SEISMIC NETWORK OPERATIONS IN ALASKA

Final Project Report

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Abstract

Most earthquakes in the United States occur in Alaska, including three-quarters of the magnitude 4+ earthquakes during the past five-year period. The balance of hazard, geography and population is unlike anywhere else in the country. Limited transportation options, singular communications links, and "daisy-chained" supply lines combine with harsh climate and loose regulation to compromise our communities' resilience. As a result, FEMA estimates Alaska's Annualized Earthquake Loss Ratio at $50 million.

This award provides support from the USGS to carry out the Earthquake Center's core functions under the auspices of the ANSS. These can be summarized broadly as operating a statewide digital seismic network, providing authoritative ANSS rapid reporting for mainland Alaska, and reporting of all seismicity in Alaska while striving to meet ANSS quality and completeness standards.

The Earthquake Center's efforts during this reporting period were directed at modernizing, expanding, and hardening our seismic network while refining our procedures for processing, reporting, and archiving data. Together, these efforts have allowed us to meet most ANSS goals while detecting more and smaller earthquakes across the state, as shown by the record 40,686 earthquakes entered into our catalog in 2014.

Work Performed

Seismicity

For this period the Earthquake Center reported 153,332 seismic events in Alaska and neighboring regions of Canada and Russia (Fig 1). These included four earthquakes with magnitudes between 7.0 and 7.9 and thirty-one earthquakes with magnitudes of six or greater. While 95% of these events were regional tectonic earthquakes, the catalog also includes 4,040 glacial quakes, 2,077 volcanic earthquakes, 1,800 quarry blasts, and 132 avalanches/rockslides or unknown type events for these years. Depths ranged from 0 to 296 km, with the deepest earthquakes concentrated in the central Aleutian Islands.

The largest earthquake occurred in the Rat Islands on June 23, 2014, with a magnitude of 7.9 and a depth of 102 km. AEC located over 2,500 aftershocks from this event through the end of reporting period, with a magnitude of completeness of 2.1. Intermediate depth earthquakes of this magnitude are a rare occurrence, but events like these present a hazard in Alaskan population centers as well as many more populous regions worldwide. Therefore, this earthquake presents a unique opportunity to study the behavior of a large intraplate event in the absence of significant societal impacts.

The second largest earthquake during the reporting period was the magnitude 7.5 Queen Charlotte Fault earthquake on January 5, 2013 in Southeast Alaska. Due to sparse local network coverage, the aftershock catalog's magnitude of completeness is relatively high at 2.5. Residents in nearby communities reported a maximum shaking intensity of V (moderate), and the earthquake was felt as far away as Seattle.

Many other large earthquakes and notable earthquake sequences occurred during the reporting period, including some with human impacts. For example, the magnitude 6.3 Skwentna event in 2014 was felt from Homer to Fairbanks and caused building evacuations in Anchorage. Also in 2014, the magnitude 6.0 Palma Bay earthquake triggered a submarine landslide that severed a major undersea cable and disrupted communications throughout Southeast Alaska. Large events were distributed widely across the state, with no region unaffected during the reporting period.

