SEISMIC NETWORK OPERATIONS IN ALASKA

Final Project Report

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Abstract

AEIC and AVO jointly operate, record and analyze data from ~500 seismic stations, with ~1100 channels of seismic data throughout Alaska and neighboring areas of Canada and Russia. Part of the operation and maintenance of the network is supported by USGS/NEHRP.

The combined Alaska Regional Seismic network comprises numerous short-period sensors, 120 broadband sensors, and 94 real-time accelerometers, 49 of which are stand-alone installations and 45 of which are co-located with broadband and/or short-period sensors.

The ANSS-supported component of the Alaska Regional Seismic Network is comprised of 34 short-period sites and 28 broadband sites (23 of which have co-located strong motion sensors), 36 real-time strong motion sites in Anchorage, and 10 real-time strong motion sites in Fairbanks.

Many of these stations are in remote areas with extreme climatic conditions and can only be reached by helicopter, after the snow has melted. The major thrust of this work is to provide continued operation of the south Alaska seismic network together with the routine analysis of the combined network data.

Investigations Undertaken

Seismicity

For the period between February 1, 2007 and January 31, 2010 AEIC reported a total of 73,237 events within the combined seismic network. Seismicity in the western Aleutian arc is supplemented by teleseismic locations in cooperation with NEIC. A map of all reported events is shown in Figure 1. The events range in depth from 0 to 280 km, with the deepest earthquakes located in the central Aleutian Arc. Figure 2 shows a cross-section across Cook Inlet region in south-central Alaska illustrating a typical WBZ seismicity distribution in the region. The magnitude range of reported events is between -0.3 and 7.1. There were 1074 events with magnitude 4.0 or above (~30 events per month on average) and 176 events with magnitude 5.0 or above (~5 events per month on average). Twenty events had magnitudes M_W 6.0 or above. The largest earthquake (M_W 7.1) occurred on December 19, 2007 in the Andreanof Islands region of Alaska.

Earthquake Sources

The AEIC routinely determines P-wave first motion focal mechanisms for earthquakes with M_L>=2.8 located within the network core area, and other special events of interest. 992 first motion focal mechanisms for this time period were determined; magnitudes ranging between 1.9 and 5.9, and depths between 0 and 222 km (Figure 3). Regional seismic moment tensors are determined for earthquakes with M_W>= 3.8 in the mainland Alaska and M_W>=4.0 in the Aleutians, depending on the data availability and broad-band station coverage. The AEIC determined a total of 172 moment tensors for this time period with the magnitudes M_W ranging between 3.7 and 6.6 (Figure 4).

2007-2010 Field Work

AEIC maintains about 243 sites throughout Alaska. Many are remotely powered and have telemetry. We made about 450 site-visits during these three years. This included routine maintenance, adding 18 new stations, closing four, adding real-time telemetry to 30 urban strong motion sensors, upgrading 6 to short period digital and upgrading 15 to digital broadband.

Upgrading included: hardening the sites by installing huts, redundant solar power systems, and back-up primary batteries. At several sites we replaced or added the old analog short period stations with broad-band digital systems. Many of the older analog short period sites required radio upgrades to comply with the new, narrow-band FM standards. Several of these had VCO upgrades to the more modern, non-gain ranging McVCO.

We added Murphy Dome to the “nodes” in Kenai, Homer, Anchorage, Palmer and Valdez, where the analog data is digitized, time-tagged and appropriately formatted for transmission over “high capacity DDS circuits" or over the internet.

The telemetry system includes about 60 Freewave digital radio links, 25 VHF/UHF analog radio links, 24 leased analog, 7 digital telephone circuits, 20 DSL and 3 VSAT satellite earth-stations. We also use internet at several village schools and leverage the University of Alaska’s intranet services at some of the "nodes.”

Changes Implemented in this Reporting Period

Summary Event Database
AEIC personnel have implemented a summary event database that combines multiple sources of event information and is then utilized by various real-time and off- line processing modules. First, the summary database receives real-time event locations and magnitudes from two independent real-time earthquake detection systems. Only one system feeds the summary database at any given time, which is set up through the orbxchange module. This provides an automatic backup mechanism in case of the failure of one of the systems. Second, the summary database incorporates reviewed event locations and magnitudes from ATWC and NEIC via an e-mail parsing mechanism. Next, quick event reviews from the seismologist on duty are entered into the database. Lastly, the analyst processes the earthquakes. All earthquake parametric information is stored in this database for two weeks and then archived into a separate database. Multiple solutions for the same event are assigned a priority level based on pre-set criteria. This database is currently used by the ShakeMap module, for the real-time earthquake map display on the AEIC website, and by a prototype system for information delivery to the Emergency Operation Centers around the state. In addition, a feature we specifically built into this system allows an event to retain unique event ID's with multiple origins set in a priority scheme. This facilitates the feeding of QDDS or EIDS systems requiring updates with a consistent event ID.

We have incorporated ~120 GSN stations into our earthquake processing. We now see events from all over the world in near real time. This considerably improves regional processing by eliminating teleseisms from falsely building into regional events. Along with our previous redesign of our processing grids and our filter of noise induced phase picks, automatic seismic event locations and magnitudes vary little from the reviewed solutions. In addition, error estimates are calculated for all automatic locations.

Implementation of ShakeMap System at AEIC
AEIC's ShakeMap (SM) system became the primary source of SM's for Alaska. The real-time SM production is controlled by the Antelope seismic monitoring system. A SM generation sequence is triggered once a new SM-eligible event appears in the event database (M>=3.5 or MMI>=II at the epicenter). This database receives automatically generated hypocenters as well as analysts-reviewed solutions from AEIC, NEIC and WC/ATWC. An association algorithm maintains the consistency of event identification numbers in the database.

A SM is generated and posted on the AEIC website a few minutes after an eligible event is recorded in the database. The processing time mostly depends on the number of waveforms that are being utilized in the calculation process. Afterwards, several SM updates may be issued for the same event as new data become available and more reliable hypocenters are calculated. Furthermore, a manual run can be executed for significant events in order to utilize any additional information, such as extended source geometry, data from additional sources, etc.

Implementation of Pipeline Seismic Monitoring Project
All 11 Pipeline seismic monitoring stations are now operational, and the ground-motion threshold alarms are implemented for the Pipeline Seismic Monitoring project. Also, additional custom Pipeline ShakeMaps are calculated for events in the pipeline corridor.

Implementation of Earthquake Notification System for Emergency Managers in Alaska
A new system has been designed to provide real-time and reviewed earthquake information to local Emergency Services offices. It is now installed in the following population centers in the state: Fairbanks, Anchorage, Valdez, Seward, Soldotna, and Kodiak, as well as the State Department of Homeland Security and Emergency Management. The system resides on a stand-

alone MAC computer that displays real time earthquakes on a state map with audio announcements of earthquake locations and magnitudes.

Network Performance Standards

1.1. Magnitude Completeness Level

Figures 5 and 6 illustrate 90% magnitude completeness levels in the AEIC authoritative region and in a high-risk urban area (Anchorage), respectively. Calculations are done using Matlab-based ZMAP package (Wiemer, 2001). In the AEIC authoritative region, Mc varies from 1.2 to 1.8, while in the Anchorage region Mc varies from 1.2 to 1.4. Both measures are below ANSS standards (2.0 for hi-risk urban and 2.5 for mod-high hazard areas). However, we suspect that in northern and western parts of the authoritative region Mc may be higher than the overall estimated values due to the more sparse network coverage.

1.2 and 1.3. Epicenter and Depth Uncertainty

Figure 7 illustrates epicenter and depth uncertainty in the AEIC authoritative region and in a high-risk urban area (within 50 km radius of Anchorage). Table 1 lists percentage of events that satisfy ANSS performance requirements in terms of epicentral and depth uncertainties, separate for 3 yearly time periods and the whole reporting period, both for the whole authoritative region and for the Anchorage region. Uncertainty measures are calculated as part of our earthquake location program and saved in a relational database (Pavlis et.al., 2004). Error ellipses are calculated for a 67% confidence level. This analysis indicates that we don't meet location error targets for all reported events yet. Larger errors are associated with smaller events that have very few arrivals and with events outside of the network core region.

Table 1: Percentage of events satisfying ANSS epicentral and depth uncertainty requirements.

Time period	Authoritative region (mod-risk)						Anchorage region (hi-risk)					
	All magnitudes			M>=2.5			All magnitudes			M>=2.0		
	# ev	epi <5 km	dep <10 km	# ev	epi <5 km	dep <10 km	# ev	epi <2 km	dep <4 km	# ev	epi <2 km	dep <4 km
Feb.2007-Jan.2008	14,461	89%	97%	1099	86%	96%	615	84%	94%	120	96%	100%
Feb.2008-Jan.2009	18,055	87%	96%	1086	81%	92%	767	71%	86%	111	83%	97%
Feb.2009-Jan.2010	18,394	79%	91%	1079	78%	91%	797	81%	81%	125	83%	91%
Feb.2007-Jan.2010	50,910	85%	95%	3264	82%	93%	2,179	74%	87%	356	87%	96%

2.1. Hypocenter Post Time

In 2009, 63% of events in the AEIC authoritative region had first hypocenter solutions posted within the 4 minute requirement (Figure 8). Mean post time latency was 4.6 min. Within the high risk area, only 35% of hypocenters were posted within the required time of 2 minutes (Figure 8). Mean post time was 5.7 min. Longer latencies are associated with smaller events that have very few detections, therefore it takes longer for the system to find an appropriate solution. For events with magnitudes 2.0 or greater in the high risk region, 78% of events had first hypocenters posted within 2 minutes, with a mean latency of 2.8 minutes. For events with magnitudes 2.5 or greater within the authoritative region, 78% were reported within the 4 minute latency requirement (Figure 9).

3.1. Reviewed Hypocenter Post Time

AEIC seismologists-on-duty routinely review events with magnitudes 3.5 or greater in the authoritative region. Not all of these events trigger earthquake alarms, since some are deep or located in

remote areas and are not likely to be felt. In 2009, 126 earthquakes required seismologist-on-duty review in the authoritative region. 48% of events were reviewed within a 30-minute window, and additional 18% reviewed with up to 1-hour delays. Only a handful of events was reviewed within a 10-minute window of the origin time. Five events within the high risk region met criteria for seismologist quick review, four had reviewed parameters posted between 12 and 30 minutes, and one event was reviewed with a 50-minute delay.

