

Comparison of pick-based and waveform-based event detectors for local to near-regional distance data from Utah



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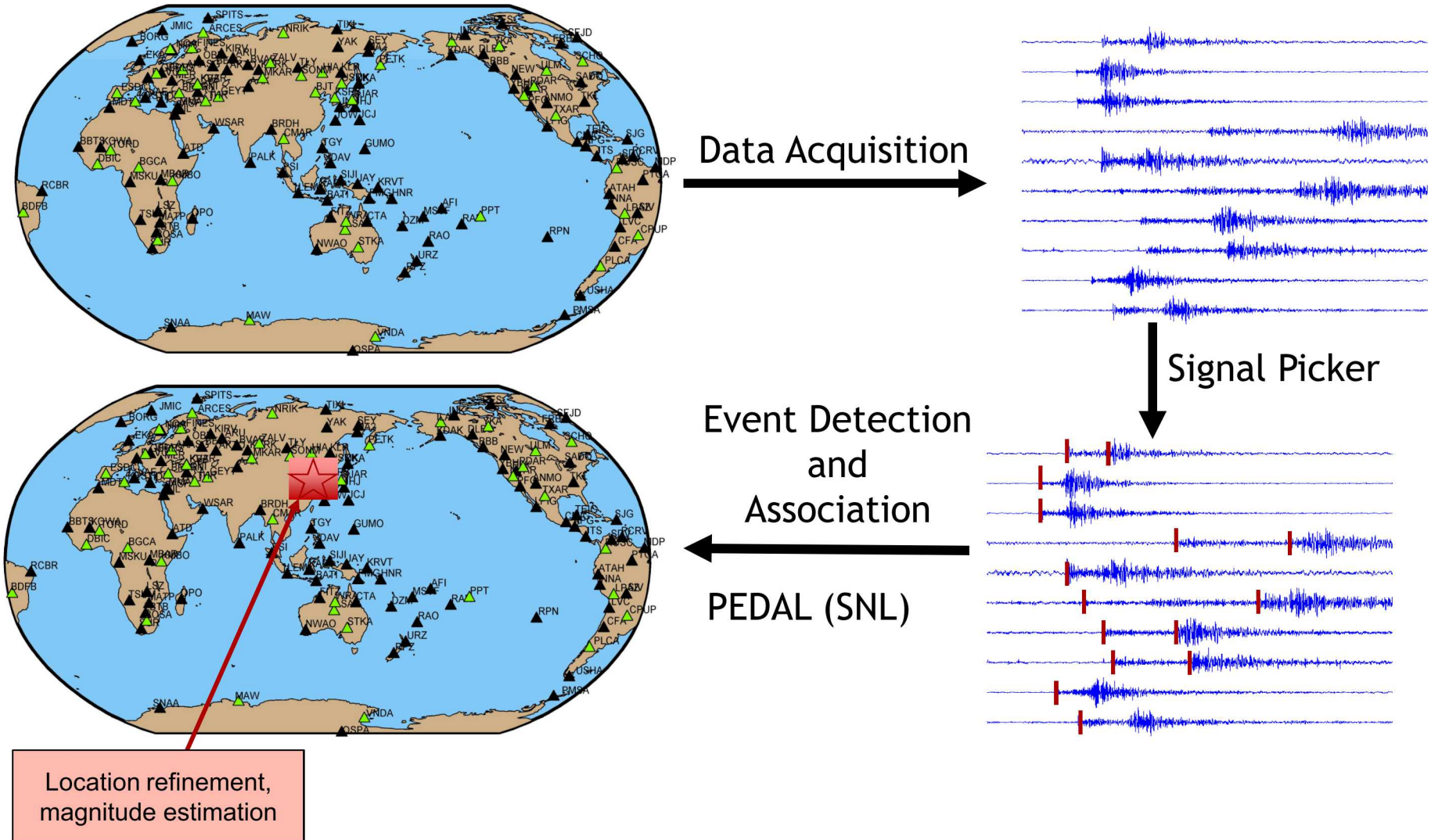


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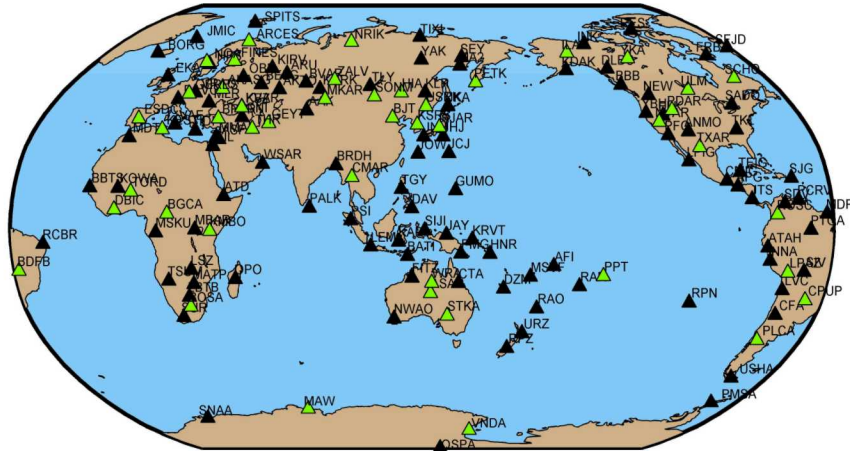
- Introduce pick and pickles-based algorithms
- Ground Truth Dataset (UUEB)
- Results
- Final thoughts and future work

THE PICK-BASED EVENT PROCESSING PIPELINE

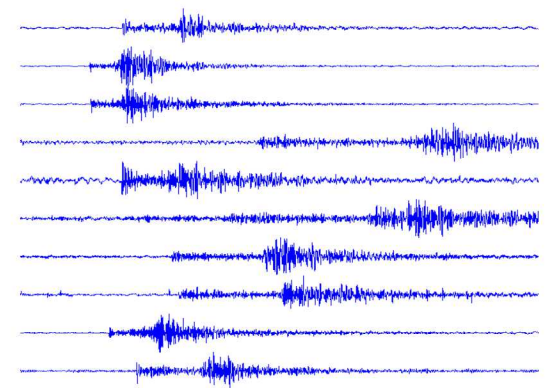


PEDAL : Probabilistic Event Detection, Association, Location

THE WAVEFORM/PICKLESS-BASED EVENT PROCESSING PIPELINE



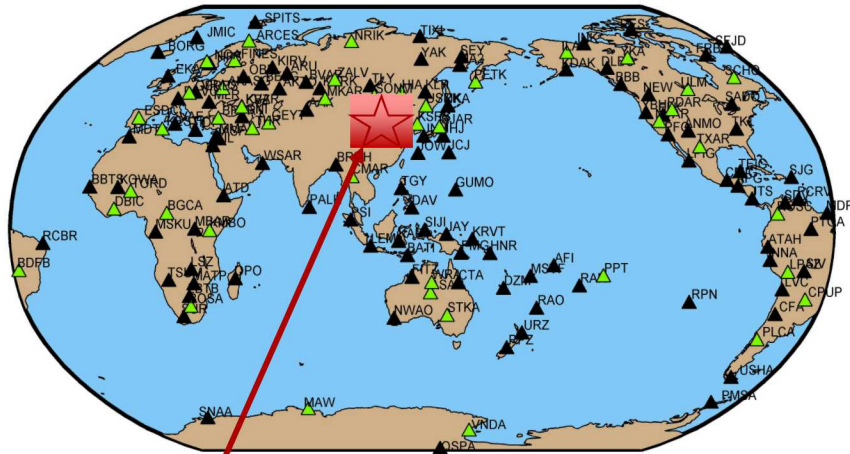
Data Acquisition



Event Detection



WCEDS (SNL)



