SSA Annual Meeting, Alaska, 2014

A Pure-Python Phase Picker and Event Associator

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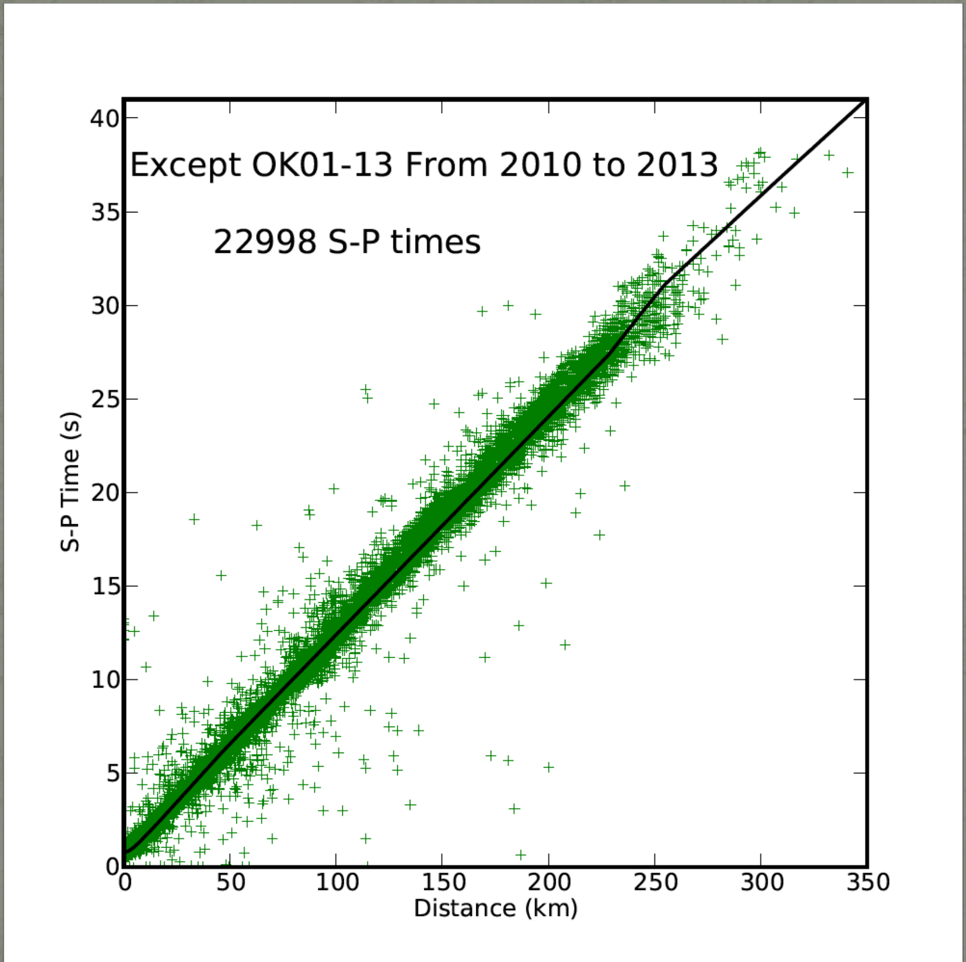
Motivation

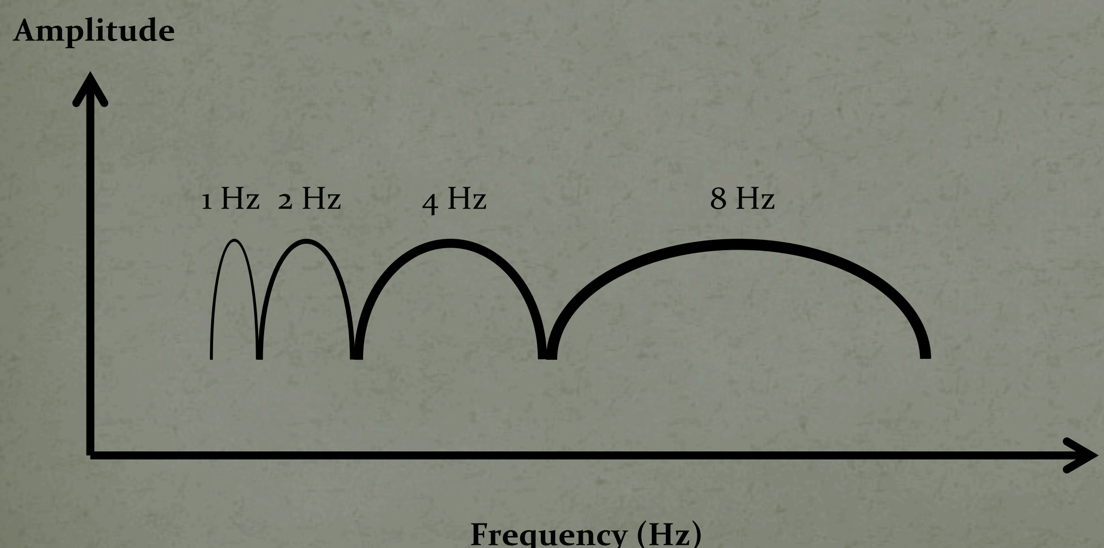


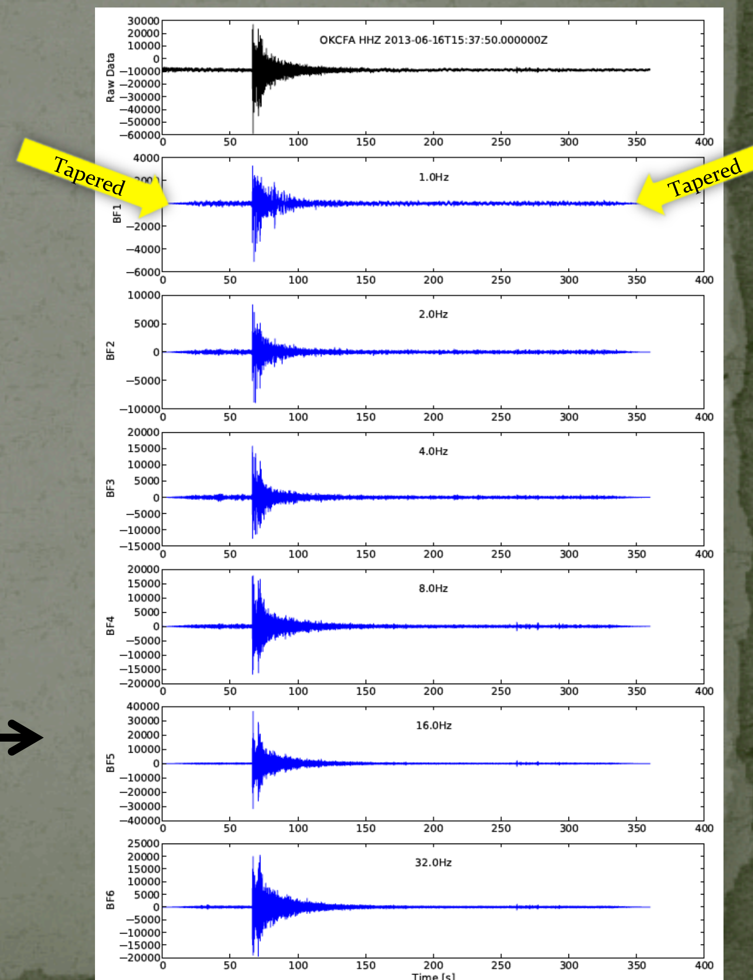
Except OK01-13 From 2010 to 2013
22998 S-P times
S-P Time (s)
Distance (km)
0
5
10
15
20
25
30
35
40
0
50
100
150
200
250
300
350

FBpicker

1. Octave Band-Pass Filter

If the sampling rate of a seismometer is 40 Hz, the Nyquist frequency is 20 Hz. We pre-define the center frequency of the minimum band is 1 Hz. The highest band centered at 8 Hz.

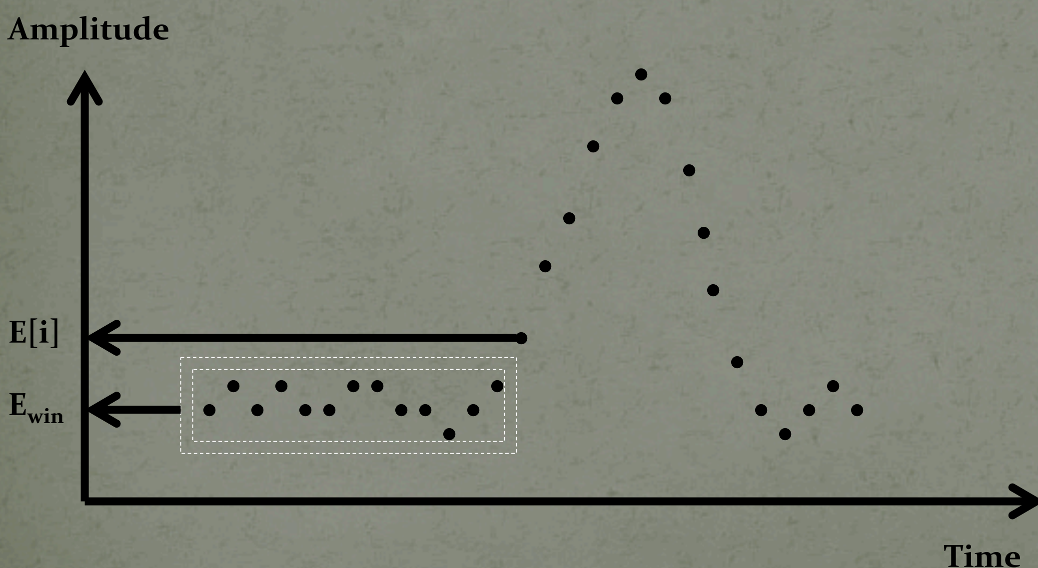




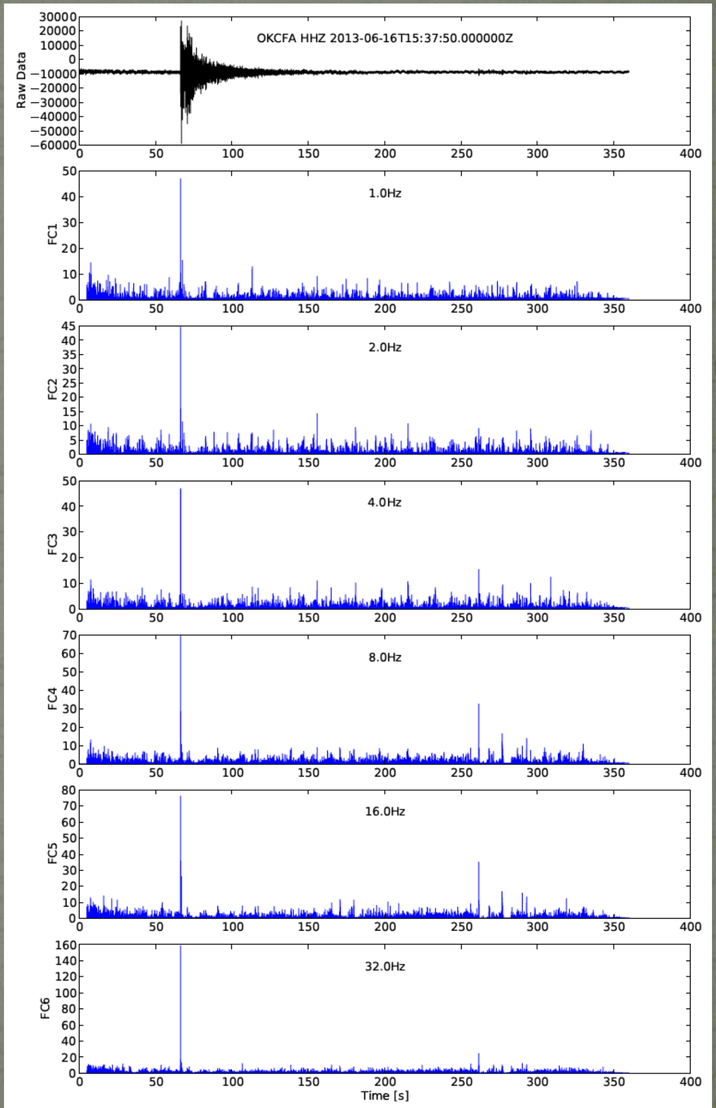
FBpicker

2. FC and Statistics [Lomax et al, 2012]

- Mode 1: RMS $$FC_n^{rms}[i] = \frac{E_n[i]}{rms(E_n[i-1-window:i-1])}$$
- Mode 2: STD $$FC_n^{std}[i] = \frac{E_n[i] - ave(E_n[i-1-window:i-1])}{std(E_n[i-1-window:i-1])}$$



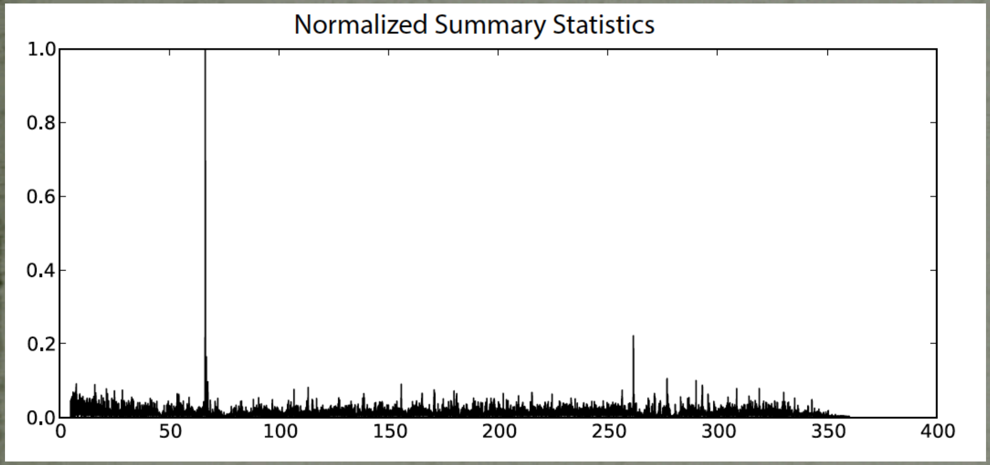
STD mode



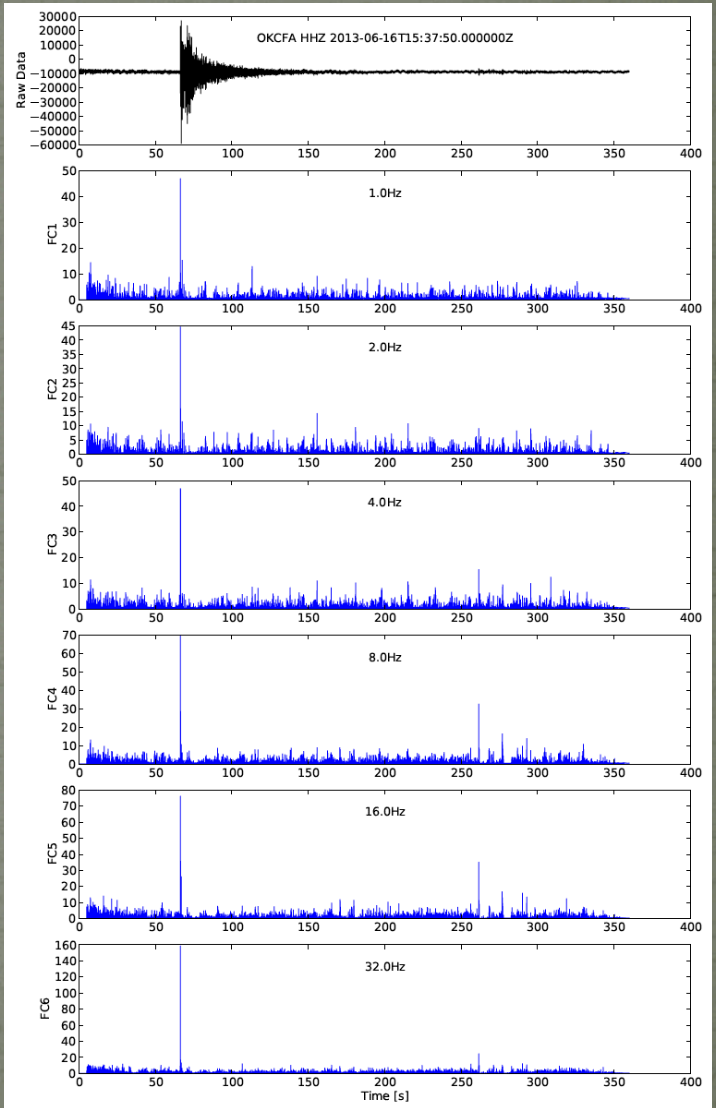
FBpicker

2. FC and Statistics

Simply taking the maximum statistic of each sample from all bands.

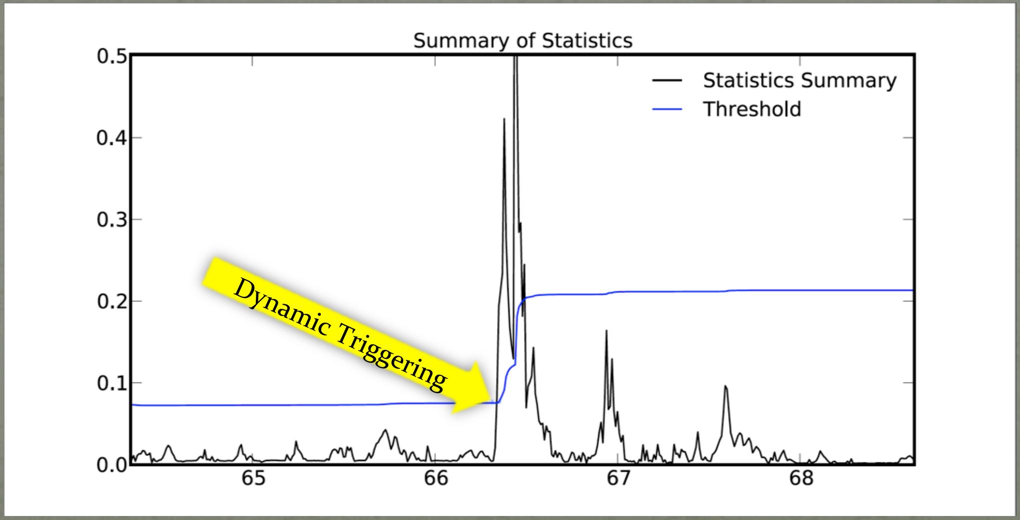


STD mode



FBpicker

3. Triggering and Declaration
   1. Dynamic threshold: running moving average window through the normalized summary statistics.
   2. Triggering: Occurs when normalized Summary statistics is greater than the dynamic threshold.
   3. Declaration: Roll back sample along normalized summary statistics until local minimum is detected.



FBpicker

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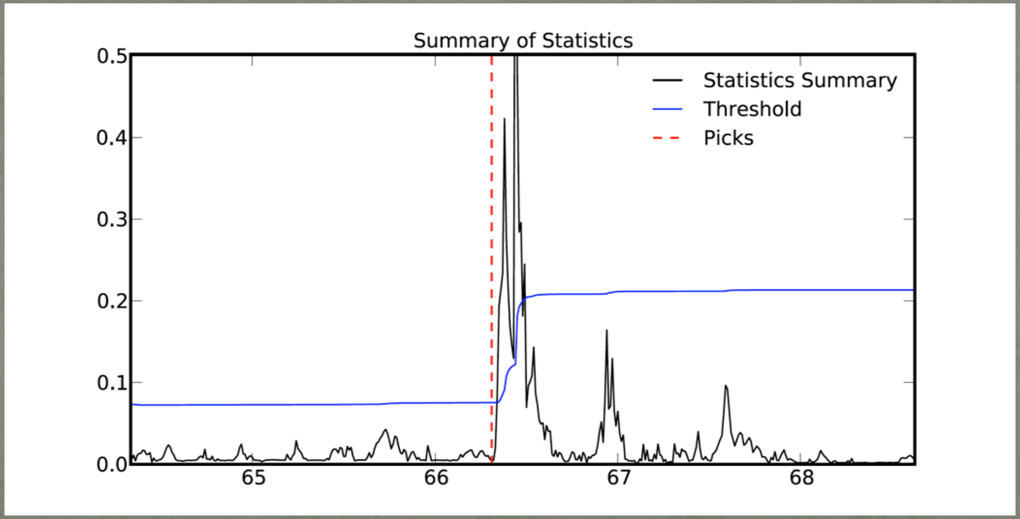

FBpicker

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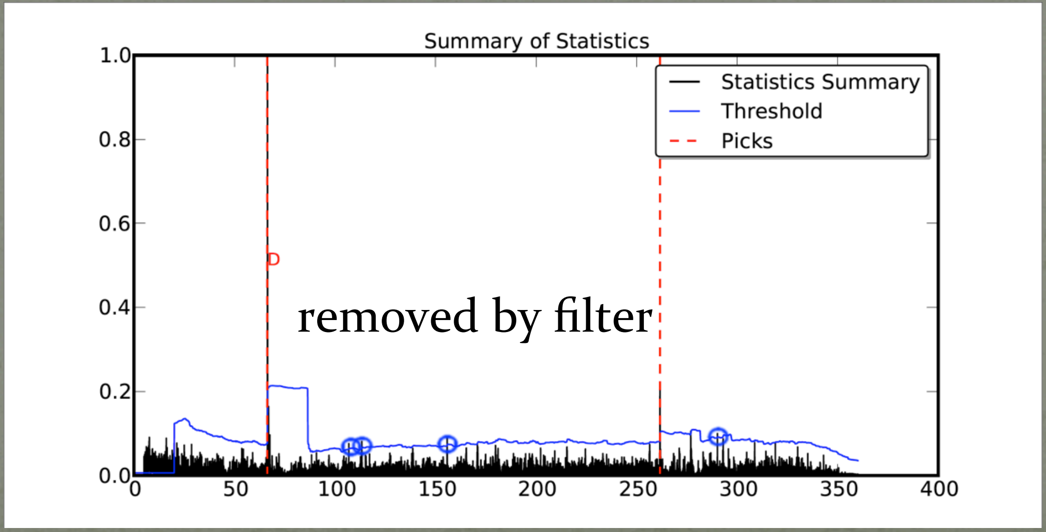


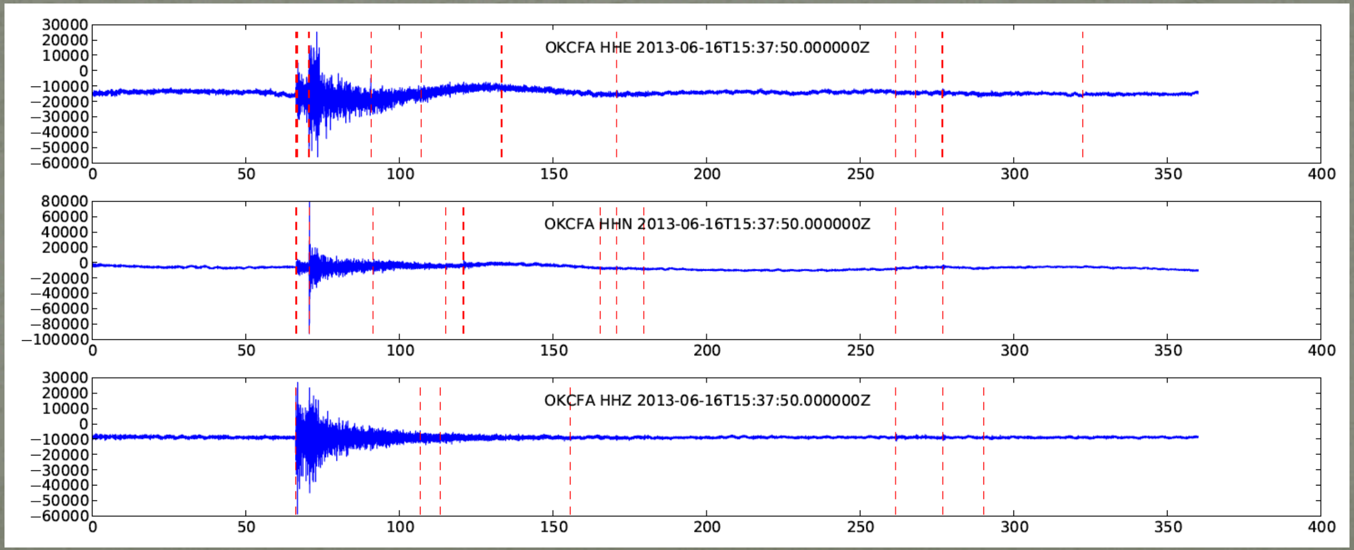
Configurable parameters:
1. Window length [t_ma=20 s]
2. Ratio of energy noise to signal [6 sigma]

FBpicker

3. False pick filtering

- False picks can also be removed by changing configurable parameters. User has couple ways to remove false picks such as changing long term, short term window sizes and threshold level.
- We can apply pick filtering.

No filter

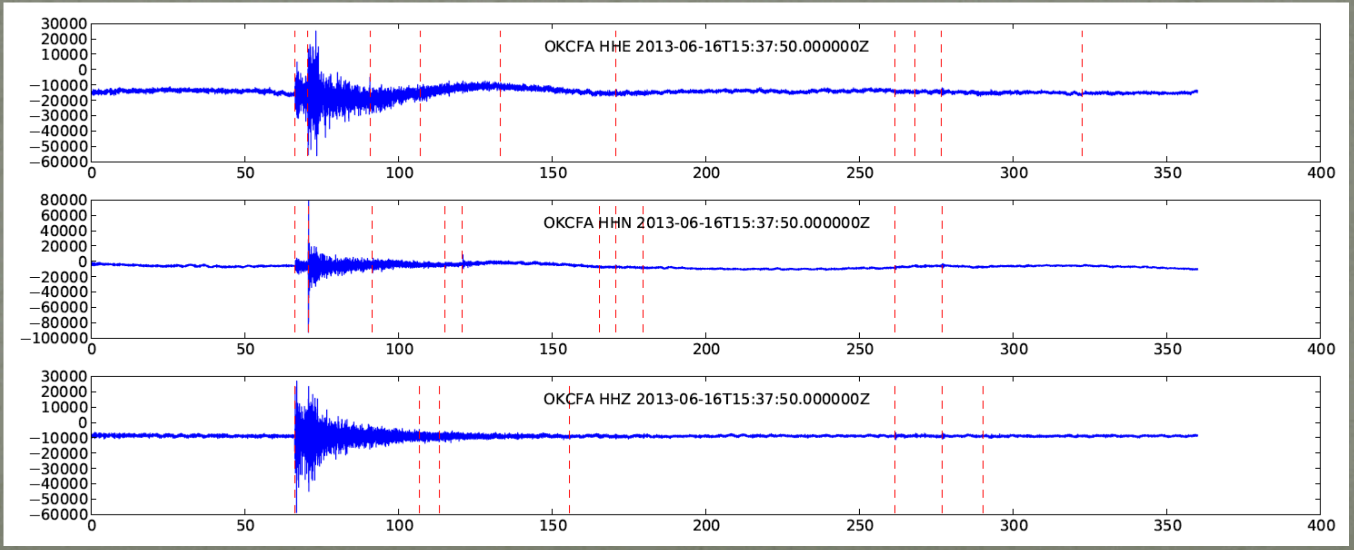


FBpicker

3. False pick filtering

    1. Do not declare a second pick, whose time to first pick is less than user-defined time length.

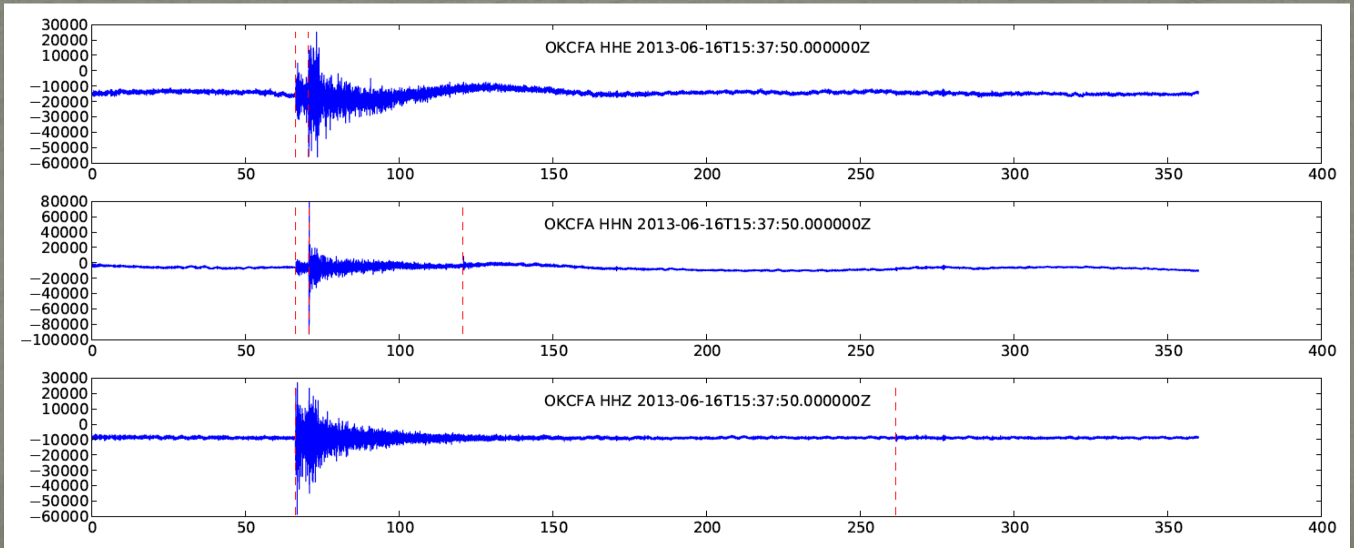
Cleaning filter 1



FBpicker

3. False pick filtering
   1. Do not declare a second pick, whose time to first pick is less than user-defined time length.
   2. Only declare picks, whose std after picking time is more than twice std before picking time in a certain window, which is configurable.

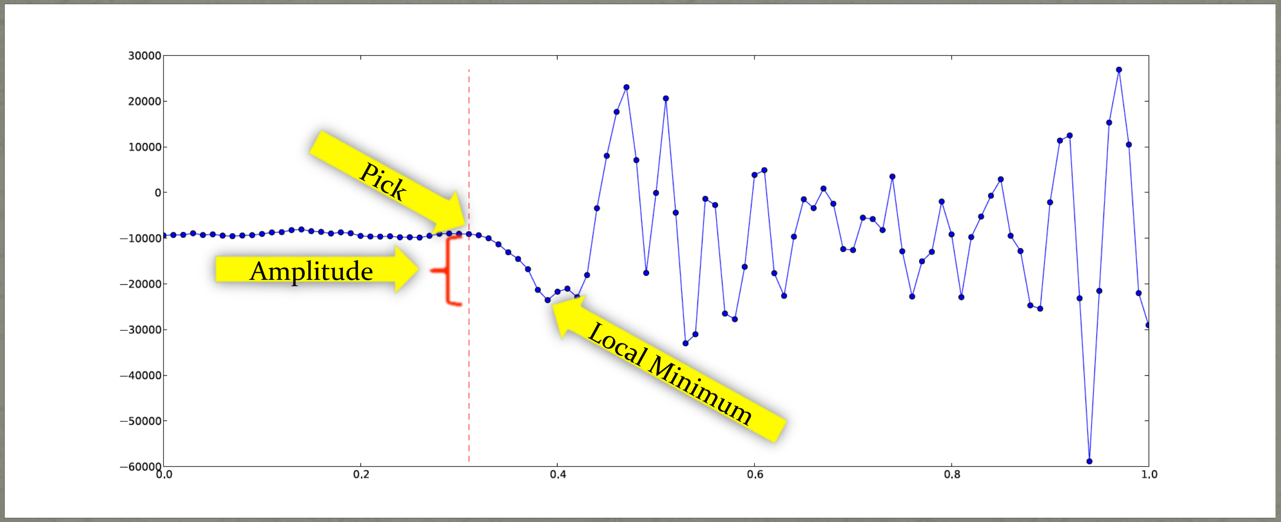
Cleaning filter 2



FBpicker

5. Polarity Determination

The polarity is determined by comparing the local maximum or minimum (absolute value to pick amplitude) in waveform after the pick and standard deviation before the pick in a user-defined time window (green dot) times a factor.



FBpicker

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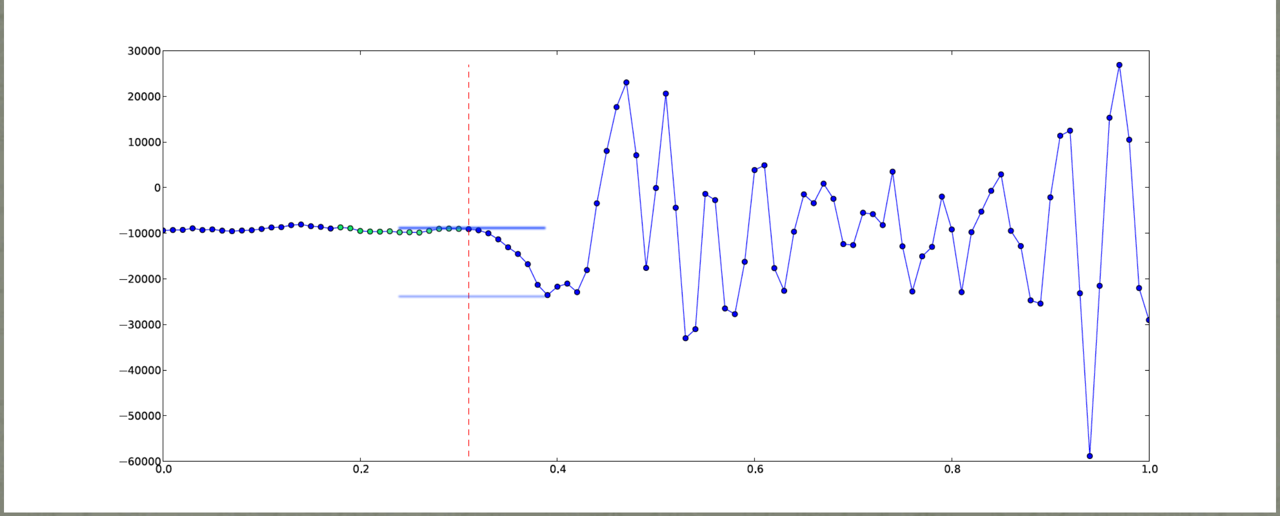
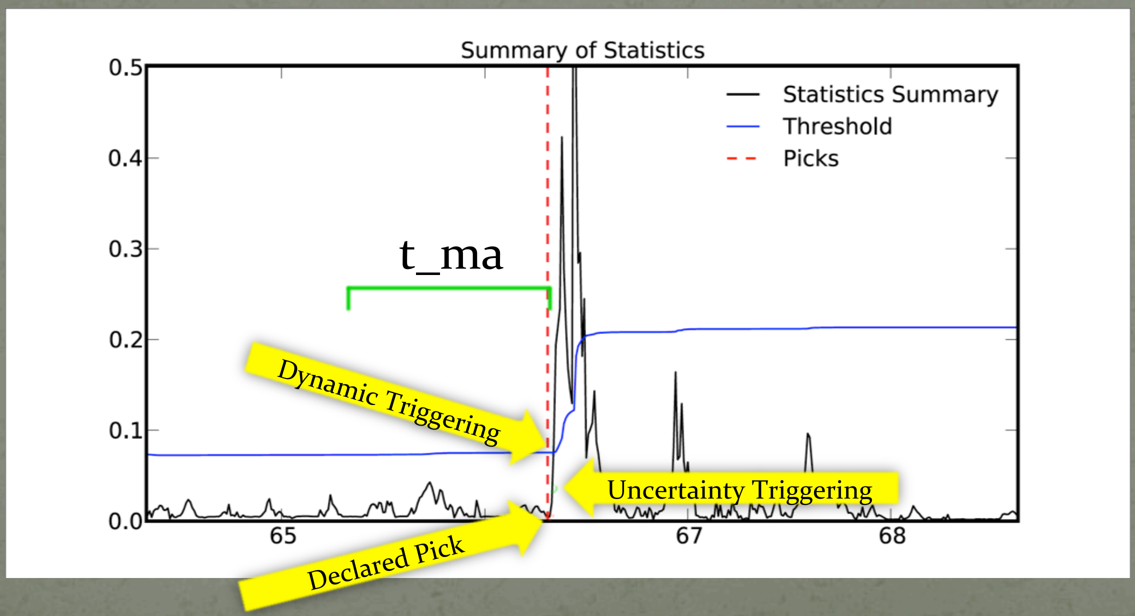


FBpicker

6. Uncertainty Determination

Uncertainty is defined as the time difference between the declared picks and the time which the energy exceeds the threshold.



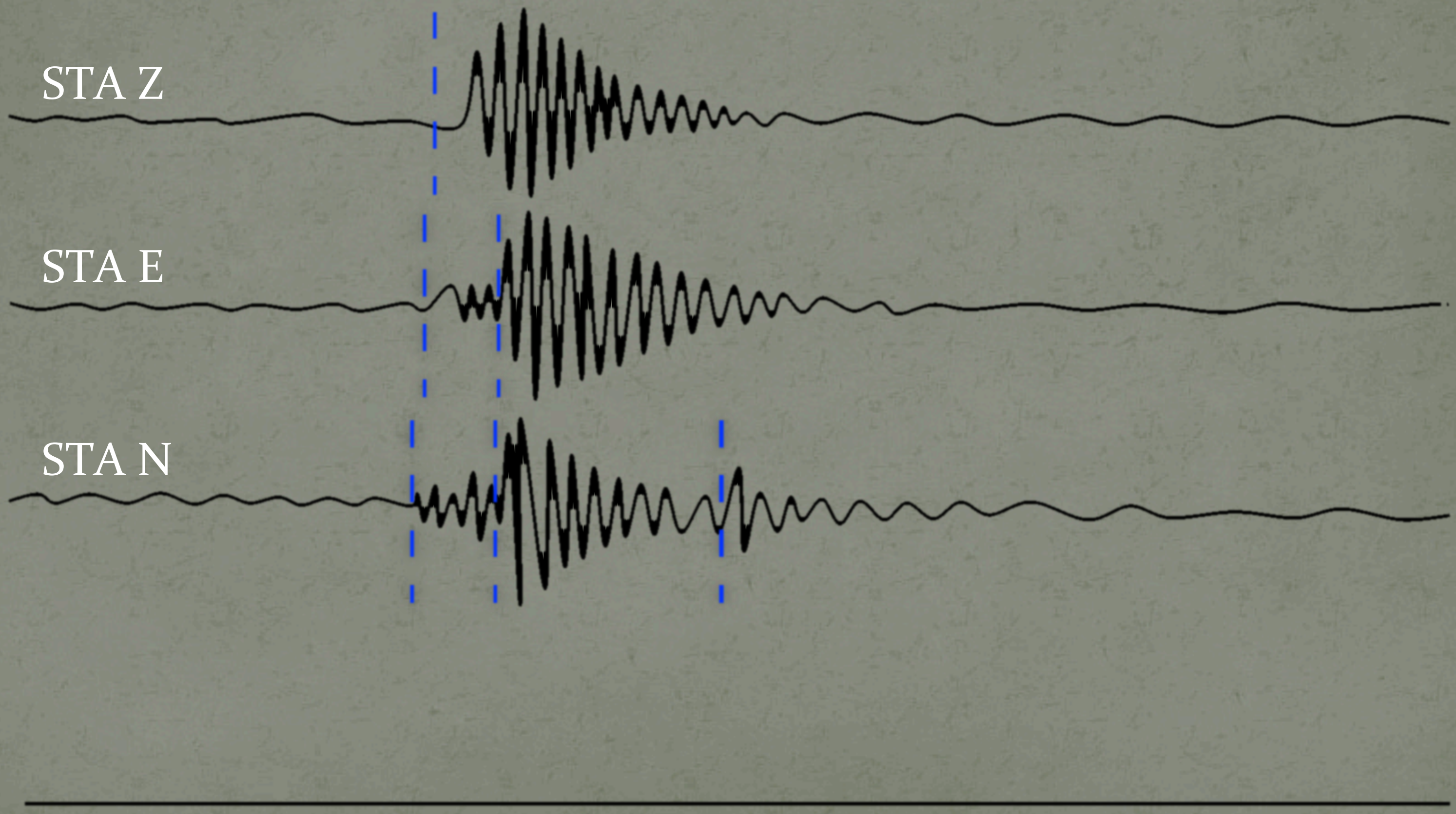
Configurable parameters:

1. Window length [t_ma=20 s]
2. Ratio of energy noise to signal for dynamic threshold [6 sigma]
3. Ratio of energy noise to signal for uncertainty triggering [3 sigma]

Associator

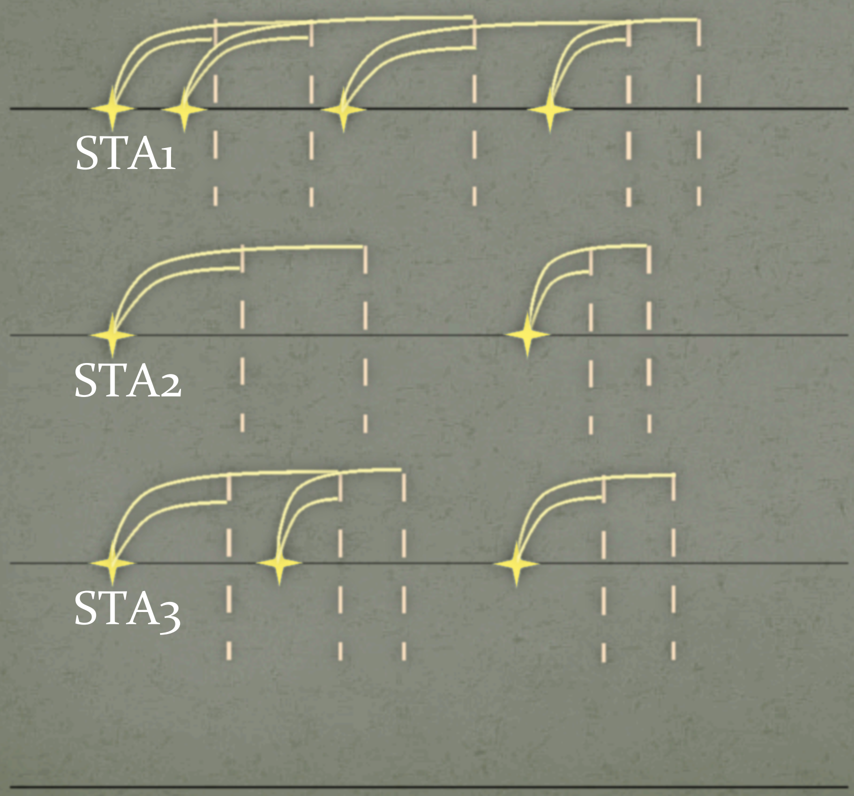
1. Pick Aggregation

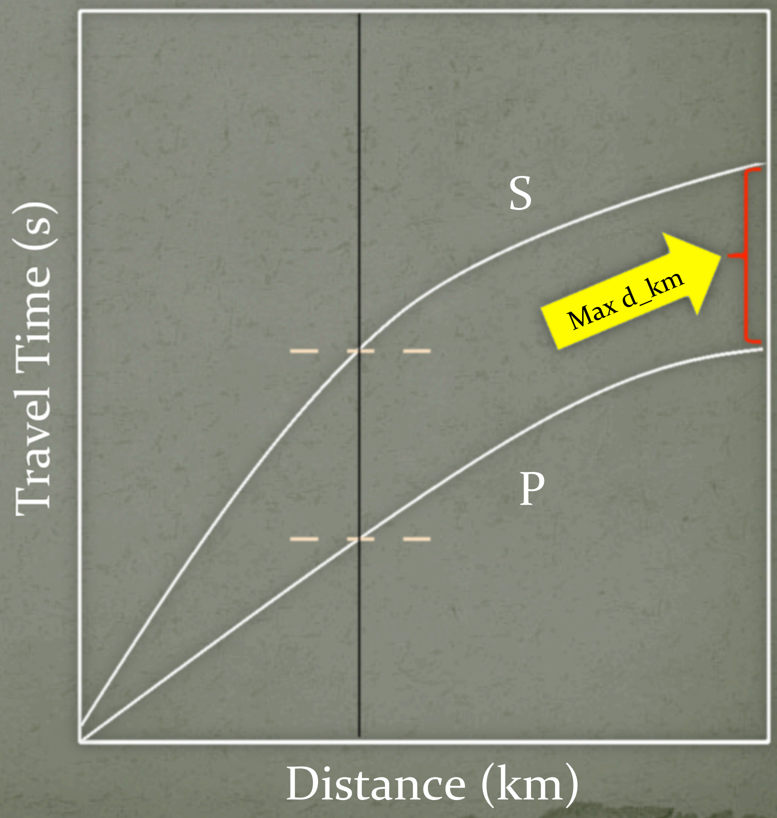
Mode: median or mean



Associator

2. Event Candidates
   - Look up travel time table by Taup [Crotwell et al, 1999]



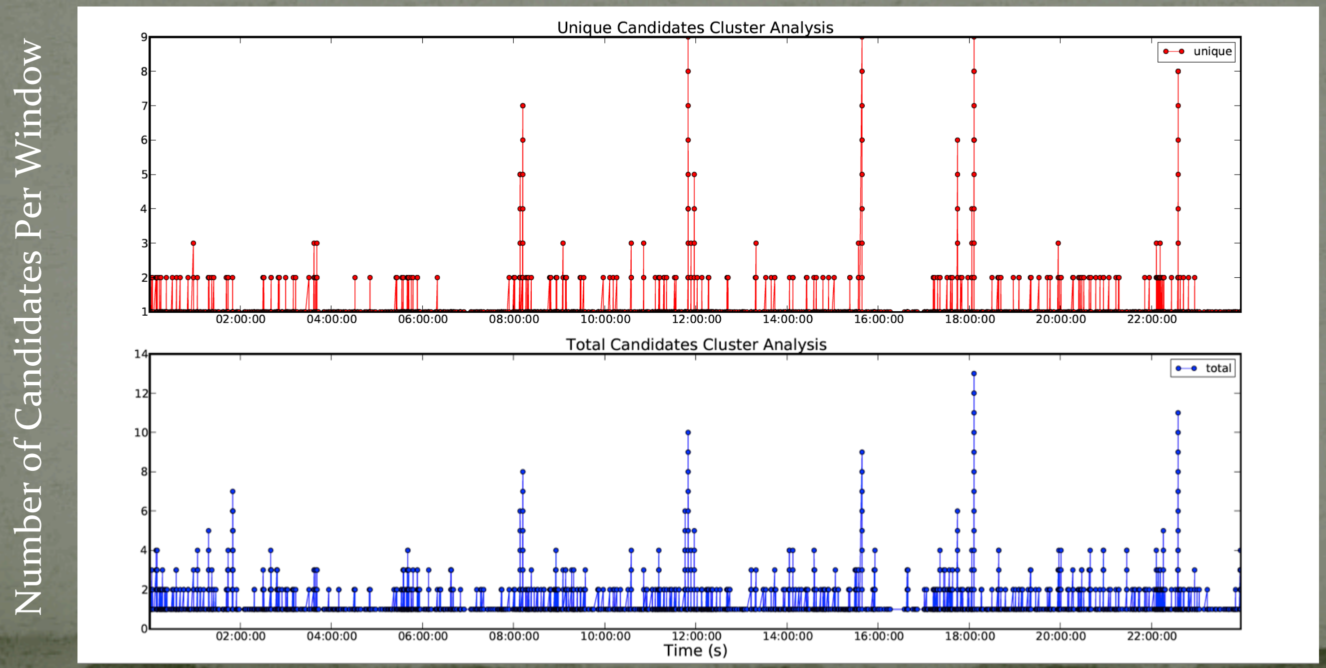


Associator

3. Associating Candidates

The whole day example of June 16, 2014. The # of Unique Station Plot indicates how many stations will be used to locate and declare an event.

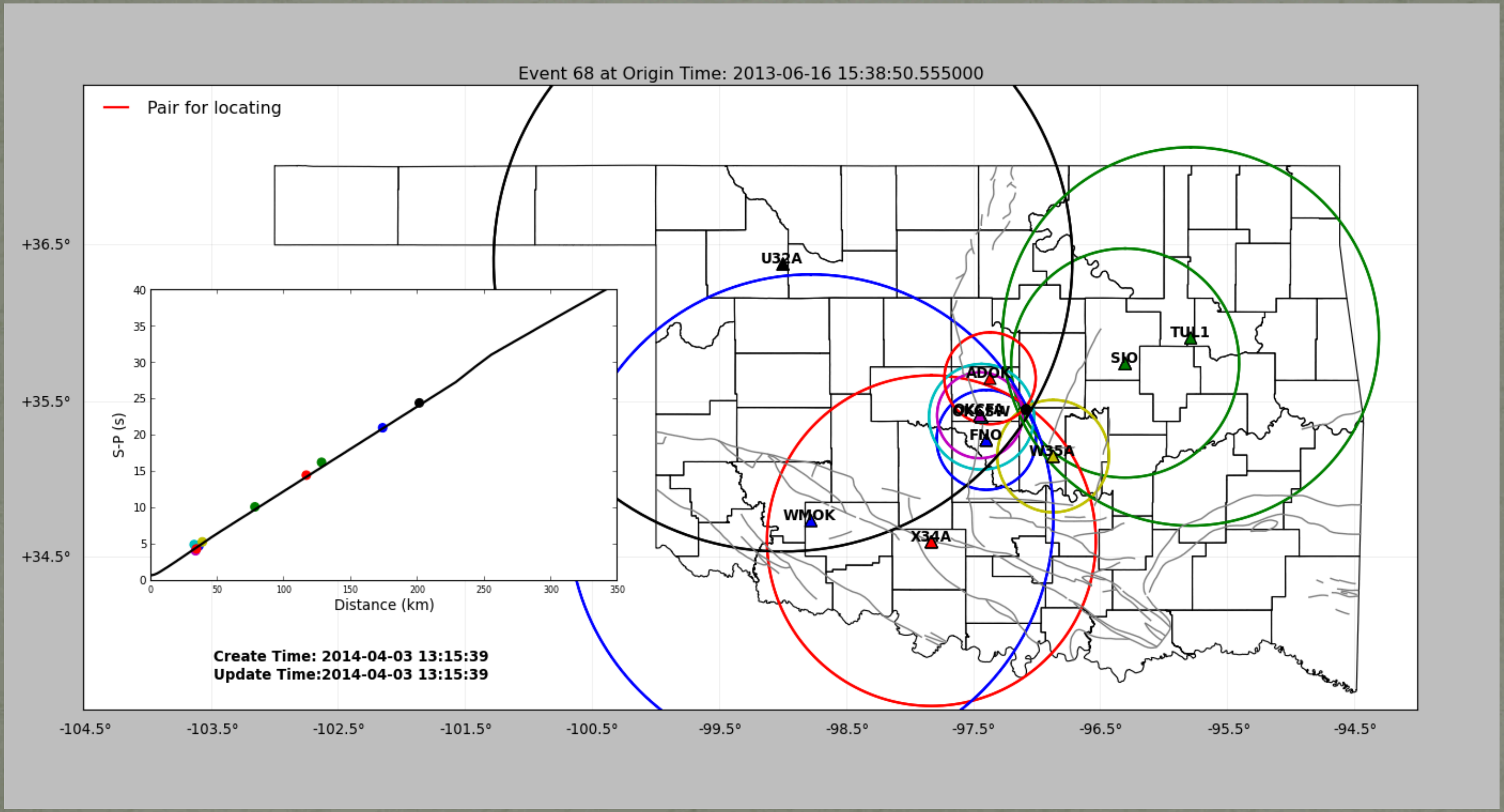
Big difference between two plots means there are many false picks and candidates from certain stations, indicating they are noisy.



Associator

4. Event Locating: event plot

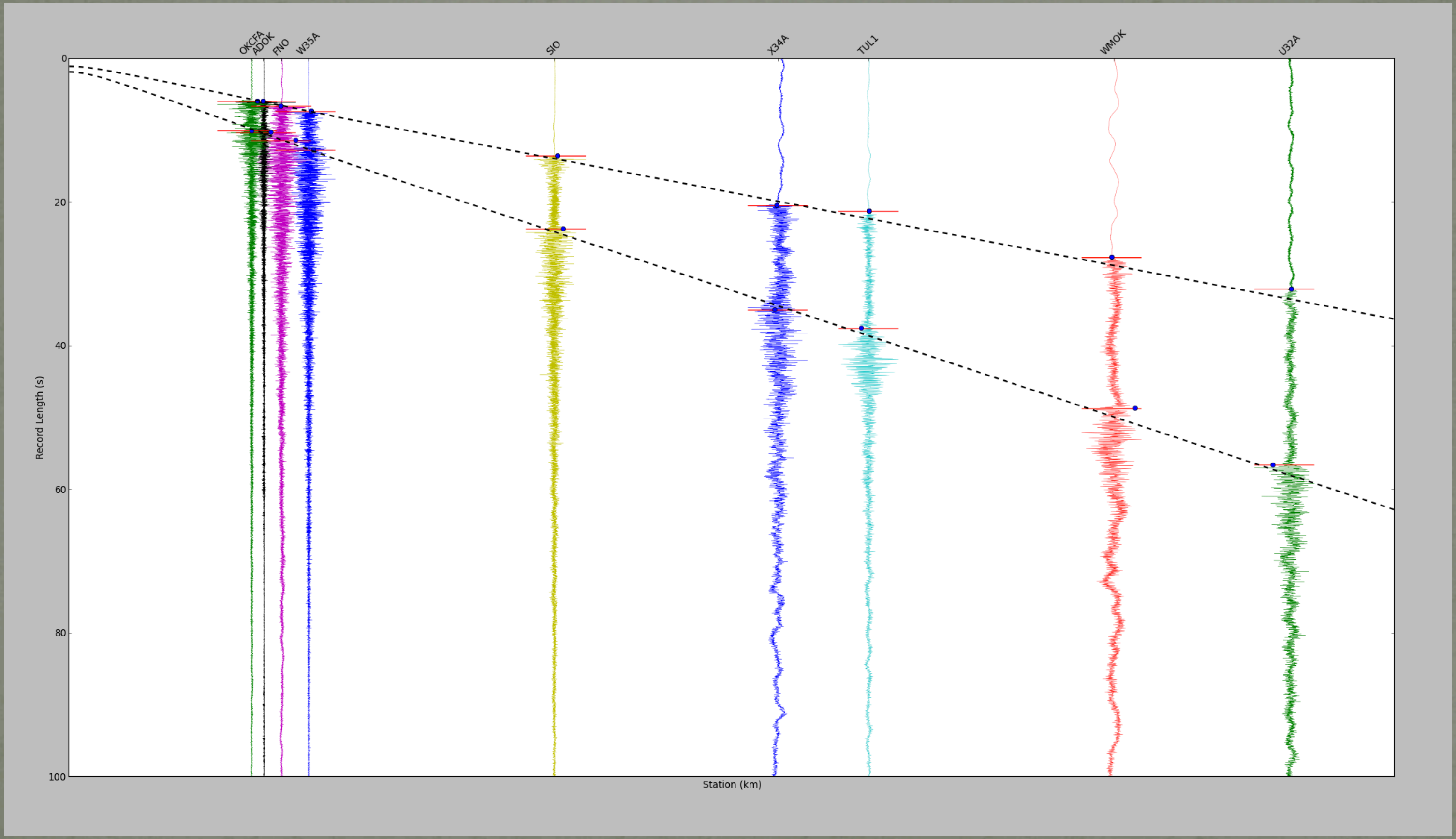
$$\frac{\partial^2 \sum_{i}^{N} (d_i - d_i^m)^2}{\partial x \partial y} = 0$$



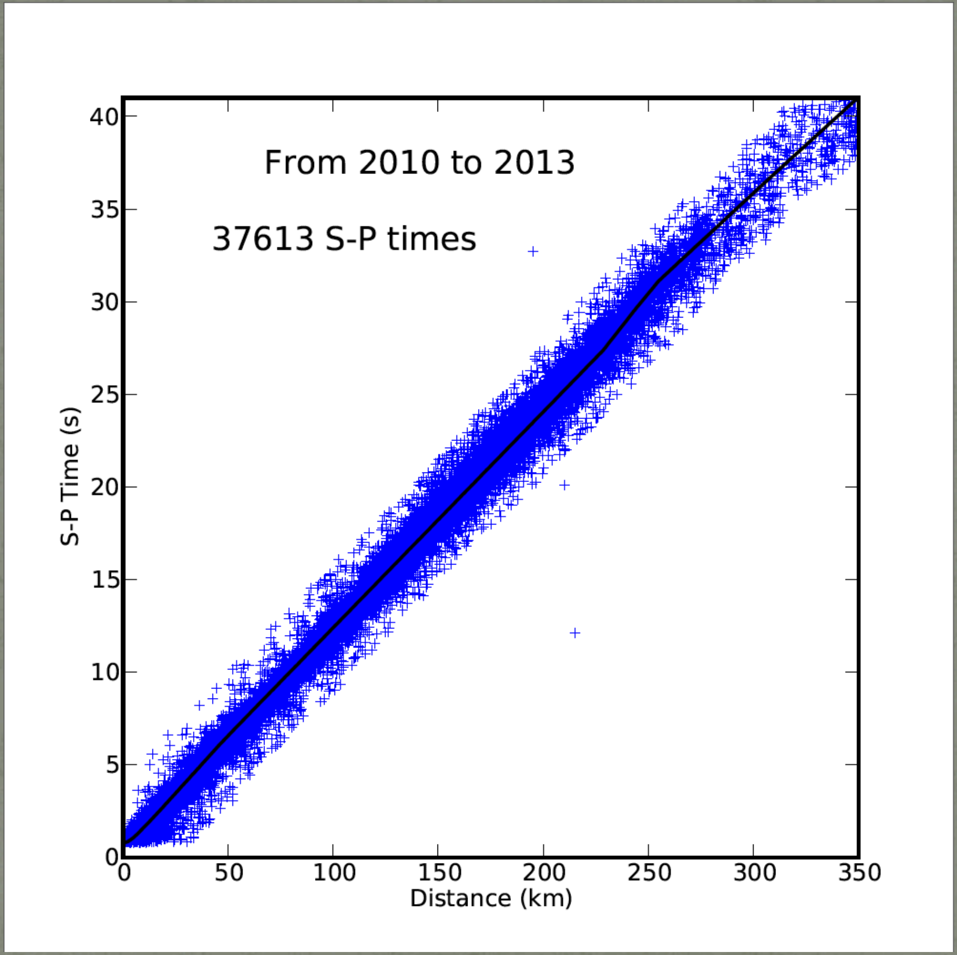
Associator

4. Event Locating: section plot

$$\frac{\partial^2 \sum_{i}^{N} (d_i - d_i^m)^2}{\partial x \partial y} = 0$$



Performance



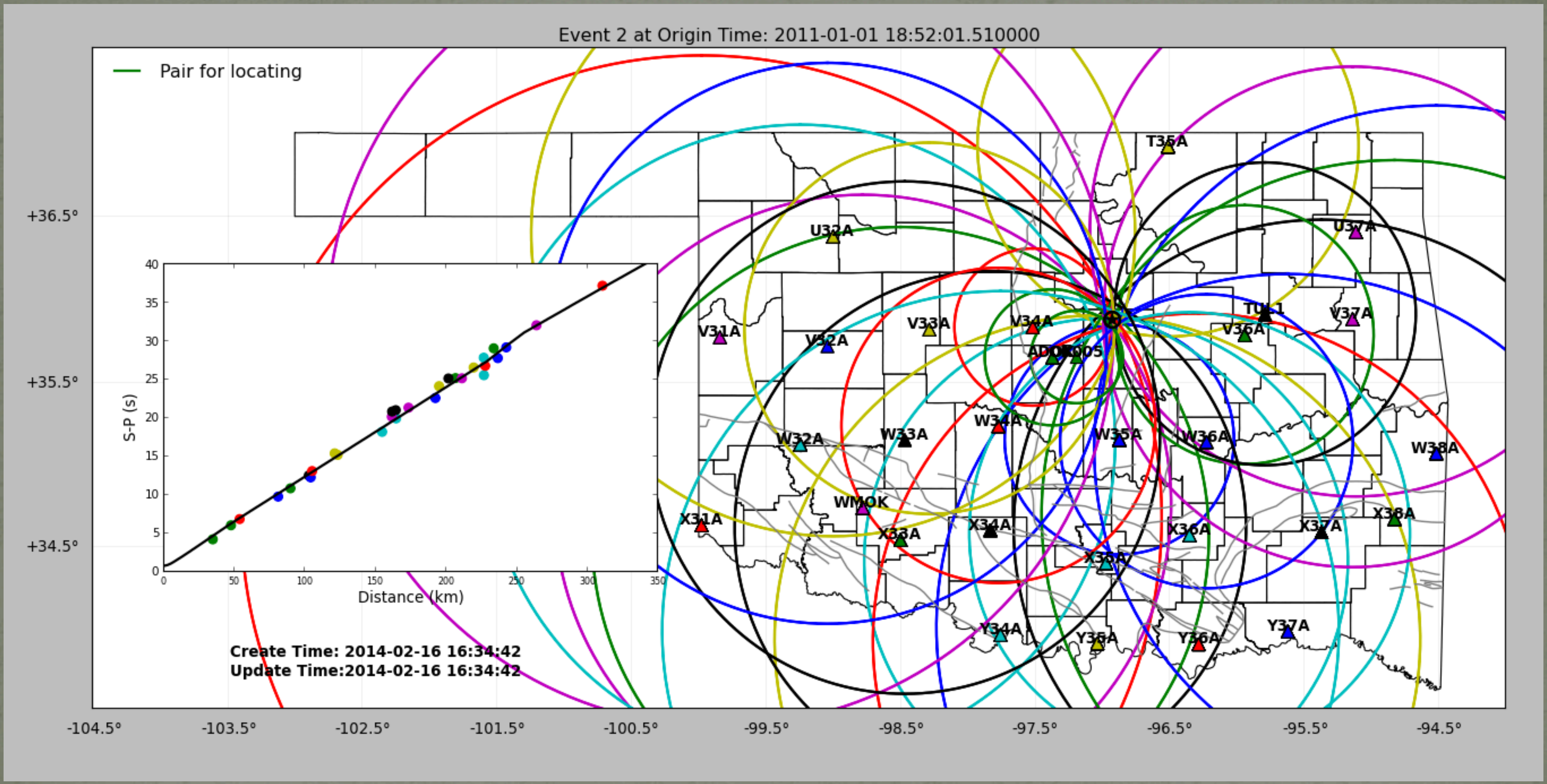
Conclusion

- The algorithm takes advantage of existing seismological and scientific Python libraries such as ObsPy (Beyreuther et al., 2010).
- The system is designed to work on a variety of instrumentation automatically adapting to different sampling rates and instrument gains.
- FBpicker enhances signal over noise through the octave-filtering.
- FBpicker triggers picks with user-defined dynamic threshold level to adapt to changing SNR.
- FBpicker uses the roll back technique to ensure the dynamic threshold level will not change the time of declared picks.
- FBpicker determines the polarity and uncertainty for each pick.
- Associator associates all overlapping candidates to identify events with origin time, location and location uncertainty.
- The plotting tools allow user to visualize system performance to modify parameters.

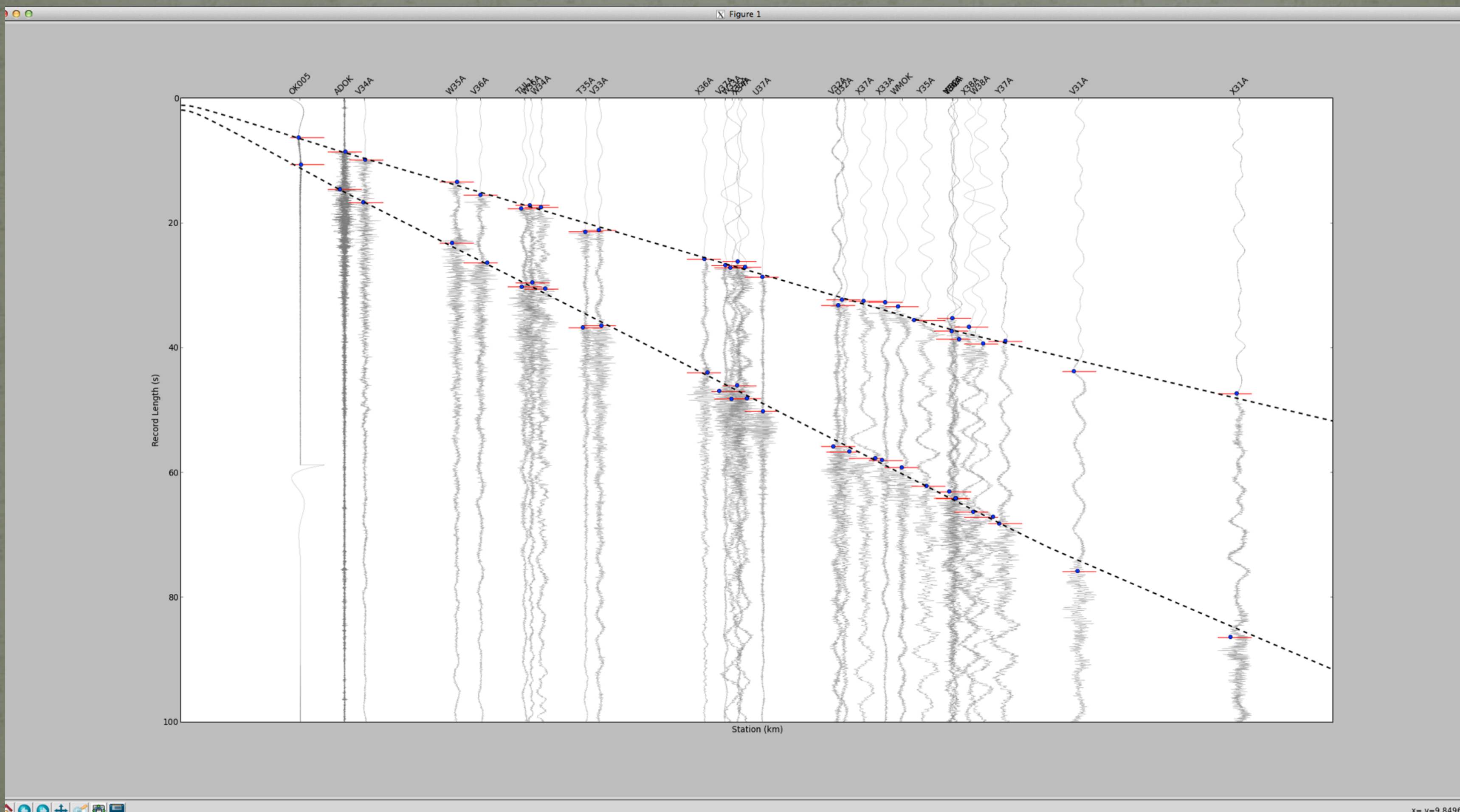
References

- Beyreuther, M., Barsch, R., