Towards Operational Moment Tensors at the Alaska Earthquake Center

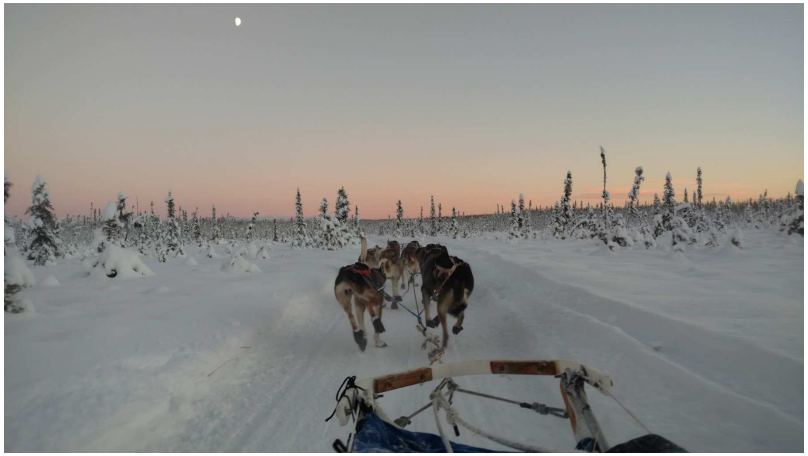
Kenneth Macpherson[1], **many collaborators**

[1]AEC, Geophysical Institute, University of Alaska Fairbanks

Antelope User's Group Meeting, 2019

Welcome to Alaska!

Welcome to Alaska!



Welcome to Alaska!

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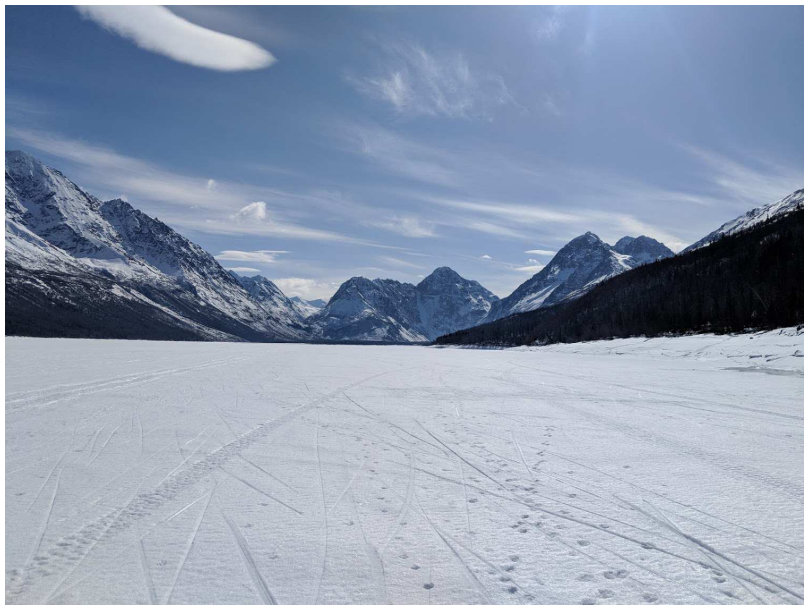

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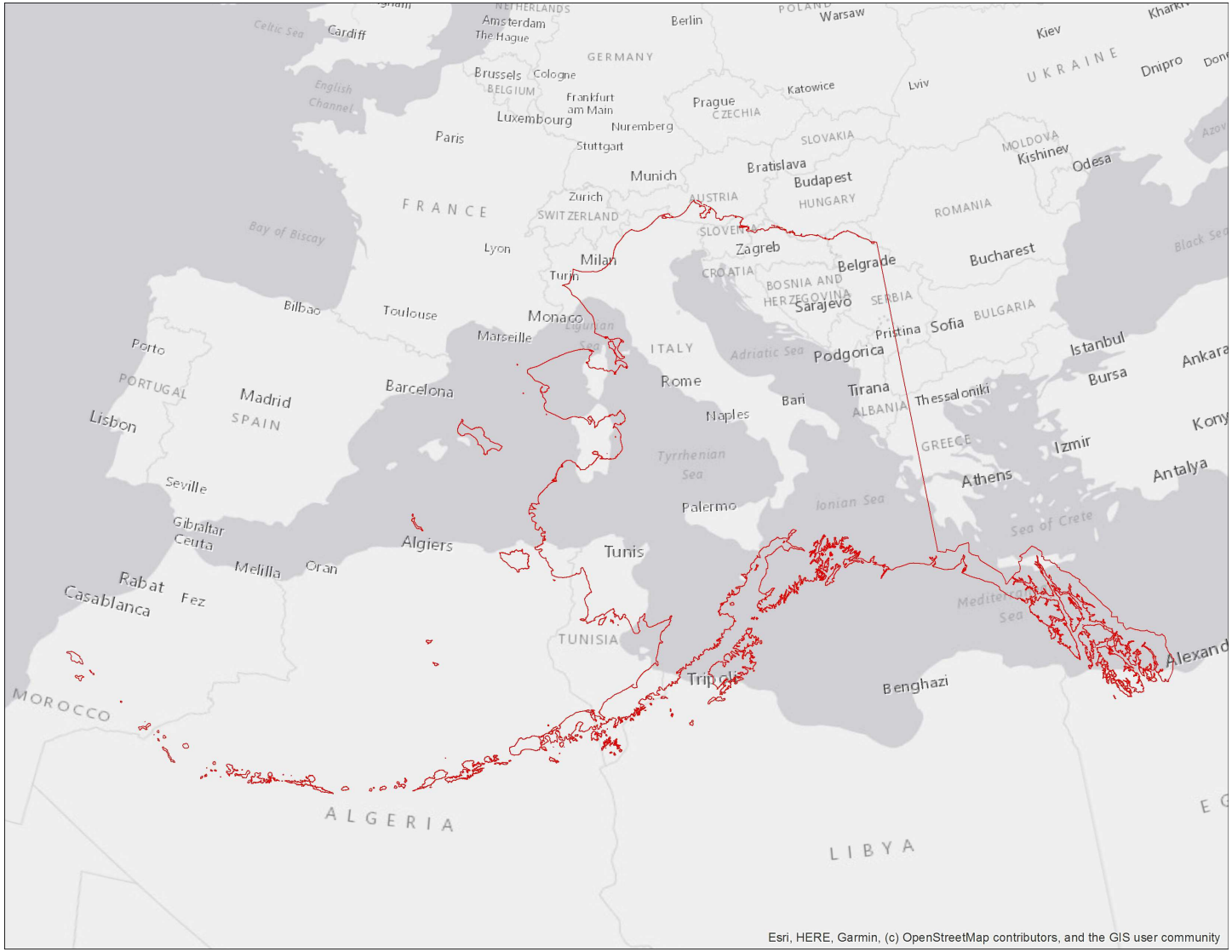

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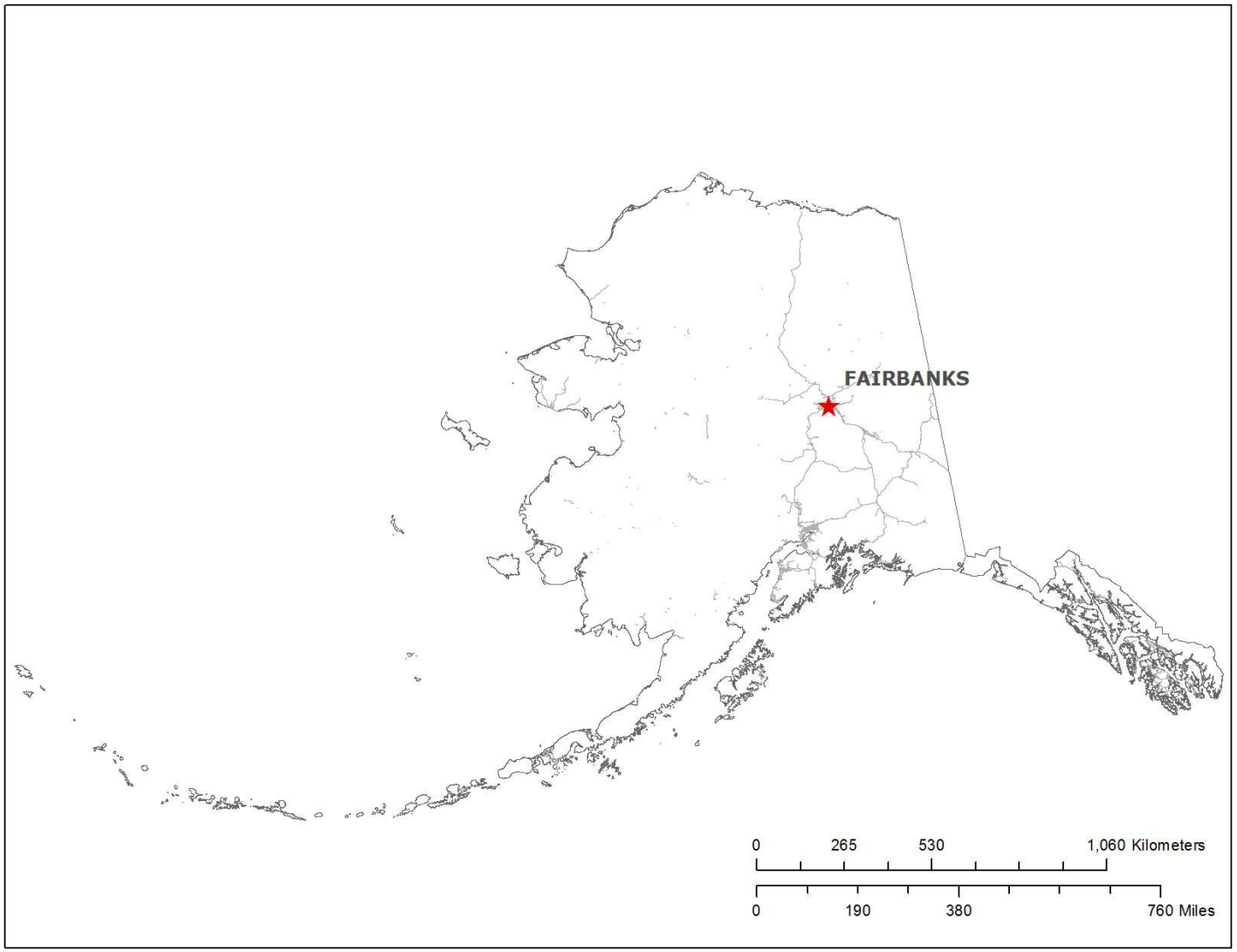


Geophysical Institute, University of Alaska, Fairbanks

"Advancing Alaska's resilience to earthquakes through monitoring, research, and public engagement"

OUR STAFF

We are scientists, engineers, data analysts, field technicians and educators with a shared passion for working in the evolving geology of Alaska. We are motivated by the reality that some of the great tragedies of our time are caused by earthquakes, as well as the knowledge that earthquakes are a powerful tool for understanding our landscape and the resources it contains.