Location refinement,
magnitude estimation



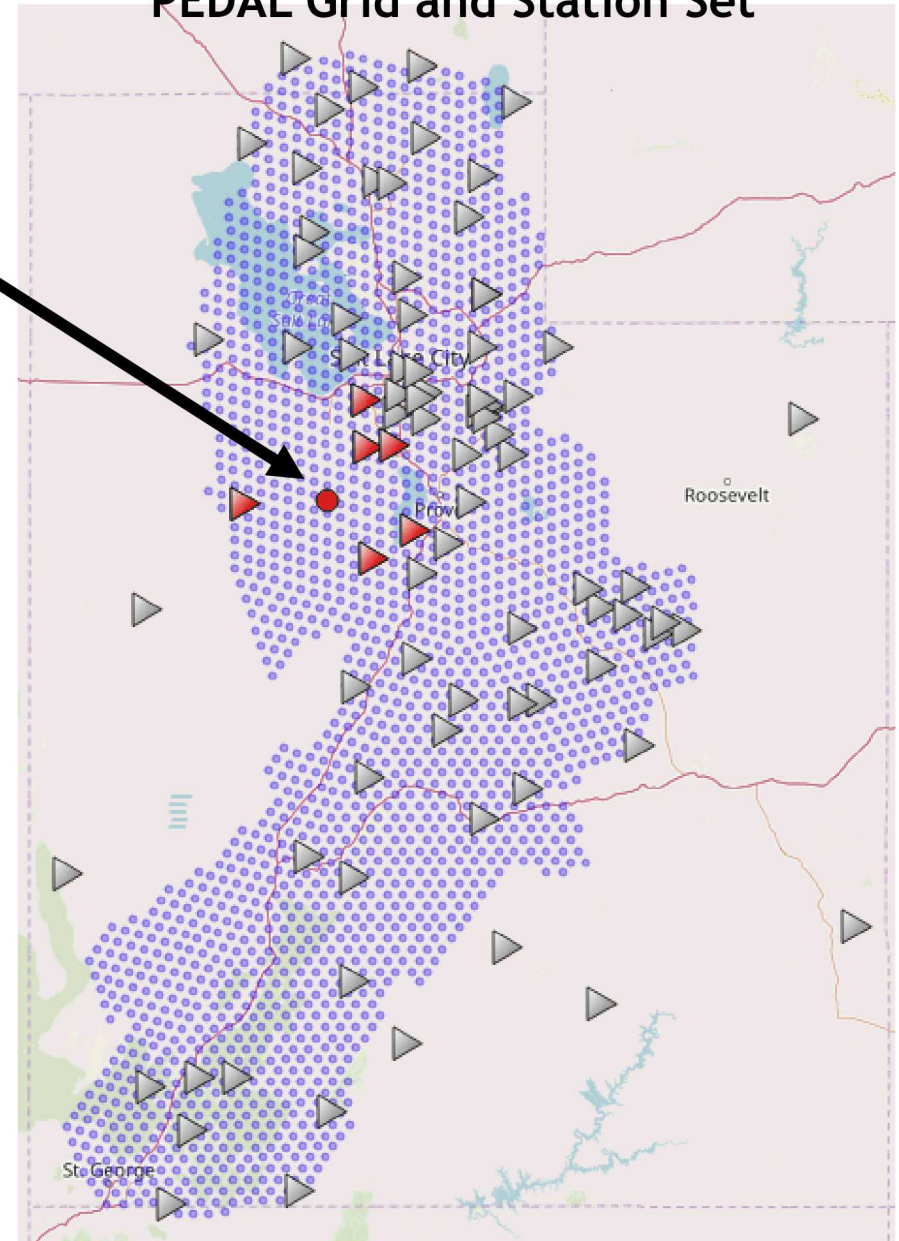
PEDAL and WCEDS are grid search algorithms

- For each grid point:
 - Compute Event Fitness
- If fitness at grid location “i” > Threshold
 - Create event at location “i”
 - Associate Signal Detections (PEDAL)
 - Iterate (WCEDS)

PROCESSING RECIPE : PEDAL

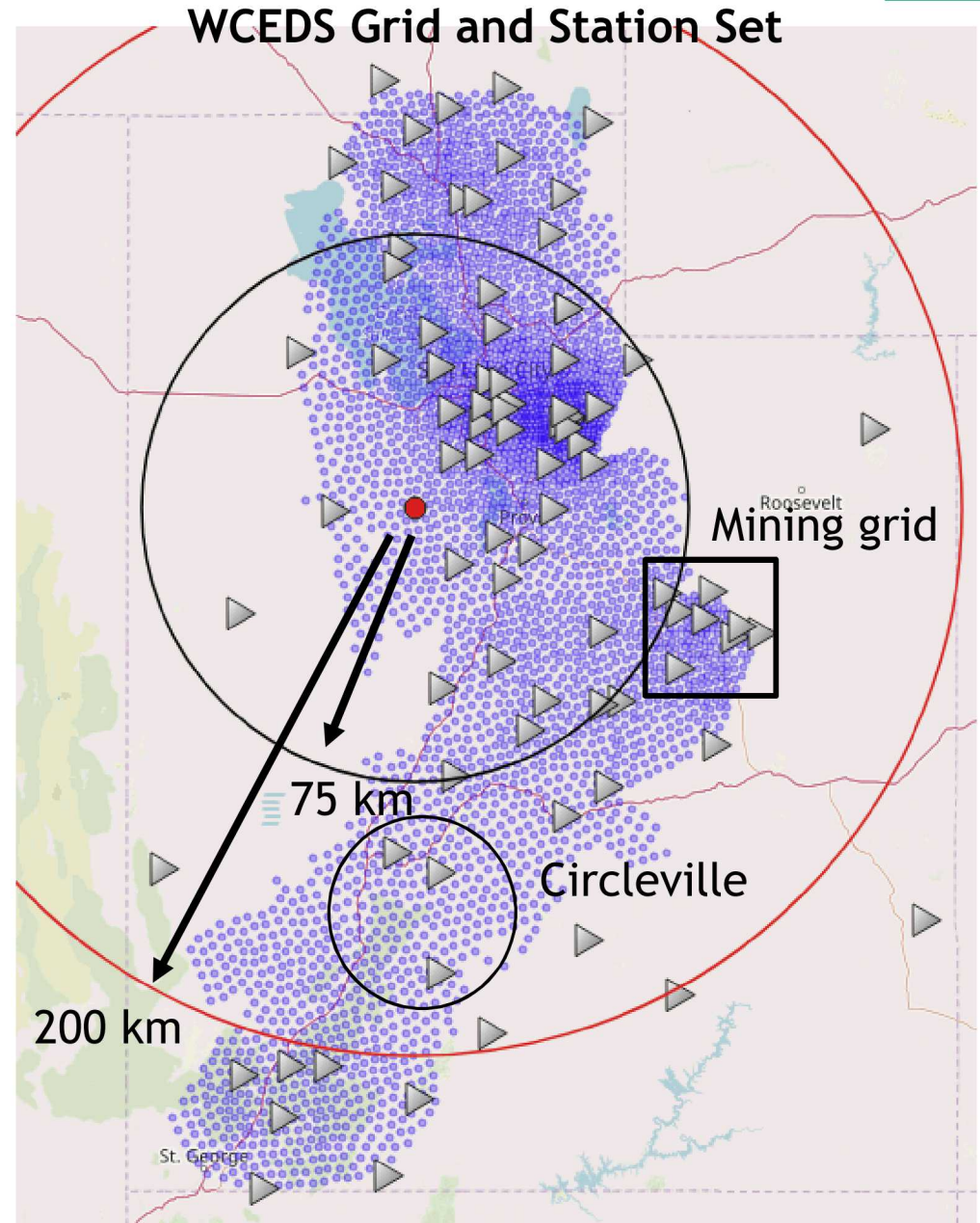
- Uniform grid (.06 deg spacing)
- For each grid point, only the 6 closest stations contribute to the initial event formation. (helped reduce false positives)
- However, all stations can have their signal detections associated with any event/grid location.
- Waveform Data transformation:
 - Signal picks generated from STA/LTA detector using 5 filter bands (hz): [0.5, 1.5] [1.0, 2.0] [1.5, 3.0] [2.0, 4.0] [4.0, 8.0]
 - AIC time refinement applied to picks
 - QC to filter spike signal detections

