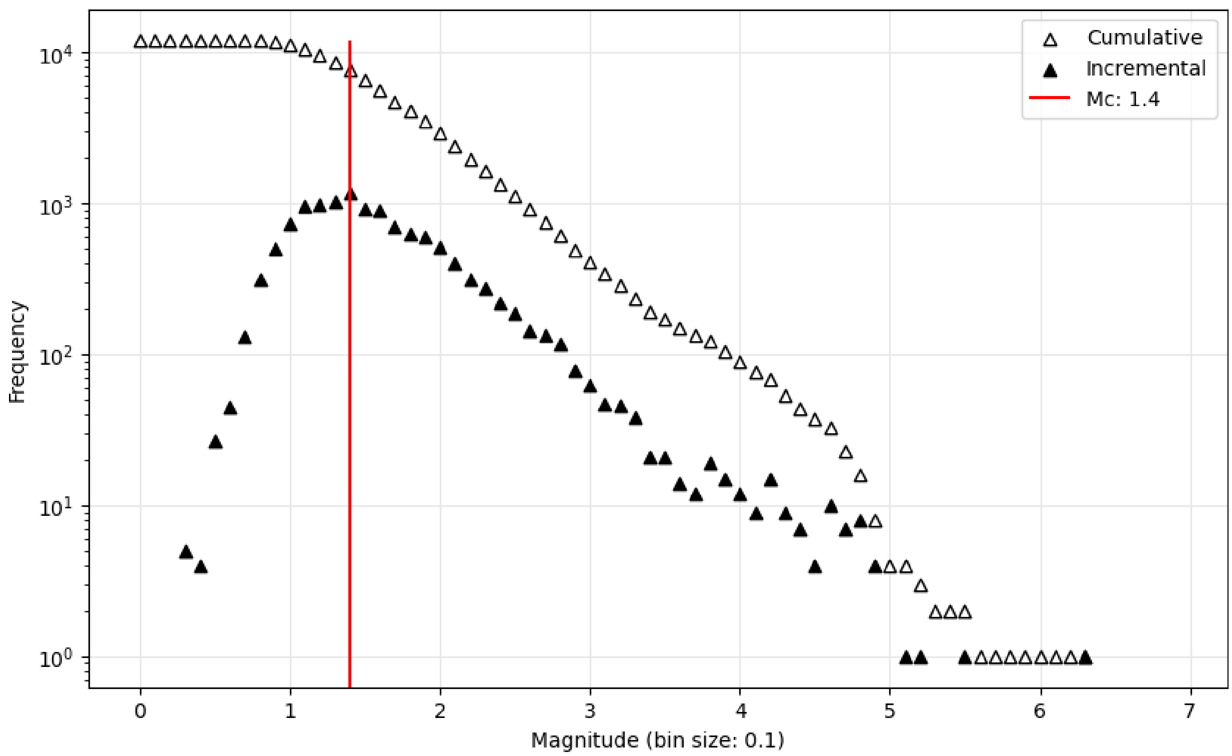


Figure 2.4*. Frequency-magnitude distribution of events for October-December, 2022 (glacial, unknown, and quarry blast types are not included).*

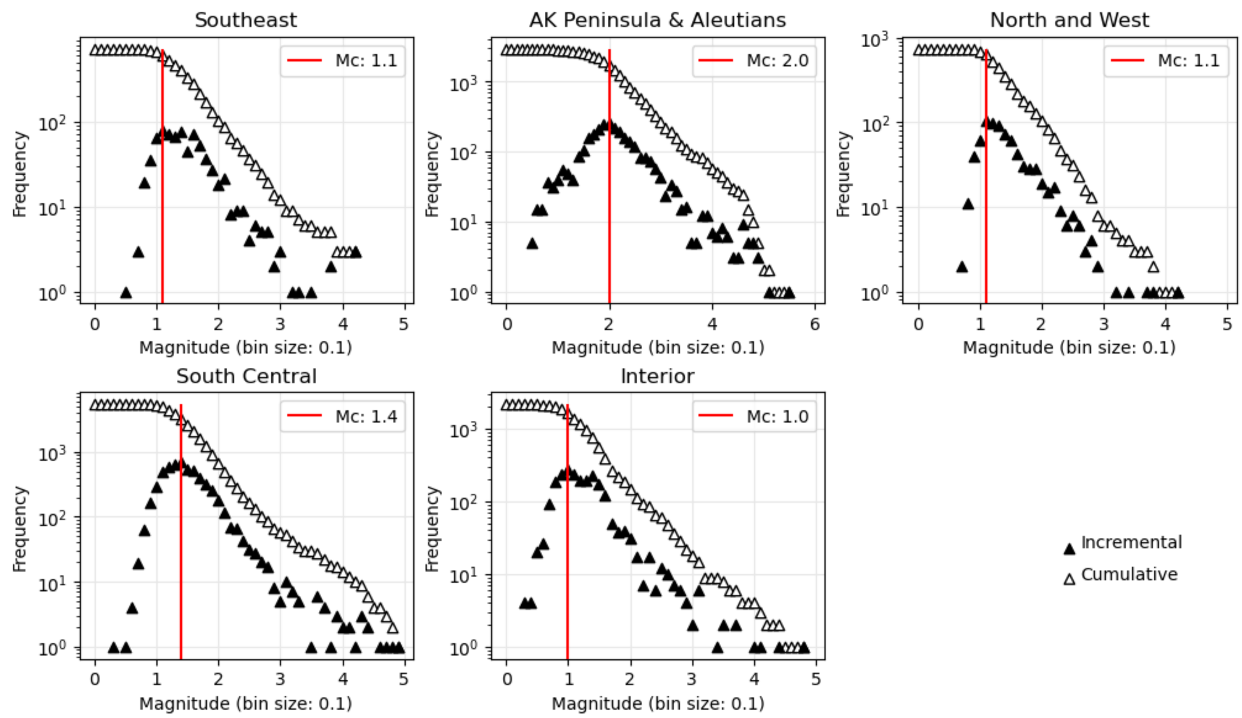


***Figure 2.5**. Cumulative distribution of events for October-December, 2022 grouped by geographic region (glacial, unknown, and quarry blast types are not included).*

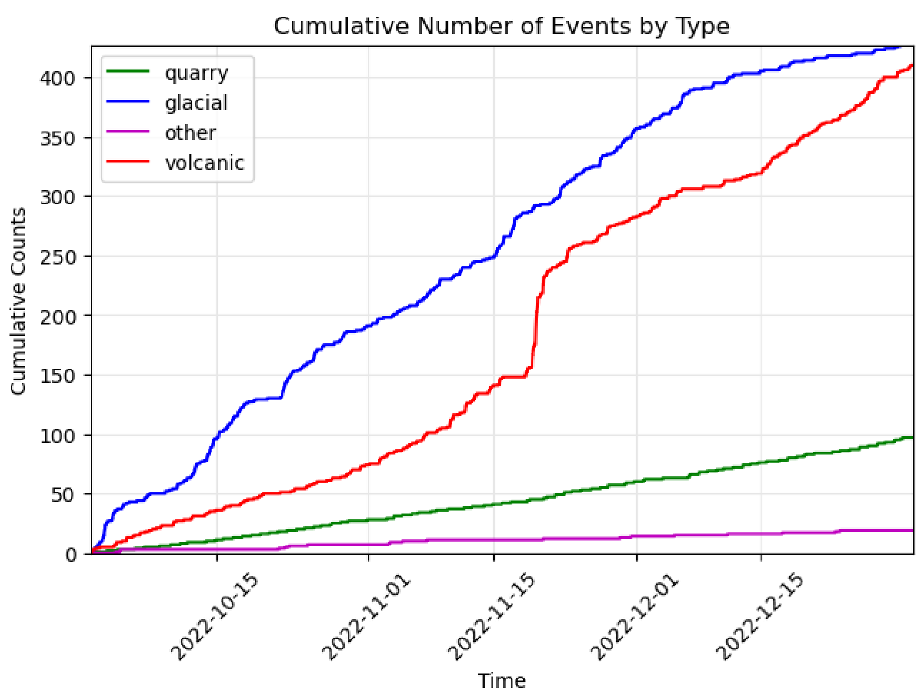


***Figure 2.6.** Cumulative number of non-tectonic seismic events for October-December, 2022 (volcanic, glacial, unknown, and quarry blast types).*

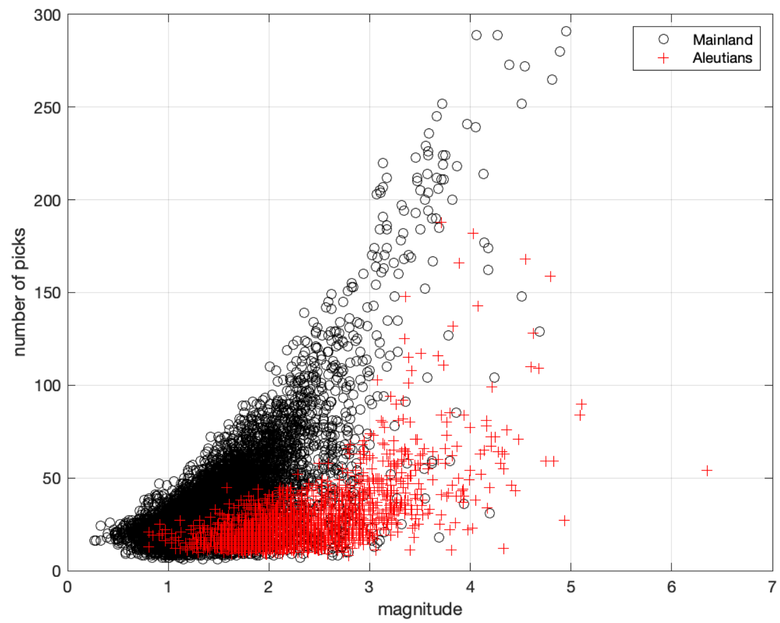


***Figure 2.7**. Phase picks depending on magnitude and region for October-December, 2022.*

The following is a description of the most notable earthquakes and sequences for this time period, starting with the new sequences.

On December 14 a magnitude 6.3 earthquake occurred at 18:40:27 UTC 28 km northwest of Amchitka in the Rat Islands region of Aleutian Islands (Figures 2.8). We recorded about 80 aftershocks with magnitudes ranging between 1.9 and 3.6, most of which occurred within a few days of the mainshock. According to its depth and source parameters, this earthquake originated inside the subducted Pacific Plate. A much larger intraslab earthquake, magnitude 7.9, occurred in this region on June 23, 2014.

The Purcell Mountains Swarm activity picked up in mid-November and continued at an increased rate for about 3 weeks (Figures 2.9 and 2.10). The largest earthquakes reached M2.7 level. This is still a lower rate as compared to the 2021 levels (Ruppert and Gardine, February 2022). Performance of the nearest seismic station G19K continued to be intermittent, which compromised detection of smaller events in the swarm. This caused a slight increase in magnitude of completeness.

Both aftershock sequences of the 2020 M7.8 Simeonof and 2021 M8.2 Chignik Earthquakes remained active, but at further decreased levels compared to earlier in 2022 (Ruppert et al., May 2022, August 2022, November 2022). The Chignik aftershock sequence remains far less active than the longer-lasting Simeonof sequence. We reported about 267 Simeonof and 63 Chignik aftershocks for this quarter. Magnitude of completeness of both sequences slightly increased this quarter due to deteriorating network performance. Only three aftershocks were over magnitude 4 for the entire quarter. The Simeonof aftershock sequence is now in its third year and the Chignik sequence in its second (Ruppert and Gardine, February 2021, February 2022).

The 2018 M7.1 Anchorage Earthquake aftershock sequence continued at a nearly the same rate as compared to the previous quarter (Ruppert et al., November 2022). The largest aftershock this quarter was M4.9 on November 18. The aftershock sequence is now in its fifth year (Ruppert and Gardine, February 2021, February 2022).

We continue to record aftershocks in the 2018 M6.4 Kaktovik and M7.9 Offshore Kodiak sequences, both at much decreased rates of less than 1 reported event per day (Ruppert and Gardine, February 2021, February 2022).

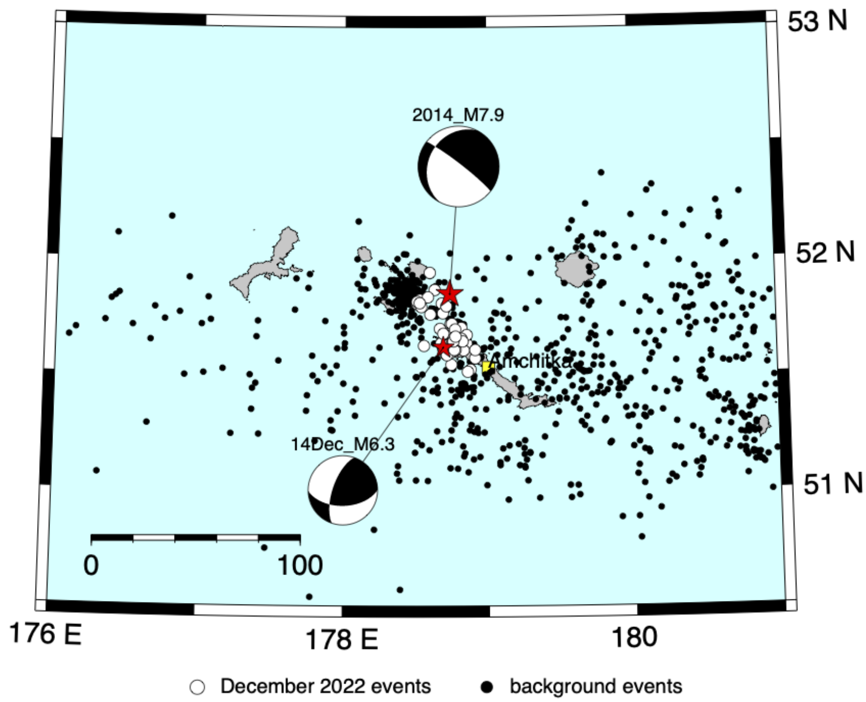


Figure 2.8. *Earthquake location map for the M6.3 December 14, 2022 earthquake in the Rat Islands. White circles are recorded aftershocks. Black circles are earthquakes recorded in the region in 2022. Focal mechanisms are from the Global CMT catalog.*

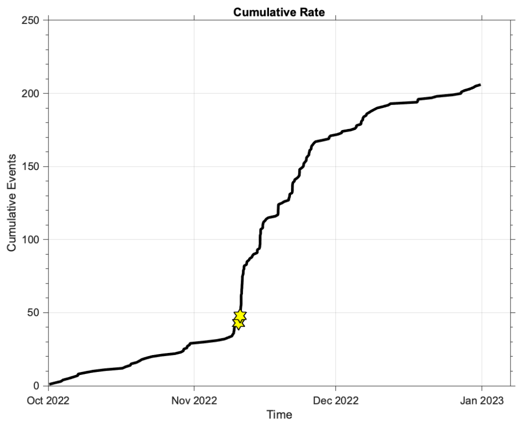


Figure 2.9. Cumulative number of events in the Purcell Mountains Swarm. Stars indicate the two largest earthquakes.