References

Pavlis, G.L., F. Vernon, D. Harvey, and D. Quinlan, The generalized earthquake-location (GEN-LOC) package: an earthquake-location library, Comp.&Geosci. 30, 1079-1091, doi:10.1016/j.cageo.2004.06.010, 2004.

Wiemer, S., A software package to analyze seismicity: ZMAP, Seism. Res. Lett. 72, 373-382, 2001.

Figures

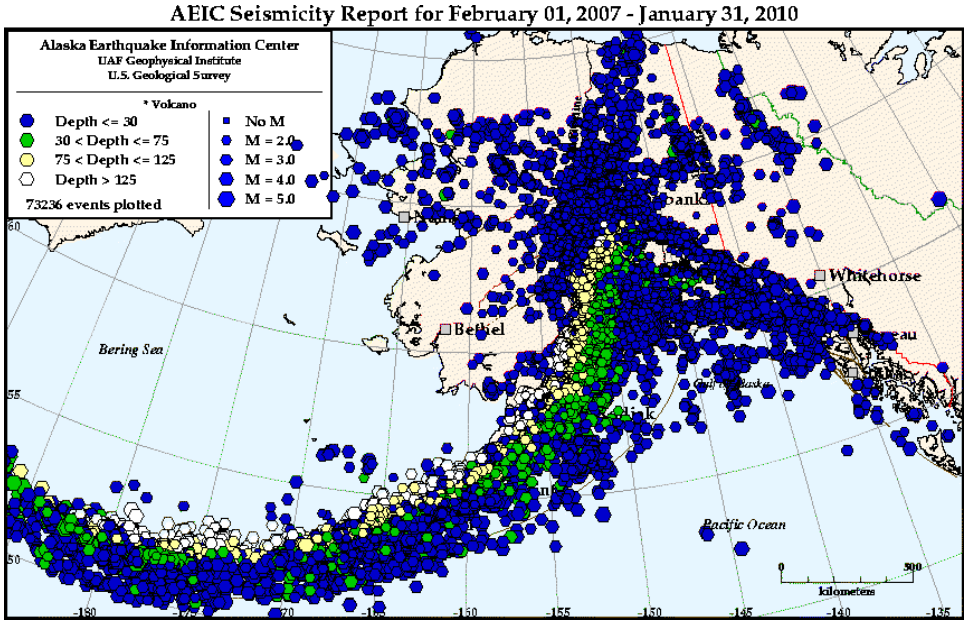


Figure 1. Map of events reported by AEIC for the period between February 1, 2007 and January 31, 2010 within the combined Alaska regional seismic network.

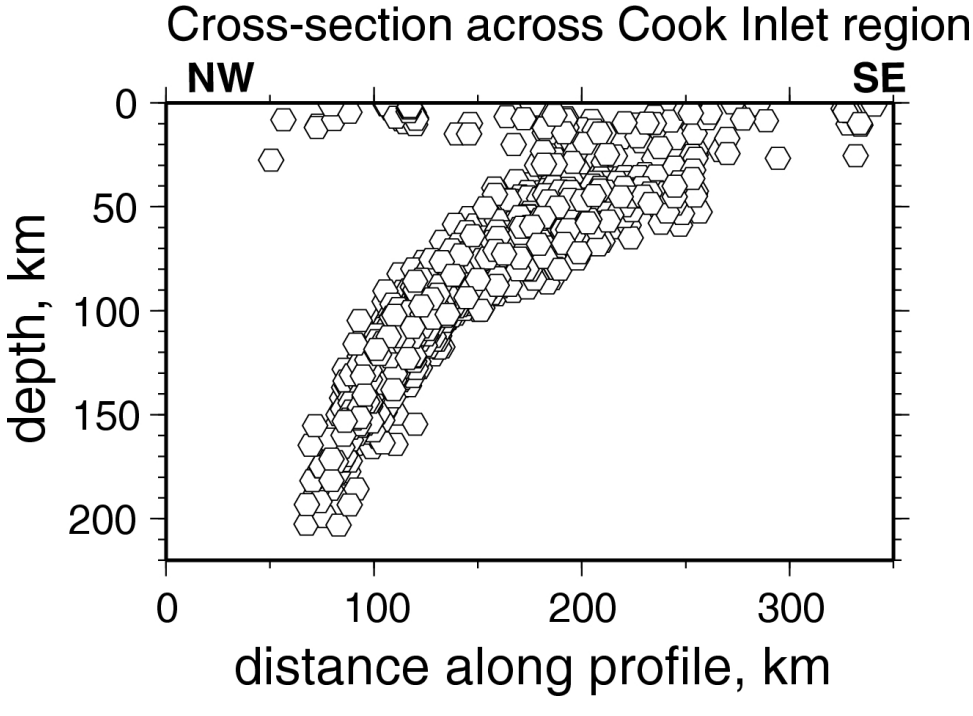


Figure 2. Cross-section across Cook Inlet region in south-central Alaska illustrating a typical WBZ seismicity distribution in the region.

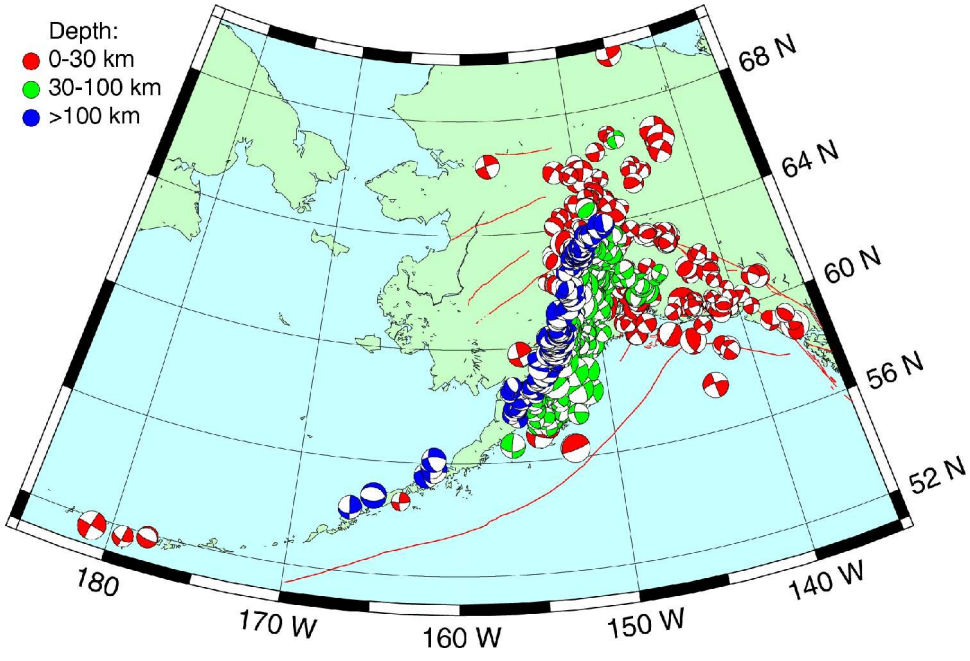


Figure 3. P-wave first motion focal mechanisms for earthquakes that occurred between February 1, 2007 and January 31, 2010.

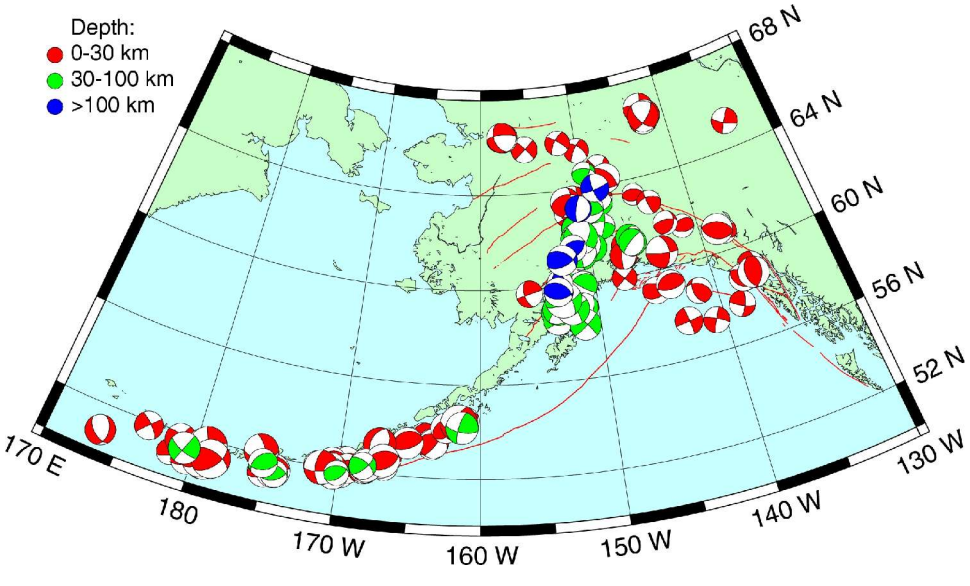


Figure 4. Regional moment tensor solutions for earthquakes that occurred between February 1, 2007 and January 31, 2010.

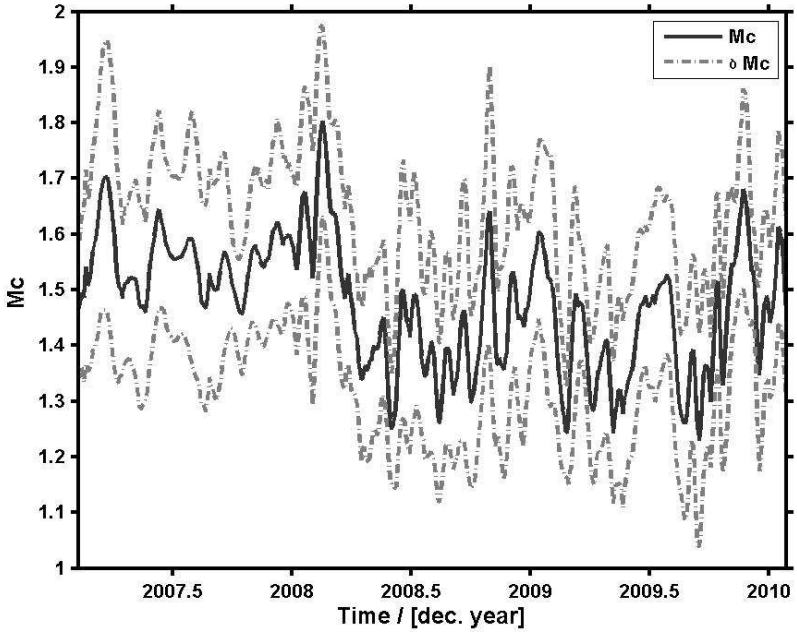


Figure 5. Magnitude completeness levels within AEIC authoritative region for February 2007- January 2010 above which 90% of earthquakes are routinely determined. Calculations are done based on 50,939 events with 500 event running window.

