Diverse Observations from the Alaska Transportable Array (ATA)

Kasey Aderhold
Project Associate

Bob Busby
TA Manager

Bob Woodward
IRIS Director of Instrumentation Services

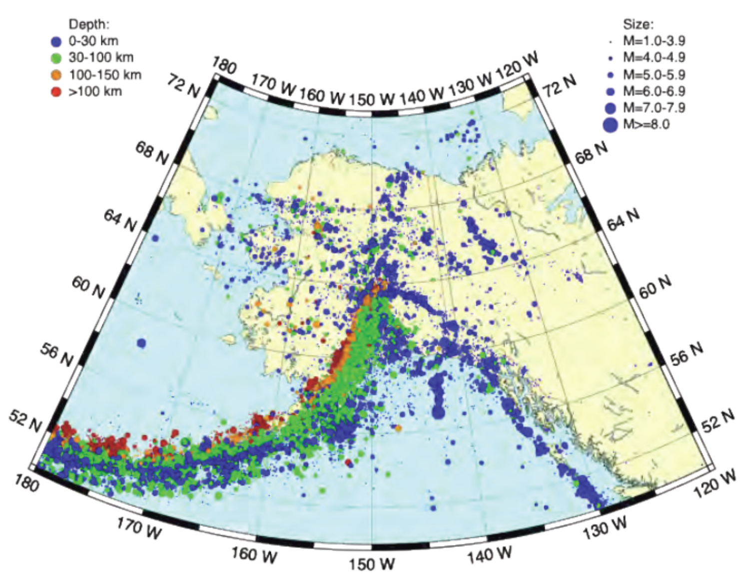
Bob Detrick
IRIS President

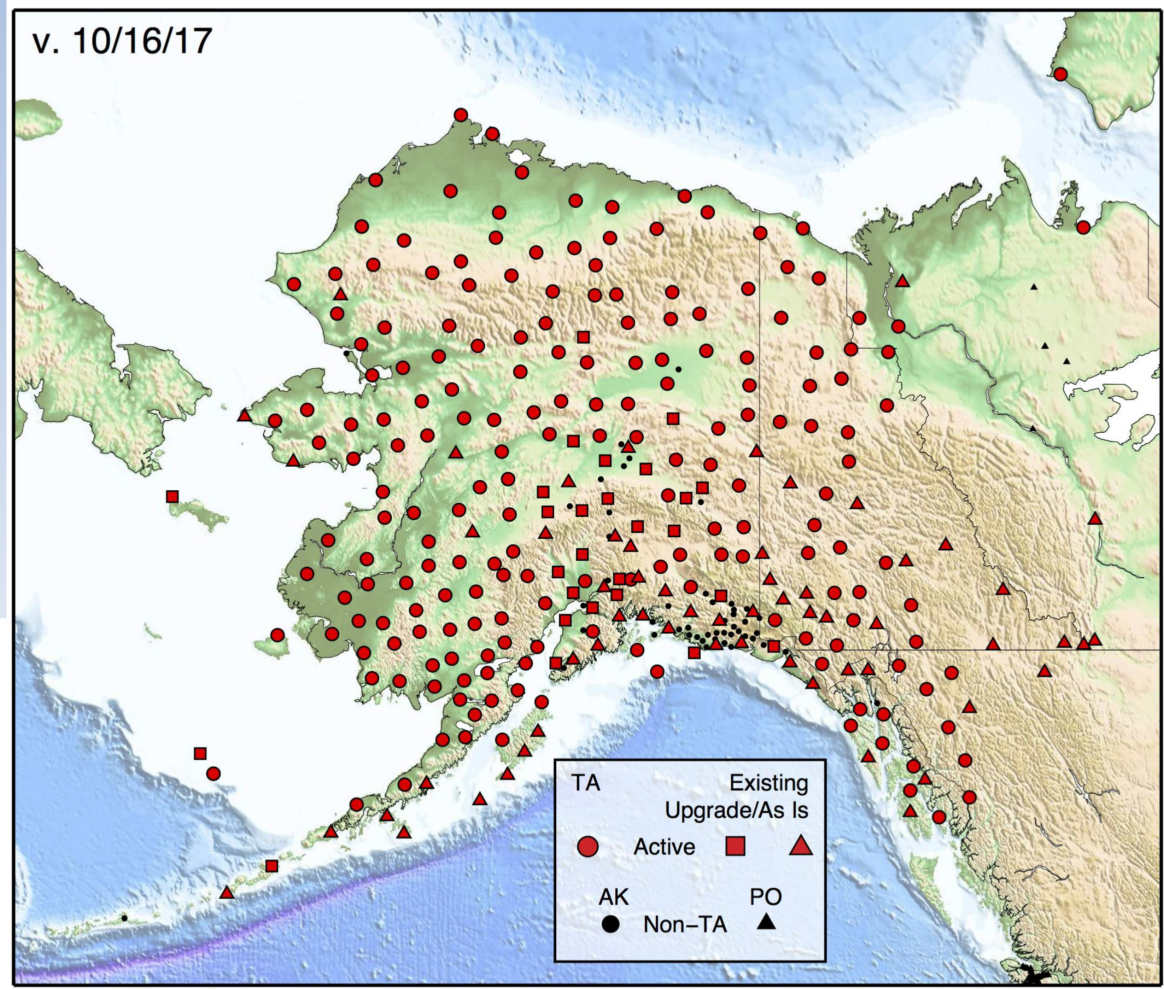
Transportable Array Observations in the Alaskan Arctic
Washington, DC
May 30, 2018

TA in Alaska / Yukon

- ~280 sites
- 85 km spacing
- Broadband seismometers, infrasound, pressure, meteorological, soil temp
- <4hr Communications
- Fully deployed 2017

Seismicity in Alaska & Yukon



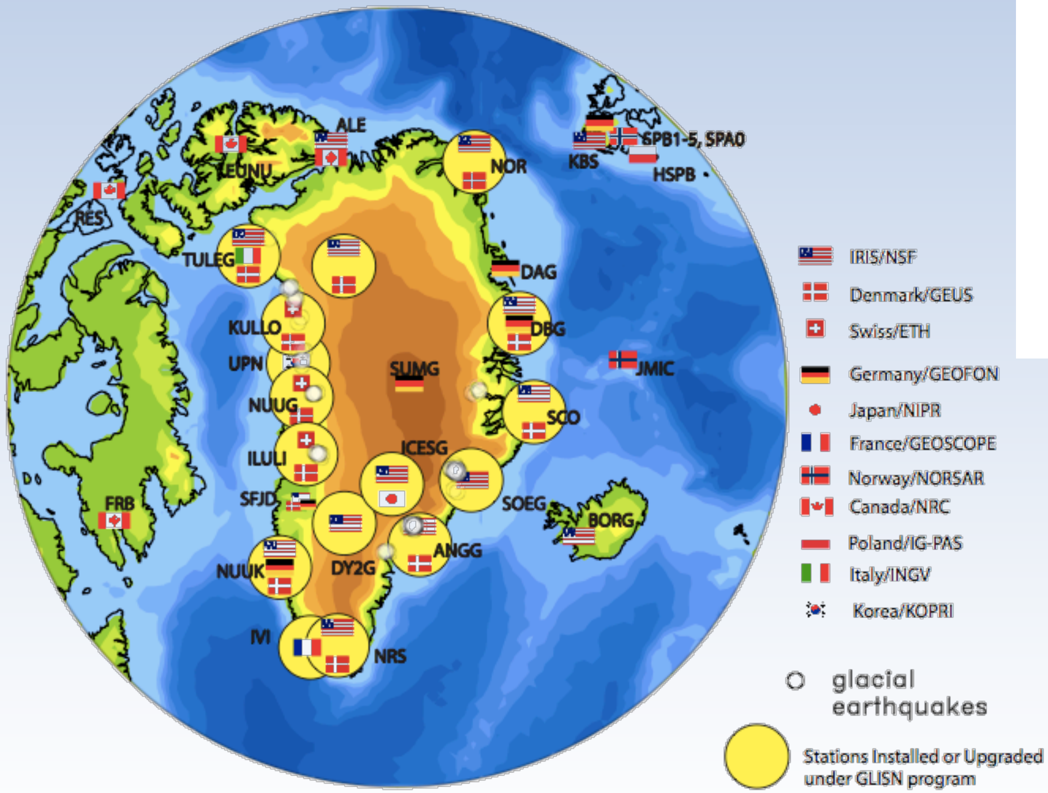


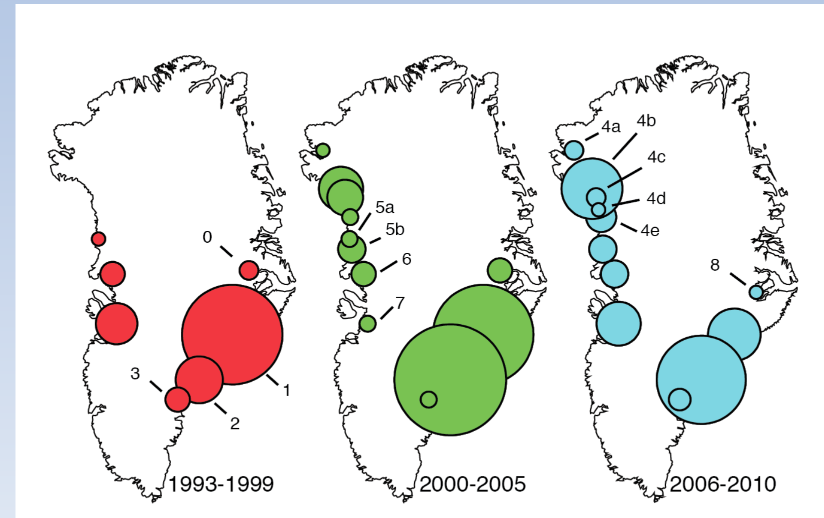
www.usarray.org/alaska

GLISN

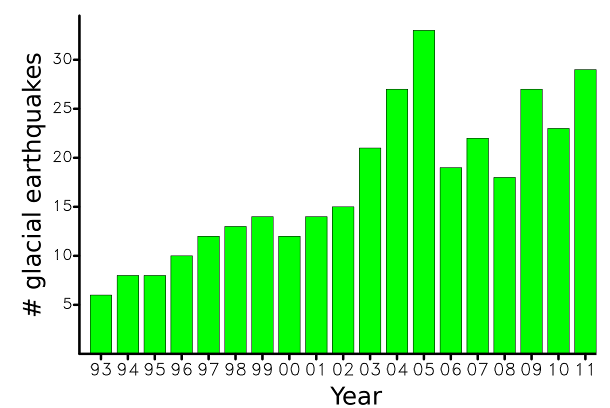
The Greenland Ice Sheet Monitoring Network (GLISN) provides a precedent for high quality, multi-modal observations yielding diverse science results

The Greenland Ice Sheet Monitoring Network (GLISN) - 2013





Spatio-temporal variation of glacial-quake occurrence



Updated after Nettles and Ekström, 2010

Science Magazine Provides a Nice Overview of Solid Earth Research Interests

Science, 06 October 2017

GEOPHYSICS

Seismic array shifts to Alaska

USArray plumbs shifting tectonic plates and offers improved earthquake monitoring

By **Julia Rosen**

As 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 of 193 seismic stations was 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 eastward across the lower 48, using the shivers of earthquakes to create a picture of the crust and mantle below North America (*Science*, 25 September 2009, 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 Mike 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 buried 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 plopped 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 Busby, 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's in a grinding collision that generates earthquakes and volcanoes. Much of the region is made up of slivers 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 could 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 offshore 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 benefit of improved earthquake monitoring in a state that experiences more temblors than even California. Before USArray arrived, the Earthquake Center operated only 130 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 are basically clouds," West says.

