

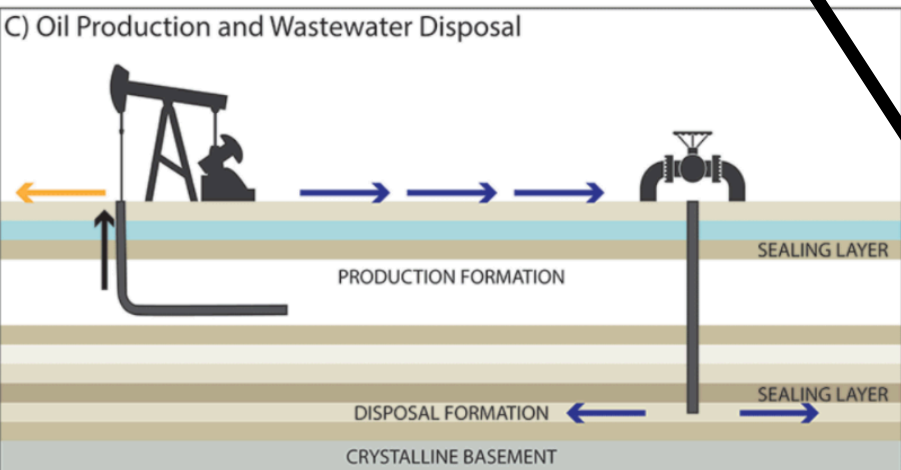
Ground Motion Duration from Unique Earthquakes in Oklahoma

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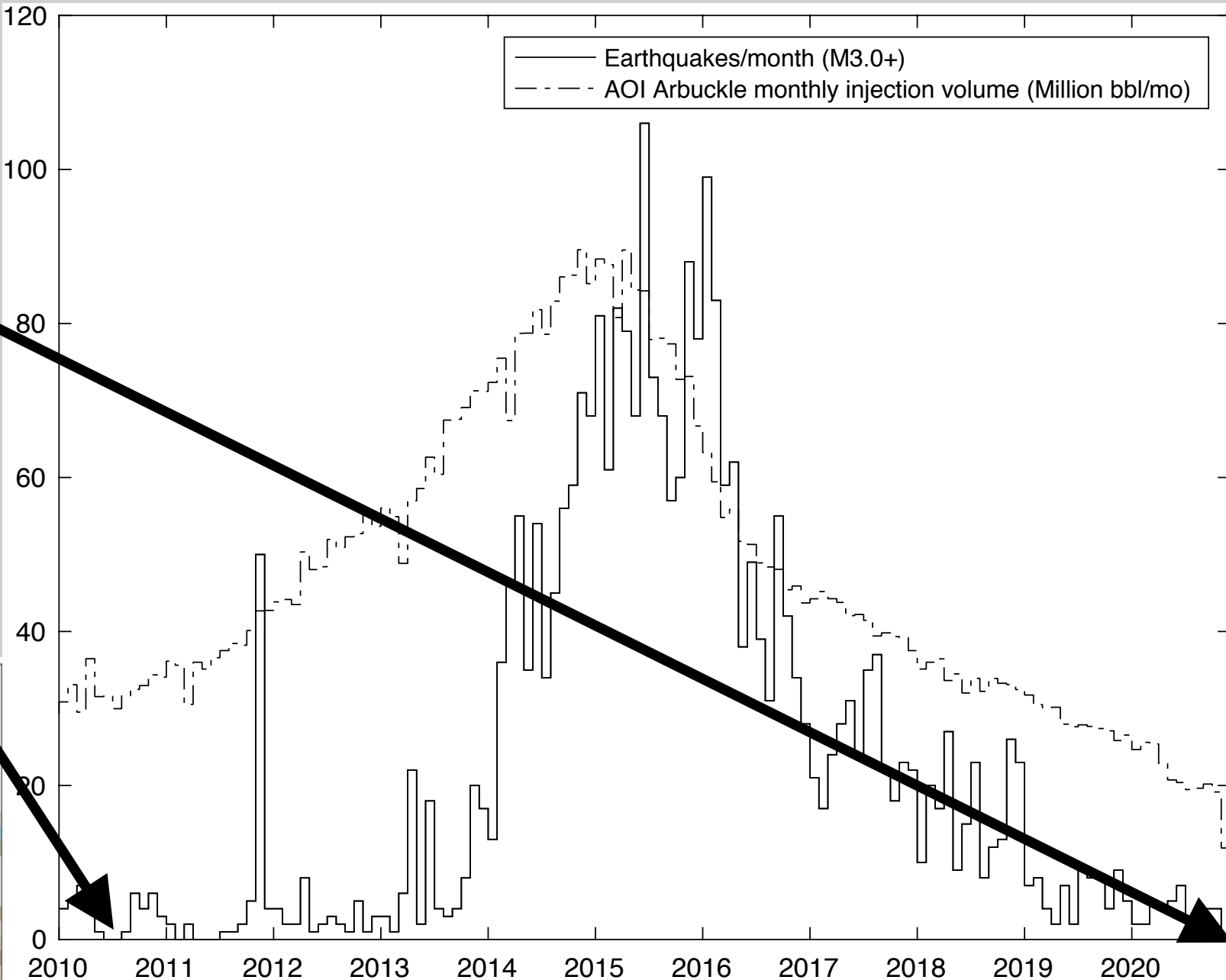


Zero M3.0+ earthquakes in Nov 2020

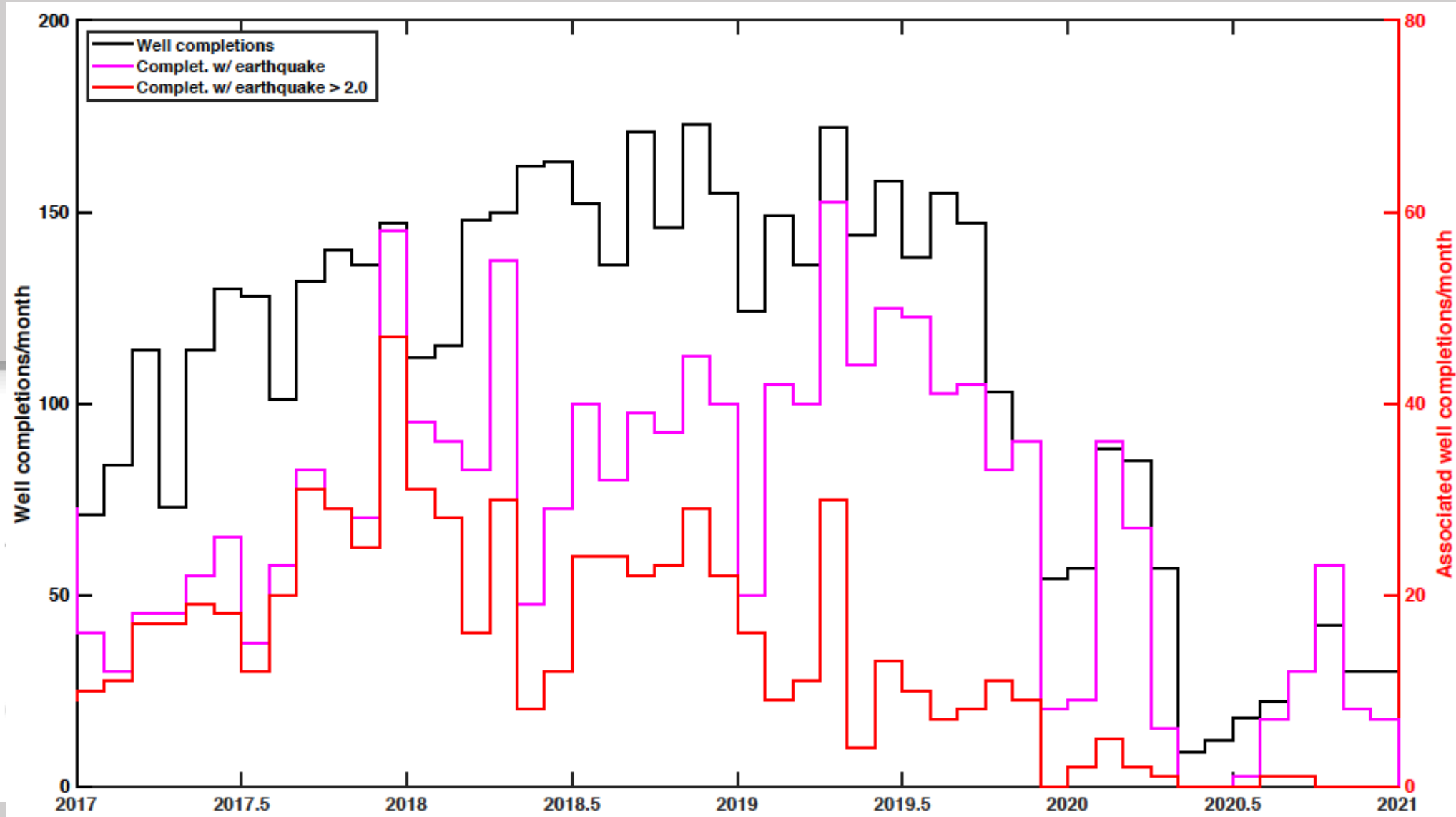
Need to go back almost a decade for the last time that happened