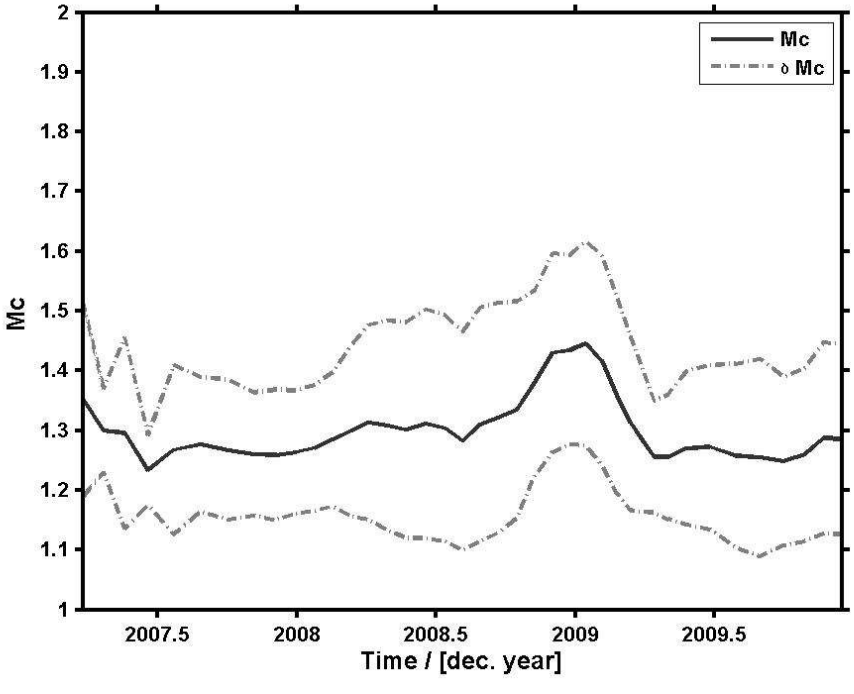


Figure 6. Magnitude completeness levels within the high-risk urban area (within 50 km radius of Anchorage) for February 2007-January 2010 above which 90% of earthquakes are routinely determined. Calculations are done based on 2,179 events with a 200-event running window.

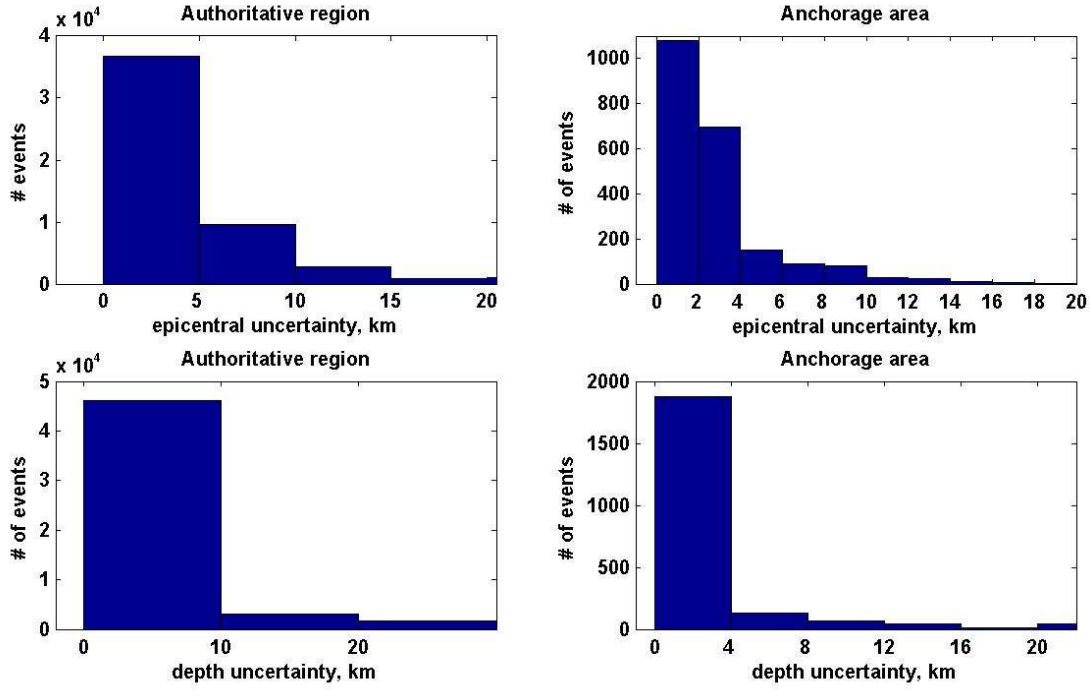


Figure 7. Epicenter (upper panel) and depth (lower panel) uncertainty for earthquakes within the AEIC authoritative region (left column) and high risk Anchorage area (right column). Events are binned according to ANSS location uncertainty standards: high risk areas - 2 km for epicentral and 4 km for depth uncertainties; mod-risk areas - 5 km for epicentral and 10 km for depth uncertainities.

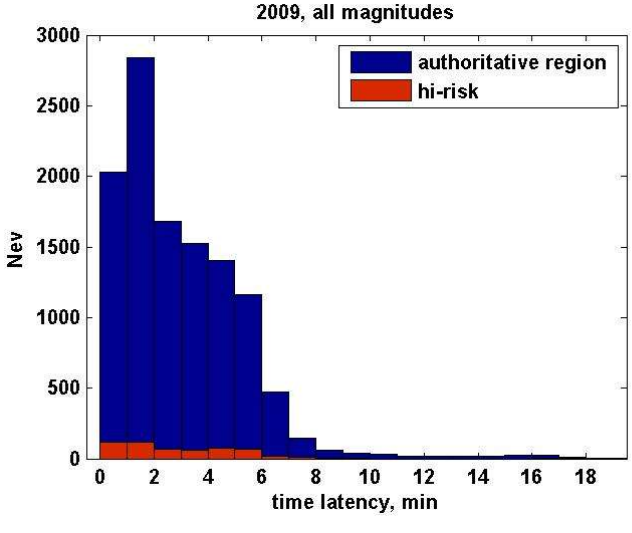


Figure 8. Time latencies between computed origin time and first posting of hypocentral information for all automatic events: authoritative region - blue bars, high risk region (Anchorage) - red bars.

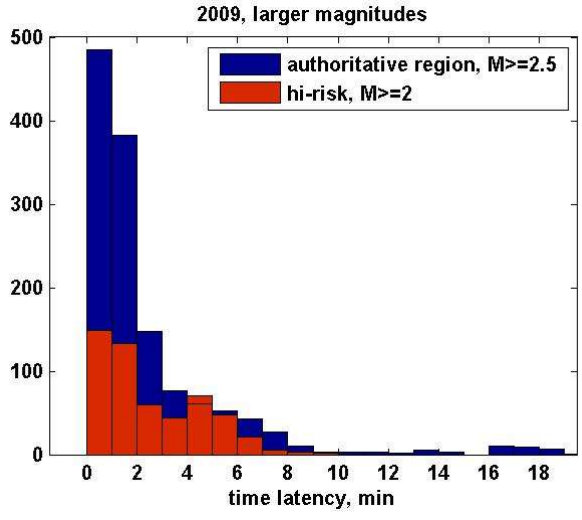


Figure 9. Time latencies between computed origin time and first posting of hypocentral information: authoritative region, magnitudes 2.5 or greater - blue bars, hi-risk region (Anchorage), magnitudes 2.0 or greater - red bars.

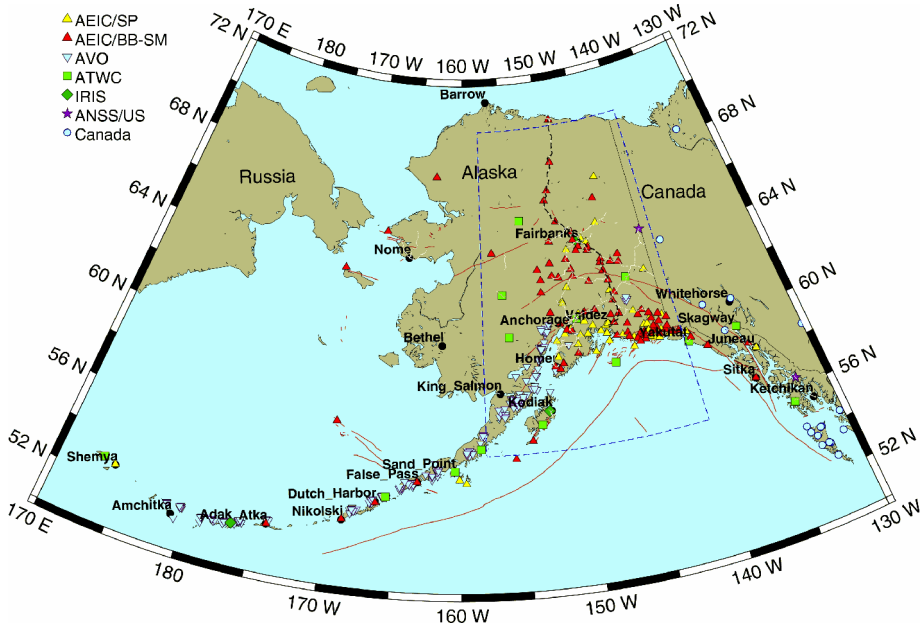


Figure 10. Stations of the combined Alaska regional network as of January 2010. AEIC-operated stations are shown in yellow (short period) and red (broadband or co-located broadband and strong motion) triangles. Also shown stations operated by: Alaska Volcano Observatory (AVO) - inverted purple triangles; Alaska Tsunami Warning Center (ATWC) - green squares; Global Seismic Network - green diamonds; Advanced National Seismic Network - purple stars; Canadian network – blue circles. The AEIC authoritative region is shown by blue dashed rectangle.