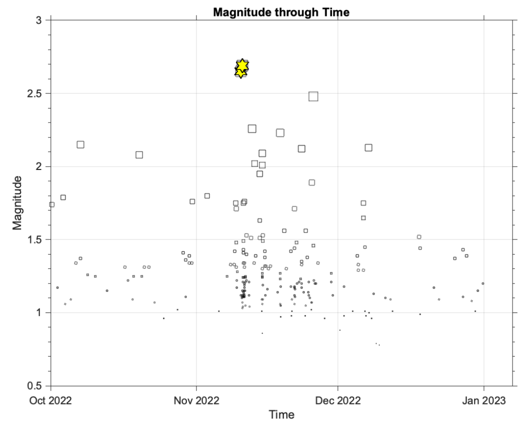


***Figure 2.10**. Time-magnitude plot of events in the Purcell Mountains Swarm. Stars indicate the two largest earthquakes.*

3. Field network

As of December 31, 2022, AEC maintains and acquires data from 253 seismic sites of the AK seismic network (see map in Figure 3.1 of Ruppert et al., May 2022). The sites can be divided into the following groups based on their locations and sensor types:

- 209 free field broadband stations, about 85 of which have co-located strong motion sensors, 107 of which have infrasound data streams, and 67 of which have meteorological sensor packages;
- 23 strong motion sites in the greater Anchorage and Mat-Su Valley region;
- 8 strong motion sites in Fairbanks;
- 7 strong motion sites located in coastal communities from Chignik to Yakutat;
- 1 structural array located in the Engineering Learning and Innovation Facility on the University of Alaska Fairbanks campus;
- 2 Netquake sites in Fairbanks that record only triggered data (these are not included in the data return rates).

Between October 1 and December 31, the network had an average data return rate of 83.7%, with the daily rates ranging from 77.7% to 87.16% (Figures 3.1 and 3.2). Data from 11 TAPS EMS stations was out between October 13-17 due to firewall issues. Overall performance remained stable with some degradation towards mid-late December due to underperforming power systems. The overall performance was still lacking and below marks of the previous five years.

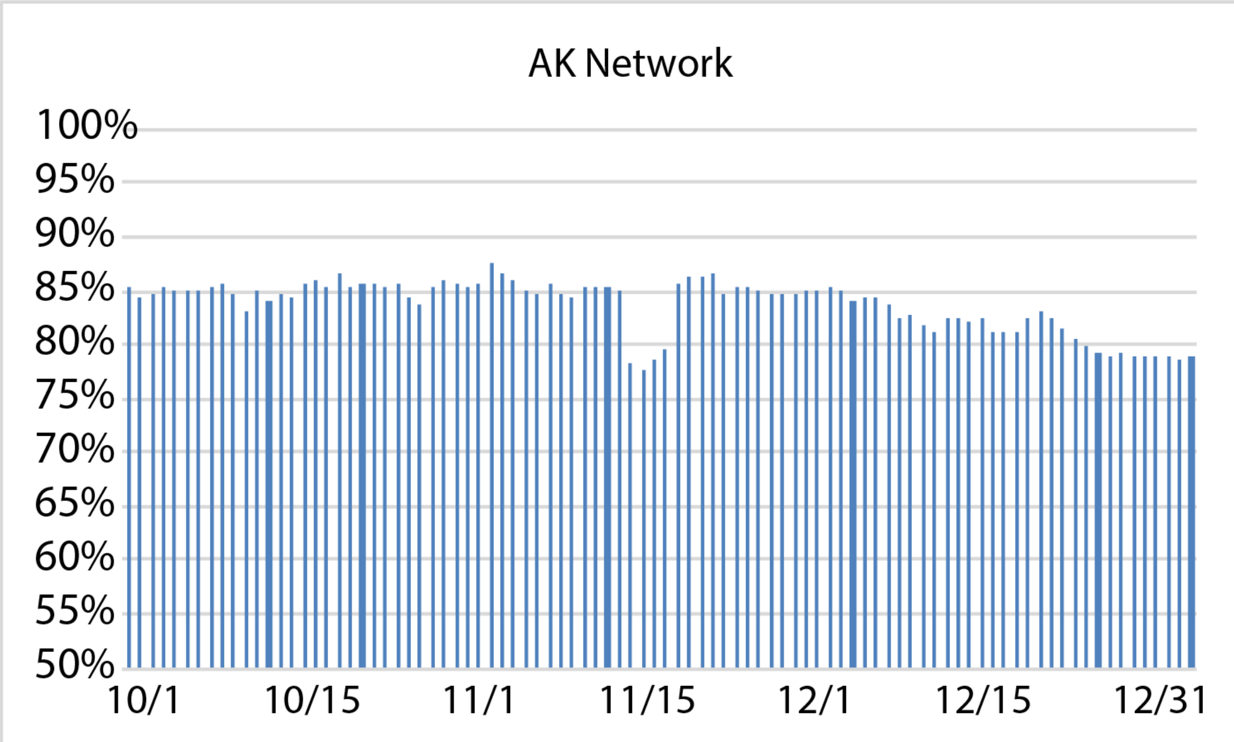


Figure 3.1. *Daily data completeness in percent for AK network in October-December 2022.*

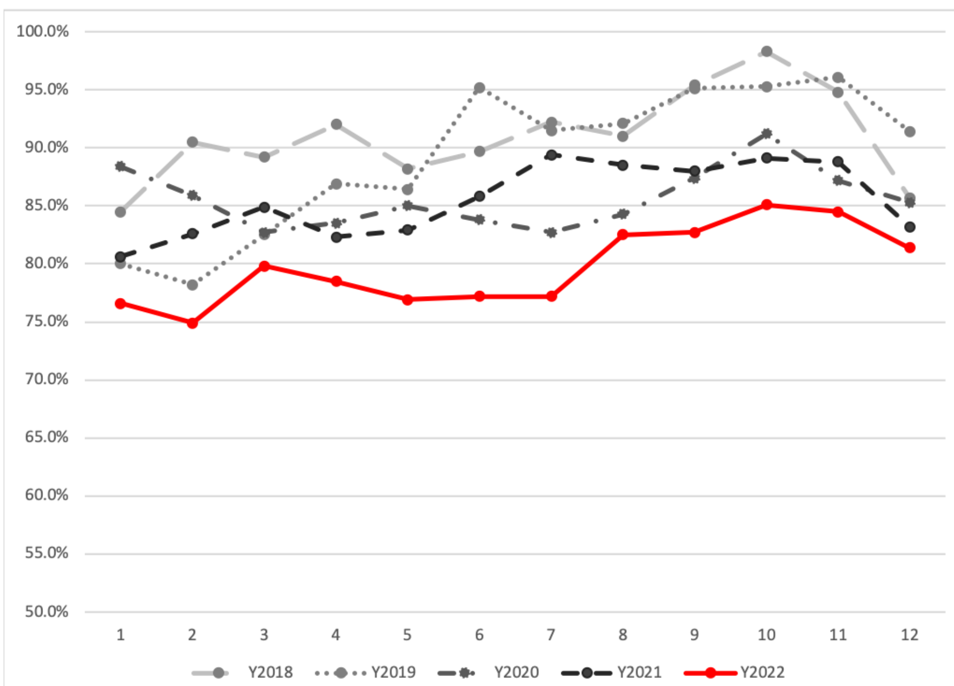


Figure 3.2. *Average monthly data completeness in percent for AK network 2018-2022.*

4. Data Quality assurance

4.1 Seismic data

Data Quality Control (QC) efforts at the center consist of data integrity (up-time, completeness, latencies) and quality (signal quality/noise performance). We define "QC" broadly as quantitative data that help assess the performance of our stations. This includes data on the overall health of the station (data completeness, clock quality, latency, etc.), as well as data specific to individual channels (broadband, strong-motion, weather, infrasound, etc.). QC metrics are values derived from the data and state-of-health channels (SOH), as well as from the IRIS MUSTANG website (http://services.iris.edu/mustang/measurements/1/). Standardized QC reports are produced weekly and include percent availability, gaps, and amplitude-related metrics (dead and pegged channel, spikes, high and low amplitudes compared to the global New High and New Low Noise Models, flat amplitudes for strong motion sensors, and dc offset).

Each piece of our QC information has multiple end-users. Maintaining a comprehensive set of QC products allows us to feed these end-uses while minimizing the need to perform one-off QC requests. Internal end-users include the field team to help steer repairs and upgrades, the analyst team to identify stations that should not be used for routine earthquake analysis, as well as project reports specific to certain stations (TsuNet, Greely, Pipeline, Donlin, etc.). We also communicate performance issues to the research community and partner organizations (Alaska Climate Research Center and the Wilson Alaska Technical Center).

Stations with the lowest data availability or sensor/datalogger failures October 1 - December 31, 2022 (also see Figure 4.1):

- Stations that continue to have 0% availability as compared to 2022 Q3: B18K, BWN, C18K, CHX, D25K, DCPH, DOT, E25K, FA02, FA09, K203, K216.00, K221, YAH, YAKA.
- Stations that now have 0% as compared to 2022 Q3: A21K, BCP, K220, K222.
- Stations that continue to have 1-50% availability as compared to 2022 Q3: BAGL, CHI, COLD, D24K, E18K, E21K, G19K, GRIN, L18K, M20K, PIN, PPD, PPLA, SII, TRF.
- Stations that now have 1-50% availability as compared to 2022 Q3: ATKA, B22K, ER03, G27K, H17K, H23K, K216.DH, K223, L19K, M19K, M26K, R18K, RKAV, TABL.
- Stations that came back during 2022 Q4 but still had 1-50% availability for the entire period: None
- BB data quality issues caused by faulty sensors and/or dataloggers: BARK (all channels), C21K (all channels), D20K (all channels), K15K (all channels), PS01 (BHN channel), PS07 (all channels), PS09 (all channels), WAT7 (BHZ channel).
- SM data quality issues caused by faulty sensors and/or dataloggers: PS07 (all channels), PS10 (horizontal channels).
- 1 site now has bad timing (no reliable GPS clock): S19K.
- Stations that have come back to above 50% availability since 2022 Q3 due to field maintenance or on their own: BARK, CYK, FYU, ISLE, K27K, KTH, L16K, MDM, MS02, O19K, O20K, PWL, SLK, SPIA, TNA, U33K.

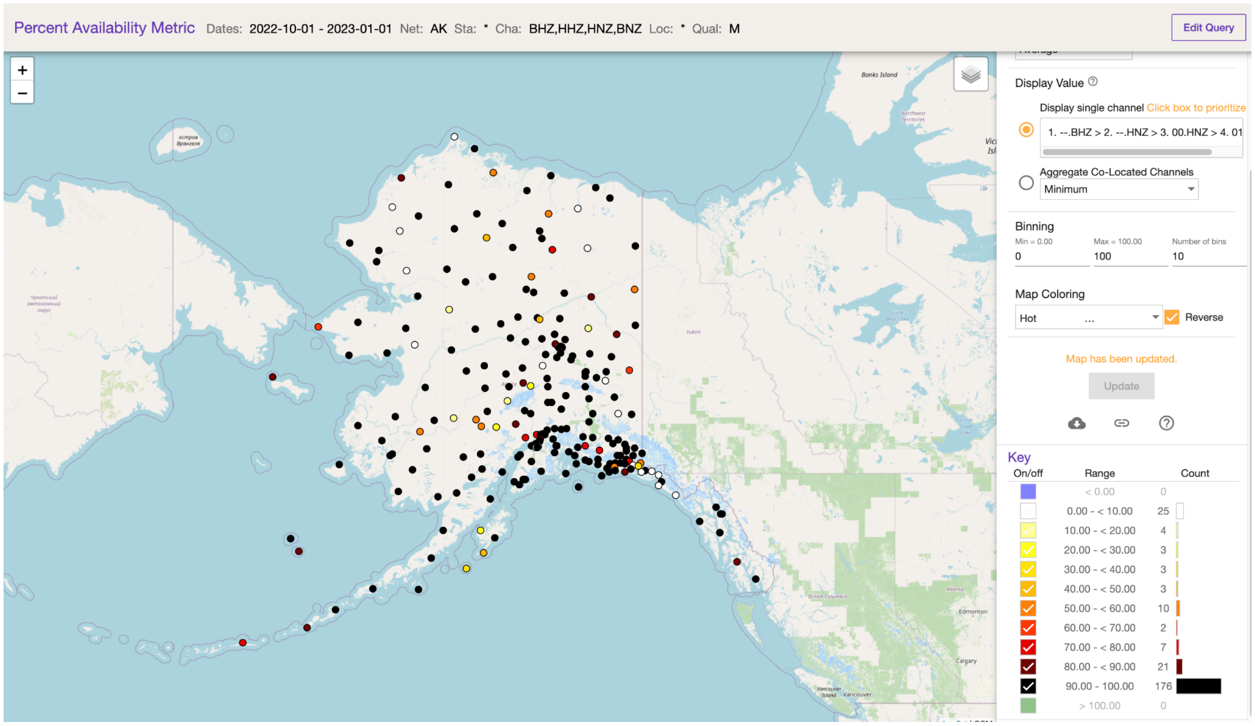


***Figure 4.1**. Map of average percent availability for all AK network broadband and strong motion stations for October 1-December 31, 2022. Black circles represent stations at 90-100% availability, white circles represent stations at 0-10% availability. Other colors represent a gradient of availability.*

4.2 Environmental data

The Earthquake Center adopted 89 stations with non-seismic instrumentation from the Earthscope Transportable Array project. All 89 stations have Hyperion infrasound and Setra microbarometer instruments. Of these stations, 67 are equipped with Viasala WXT weather packages (7 channels recording wind speed and direction, humidity, barometric pressure, temperature, and rain/hail gauges). In total, we record 825 individual environmental channels.

We run monthly QC checks of these environmental channels, quantifying the percent availability for each instrument, as well as scanning for periods of non-physical values and flat data return. A channel will flag as “flat” if over 20% of the samples are non-unique. For non-physical values, we conducted a literature review of the global maximum/minimum values for each of the environmental channels we acquire. For example, if a temperature sensor reports a measurement below -60 C or above 70 C, we flag that as non-physical. Please note that these monthly environmental QC reports do not fall on calendar months, but instead run from the 7th to the 6th of the next month, due to reporting requirements of the Synoptic National Mesonet Program. This report is for October 7 through January 6, 2022.

