

EarthScope's Transportable Array:

Robert Busby, TA Manager

Kasey Aderhold, Project Associate

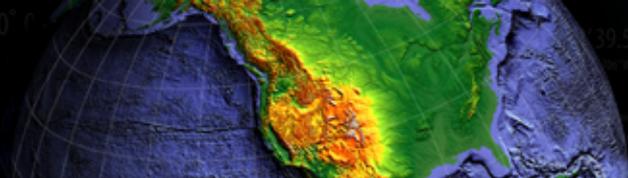
Max Enders, Deployment Coordinator

*Transportable Array Opening Gala Oct 18, 2017
Anchorage, AK*



- Overview of TA project and what it does.
- Brief look at Building the TA in Alaska
- Status and Plan for TA in Alaska / Yukon
 - Array is now completely installed
 - Will operate for two years
 - Stations begin to be removed summer 2019, completed in summer 2020. Some stations are likely to remain.
- Novel research topics in the region

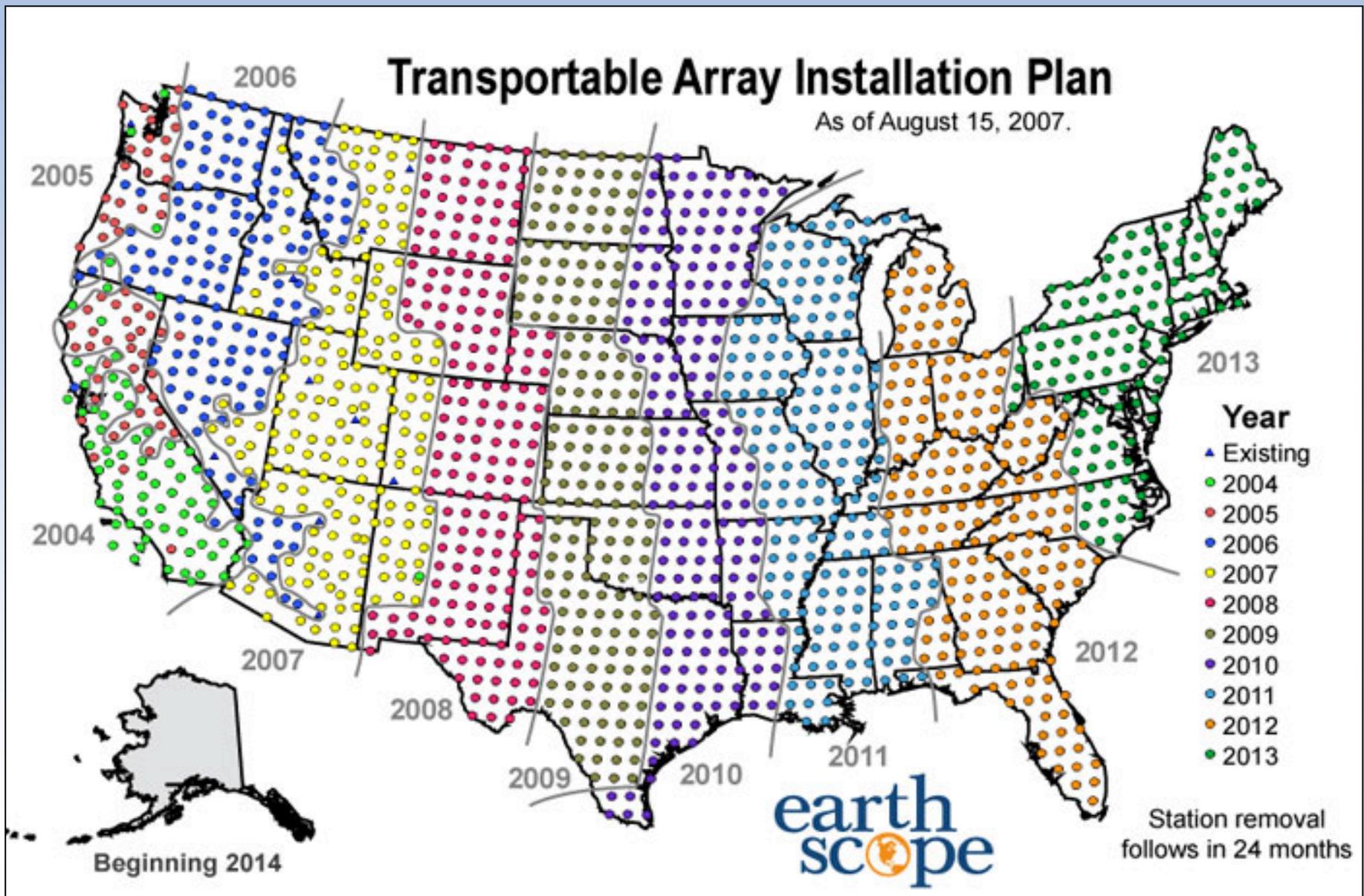
From NSF: Transformative research involves ideas, discoveries, or tools that radically change our understanding of an important existing scientific or engineering concept or educational practice . . .

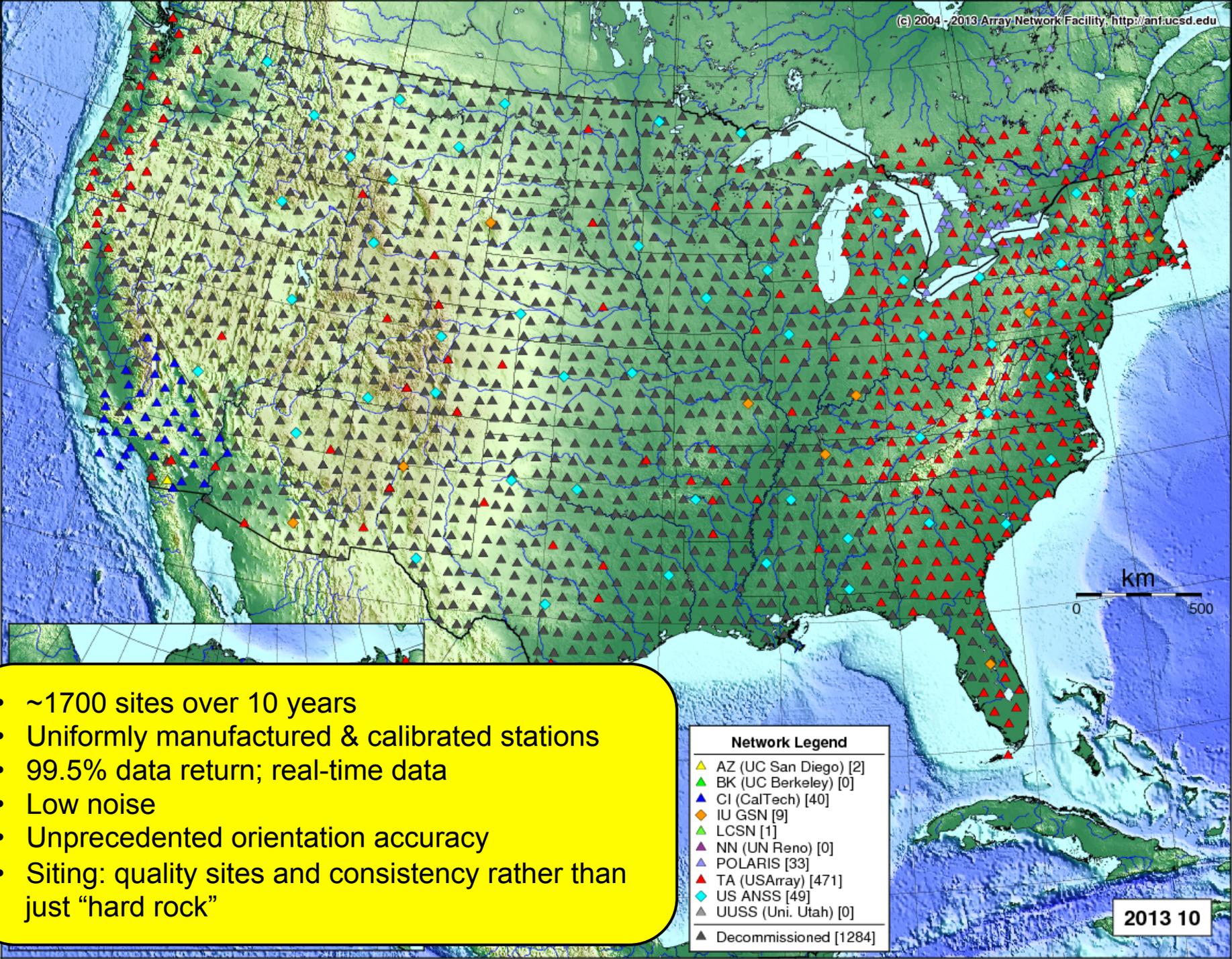


The TA: 15 Year Plan

Transportable Array Installation Plan

As of August 15, 2007.