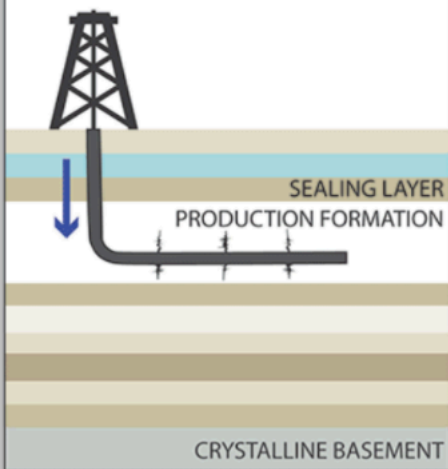
Rubinstein and Mahani, 2015



Increased Fracking associated earthquakes

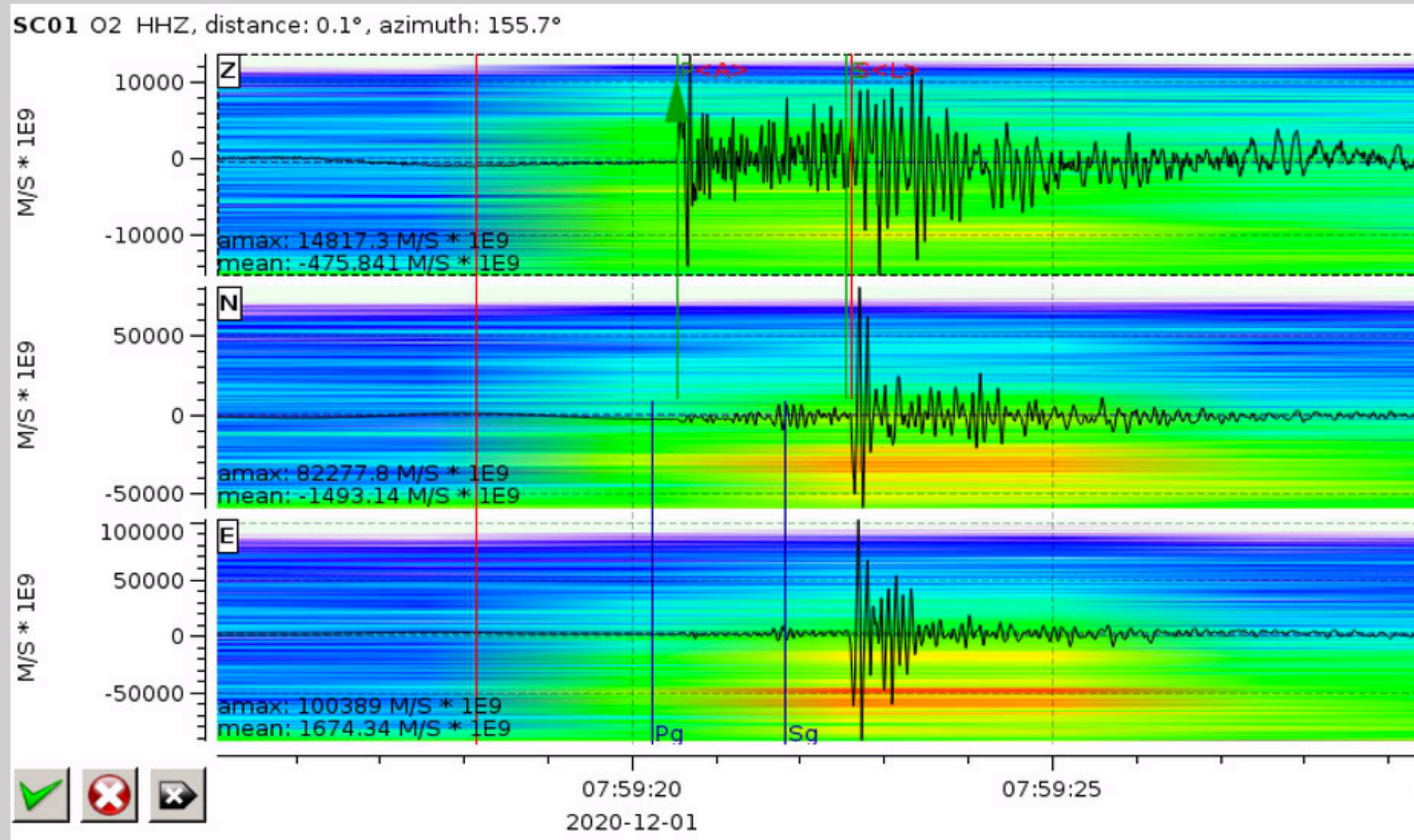


A) Hydraulic Fracturing of a Production Well



Rubinstein and Mahani, 2015

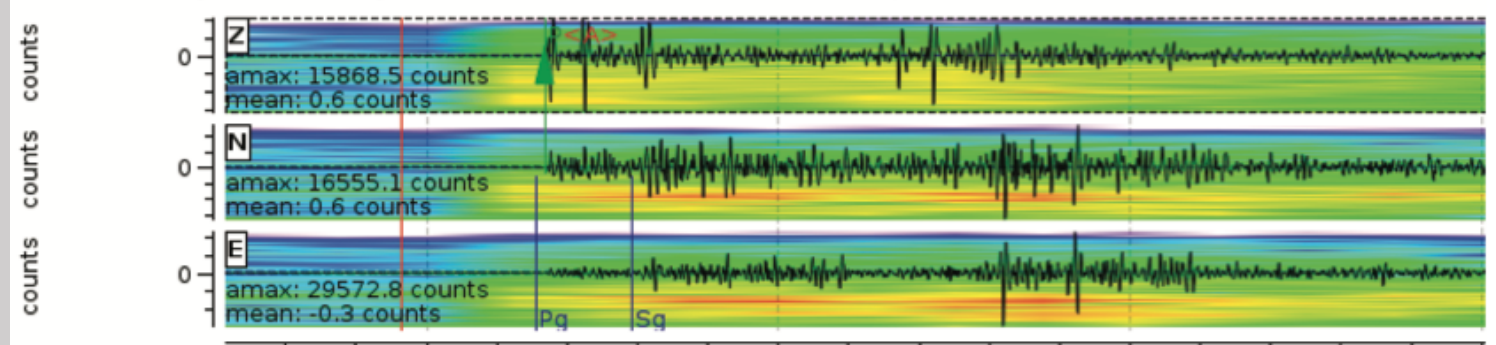
A single earthquake



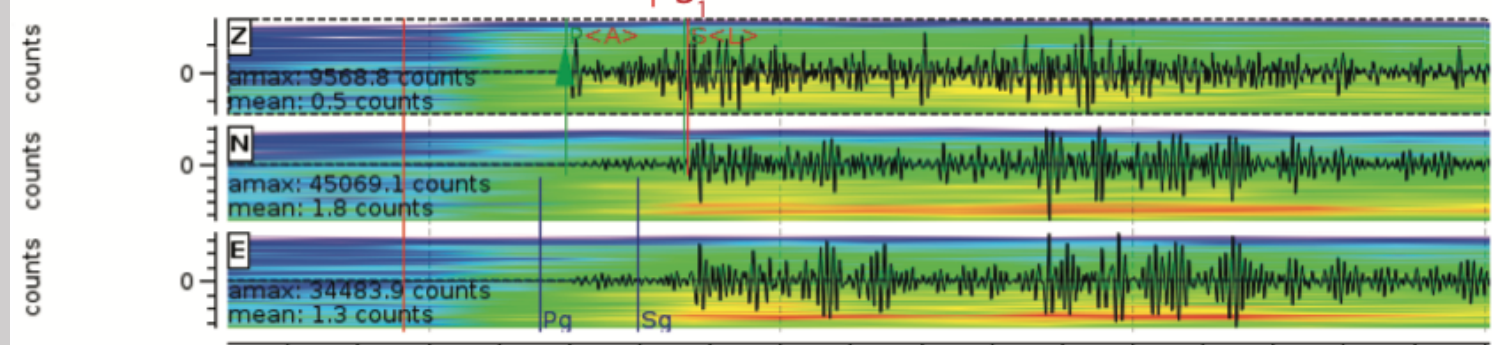
Twin earthquakes

Two earthquakes occurring close in time and space

SC19 02 HHZ, distance: 0.2°, azimuth: 216.4°



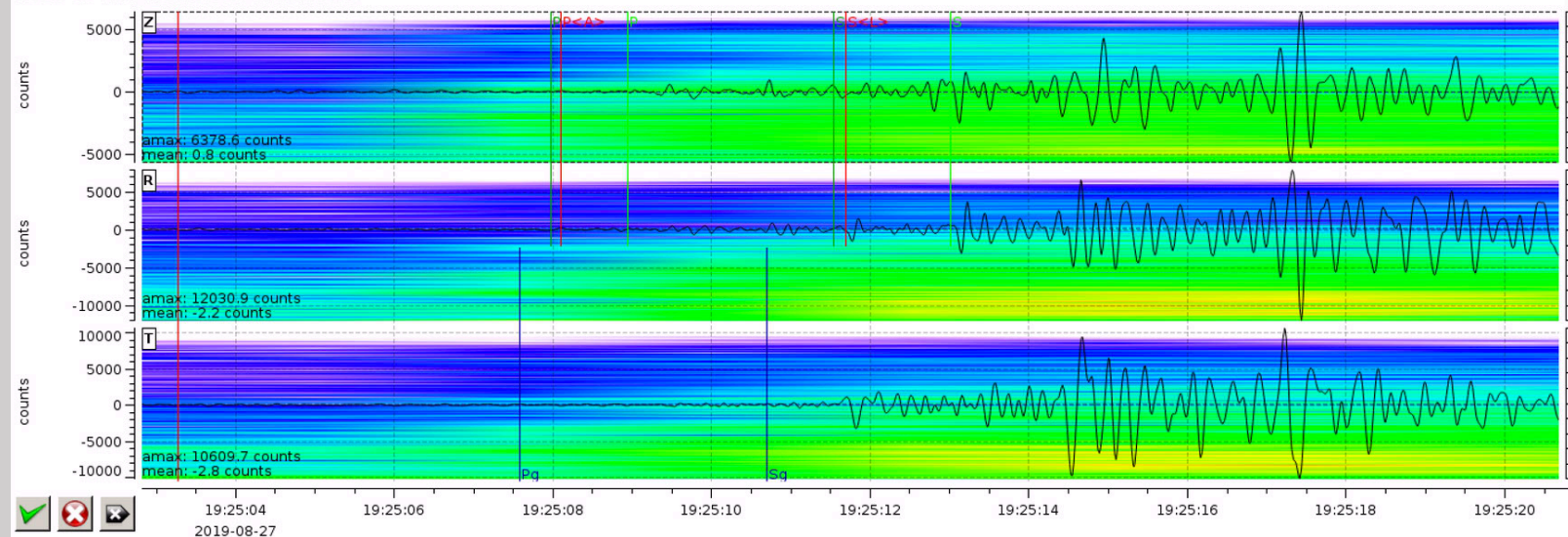
SC18 02 HHZ, distance: 0.2°, azimuth: 42.5°