First quarter of 2022 was marked by very poor performance, with 75% of the network experiencing instrumentation malfunctions at some point. We attributed these difficulties to harsh winter conditions. Second quarter of 2022 was significantly better, confirming our hypothesis that harsh winter weather conditions were to blame for instrument failures. By June, 74% of stations were reporting data availability over 90%, compared to only 25% of stations in February. The third quarter of 2022 was stable, with 73% of stations reporting over 90% data availability from July through September. The fourth quarter saw a transition back into poor winter performance, with the number of stations reporting 90% data availability dropping from 71% to 62%. Nevertheless, this is still higher than the 51% recorded during the first month of last year.

5. Real-time earthquake detection system

The Earthquake Center is the authoritative source of earthquake information in Alaska. Our real-time automated earthquake detection system is tuned to rapidly determine locations and magnitudes of seismic events in the state and disseminate this information to state and federal agencies, scientists, and the general public via website and other data feeds. The real-time earthquake detection system at AEC is based on the Antelope software package from BRTT, Inc.

First, waveforms are being continuously scanned by the *orbdetect* module to identify seismic arrivals. When a group of concurrent arrivals is identified, the *orbassoc* module searches over several pre-calculated three-dimensional grids to find the best fit for the set of arrivals. Each successful association is relocated by the *orbgenloc* module. Once the event is located, its magnitude is calculated through the *orbevproc* module. Automatic and reviewed locations and magnitudes along with the set of associated arrivals and other information are written into the real-time earthquake database (CSS3.0) by the *orb2dbt* module. The real-time earthquake locations and magnitudes are determined within 2-5 minutes of the event occurrence, depending on the event location and size.

Beginning in January 2021, we have been producing monthly reports on the performance of the real-time detection system. We document numbers of detected events (Figure 5.1), percent of bogus events that get deleted by the duty seismologist, percent of events with automatic magnitudes computed, location errors, detection latencies (Figures 5.2 and 5.3), and overall magnitude of completeness (Figure 5.4). We compare some metrics to ANSS (Advanced National Seismic System) performance standards, for example 2 minutes latency post time for hypocenters in High-Risk areas. This performance evaluation project is still in its initial testing stages; we expect it to evolve in future quarterly reports. See Table 2 for detailed information on some of the current metrics.

During the October-December 2022 time period we reported 8,569 automated events in Alaska and neighboring regions (Figure 5.1). This is 8% more detections than in the previous quarter. November 18, 2022 had the highest number of detections. November 22 had several events with longer detection delays but recovered fairly quickly (Figure 5.2). October 13 had some slight delays in magnitude calculations, but were still mostly within the ANSS standard of 2 minutes (Figure 5.3).

There were 41 earthquake alarms during this reporting period. Our goal is to have duty-seismologist-reviewed solutions for alarm events within 20 minutes. No alarm events were reviewed with a larger delay (Figure 5.5).

Table 5.1. *Real-time earthquake detection system performance.*

Metric	**October**	**November**	**December**
Number of automatic event detections	2,821	2,859	2,889
First origin latency below ANSS 2 min standard	75%	72%	71%
Number of automatic events with magnitudes	2,294	2,249	2,225
Percent origins with magnitudes	81%	79%	77%
First magnitude latency below ANSS 3 min standard	52%	50%	53%
Magnitude latency from origin post time below ANSS 2 min standard	98%	97%	98%
Events deleted by duty seismologist	13%	14%	13%
Magnitude of completeness	1.9	1.3	1.5
Number of earthquake alarms	17	13	11
Number of ShakeMaps	55	42	33
ShakeMap latency below ANSS 15 min standard	80%	88%	83%

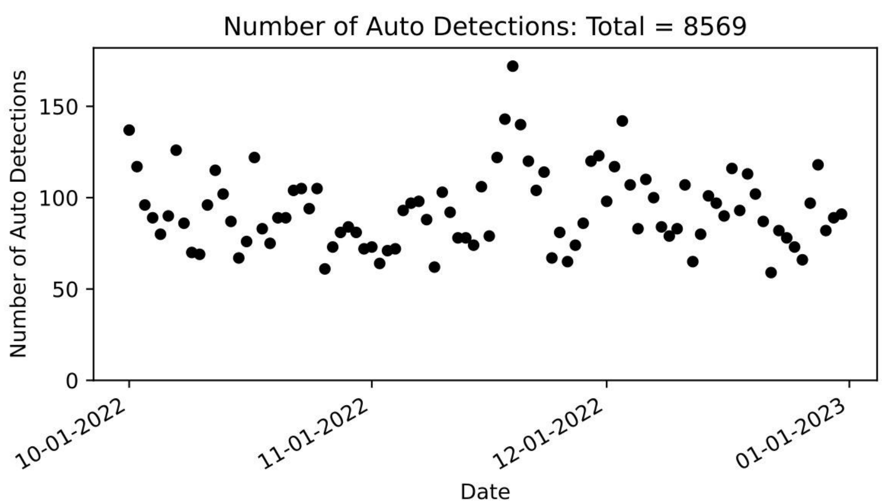


Figure 5.1. *Number of automatic event detections for each day. November 18, 2022 had the highest number of detections.*

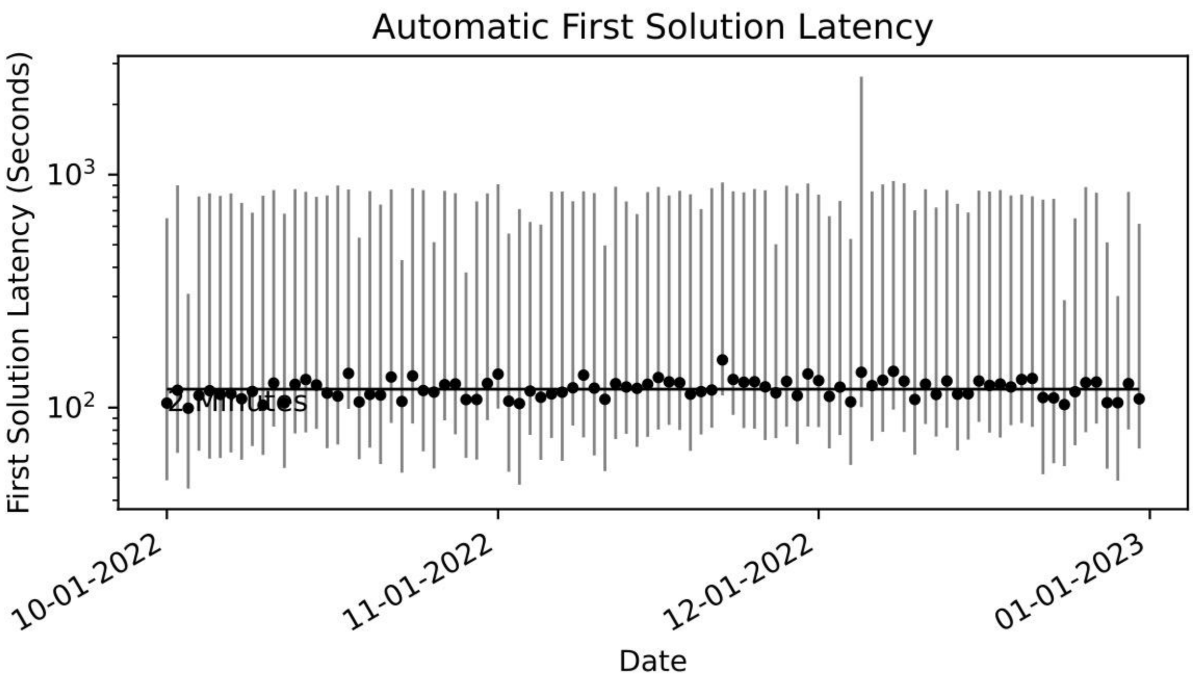


Figure 5.2. *Average daily latency (dots) and range (lines) of the first automatic solution for each event. November 22 had longer detection delays but recovered fairly quickly.*

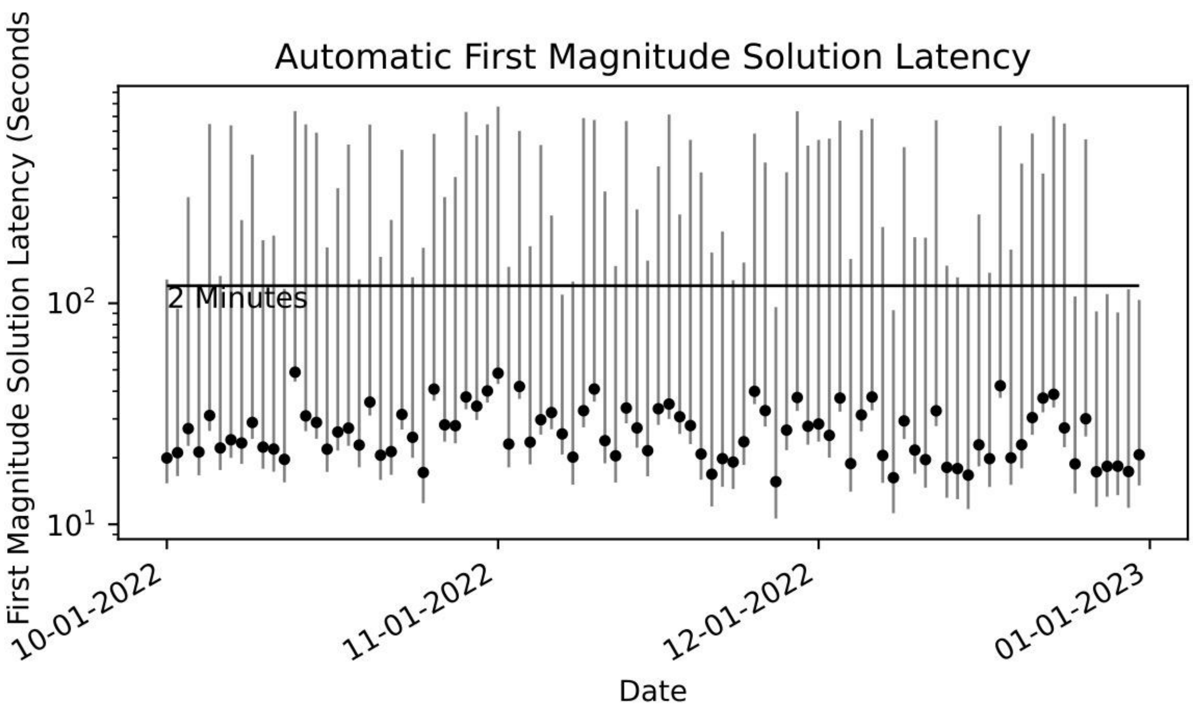


Figure 5.3. *Average daily latency (dots) and range (lines) of the first automatic magnitude for each event after the event detection.*

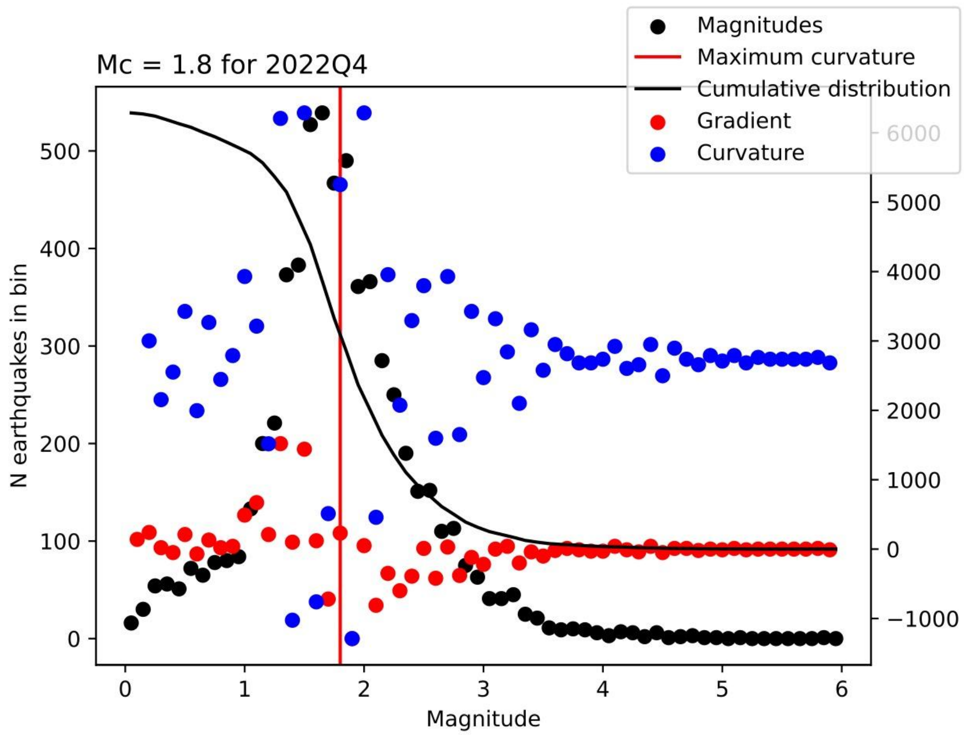


Figure 5.4*. Magnitude of completeness of the automatic catalog for the reporting time period.*

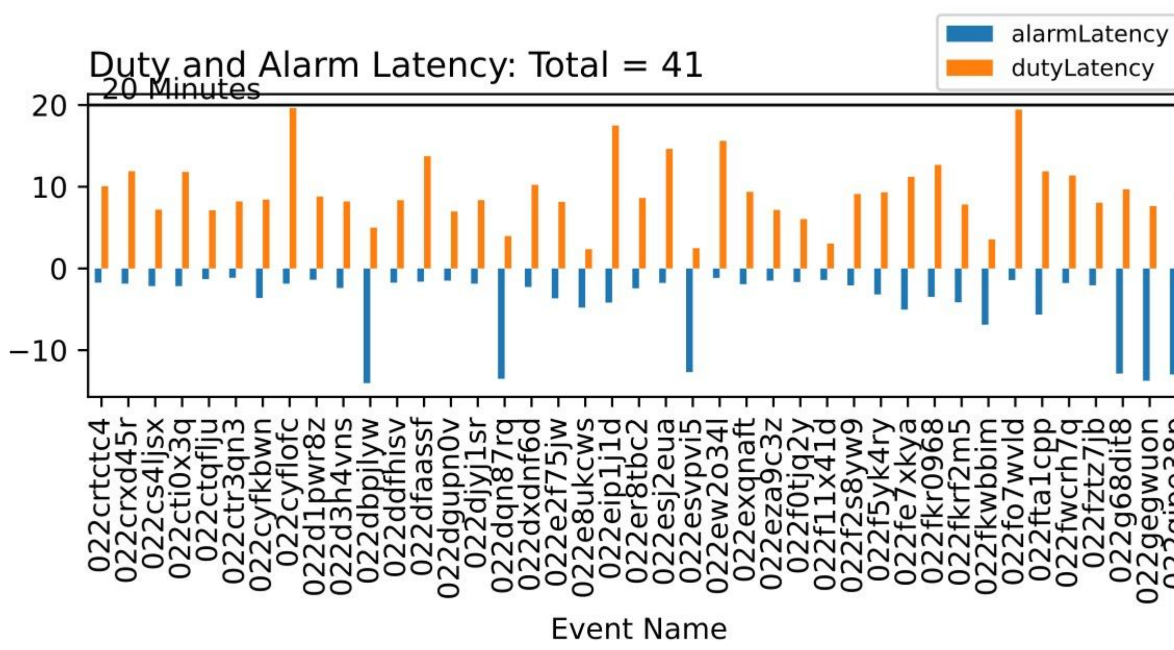


Figure 5.5*. Earthquake alarm and duty review latency from alarm time (bottom of the blue bar is origin time, top of the orange bar is duty review post time, 0 is time of the alarm). Earthquakes are labeled with their event names.*

6. Computer systems

6.1 Computer resources

The Earthquake Center operates a computing cluster hosting an enterprise-grade virtual environment for nearly all operational needs. During this quarter, no major hardware upgrades were performed. We have begun to deploy staging virtual systems, which mirror production systems but operate in a separate environment to allow for consistency and testing prior to deploying major software changes.