Reporting

During the contract period, the Alaska Earthquake Information Center has released the following documents and publications on a regular basis:

Weekly Seismicity Reports
Weekly reports include summary listings of all located earthquakes in or near Alaska for the previous week along with the following information for each event: date and time of origin; latitude, longitude and hypocentral depth; magnitude; solution quality parameters; and a brief comment regarding approximate region, alternate magnitudes, and any felt information. Each weekly listing also includes an epicenter map of the whole state (including the Aleutian Islands), a close-up map focusing on the more heavily populated central and south central regions, and a brief verbal summary of largest or most significant earthquakes to have occurred during the week. The seismicity maps and earthquake summaries are available over the Worldwide Web, updated on a weekly basis.

Monthly Earthquake Catalogs
Approximately two to four months after the end of each month, AEIC issues "Earthquakes in Alaska," a monthly catalog of earthquakes in and near Alaska. Each catalog includes the following: full-state seismicity maps; south-central seismicity maps; cross-sections of the two Wadati-Benioff Zones that exist beneath Alaska; and a comprehensive listing of the month's earthquakes including additions from the National Earthquake Information Center, the Pacific Coast and Alaska Tsunami Warning Center, and data from the Geological Survey of Canada where appropriate. A "Highlights" section discusses in detail several of the month's most interesting or significant earthquakes, each of which is presented with an individual map and, when available, its focal mechanism. Detected and located mine and quarry blasts are also itemized in the monthly catalogs.

Information Releases
As a part of the 24-hour earthquake monitoring carried out by AEIC, earthquakes with magnitudes large enough to be considered significant (M>=3.5 in the mainland Alaska and M>=4.0 in the Aleutians), or earthquakes which were felt by locals, will have a formal "Information Releases" issued. The Information Release is sent out in two forms: electronic mail is broadcast to a suite of recipients along with a text message providing location, magnitude and any other pertinent information. Also, a FAX release is transmitted including all the above information as well as a map illustrating the epicenter of the earthquake. These email and FAX releases are sent to numerous state, local, and federal government agencies, news media, utilities, other seismic observatories, and interested parties. In addition, all Information Releases are now available on the Web.

ANSS Catalog Contribution
We have implemented regular submission of our earthquake catalogs to the ANSS system at UC Berkeley. Catalogs are submitted several days after completion of each day's processing.

Outreach and Education
During the contract period, faculty, staff, and students at AEIC conducted a variety of outreach activities to school children and the general public, as well as local, state, and federal government officials. These activities included lectures, tours, interviews and correspondence. Our outreach

contacts took the form of AEIC facility tours, offsite demonstrations, public speaking engagements, responses to e-mail and telephone inquiries, and interviews with the news media.

Tours of the seismology laboratory were conducted an average of twice each month throughout the year. School groups and members of the general public, as well as emergency managers and visiting professionals, were shown AEIC facilities at the UAF Geophysical Institute. They were introduced to Alaska seismicity along with the methods and equipment employed by AEIC to monitor seismic activity and respond to significant earthquakes.

AEIC operated an earthquake information booth at the annual Tanana Valley State Fair in Fairbanks, and at the University of Alaska Fairbanks' annual "Science Potpourri" outreach event. Science Potpourri is a day-long event in which children and families are able to participate in experiments and demonstrations put on by the various departments within the UAF College of Natural Sciences. The earthquake information booth was staffed by AEIC personnel at each venue and featured an interactive display explaining how earthquakes happen and how seismometers are used to detect earthquake signals. AEIC staff also answered the public's questions during these events and distributed literature on earthquakes and emergency preparedness.

AEIC personnel responded to numerous e-mail and telephone inquiries from statewide news media regarding earthquake activity throughout the year.

Through the AEIC website, members of the public are able to access near-real time earthquake information and may submit "felt reports" through a link to the USGS Earthquake Hazards program. Felt reports submitted to AEIC by the public have resulted in numerous earthquake information releases for seismic events that were not large enough to automatically trigger AEIC's earthquake alarm system. In this way, the public has been able to participate in the earthquake monitoring process and assist AEIC in our response to seismic activity. The AEIC website also provides descriptions of personnel, network topology, network processing, earthquake occurrence, research activities, and links to a variety of related sites.

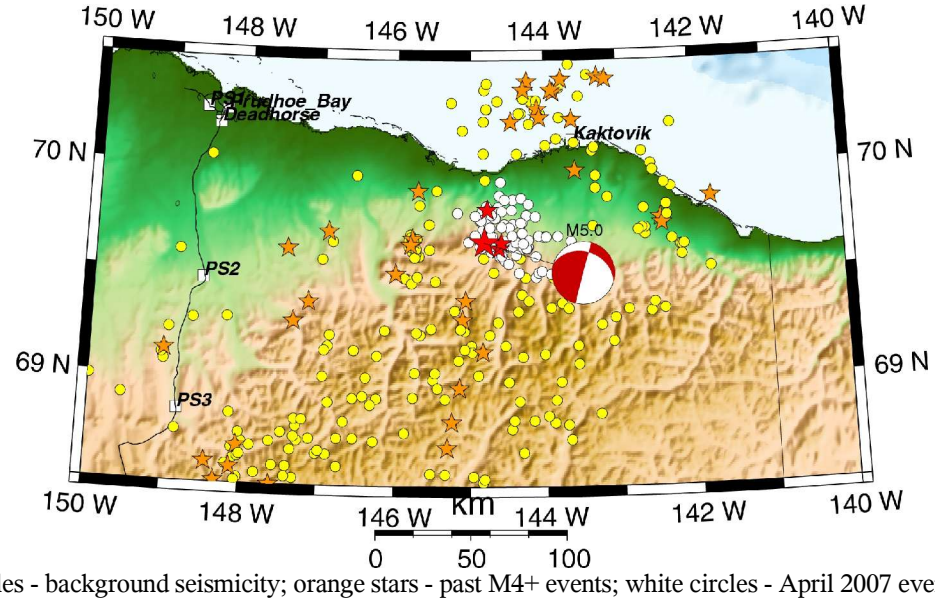
Significant Events

April 2007 Earthquakes northeast of Brooks Range

The Alaska Earthquake Information Center recorded an unusual sequence of earthquakes northeast of Brooks Range in April 2007. The sequence started with a few minor events (magnitude 3+) on April 8th. The largest earthquake (M5.0, large red star) occurred on April 28 at 5:20 UTC (April 27, 9:20 pm ADT). As of the end of April, AEIC have located 75 events in the area (white circles). Four events had magnitudes greater than 4.3 (red stars). A few events were felt in Kaktovik, located 37 miles (60 km) NE of the earthquake source area. Due to sparse seismic network coverage in the area (the nearest station is located 152 miles away), accuracy of the earthquake locations is poor, especially for the smaller events recorded by very few stations.

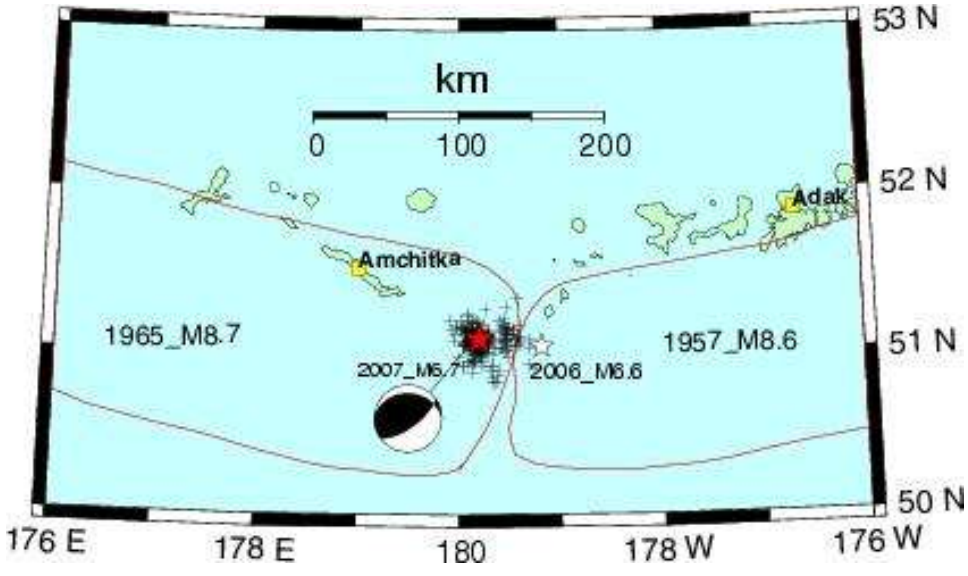
Seismicity in this region is characterized by a diffuse zone of activity extending from northeast Brooks Range, across the coastal plane and onto the Beaufort Shelf. Background seismicity is shown by yellow circles, while past magnitude 4 and greater earthquakes are indicated by orange stars. In 2006, five magnitude 4+ earthquakes occurred in this general area, with the largest event of M4.6 on February 20, 2006. Focal mechanisms obtained from the waveform modeling for the 2006 and 2007 events are consistent with the left-lateral strike-slip motion along this NE-trending

zone of seismicity, i.e. the northeast Brooks Range is moving northward relative to the lowland to the west.



yellow circles - background seismicity; orange stars - past M4+ events; white circles - April 2007 events; red stars - M4+ April 2007 events

M6.7 August 2, 2007 Andreanof Islands Earthquakes



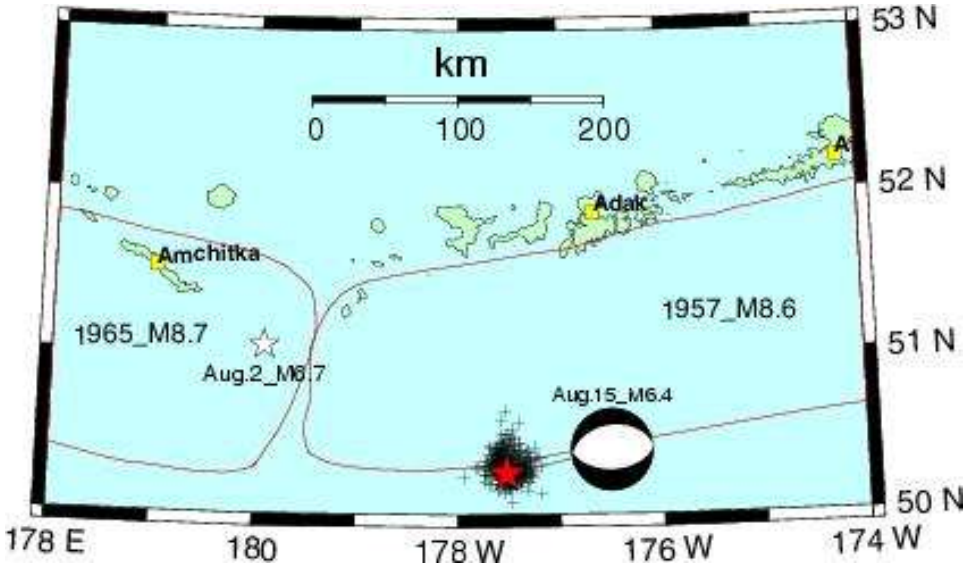
On August 2, 2007, at 3:21 am UTC (August 1 at 7:21 pm ADT), a strong earthquake (magnitude 6.7) occurred in the Andreanof Islands region of the Aleutian Islands (red star on the above map). The event was situated 86 kilometers (53 miles) east-southeast of Amchitka and 243 km (152 miles) west-southwest of Adak. No reports of this event being felt were received by AEIC. This earthquake is the largest to occur in the region since the magnitude 6.6 event on July 8, 2006 (white star on the map).