- ~1700 sites over 10 years
- Uniformly manufactured & calibrated stations
- 99.5% data return; real-time data
- Low noise
- Unprecedented orientation accuracy
- Siting: quality sites and consistency rather than just “hard rock”

Network Legend	
▲	AZ (UC San Diego) [2]
▲	BK (UC Berkeley) [0]
▲	CI (CalTech) [40]
◆	IU GSN [9]
▲	LCSN [1]
▲	NN (UN Reno) [0]
▲	POLARIS [33]
▲	TA (USArray) [471]
◆	US ANSS [49]
▲	UUSS (Uni. Utah) [0]
▲	Decommissioned [1284]

2013 10

Imaging Earth structure from 8km depth to more than 800km

backprojections

Slice

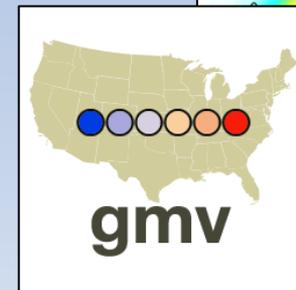
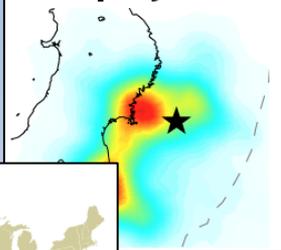
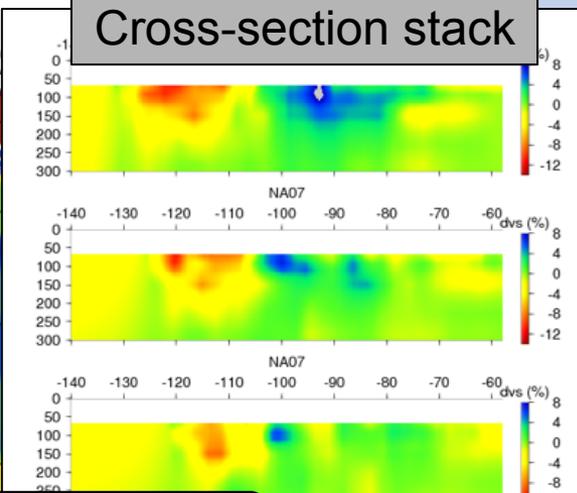
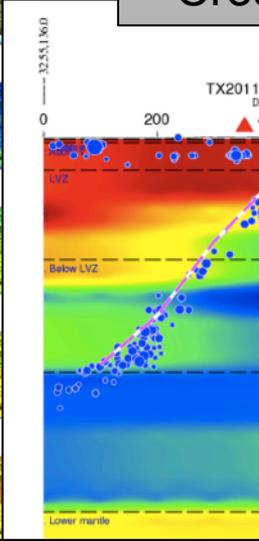
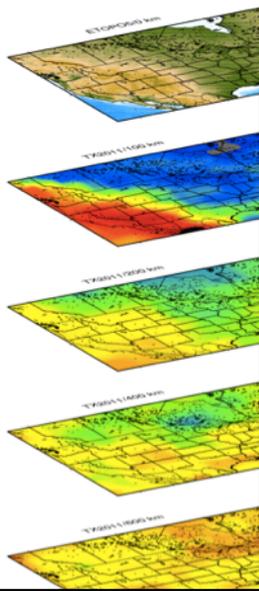
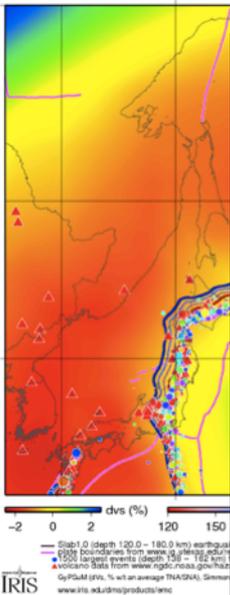
Kamchatka/Kurils/Japan, GyPSuM dvS,

140°E

Slice - stack

Cross-section

Cross-section stack



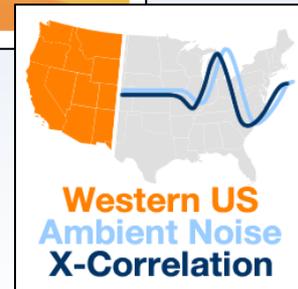
gmv



event plots



Infrasound



Western US Ambient Noise X-Correlation

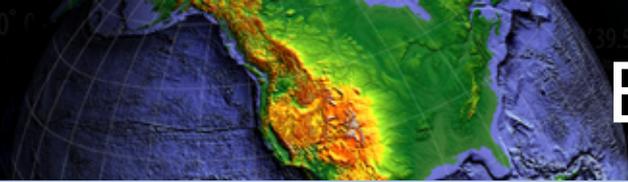
Example Product: Earth Model Collaboration

- to topography (km X10) based on ETOP
 - named boundaries of PEMO
 - plate boundaries from www.jg.utexas.edu
 - Slab1.0 depth from earthquake.usgs.gov
 - events (M >= 5 and depth 0.0 - 800.0 km)
 - volcano data from www.ngdc.noaa.gov
 TX2011 (dvS, % perturbation)
 www.iris.edu/dms/products/ems

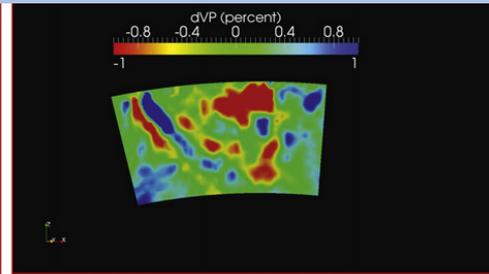
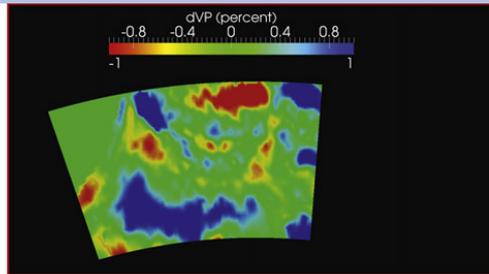
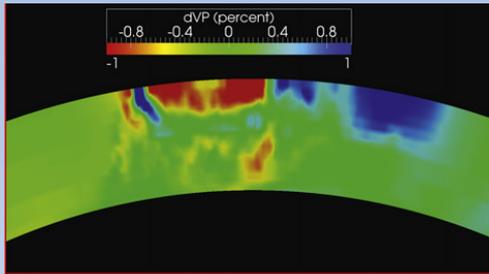
NA07 (dvS, % w1 MC35), Badie & Van der Lee, 2007, along latitude 40.00
 NA07 (dvS, % w1 MC35), Badie & Van der Lee, 2007, along latitude 36.00
 NA07 (dvS, % w1 MC35), Badie & Van der Lee, 2007, along latitude 32.00
 NA07 (dvS, % w1 MC35), Badie & Van der Lee, 2007, along latitude 28.00
 www.iris.edu/dms/products/ems

A rich set of higher order data products

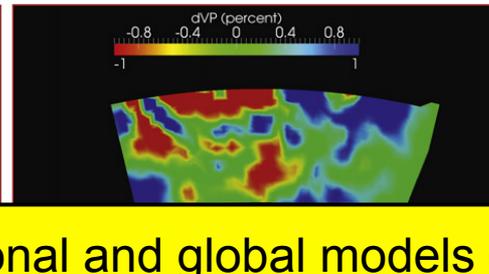
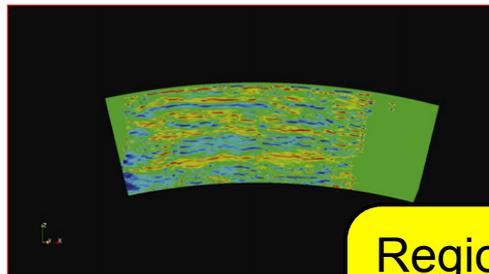
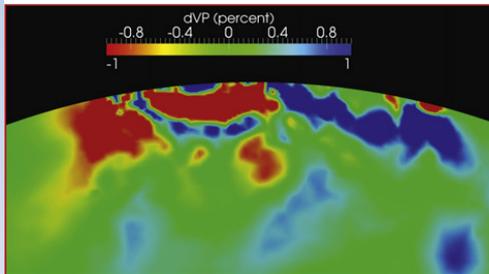
Other products



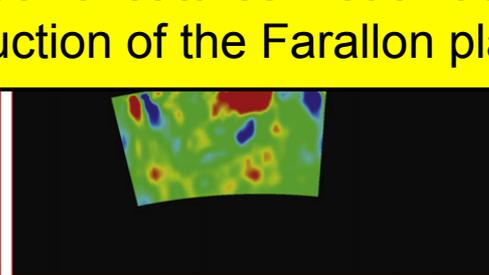
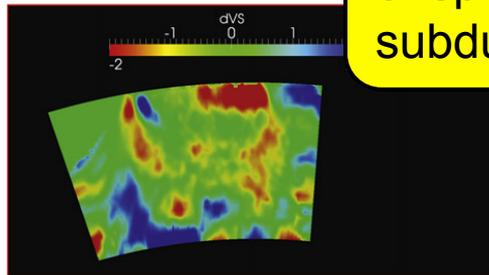
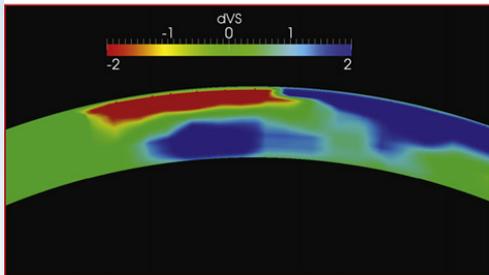
Body Wave Tomography



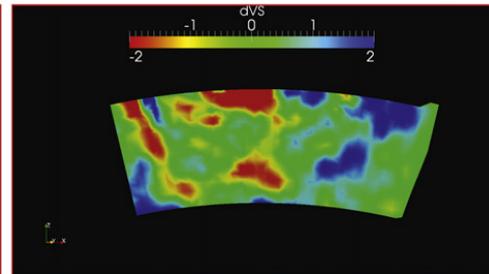
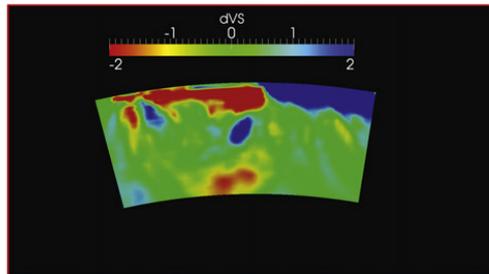
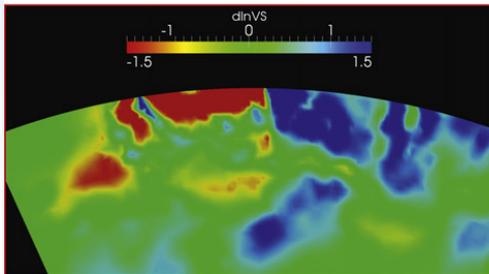
P wave models