Meteorologists have piggybacked 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 5 years. That includes $45,000 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 in place well before Busby's team begins disassembling the array in the summer of 2019. 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." ■

Julia Rosen is a journalist in Portland, Oregon.

A USArray seismic station is deployed near the Ungalikthiuk River in Alaska.

PHOTO: JEREMY MINER

Published by AAAS

". . . these stations will plumb Alaska's depths, illuminating deep-Earth structures as well as registering the shallow tremors of earthquakes and volcanic eruptions"

"Scientists will begin to examine one of the most active subduction zones on the planet"

"Studying the thickness of Alaska's crust could help geologists better define these fragments and understand how the state was assembled"

". . . improved earthquake monitoring in a state that experiences more temblors than even California"

". . . improve mapping of the state's poorly defined fault"

"Meteorologists have piggybacked on the stations' ability to collect and transmit data . . . the data have already improved forecasts. In a place where many people get around in small planes, that can save lives."

Seismicity

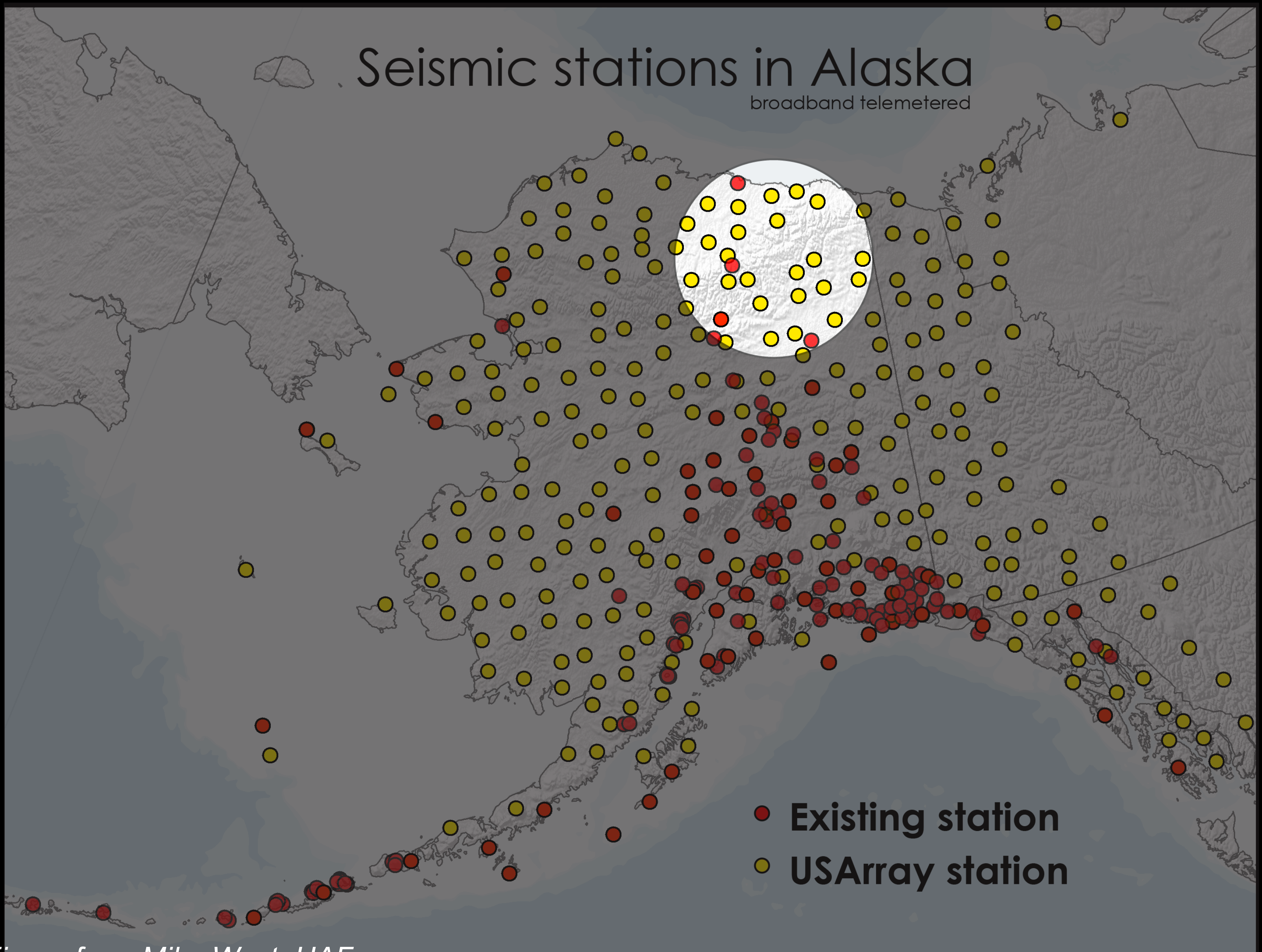
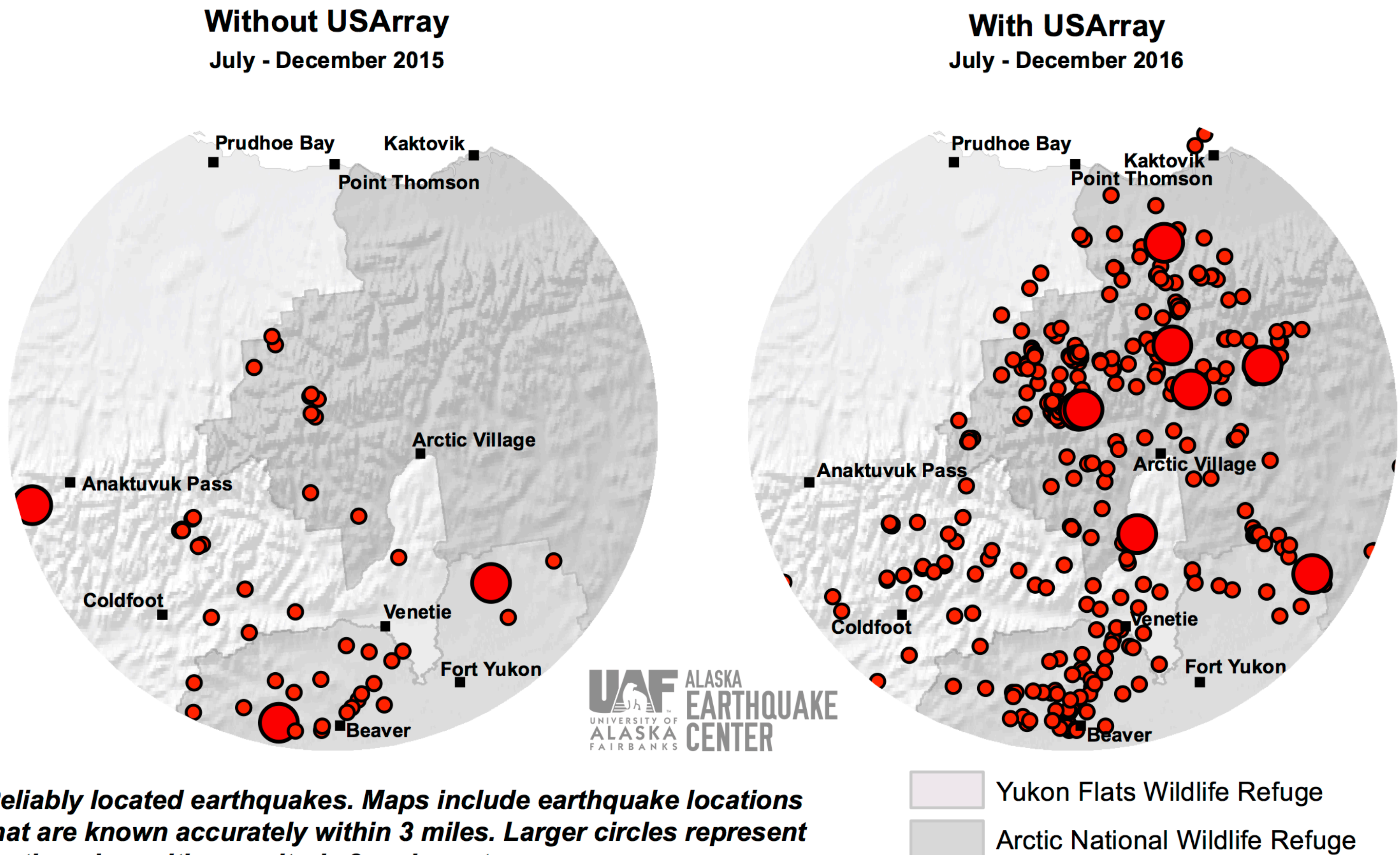


