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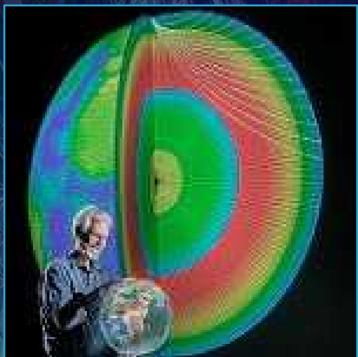

Infrasound and seismic event detection

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Thanks to: Christopher Young, Sanford Ballard, Megan Slinkard, and Kristine Pankow

Exceptional service in the national interest

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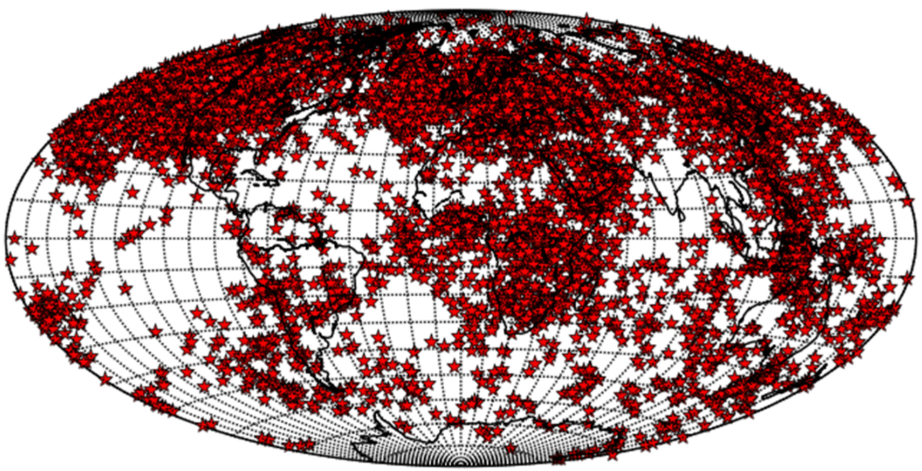
Infrasound Event Detection

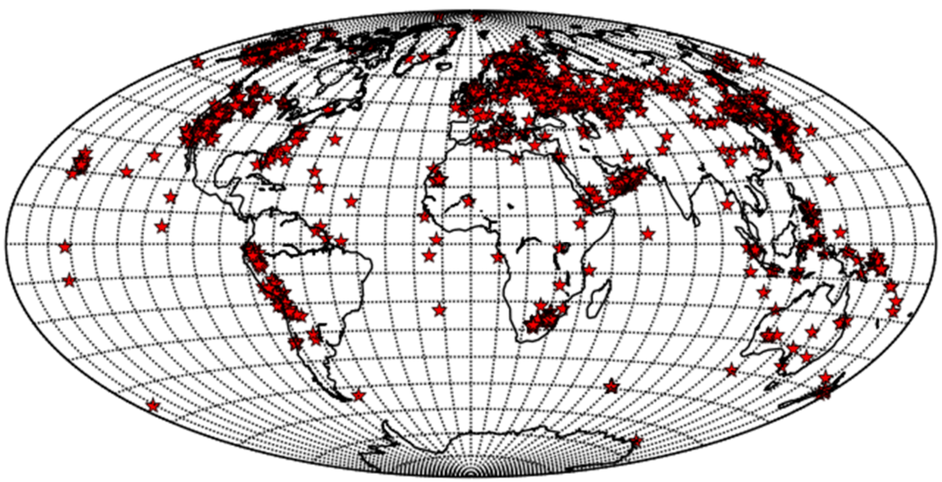
- The major problem facing the IDC for global infrasound event detection problem is managing false alarms
  - The percentage of false alarms is ~90% based on the difference between automatic and analyst-reviewed IDC catalogs