PEDAL Grid and Station Set

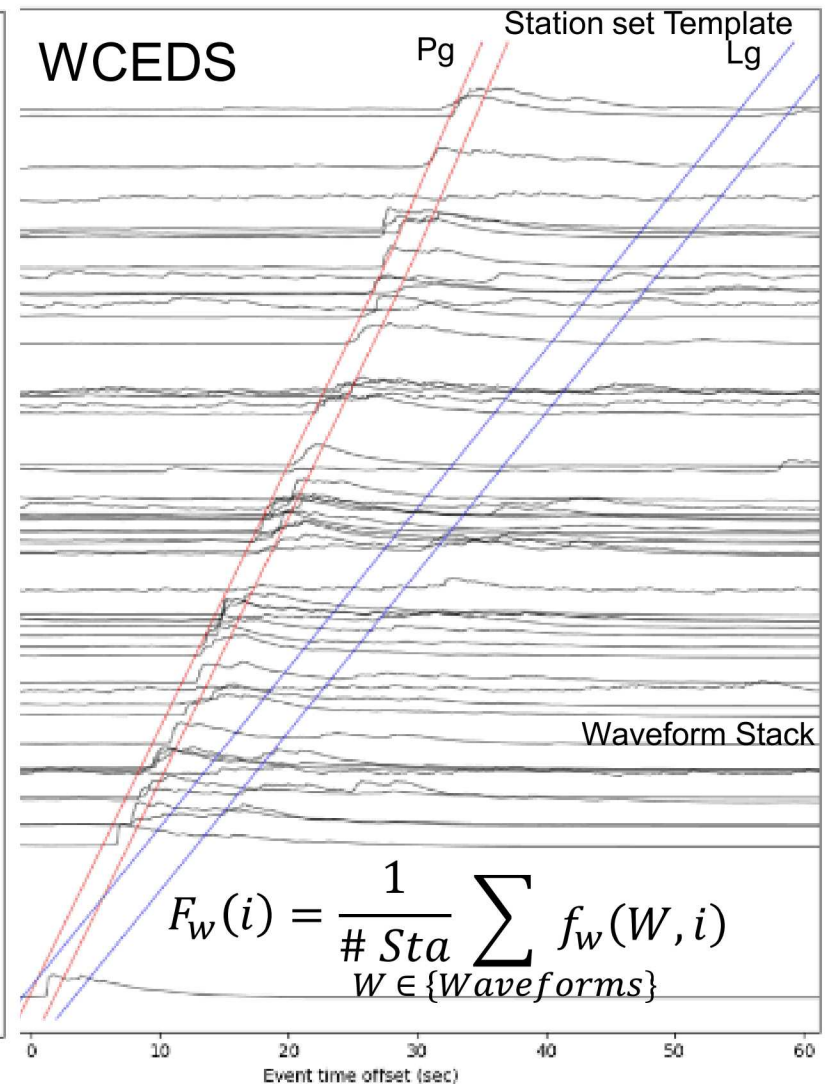
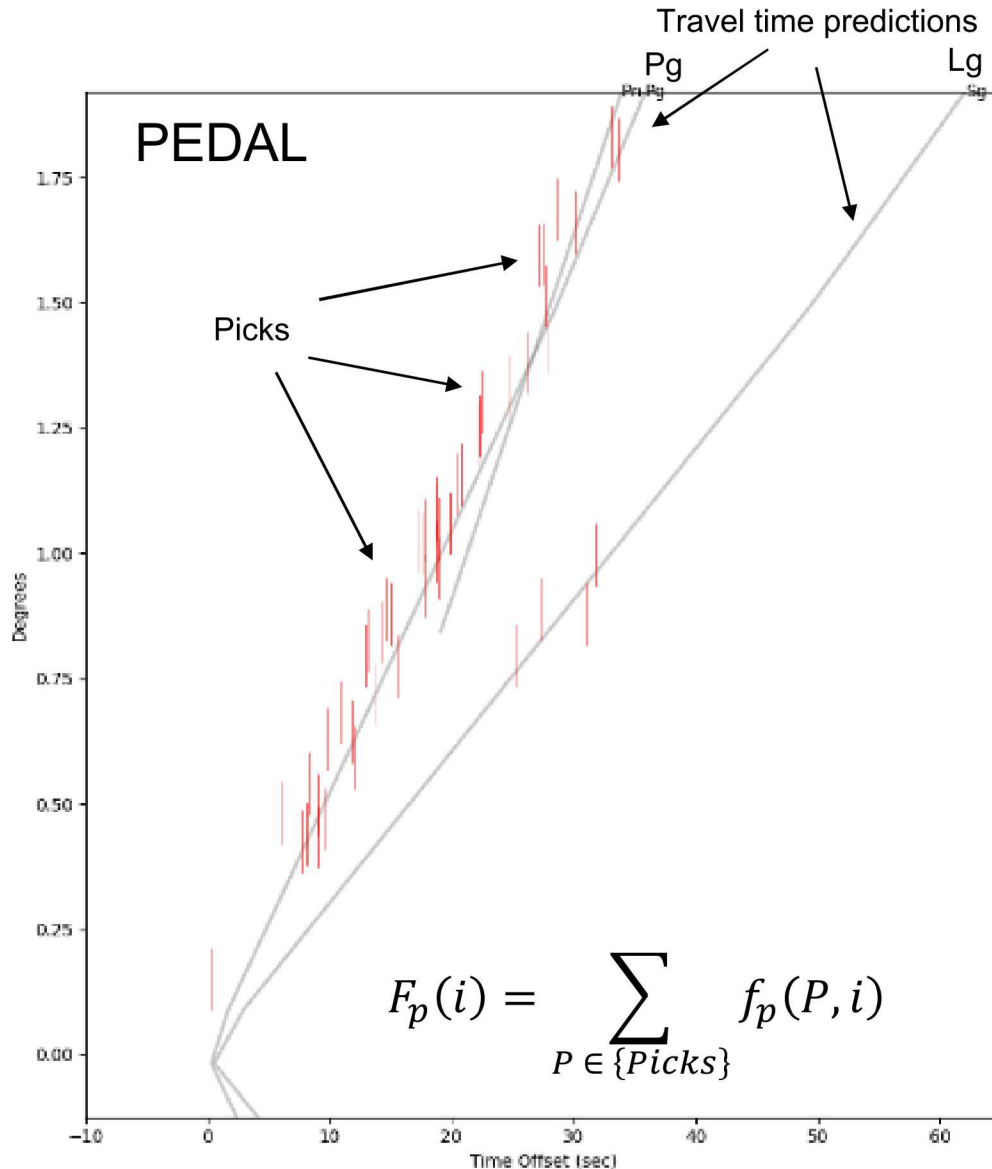


PROCESSING RECIPE: WCEDS

- For each grid point:
 - 1st iteration (Network wide events): stations within 200 km [.5hz ,4hz]
 - 2nd iteration (Smaller events): stations within 75 km for second pass [.5hz, 4hz]
- Circleville: stations within 75 km [4hz, 8hz]
- Mining grid iteration - for each grid point
 - Filter band [4hz, 8hz], Only stations in mining grid
- Data transformation:
 - Bandpass filter (see filter bands below)
 - STA/LTA (3, 60) secs to rectify and enhance signals (WCEDS waveform stack.)

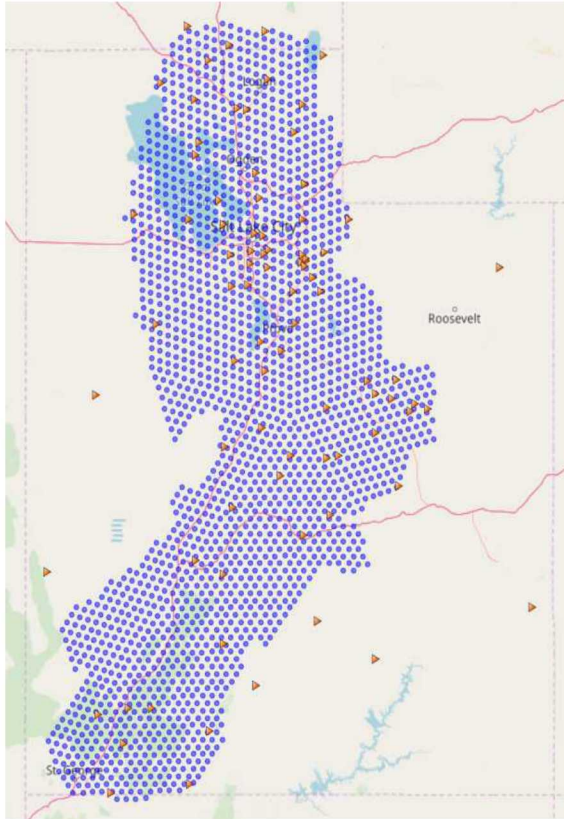


Same Event as viewed by PEDAL and WCEDS at grid location “i”