Figure from Mike West, UAF

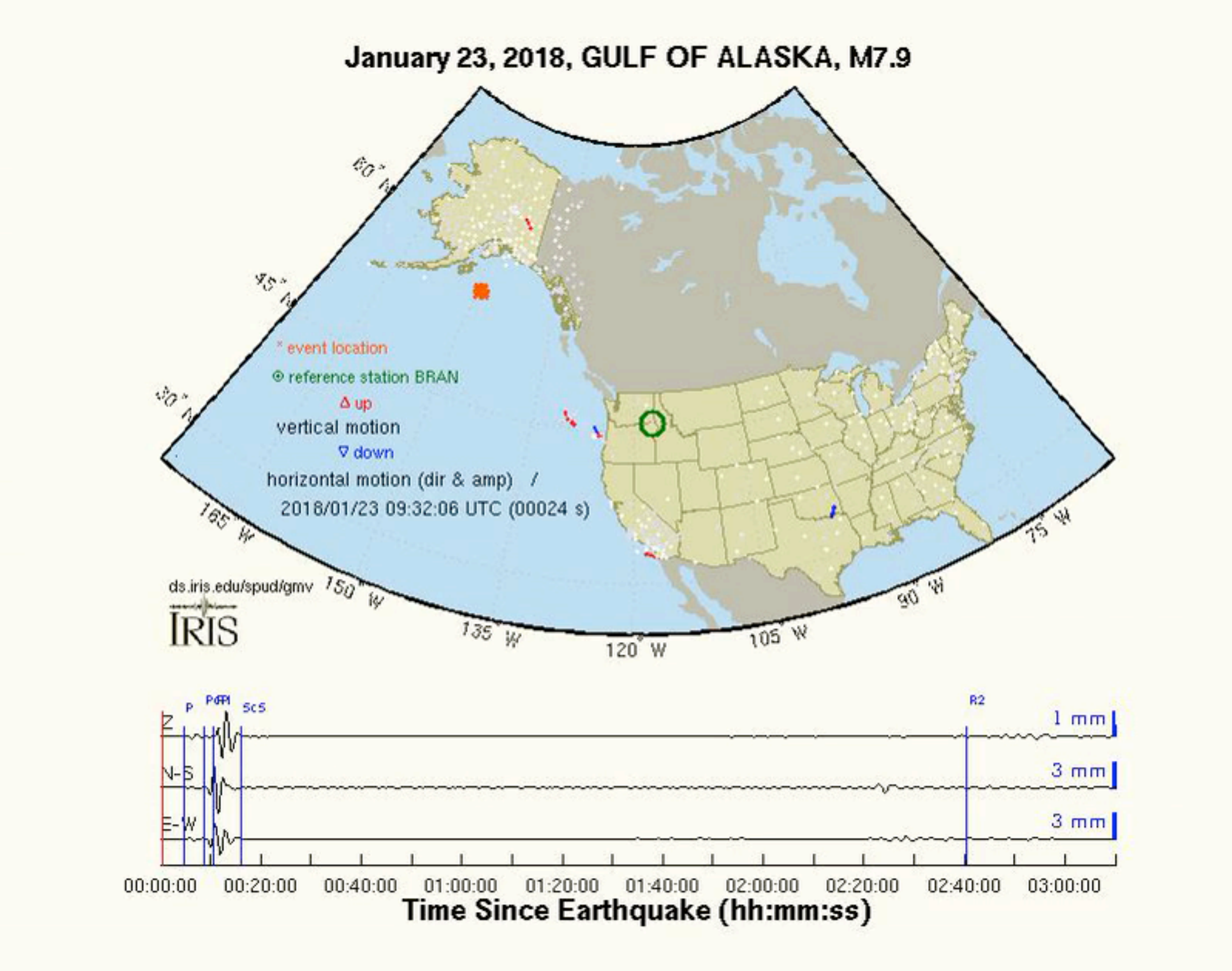
Seismicity



Reliably located earthquakes. Maps include earthquake locations that are known accurately within 3 miles. Larger circles represent earthquakes with magnitude 3 and greater.

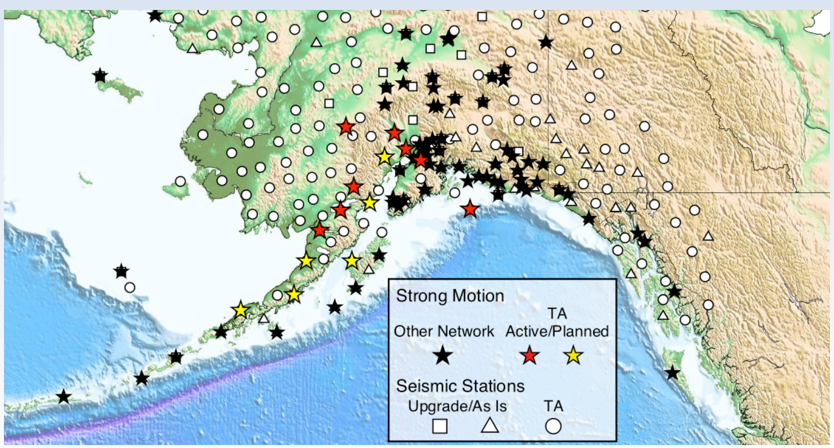
Figure from Mike West, UAF

Propagating Seismic Energy is Used to Probe the Earth's Interior



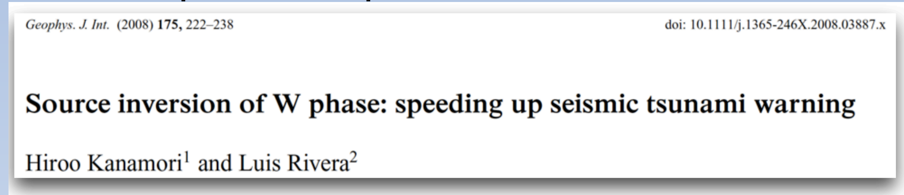
Tsunami

Large tsunamigenic earthquakes in the subduction zone can be characterized with real time data from broadband and strong motion sensors, using a variety of techniques, including the W-phase method for magnitude estimation



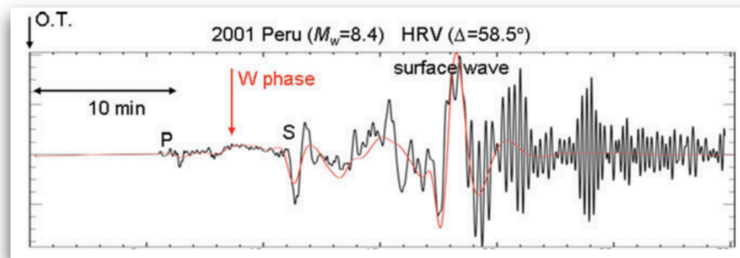
Strong Motion sensors (stars) stay on-scale even in the largest earthquakes

W-Phase and Rapid Earthquake Characterization

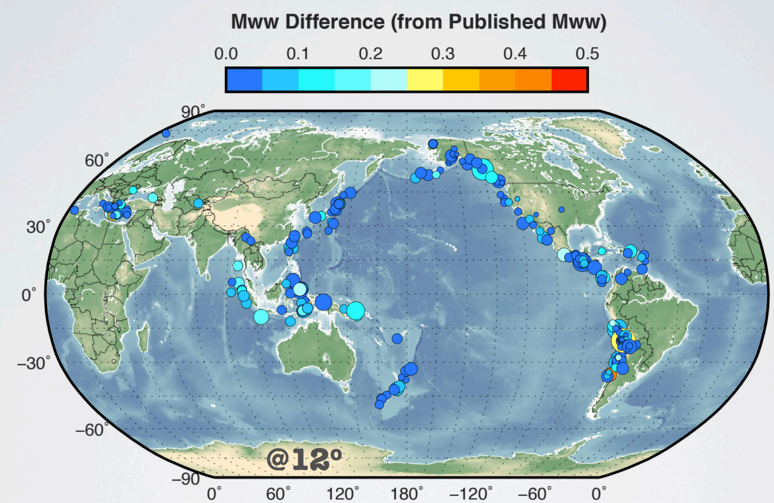

Geophys. J. Int. (2008) 175, 222–238 doi: 10.1111/j.1365-246X.2008.03887.x

Source inversion of W phase: speeding up seismic tsunami warning

Hiroo Kanamori[1] and Luis Rivera[2]



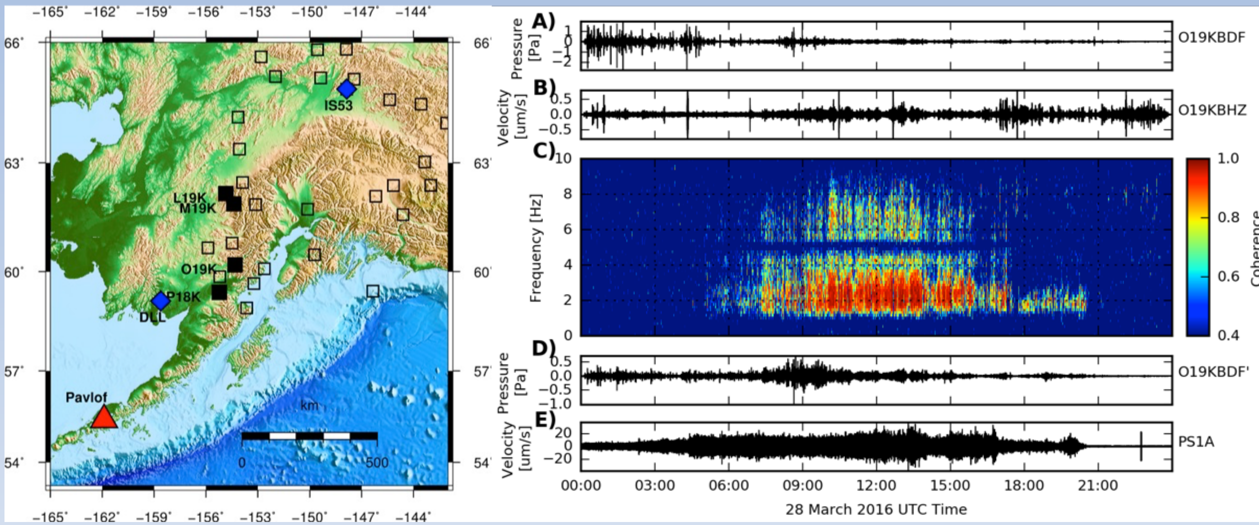
Global W Phase: Rapid Mww Vs Published Solution



These results imply that, for response purposes, we can accurately characterize magnitude very rapidly, given a locally dense distribution of stations (i.e., a regional network).

G. Hayes, USGS

Volcano Infrasound



Fee et al, Science, 2017

4 TA stations recorded the March 2016 Pavlof eruption (before network was fully deployed)

Recording shows the eruption on infrasound channel (BDF) and seismic channel (BDF)

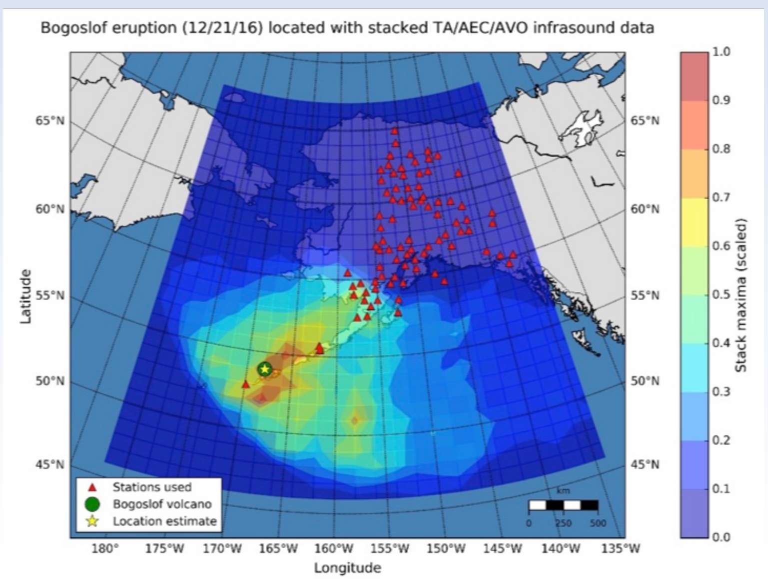


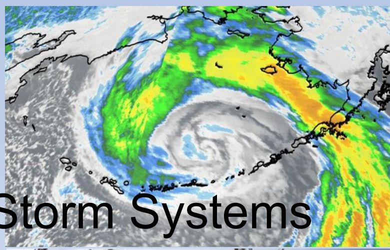
Figure from David Fee, AVO/UAFGI

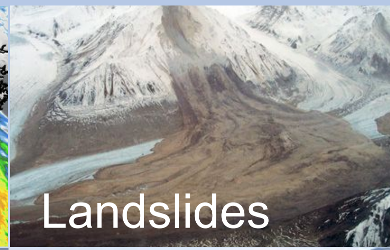
December 2016 Bogoslof eruptions recorded by more TA stations after the 2016 field deployment