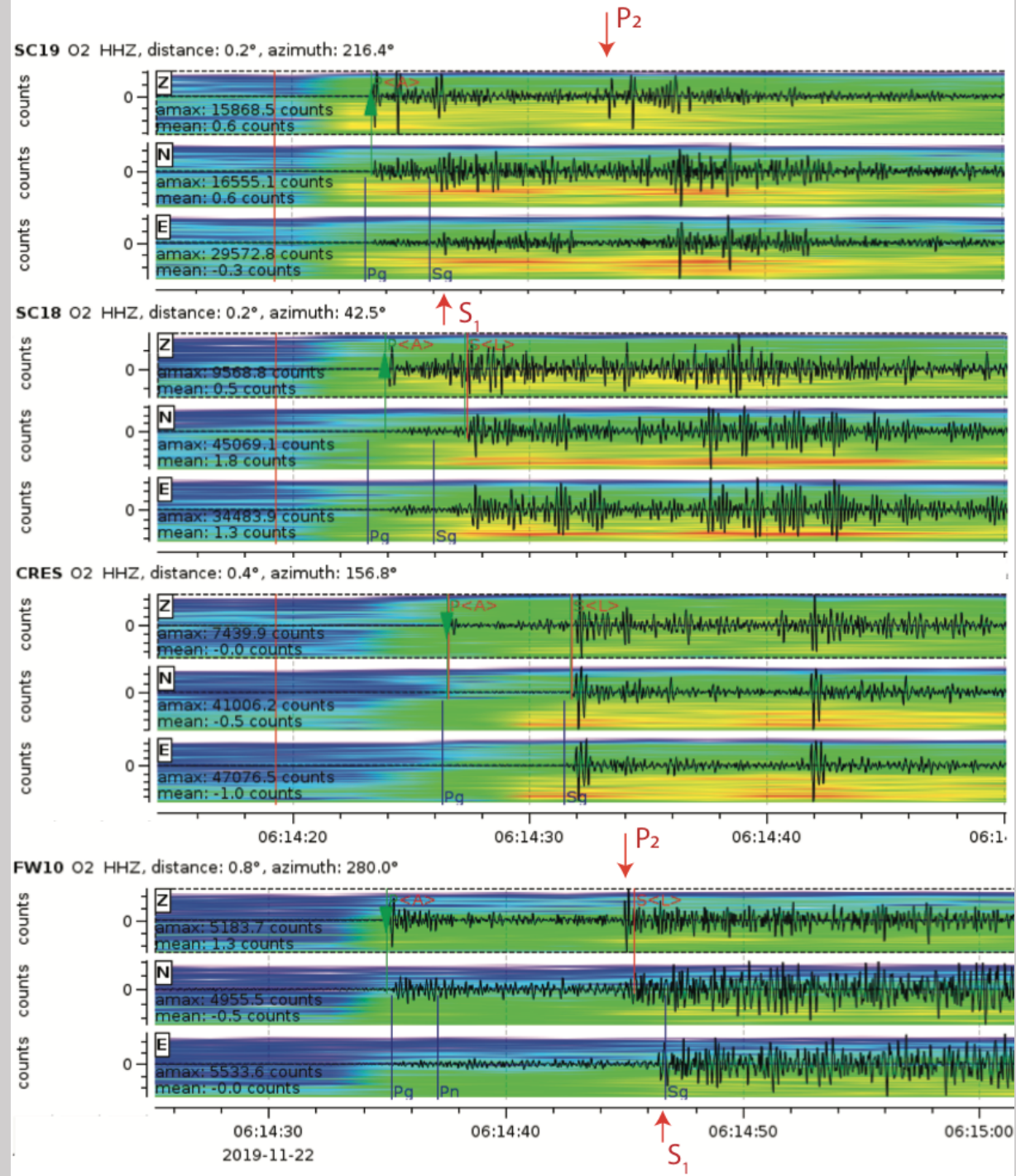
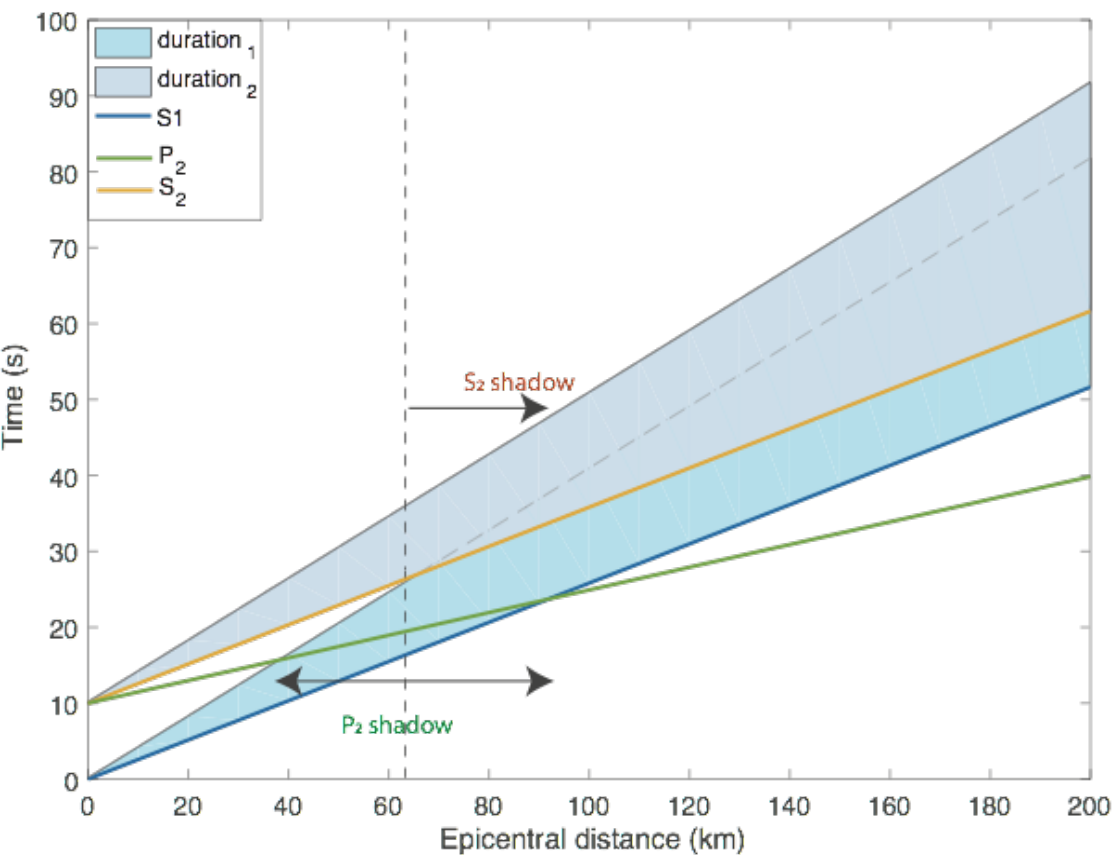
Multi-phased earthquake