Michael West
State Seismologist

Natalia Ruppert
Seismologist

Matt Gardine
Operations Seismologist

Scott Dalton
Field Operations Manager

Ken Macpherson
Product Manager

Mitch Robinson
System Administrator

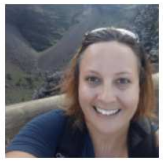
Elena Suleimani
Tsunami Modeler

Dmitry Nicolsky
Tsunami Modeler

Nate Murphy
Seismic Network Technician

Lucas Cheek
Software Developer

Pete Reynoldson
Logistics Coordinator



Heather McFarlin
Data Specialist

Ian Dickson
Communications Specialist

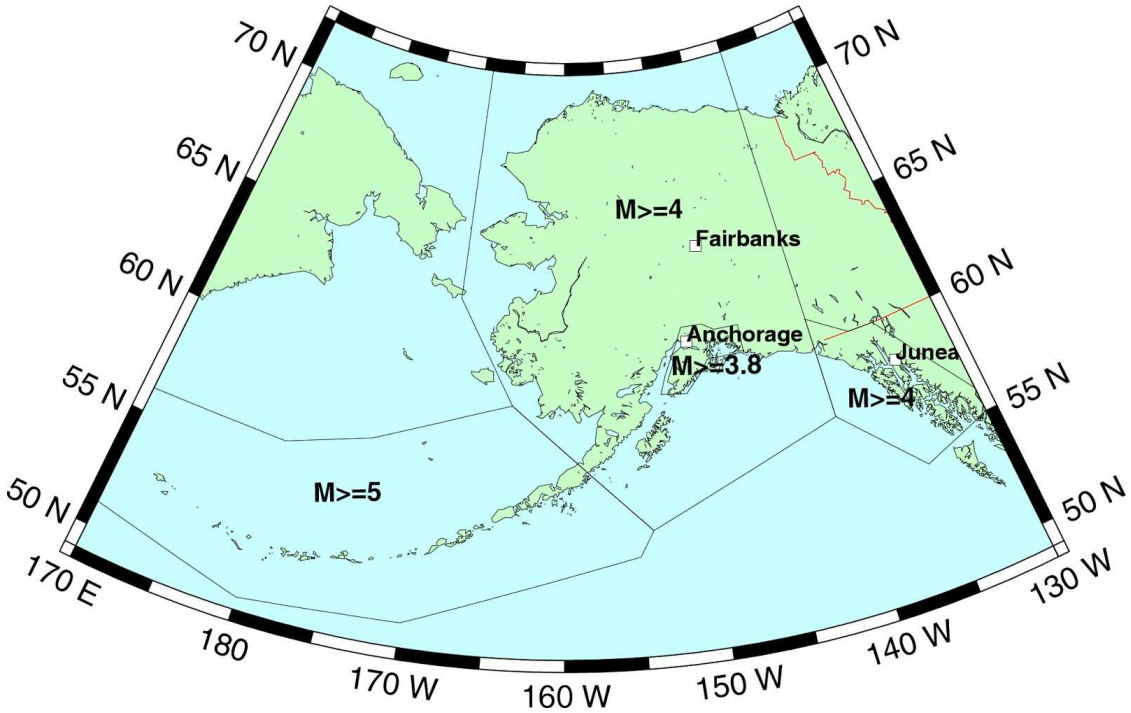
Miriam Braun
Seismic Data Analyst

Lea Gardine
Outreach Coordinator

Natalia Kozyreva
Lead Seismic Data Analyst

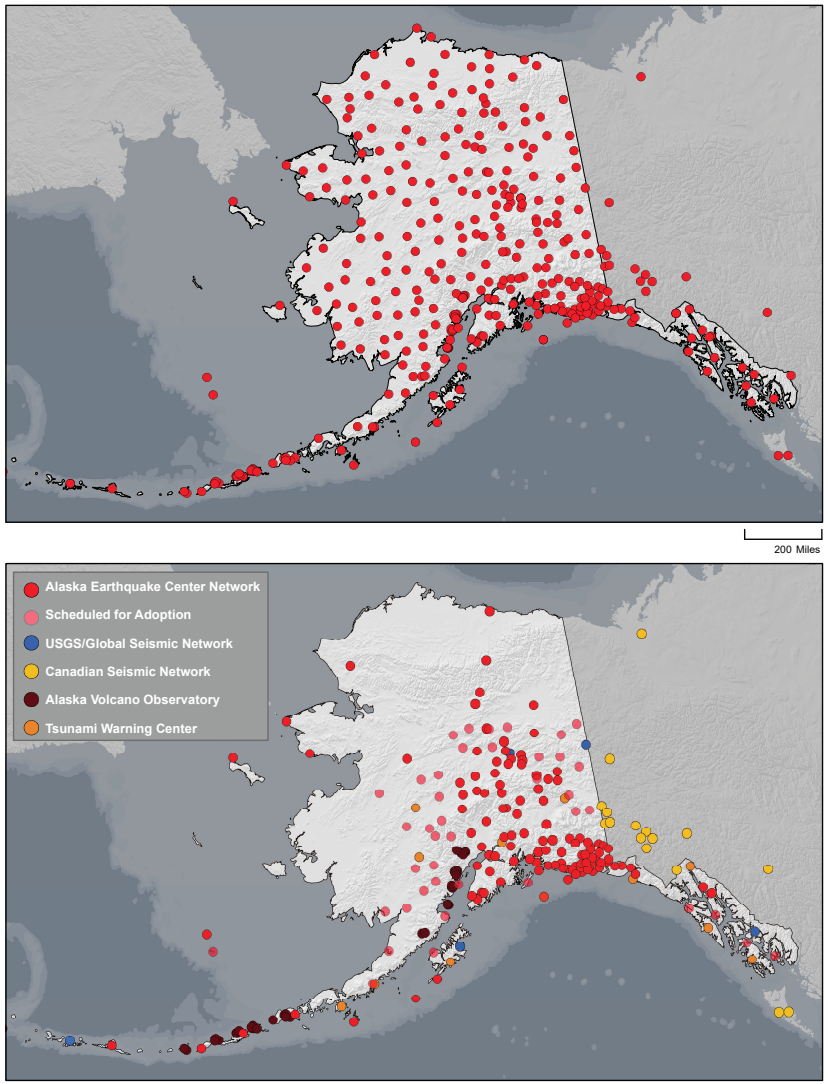
Dara Merz
Research Technician

"Advancing Alaska's resilience to earthquakes through monitoring, research, and public engagement"

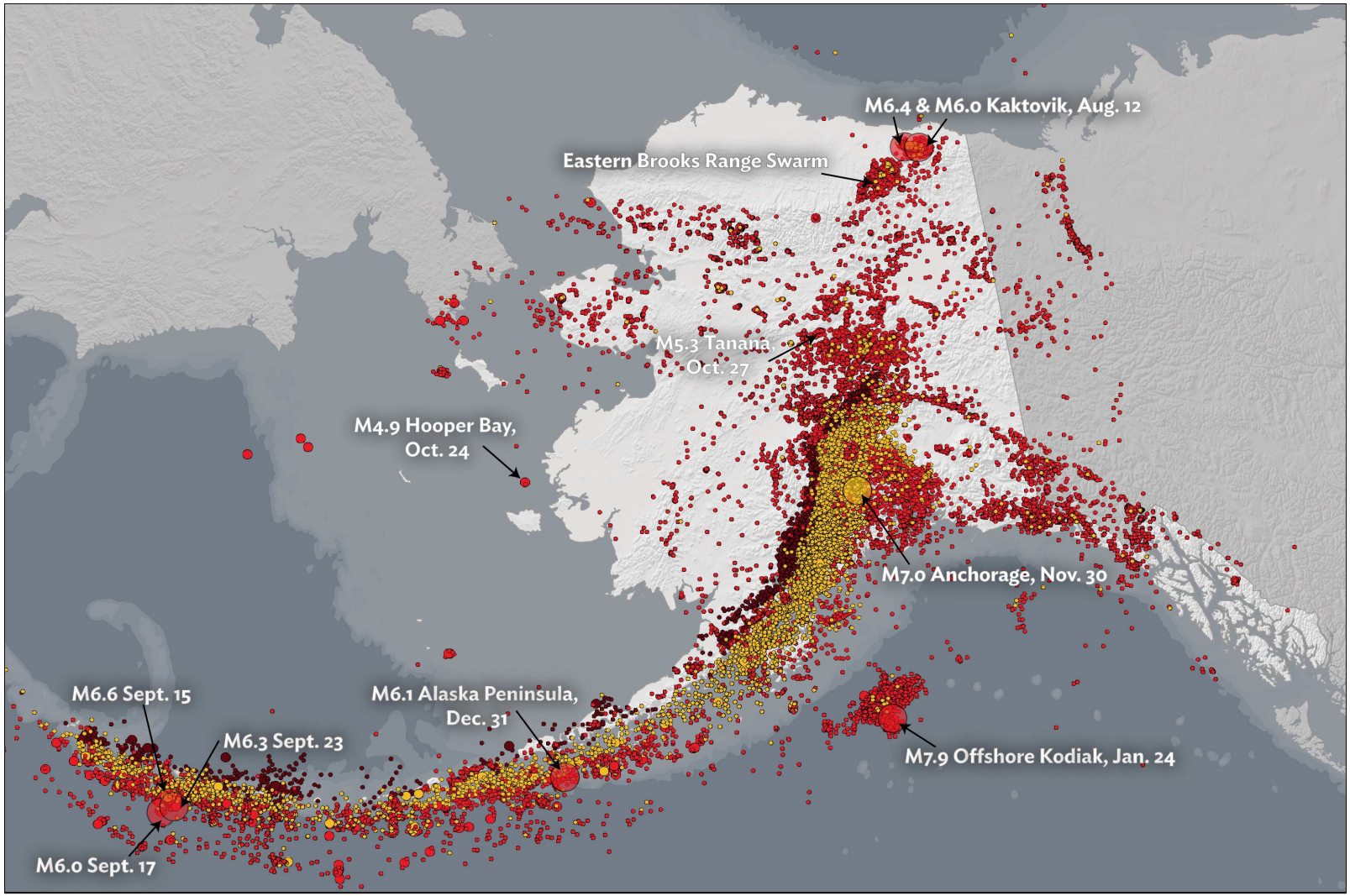


- $24 \times 7 \times 365$ event response
- reviewed solution for all alarm events within 20 minutes
- reviewed solution for all felt events