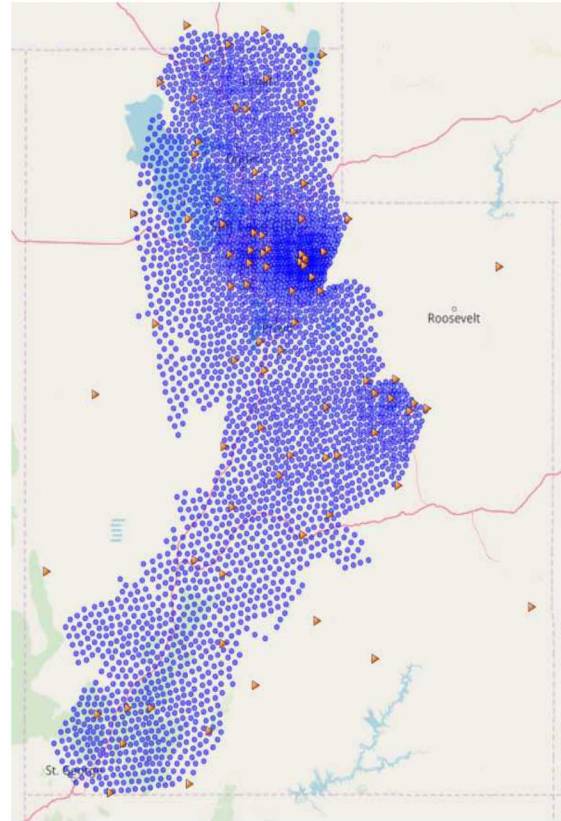


PEDAL VS. WCEDS GRIDS

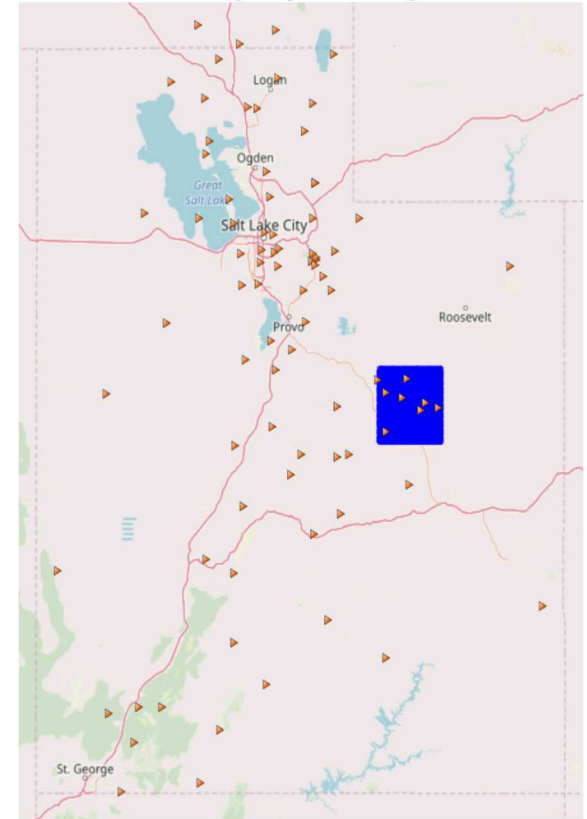
PEDAL
.06 deg spacing



WCEDS UTAH
[.01, .1] deg spacing



WCEDS Books Cliff
.01 deg spacing



- Both grids limited to regions of historic events in UUSS catalog to limit false events.
- WCEDS uses 2 grids (differences in spacing and location).
- PEDAL uses 1 grid, but making it finer did not improve results.

Ground Truth Bulletin: Unconstrained Utah Event Bulletin (UUEB)

The **UUEB** was developed to evaluate signal detection and event association algorithms.

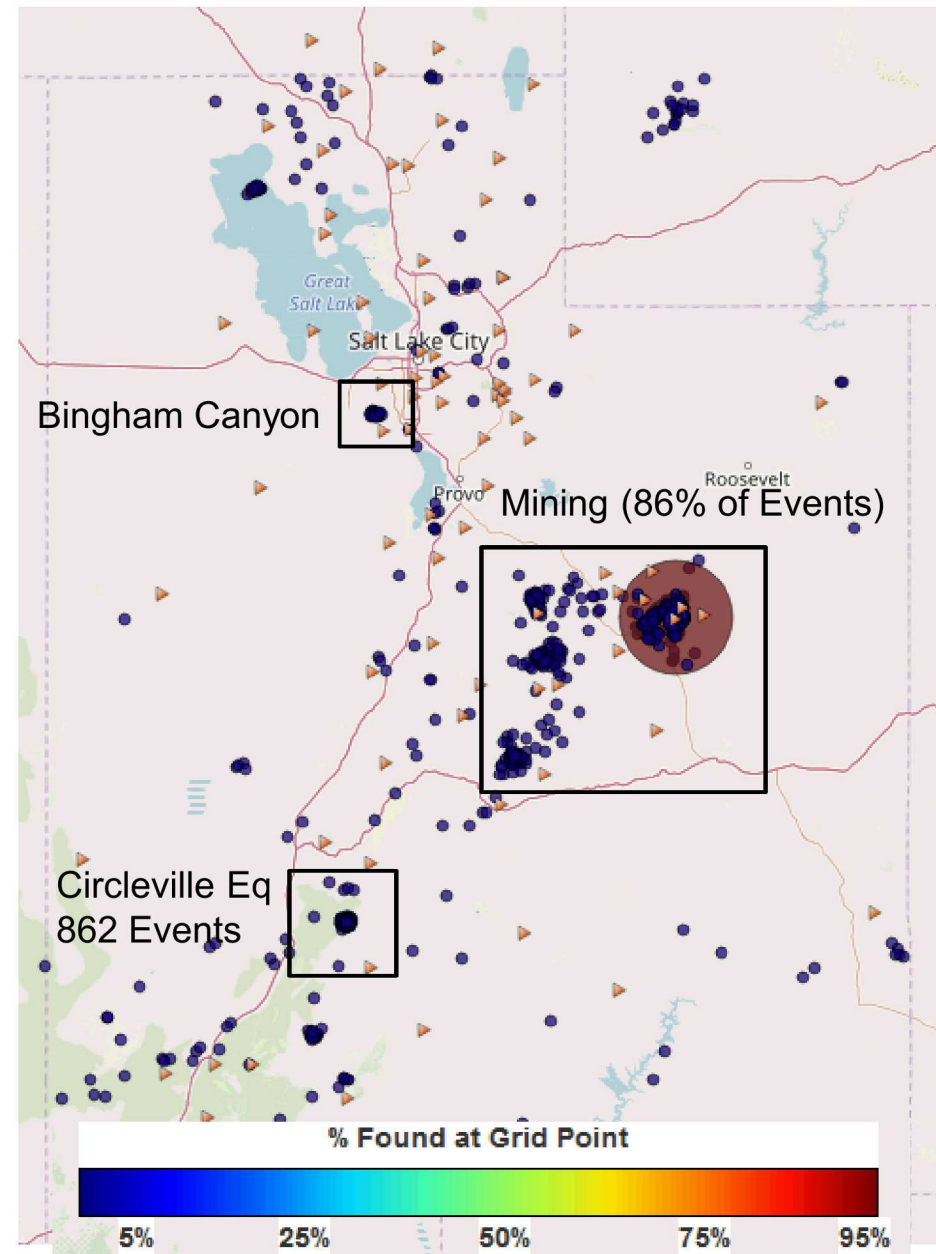
UUEB network for the Jan 1-14, 2011 time-period.

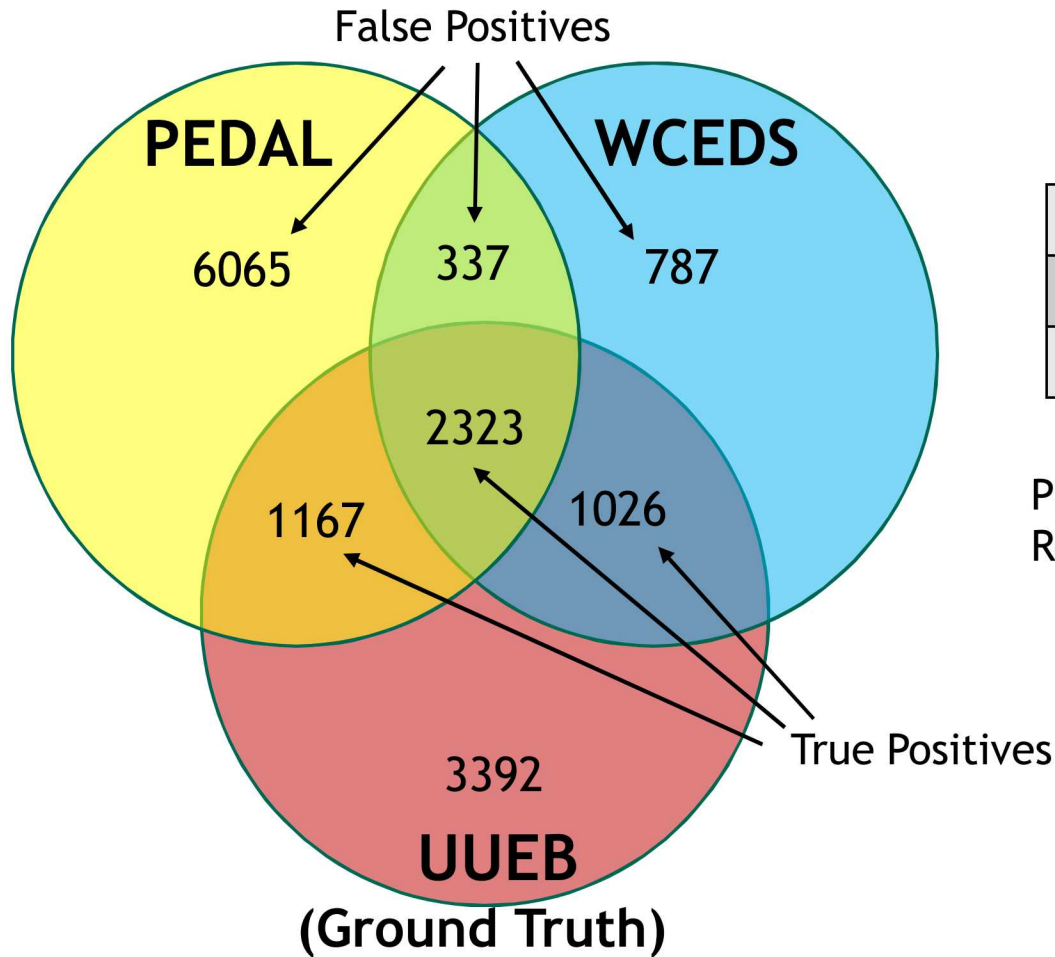
Overview:

- 7,889 events
- All events ≥ 3 associations
- $\sim 3/4$ of events have 5-9 defining stations

Seismicity:

- M_w 4.5 EQ + aftershock sequence near Circleville, Utah (862 events)
- Coal mine explosions in central Utah
- Bingham Canyon quarry blasts
- Central Utah Coal mine account for $\sim 86\%$ of events.