Regional and global models enable studies of specific features – such as the subduction of the Farallon plate



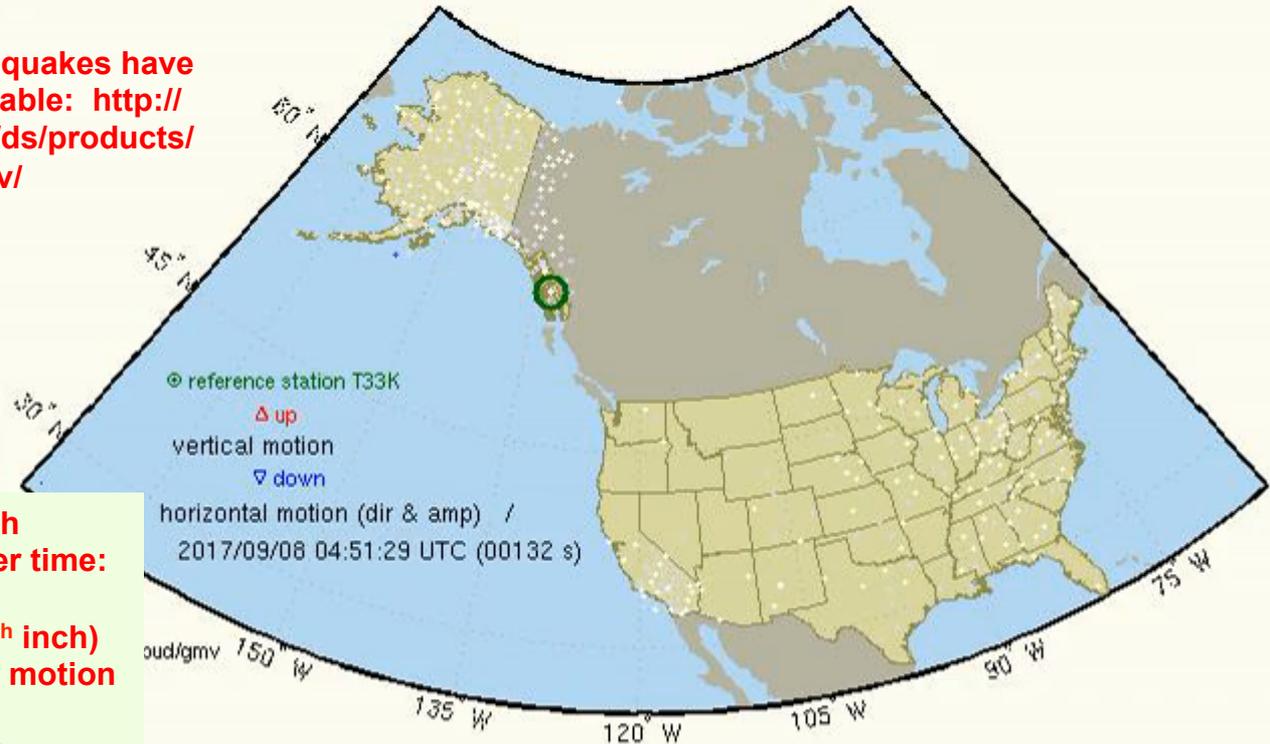
S wave models



Ground Motion Video (GMV)

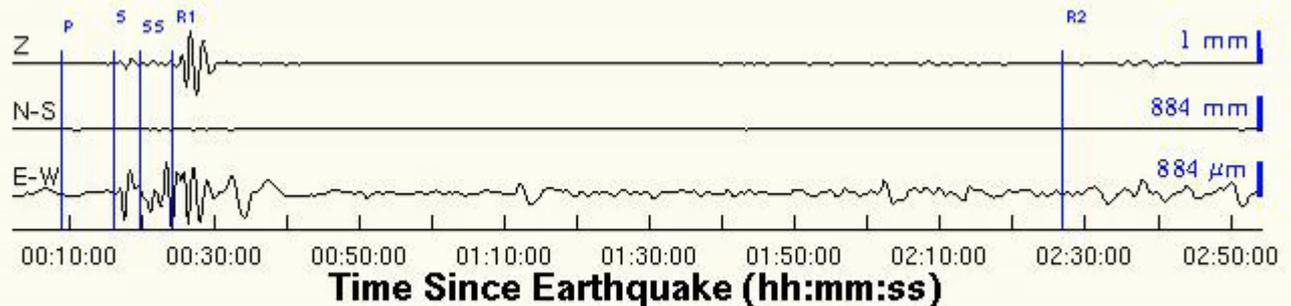
September 08, 2017, NEAR COAST OF CHIAPAS, MEXICO, M8.0

Many earthquakes have views available: <http://ds.iris.edu/ds/products/usarraygmv/>

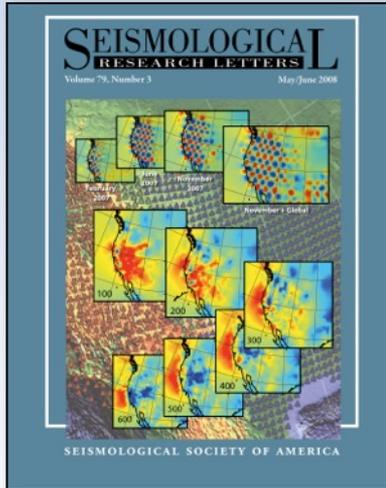


Displays ground motion at each station from an earthquake over time: RED goes up, BLUE goes down, (about 1/16th inch) STICK FLAGS show horizontal motion

This video is 3 hours of motion.



- A very small sample of recent results
- Illustrates some of the ways USArray has enabled the research



Seismic array shifts to Alaska
USArray plumbs shifting tectonic plates and offers improved earthquake monitoring

By Julia Rosen

A fall takes hold, it's getting darker in Alaska. But underneath the state, the lights just turned on. On 27 September, near the coastal city of Wainwright, the last 193 seismic stations were installed—completing a grid of 280 instruments that stretches across Alaska and northwest Canada, and kicking off the final phase of the USArray project. In 2004, the phalanx of transportable stations began advancing outward across the lower 48, using the shivers of earthquakes to create a picture of the crust and mantle below North America. On 27 September 2006, p. 1620). Now, for the next 2 years, these stations will plumb Alaska's depths. Illuminating deep-Earth structures as well as registering the shallow tremors of earthquakes and volcanic eruptions. "This is a once-in-a-generation experience for those of us in Alaska science," says John West, the director of the Alaska Earthquake Center at the University of Alaska (UA) in Fairbanks.

Moving the array to Alaska wasn't easy. Stations had to be outfitted with banks of batteries for storing solar power through the long, dark Arctic winter. And because many stations lay in rugged terrain beyond roads, they could not be hauled using a backhoe. Instead, only the seismometers went in drilled holes in the ground, and the other hardware was packed inside refrigerator-sized sheds that could be suspended from helicopters and plucked down in far-flung spots. "We have to flip a few switches, and plug some cables in, but it's basically ready to go," says Robert Budy, who manages the array for the Incorporated Research Institutions for Seismology, the Washington, D.C.-based organization that operates USArray for the National Science Foundation (NSF).

With the \$40 million project in place, scientists will begin to examine one of the most active subduction zones on the planet, where the Pacific Ocean's tectonic plate dives under North America in a grinding collision that generates earthquakes and volcanoes. Much of the region is made up of shivers of marine sediments and rocks that were scraped off the subducting slab and onto the continent. Studying the thickness of Alaska's crust could help geologists better define these fragments and understand how the state was assembled, says Jeff Freymueller, a geophysicist at UA.

Researchers also want to get a glimpse of the subducting slab itself. Deep parts of the slab may have broken off entirely, which would perhaps explain the absence of deep earthquakes in Alaska. "There's a couple hundred million years of oceanic crust going down, and we don't know where it went," Freymueller says. Ocean plates drag a lot of water down with them, and recent work suggests much of it may be trapped in minerals in deeper parts of the slab. If true, that may help explain how water is returned to the mantle, or if the water is slowly released, how it feeds distant volcanoes. Using off-shore instruments to complement the array, researchers will look for signs that hydrated minerals are slowing down seismic waves.

West is most excited about the side benefits of improved earthquake monitoring in a state that experiences more tremors than even California. Before USArray arrived, the Earthquake Center operated only 193 seismic stations, which left areas larger than Kansas unmonitored. West says the new stations have already helped his team pinpoint earthquakes more quickly and accurately. That should not only lead to better tsunami warnings, but also improve mapping of the state's poorly defined faults—the interfaces where earthquakes occur. "If you look at a map with all the dots of earthquakes on it, they're basically cloudy," West says. Meteorologists have piggbacked on the stations' ability to collect and transmit data. Roughly half of the stations have been outfitted with weather instruments and Carven Scott of the National Weather Service's Alaska Region in Anchorage says the data have already improved forecasts. In a place where many people get around in small planes, that can save lives. These benefits explain why many Alaska scientists want some of the stations to stay in the state for the long run. "If we completely failed to keep any of those stations, it would really be a catastrophic missed opportunity," Freymueller says. There's a precedent for transferring ownership of USArray stations to other agencies—some stayed behind in the Pacific Northwest and eastern United States for seismic monitoring.