A single earthquake with multiple phases

MOOR OK HHZ, distance: 0.2°, azimuth: 118.0°



Twins: P and S wave shadow

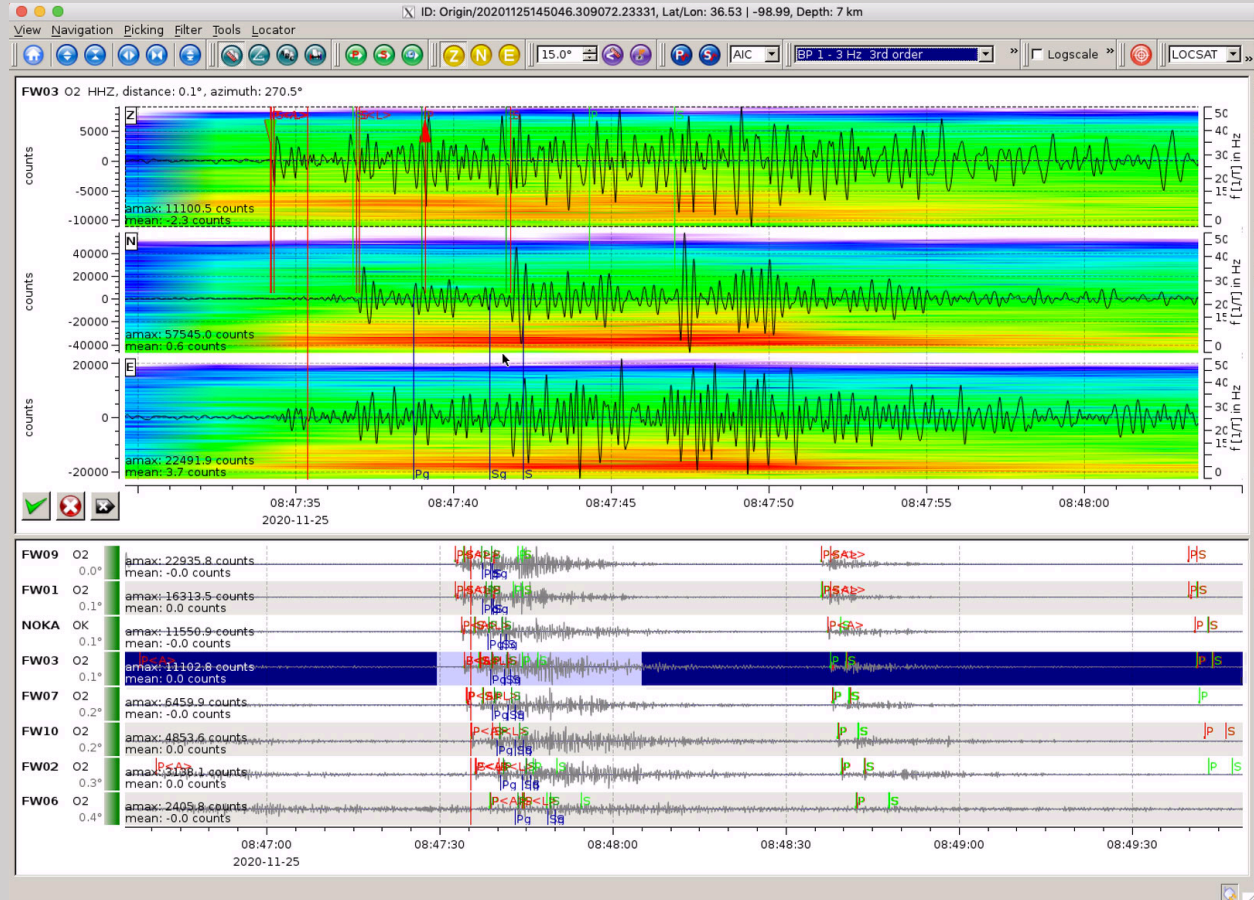


Training

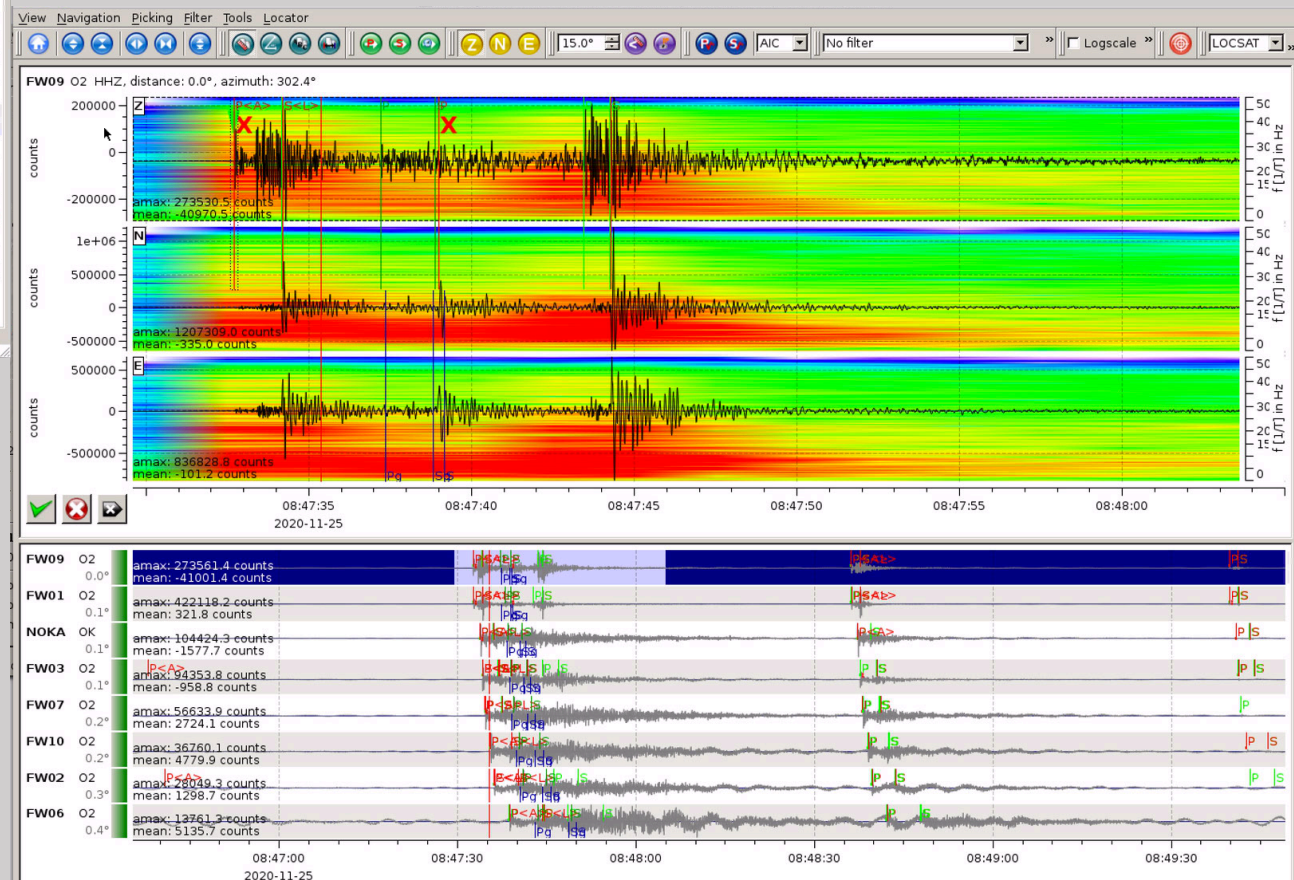
vs

Data



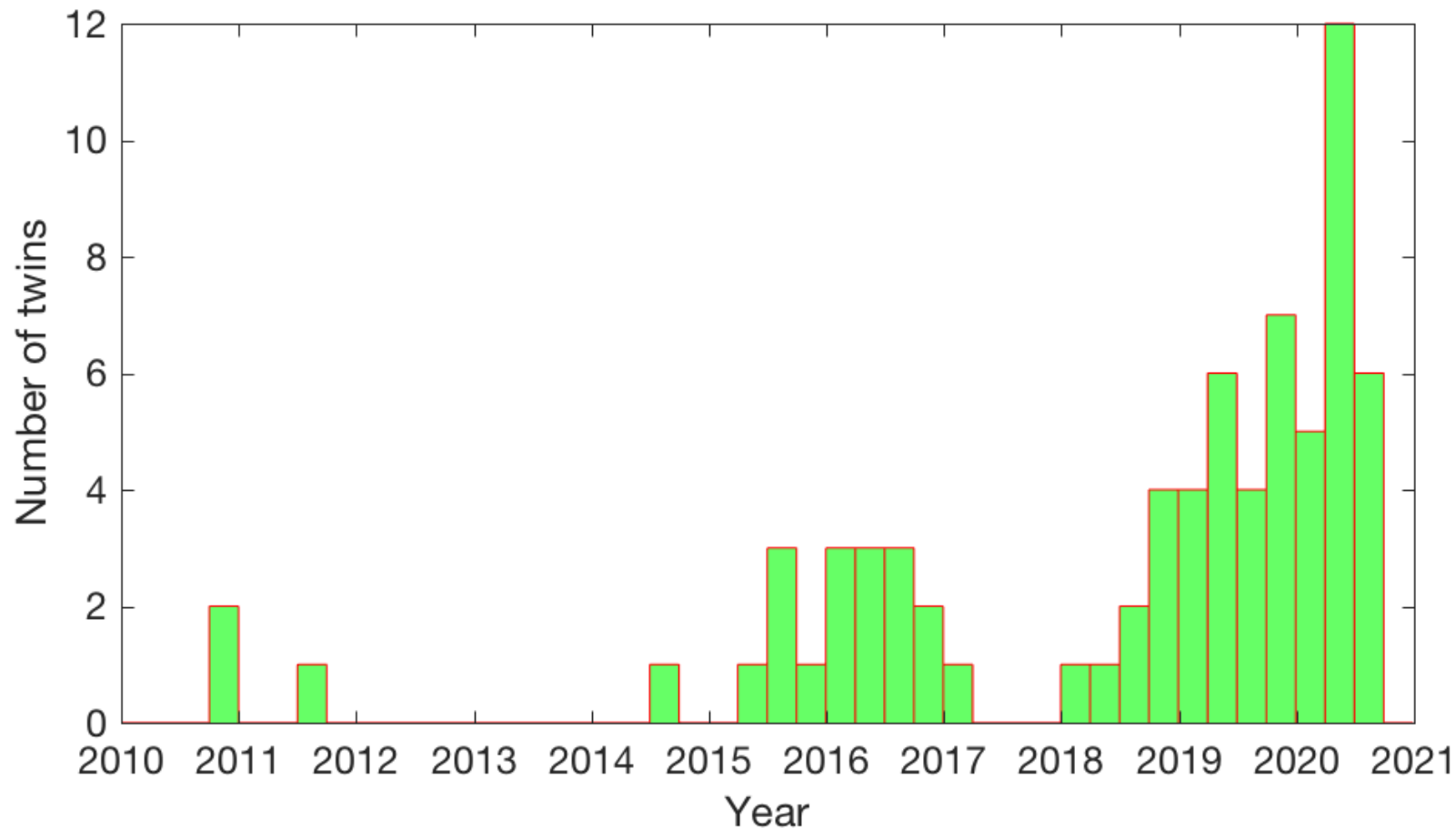
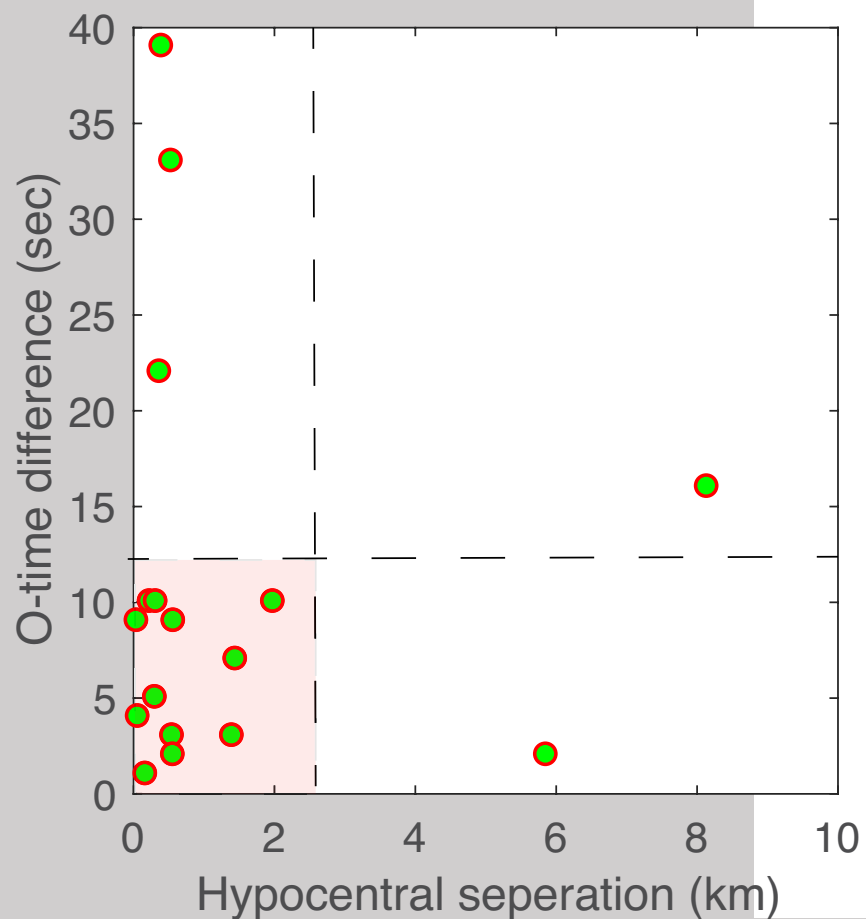


Robust seismic network

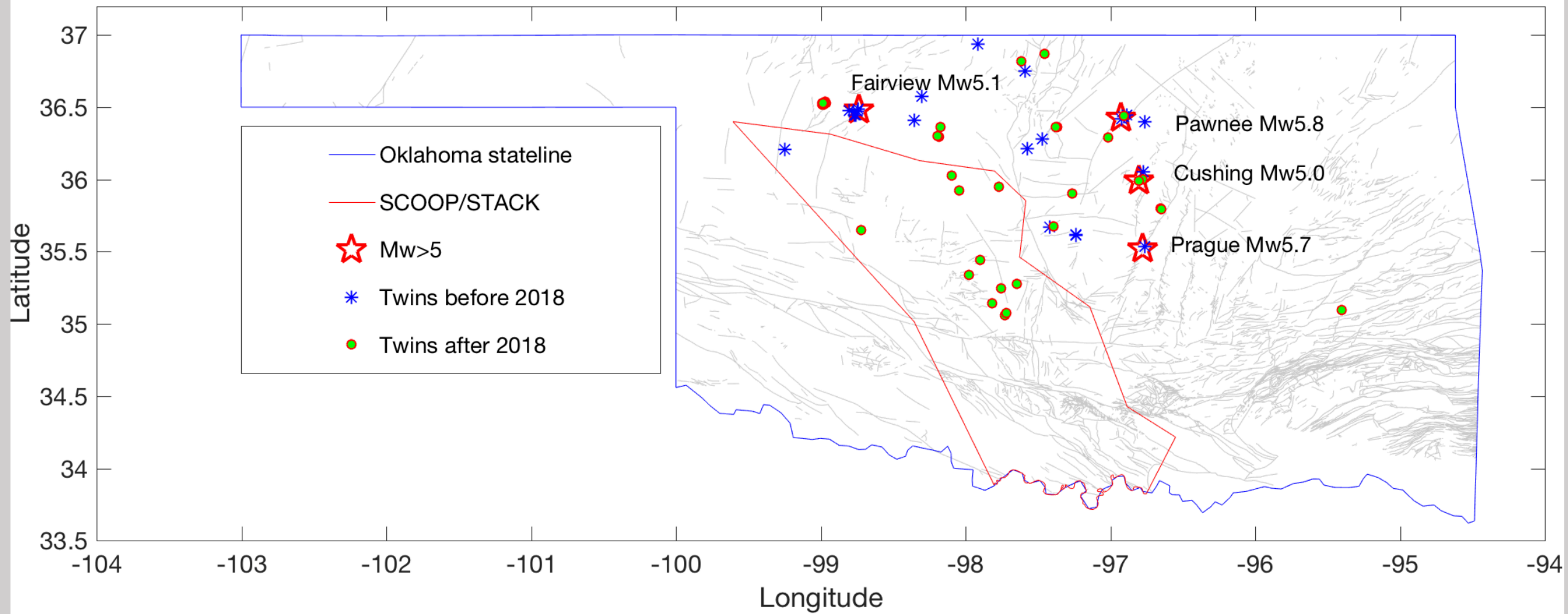


Machine learning: Easy-quake

Twins Since 2010



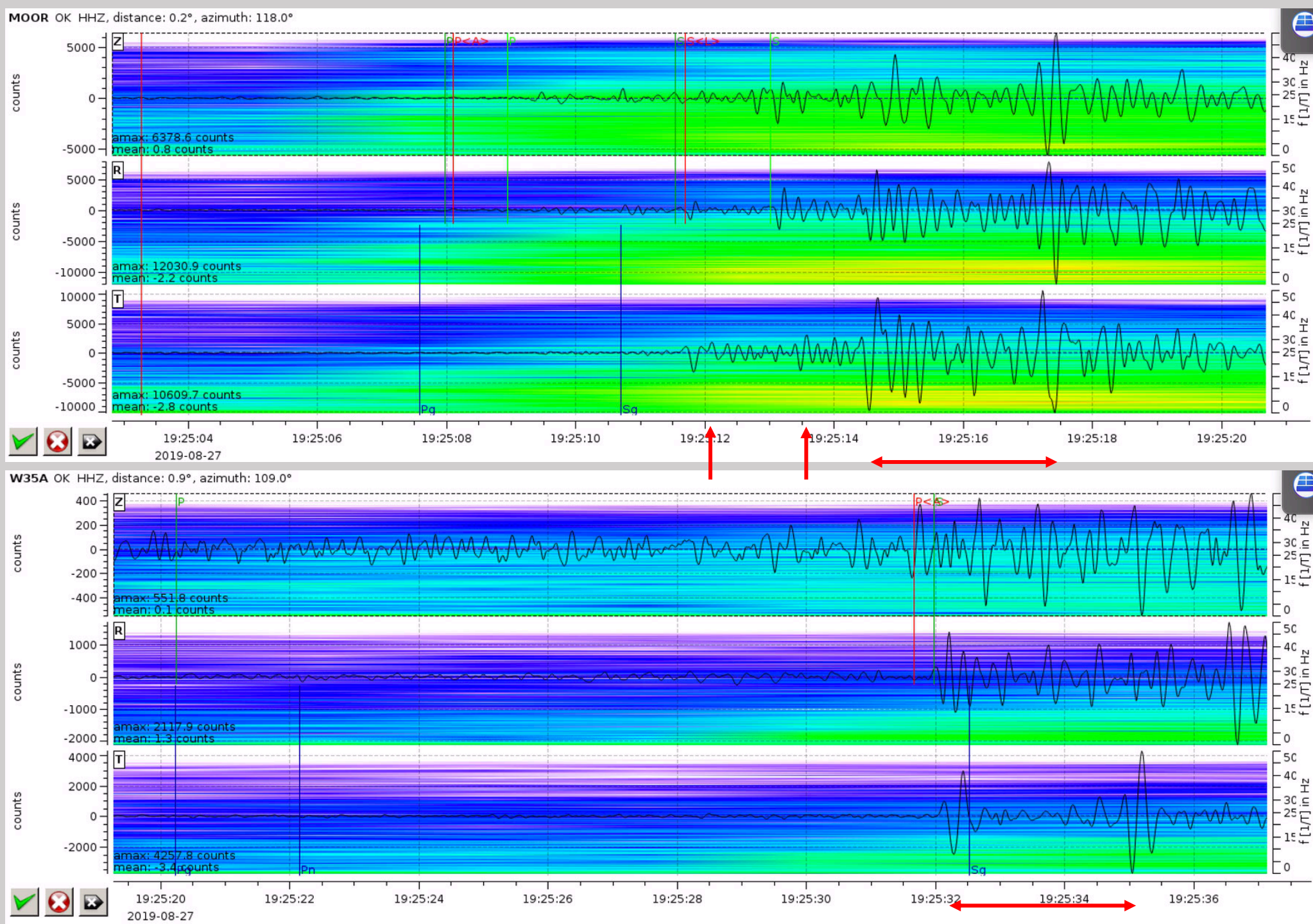
Twins Distribution



Multi-phased earthquake

The multiple phases
are more common in
some particular
stations

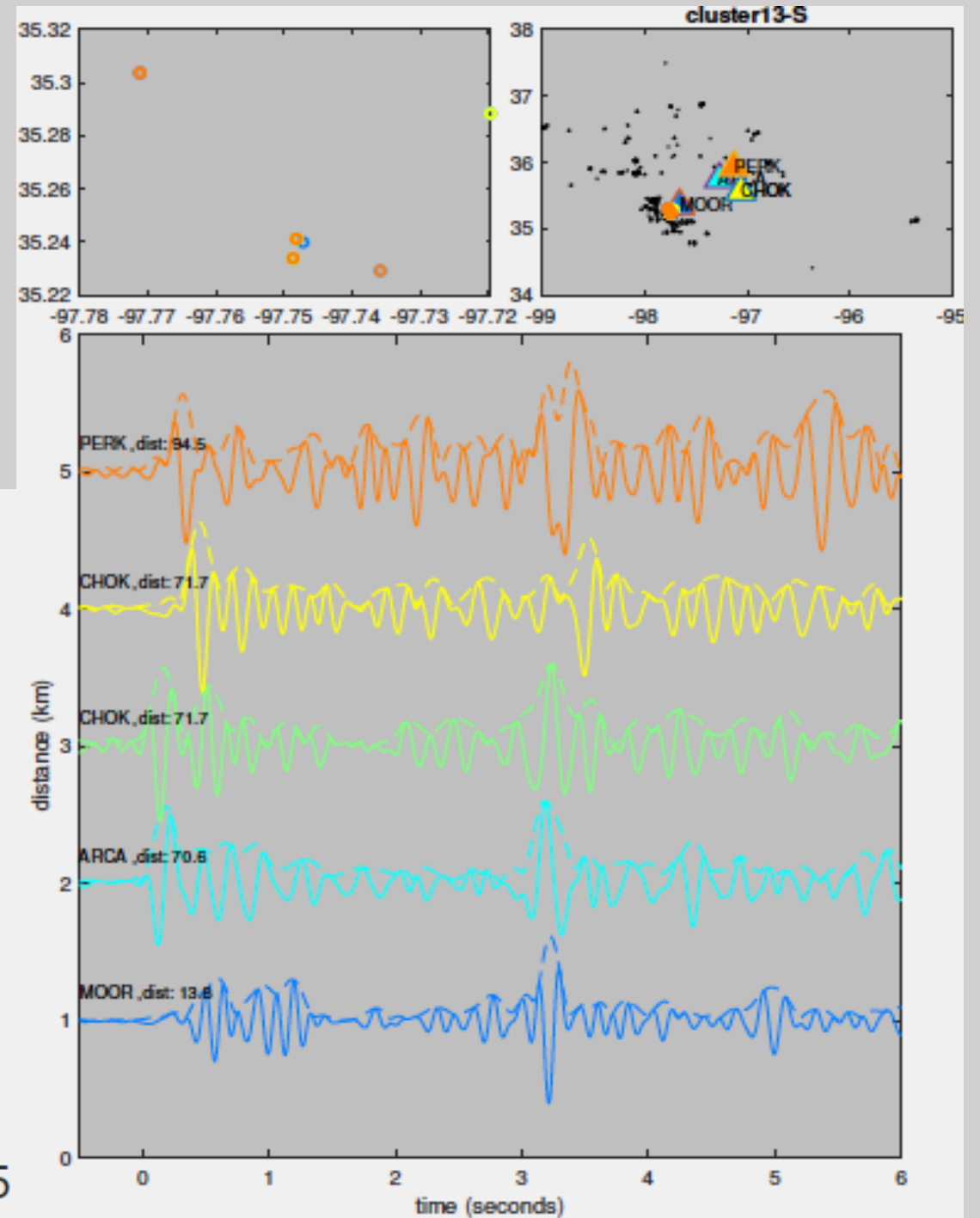
Rotated waveforms
and
bandpass filtered
1-5 Hz



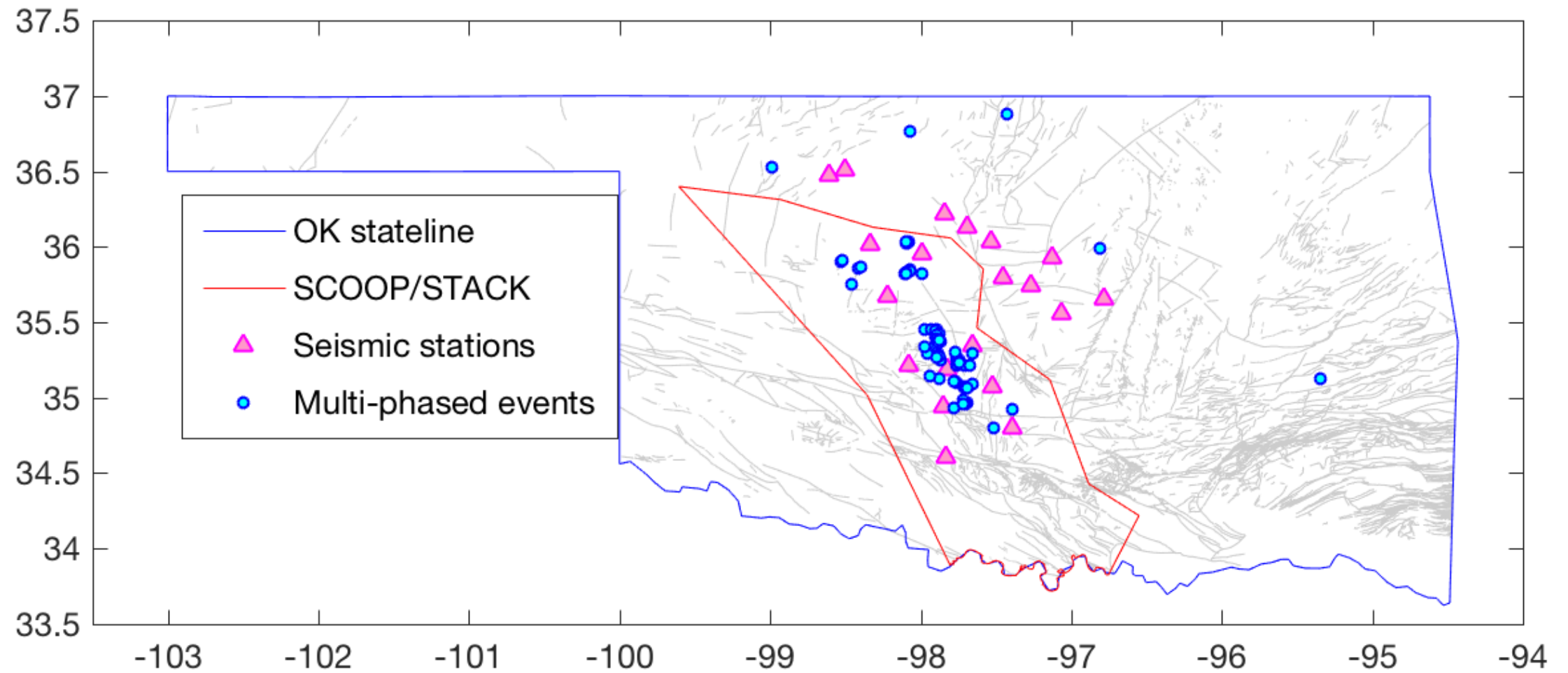
Correlation and clustering

- We apply waveform correlation and clustering around the P and S arrival separately.

Clusters have a **common phase time difference** that is **invariant of hypocentral distance** across the recording stations

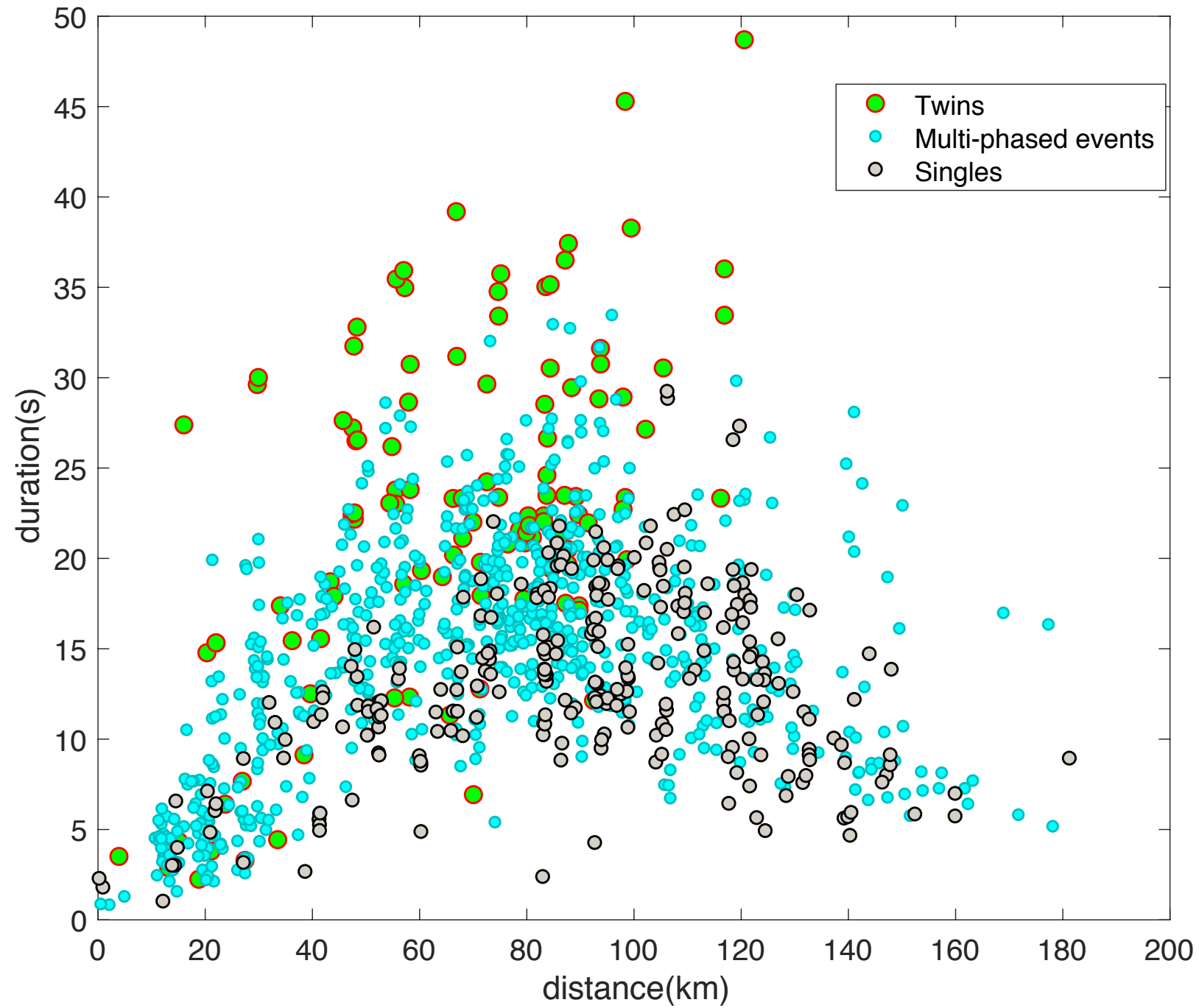
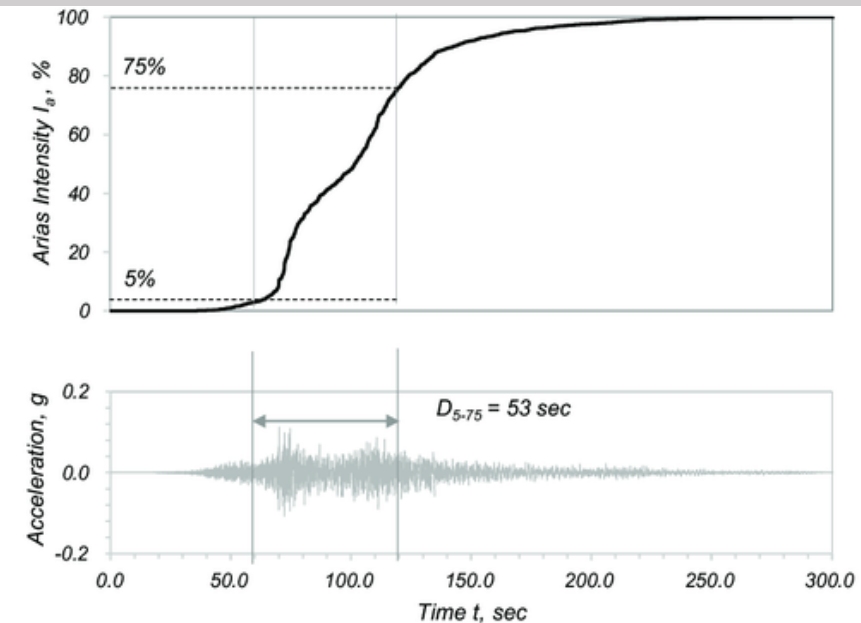


Multiple phases Distribution



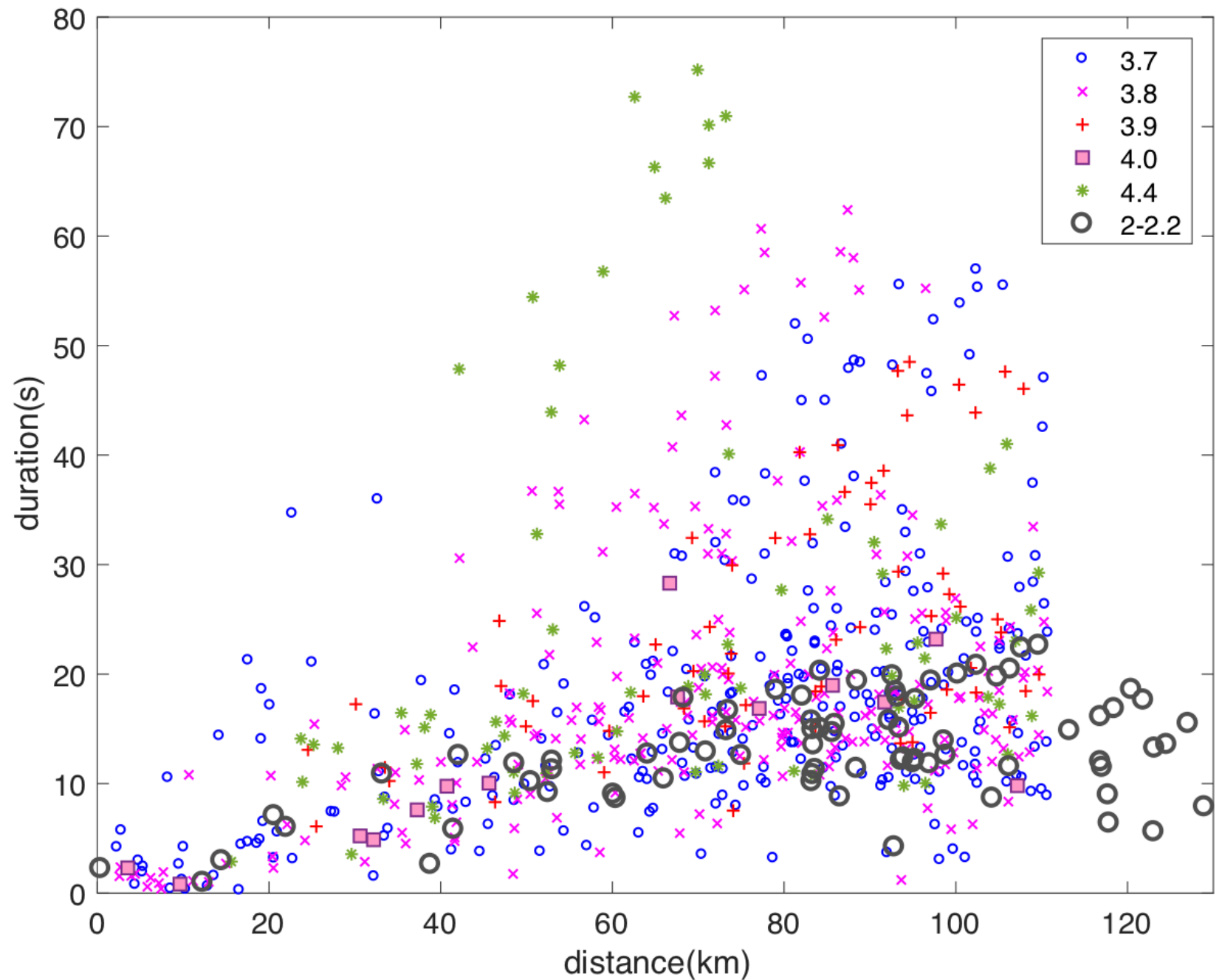
Elongated ground motion duration

$m_L 1.8-2.4$

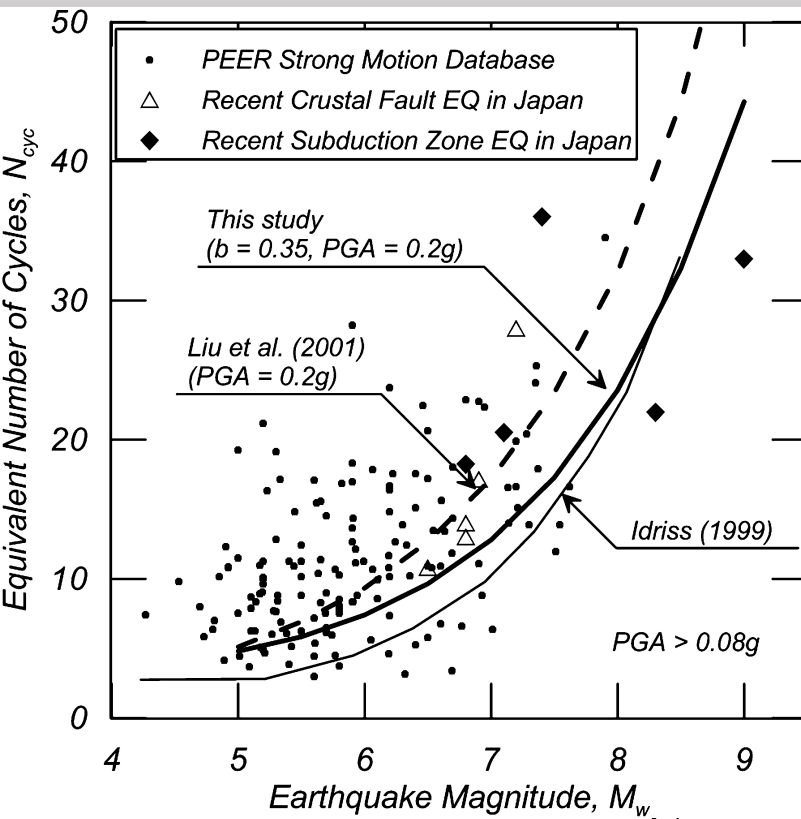


Elongated ground motion duration

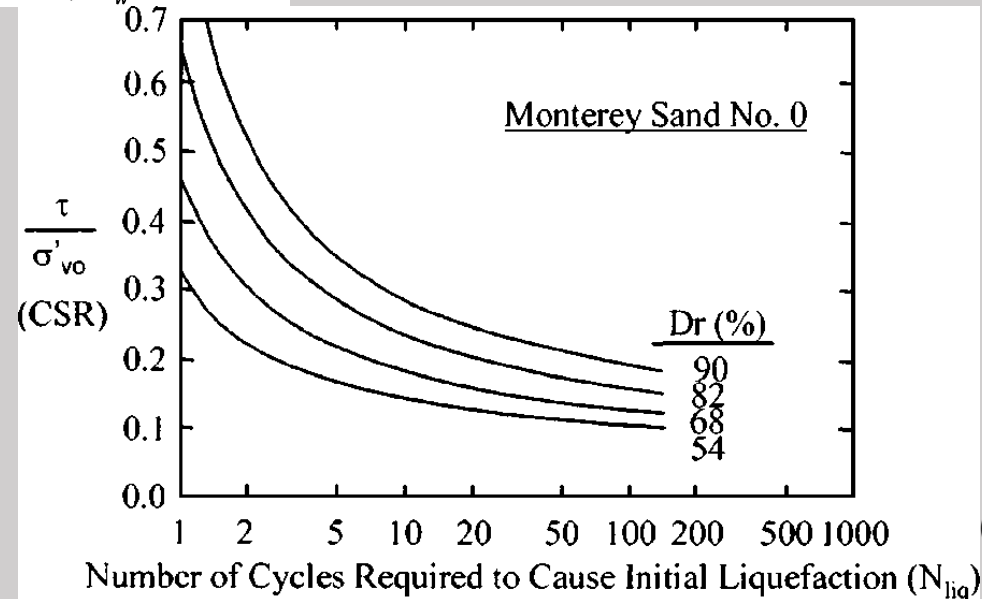
m_L 3.7-4.4



Effect of duration

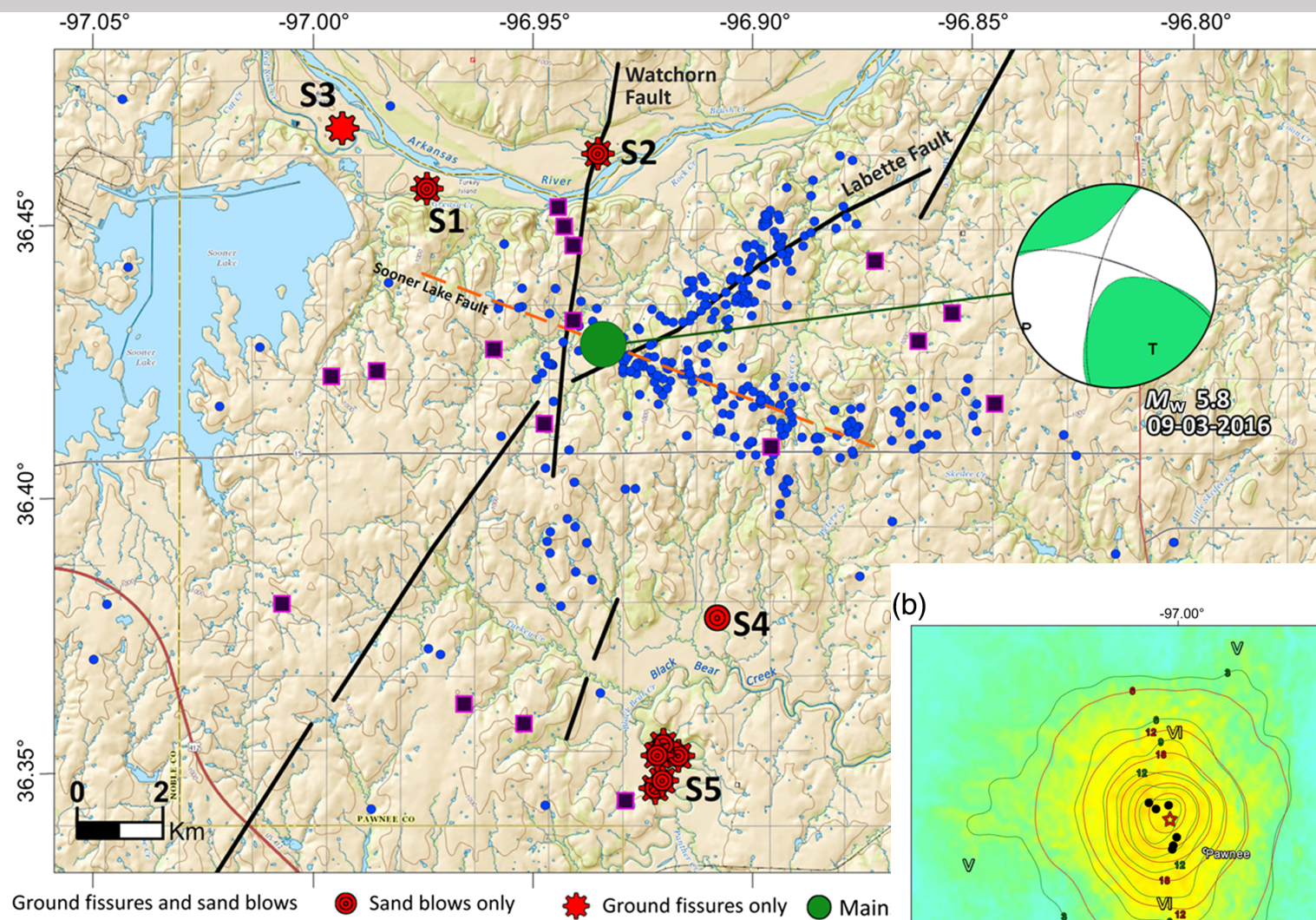


(Kishida and Tsai, 2014)



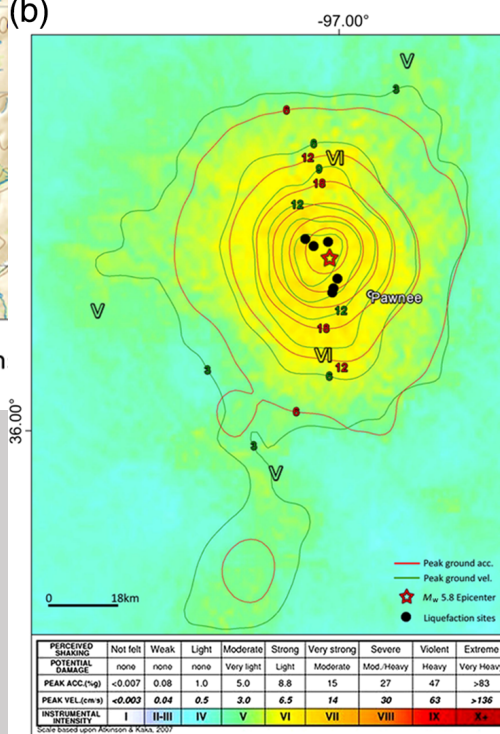
(Green and Terri, 2005; adpt from DeAlba et al. 1975)

(a)

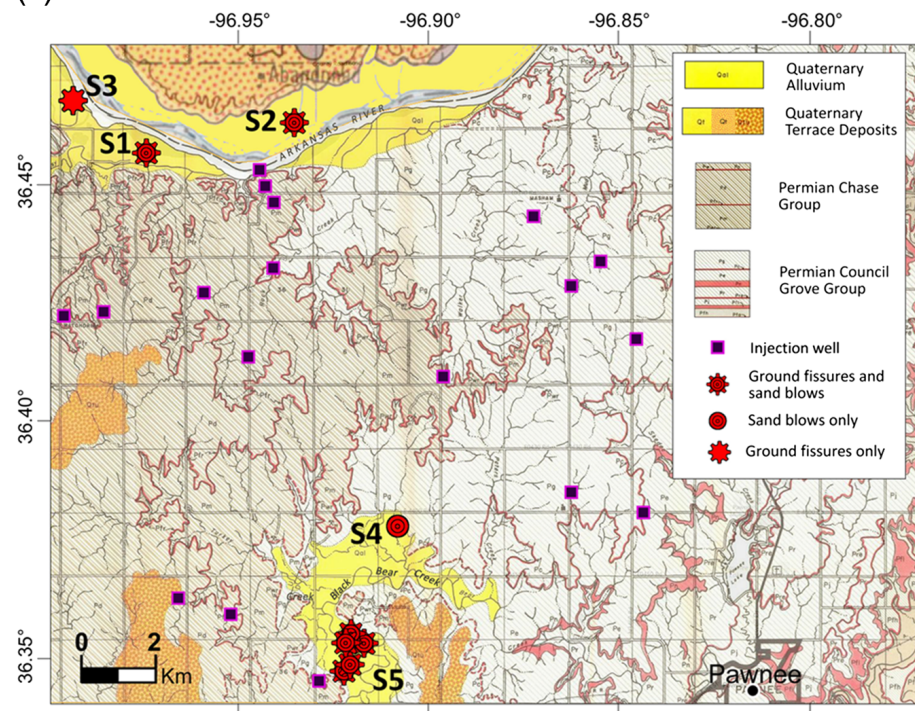


Liquefaction

(b)