	Precision	Recall
WCEDS	75%	42%
PEDAL	35%	44%

Precision = # True Positive / # Events Found

Recall = # True Positive / # UUEB Events

Agglomerative Clustering used to create Venn diagram

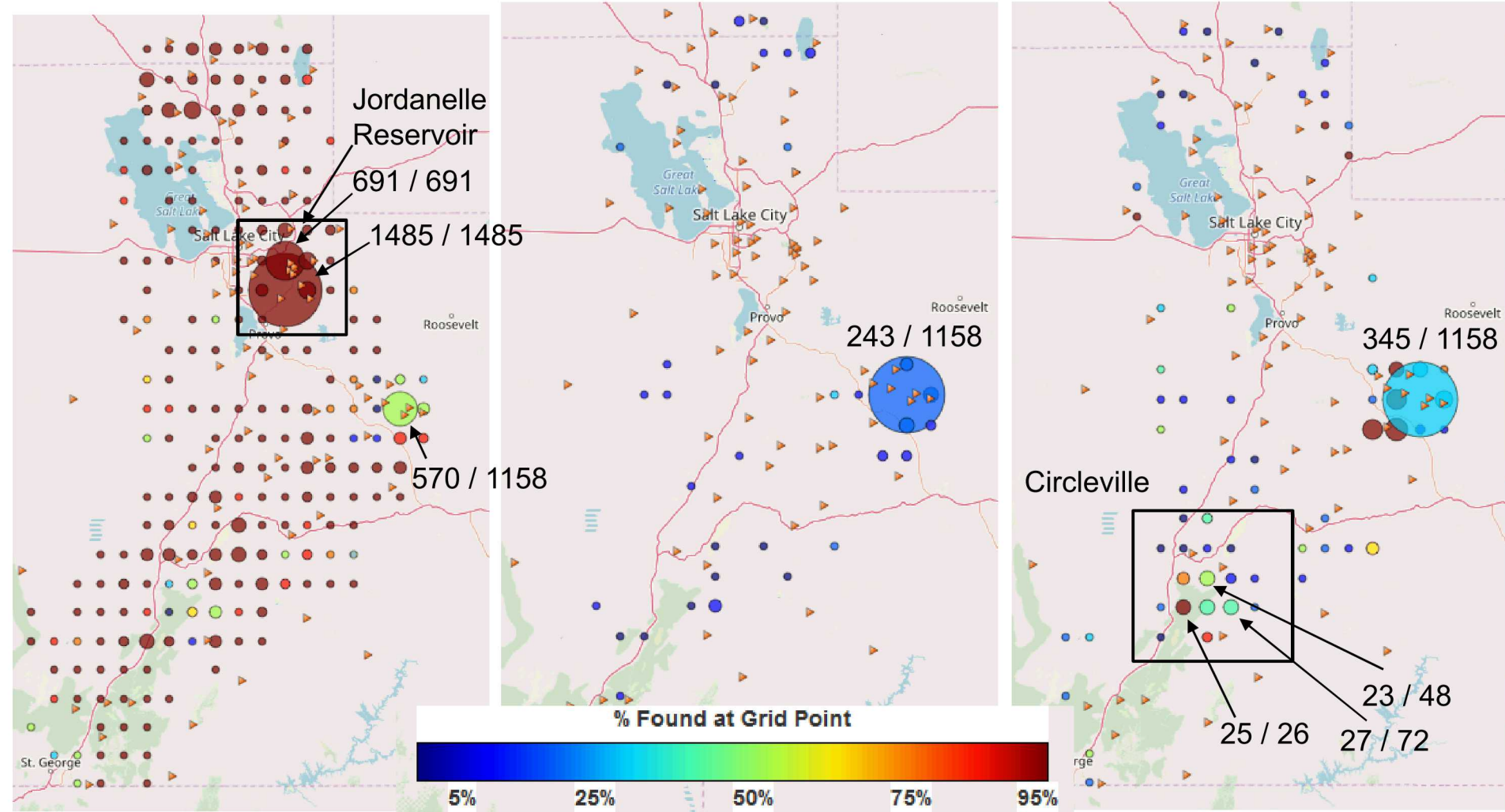
- Time delta: 10 sec
- Dist delta: 45 km $\approx$ (.4 deg)

FALSE POSITIVE LOCATIONS

PEDAL Only

PEDAL and WCEDS

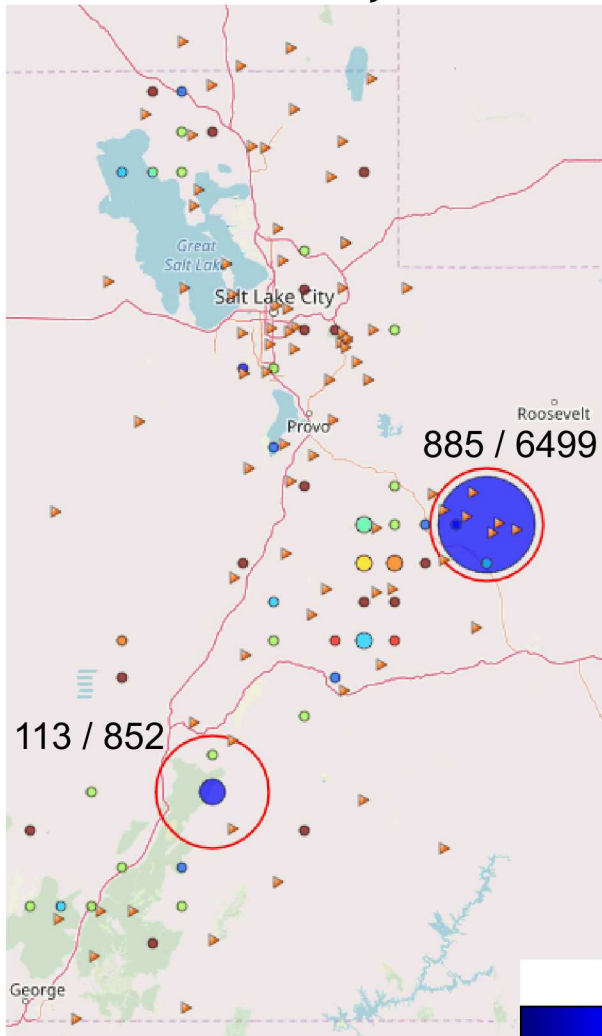
WCEDS Only



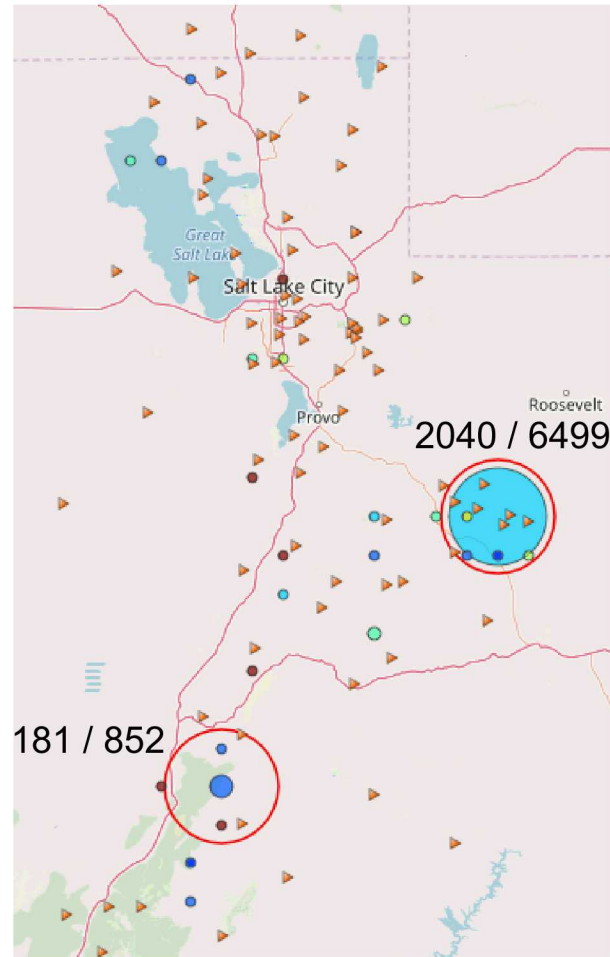
- PEDAL builds false events throughout much of the grid.
- PEDAL is finding Jordanelle Reservoir seismicity - These events aren't in the UUEB because of the locations never converged.
- WCEDS false events are limited mostly to Circleville and central mining region.