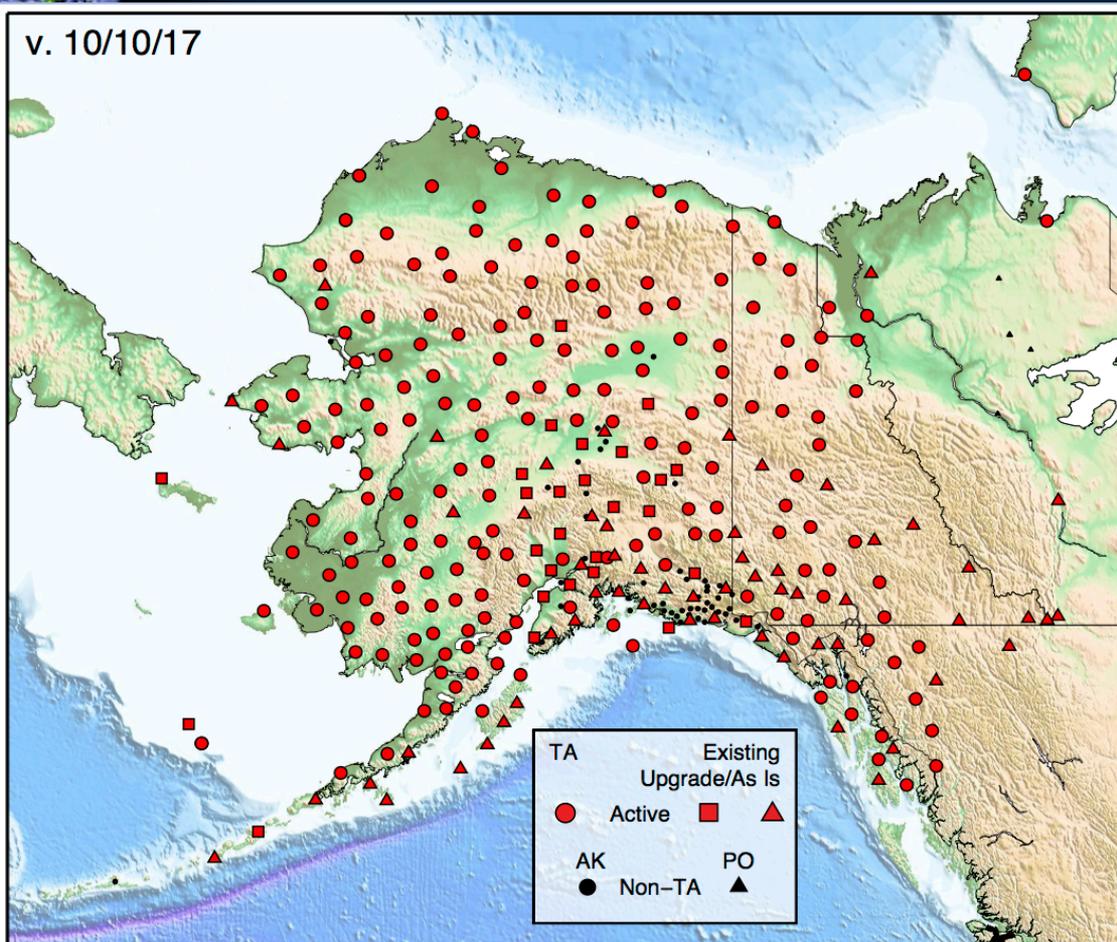
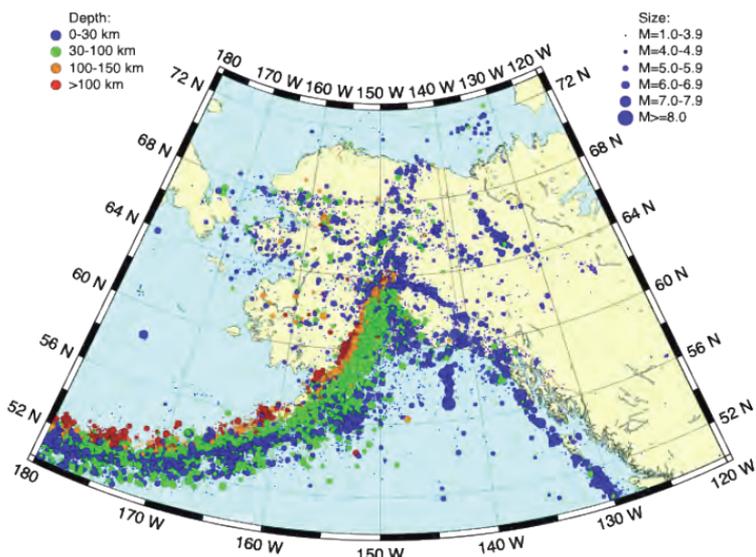
Ideally, says West, a consortium of state and federal agencies who use array data would come up with the funding to buy 80 stations from NSF. He calculates it could be done on an annual budget of \$3.5 million, spreading the cost over 15 years. That includes \$46,000 to purchase each station—a bit less than the \$65,000 each took to build—and more to maintain and operate them. West says it's a rare opportunity to acquire state-of-the-art instruments, already installed.

Though the array has just started operating in Alaska, the clock is ticking. Freymueller says a plan needs to be placed well before Bush's term begins dismantling the array in the summer of 2010. West is optimistic Alaska will be able to keep some of the instruments, but he's already mourning the rest. "I will cry the day that they begin to remove those stations," he says.

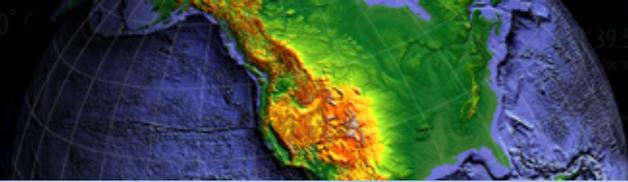
Julia Rosen is a journalist in Portland, Oregon.

- ~280 sites [2017]
- 85 km spacing
- Broadband Seismometers
Infrasound, pressure meteorological, Soil Temp
- <4hr Communications
- Fully deployed 2017

Seismicity in Alaska & Yukon



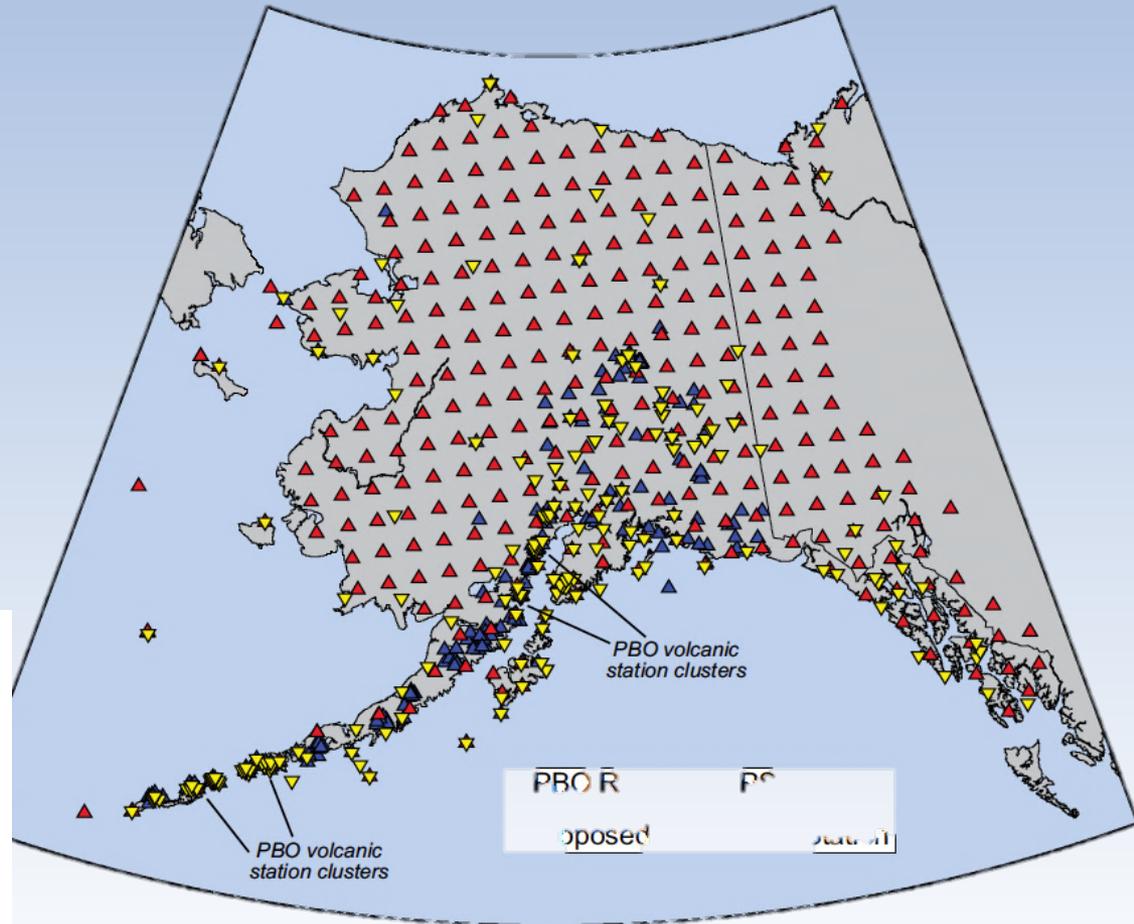
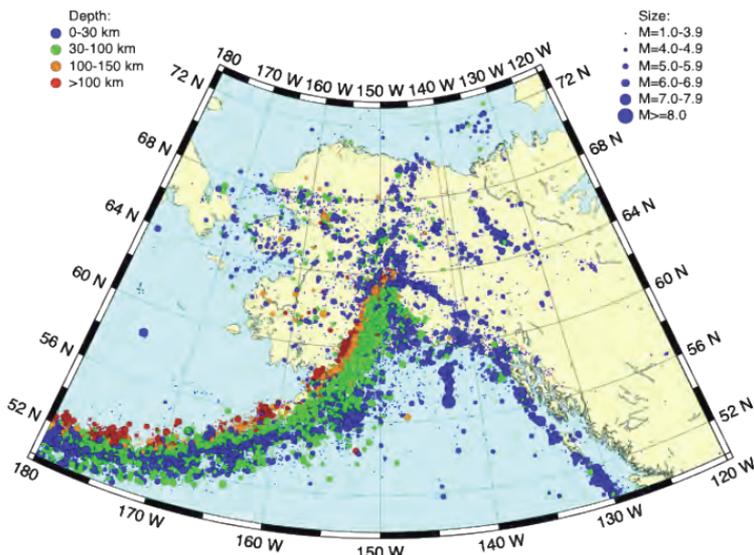
www.usarray.org/alaska