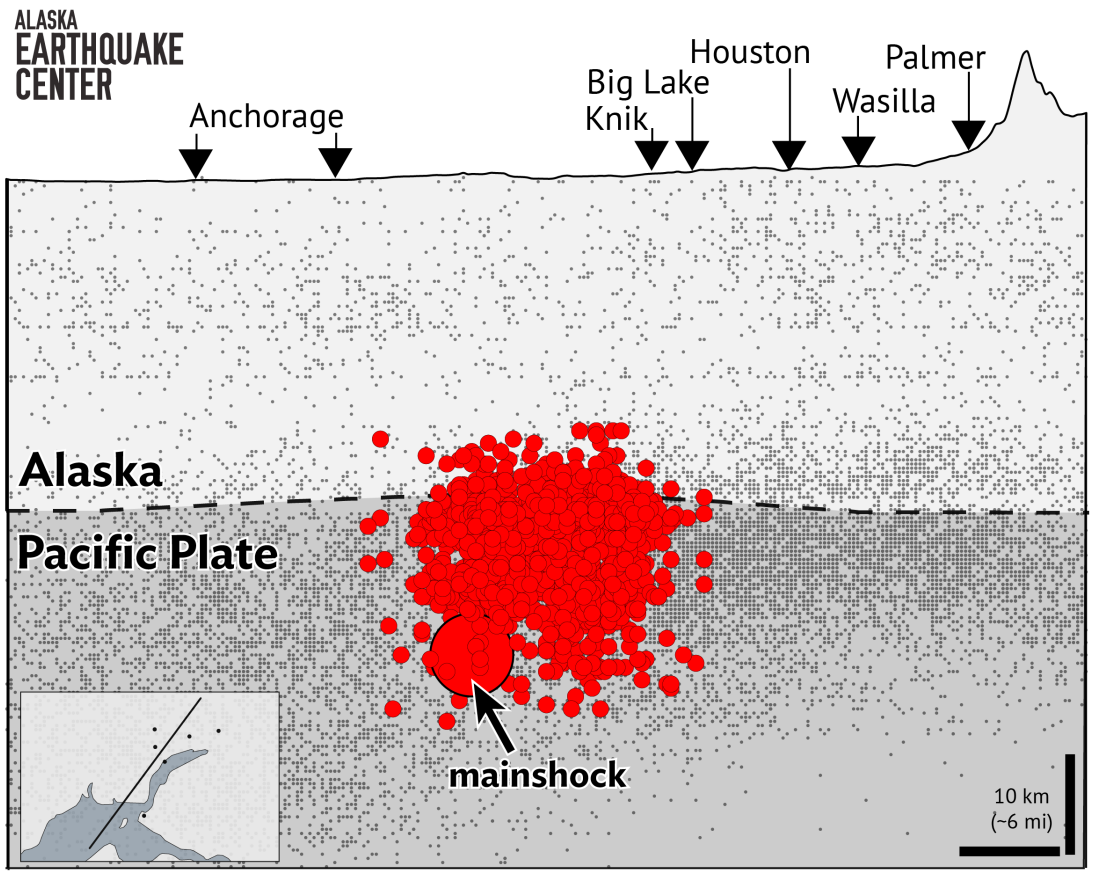
The Alaska Earthquake Center



2018: A Big Year for the Alaska Earthquake Center



November 30, 2018 M_w7.1 Anchorage Earthquake

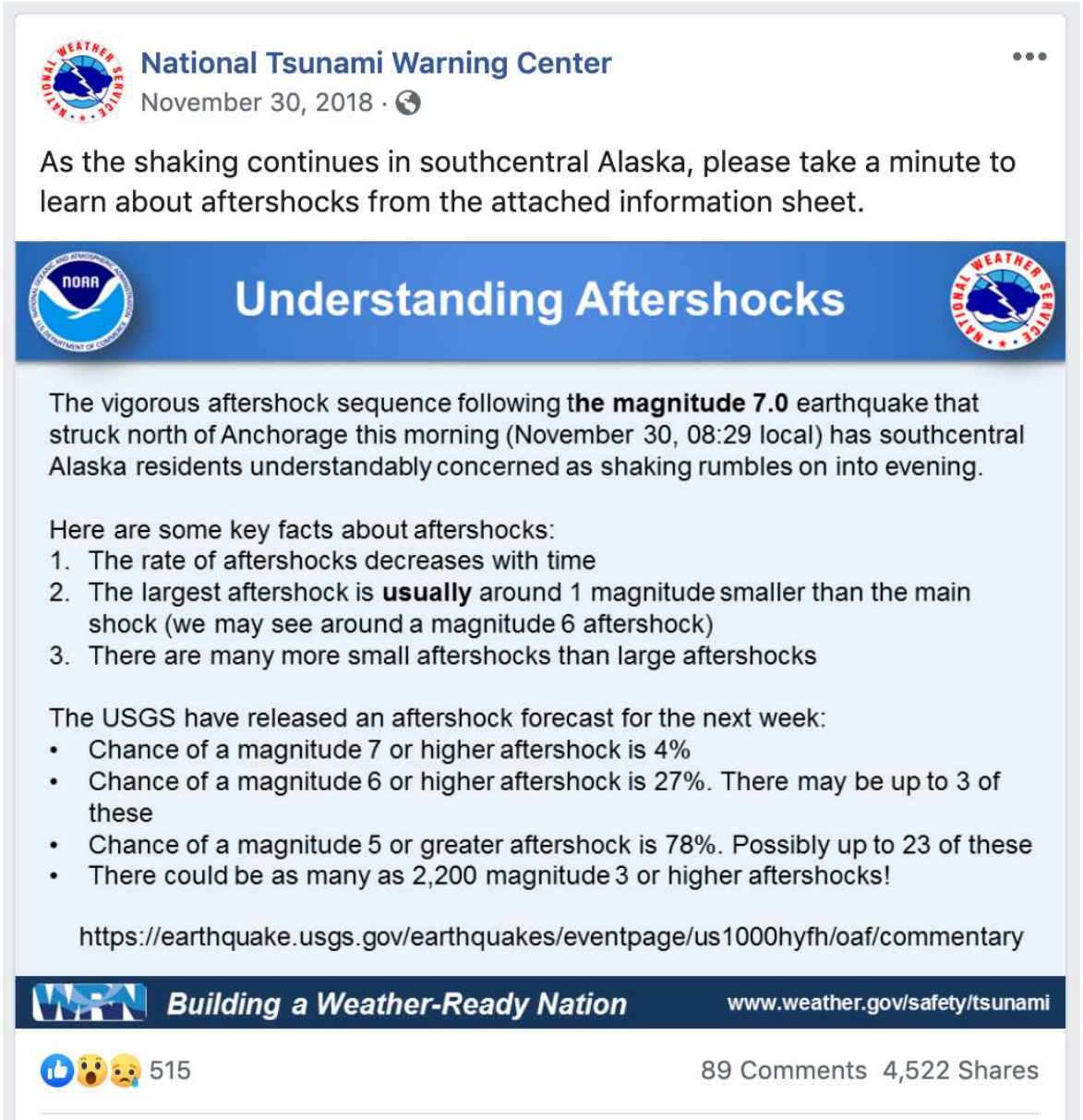


November 30, 2018 M_w7.1 Anchorage Earthquake

ADN

- Widespread damage from ground motions in southcentral Alaska
- Local tsunami warning
- Vigorous aftershock sequence having profound psychological impact on local population

Anchorage Aftershocks!



National Tsunami Warning Center
November 30, 2018 ·

As the shaking continues in southcentral Alaska, please take a minute to learn about aftershocks from the attached information sheet.

Understanding Aftershocks

The vigorous aftershock sequence following t**he magnitude 7.0** earthquake that struck north of Anchorage this morning (November 30, 08:29 local) has southcentral Alaska residents understandably concerned as shaking rumbles on into evening.

Here are some key facts about aftershocks:

1. The rate of aftershocks decreases with time
2. The largest aftershock is **usually** around 1 magnitude smaller than the main shock (we may see around a magnitude 6 aftershock)
3. There are many more small aftershocks than large aftershocks

The USGS have released an aftershock forecast for the next week:

- Chance of a magnitude 7 or higher aftershock is 4%
- Chance of a magnitude 6 or higher aftershock is 27%. There may be up to 3 of these
- Chance of a magnitude 5 or greater aftershock is 78%. Possibly up to 23 of these
- There could be as many as 2,200 magnitude 3 or higher aftershocks!

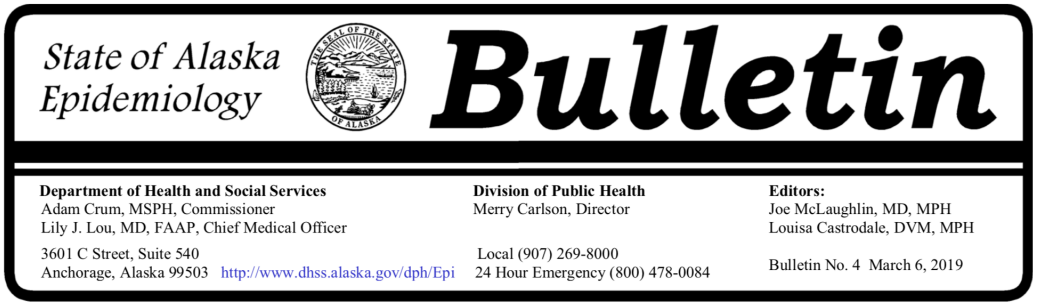
https://earthquake.usgs.gov/earthquakes/eventpage/us1000hyfh/oaf/commentary

Building a Weather-Ready Nation www.weather.gov/safety/tsunami

515 89 Comments 4,522 Shares

Anchorage Aftershocks!

Anchorage Aftershocks!



State of Alaska Epidemiology **Bulletin**

Department of Health and Social Services
Adam Crum, MSPH, Commissioner
Lily J. Lou, MD, FAAP, Chief Medical Officer

3601 C Street, Suite 540
Anchorage, Alaska 99503 http://www.dhss.alaska.gov/dph/Epi

Division of Public Health
Merry Carlson, Director

Local (907) 269-8000
24 Hour Emergency (800) 478-0084

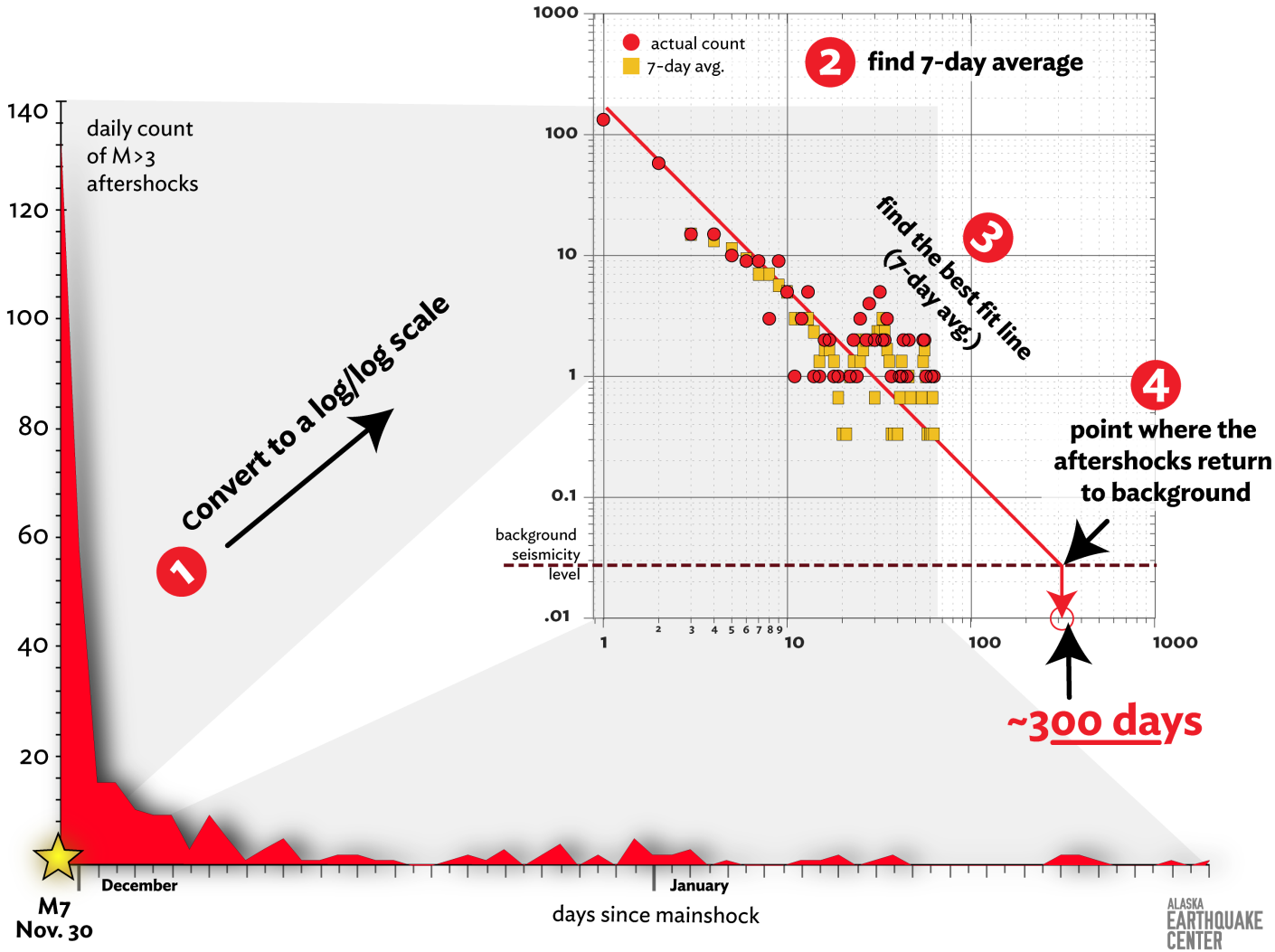
Editors:
Joe McLaughlin, MD, MPH
Louisa Castrodale, DVM, MPH

Bulletin No. 4 March 6, 2019

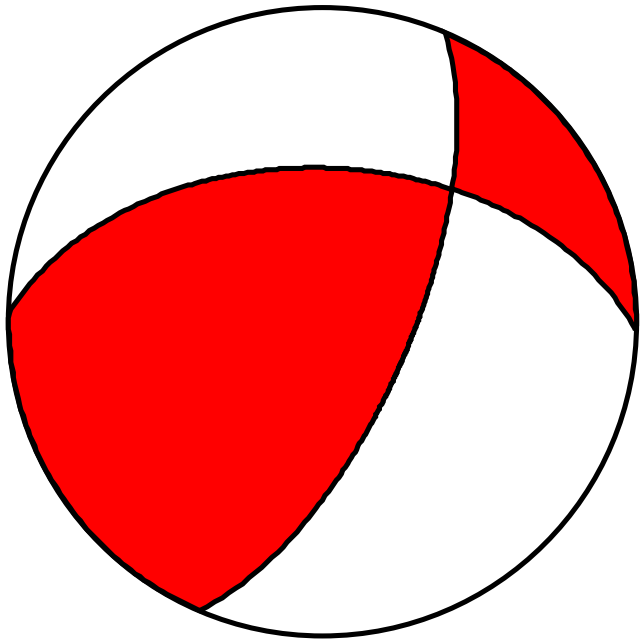
2018 Southcentral Alaska Earthquake Survey Findings

- Study found high-levels of untreated stress and anxiety
- 78 percent noted increased feelings of anxiety, fear, distraction, worry, trouble sleeping, and panic attacks
- Social media outreach

Anchorage Aftershocks!