The AEIC located about 270 aftershocks with magnitudes 1.5 and greater through the end of the month (crosses). Of these, fifteen had magnitudes 4.0 and greater. The largest aftershock (M5.3) occurred 3 hours after the mainshock.

The August 2 earthquake occurred in the area separating the rupture zones of the 1965 M8.7 Rat Islands earthquake to the west and the 1957 M8.6 Andreanof Islands earthquake to the east (approximate extent of the rupture zones is shown in red). The westernmost area of the 1957 fault zone was re-ruptured repeatedly in the 1986 M8.0 and 1996 M7.9 earthquakes. The eastern portion of the 1965 fault zone was re-ruptured recently in the M7.7 earthquake on November 17, 2003. While the June 2006 sequence of earthquakes was located near the westernmost end of the 1957 rupture zone, the current event was located across the rupture zone boundary at the easternmost end of the 1965 rupture. All these events ruptured the boundary between the subducting Pacific and overriding North American plates.

Within the past ten years, the region shown on the map had on average two magnitude 6 or greater events per year. The Aleutian megathrust, where the two plates are being forced directly into one another, is one of the world's most active seismic zones.

M6.4 August 15, 2007 Andreanof Islands Earthquakes



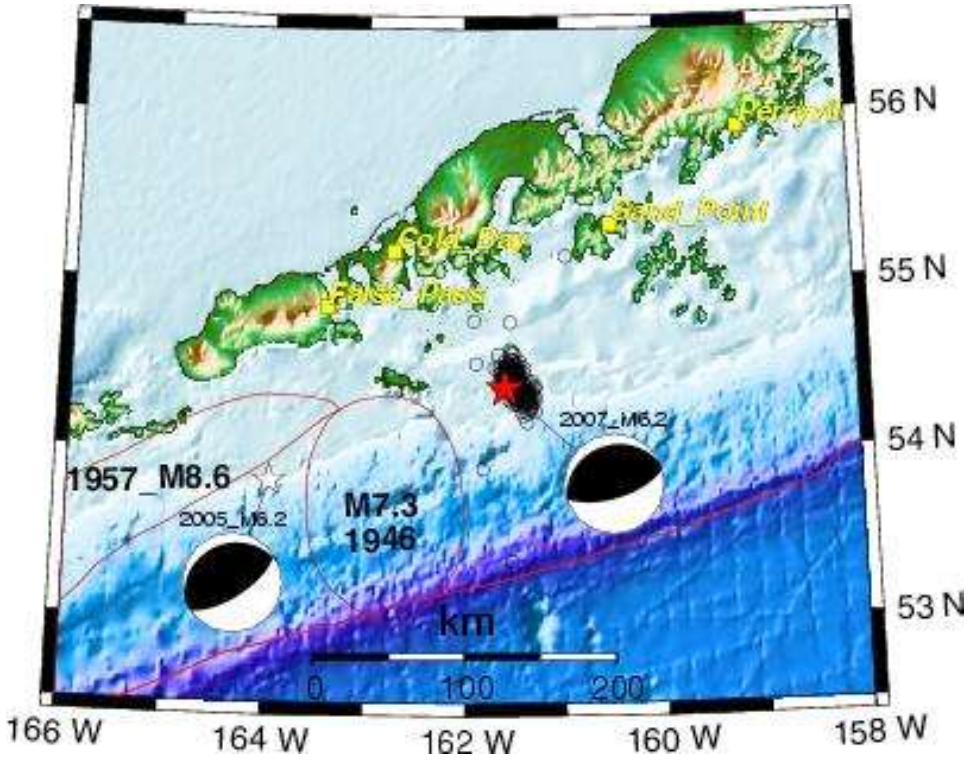
On August 15, 2007, at 10:22 pm UTC (12:22 pm ADT), a strong earthquake (magnitude 6.4) occurred in the Andreanof Islands region of the Aleutian Islands (red star on the above map). The event was situated 189 kilometers (118 miles) SSW of Adak and 282 km (176 miles) ESE of Amchitka. It was felt at Adak. No reports of damage have been received. This earthquake is the second magnitude 6+ event to occur in the region this month. A magnitude 6.7 earthquake (white star on the map) occurred on August 2 and was located 190 km (119 miles) NW of the M6.4 earthquake of August 15.

The AEIC located about 370 aftershocks of the M6.4 event within the first week after the mainshock. Of these, three had magnitudes 4.0 or greater. The largest aftershock (M5.3) occurred about 8 hours after the mainshock.

The August 15 earthquake occurred in the outer rise area of the Aleutian trench. The waveform radiation pattern indicates normal faulting which is typical for the outer rise events. This event was originated inside the subducting Pacific plate and is result of the plate bending as it enters the mantle. It was located updip of the rupture zone of the 1957 M8.6 Andreanof Islands earthquake (approximate extent of the rupture zones is shown in red).

The Aleutian megathrust, where the Pacific tectonic plate is being forced underneath the North American plate, is one of the world's most active seismic zones. Within the past ten years, the region shown on the map had on average two magnitude 6 or greater events per year.

M6.3 October 2, 2007 Alaska Peninsula Earthquake

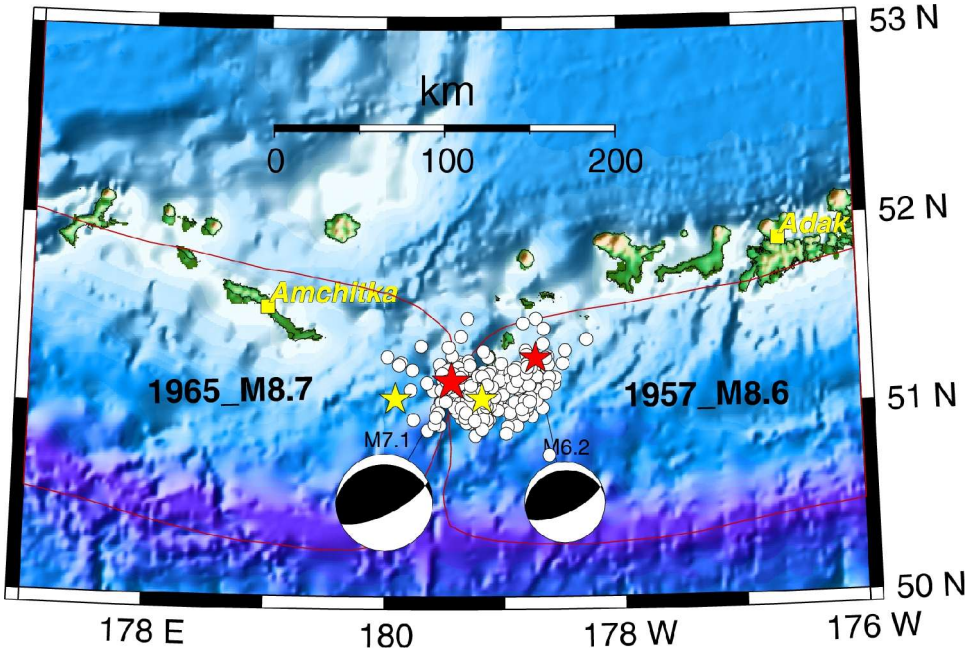


The Alaska Earthquake Information Center located a strong earthquake (magnitude 6.3) that occurred on Tuesday, October 2, 2007 at 10:00 AM local time (18:00 UTC) in the Alaska Peninsula region (red star on the above map).

The AEIC located over 300 aftershocks with magnitudes greater than 2 in two weeks after the mainshock (open circles). Eight aftershocks had magnitudes greater than 4 and three had magnitudes greater than 5. The two largest aftershocks of magnitude 5.2 occurred three minutes and three hours after the mainshock. The mainshock and the largest aftershock were felt in the Alaska Peninsula communities.

This earthquake is the largest to occur in the region since the M6.2 event on November 20, 2005 (white star on the above map).