SEL3 for 2014



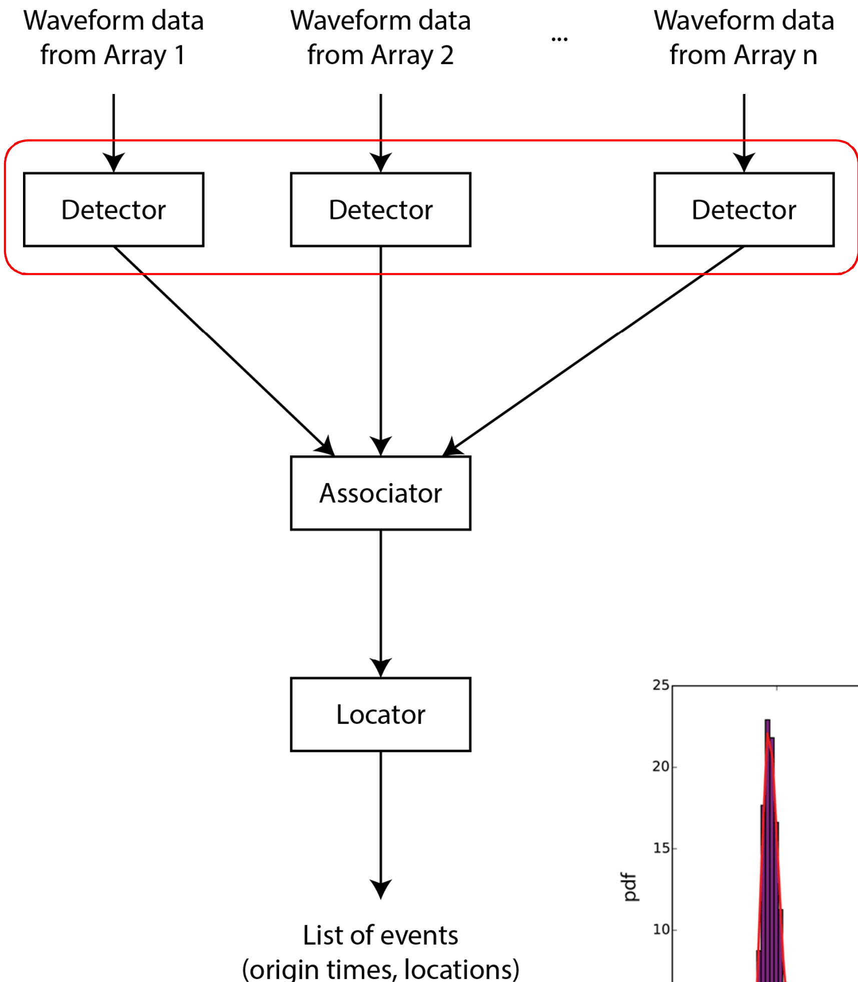
The automatic catalog

LEB for 2014



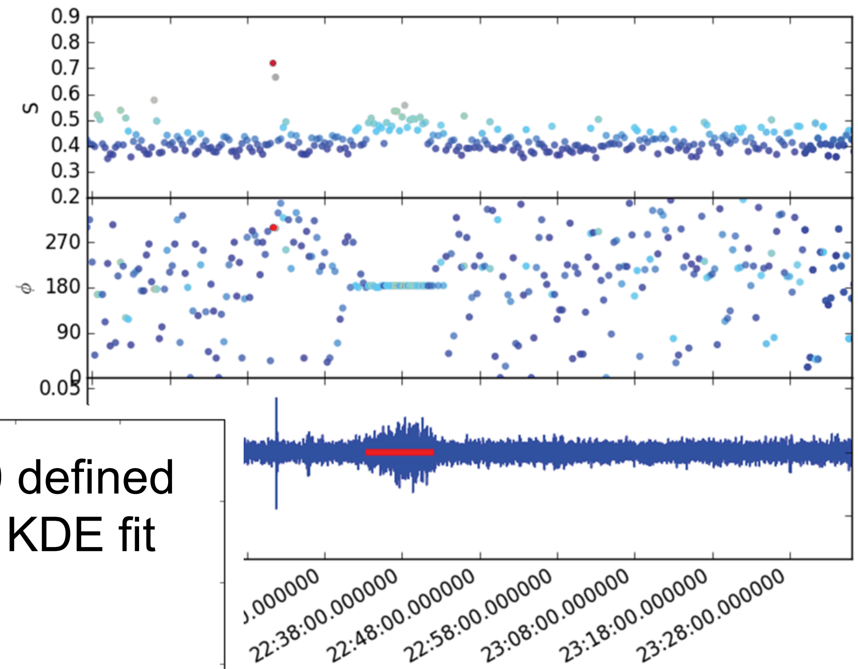
The analyst-reviewed catalog

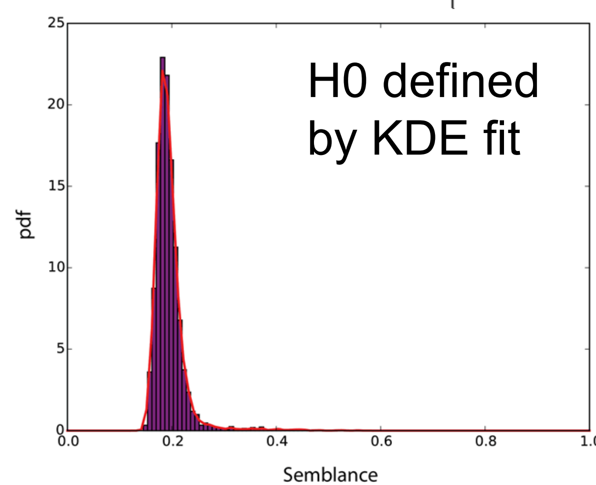
Method: Detection



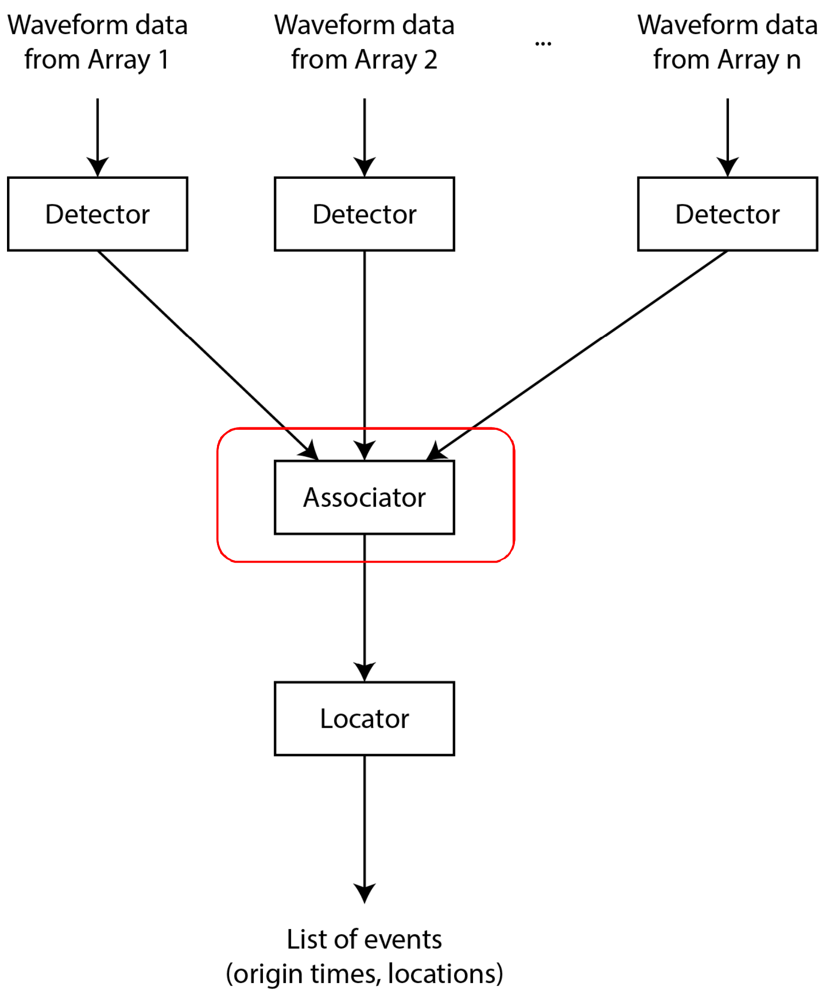
Multivariate detector combines coherent power and stationary source detectors

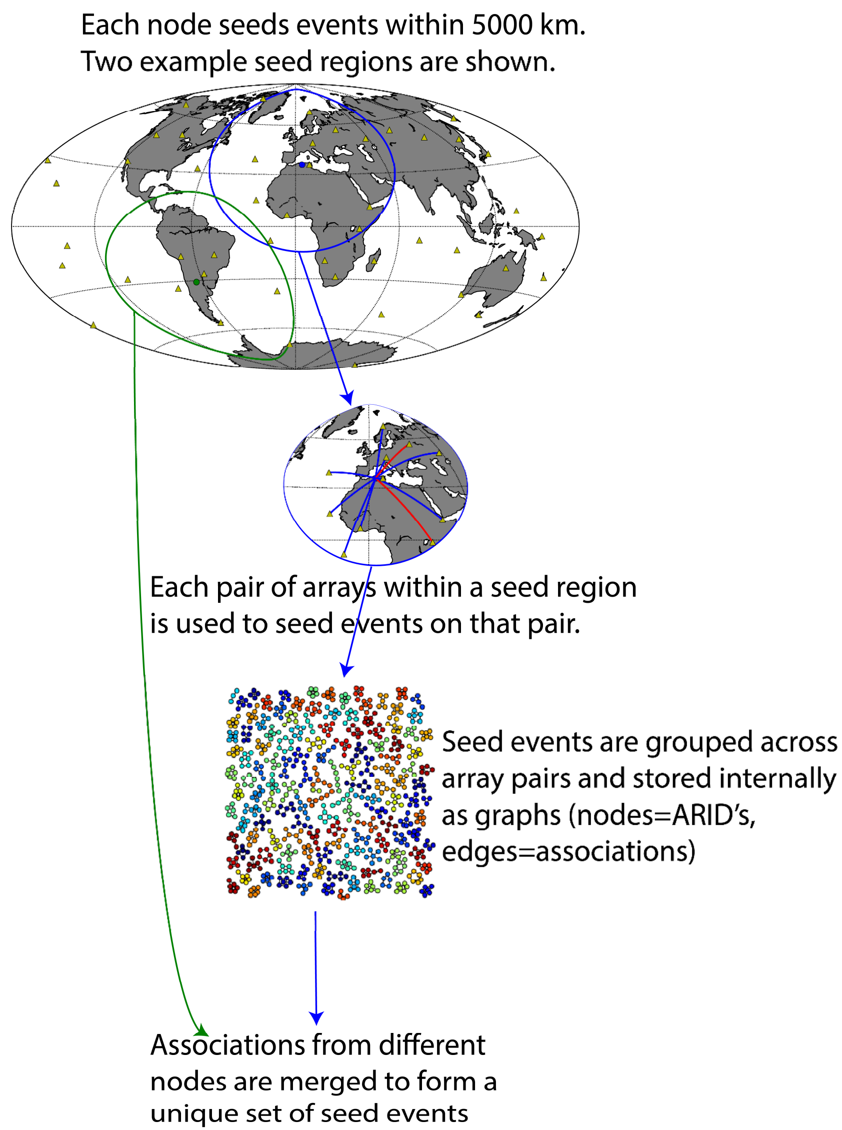
Detectors combined using Fisher's method: $\chi^2 = -2\sum_{i=1}^{k}\ln(p_i)$