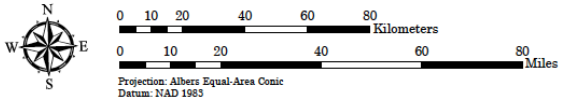
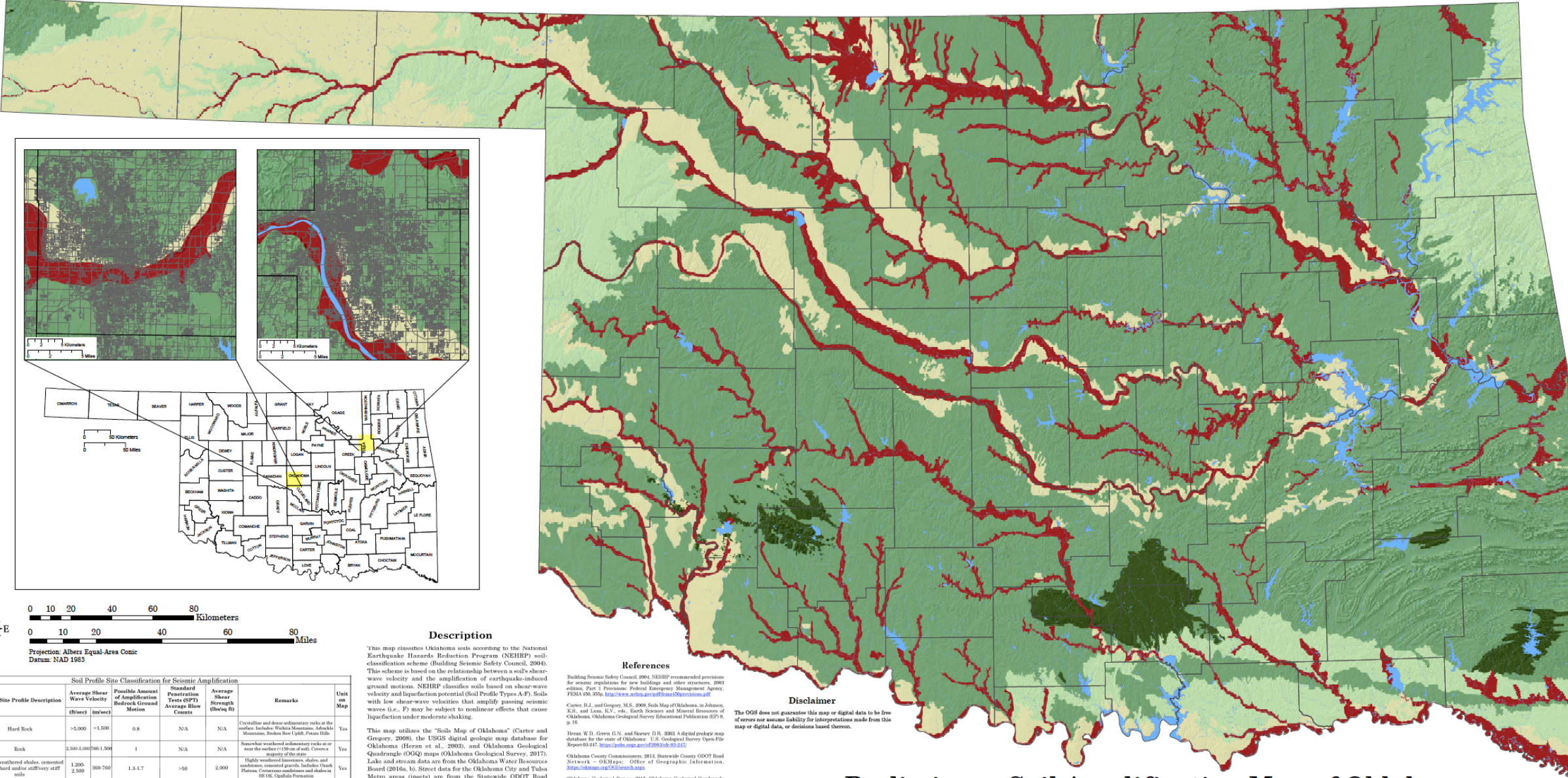
(c)



Kolawole et al 2017

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%)	<0.007	0.08	1.0	5.0	8.8	15	27	47	>83
PEAK VEL.(cm/s)	<0.003	0.04	0.5	3.0	6.5	14	30	63	>136
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Abbotson & Kott, 2007



Soil Profile Site Classification for Seismic Amplification		Possible Amount of Amplification				Standard Penetration Tests (SPT) Average Blow Counts		Average Shear Strength (kPa)		Remarks	Unit on Map
Soil Profile Type	General Site Profile Description	Average Shear Wave Velocity (ft/sec)	Average Shear Wave Velocity (m/sec)	Bedrock Ground Motion	Average Shear Strength (kPa)	Average Shear Strength (kPa)	Average Shear Strength (kPa)	Average Shear Strength (kPa)	Average Shear Strength (kPa)		
A	Hard Rock	>5,000	>1,500	0.8	N/A	N/A	N/A	N/A	N/A	Crystalline and dense sedimentary rocks at the surface. Includes Wichita Mountains, Adirondack Mountains, Snake River Gorge, Pecos Valley.	Yes
B	Rock	2,500-5,000	760-1,500	1	N/A	N/A	N/A	N/A	N/A	Somewhat weathered sedimentary rocks at or near the surface (<130 cm of soil). Covers a majority of the state.	Yes
C	Replith, weathered shales, cemented gravels, hard and/or stiff clay	1,200-2,500	360-760	1.5-1.7	>50	2,000	2,000	2,000	2,000	Highly weathered limestone, shales, and sandstones, cemented gravels, includes: Dark Plains, Cross-timber sandstone and shales in NE OK, Ogallala Formation.	Yes
D	Sands, silts, and/or stiff clay	600-1,200	180-360	1.5-2.4	15-50	1,000-2,000	1,000-2,000	1,000-2,000	1,000-2,000	Hard that is generally not saturated with water. Includes: Pecos sand and loam, Quaternary terrace deposits.	Yes
E	Soil profile with more than 10 ft (3m) of soft clay defined as soil with Plasticity Index > 30, water content > 60	<600	<180	1.5-3.5	<15	<1,000	<1,000	<1,000	<1,000	Not mappable at this scale	No
	Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible, weakly cemented soils	N/A	N/A	Site Specific Investigation should be conducted - can be < 1 to as high as 10 s	<15	<1,000	<1,000	<1,000	<1,000	Any saturated or partially saturated sands. Includes: Quaternary alluvium	Yes

Description

This map classifies Oklahoma soils according to the National Earthquake Hazards Reduction Program (NEHRP) soil-classification scheme (Building Seismic Safety Council, 2004). This scheme is based on the relationship between a soil's shear-wave velocity and the amplification of earthquake-induced ground motions. NEHRP classifies soils based on shear-wave velocity and liquefaction potential (Soil Profile Types A-F). Soils with low shear-wave velocities that amplify passing seismic waves (i.e., P) may be subject to nonlinear effects that cause liquefaction under moderate shaking.

This map utilizes the "Soils Map of Oklahoma" (Carter and Gregory, 2008), the USGS digital geologic map database for Oklahoma (Horn et al., 2003), and Oklahoma Geological Quadrangle (OGQ) maps (Oklahoma Geological Survey, 2017). Lake and stream data are from the Oklahoma Water Resources Board (2016a, b). Street data for the Oklahoma City and Tulsa Metro areas (metros) are from the Statewide ODOT Road Network (Oklahoma County Commissioners, 2013). The underlying DEM is 30m resolution (U.S. Geological Survey, 2016).

The map was produced and drafted in ArcGIS 10.4 and reviewed by David Brown and Ted Satterfield. Russell Standridge assisted in drafting the map. Work was funded by a grant through the Oklahoma Governor's office. This map is for informational purposes only and should not be used to determine liquefaction potential for specific sites. Further mapping and geotechnical measurements should be conducted in areas of concern.

References

Building Seismic Safety Council. 2004. NEHRP recommended provisions for seismic regulations for new buildings and other structures. 2003 edition, Part 1 Provisions. Federal Emergency Management Agency, FEMA 06-259p. http://www.fema.gov/NEHRP/NEHRP_06-259p.pdf

Carter, J.L., and Gregory, M.S. 2008. Soils Map of Oklahoma. In Johnson, K.L., and Lamm, G.V., eds., Earth Sciences and Mineral Resources of Oklahoma. Oklahoma Geological Survey Educational Publication (EGS 9, p. 9-16).

Horn, W.D., Green, G.N., and Shaver, D.H. 2003. A digital geologic map database for the state of Oklahoma. U.S. Geological Survey Open-File Report 03-447. <http://pubs.usgs.gov/of/2003/of-447/>

Oklahoma County Commissioners. 2013. Statewide County ODOT Road Network - OKMaps: Office of Geographic Information. <http://okmaps.org/OKMaps.asp>

Oklahoma Geological Survey. 2017. Oklahoma Geological Quadrangle maps 1:50,000 (2017). <http://www.okgeologicalsurvey.com/OGQ/>

Oklahoma Water Resources Board. 2016a. OWRB - Lakes of Oklahoma - OWRB Surface Water Data. Oklahoma Water Resources Board. <http://www.okwr.org/OWRB/SurfaceWaterData.aspx>

Oklahoma Water Resources Board. 2016b. OWRB - Major Streams - OWRB Surface Water Data. Oklahoma Water Resources Board. <http://www.okwr.org/OWRB/SurfaceWaterData.aspx>

U.S. Geological Survey. 2016. 1-Arc-second Digital Elevation Models (DEM) - USGS National Map 30EP Downloadable Data Collection. U.S. Geological Survey. <http://nationalmap.gov/>

Disclaimer

The OGS does not guarantee this map or digital data to be free of errors nor assume liability for interpretations made from this map or digital data, or decisions based thereon.

Preliminary Soil Amplification Map of Oklahoma According to the National Earthquake Hazard Reduction Program (NEHRP)

Brittany N. Pritchett, Jefferson C. Chang, Julie M. Chang, Neil H. Suneson, and Jacob I. Walter
2017
Scale 1:500,000

Last word!

Robust seismic network