TRUE POSITIVE LOCATIONS

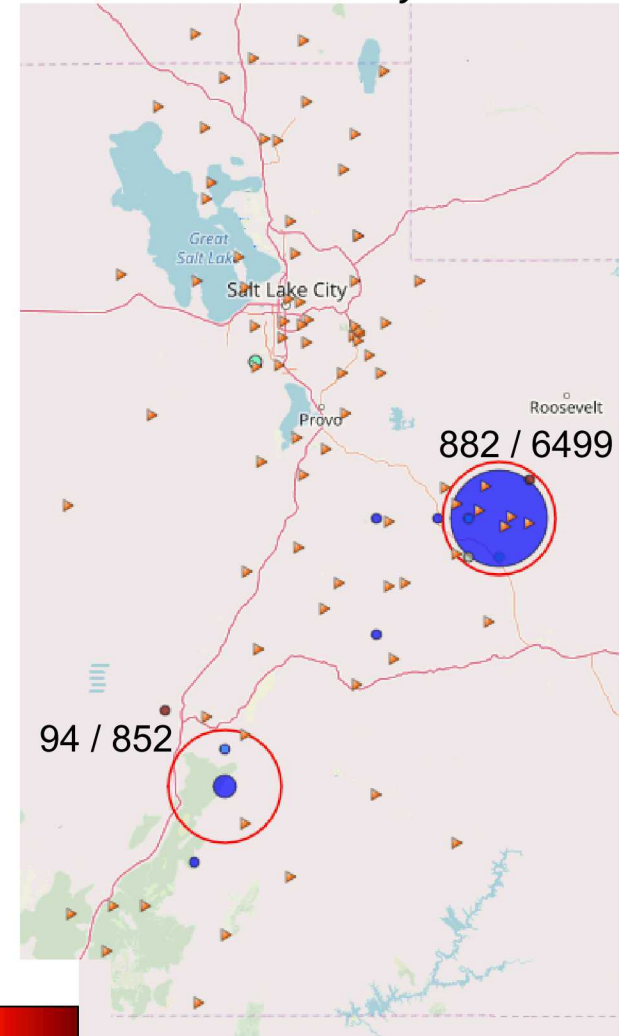
PEDAL Only



PEDAL and WCEDS



WCEDS Only



% Found at Grid Point

5%

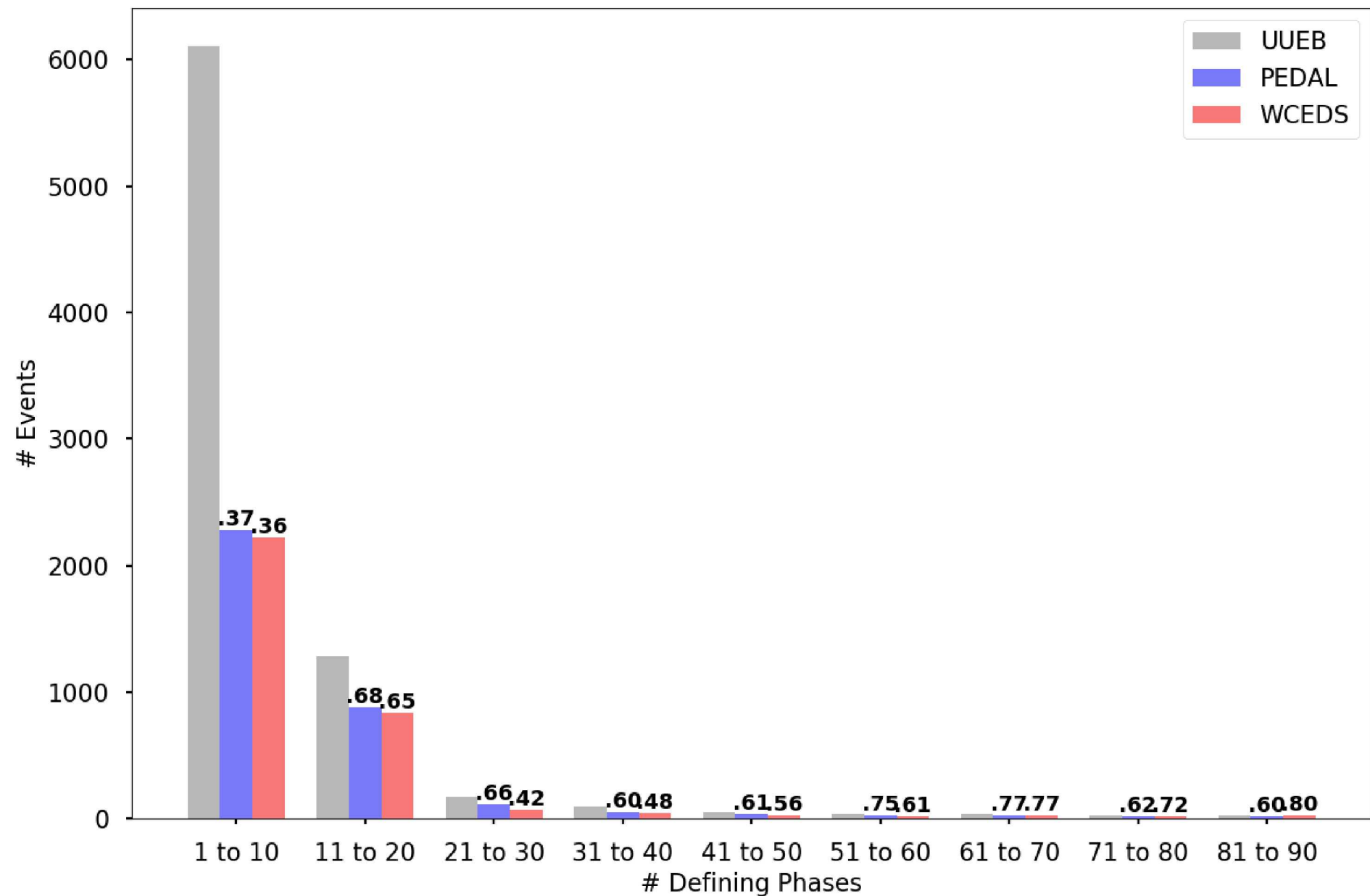
25%

50%

75%

95%

True Positive Event Magnitudes



**PEDAL****WCEDS**

Recall at expense of Precision

Great Precision and Good Recall

Harder to tune:
signal picker, fitness function

Easier/more intuitive to tune

Data QC absolutely necessary

QC “for free”
(Averaging in the fitness function)

Signal association

Not a real associator

Future Work

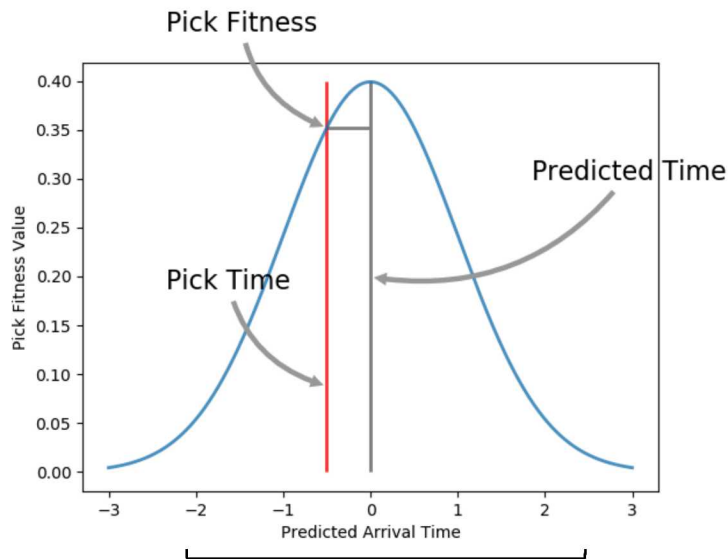
- Both algorithms need tuning to find more of the < smaller events (# def <=10)
- Combine the algorithms - WCEDS style event formation with WCEDS, Association with PEDAL
- Better picker for PEDAL - Machine Learning/Deep Learning
- Global association with multiple regional event builders and a global event builder



PEDAL

$$F_p(i) = \sum_{P \in \{Picks\}} f_p(P, i)$$

$$f_p(P, i) = e^{-\left(\frac{\Delta t}{\sigma}\right)^2}$$

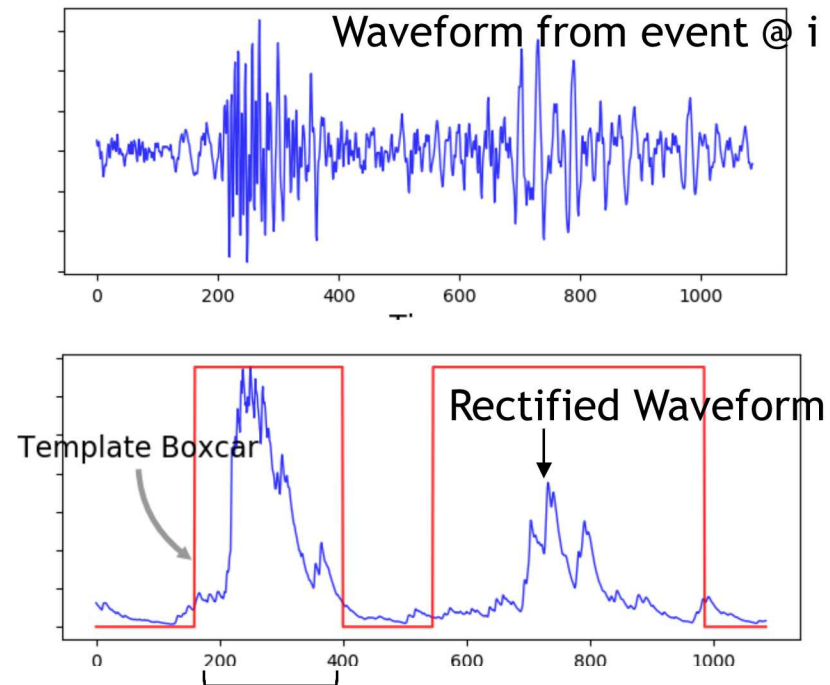


Uncertainty controlled by:

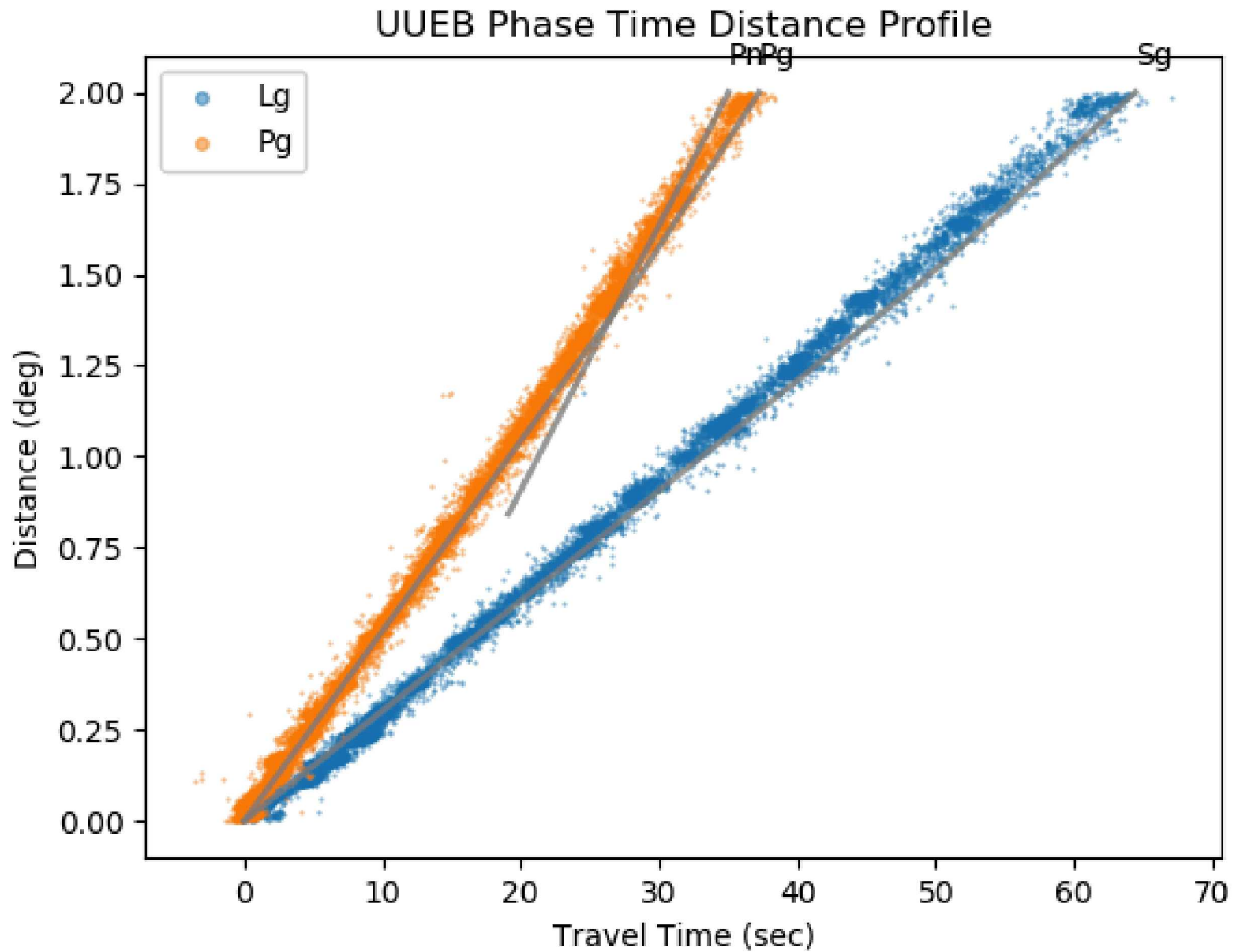
$$\delta = \delta_{model} + \delta_{pick} + \delta_{grid}$$

WCEDS

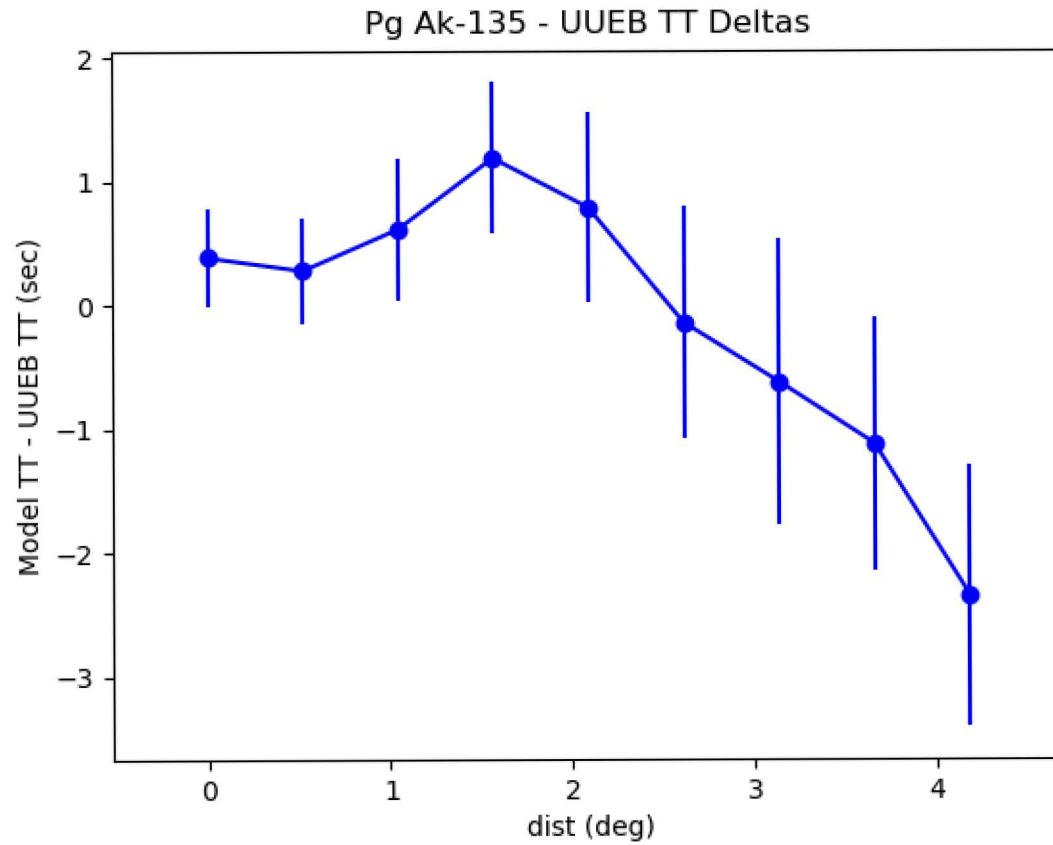
$$F_w(i) = \frac{1}{N} \sum_{W \in \{Sta Waveforms\}} f_w(W, i)$$