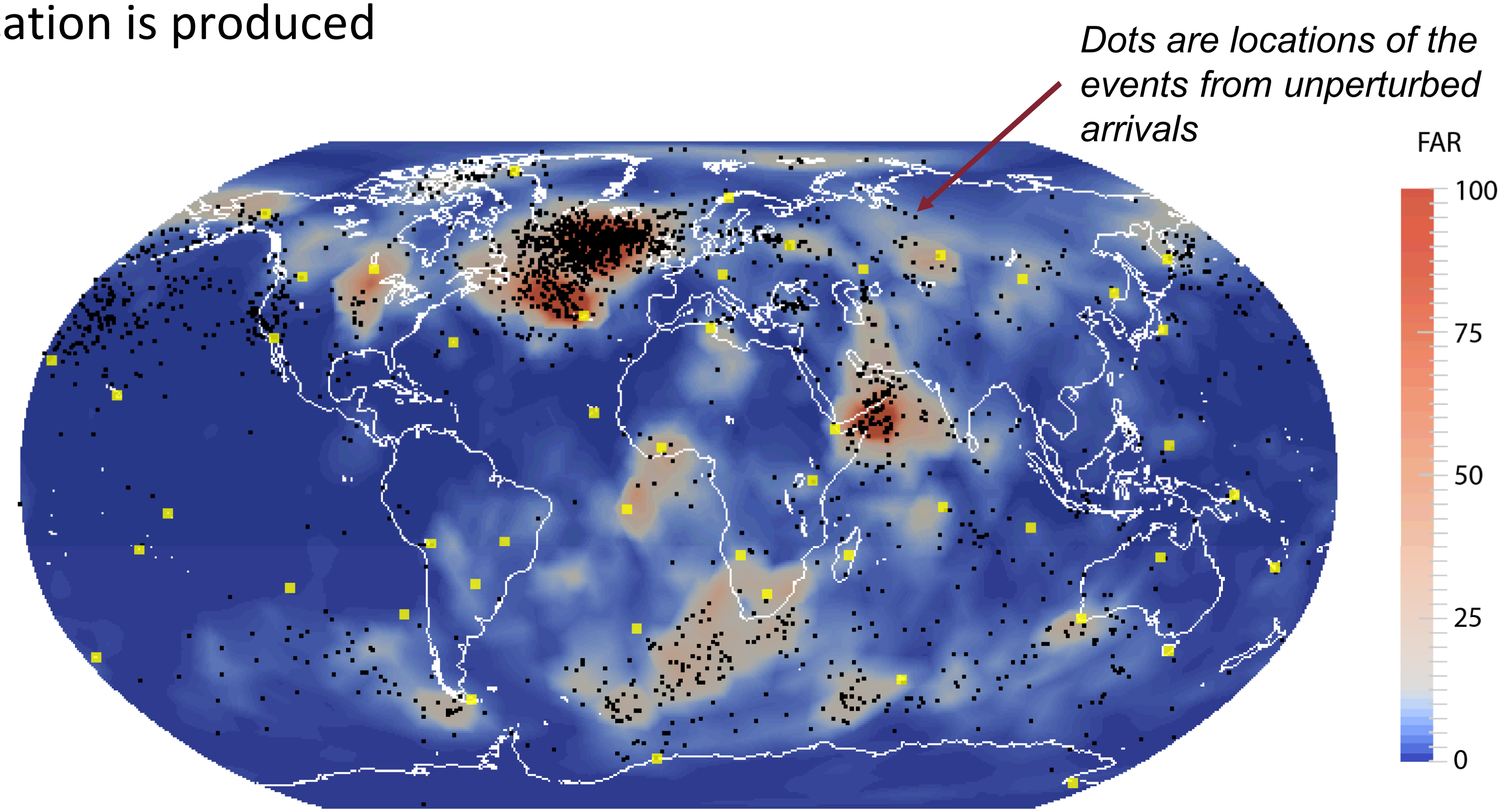
Method: Association





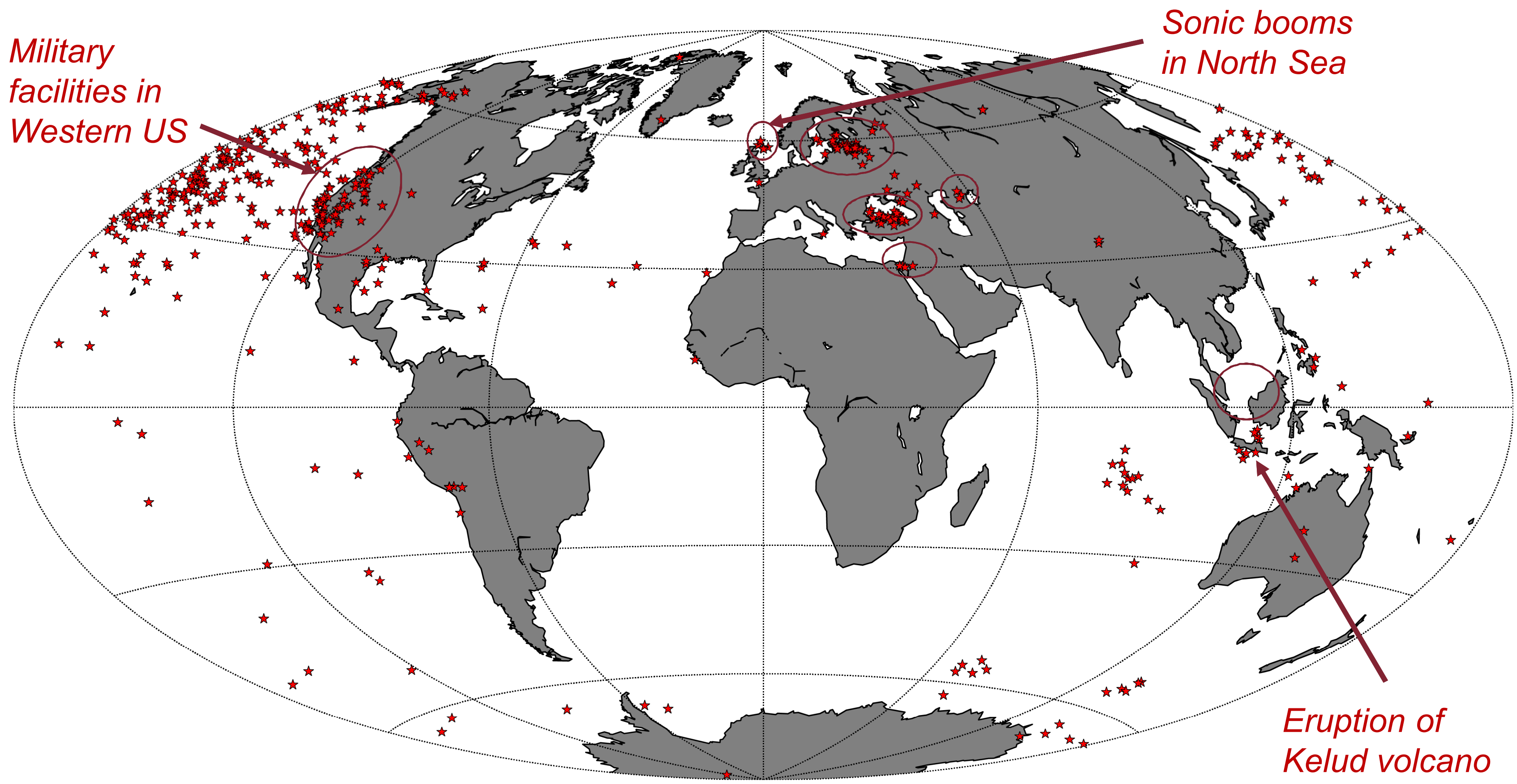
Assessment of the False Alarm Rate (FAR)

- The FAR/year is assessed by perturbing the set of 144,774 signals detected in 2014 such that real events are not formed, then applying association & location algorithms
- This experiment is repeated 10 times and a map of mean FAR as a fn. of location is produced



Locations of events in 2014 in the Sandia Infrasound Catalog

- To build real event clusters of real events, we remove events from sub-regions where the number of events formed with perturbed detections is < 2× the number of events formed with unperturbed detections.