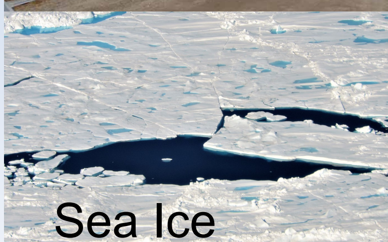
Collaborative NSF project #1614323 between UC Santa Barbara, UAF, and USGS-AVO to develop operational eruption detection and location algorithm using TA infrasound data

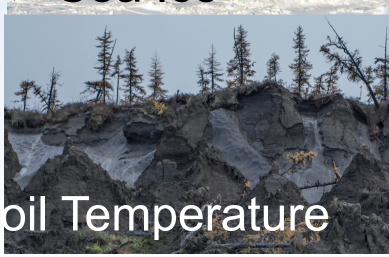
The ATA Provides an Arctic Observing Platform

Observations possible with Current Instrumentation

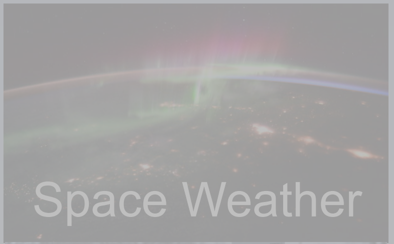


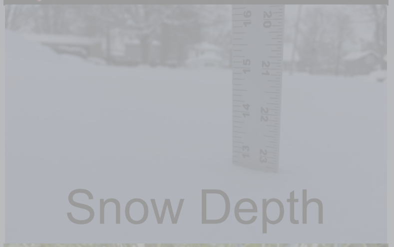




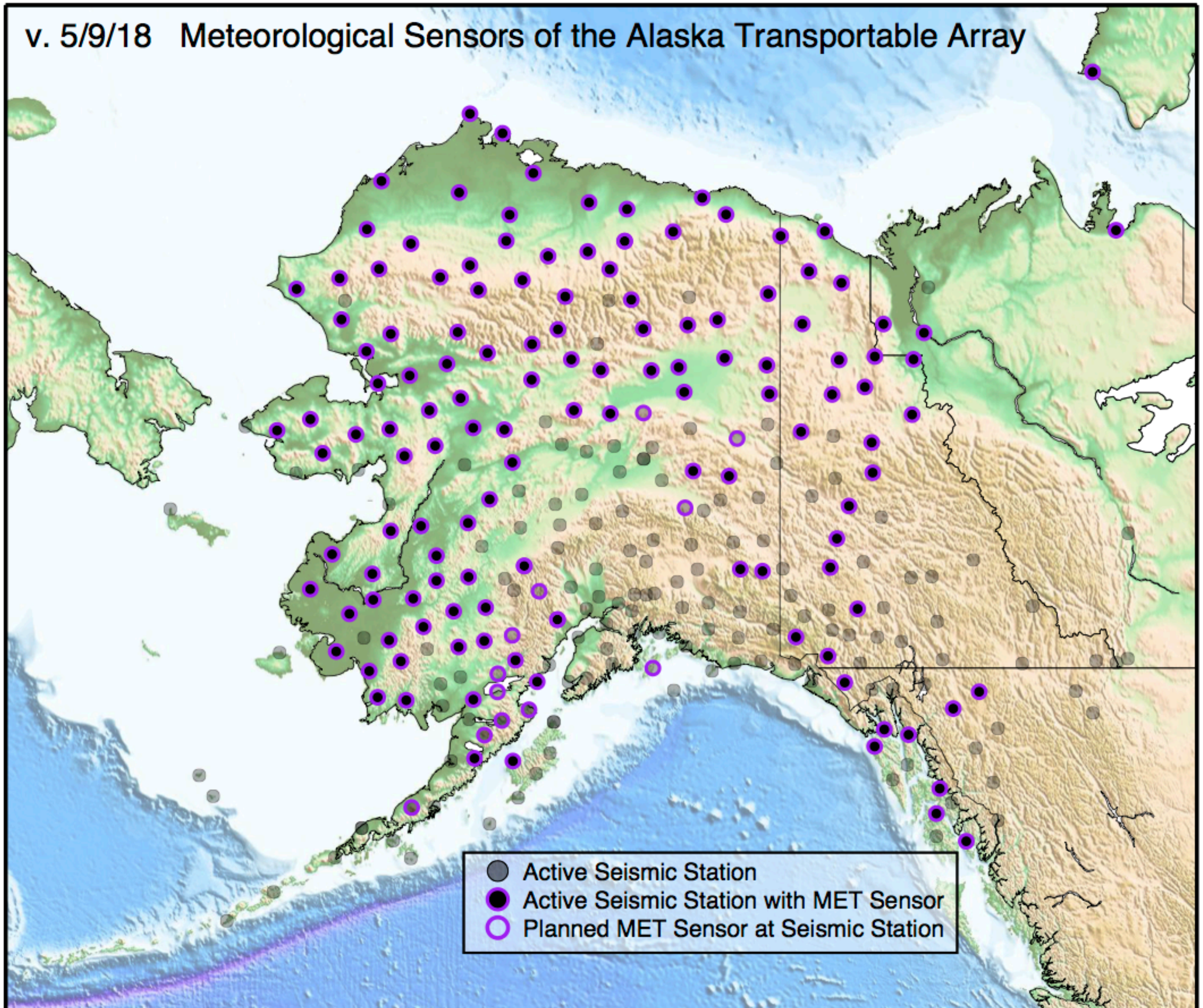


Observations Possible with Additional Instrumentation





Met Sensors in AK



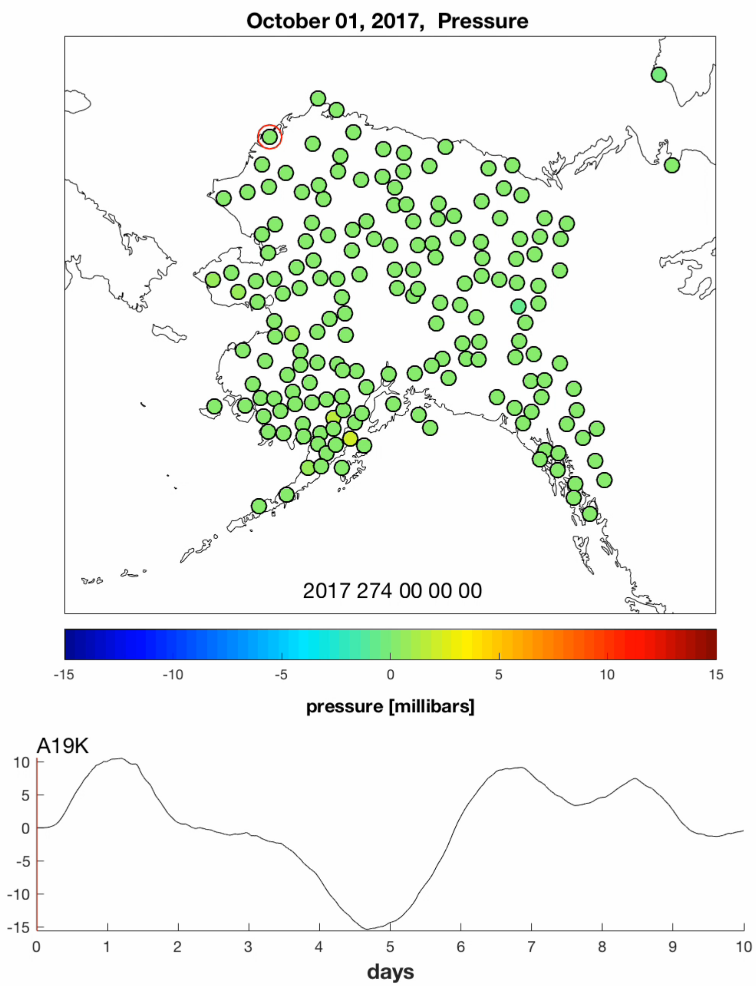
42 TA supplied, NSF
35 UCSD, NSF
32 NOAA NWS
40 NASA ABoVE
2 Yukon
============
151 sensors

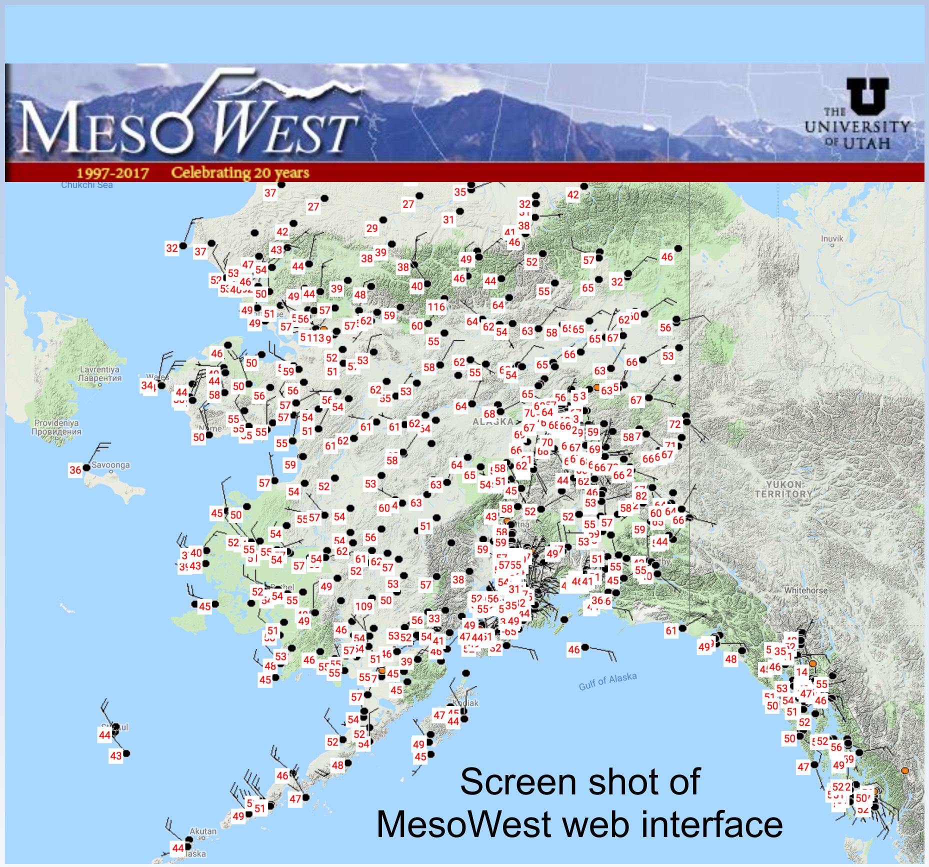
129 installed
16 planned
============
145 stations