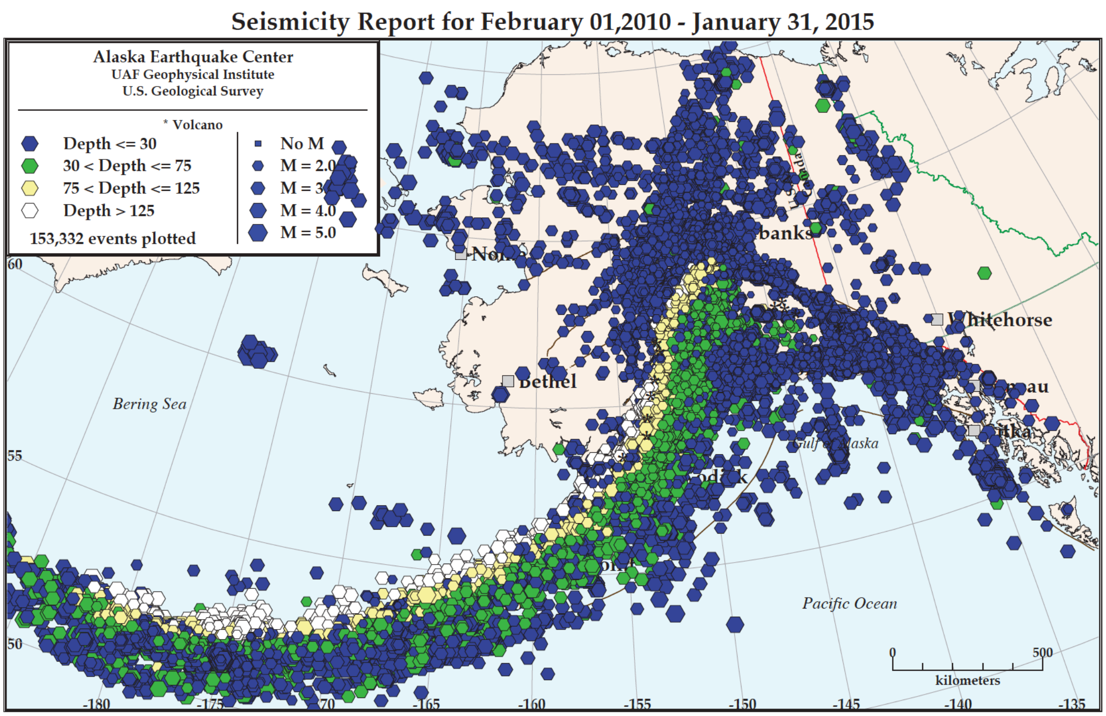

Figure 1. 153,332 seismic events were recorded in Alaska and neighboring regions of Canada and Russia during this reporting period.

Seismic Network

The Alaska Earthquake Center maintains a statewide network of 128 seismic monitoring stations along with the nine-station Fairbanks strong motion network and a number of communications sites. About 70% of these locations are accessible only by chartered helicopters or small planes. This award supports operation and maintenance of stations in the densest part of our network, the high-risk Southcentral Alaska region.

Fieldwork during the first three years of this award was dedicated largely to modernizing and expanding the AK regional network, especially the sub-networks in Southcentral Alaska (Fig 2). Most importantly, we upgraded twenty southcentral stations from short period to ANSS-standard digital broadband standards. Fifteen of these upgrades were performed as part of the ARRA-funded ANSS upgrade project. Additionally, we permanently adopted fifteen digital broadband research stations by replacing PASSCAL-owned equipment with our own equipment, purchased mainly with state funds. We also upgraded ten additional southcentral stations with new Q330 dataloggers and augmented our Kenai Peninsula sub-network with two new digital broadband stations.