Pick-based vs. Stack-based Methods

- The standard paradigm for seismic data processing breaks the event detection problem down into two main processing levels:

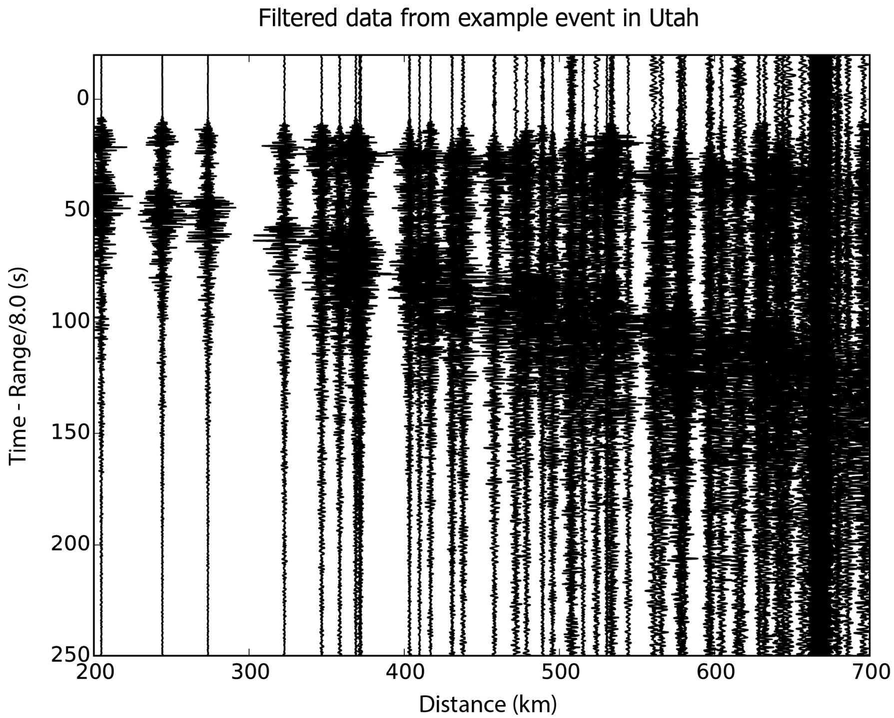
Processing Level	Processing Function	Prerequisites
Station-level	• Detect signals • Pick onset times • Identify phases	• Signal model
Network-level	• Associate phases across a network • Locate event	• Phase picks (from station-level) • Earth model • Propagation model

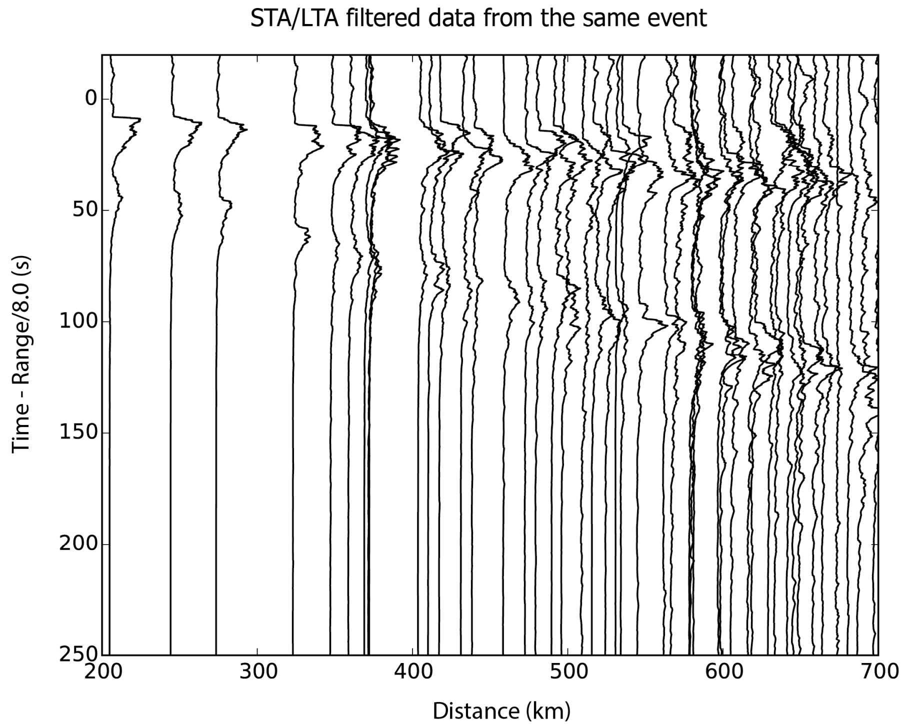
- A second class of methods exist, which we refer to as 'stack-based' methods:

Reverse-Time Migration, or WCEDS	Grid search over event hypotheses, focusing power in waveforms back towards each node.
WCEDS	Grid search over event hypotheses, correlating waveforms against an empirical stack for each node.

WCEDS Method

- WCEDS(E) exploits leading-order time-versus-distance properties of the seismic wavefield in a region of study – No assumptions of phases or travel times needed.

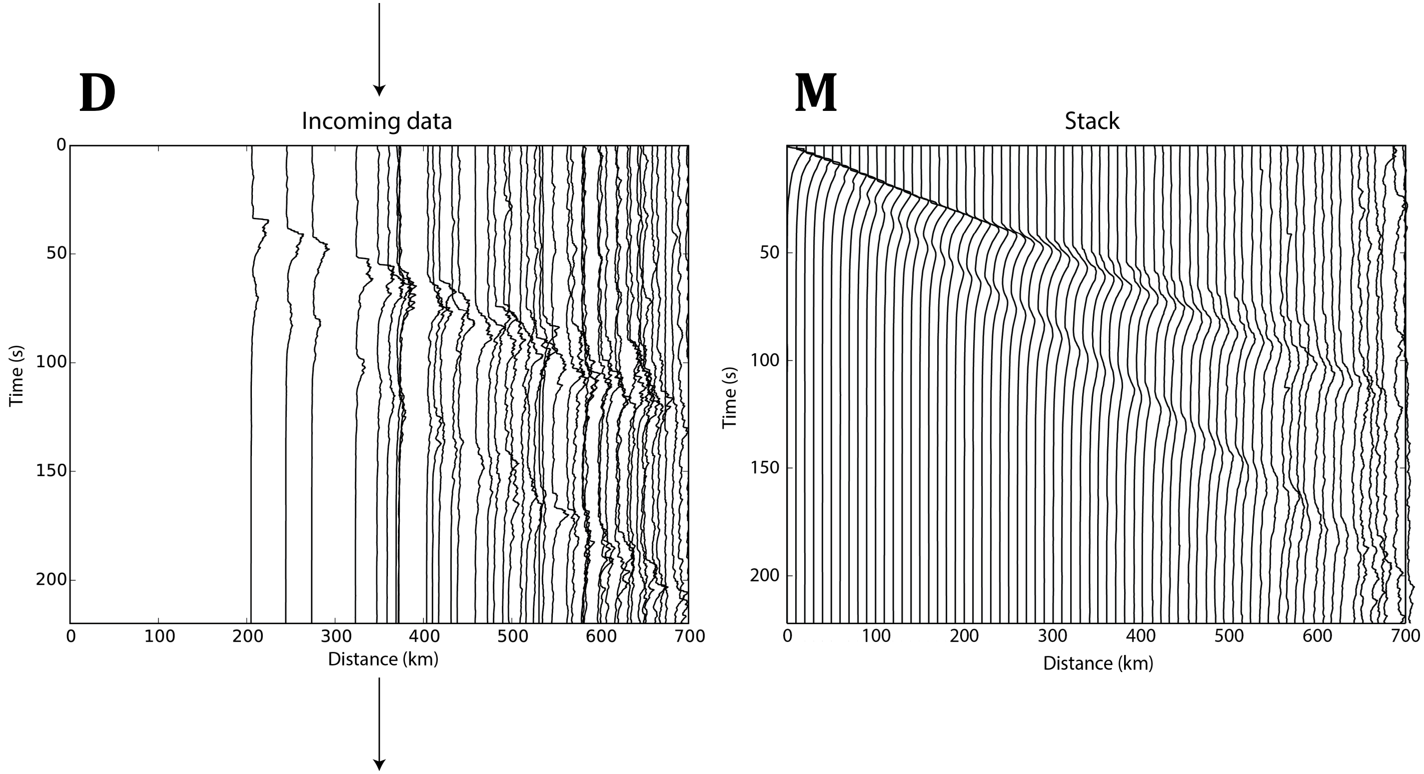




- Raw waveforms are very sensitive to source properties and specific source-receiver paths.
- STA/LTA filter removes high frequency effects – waveforms represent observed phases and travel time properties in a region.