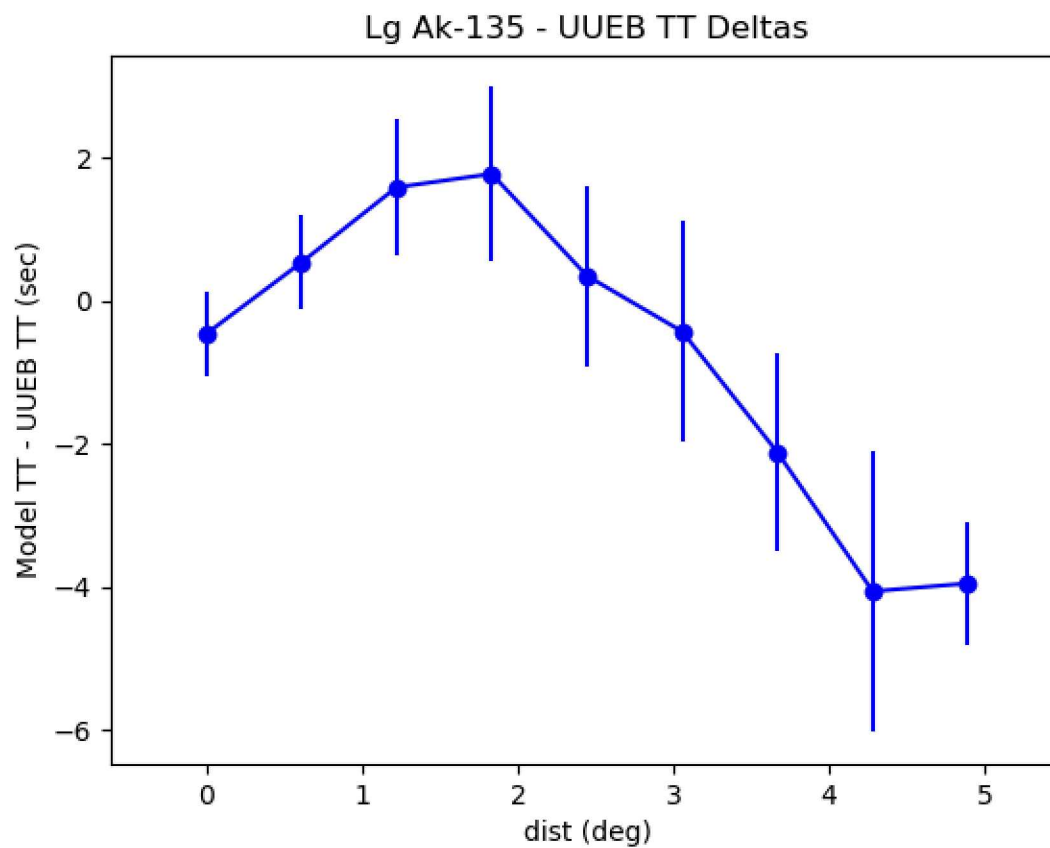


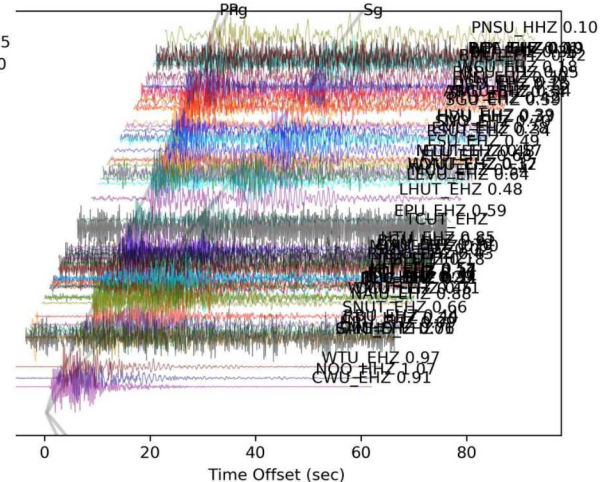
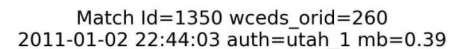
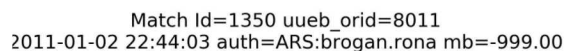
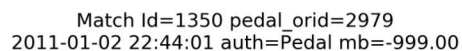
Uncertainty is fixed.



AK-135 travel time – UUEB travel time Pg Residuals



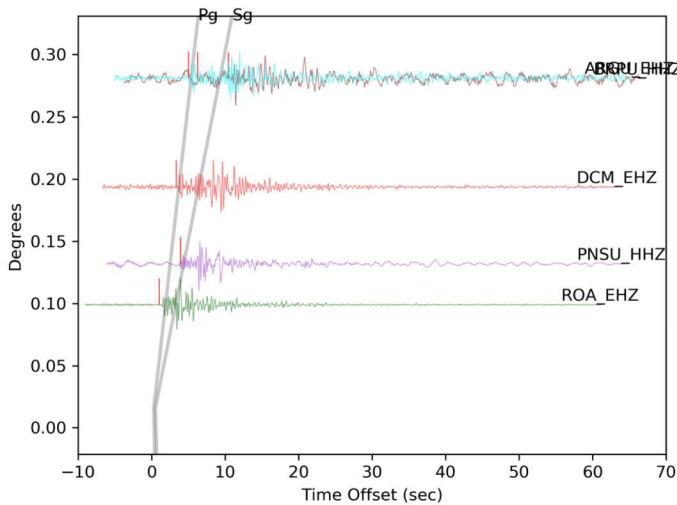




WCEDS, PEDAL, UUEB Mining Event Example

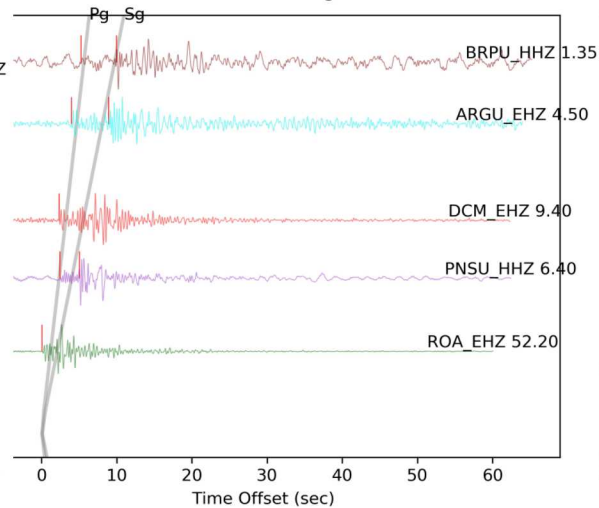
PEDAL

Match Id=272 pedal_orid=412
2011-01-01 03:49:49 auth=Pedal mb=-999.00



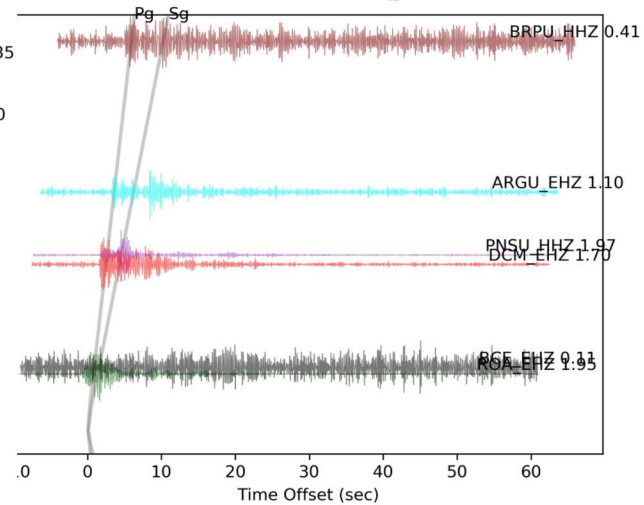
UUEB

Match Id=272 uueb_orid=988
-01-01 03:49:51 auth=ARS:brogan.rona mb=-999.00



WCEDS

Match Id=272 wceds_orid=68
2011-01-01 03:49:52 auth=bc_1 mb=1.21



PEDAL VS. WCEDS RESULTS (WCEDS PG AND LG)