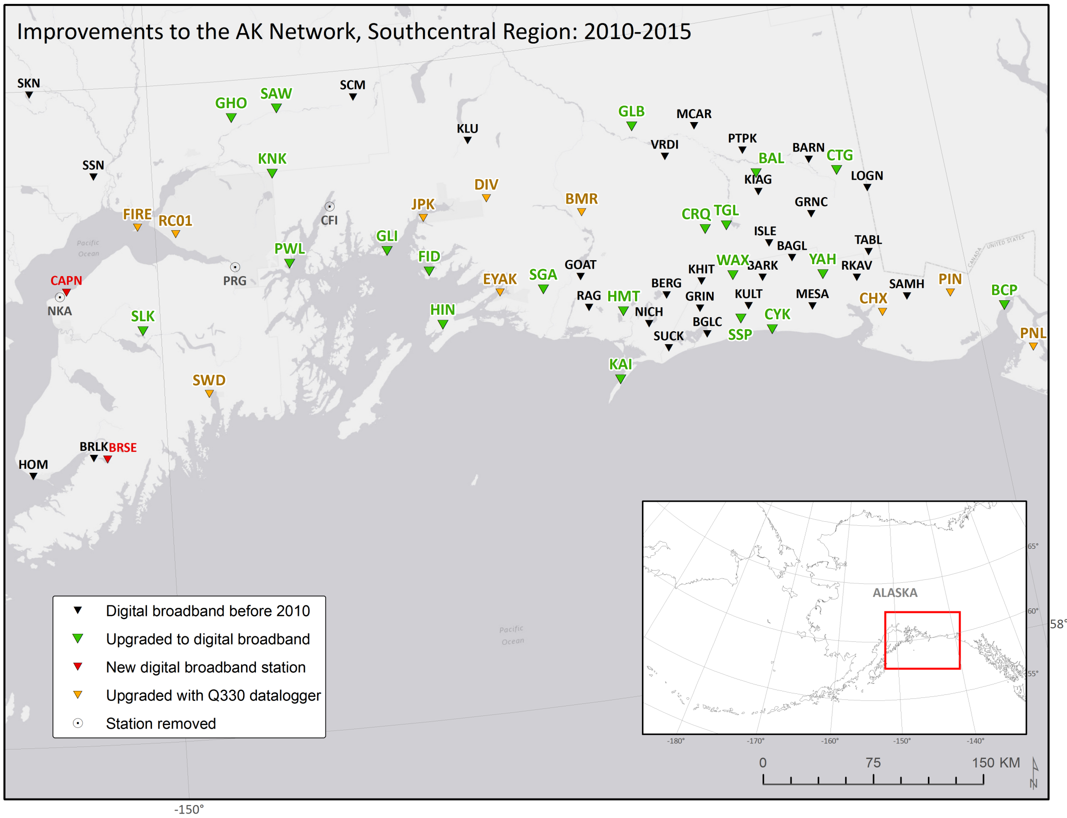

Figure 2. Modernization of the Southcentral Area Network.

During the same period, we upgraded 19 Anchorage-area strong motion stations with ARRA-funded Basalt and Episensor instruments provided by NSMP, installed two new strong motion stations with ARRA-provided instruments, and used state funds to bring several Fairbanks-area strong motion stations back online.

Beginning in 2013, our focus shifted away from modernization and expansion towards improving data quality and data return. Redesigns of our power systems and radio networks reduced station outages and maintenance trips, while judicious network reconfiguration allowed us to eliminate expensive satellite uplinks in Ultima Thule and McCarthy as well as numerous leased circuits. Support from this award made possible the many flight and technician hours needed to perform this work.

The results of our improved telemetry and station power can be seen in Figure 3. Our data return rate has gone up each year since 2011, with a total gain in annual average of about 8%. Much of this improvement came from higher data return during the difficult winter months (a 30% improvement for January), especially from critical southcentral sub-networks.