"It is being used directly for situational awareness. The data is also directly being in the RTMA/URMA analysis for Alaska and our local analysis These analysis are used to verify our forecasts, situational awareness, and for ground truth to post-process modeling systems."
- Gene Petrescu, NWS

Atmospheric Studies

Continuous, real-time time series

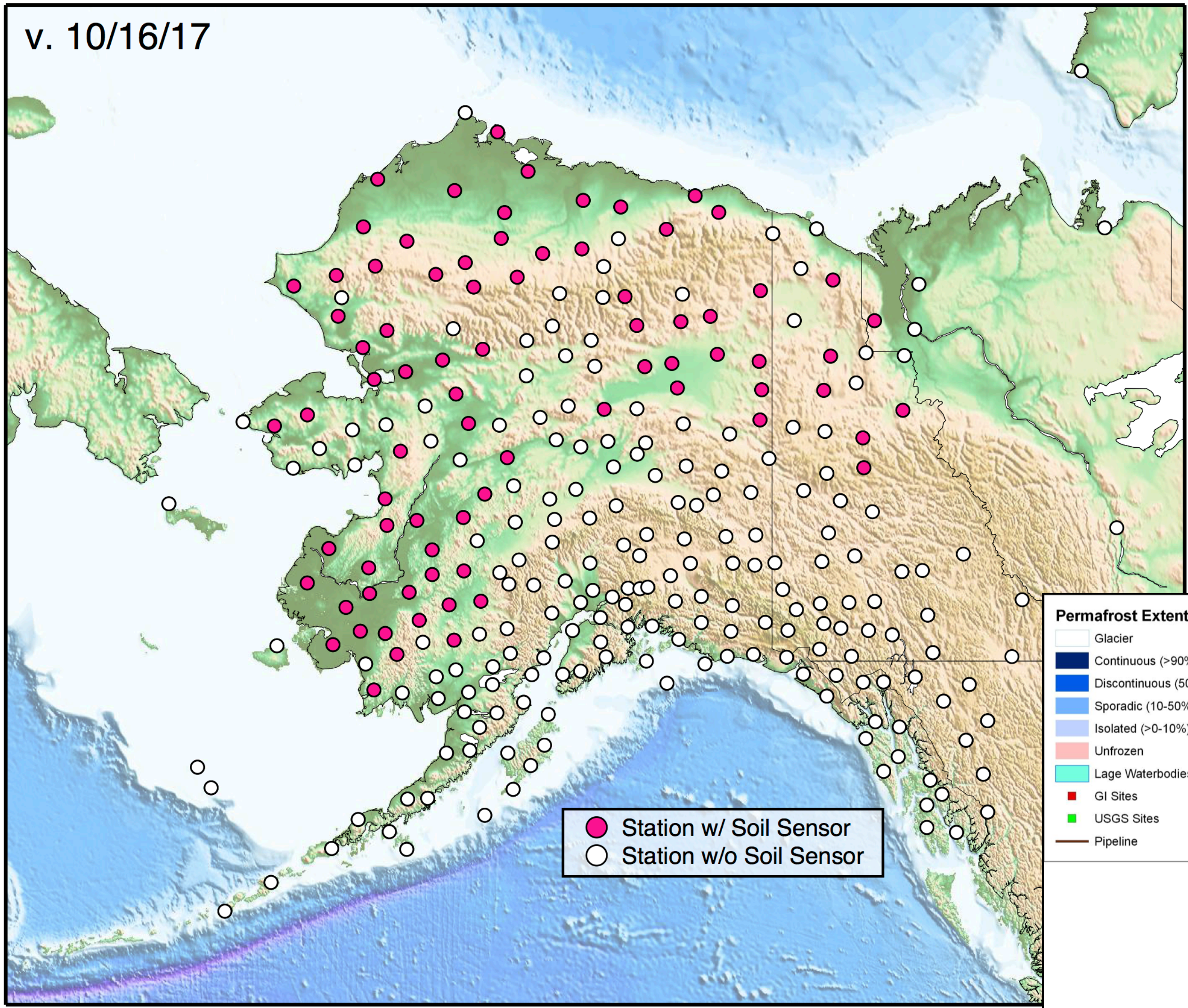




All meteorological data are contributed to MesoWest in real-time

Movie shows 10 days of pressure variations across array

Soil Temperature Profile



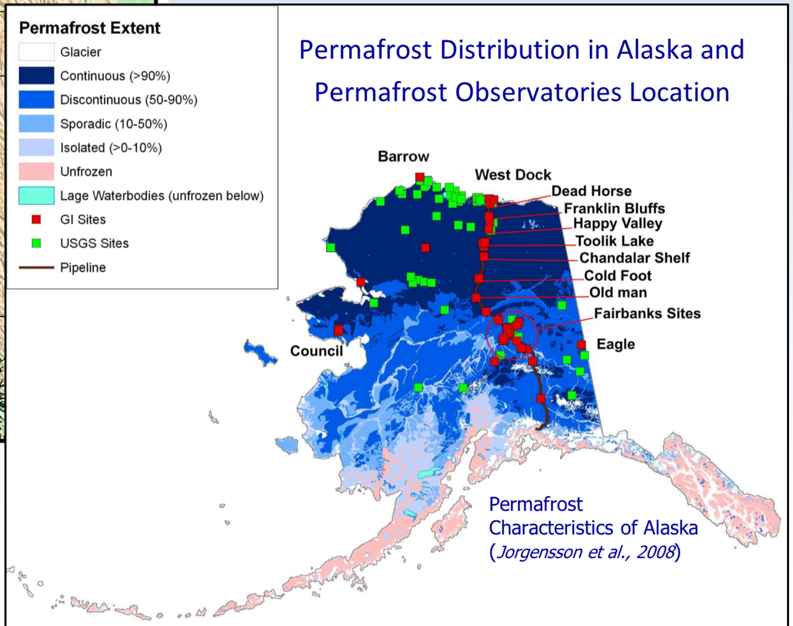
(78) Stations Supported by:

- NASA ABoVE
- Yukon Geo Survey

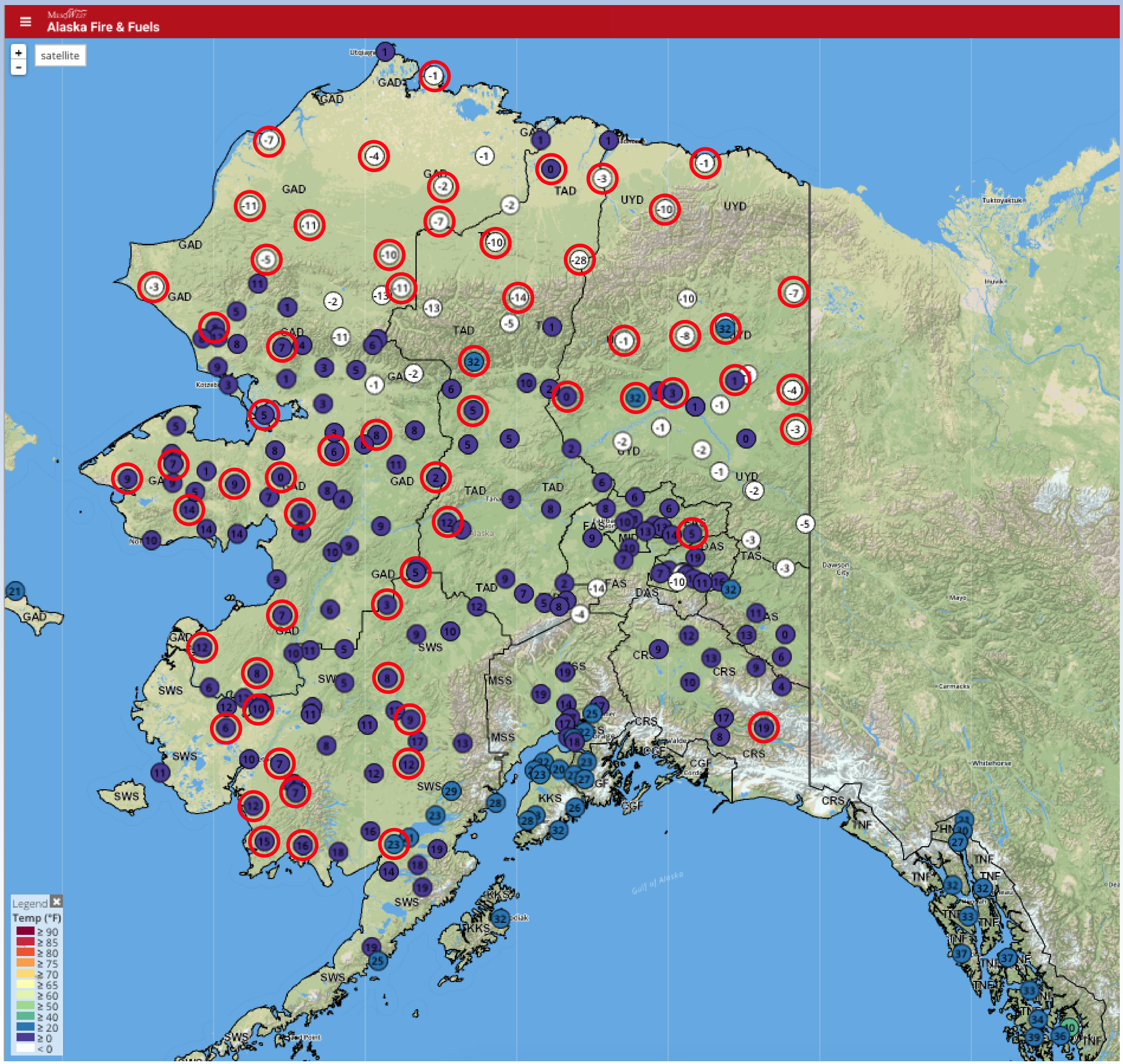
1-2.5M depths
w/ 4 to 8 thermistors

Data stored locally

UAF Permafrost Group
V. Romanovsky
P. Lipovsky



Wildfire Management



https://akff.mesowest.org/map, red circles are TA stations

Alaska Fire & Fuels is an interagency resource for fire weather and fuel conditions throughout Alaska