Current status is as follows:

Number of hosts	Total CPUs	Total CPU (GHz)	Total RAM (GB)	Total vSAN storage (TB)
4	96	258.62	1022.49	41.92

Resource utilization is as follows:

Virtual Systems				Operating System	
Production	Staging	Development	Users	CentOS	Windows
22	16	20	6	61	3

6.2 Waveform storage

The Earthquake Center maintains a permanent archive of all available seismic data in the state in miniSEED format. Continuous waveforms have been stored since 1997, and segmented data is available from 1988-2012. Currently, AEC has 61.7 TB in continuous waveform data and 1.1 TB of segmented data. During the quarter, we acquired and archived 1.02 TB of new data (Figure 6.2.1).

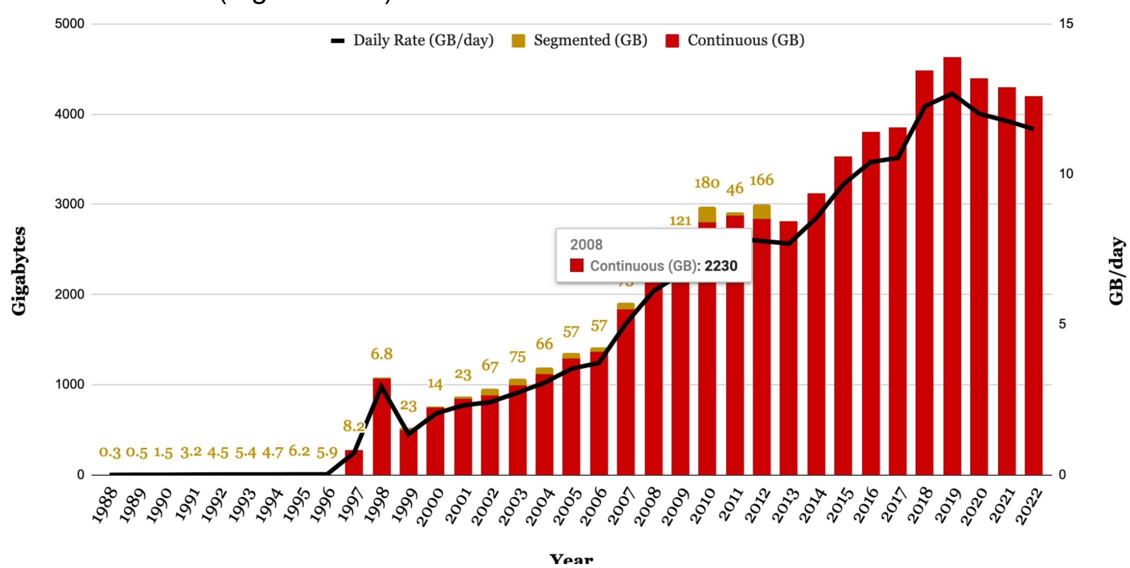


Figure 6.2.1. *Digital waveform archival storage for continuous (red) and segmented (brown) data.*

6.3 Metadata

AEC maintains metadata in css3.0 format for internal use, and provides dataless SEED volumes to IRIS for public distribution. During this quarter, the following station entries were modified:

- Stations added: BE01, BE02
- Stations modified: ANM, BAL, BESE, D17K, E18K, F15K, F18K, FIRE, GOAT, H24K, P17K, R32K, RAG, S31K, V35K, WRH
- Stations removed: None

We have paused adding new station metadata into the Station Information System (SIS). At the end of this quarter, we have successfully loaded 48 sites into production SIS. These sites cover the entire Southern Tier adoption, as well as a few additional sites that shared a similar configuration with Southern Tier sites. Additional sites will be loaded in Q1 of 2023.

6.4 Software development

During this time, our active code branches under the following scopes of work were:

Antelope	Website	Other
11	1	3

With new staff onboard, we implemented a new software development workflow which emphasizes branching of repositories instead of commits into the ‘master’ branch. As a result, our previous metric tracking number of commits in a repository has been replaced by a metric tracking the number of active branches in a given repository. This captures the active work being performed in a given code segment better than a simple raw count of commits.

During Q4 of 2022, we continued to unify our Antelope codebase into Python. Approximately 75% of the legacy code has been ported, although we have not deployed the new code operationally yet. We have also started the process of transitioning our primary website host from on-premises virtualized machines into an Amazon Web Services (AWS) framework.

Projects included work on tuning the real-time system automatic earthquake detection and location algorithms and a report tool for generating catalog statistics on-demand.

7. Fieldwork

During the reporting period, Earthquake Center staff visited 22 field sites to resolve data outages, GPS timing issues, and to perform planned upgrades, cleanup, and/or preventative maintenance. Eight staff members conducted visits, for a total of 65 person-days of site maintenance work during the reporting period.

The AEC field season continued into the fourth quarter of 2022, with the final trips of the calendar year concluding during the first week of November. The field work during this quarter concentrated on repairing sites that developed telemetry problems during the 2022 field season and completing annual inspections of our seismic monitoring sites located at Trans-Alaska Pipeline System (TAPS) facilities. Snow and poor weather conditions forced AEC to cancel the remaining helicopter-based fieldwork starting mid-October.

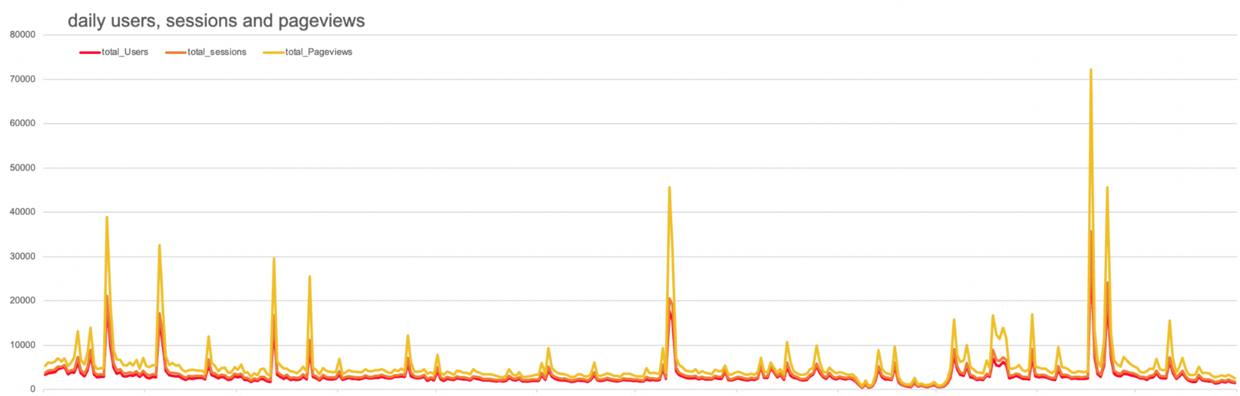
During October 10-12, two field technicians completed site inspections and minor repairs at the three southernmost TAPS facilities. Similarly, from October 11-15, three field technicians completed inspections at the two northernmost TAPS facilities and visited AK.D24K for minor site repairs to bring that site back online. From October 16-13, two field technicians visited two sites in southeast Alaska, AK.BESE and AK.U33K, to complete follow-up work from previous maintenance on sites in Southeast Alaska. During November 1-5, two technicians completed maintenance at multiple strong-motion sensor sites located throughout the Anchorage area. Wrapping up the fieldwork for Q4, an AEC technician visited AK.A21K in Utqiagvik during November 3-5 in order to attempt to bring that site back online.

8. Social media and outreach

The Alaska Earthquake Center maintains a vibrant and dynamic social media presence on Facebook and Twitter. Since its initiation in 2013, we have amassed nearly 50,000 followers across the two platforms. Our social media posting strategy takes a multifaceted approach to public engagement. Social media is one of the primary ways that earthquake information is shared and that remains our primary focus. We also seek to highlight the human element of the center. We do not produce autogenerated posts. We aim to have 50% of our posts be related to recent earthquakes. The remaining 50% is divided between topics that highlight the various aspects of the center itself. We also acknowledge that we can fill a vital role in helping to amplify the messaging of our partner agencies.

8.1. Website

During the fourth quarter of 2022, we had nearly 325,000 users visit our website. This amounted to 382,000 sessions (number of times users entered our website) and 633,000 pageviews (number of individual web pages visited). Figure 8.1.1 shows the daily distribution of users, pageviews, and sessions for the year to date.



-

Figure 8.1.1. *Total number of website users (red), sessions (orange), and pageviews (yellow) per day in 2022.*

Our web traffic is rarely quiet. On our "slowest" day between October 1-December 31, we still had more than 1,100 users on our site. The recent earthquake map page and recent earthquake list (a page for lower bandwidth users) combined accounted for 70% of users during the reporting period. These two pages typically account for approximately 75% of site visitors. There was a significant spike in activity on November 17th after a M4.1 near Salcha and a M4.9 near Anchorage.

In recent years we have made our website and content more mobile friendly, based on trends seen in device usage. More people visit our site on mobile devices (Figure 8.1.2). Tablets and mobile devices such as phones accounted for 73% of website sessions.

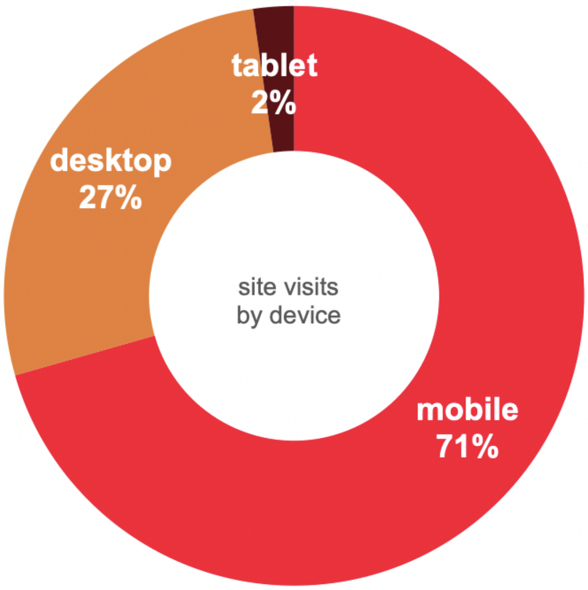


***Figure 8.1.2**. Percentage of website sessions for the three major device types, mobile (e.g., phones), tablets, and desktop computers.*

8.2. Twitter

In the fourth quarter of 2022, we gained approximately 200 followers, bringing our total following to over 25,200. Follower growth was lower than normal due to the large number of people who left Twitter following Elon Musk's takeover of the company. Because of the nature of Twitter, we often post frequent or threaded content to convey our messages. Figure 8.2.1 shows the distribution of post types for the 83 tweets made this quarter. Figure 8.2.2 shows the number of posts made per day and the number of impressions per day for the entire year. Impressions represent the number of times our tweet is shown on a screen. The number of impressions does not scale directly with the number of posts based on the Twitter algorithm, as evidenced by the days with impressions and no posts. This is used to determine how often our followers view our posts.

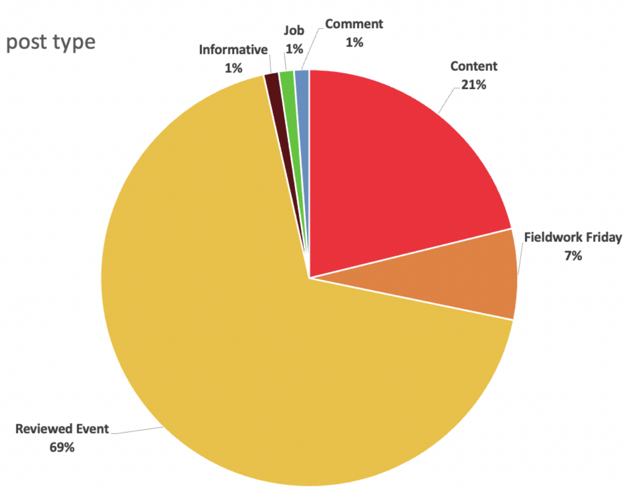


***Figure 8.2.1.** Post type distribution for tweets for the fourth quarter of 2022.*

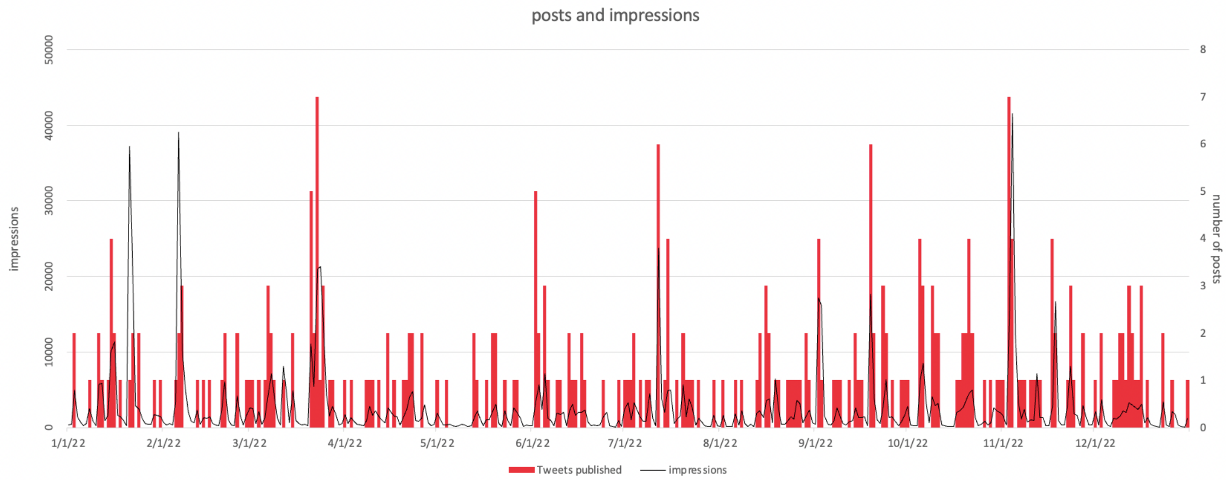


***Figure 8.2.2**. Number of posts per day (right axis, red bars) compared to the number of impressions received per day (left axis, black line) in 2022.*

There were several spikes in impressions (Figure 8.2.2) during this period, related to felt earthquakes. Our engagement rate with time (Figure 8.2.3) remained the same during this quarter, averaging around 5%, with a high around 12% on December 11.