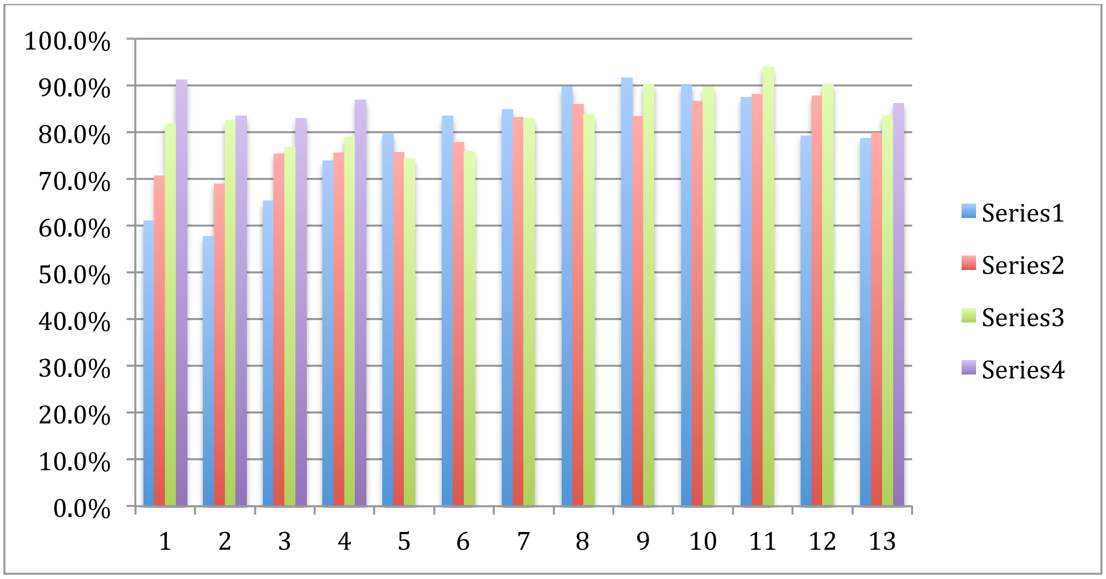

Figure 3. 2012-2015 monthly data return rates for AK network (2012-blue, 2013 – red, 2014 – green, 2015-purple). Column 13 indicates average annual rate of return.

By the end of the reporting period, advancements in data return, quality of instrumentation, and network density had enabled us to report more and smaller earthquakes (Fig 4). Magnitude of completeness for the catalog decreased from 1.4 to 1.1 in the Southcentral and Interior Alaska regions.

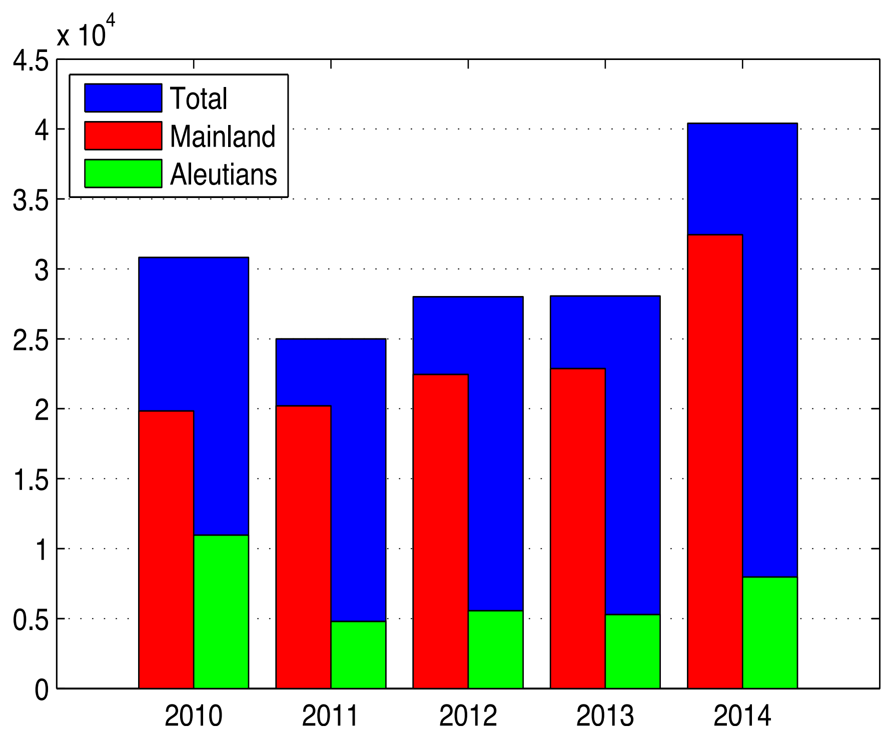

Figure 4. Seismic events reported in Alaska and neighboring regions of Canada in 2010-2014. Note steady increase in numbers of reported events for mainland Alaska. This increase can be attributed to improvements in field instrumentation and network performance.

Equally important, we have dedicated ourselves to stewardship of the remote places we rely on for data. Whenever possible, we remove disused equipment and infrastructure, much of it dating to the 70s and 80s. In a few cases, such as Portage Glacier and College Fiord, we have completely cleaned up and closed out sites that had become redundant. This is expensive, helicopter-intensive work.

Data Analysis

In addition to the 136 AEC-operated field sites, we import data in real time from about 300 other stations in Alaska and 100 Global Seismic Network stations around the world. The non-AEC stations in Alaska are operated by several of our partners, including the Alaska Volcano Observatory (210 stations), National Strong Motion Project (40), National Tsunami Warning Center (15), USArray (14), and others. Altogether, data from about 550 stations is processed simultaneously as a combined dataset for detections of local, regional and teleseismic events.

The 2014 record of 40,000 located events is attributable not only to improved instrumentation but also exploitation of those improvements through better data analysis. During the reporting period we established a stable team of experienced analysts and implemented ongoing evaluation and training to ensure consistent, high-quality processing of events, including special attention to manual scanning procedures and classification of different event types. This human element is complemented by ongoing refinement of our automatic location algorithms (Fig 5).

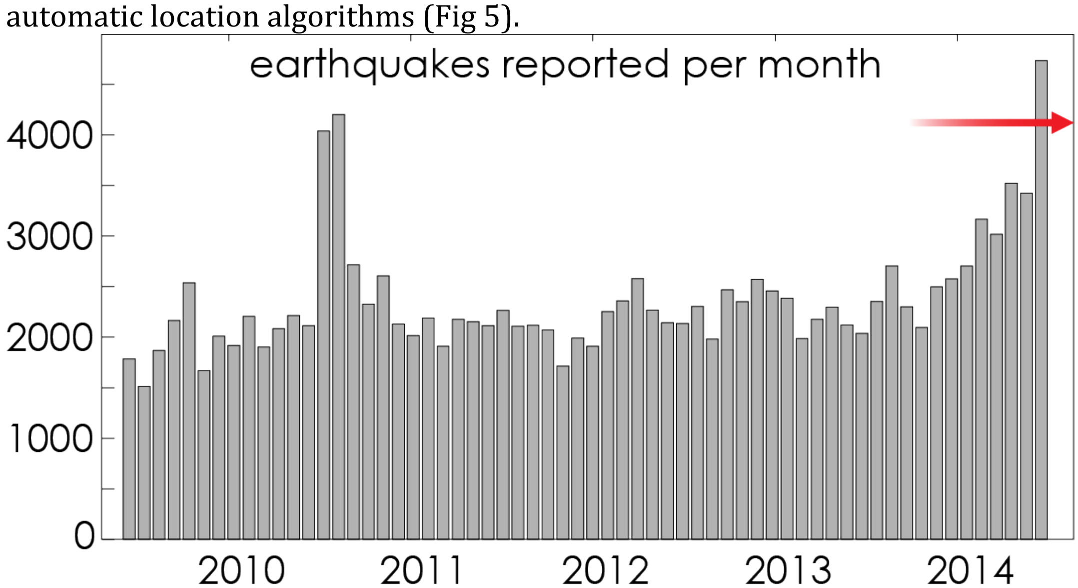

Figure 5. Earthquake reporting trend over the past five years. Earthquake reporting rates are up sharply since fall 2013. This reflects improved station up time and the implementation of more aggressive detection thresholds. Mid-2014 also reflects a confluence of aftershock sequences.

On the computing side, during this reporting period we migrated completely from Sun to MacPro work stations while executing two major upgrades to Antelope, our acquisition software. We are now in the process of upgrading our server infrastructure and migrating vital computing infrastructure out of our lab and to the more robust computing center in the Butrovich Building, which houses the university's statewide Office of Information Technology. This is a critical component in our continuity of operations plan.

This reporting period also saw our transition to ShakeMap 3.5 along with work to improve AEC-produced ShakeMaps by refining how our attenuation models and event magnitudes are chosen.

Progress on Metadata Development and Implementation
The station metadata manager updates the Earthquake Center master station database after any implemented field changes. The metadata is then submitted to IRIS DMC in the form of dataless SEED files. Accuracy of station metadata is validated through analysis of magnitude residuals, calibration pulses and visual waveform inspection. Beginning in 2012, the Earthquake Center began working with Dr. Carl Tape of GI-UAF on waveform modeling for validating sensor orientation. Several sensor mis-orientations in the AK and AT networks were identified from the analysis and later corrected in the field.

Data Management
Waveforms and picks are available to ANSS participating networks according to ANSS standards (within 30 seconds for high-risk urban and mod-high hazard areas, 60 seconds for national standard).