Why we like moment tensors



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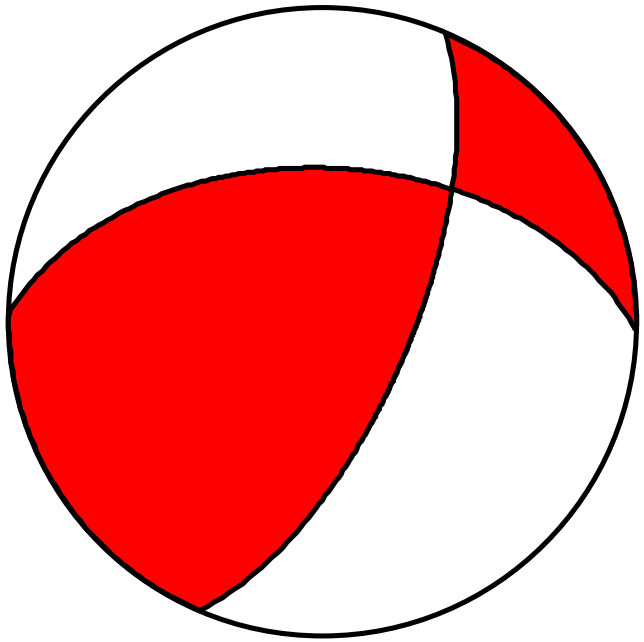
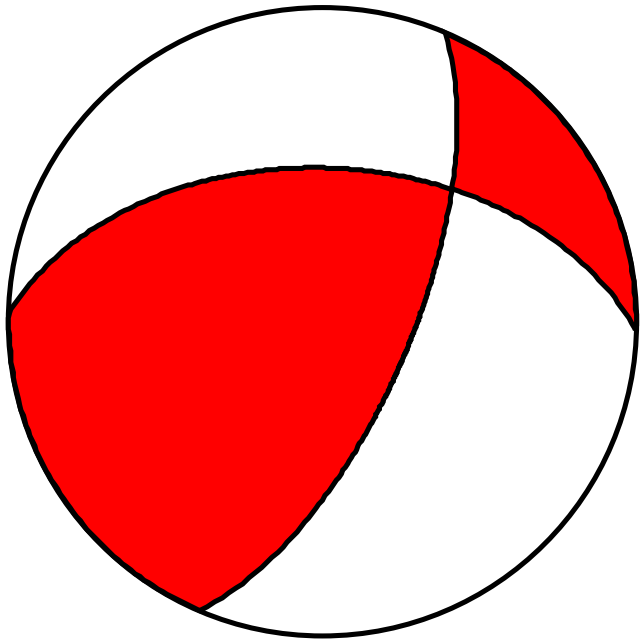


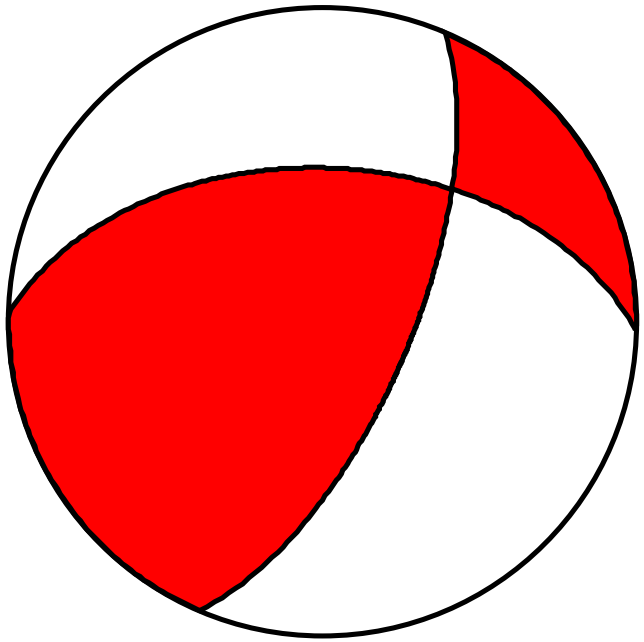
- Event situational awareness

Why we like moment tensors



- Event situational awareness
- M_w is more reliable than m_l for large events

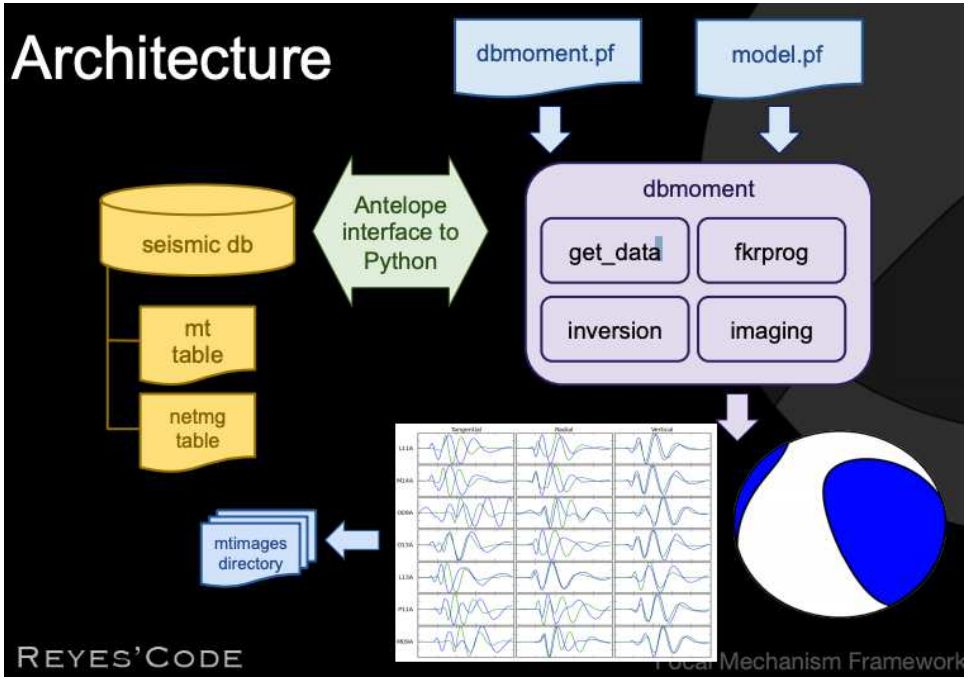
Why we like moment tensors



- Event situational awareness
- M_w is more reliable than m_l for large events
- concise summary of an event that can be pushed to the public

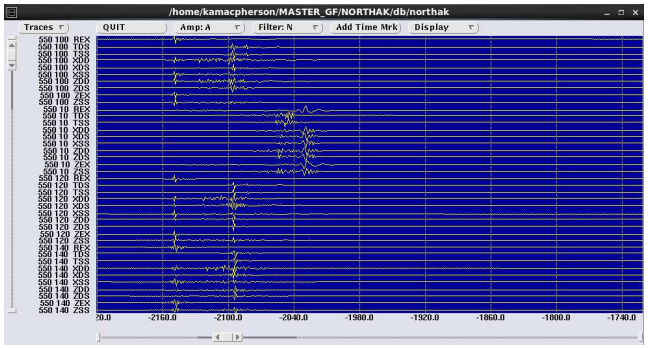
Method

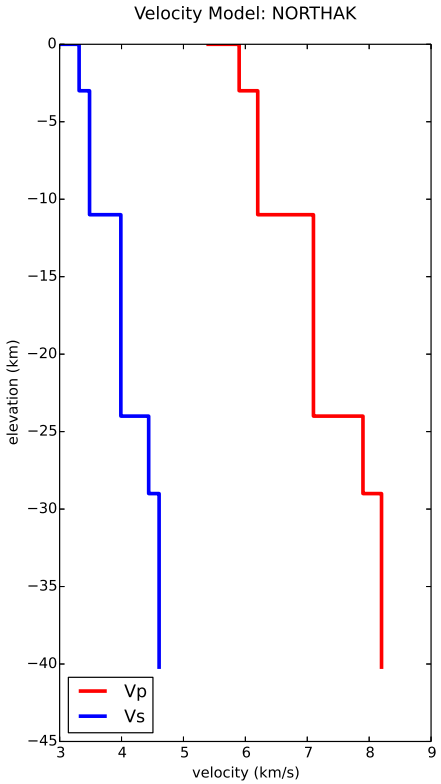
- Regional moment tensor
- $\Delta \leq 500$km
- Antelope port of TDMT (Dreger, 2003)
- Uses Antelope Python libraries (Lindquist,2008)
- Bandpass between 0.02 and 0.04 Hz
- $4.0 \leq M_w \leq 7.5$