WCEDS Method

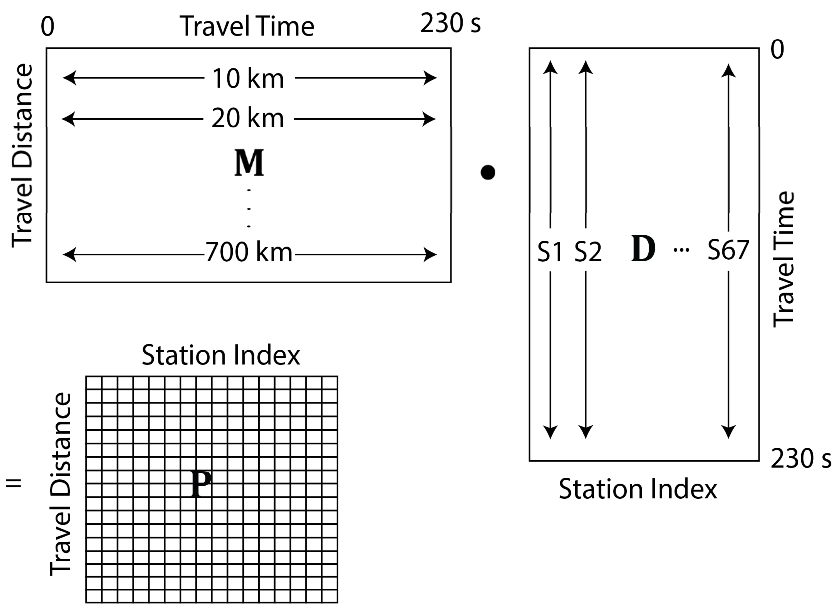
- Historical data are used to generate an image of the time-versus-distance STA/LTA stack
- Incoming data are ‘correlated’ against this stack

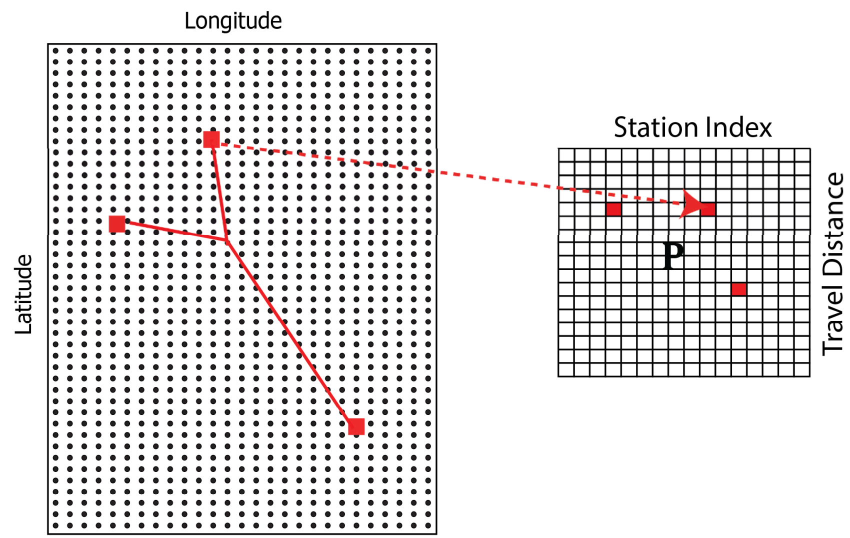


WCEDS Method

$$\mathbf{P}_w = \left(\mathbf{M}\cdot\mathbf{D}\right)^T$$

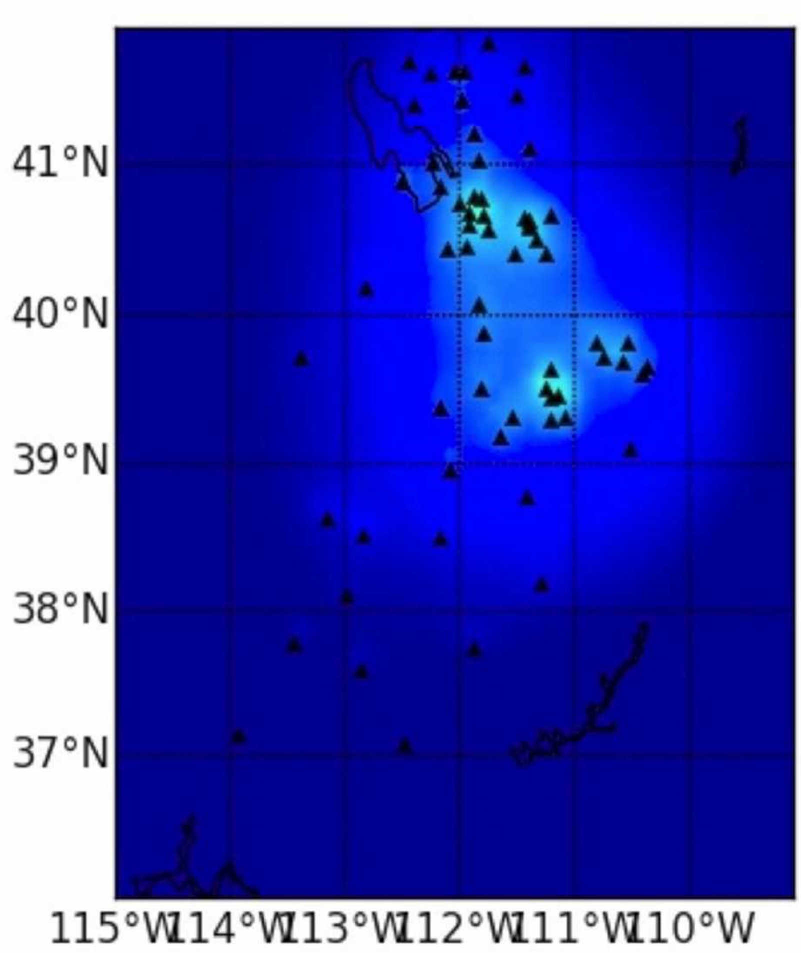
$$c = \frac{1}{N_S}\sum_{k=1}^{N_S}\left(\frac{p_{i_k j_k}}{N_T}\right)$$





- Data are correlated over a set of nodes representing possible locations using an efficient dot product formulation