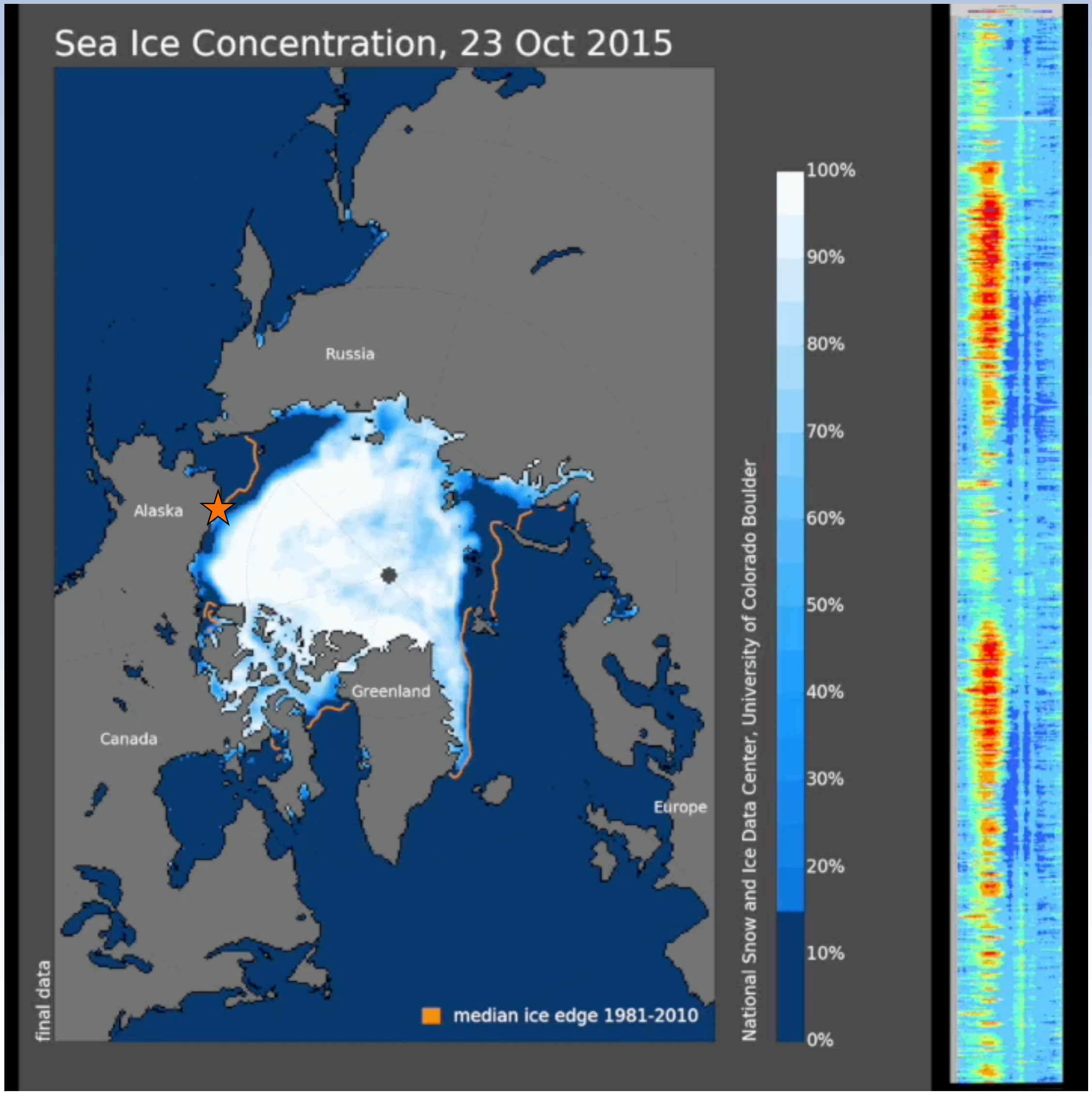
During an average Alaska fire season, there are about 500 fires and approximately 1 million acres are burned

Data from TA stations with meteorological sensors assimilated through MesoWest

TA stations fill in large coverage gaps across the state

Arctic Sea Ice Dynamics

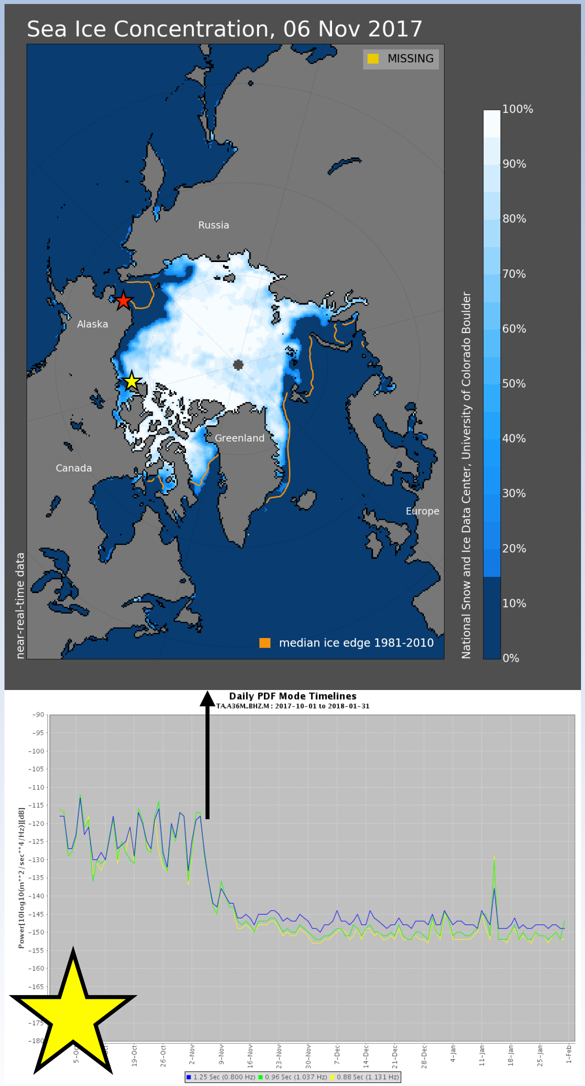
Movie below (play in full screen mode) illustrates how wave-induced seismic noise is modulated by the presence / absence of sea ice.

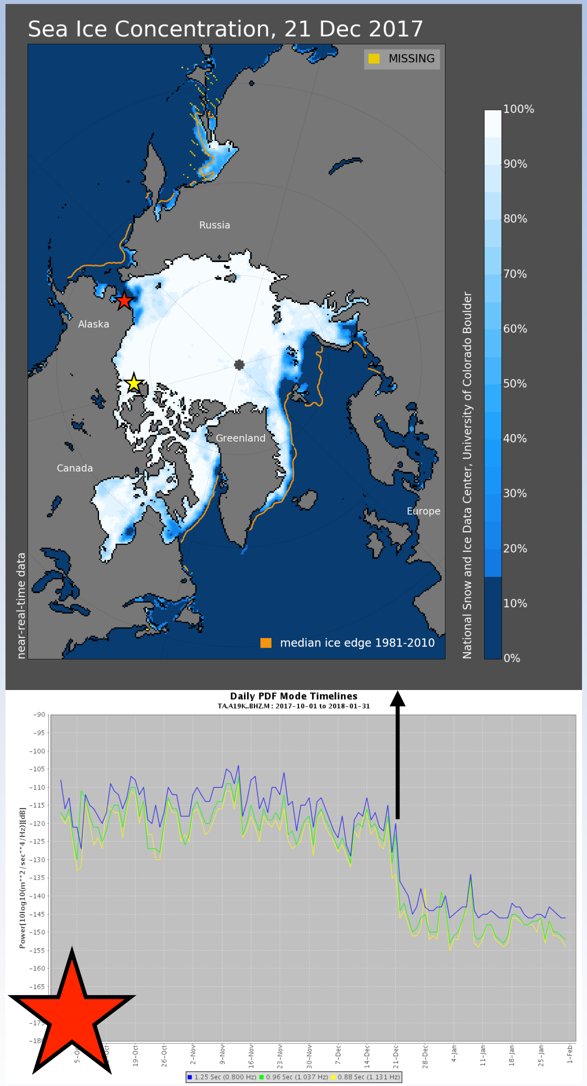


- Abrupt seasonal changes in the characteristics in seismic noise
- Amplitude of seismic noise at short periods decreases on northern coastal stations as sea ice becomes landfast

High noise (red) corresponds to open water

Arctic Sea Ice Dynamics





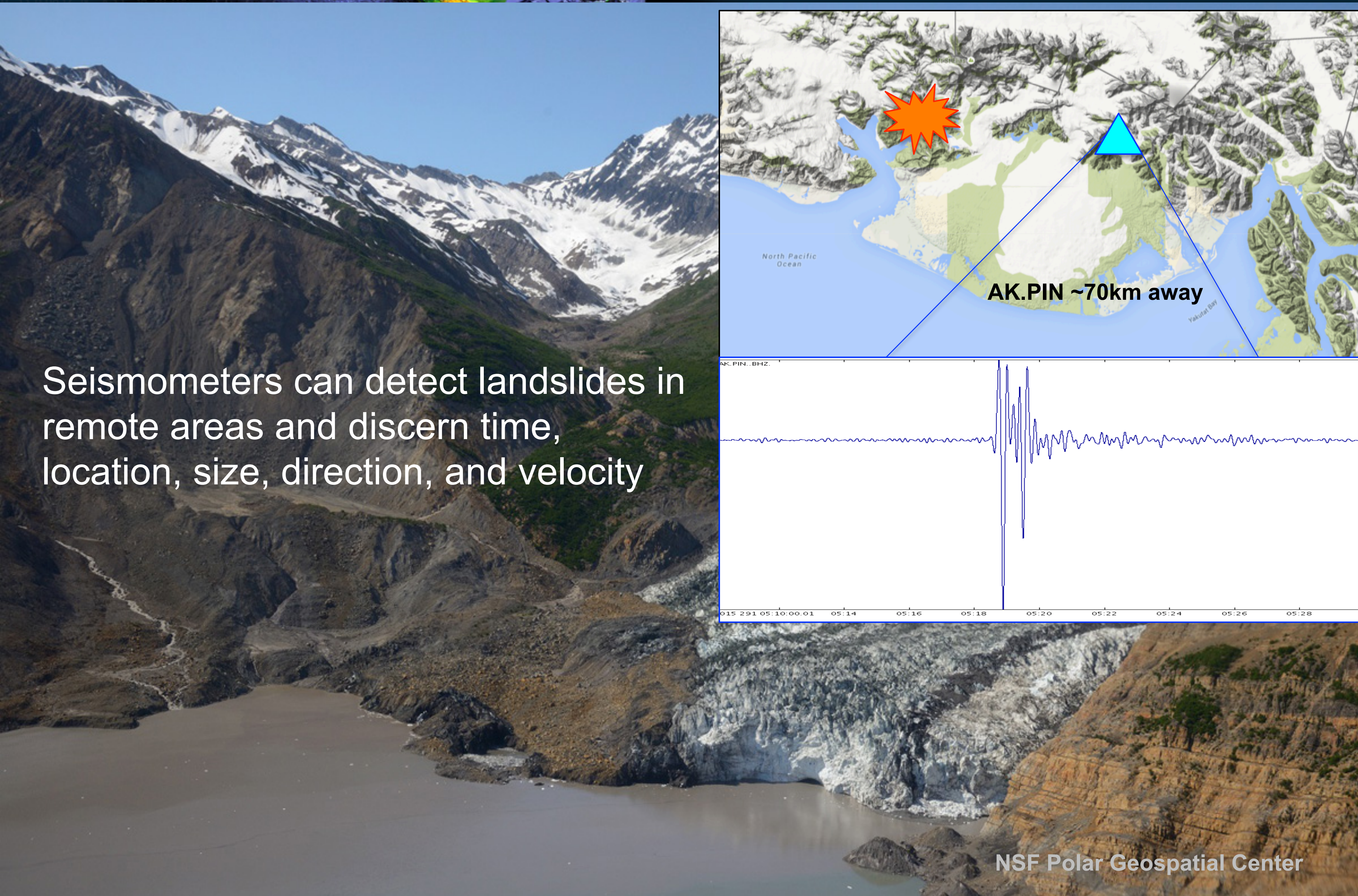
- Example: Same four-month time period and scale for two stations with different freeze-up dates

Time series show power in seismic data as a function of time.

Decrease in power is coincident with freeze-up.

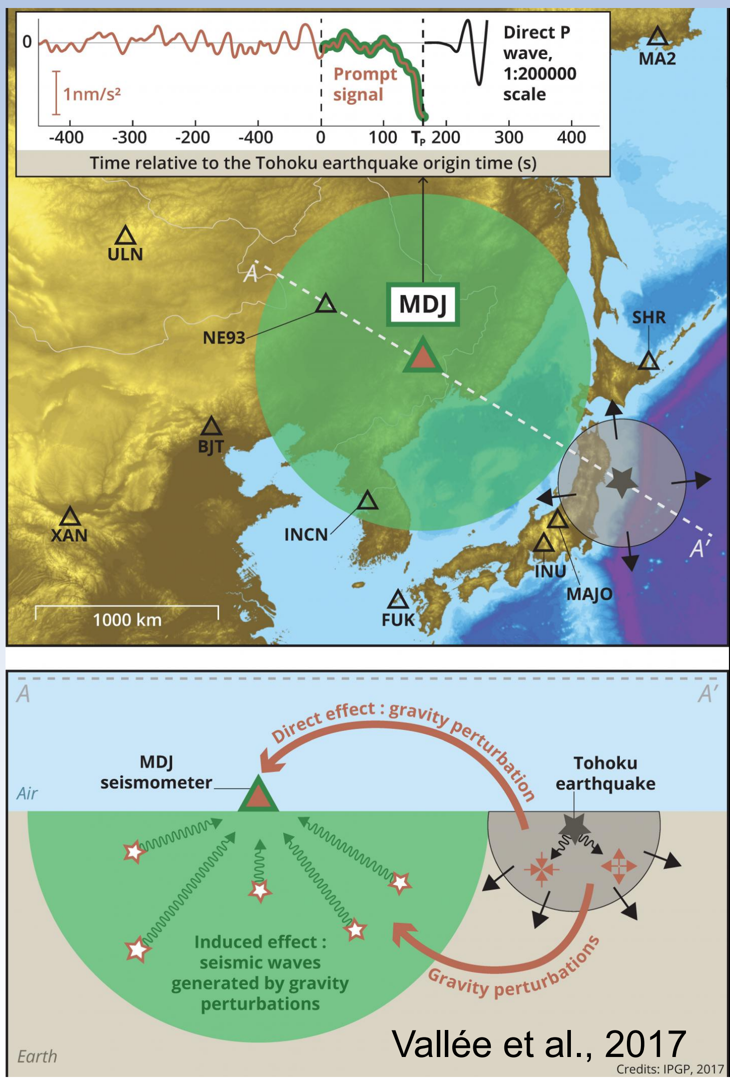
Landslides

Seismometers can detect landslides in remote areas and discern time, location, size, direction, and velocity

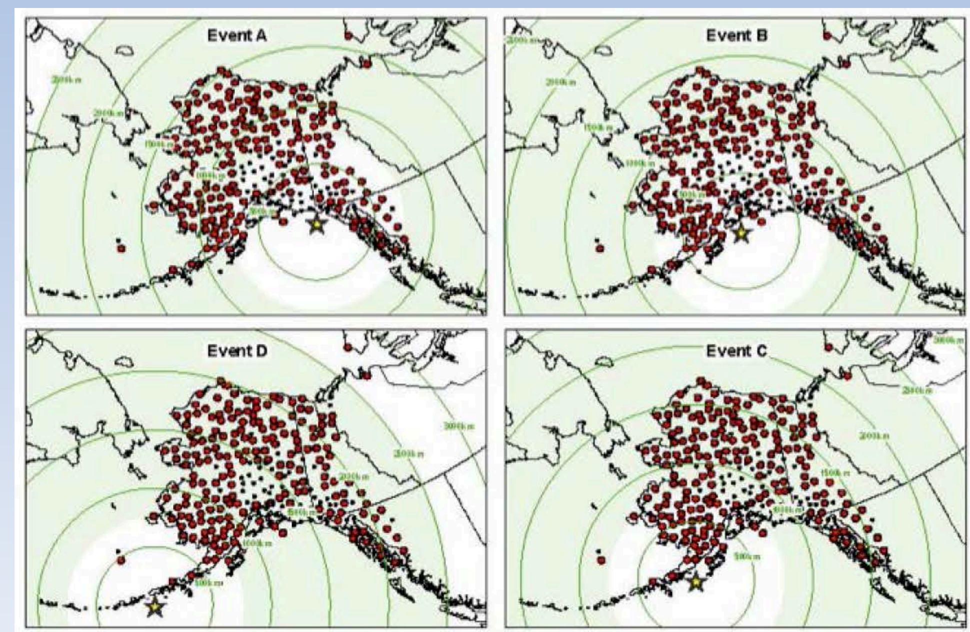


Potential to Observe Elasto-gravity Signals from Great Earthquakes

Elastogravity Signals Could Enable Rapid Characterization of Great Earthquakes



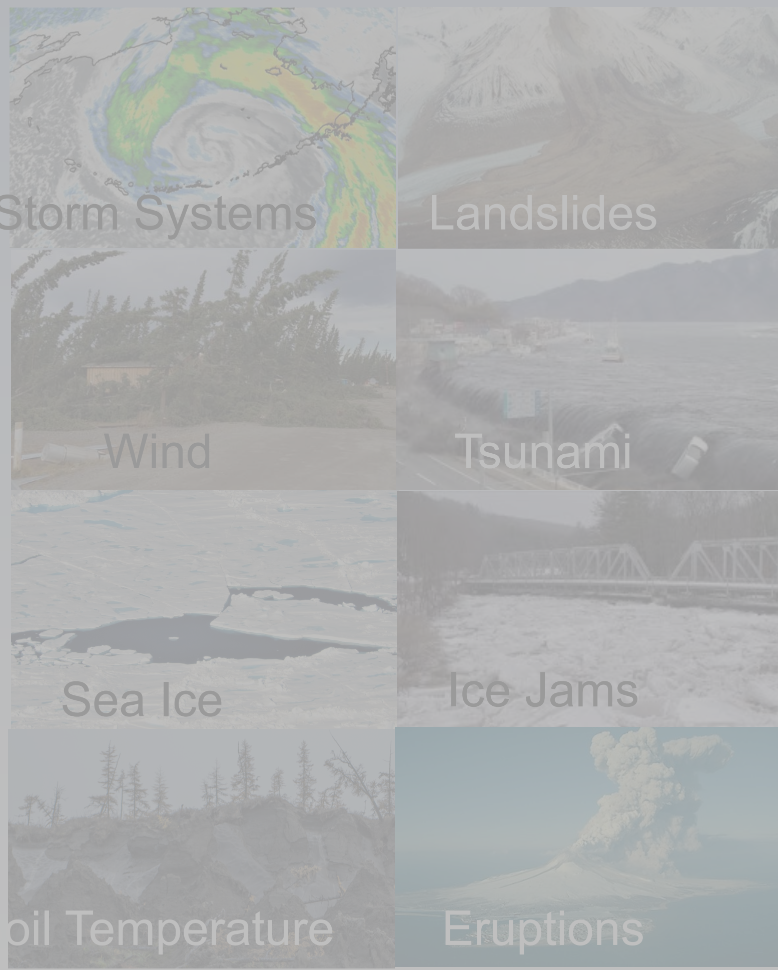
Vallée et al., 2017



An illustration of four hypothetical events, showing that stations in the northern part of Alaska (green shading) fall in the optimum observing range of ~750 – 2,500 km for events anywhere along the subduction zone (radii of circles increment by 500 km relative to hypothetical source locations)

The ATA Provides an Arctic Observing Platform

Observations possible with Current Instrumentation

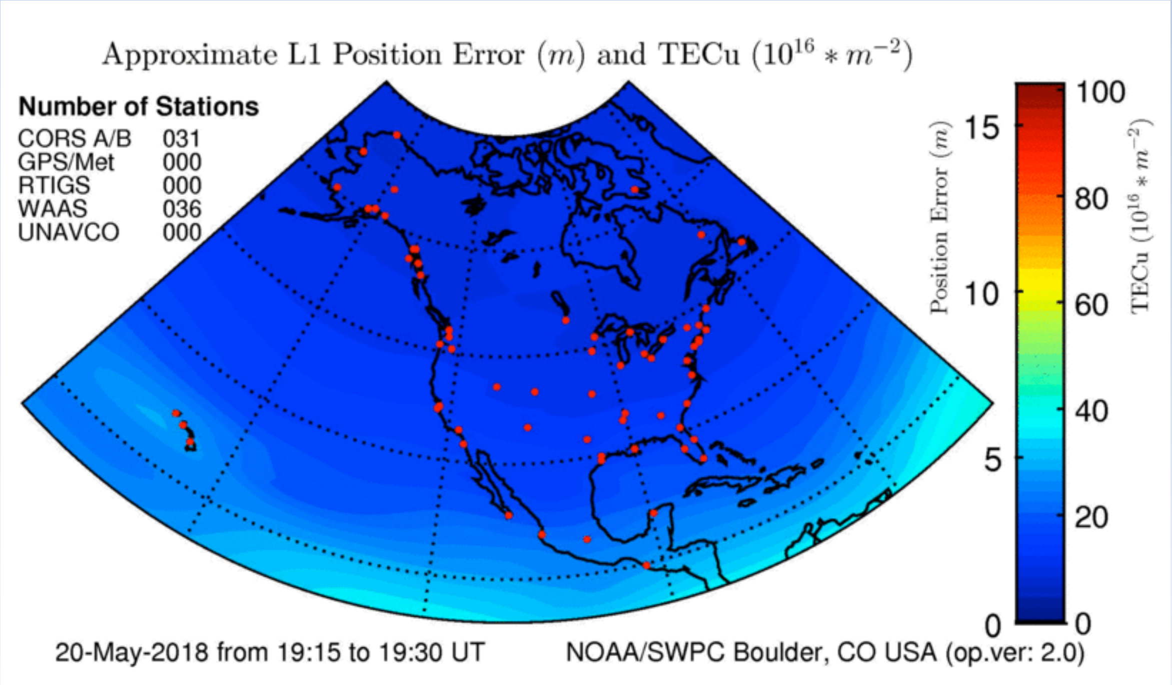


Observations Possible with Additional Instrumentation

Potential for TEC Observations

- Opportunity to expand TEC observation coverage
- Appropriate GNSS receivers are consistent with power and telemetry capabilities at ATA sites
- Presently exploring an opportunity to host receivers being deployed by the NSF-funded MACAWS project

North American Total Electron Content
Results from NOAA Space Weather Prediction Center