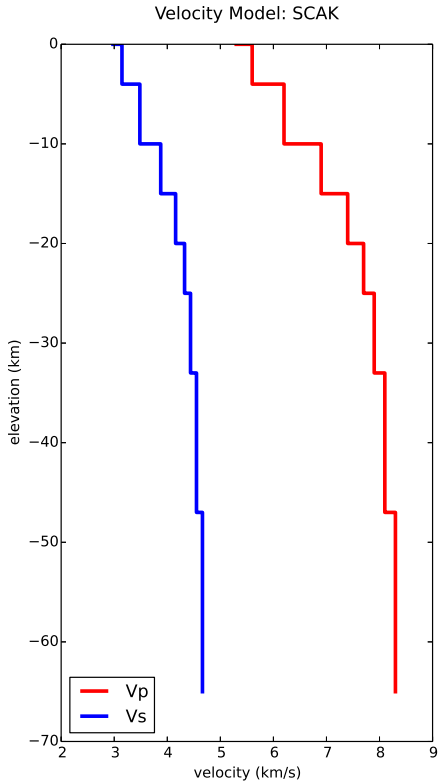



```
>> dbmoment db_name orid
```

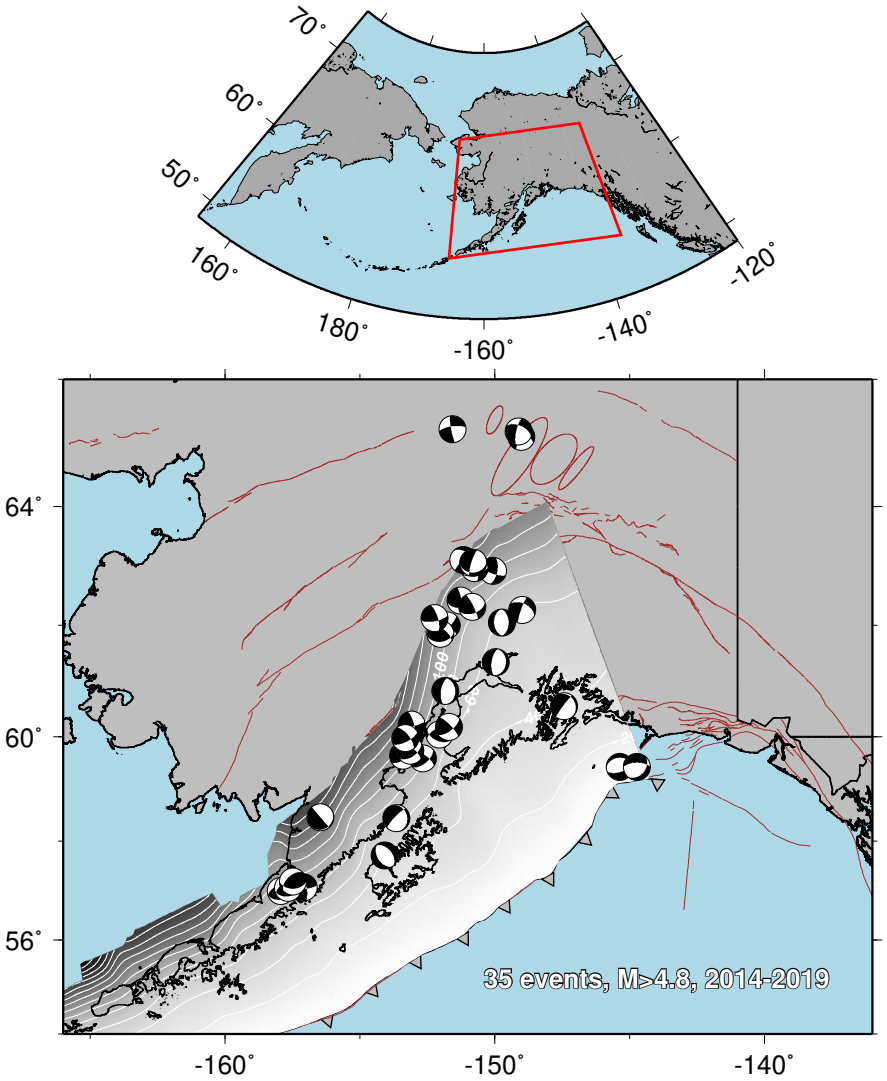
Green's functions







Data Set



- 39 target events
- $4.8 \leq M_w \leq 7.1$
- Southcentral Alaska

Results

AEC Moment Tensors

Macpherson and collaborators

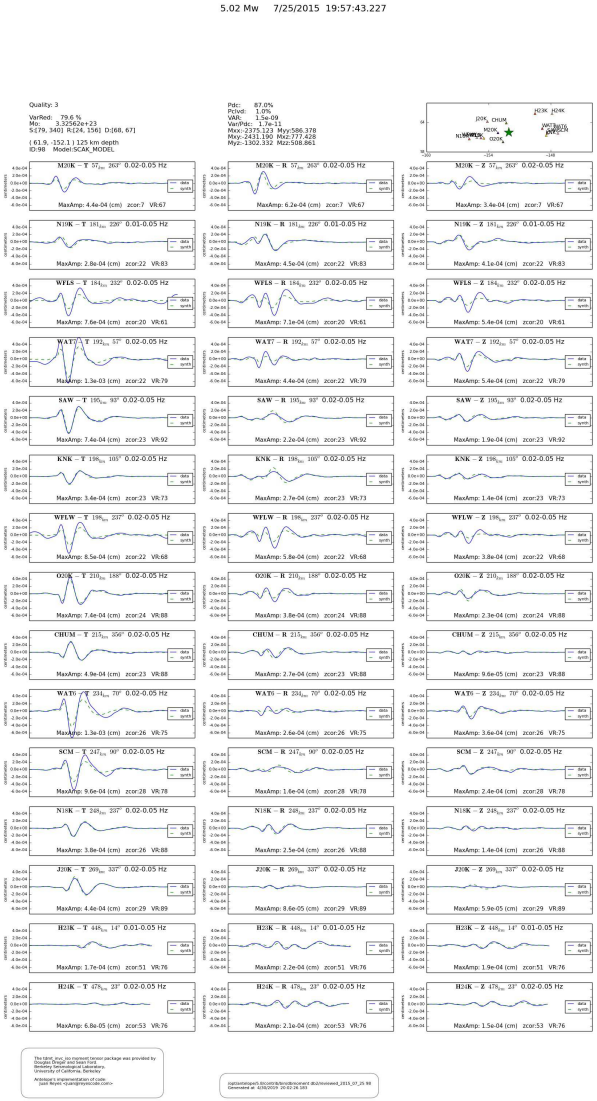
intro to Alaska

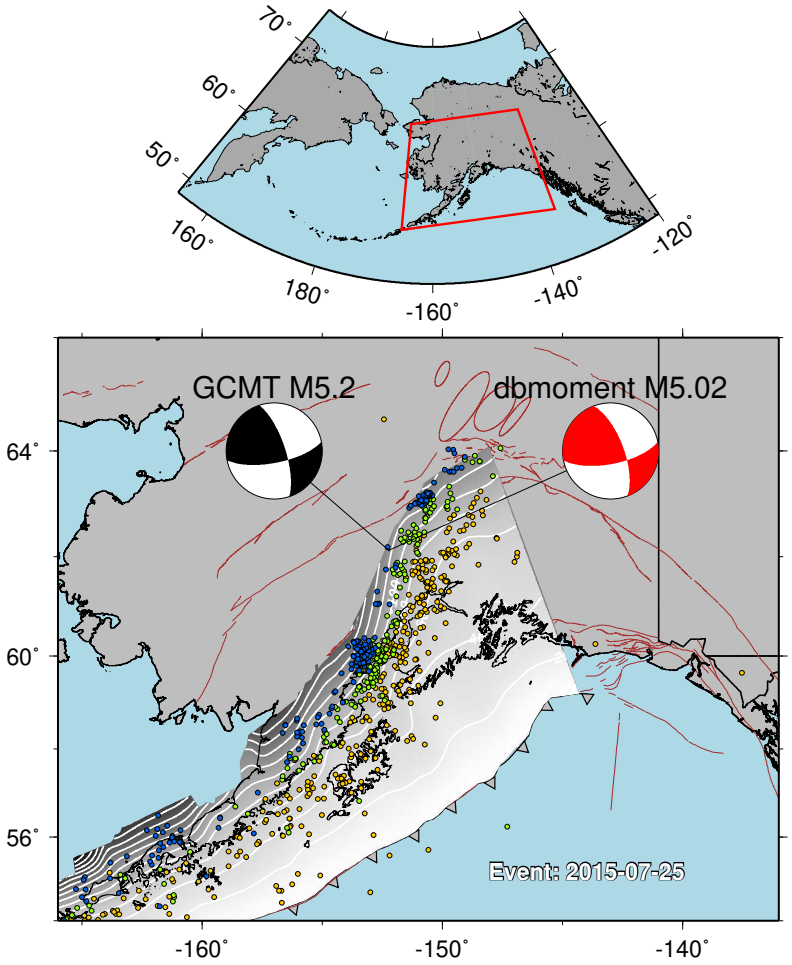
intro to the AEC

recent Alaska seismicity

moment tensors: regional

moment tensors: continuous scanning





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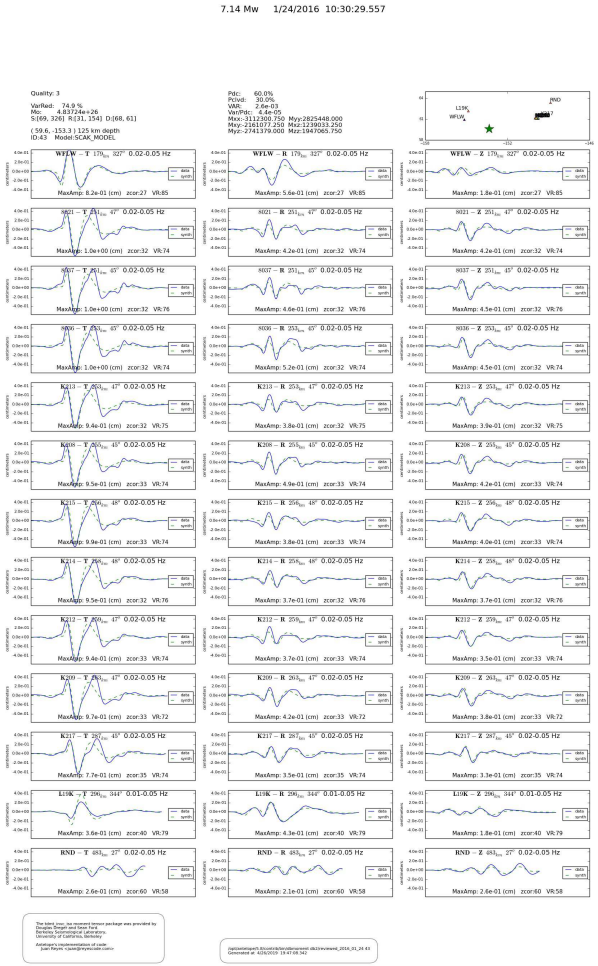