We archive continuous waveforms for essentially all non-structural seismic stations in the state. Continuous broadband channels for the AK network are sent to the IRIS DMC as they are acquired, and continuous strong motion data for the AK and NP networks is sent to the strong motion center in Menlo Park as it is acquired. A subset of broadband stations from the AK network is sent to the National Tsunami Warning Center in real time, and a subset of broadband and short period stations is shared with the Alaska Volcano Observatory as the data is acquired.

Continuous waveform archives on RAID disks are available from 1998. Continuous waveforms prior to 1998 are available on tapes, though we continue to transfer historical data from tapes to RAID disks. Segmented waveform archives are available from 1988 through 2012. We discontinued segmented archiving in 2013.

Processed event parametric data (hypocentral parameters and magnitudes) is available on the AEC website through the recent events map for the last three days and through the PDL system for the last seven days. Full event catalogs are available through the AEC web catalog search with about a three-month delay and through the online ANSS catalog with delays of three to seven days. All processed event data is submitted to the ANSS catalog (with no magnitude cut-off), including quarry blasts, glacial quakes, and rock/ice avalanches. Automatic event data is available with delays of one to five minutes through the AEC recent earthquakes page and the NEIC realtime web maps (through the PDL and recently COMCAT system). These are filtered based on various criteria to ensure mislocated and bogus events do not reach the public.

Progress on ANSS Integration

We receive real-time waveform data from the National Tsunami Warning Center (about 15 stations), Alaska Volcano Observatory (about 200 stations), Canadian Seismic Network (about 30 stations), TA sites in Alaska and Canada (14 stations), ANSS backbone network (2 sites in Alaska) and Global Seismic Network (about 100 stations). Alaska TA stations are a new addition to the combined regional network.

The waveform data is integrated into real-time and off-line data processing at AEC and sent in real time to the NTWC (subset of regional broadband stations), AVO (all regional stations), IRIS (all AK broadband stations), NEIC (subset of AK broadband stations), and NSMP (Anchorage strong motion sites).

Continuity of operations

Keeping the Earthquake Center functioning during an emergency remains a challenge, but we are actively working to increase our resilience. In 2014 we scrapped our partial 2010 continuity of operations plan in favor of a new emergency response plan based on accepted principles of incident response management. Implementation is in the early stages, but this plan creates a framework that should function well in all types of emergencies.

Remaining challenges include the absence of automated backup power, which makes interruption of data flow likely in the event of an off-hours power outage. We also have no backup facility to work from in the event that the Geophysical Institute is cut off from power or communications or if it is evacuated.

If the Earthquake Center should go offline during an emergency, the Anchorage AVO office and NTWC operations center in Palmer would continue producing reviewed earthquake locations for significant events in the state. However, when the Earthquake Center is offline, most seismic data in the state becomes inaccessible. This includes most of the in-state data relied on by NTWC for rapid tsunami forecasting.

Meeting ANSS goals

The magnitude of completeness is about 1.0-1.2 in the most densely instrumented parts of the network (central Denali Fault region including areas north as far as Fairbanks and south as far as Anchorage, upper Cook Inlet, Kenai Peninsula, Prince William Sound and St. Elias regions). Therefore, the requirement of 2.0 completeness for high-risk urban areas in Alaska (Anchorage) is met (Standard 1.1). The magnitude of completeness is higher than 2.5 for the central and western Aleutian Islands, southeast Alaska, the Seward Peninsula, and areas to the north (including some of the pipeline corridor). For these regions the magnitude of completeness is 3.0 at best, achieved only in parts of the Aleutian arc where short-period analog seismic data is available (Fig 6). The value for Mc is difficult to estimate for the remaining regions since very little data is available for the analysis due to lack of instrumentation.