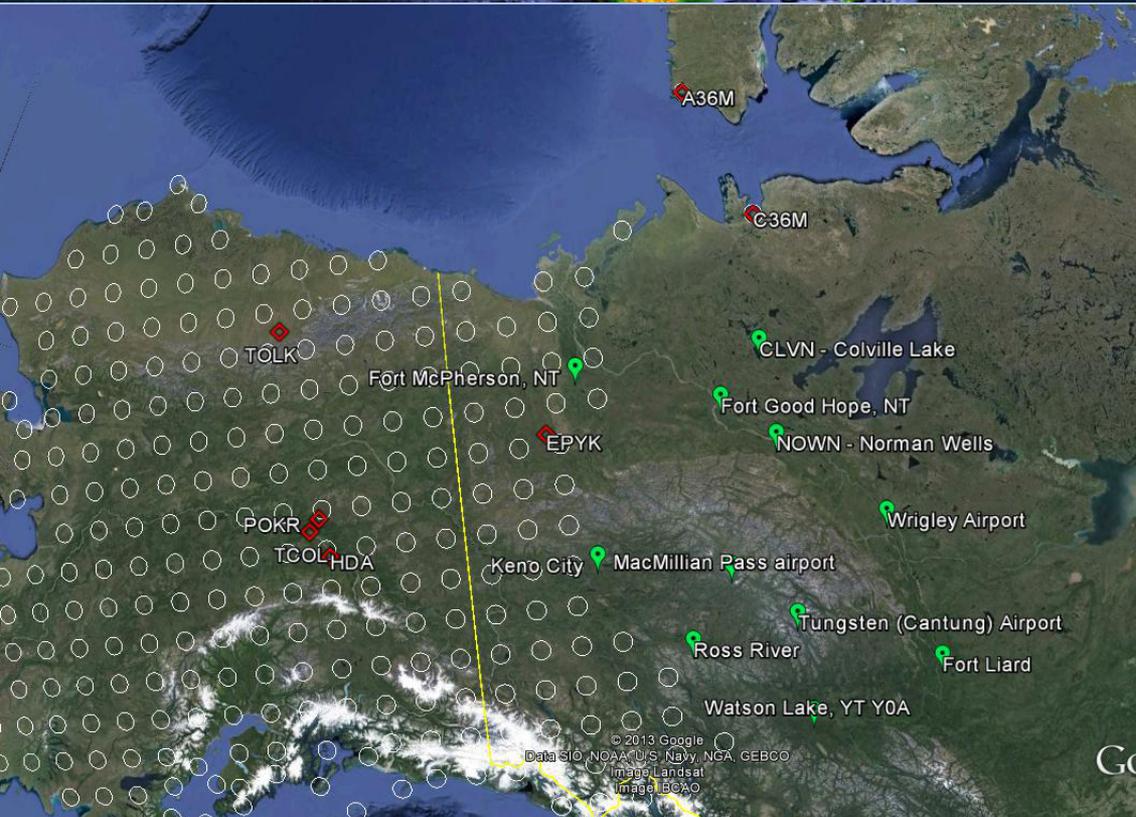


TA in Alaska / Yukon

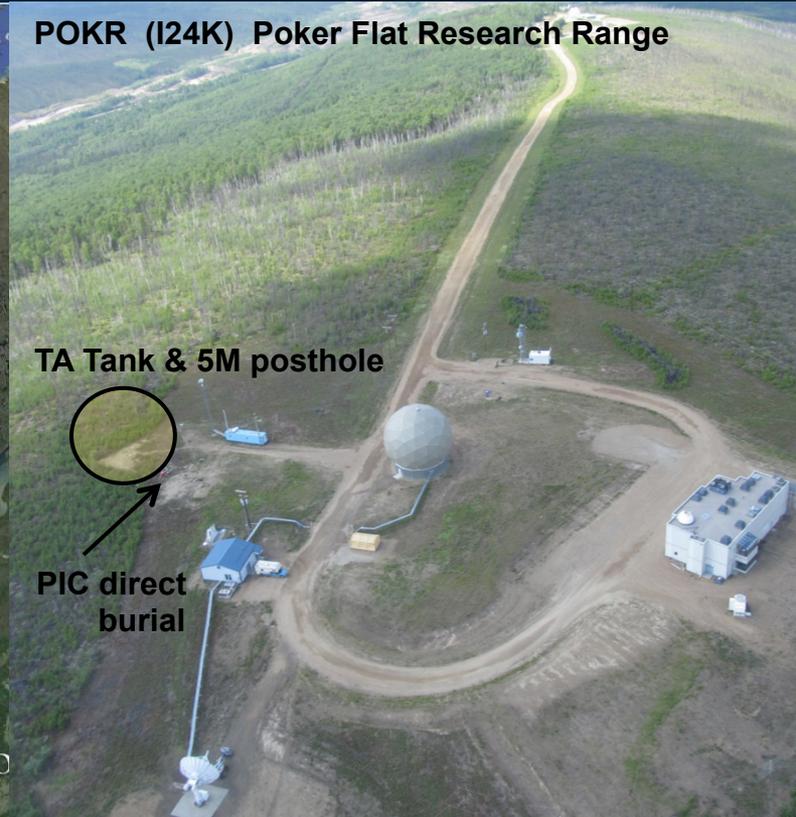
- ~290 sites [2013]
- 85 km spacing
- Broadband Seismometers
 - Infrasond, pressure
 - Some met packages
- Communications
- fully deployed 2017

Seismicity in Alaska & Yukon





POKR (I24K) Poker Flat Research Range



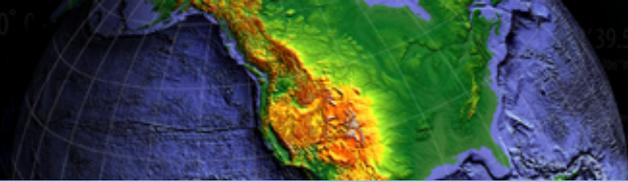
Station	Location	Hole Type	Sensor	Depth (m)	Started
TCOL (--)	CIGO, Fairbanks, AK (adjacent to COLA)	Augered 8" PVC casing	STS-4B	10	10/9/2012
TCOL (01)	CIGO, Fairbanks, AK (adjacent to COLA)	Augered 8" PVC casing	STS-4B	5	10/9/2012
HDA	Harding Lake AK (replaced AK.HDA)	Augered 8" PVC Casing	T120PH	5	10/4/2012
POKR (--)	Poker Flat Research Range, AK	TA Tank into rock	T240	2	10/12/2012
POKR (01)	Poker Flat Research Range, AK	Augered 8" PVC casing	T120PH	5	10/12/2012
EPYK	Eagle Plains YT	Cored in rock	T120PH	1.4	10/15/2012

C36M-Paulatuk



A36M-Sachs Harbor

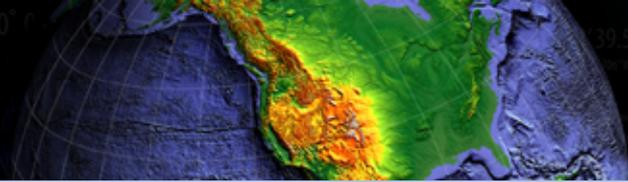




In **2011-2014**, as project proponents we visited numerous agencies and stakeholders. Informational meetings, gathering requirements for application materials and understanding the timeline and process for obtaining permits.

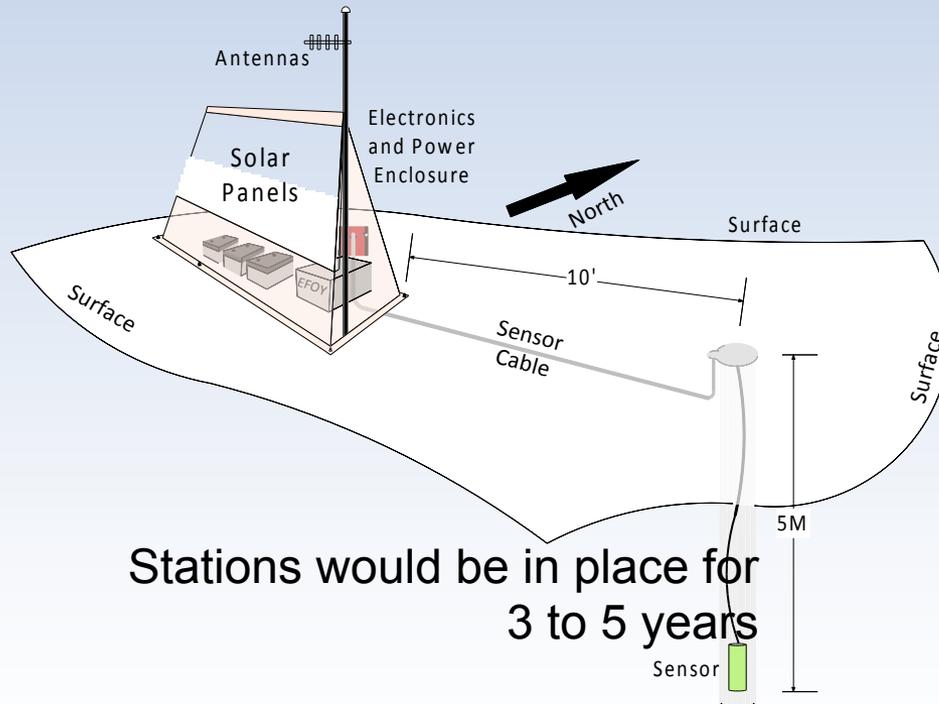
We began by visiting **6 Native Corporation** Offices with maps and handouts, had a booth for two years at **AFN** and in Canada visited 10 villages to reach out to **15 First Nations**. Participated in Subsistence Advisory panels in Barrow and Anchorage.

BLM Anchorage, Fairbanks and NPRA District Offices
National Park Service
US Fish & Wildlife
US Forest Service
State of Alaska DNR and DOT
Yukon Lands
Parks Canada



Basic Description of Buried Sensor Design for AK

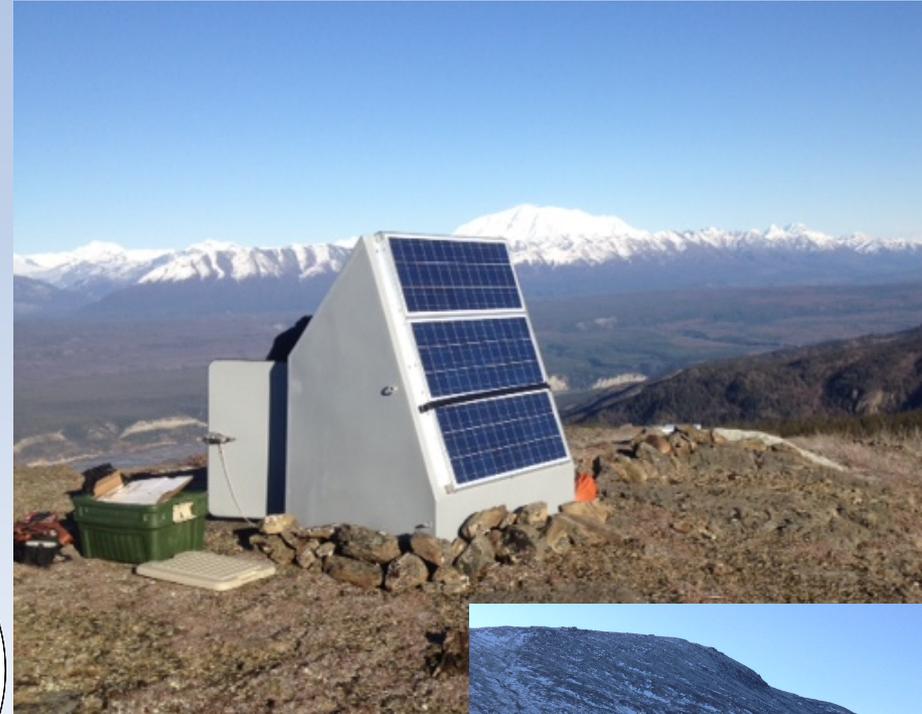
- Sensor: 3 component Broadband seismometer & auxiliary sensors
- Datalogger & local data storage
- Power & data telemetry

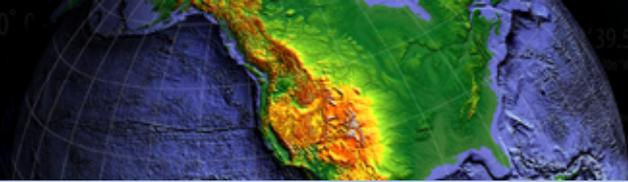


Stations would be in place for
3 to 5 years

Footprint ~10 feet X 20 feet

N25K Seismic Station





Sensor Emplacement

Most sites are installed via helicopter with custom portable drill.

Drill a 6 inch diameter hole 3 m into soil or rock. A steel casing follows bit and is grouted into place. In soil, an auger bit and PVC casing can reach depths of 5m.

3-4 person team constructs site and installs equipment



Drill on sling, and onsite below

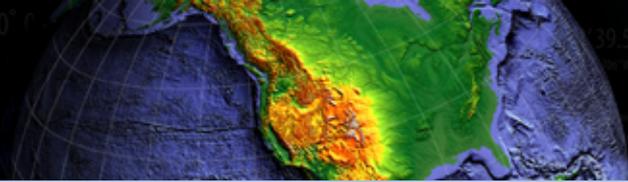
Hammer drill, N25K



Hammer Drilling, AK.SCRK



Mike Lundgren auger in Palmer AK



Deployment Operations

Work from a hub and jump sequentially between sites until ending at next hub

Usually a two helicopter operation-lift Helicopter (A-Star-B3) and a support Helicopter (R66 or Long Ranger)

A Daily evaluation of weather, fuel, fire to advance the plan.



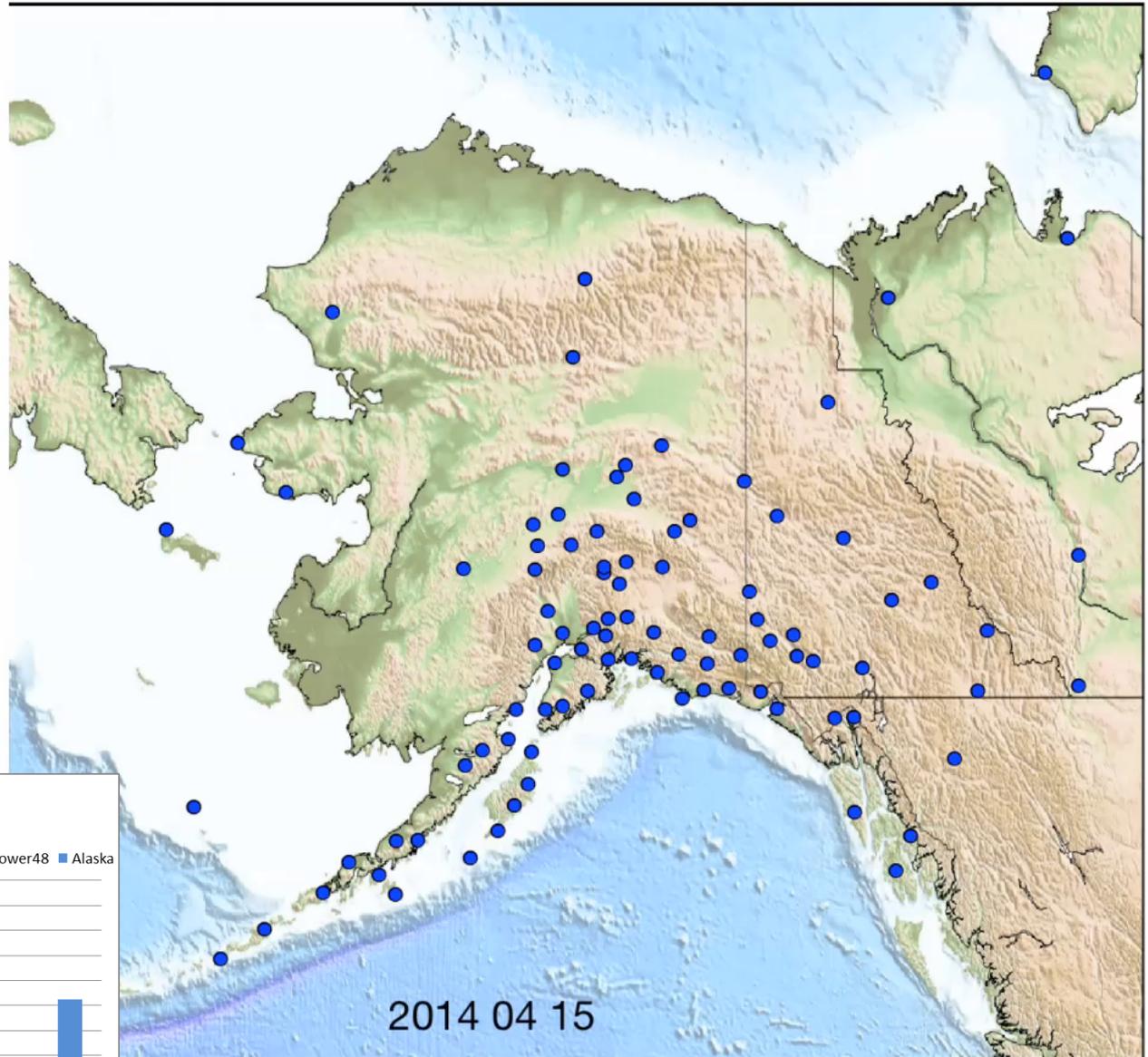
Forest Fires, Old Crow Yukon 2017



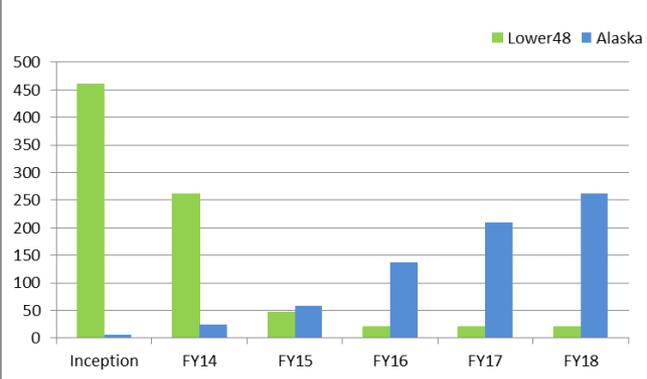
Hub location with drill, Helo, Fuel, huts

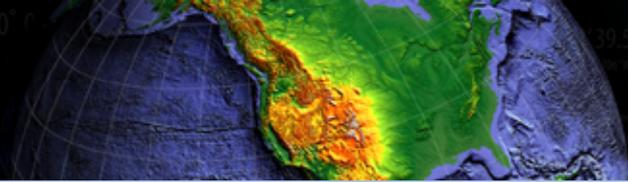


Deployment of Alaska Transportable Array



Stations Deployed



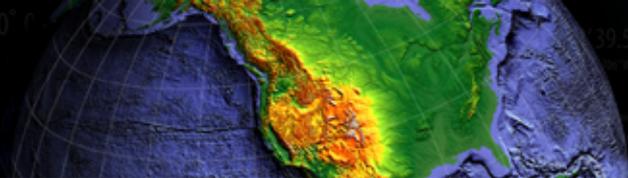


Seismology Partners:

UAF Alaska Earthquake Center (AEC)
USGS Alaska Volcano Observatory
NOAA Tsunami Warning Center
EarthScope Plate Boundary Observatory (PBO)

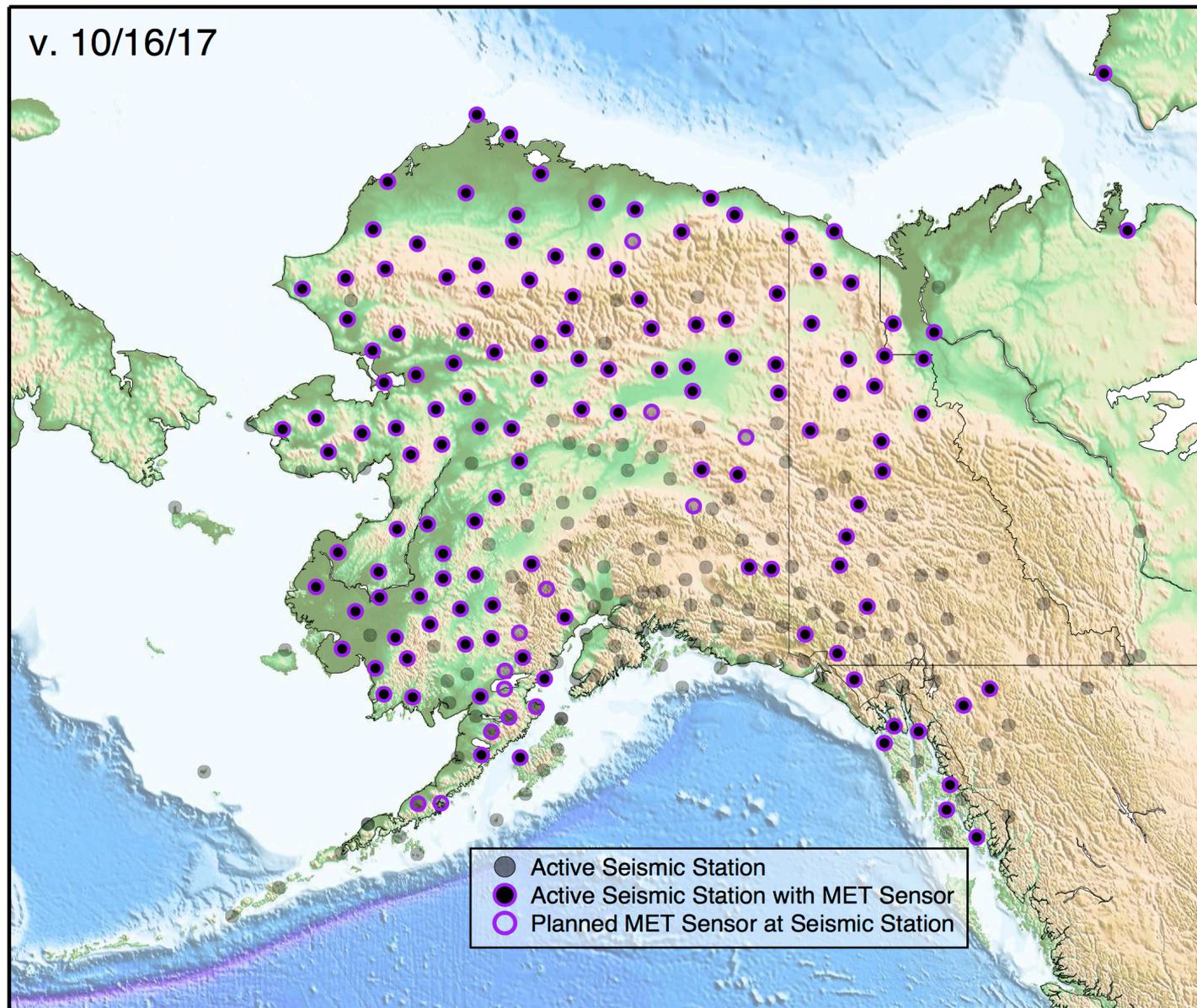
Other Science Partners:

NASA Arctic Boreal Verification Experiment (ABoVE)
Soil Temperature and Meteorological Instruments
National Weather Service Alaska Region
Yukon Wildlands Fire Division



Met sensors in AK

v. 10/16/17

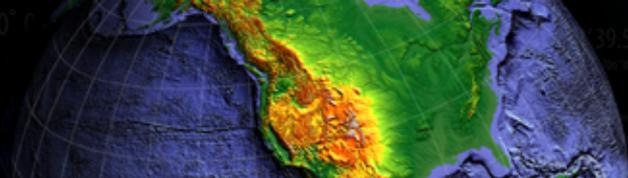


30 TA supplied, NSF
35 UCSD, NSF
27 NOAA NWS so fa
40 NASA ABoVE
2 Yukon

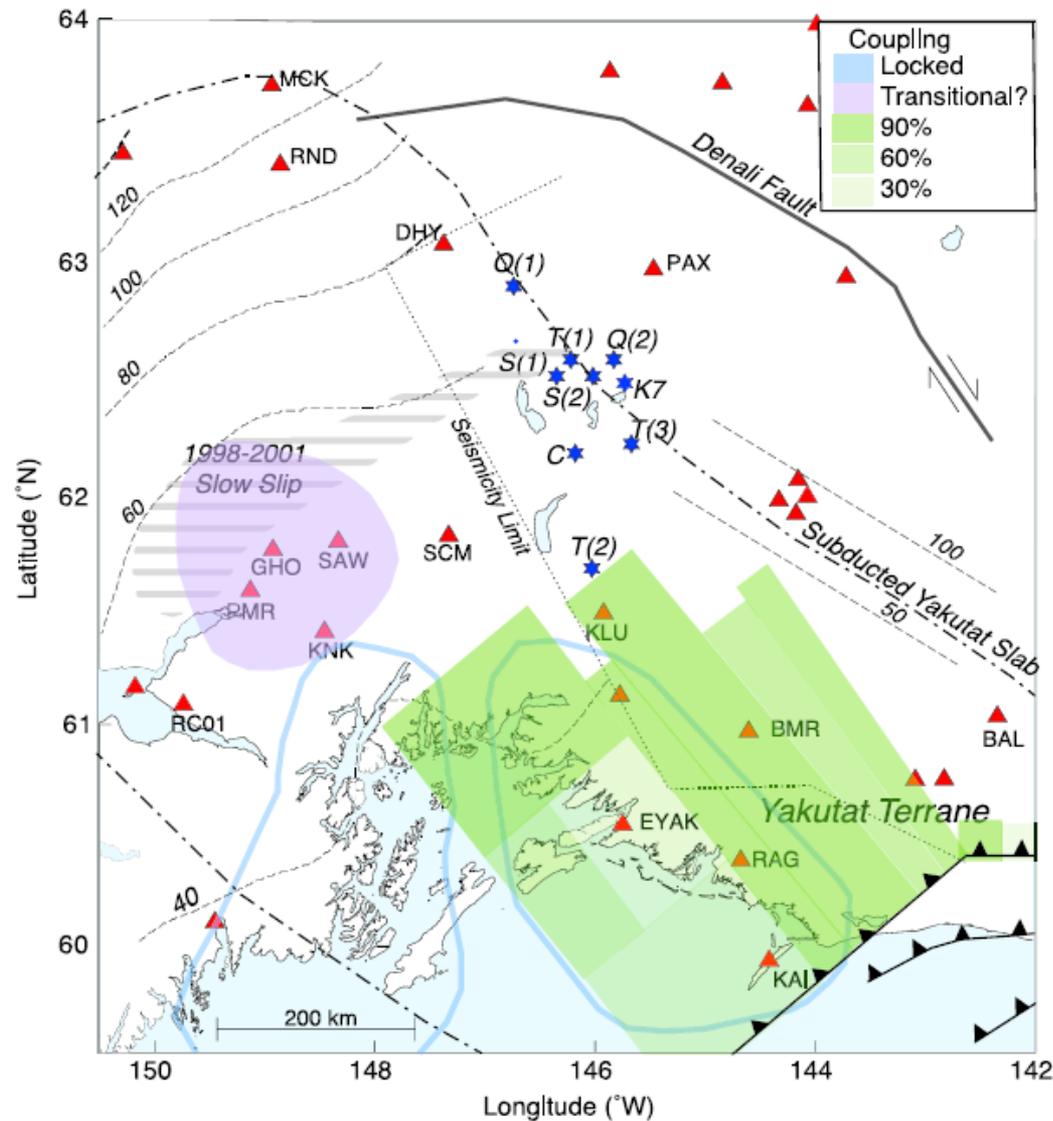
=====
134 sensors

132 installed
13 planned
=====
145 stations

- Seismicity: Earthquakes in ANWR and Noatak and other regions
- Tremor observations:
 - Gomberg & Prejean JGR 16Dec2013
 - Canada-PGC
- Environmental monitoring
 - Sea ice thickness from Seismic background spectra
 - Meteorological Sensors added to array
 - Soil Temperature Profiles added to array