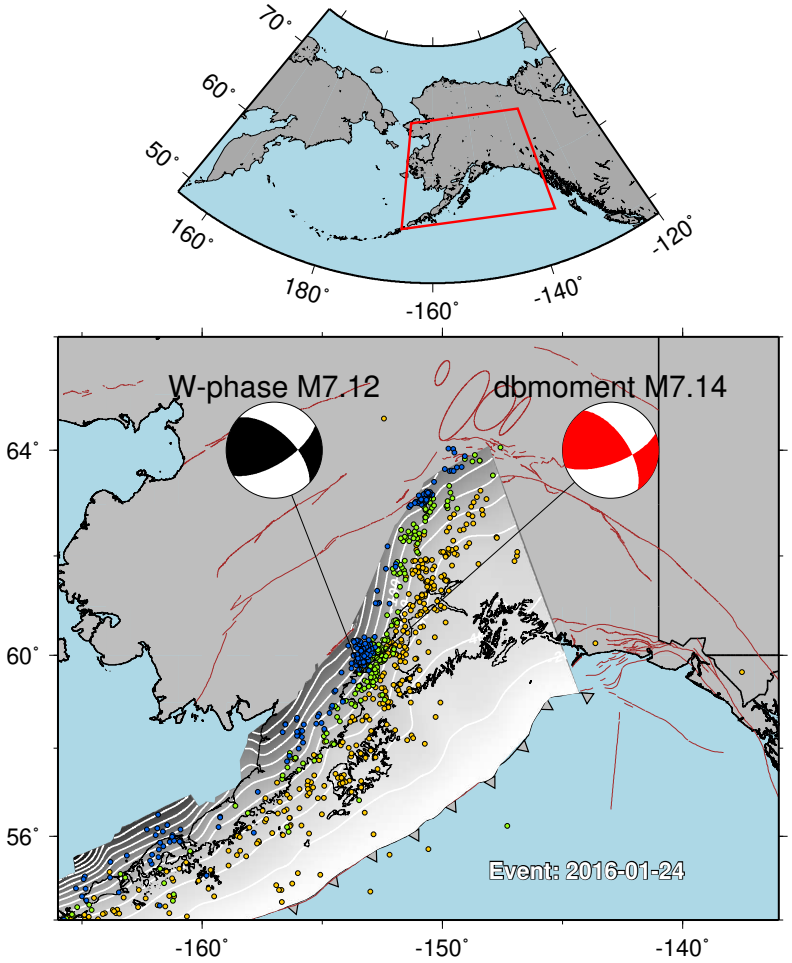

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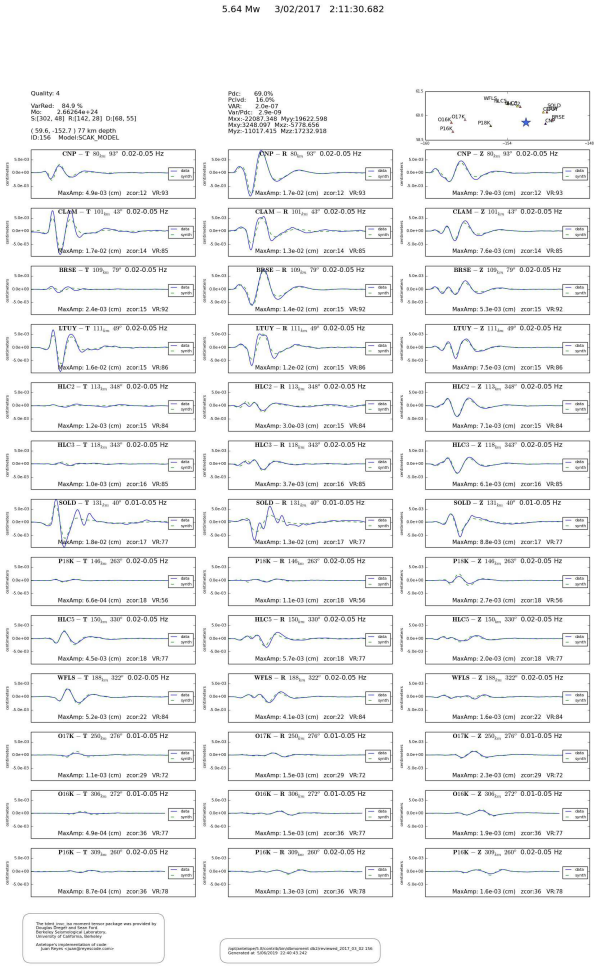

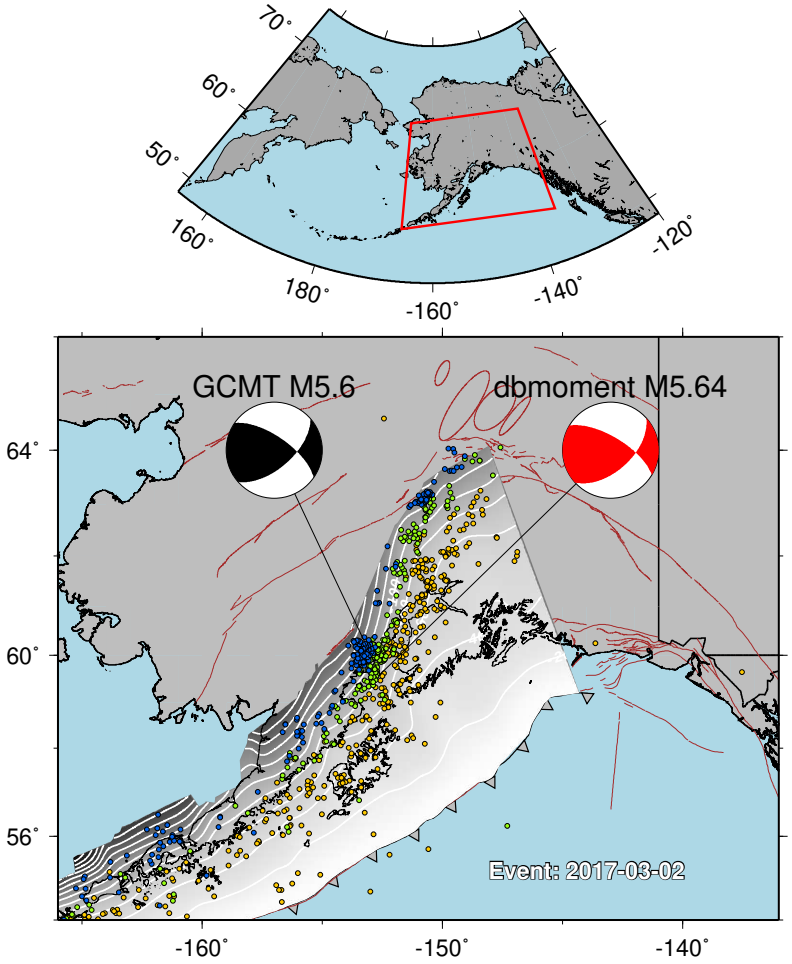

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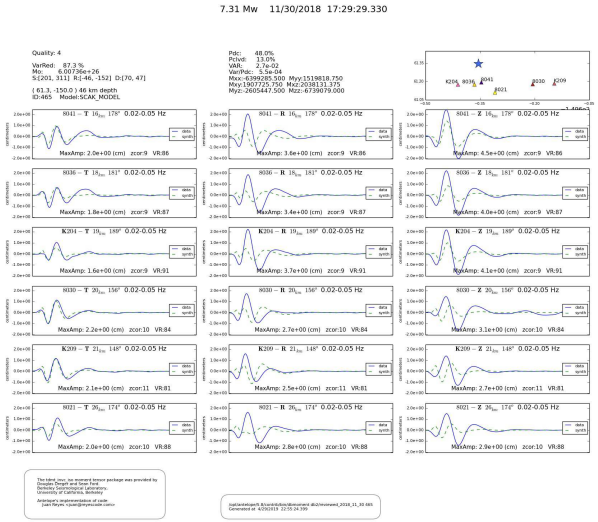

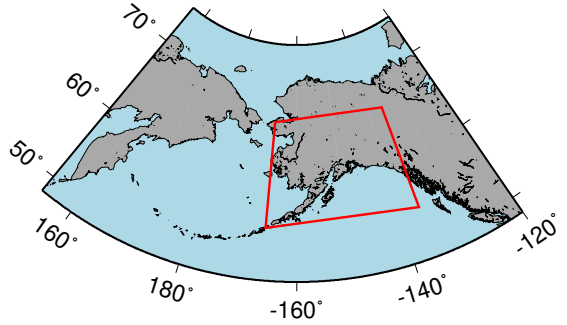

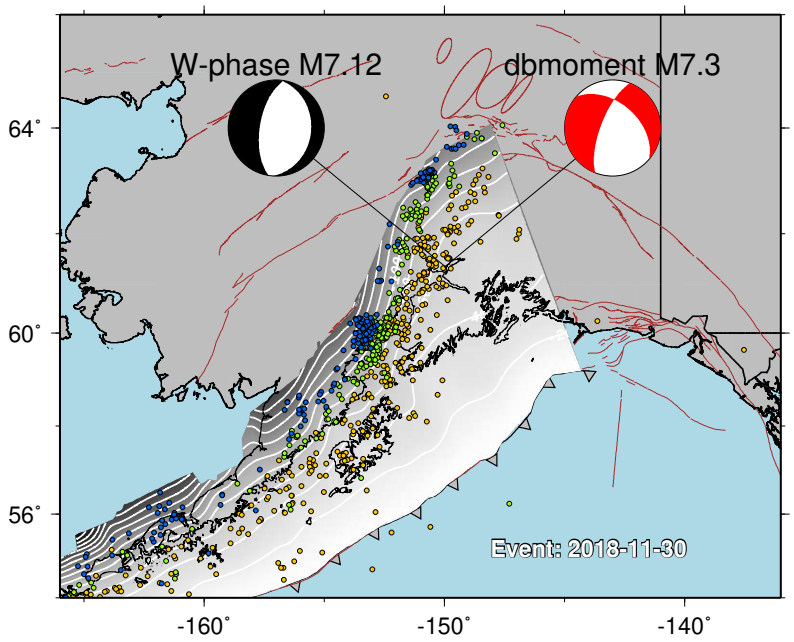

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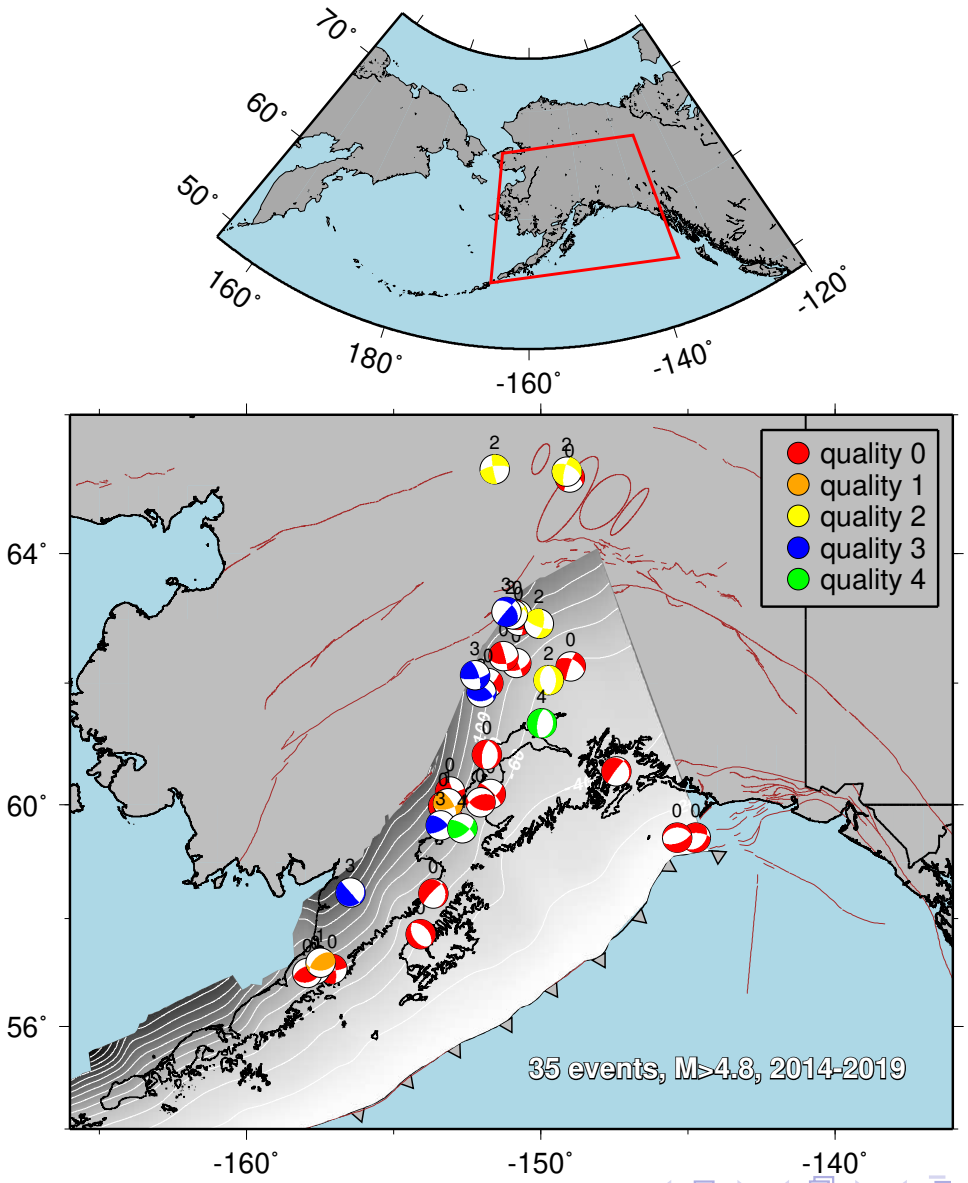