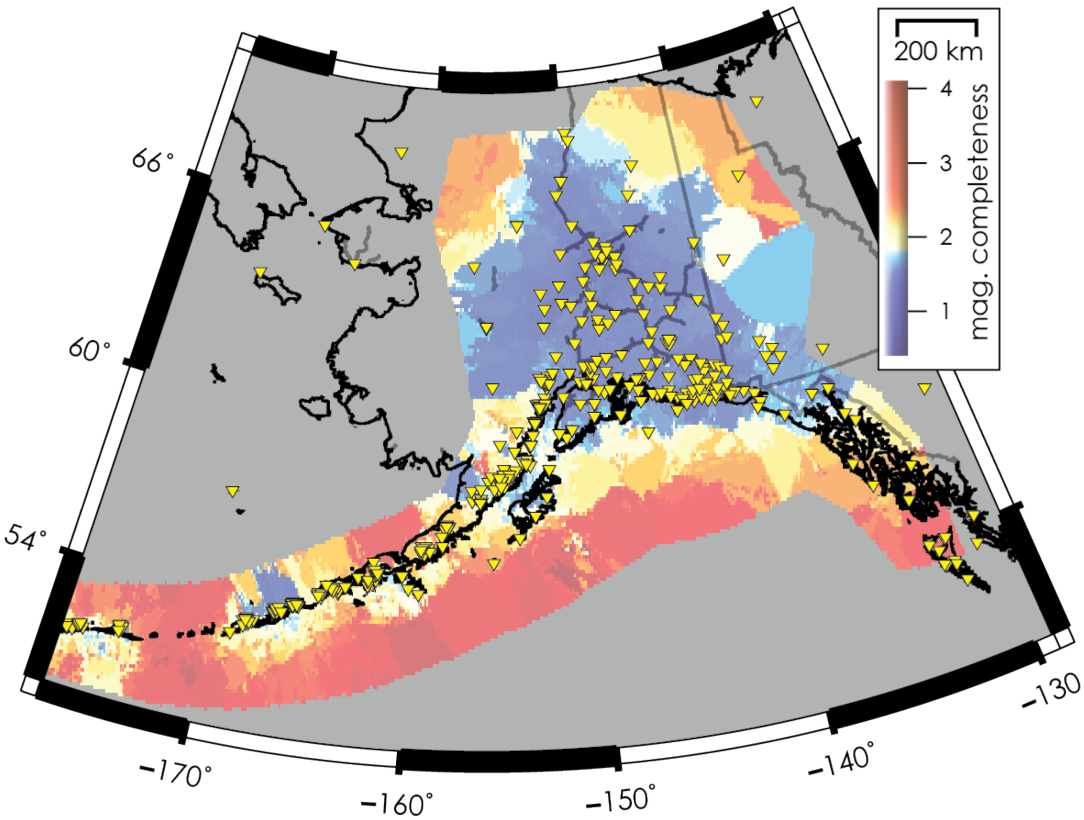

Figure 6. Magnitude of completeness based on the past five years of catalog data. ANSS performance targets for magnitude are successfully met in south-central Alaska and the Interior. Much of northern, western and southeast Alaska fall within the moderate-high hazard area, but are insufficiently instrumented to achieve the 2.5 magnitude of completeness proscribed by the ANSS performance standards.

Epicenter and depth uncertainties vary across the network. Uncertainties are best (less than 5 km) in areas with lowest magnitude of completeness. Values less than 20 km are achieved over a wider area, from Kodiak Island in the south to Fairbanks in the north, and from the Yakutat area in the east to the Denali National Park in the west. However, uncertainties are greater than 20 km for much of the Aleutian Islands, and again, in the west, north, and southeast of Alaska.

The ANSS hypocenter post time standards of two minutes for high-risk urban areas and four minutes for moderately high hazard areas have been achieved in Alaska for nearly all cases (Standards 2.1 and 2.2). During large aftershock sequences, there may be a delay in the final processing of a large number of detections.

While we were able to achieve improvements in magnitude of completeness and location errors after modernizing our network with digital telemetry and broadband sensors, we believe that a key factor in improved capabilities in terms of magnitude of completeness and location uncertainties would be augmenting the existing seismic network with new stations in sparsely instrumented areas.

The best opportunity for this improvement will be selective adoption of USArray stations at the end of their Alaska deployment. The Earthquake Center is already fully involved in the USArray project, coordinating with IRIS personnel to achieve a successful deployment while positioning Alaska for better statewide monitoring moving forward. This will be an important focus over the next five years, much in the way that modernizing the southcentral network was a keystone accomplishment of the last five.

Bibliography

This cooperative agreement had no research component. Funds from this award were not used to support research and were not used to prepare of publications.