WCEDS Method



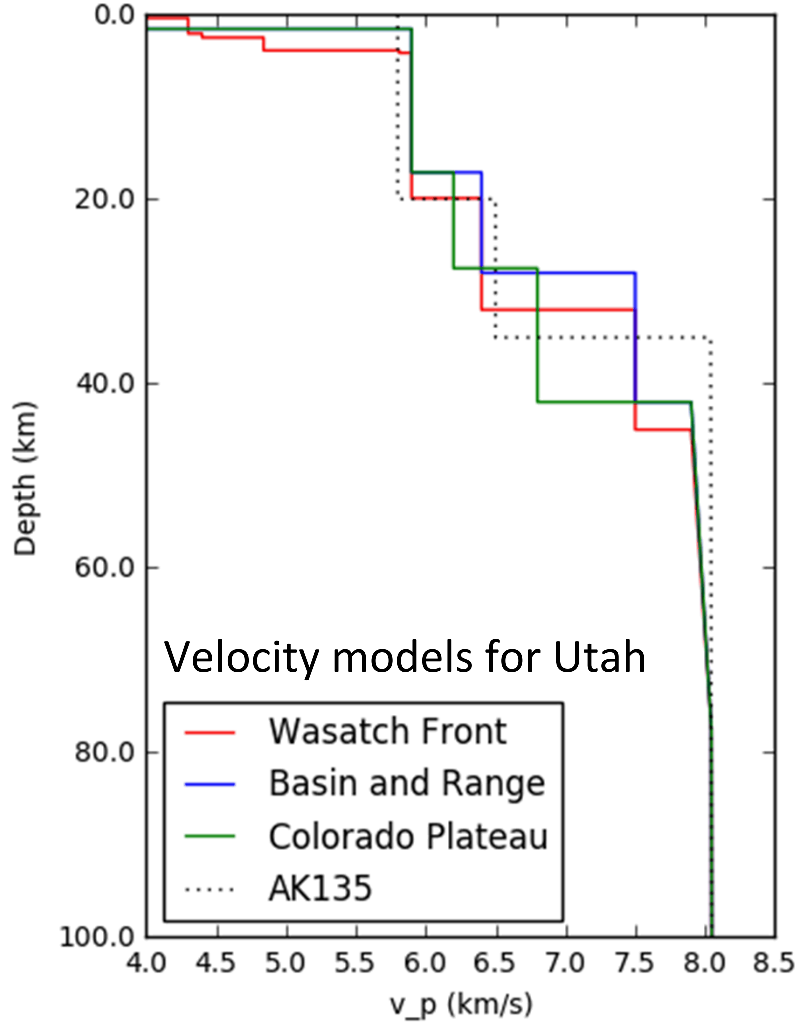
RTM Method

- This is also a grid search over event hypotheses, but in this case we use travel-time predictions for the regional phases.
- If the travel time prediction for a source at point η to station n is $t_{\eta n}$, then, for a single phase, we calculate:

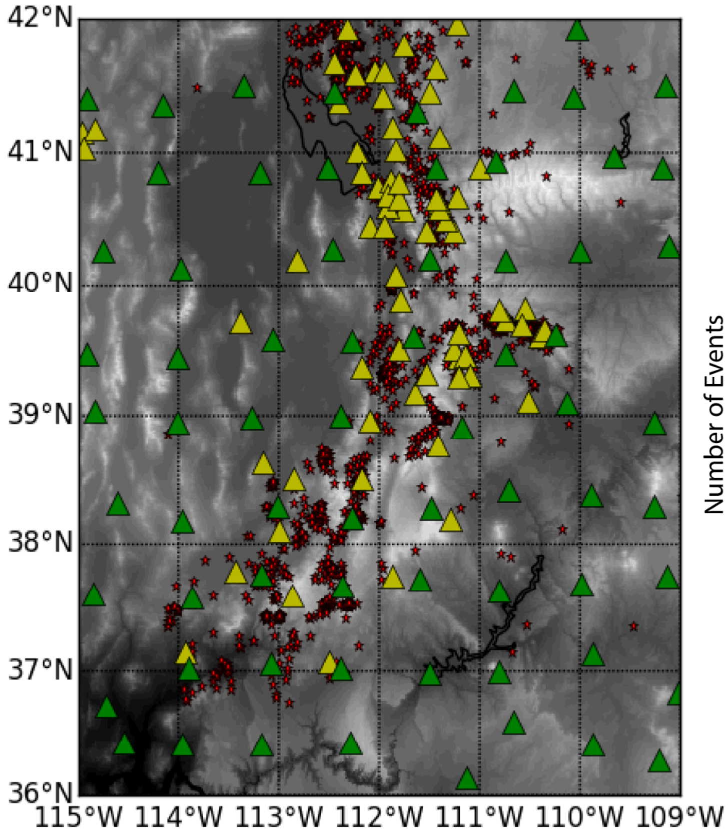
$$\mathcal{L}(\tau, \underline{r}) = \sum_{i=1}^{N}\left[\sum_{m=-M}^{M} a\left(\tau + t_{\eta n} + m\delta t\right)\right],$$

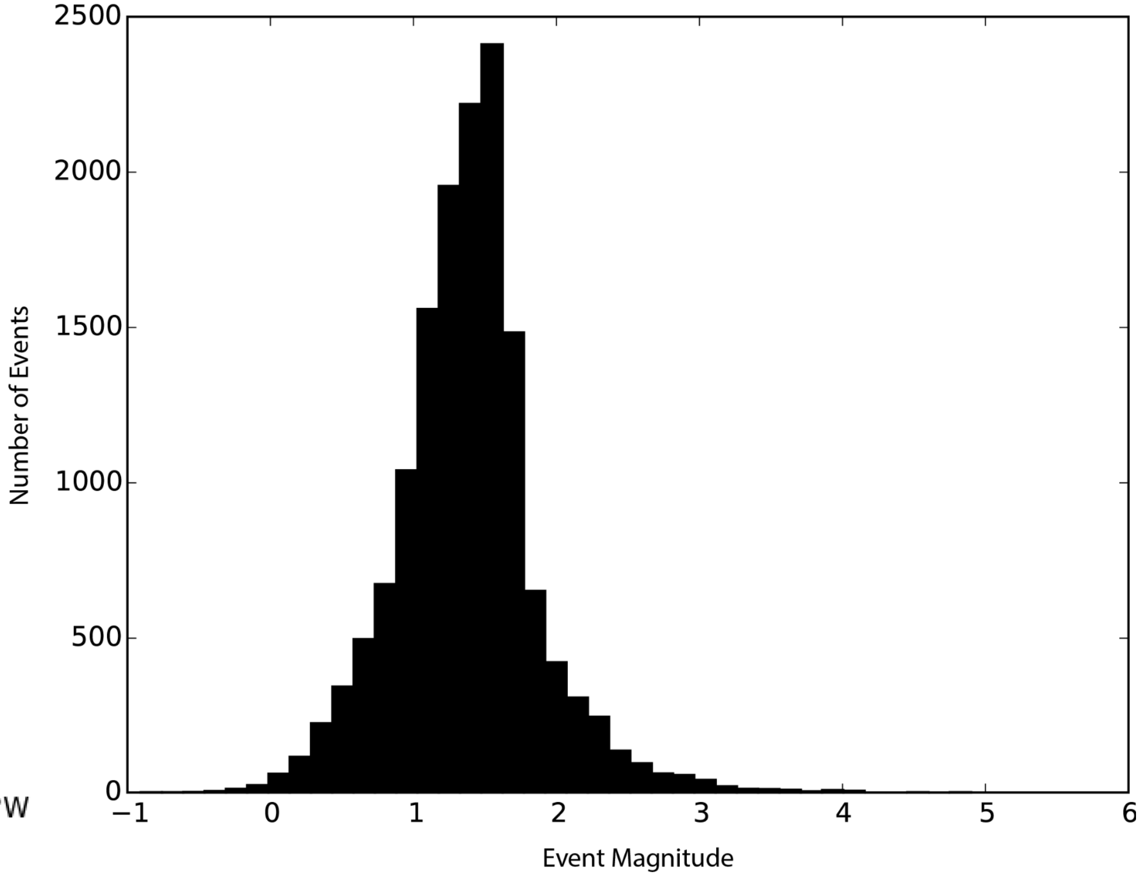
where N is the number of stations, τ is the trial origin time, $\underline{r} = (\phi, \lambda)$ is the location, $2M$ is the number of points in a time window centered on the predicted arrival time, and δt is the sampling window.