M7.1 December 19, 2007 Andreanof Islands Earthquake



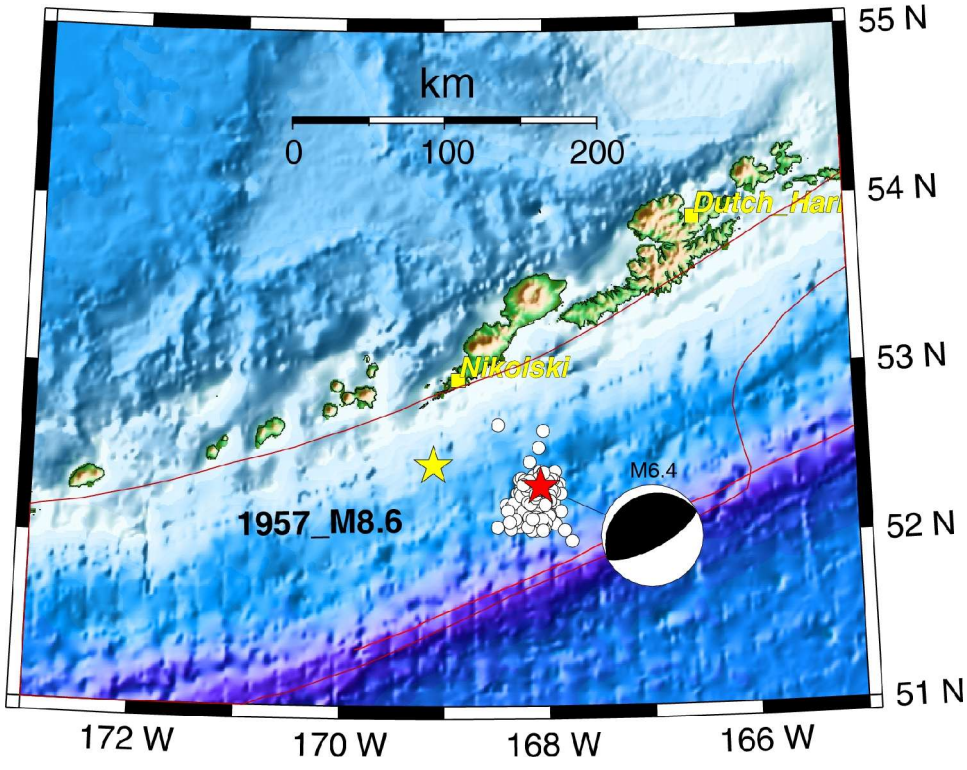
A major earthquake (magnitude 7.1) occurred in the Andreanof Islands region of the Aleutian Islands on December 19, 2007 at 12:30 am AKST (9:30 UTC) (red star on the above map). The event was situated 116 kilometers (73 miles) ESE of Amchitka and 209 km (130 miles) WSW of Adak. It was felt strongly on Adak, but did not cause damage.

The AEIC located over 250 aftershocks through the end of December (magnitudes 2.0 and greater, white circles). Of these, eleven had magnitudes 5.0 or greater. The largest aftershock (M6.2) occurred on December 20 at 10:24 pm AKST (December 21, 7:24 am UTC).

The M7.1 earthquake occurred in the area separating the rupture zones of the 1965 M8.7 Rat Islands earthquake to the west and the 1957 M8.6 Andreanof Islands earthquake to the east (approximate extent of the rupture zones is shown in red). The most significant recent earthquakes in the area, M6.6 July 8, 2006 and M6.7 August 2, 2007, occurred to the east and west of the M7.1 event, respectively (yellow stars on the above map). The westernmost area of the 1957 fault zone re-ruptured repeatedly in the 1986 M8.0 and 1996 M7.9 earthquakes. The eastern portion of the 1965 fault zone was re-ruptured recently in the M7.7 earthquake on November 17, 2003.

All these events occurred along the megathrust boundary between the subducting Pacific and overriding North American plates. Within the past ten years, the region shown on the map had on average two magnitude 6 or greater events per year. The Aleutian megathrust, where the two plates are being forced directly into one another, is one of the world's most active seismic zones.

M6.4 December 26, 2007 Fox Islands Earthquake

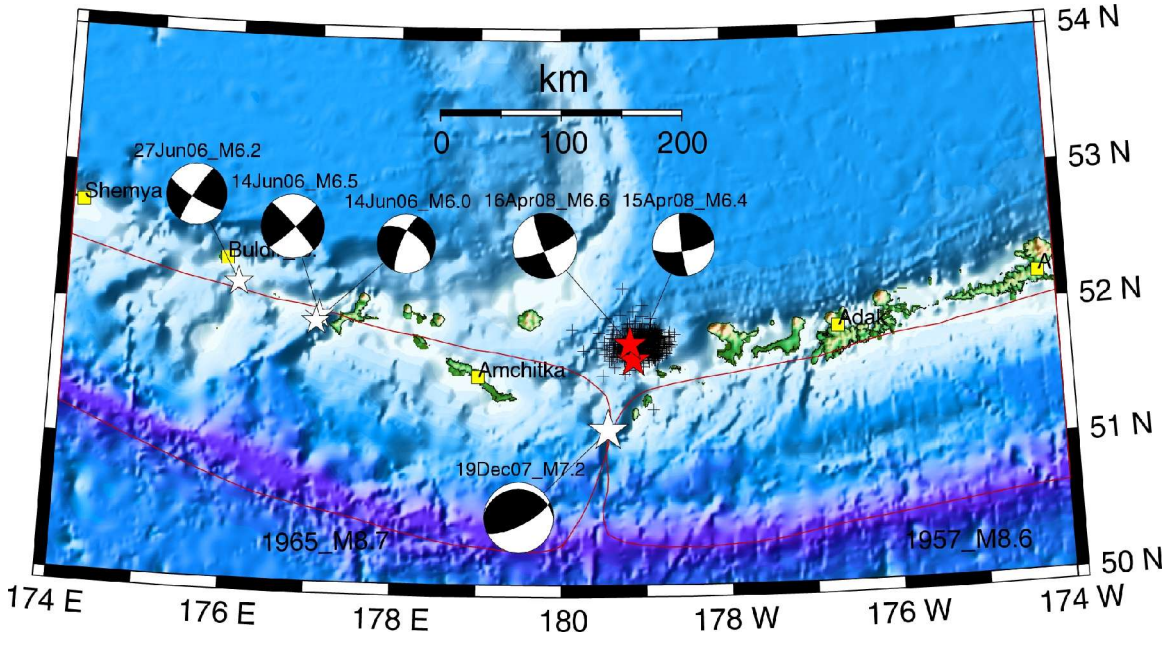


The Alaska Earthquake Information Center located a strong earthquake that occurred on Wednesday, December 26, 2007 at 1:04 pm AKST (22:04 pm UTC) in the Fox Islands region of Alaska (red star on the above map). The AEIC located over 160 aftershocks through the end of the month (magnitudes 2 and greater, white circles). The largest aftershock of magnitude 5.0 occurred on December 29 at 1:57 pm AKST (22:57 pm UTC).

This is the largest event to occur in the region since the M6.4 earthquake on May 10, 2006 (yellow star). The December 26 earthquake occurred on the convergent boundary between the subducting Pacific and overriding North American crustal plates. This region, where the two plates are being forced directly into one another, is one of the world's most active seismic zones. Over one hundred earthquakes of magnitude seven or larger have occurred along this boundary in the past hundred years. A separate map illustrates the recent earthquakes as circles, superimposed on stippled areas illustrating the rupture zones of major earthquakes. Generally speaking, the magnitude of an earthquake is roughly proportional to the area involved in its faulting. Each major rupture is labeled with the earthquake's year and a black dot indicating the epicenter for the associated earthquake. With the exception of the Unalaska and Shumagin seismic gaps, all portions of this plate boundary have ruptured within the past hundred years.

The 1957 Mw 8.6 Andreanof Islands earthquake ruptured a ~600 km-long portion of the plate boundary in central Aleutian Islands. The current sequence of earthquakes is located within the eastern segment of the 1957 rupture zone.

M6.4 and 6.6 April 15 and 16, 2008 Andreanof Islands Earthquakes



On April 15, 2008, at 22:59 UTC (2:59 pm ADT) a strong earthquake (magnitude 6.4) occurred in the Andreanof Islands region of the Aleutian Islands. It was followed by a larger earthquake of magnitude 6.6 on April 16 at 5:54 UTC (April 15, 9:54 pm ADT) (red stars on the above map). The events were situated about 124 km (77 miles) ENE of Amchitka and 179 km (112 miles) W of Adak.

The AEIC located over 400 aftershocks in the first 5 days of the sequence (crosses). The largest aftershock of magnitude 5.0 occurred on April 18 at 20:51 UTC (12:51 pm ADT). These earthquakes are the largest to occur in this region since the magnitude 7.2 event on December 19, 2007 (large white star on the map).

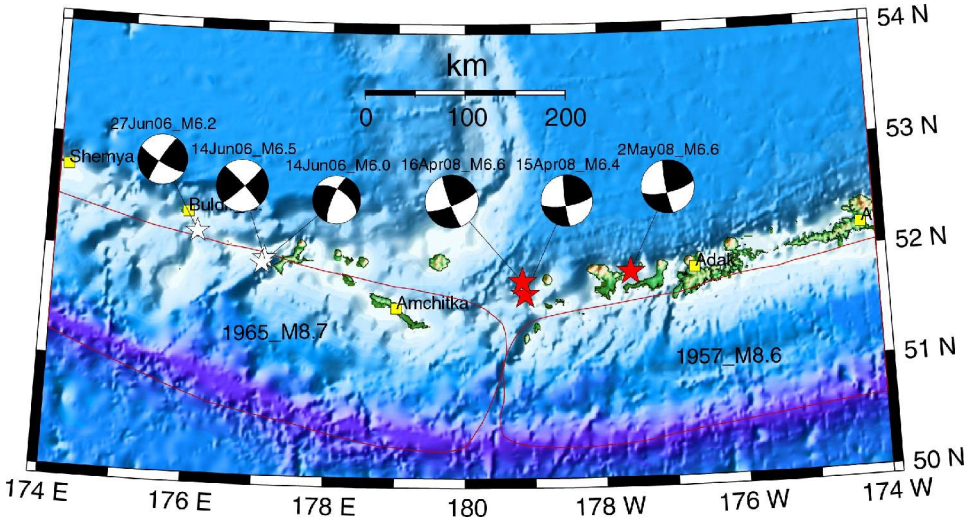
The April 2008 earthquakes occurred in the area separating rupture zones of the 1965 M8.7 Rat Islands earthquake to the west and the 1957 M8.6 Andreanof Islands earthquake to the east (approximate extent of the rupture zones is shown in red). In the last five years, sixteen M6-7 and three M7+ earthquakes occurred within the area shown on the above map. Most of these events occurred on the plate interface between the subducting Pacific and overriding North American plates.

The current sequence of events is of a different origin than the abovementioned underthrusting events. The faulting parameters estimated from the waveform inversion indicate a strike-slip type of motion for both mainshocks. Their locations, which are shallow and above the down-dip end of the locked interface, are consistent with the events occurring within the crust of overriding North American plate. In June 2006, a similar sequence of earthquakes occurred about 200 km to the west of the April 2008 events (smaller white stars on the map).

In the western Aleutians, the crust is partitioned into rotating blocks such as the Buldir and Near blocks. In addition in this region, direction of convergence between the two tectonic plates is oblique to the plate interface. The 2008 and 2006 strike-slip events could indicate relative motions of the crustal blocks or slip partitioning between the plate subduction and strike-slip faults in the

region.

M6.6 May 2, 2008 Andreanof Islands Earthquake



On May 2, 2008, at 1:33 UTC (5:33 pm ADT) a strong earthquake (magnitude 6.6) occurred in the Andreanof Islands region of the Aleutian Islands. The event was situated about 64 km (40 miles) W of Adak and 238 km (149 miles) E of Amchitka. It was felt strongly on Adak. No reports of damage have been received.

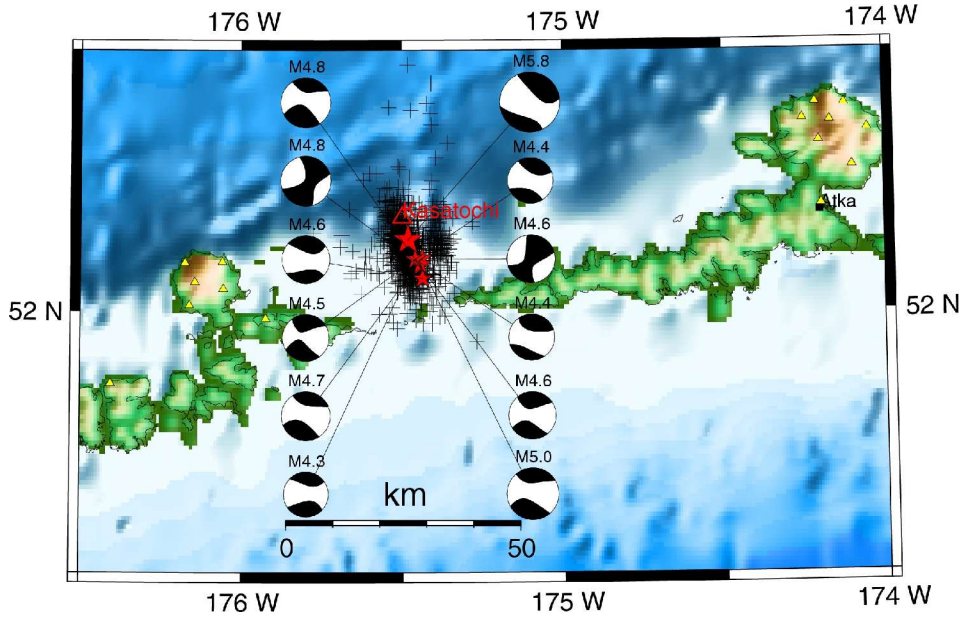
The AEIC recorded nearly 1,500 aftershocks through the end of May. The largest aftershock was magnitude 5.0 and occurred on May 8 at 14:12 UTC. On April 15 and 16, magnitude 6.4 and 6.6 earthquakes, respectively, occurred about 110 km (69 miles) to the west of the May 2 event.

The strongest known earthquakes in this region are the 1965 M8.7 Rat Islands earthquake to the west and the 1957 M8.6 Andreanof Islands earthquake to the east (approximate extent of the rupture zones is shown in red). In the last five years, eighteen M6-7 and three M7+ earthquake occurred within the area shown on the above map. Most of these events occurred on the plate interface between the subducting Pacific and overriding North American plates.

The April and May 2008 M6+ events are of a different origin than the abovementioned underthrusting events. Faulting parameters estimated from the waveform inversion indicate strike-slip type of motion for the mainshocks. Their locations, which are shallow and above the down-dip end of the locked interface, are consistent with the events occurring within the crust of the overriding North American plate. In June 2006, a similar sequence of earthquakes occurred about 300 km to the west of the May 2008 events.

In the western Aleutians, the crust is partitioned into rotating blocks such as the Buldir and Near blocks. In addition in this region, direction of convergence between the two tectonic plates is oblique to the plate interface. The 2008 and 2006 strike-slip events could indicate relative motions of the crustal blocks or slip partitioning between the plate subduction and strike-slip faults in the region.

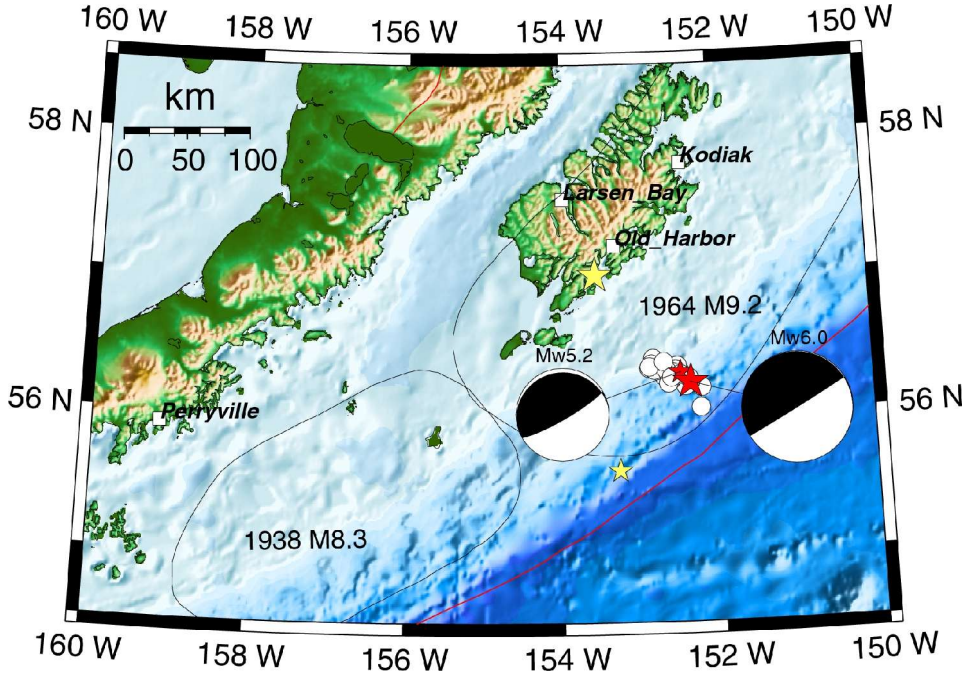
Earthquake swarm associated with the August 2008 Kasatochi eruption



On August 6, 2008, a vigorous seismic swarm was detected in the vicinity of Kasatochi volcano in the Andreanof Islands. Starting at 15:00 UTC on August 6, the intensity and frequency of the earthquakes rapidly increased resulting in ~1,100 events located over the course of 48 hours during the most energetic part of the swarm. The largest earthquake, magnitude 5.8, occurred about 27 hours into the sequence and about 3.5 hours before the first aerial ash discharge from Kasatochi was detected by the Alaska Volcano Observatory through satellite data. This discharge was followed by two more explosions, also detected via satellite monitoring. The 3rd explosion consisted of nearly continuous ash emissions and declined in frequency and intensity through ~22:00 UTC on August 8. The seismic swarm intensity started to decline at ~18:00 UTC on August 8, and continued to decline through the end of August.

Overall, there is a strong causative relation between behavior of the seismic swarm and the eruption episodes. Due to seismic network limitations in the region (all stations are in a linear array along the island arc), determining accurate locations of the Kasatochi seismicity became a challenge. The locations have much larger uncertainties in the N-S direction than in the E-W direction, and overall are poorly constrained. Moment tensor inversions of the 12 largest events resulted in solutions with large non-double-couple components. The consistent orientation of the moment tensors, combined with rupture lengths of a typical magnitude 5.8 earthquake and knowledge of the likely regional stress field, suggests intrusion of a dike system. This dike system may extend several kilometers from the volcano in a possible orientation ranging from NNW-SSE to E-W.

M6.0 March 30, 2009 Kodiak Island Earthquake



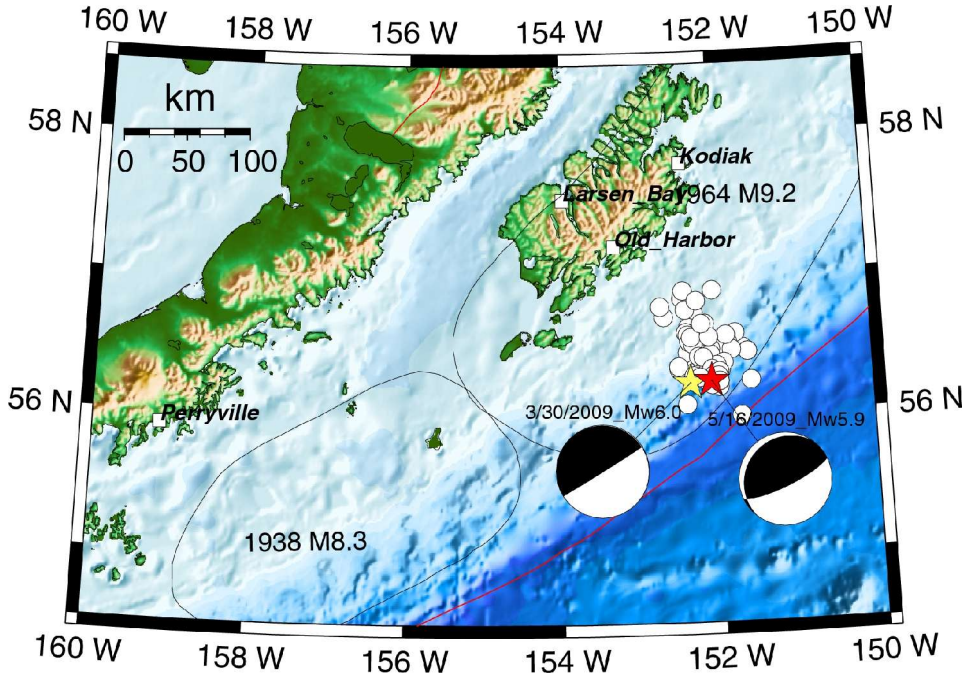
The Alaska Earthquake Information Center located a strong earthquake (magnitude 6.0) that occurred on March 30, 2009 at 7:13 am UTC (March 29, 11:13 pm AKDT) in the Kodiak Island region (larger red star on the above map). This event was felt widely on Kodiak Island and as far as Anchorage. It was preceded by a magnitude 5.2 foreshock at 3:42 am UTC (March 29, 7:42 pm AKDT).

The AEIC located a total of 19 earthquakes in this cluster on March 30 and 6 aftershocks on March 31. Three of the aftershocks were greater than magnitude 4, the largest of which (magnitude 4.9) occurred at 17:38 UTC on March 30. Due to the offshore location of the cluster, only events with magnitudes of about 2.8 and higher could be detected.

This is the largest event to occur in the region since the M6.9 earthquake on on January 10, 2001 (larger yellow star). A magnitude 5.9 earthquake occurred on May 25, 2008 (smaller yellow star) in the vicinity of the March 30 cluster. According to the depth and source mechanisms of the March 30 earthquakes, they occurred on the convergent boundary between the subducting Pacific and overriding North American crustal plates.

In 1964, the M9.4 Great Alaskan earthquake ruptured a ~800 km-long portion of the plate boundary from Prince William Sound to Kodiak Island. In 1938 a portion of the plate interface to the southwest of Kodiak Island ruptured in a M8.3 earthquake. The current sequence of earthquakes is located within the Kodiak segment of the 1964 rupture zone.

M5.9 May 16, 2009 Kodiak Island Earthquake



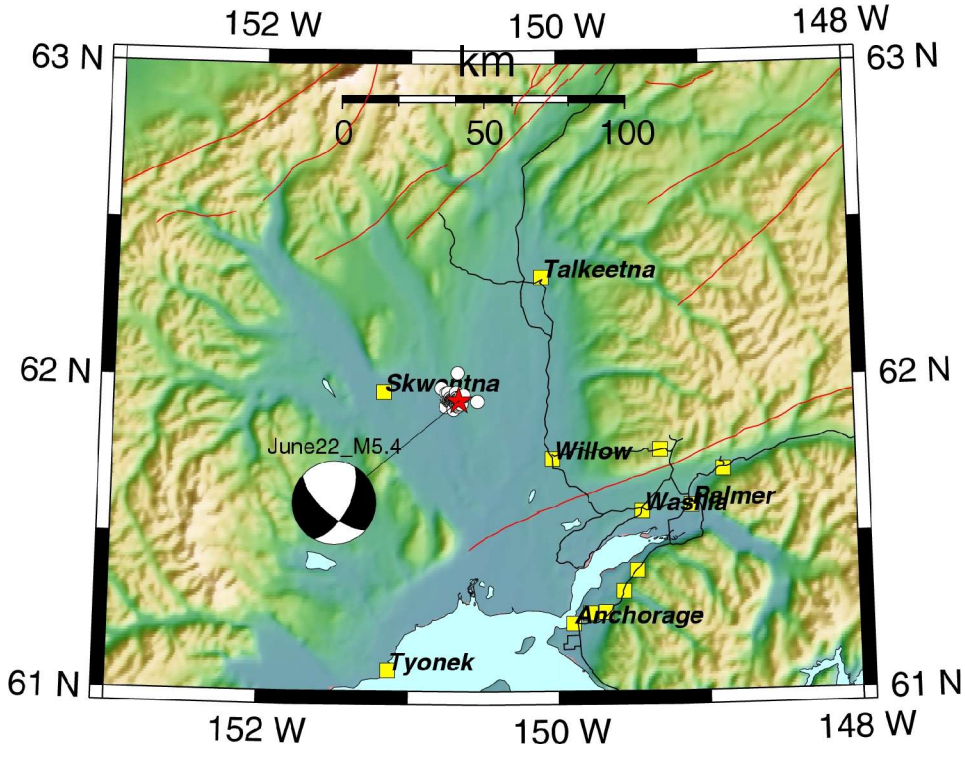
The Alaska Earthquake Information Center reported a moderate earthquake (magnitude 5.9) that occurred on May 16, 2009 at 18:22 UTC (10:22 am AKDT) in the Kodiak Island region (red star on the above map). It was located about 80 miles SE of the nearest population center of Old Harbor. No reports of this event being felt have been received. The mainshock was preceded by a magnitude 5.0 foreshock one minute earlier. This sequence started one day earlier with a M4.2 earthquake on 5/15 at 17:38 UTC (9:38 am ADT). The AEIC located a total of 83 earthquakes in this cluster through the end of May. Due to the offshore location of the cluster, only events with magnitudes of about 2.0 and higher could be detected.

A similar sequence of earthquake occurred in this locality in March-April of 2009, with the mainshock of mangitude 6.0 on March 30 (yellow star). This particular area has had a higher level of seismic activity than other neighboring areas off Kodiak Island (see map).

According to the depth and source mechanisms of both the March-April and May 16 earthquakes, they occurred on the convergent boundary between the subducting Pacific and overriding North American crustal plates.

In 1964, the M9.4 Great Alaskan earthquake ruptured a ~800 km-long portion of the plate boundary from Prince William Sound to Kodiak Island. In 1938 a portion of the plate interface to the southwest of Kodiak Island ruptured in a M8.3 earthquake. The current sequence of earthquakes is located within the Kodiak segment of the 1964 rupture zone.

M5.4 June 22, 2009 Skwentna Earthquake



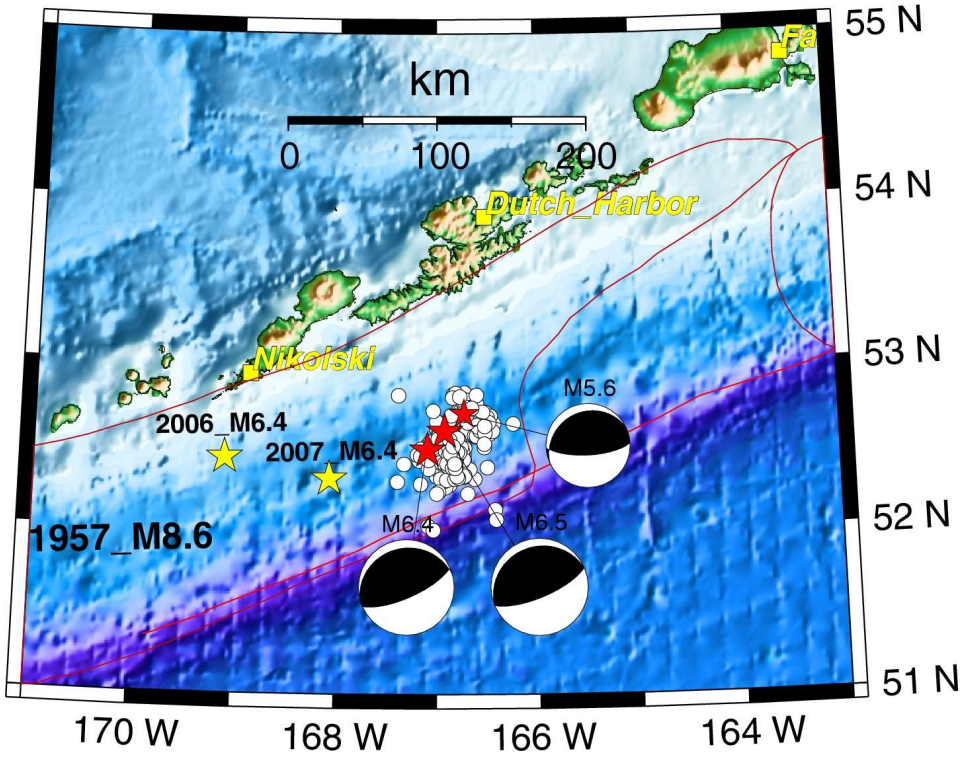
On June 22, 2009 at 11:28 am AKDT (19:28 UTC) the Alaska Earthquake Information Center located a magnitude 5.4 earthquake, 38 miles (62 km) deep, about 17 miles east of Skwentna (red star on the above map). AEIC staff have located about 50 aftershocks through 9 am AKDT of June 26 (white circles on the above map). The largest aftershocks were three magnitude 4.1 events that occurred half-hour, 21 hours and 4 days after the mainshock, respectively.

The mainshock was felt widely in southcentral Alaska and as far as Homer in the south, Fairbanks in the north and Cordova in the east. Some aftershocks were also felt over a smaller area. No reports of damage have been received. Maximum intensity of shaking was in Trapper Creek, V, light. See Did You Feel It archive for distribution of felt reports.

The tectonic framework of Alaska is dominated by subduction of the Pacific plate underneath the North American plate along the southern Alaska margin and the Aleutian Islands. In southern Alaska, earthquakes inside the subducting plate occur down to a depth of 130 miles (220 km). According to its depth, the M5.4 earthquake and its aftershocks occurred inside the subducted Pacific plate. These events are common in the Cook Inlet region. On average during last 20 years, one earthquake of magnitude 5 or greater occurred in a 100 mile radius of the June 22 event, and once every two years in a 50 mile radius.

Waveform modeling and analysis of the P-wave first motions of the M5.4 earthquake and its aftershocks indicate a normal type of faulting. As the Pacific plate slides into the mantle, it is being pulled by its own weight, causing extensional earthquakes.

M6.5 and 6.4 October 13, 2009 Fox Islands earthquakes



A magnitude 6.5 earthquake occurred on Monday, October 12, 2009 at 9:37 pm AKDT (October 13, 05:37 am UTC) in the Fox Islands region of Alaska (red star on the map). It was located 136 km (85 miles) ESE of Nikolski and 146 km (91 miles) S of Dutch Harbor. Another strong earthquake of magnitude 6.4 occurred on Tuesday, October 13 at 12:21 pm AKDT (20:21 UTC) in the same area (red star on the map). The AEIC staff located 440 aftershocks (open circles) through the end of October, 13 of which had magnitudes 4 or greater. The largest aftershock of magnitude 5.6 (small red star) occurred on Wednesday, October 15 at 4:13 pm AKDT (October 16, 00:13 UTC).

An M6.5 earthquake was reported felt in Nikolski and Unalaska, intensity III, weak. See Did You Feel It archive for distribution of felt reports.

This is the largest event to occur in the region since the M6.4 earthquake on December 26, 2007. Another magnitude 6.4 earthquake occurred in the region on May 10, 2006 (yellow stars). October 2009 sequence of earthquakes occurred on convergent boundary between the subducting Pacific and overriding North American crustal plates. This region, where the Pacific plate is being forced under the North American plate, is one of the world's most active seismic zones. In 1957, the magnitude 8.6 Andreanof Islands earthquake ruptured a ~600 km-long portion of the plate boundary in the central Aleutian Islands. The current sequence of earthquakes is located near eastern end of the 1957 rupture zone.

Waveform modeling of the mainshocks and largest aftershocks indicate thrust type of faulting, consistent with the slip on plate interface.

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