Potential for Soil Moisture / Snow Depth / Vegetation Observations

GPS Interferometric Reflectometry possible with hut-top antenna mount

Multi-pathing to GPS antenna samples nearby ground conditions (~30-40 m radius around antenna)

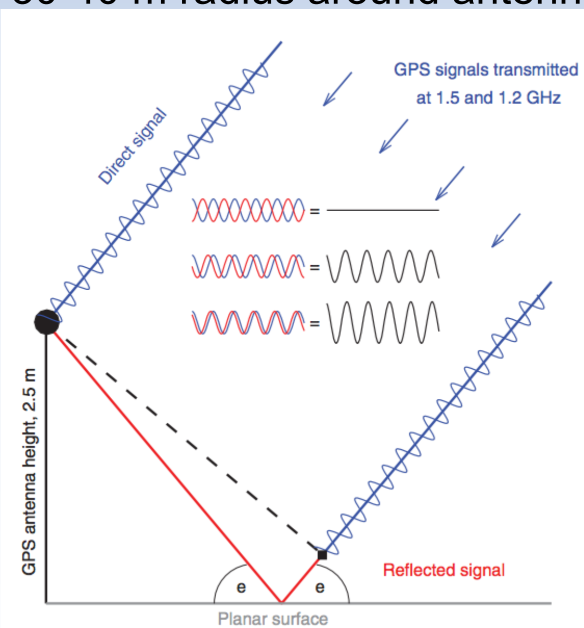
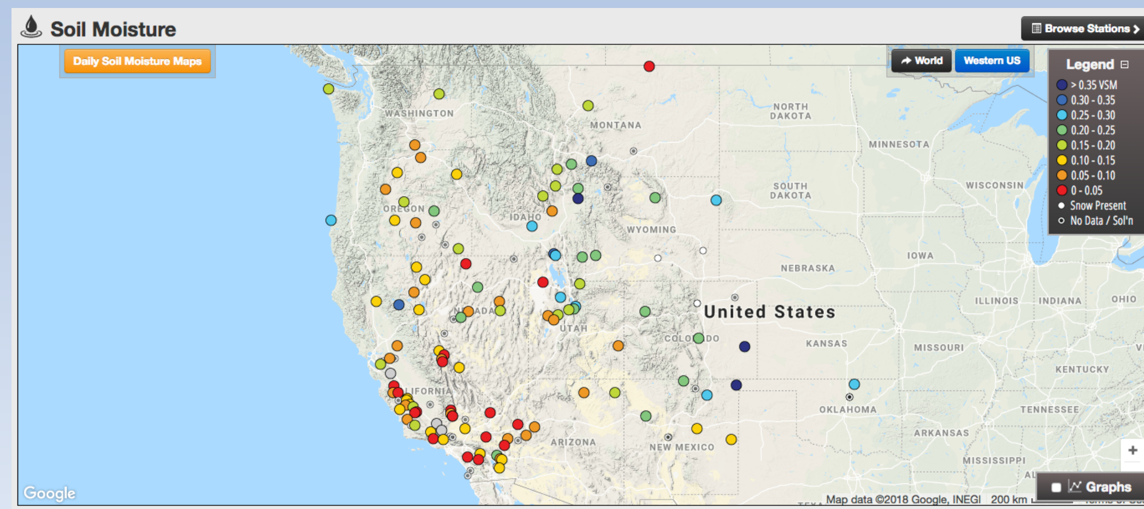


FIGURE 1 | Multipath geometry for a horizontal planar reflector. Satellite elevation angle is designated by the variable *e*. A GPS antenna measures the interference between the direct (blue) and reflected (red) signals. Examples of this interference are shown in the inset.

Figure from: K.M. Larson, WIREs Water 2016. doi: 10.1002/wat2.1167



From the PBO H_2O Portal at http://xenon.colorado.edu/portal

Recent work has demonstrated the effective use of GPS for sampling the soil moisture, snow depth, and vegetation properties in the immediate vicinity of the GPS antenna.

Soil Moisture:

Larson, K.M., E.E. Small, E. Gutmann, A. Bilich, J. Braun, V. Zavorotny, Use of GPS receivers as a soil moisture network for water cycle studies, Geophys. Res. Lett., 35, L24405, doi:10.1029/2008GL036013, 2008.

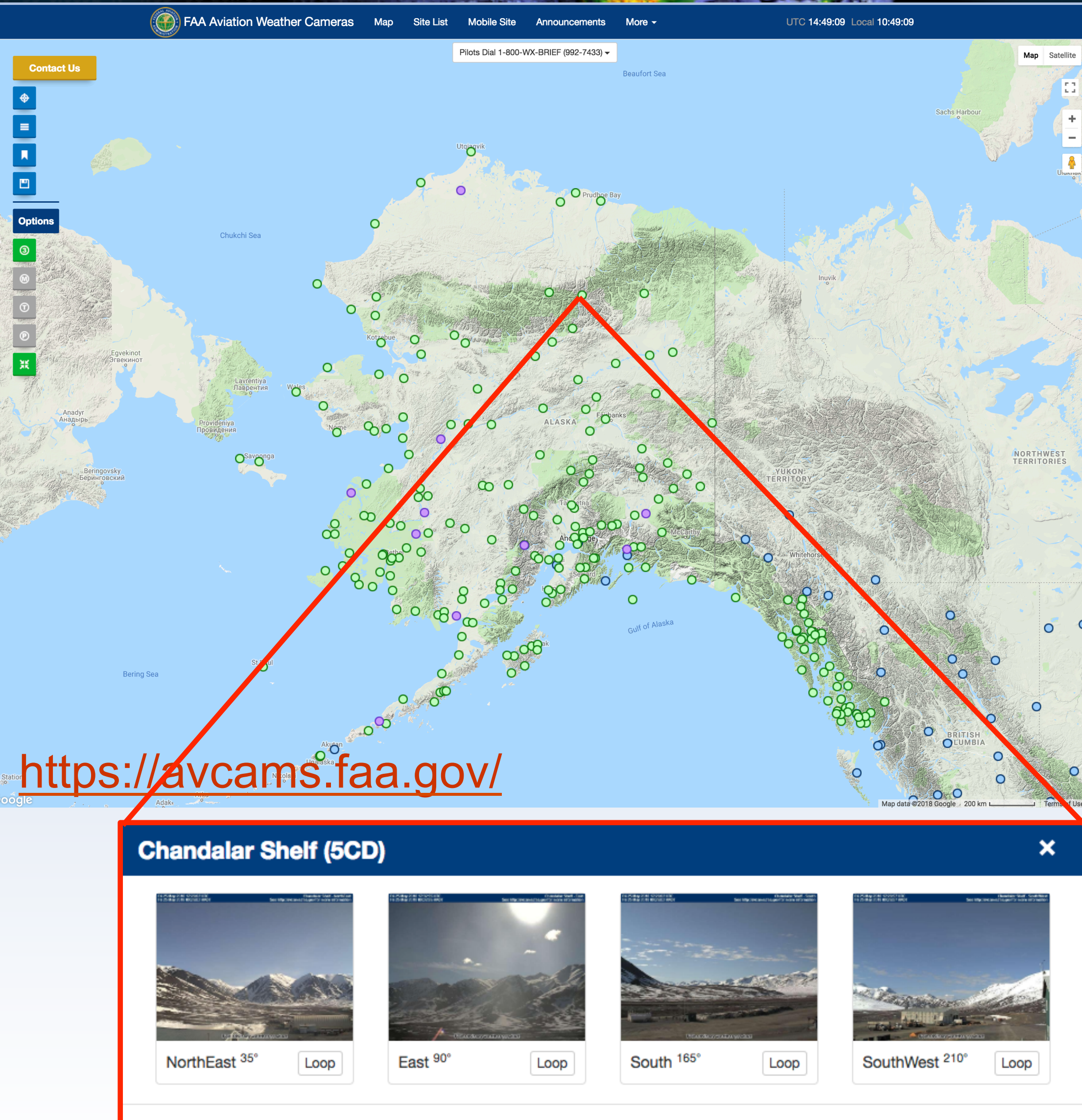
Snow Depth:

Larson, K.M., E. Gutmann, V. Zavorotny, J. Braun, M. Williams, and F. Nievinski, Can We Measure Snow Depth with GPS Receivers?,Geophys. Res. Lett., 36, L17502, doi:10.1029/2009GL039430, 2009.

Vegetation:

Small, E.E., K.M. Larson, and J. J. Braun, Sensing Vegetation Growth Using Reflected GPS Signals, Geophys. Res. Lett. 37, L12401, doi:10.1029/2010GL042951, 2010.

Aviation Weather



https://avcams.faa.gov/

Webcam program began in 2007, by 2014 there had been an 86% reduction in weather related accidents in Alaska

Low power, rugged cameras could be integrated at key TA stations

The FAA webcam website for Alaska aviation is heavily utilized

Meteorological data from TA stations already helping aviators in poorly sampled areas

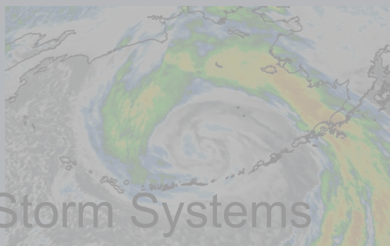
TA sites could infill existing FAA coverage

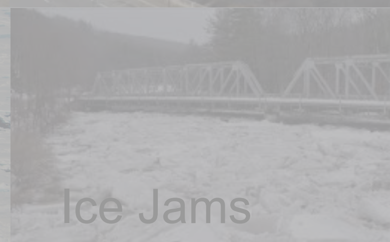
Alaska has more active aviation pilots per capita than any other state (DOT, 2004)

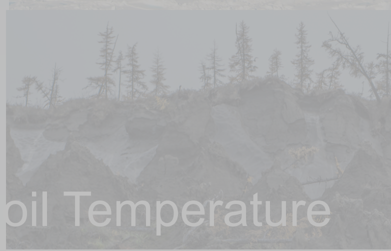
Rank	States	Amount
# 1	Alaska:	1.313 per 100 people
# 2	Montana:	0.407 per 100 people
# 3	Colorado:	0.393 per 100 people
# 4	North Dakota:	0.383 per 100 people
# 5	Wyoming:	0.363 per 100 people
# 6	New Hampshire:	0.334 per 100 people
# 7	Idaho:	0.331 per 100 people
# 8	Washington:	0.33 per 100 people
# 9	Arizona:	0.31 per 100 people
# 10	Utah:	0.3 per 100 people

The ATA Provides an Arctic Observing Platform

Observations possible with Current Instrumentation







Observations Possible with Additional Instrumentation

Summary

- An Observational Approach encompassing a large geographic area with uniform, high station density-not unique to seismology.
  - Transformational science
  - “Swiss Army Knife” of capabilities

For More Information

On the Web

- EarthScope
  www.earthscope.org
- USArray
  www.usarray.org/alaska
- National Science Foundation
  www.nsf.gov

Questions? Contact:

Bob Busby, busby@iris.edu, Transportable Array Manager

Bob Woodward, woodward@iris.edu, IRIS Director of Instrumentation Services

EarthScope is funded by the National Science Foundation.