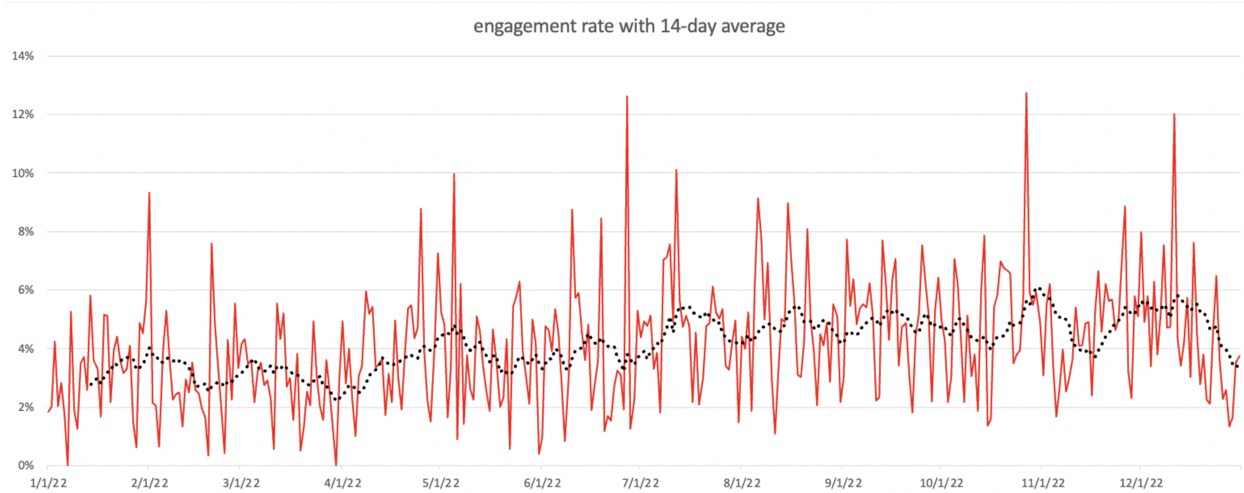


***Figure 8.2.3.** Twitter engagement rates with time (red line) and 14-day moving average (black dotted line) in 2022.*

Figure 8.2.4 shows impressions and engagements based on tweet type. Reviewed events accounted for 53% of impressions and 59% of engagements. #FieldworkFriday posts accounted for 8% of impressions and 9% of engagements, while other content posts drew 36% of impressions and 28% of engagements. All other posts (comments, informative, and job) accounted for 3% of impressions and only 4% of engagements.

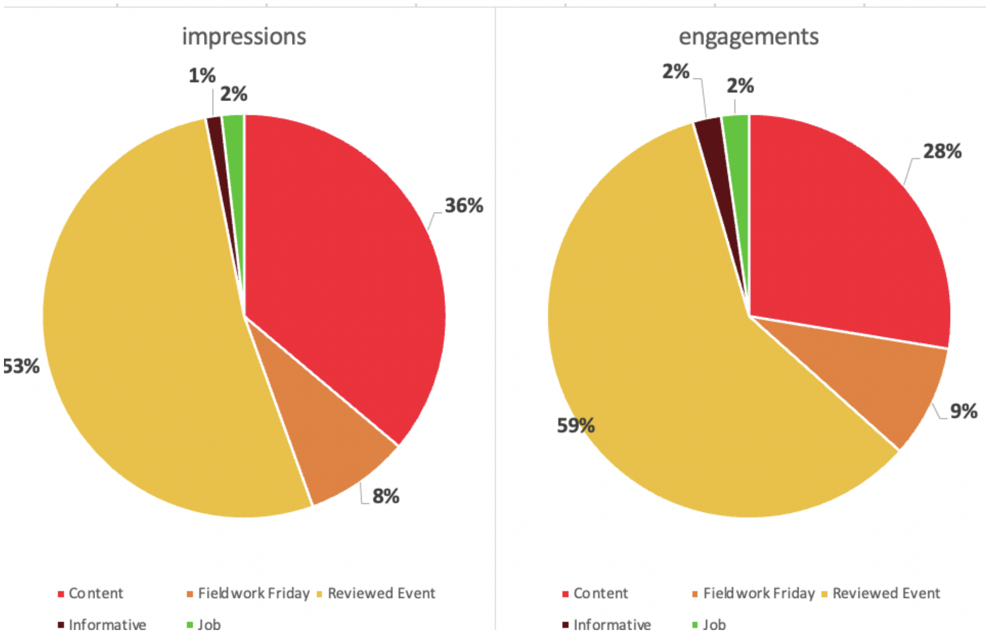


Figure 8.2.4. *Percentages of impressions and engagements based on tweet type.*

8.3. Facebook

Our Facebook Page was created in December 2020. It is our primary posting platform on Facebook. Our Facebook Group, created in 2013, is mainly used to share content posted to our page, and occasional posts from group members. Membership to the group remains high, at nearly 20,000.

During the fourth quarter of 2022, we attracted about 1,500 new Page Likes/Follows, bringing our count to about 12,500. As is the trend with felt earthquakes, we receive a follower boost after each event. Our largest increase was following a M4.5 earthquake that occurred near Old Harbor on October 12.

The distribution of post type is shown in Figure 8.3.1. Reviewed events accounted for 73% of the 70 posts made in the fourth quarter and represented 66% of reach. Twenty-six percent of posts were content related, and represented 28% of reach. Job posts accounted for a combined total of 1% of posts and 6% of reach.

Facebook has once again changed how they show metrics, making it impossible to track daily engagement rates using their Meta Business Suite. We can track the engagement rate of posts, and more widely felt events tend to receive the most engagement. (Figure 8.3.2).

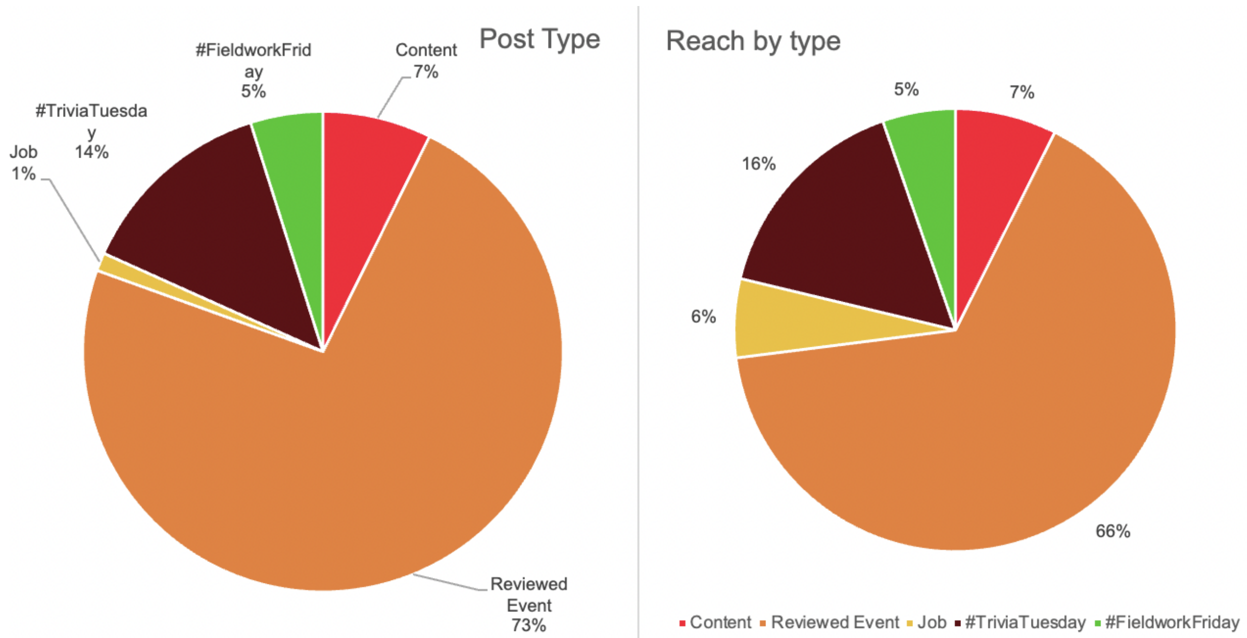


Figure 8.3.1. *Distribution of Facebook Page posts by type (left) and audience reach by type (right).*

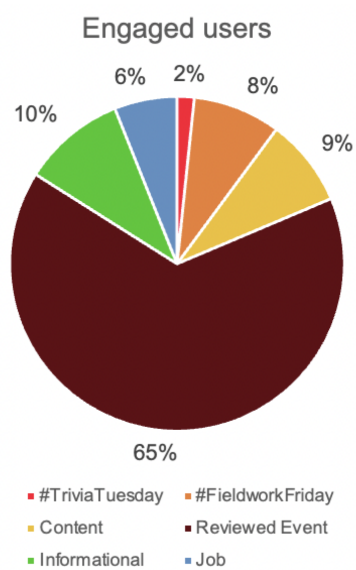


Figure 8.3.2. *Percentages of daily engaged users by post type.*

9. Publications and presentations

Names in **bold** are Earthquake Center staff. Names in ***bold italic*** are students affiliated with the Earthquake Center, and names in *italic* are students not directly affiliated with the center.

9.1. Publications

Grassi, B. (2022). Alaska Seismic Stations Keep Watch for Tsunamis. *CICOES Magazine.* UW/UAF/OSU. (Annual publication, Published 12/28/20).

Paris, G. M., A. J. Michael (2022). An Interactive Viewer to Improve Operational Aftershock Forecasts. *Seismological Research Letters*; 94 (1): 473–484. (Electronically 11/4/2022, published in January 2023 Volume).doi: https://doi.org/10.1785/0220220108

Ruppert, N. A., S. Cotton, M. Gardine, B. Grassi, S. G. Holtkamp, H. McFarlin, N. Murphy, M. E. West, and S. Wiser (November 2022). *Alaska Earthquake Center Quarterly Technical Report July-September 2022*. UA ScholarWorks, 46 pp., http://hdl.handle.net/11122/13048.

9.2. Public Presentations

Date	Presenter(s)	Event/Workshop	Title	Virtual/ In person
10/11	**Michael West**	National Implementation Committee of the Advanced National Seismic System	Key ANSS points from Alaska	In person
10/14	**Elena Suleimani**	Anchorage emergency management tsunami working group	Preliminary tsunami hazard maps of Anchorage and Upper Cook Inlet.	In person
10/19	**Natalia Ruppert**	Basin and Range Earthquake Summit (Salt Lake City, Utah)	Towards Earthquake Early Warning in Alaska	Hybrid
10/26	**Michael West**	U.S. Arctic Research Commission	USArray and the Alaska Geophysical Network: A multi-sensor observing network across the US Arctic	In person
11/15	**Elena Suleimani**	International tsunami conference, Moscow, Institute of Oceanography of RAS	Tsunami hazard mapping in Alaska	Hybrid
12/2	**Elena Suleimani,** Barrett Salisbury	Meeting with the emergency officials in Girdwood	Tsunami Hazard Map of Girdwood, Alaska	Hybrid
12/2	**Elena Suleimani**	Girdwood Middle School	Tsunamis in Alaska and around the world	In person

12/3	**Elena Suleimani,** Barrett Salisbury	Meeting with the public and emergency officials in Hope	Tsunami Hazard Map of Hope, Alaska	In person
12/8	**Elena Suleimani**	Webinar of the Geophysical Surveys of Russian Federation	Tsunami source characterization for deterministic tsunami hazard assessment in Alaska	Virtual
12/13	**Elena Suleimani** (presenter)**,** James Barrett Salisbury, **Dmitry Nicolsky, Michael West**	American Geophysical Union Fall Meeting 2022	Evaluating Tsunami Hazard for Anchorage and Upper Cook Inlet, Alaska	In person (poster)
12/14	***Alexander Fozkos*** (presenter), **Michael West, Matt Gardine**	American Geophysical Union Fall Meeting 2022	Initial Warning Time Estimates for Earthquake Early Warning in Alaska	In person (poster)
12/14	**Lea Gardine, Elena Suleimani, Dmitry Nicolsky, Beth Grassi** (presenter)**, Michael E. West, Natalia A. Ruppert, Brad Lobland**	American Geophysical Union Fall Meeting 2022	Alaska's Equity-focused Approach to Addressing Community-specific Tsunami Hazards	In person (poster)
12/15	***Sarah Noel*** (presenter), **Michael West**	American Geophysical Union Fall Meeting 2022	Assessing Machine Learning Assisted Phase Detection on the Alaska Seismic Network	In person (poster)
12/15	***Akash Kharita,*** Marine Denolle, **Michael West**	American Geophysical Union Fall Meeting 2022	Multi-Station Analysis of Icequakes and Earthquakes in Southern Alaska using Random Forests	In person (poster)
12/15	**Gabriel Low** (remote presenter)**, Michael West** (presenter)**, Lea Gardine, Tammy Bravo, Jessica Larsen**	American Geophysical Union Fall Meeting 2022	Engaging Rural Alaskan Youth in Geohazard Education, Advocacy, and Competitive Academics	In person (poster) with remote video call discussion

9.3. Lunch Seminar Talks

Lunch seminar talks are informal opportunities for faculty, staff, students, and guest speakers to present their research.

Date	Presenter	Title	Virtual/ In person
11/14	Julien Thurin (UAF postdoc)	Inverting for the series of explosive subevents of the January 2022 Hunga-Tonga submarine volcanic eruption	Hybrid
11/17	Louise Maubant (MIT)	Extracting tectonic signal from InSAR time series along subduction zones	Hybrid
11/30	Carolyn Parcheta (Hawaii Volcano Observatory)	Improving studies of tephra physical properties: the new HVO tephra lab and the 2018 eruption	Hybrid
12/1	Jordan Bishop (UAF)	Deep learning categorization of infrasound array data	Hybrid

10. References

Ruppert, N. A., and L. Gardine (February 2021). *2020 Alaska seismicity summary*, ScholarWorks@UA, 16 pp., http://hdl.handle.net/11122/11865.