Triggered motion from distant Earthquakes

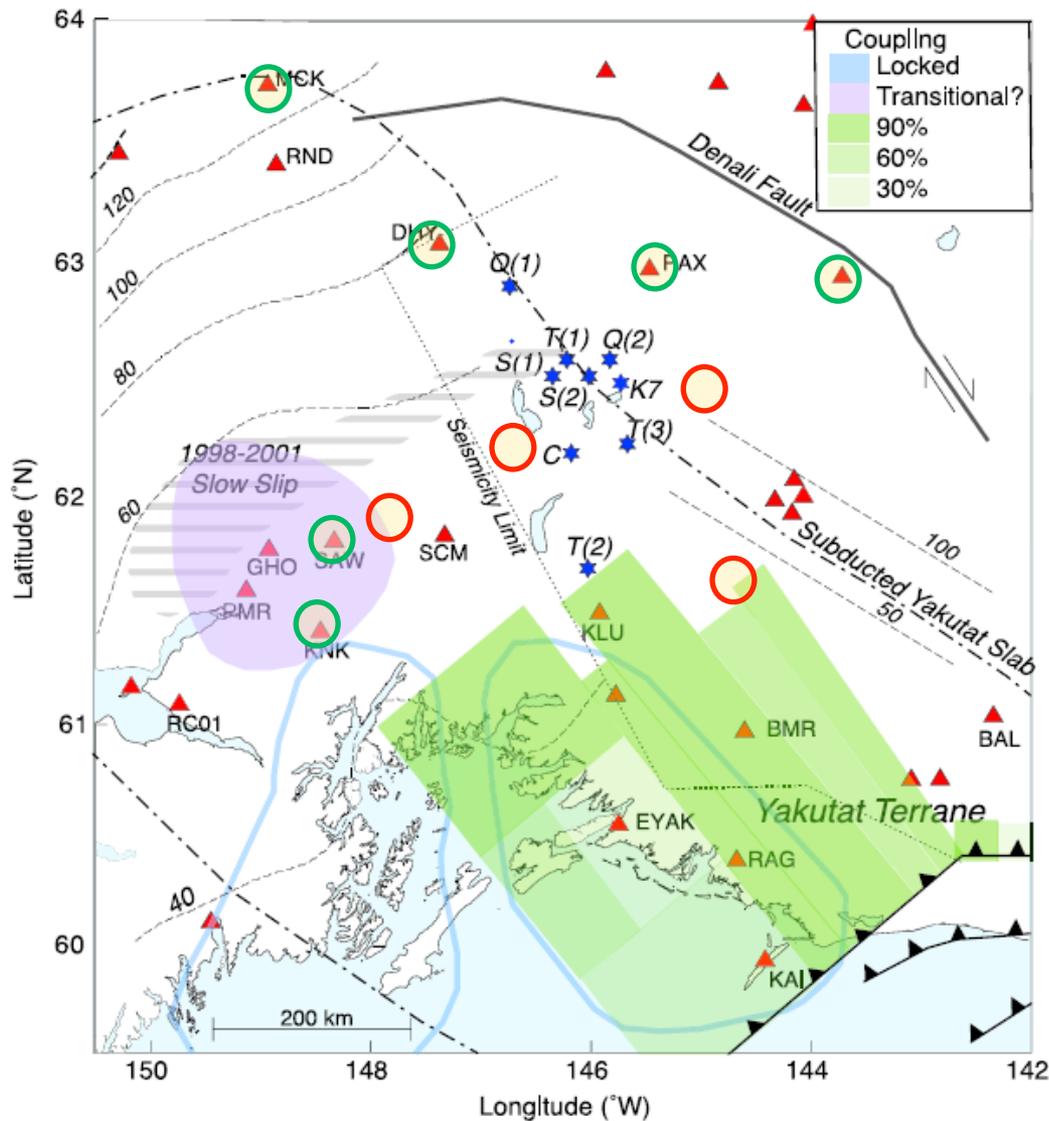


Blue Stars indicate locations of Tremor events triggered by large teleseismic earthquakes. No corresponding slip is observed.

JGR Dec 2013, Gomberg & Prejean
DOI 10.1002/2013JB010273, 2013

Figure 5. Map of epicenters of mainland tremor sources.

Triggered motion from distant Earthquakes

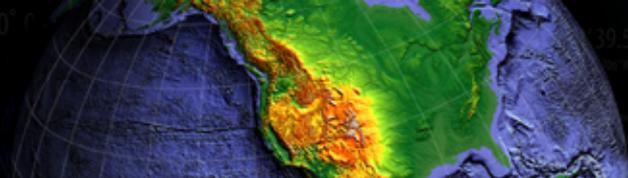


Blue Stars indicate locations of Tremor events triggered by large teleseismic earthquakes. No corresponding slip is observed.

- New TA Station
- Upgraded Station

JGR Dec 2013, Gomberg & Prejean
DOI 10.1002/2013JB010273, 2013

Figure 5. Map of epicenters of mainland tremor sources.



Network of ~280 seismometers and other sensors recording a variety of signals

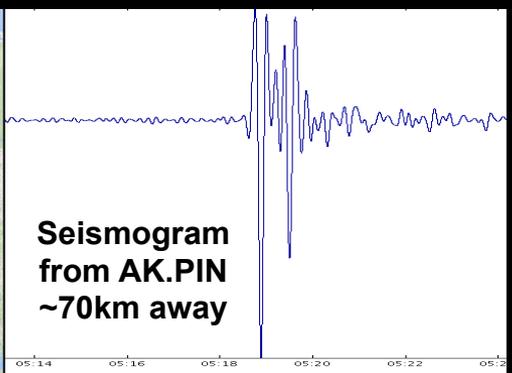
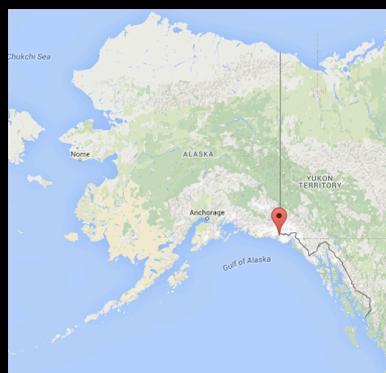
Example: 2015 Tyndall landslide



Ocean Waves



Wind



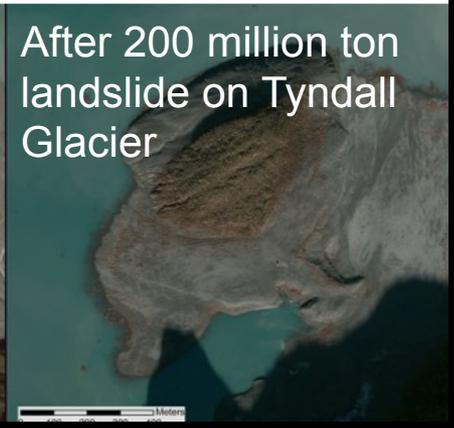
Seismogram from AK.PIN ~70km away



Wildlife



Storm Systems



After 200 million ton landslide on Tyndall Glacier



Landslides



Glacial Activity

Network of ~280 seismometers and other sensors recording a variety of signals

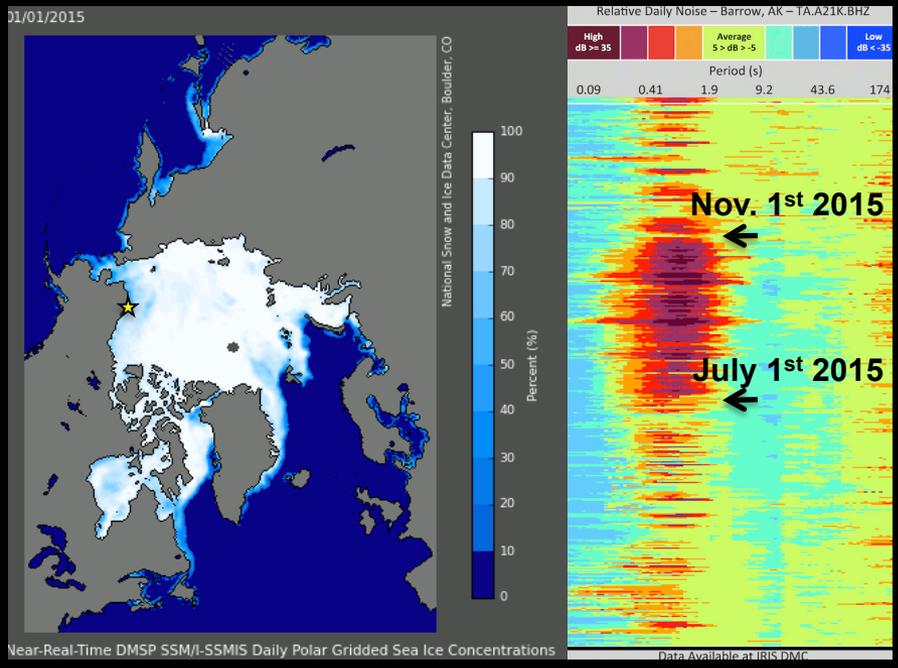
Example: 2015 Sea Ice extent



Ocean Waves



Wind



Wildlife



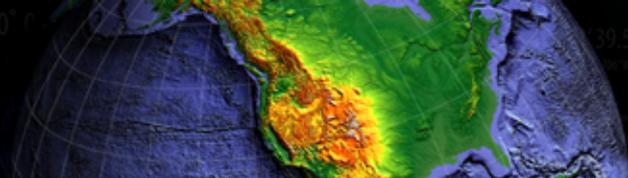
Storm Systems



Landslides



Glacial Activity

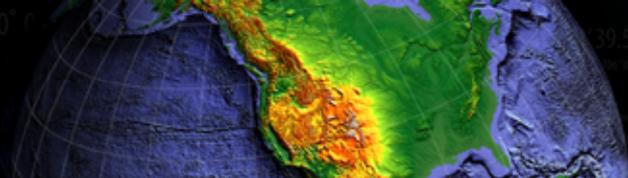


The Transportable Array has been transformative

- The TA has been successfully deployed in a challenging frontier region.
- The TA has established a foundation for research in seismology and hazard monitoring.
- Multiple Sensors engage interdisciplinary science

**Transformative research involves . . .
tools that radically change our
understanding . . .**





On the Web

- EarthScope
www.earthscope.org
- USArray
www.usarray.org
- PBO
pboweb.unavco.org
- National Science Foundation
www.nsf.gov

EarthScope is funded by the National Science Foundation.



EarthScope is being constructed, operated, and maintained as a collaborative effort with UNAVCO, IRIS, and Stanford University, with contributions from the US Geological Survey, NASA and several other national and international organizations.