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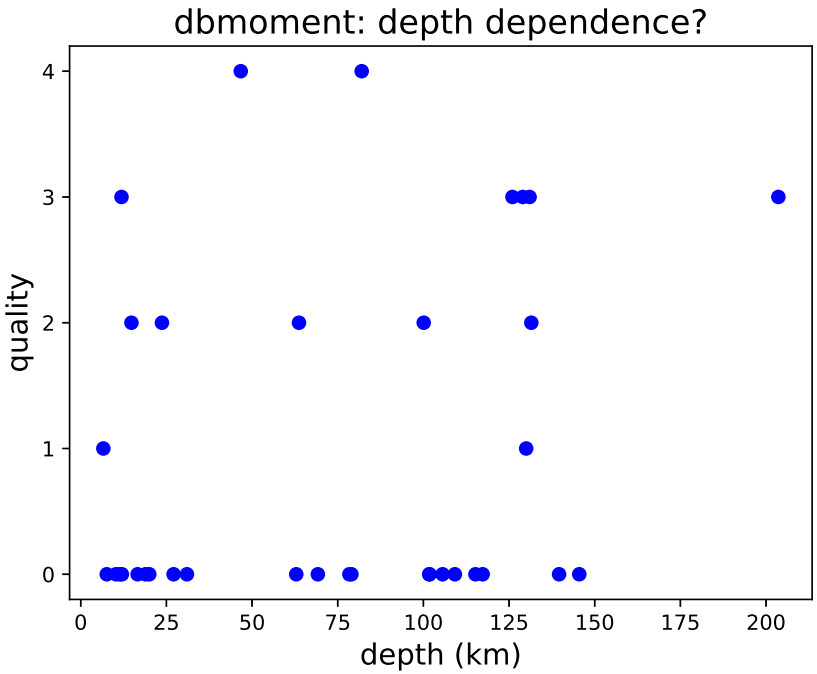

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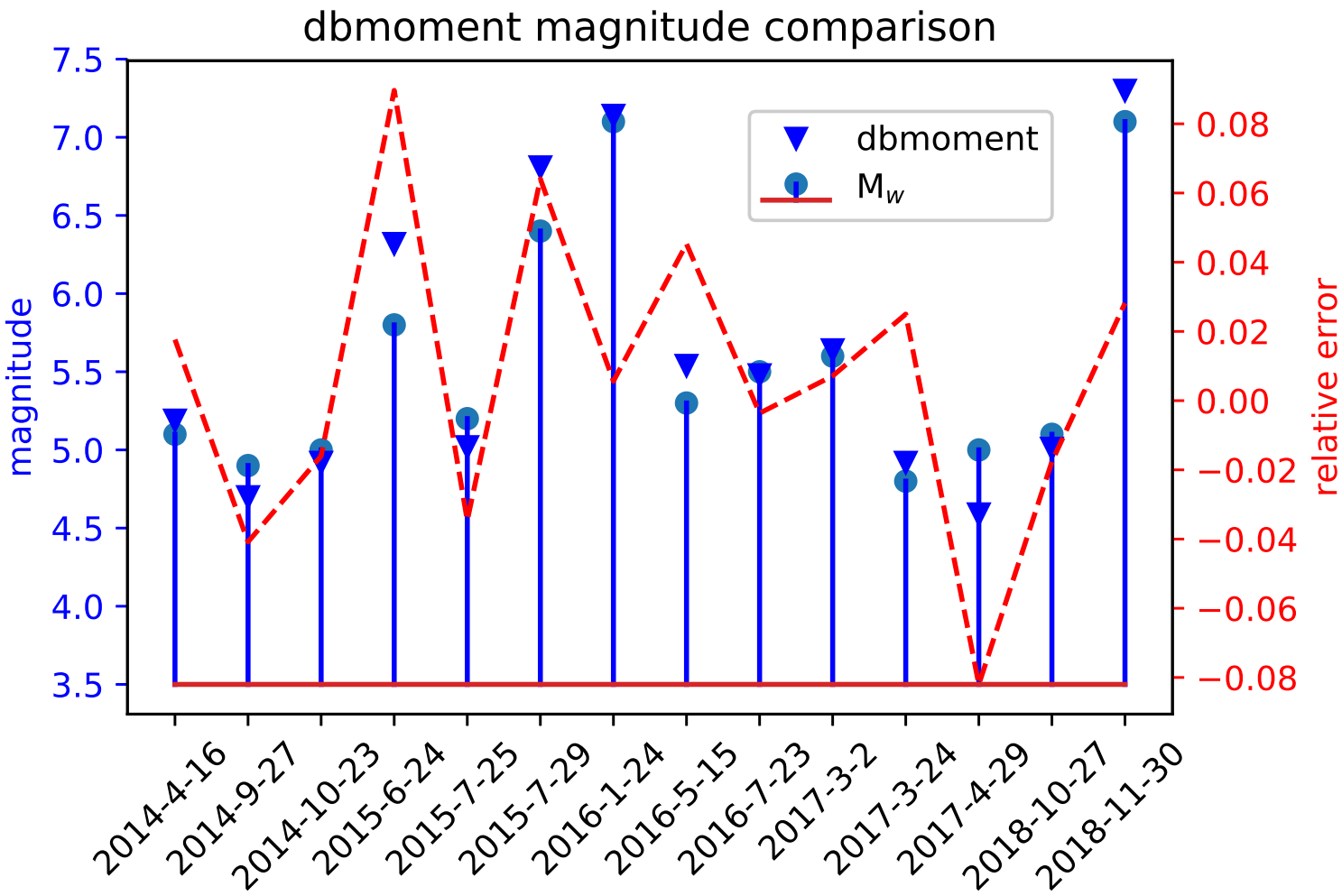


Results

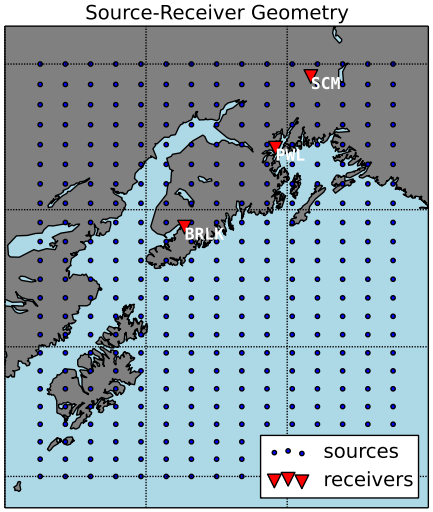
- Need to benchmark with many additional events
- Develop an interface to make dbmoment accessible to the duty seismologist
- Interface should provide an option to publish to website
- Train duty seismologists for moment tensor duties

Continuous moment tensor scanning

> *"In the view of monitoring the long-period SWF [seismic wave field] presented above, a seismometer (or seismic station) can be considered as a machinery to correlate the long-period vibration with the vibration predicted by virtual sources."*

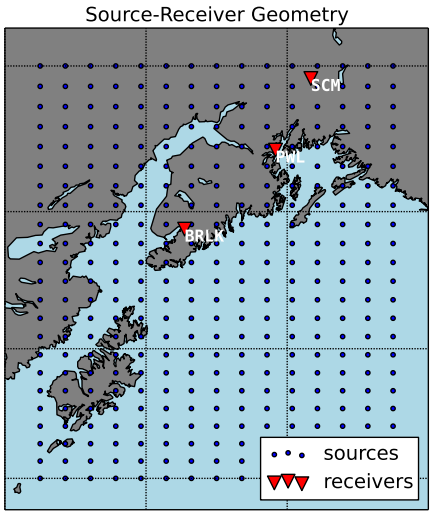
(Kawakatsu, 1998)

Continuous moment tensor scanning - how it works



the data we observe at a station = predicted waveform · source

Continuous moment tensor scanning - how it works



the data we observe at a station = predicted waveform · source

$$\mathbf{d} = \mathbf{Gm}$$

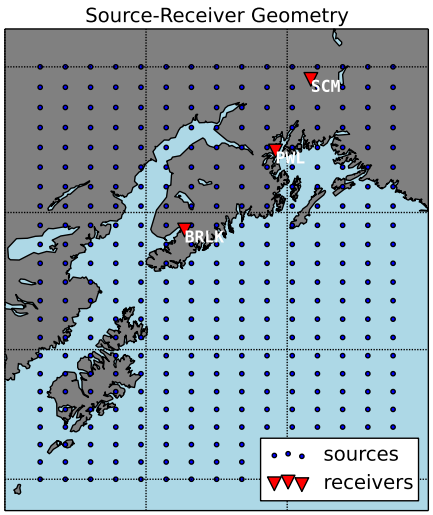
Continuous moment tensor scanning - how it works

the data we observe at a station = Green's functions · source

$$\mathbf{d} = \mathbf{Gm}$$

$$\begin{pmatrix} d_1 \\ d_2 \\ \vdots \\ d_n \end{pmatrix} = \begin{pmatrix} G_{11} & G_{12} & G_{13} & G_{14} & G_{15} & G_{16} \\ G_{21} & G_{22} & G_{23} & G_{24} & G_{25} & G_{26} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ G_{n1} & G_{n2} & G_{n3} & G_{n4} & G_{n5} & G_{n6} \end{pmatrix} \begin{pmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \\ m_5 \\ m_6 \end{pmatrix} \quad (1)$$

Continuous moment tensor scanning - how it works

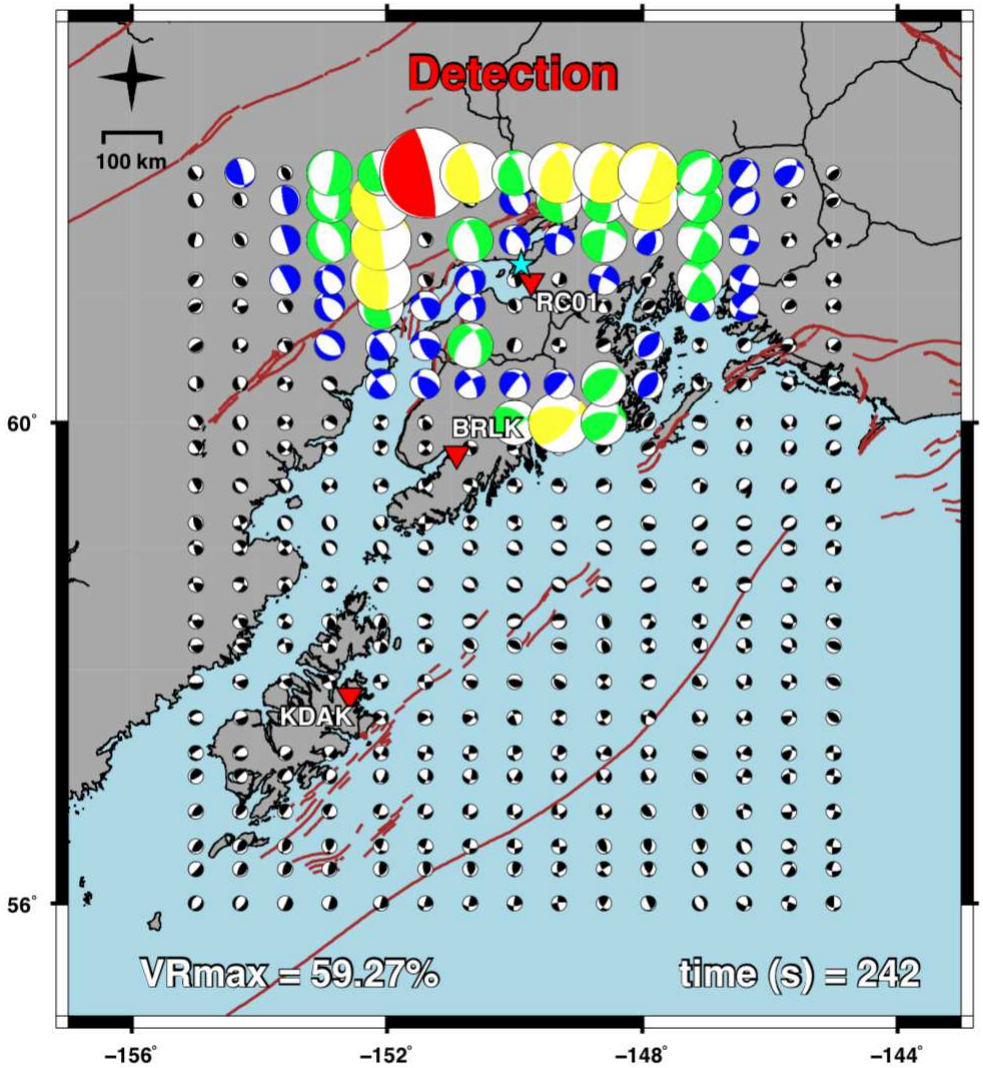


$$\mathbf{m} = \left[\left(\mathbf{G}^\top \mathbf{G} \right)^{-1} \mathbf{G}^\top \right] \mathbf{d}$$