Ruppert, N. A., and L. Gardine (February 2022). *2021 Alaska seismicity summary*, ScholarWorks@UA, 23 pp, http://hdl.handle.net/11122/12683.

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Ruppert, N. A., S. Cotton, L. Gardine, M. Gardine, B. Grassi, S. G. Holtkamp, H. McFarlin, N. Murphy, and M. E. West (August 2022). *Alaska Earthquake Center quarterly technical report April-June 2022*, ScholarWorks@UA, 40 pp., http://hdl.handle.net/11122/12956.

Ruppert, N. A., S. Cotton, M. Gardine, B. Grassi, S. G. Holtkamp, H. McFarlin, N. Murphy, M. E. West, and S. Wiser (November 2022). *Alaska Earthquake Center Quarterly Technical Report July-September 2022*, ScholarWorks@UA, 46 pp., http://hdl.handle.net/11122/13048.

Appendix A: Data availability for broadband stations from the AK network.

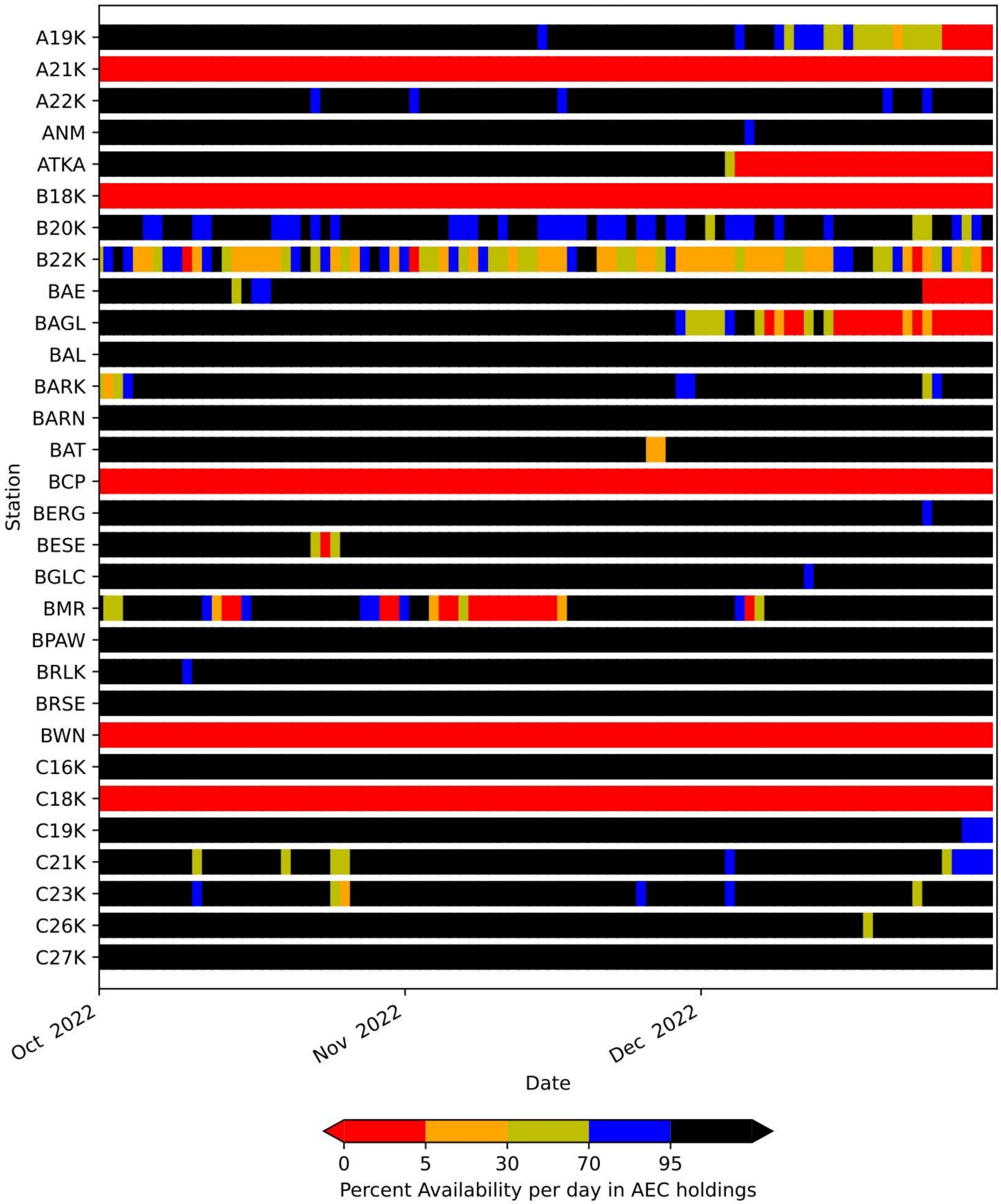

Figure A1. *Data availability for stations A19K-C27K (listed alphabetically). BAT is a new site installed in July 2021.*

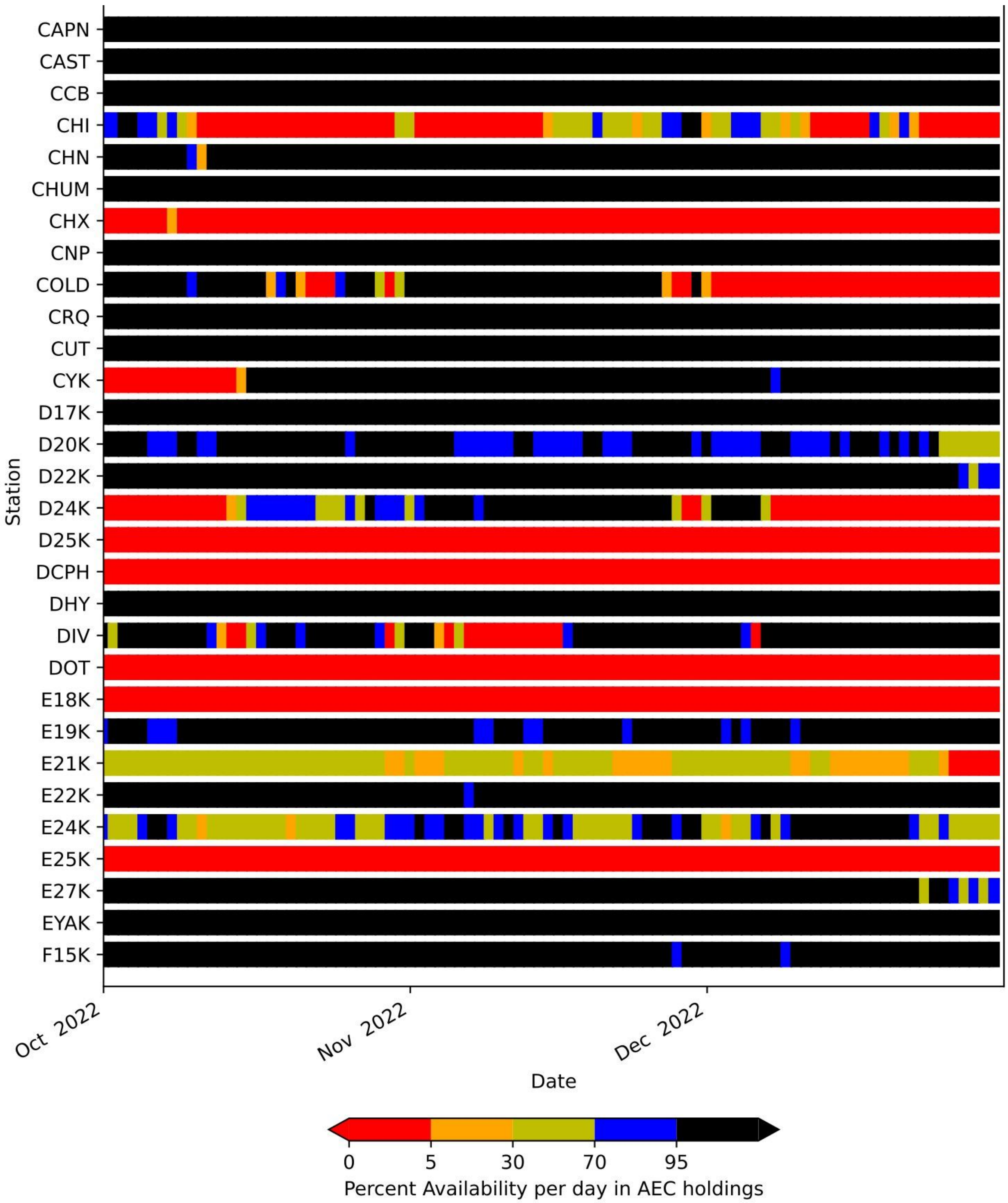

***Figure A2**. Data availability for stations CAPN-F15K (listed alphabetically).*

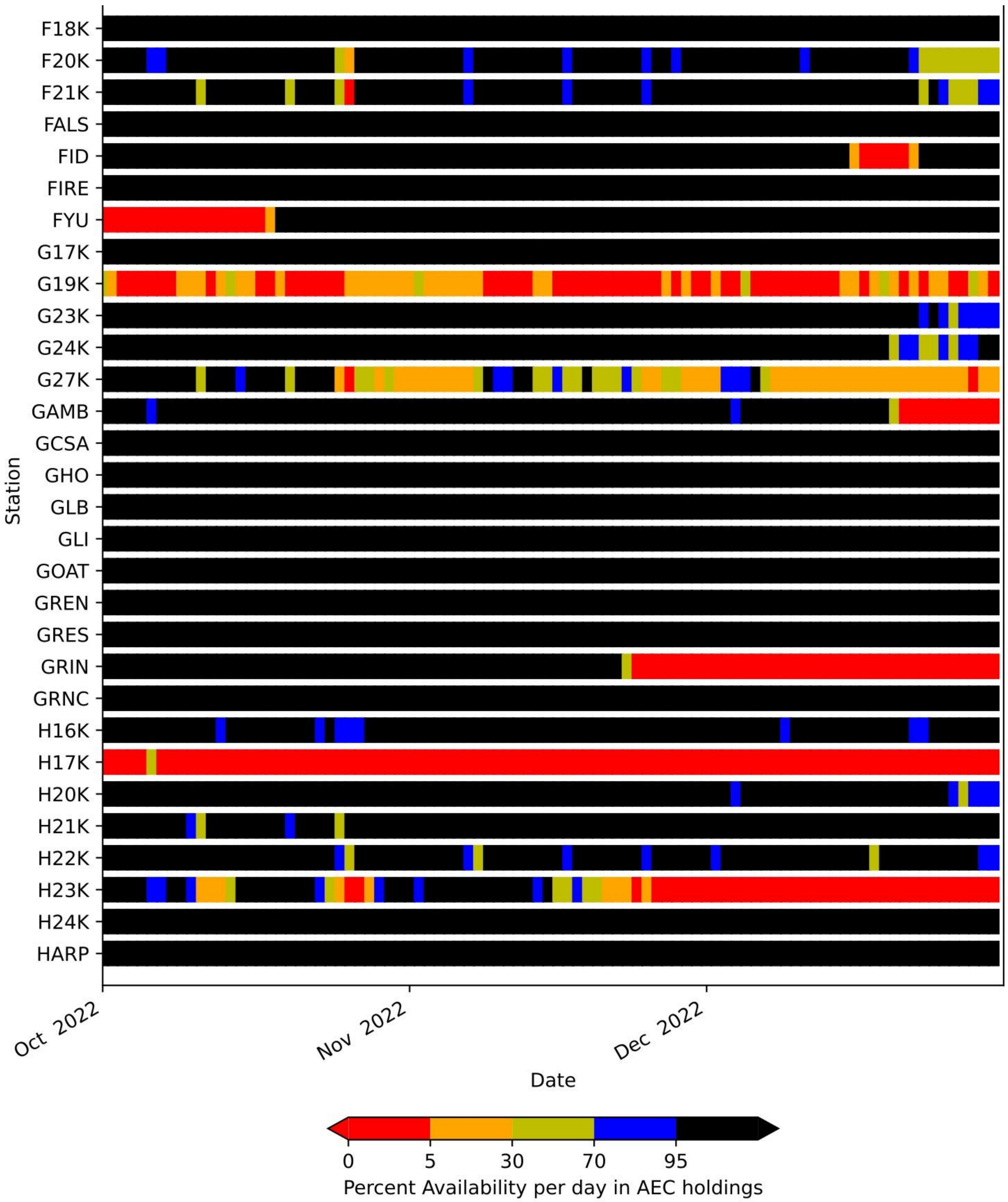

***Figure A3**. Data availability for stations F18K-HARP (listed alphabetically).*

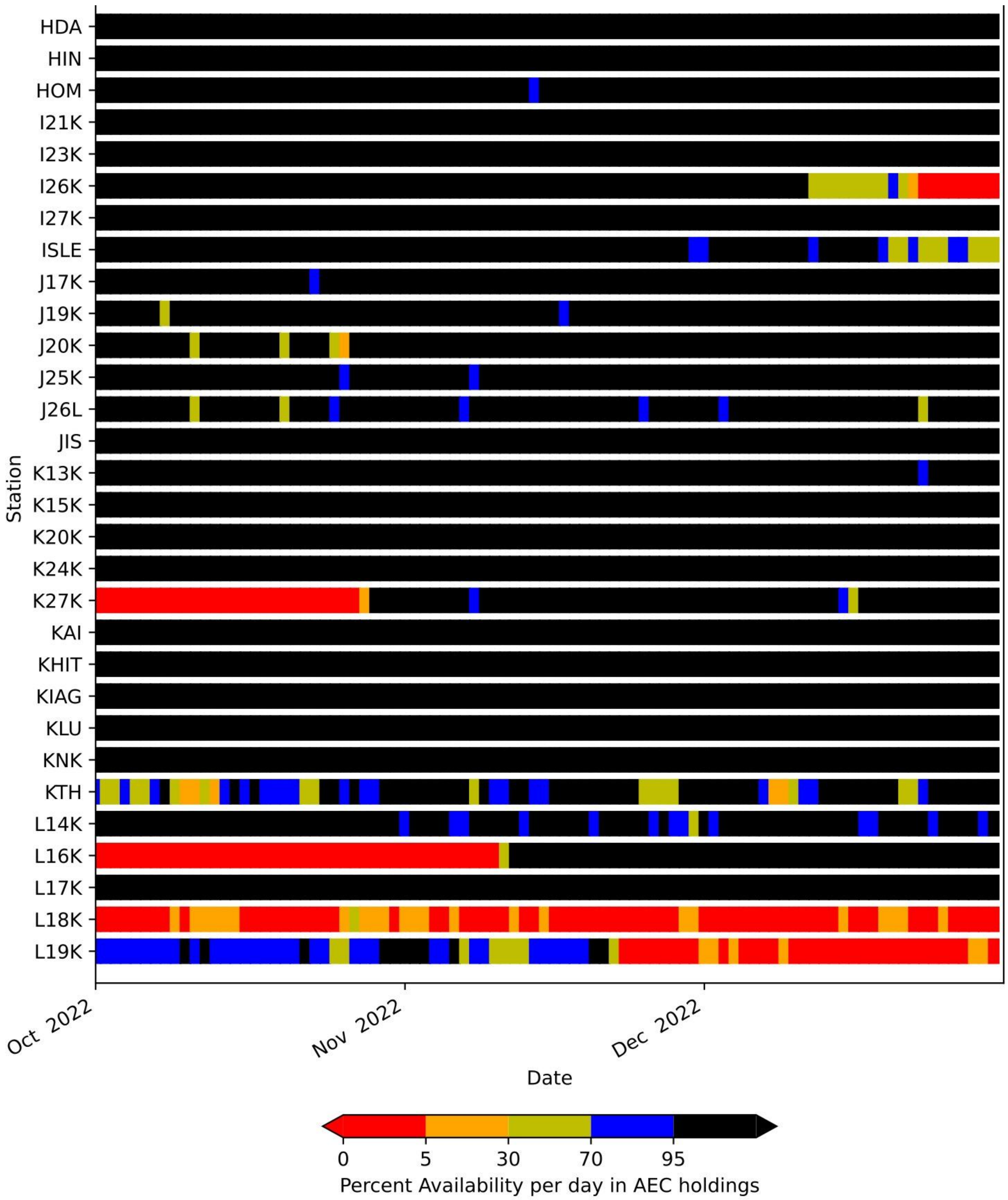

***Figure A4**. Data availability for stations HDA-L19K (listed alphabetically).*

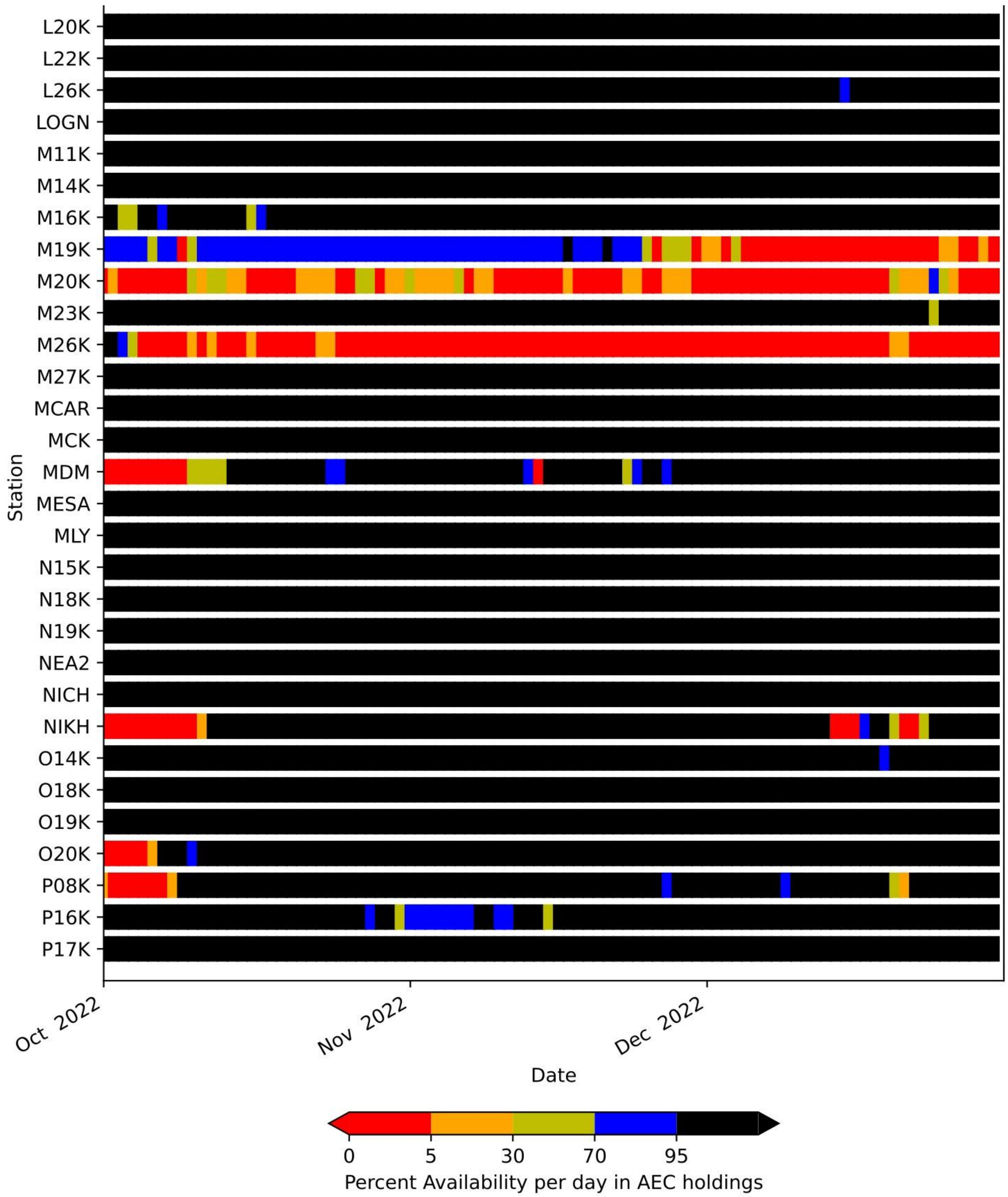

***Figure A5**. Data availability for stations L20K-P17K (listed alphabetically).*

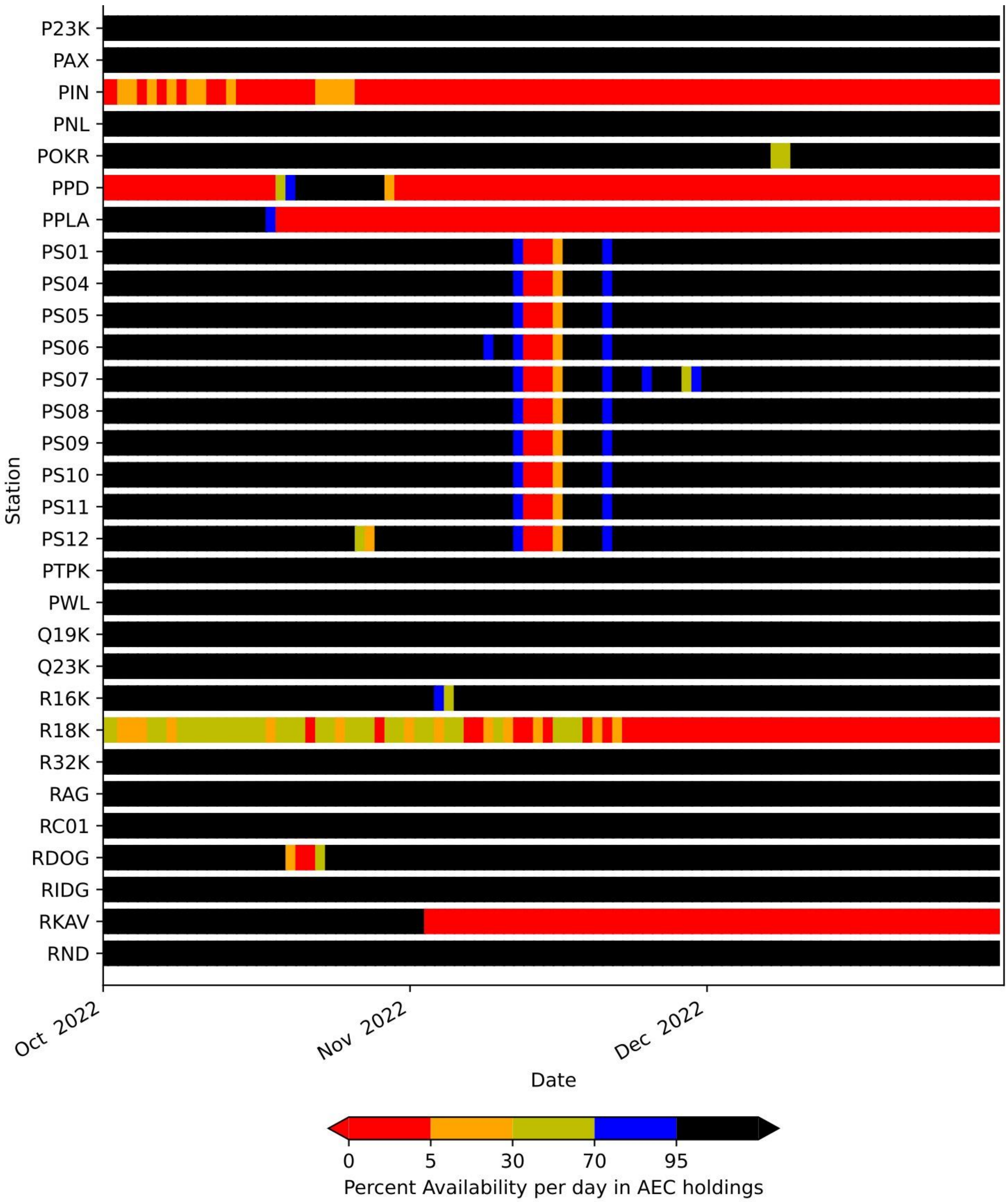

***Figure A6**. Data availability for stations P23K-RND (listed alphabetically).*

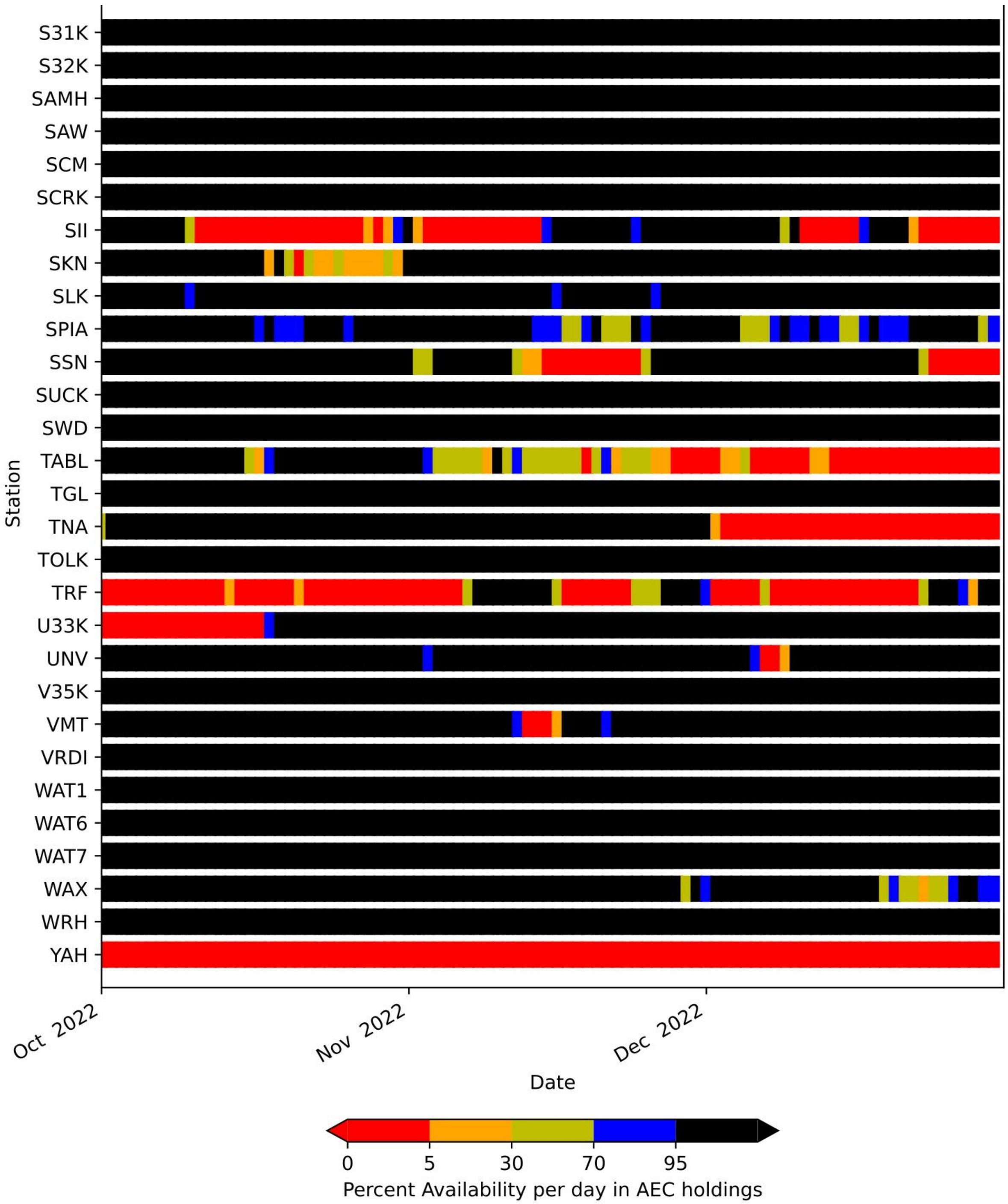

Figure A7*. Data availability for stations S31K-YAH (listed alphabetically).*

Appendix B: Gaps for broadband stations from the AK network.

***Figure B1**. Number of gaps per day[1] for stations A19K-C27K (listed alphabetically).*

[1] Stations with 0% data availability are denoted in the same color as stations with 0 gaps.

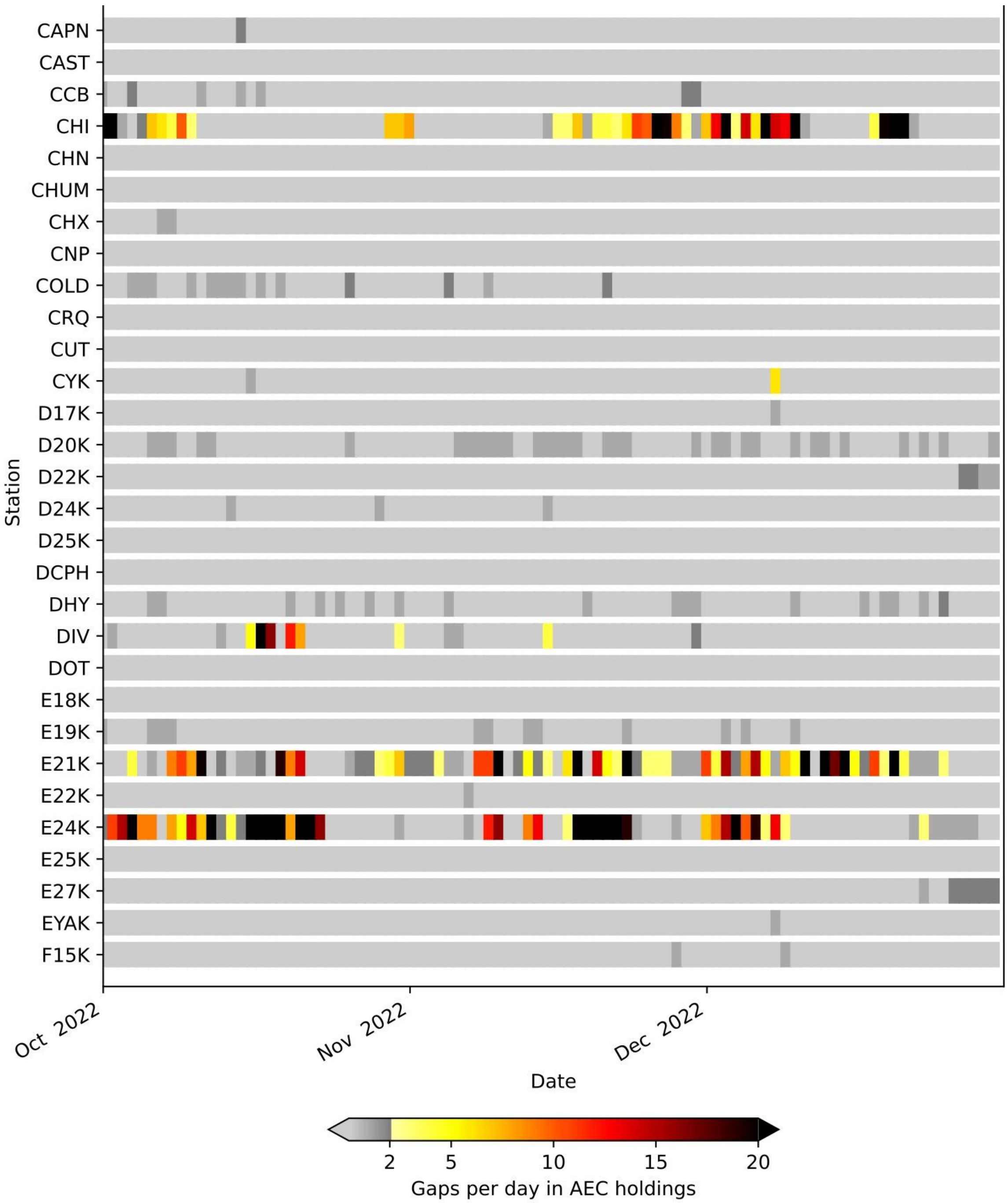

Figure B2*. Number of gaps per day for stations CAPN-F15K (listed alphabetically).*

***Figure B3**. Number of gaps per day for stations F18K-HIN (listed alphabetically).*

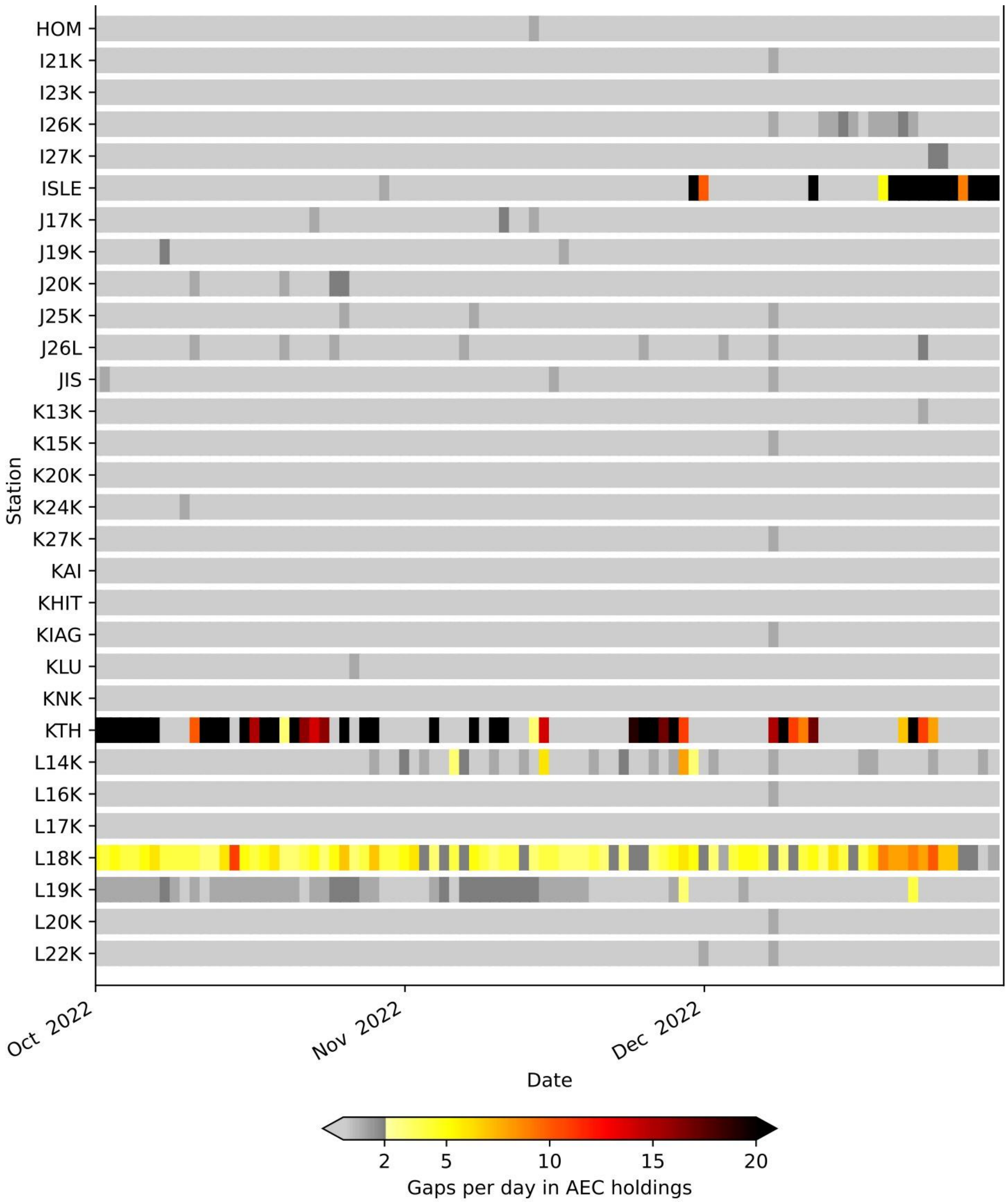

***Figure B4**. Number of gaps per day for stations HOM-L22K (listed alphabetically).*

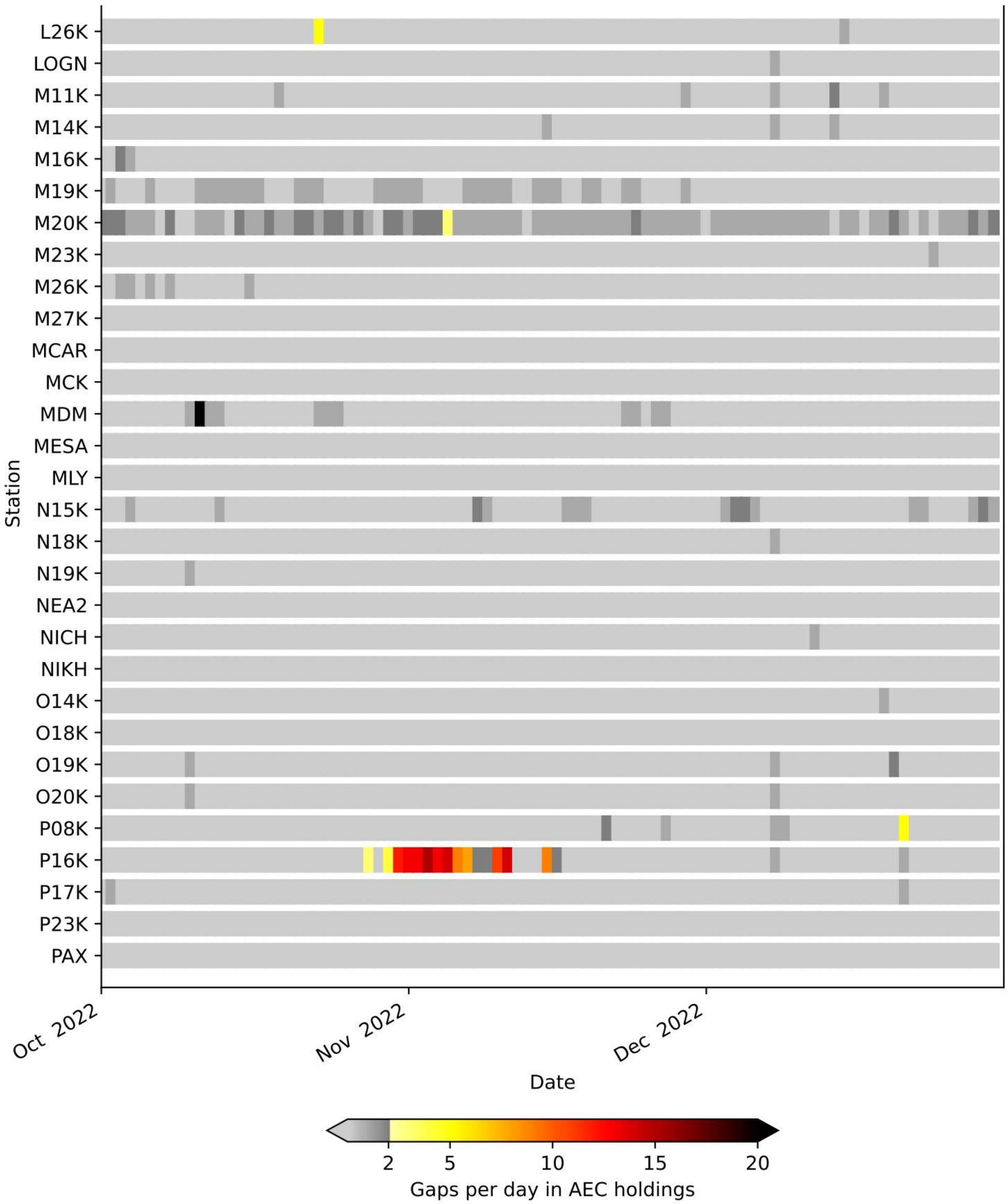

***Figure B5**. Number of gaps per day for stations L26K-PAX (listed alphabetically).*

***Figure B6**. Number of gaps per day for stations PIN-S32K (listed alphabetically).*

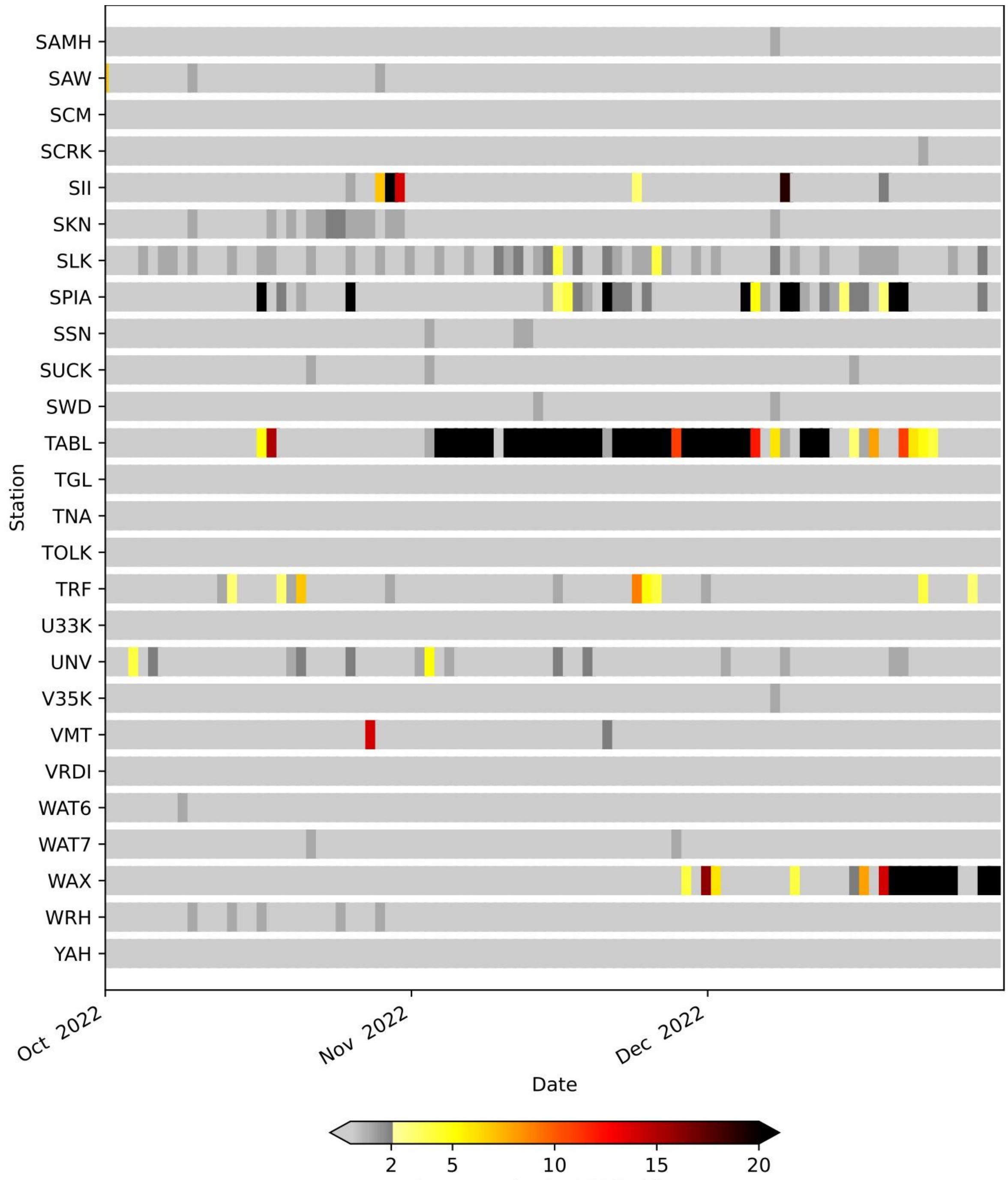

Figure B7*. Number of gaps per day for stations SAMH-YAH (listed alphabetically).*