- This approach is similar to the implementation of Young et al. (1996)



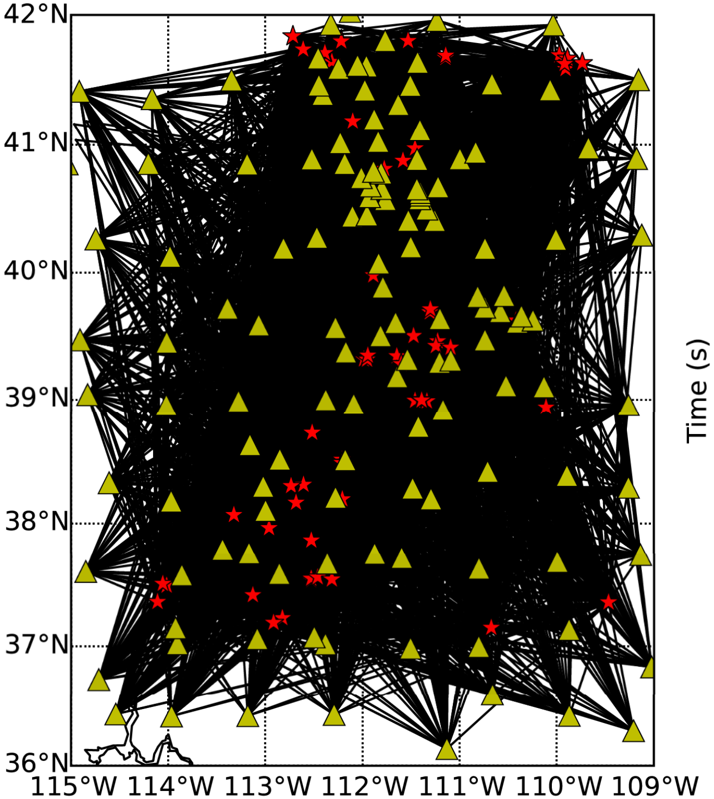
Dataset

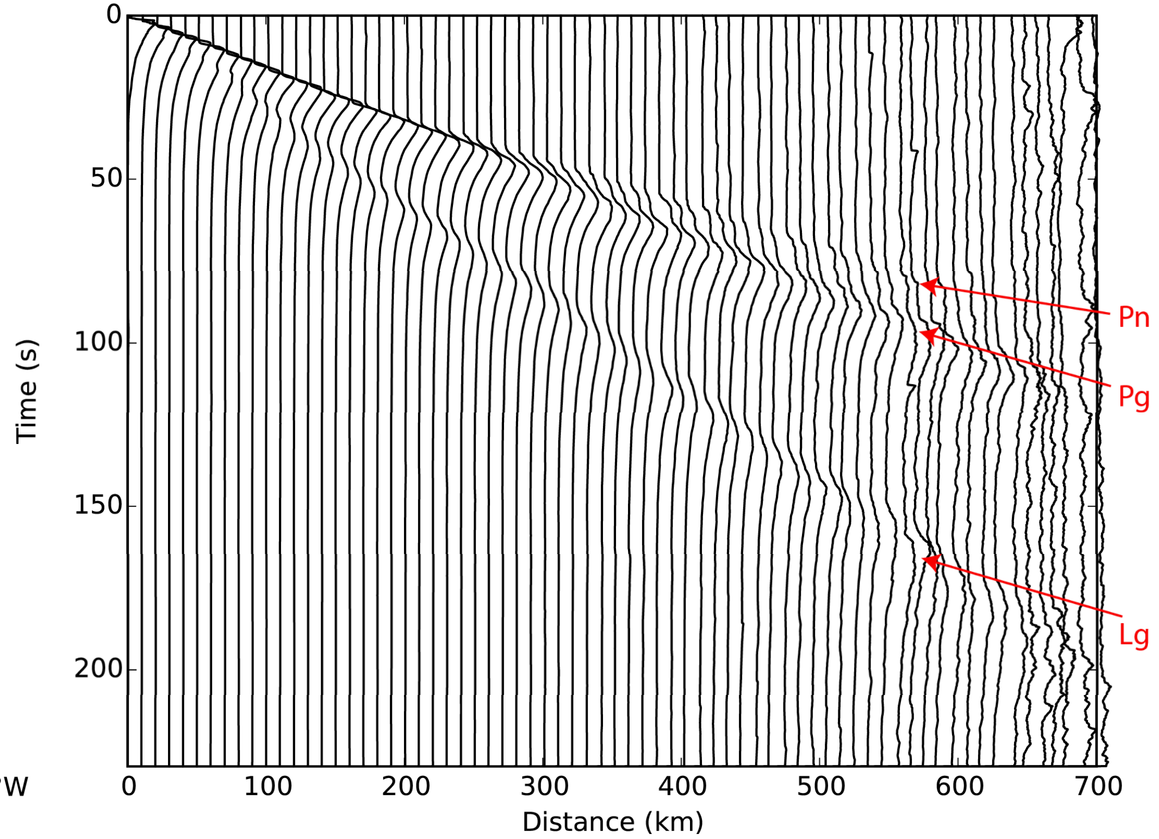




- Utah is chosen for testing WCEDS as it has a high density of stations, enabling experimentation with decimation, and a large number of low-magnitude events.

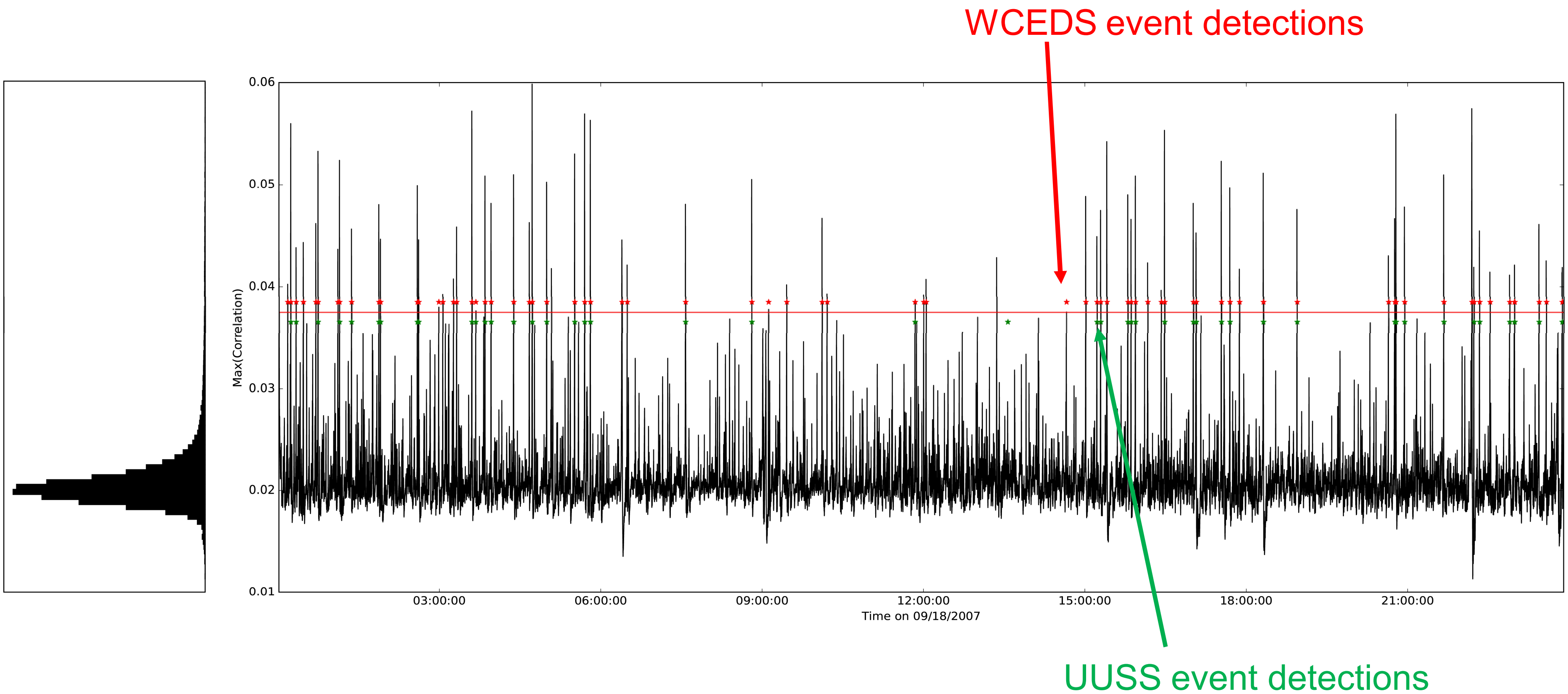
1D Time-vs-Distance Stack





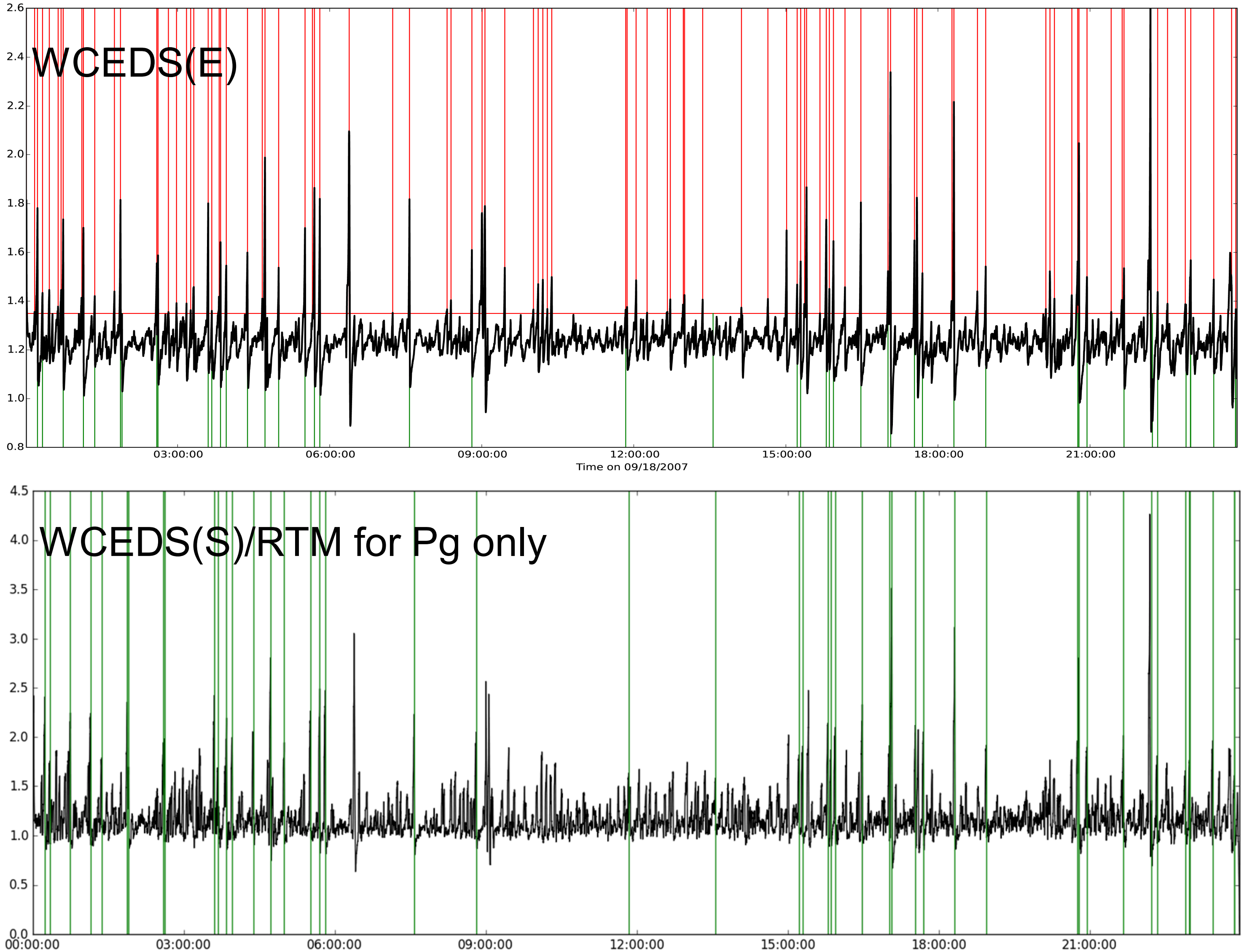
- A time-versus-distance stack is constructed using all 77 events larger than M=2.5 in a two year period → 8951 source-receiver paths

Results from 1-day of data with WCEDS



- In a 1-day period where UUSS report 47 events, WCEDS is tuned to detect 46 out of 47 events and detects an additional 26 analyst-confirmed events
- The new events are in a region of induced seismicity where UUSS use a high threshold

WCEDS(E) vs. WCEDS(S)/RTM



Event Locations

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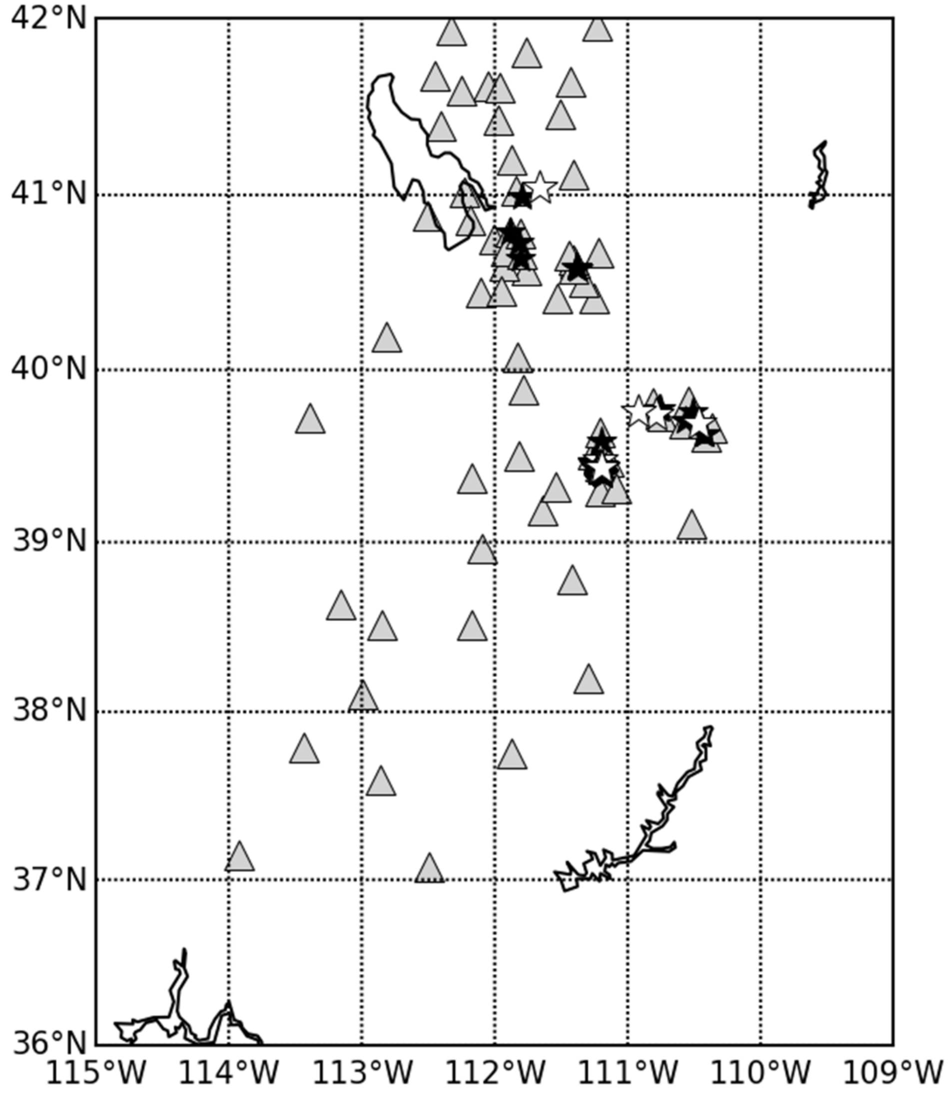

- Locations of events detected by WCEDS (black stars) and UUSS events (white stars)

Conclusions

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Infrasound

- We are developing techniques for detecting clusters of infrasound events and large infrasound events on the global IMS network

Seismic

- We have enhanced the WCEDS algorithm for event detection, finding that it is a viable alternative to the standard pick-based method implemented by UUSS for Utah.
- WCEDS(E) does not require an Earth model or a signal model, but assumes access to historical data and that a 1D time-versus-distance stack is adequate
- WCEDS(S)/RTM does not require historical data and can account for 3D effects more naturally, but does require an Earth model