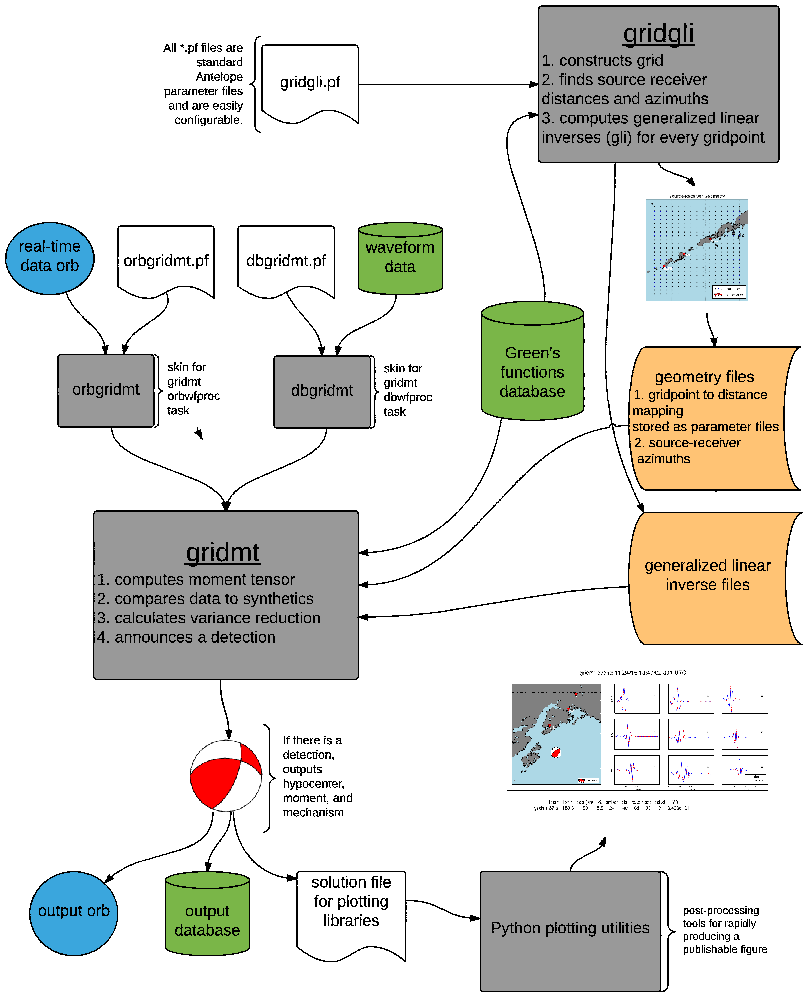
Continuous moment tensor scanning - how it works

$$\mathbf{m} = \left[\left(\mathbf{G}^\top \mathbf{G} \right)^{-1} \mathbf{G}^\top \right] \mathbf{d}$$

Software overview



Software overview



gridgli

Python tool for preparing monitoring grids

- grid coordinates
- Finds unique source-receiver-offsets and azimuths
- Loads and filters required Green's functions
- Computes the gli for each grid point
- Easy to read and maintain

```
def gli(G):

    # Use numpy to compute the generalised
    linear inverse
    G = G.transpose() # G is transposed by the
    Aurelie equations, so we flip it!
    GTG = np.dot(G.transpose(), G)
    GTGI = np.linalg.inv(GTG)
    GLI = np.dot(GTGI, G.transpose())

    return GLI
# End the gli function
```

gridmt skins

- **dbgridmt** is a skin for the gridmt dbwfproc task. Wriiten in C.
  - Reads pre-recorded waveforms from an Antelope db
  - Is useful for testing gridmt or for quickly populating moment tensor catalogs from long time series
  - Easily configurable via standard Antelope parameter files,
- **orbgridmt** is a skin for the gridmt orbwfproc task.
  - Reads real-time data from an Antelope orb
  - This is the operational skin

gridmt skins

Easily configurable with standard Antelope parameter files

```
gridmt_params &Arr{

# Fundamental 'gridmt' parameters:
        num_sta     3
        num_pts     380
        num_lat     23
        num_lon     15
        num_dep     16
        num_iso     5
        verbose       1

# Variance reduction threshhold (%)
 det_tol           55
```

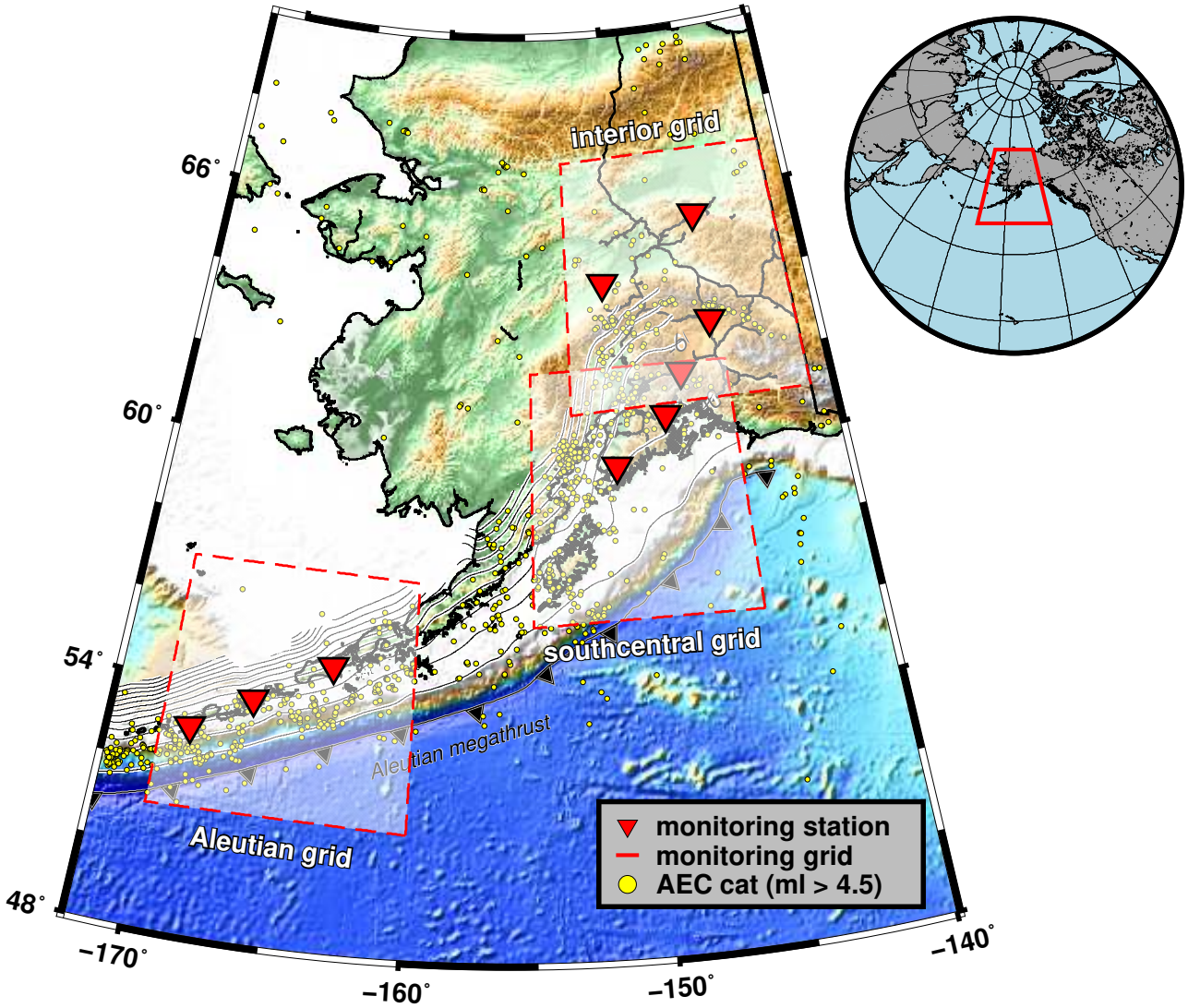
dbgridmt.pf

gridmt

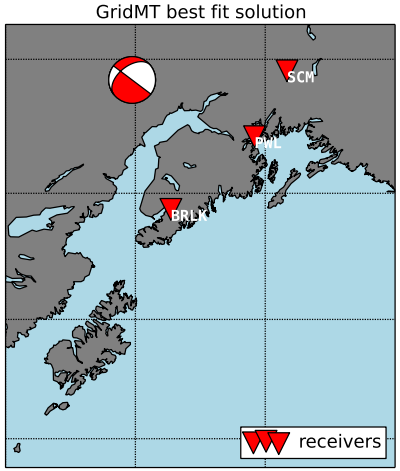
gridmt is the computational heart of the scanner.

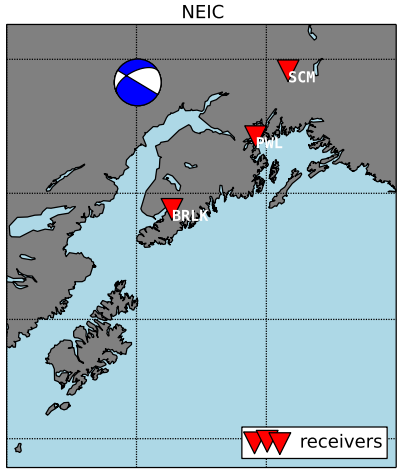
- Compares predicted and observed waveforms
- Announces detections
- Outputs hypocenter, M_w, and mechanism to a db, an orb, and as text

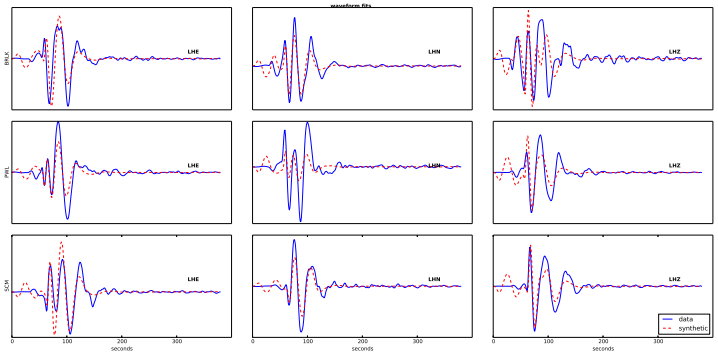
Monitoring regions



June 24, 2015 event near Willow, AK







SOLUTIONS:	AEC_gridmt	NEIC
longitude	-151.1°	-151.96
latitude	61.7°	61.66°
depth (km)	100.0	114.0
θ	307.0°	301.0°
δ	56.0°	53.0°
λ	109.0°	118.0°
M_w	5.7	5.77

Grazie! Questions or comments?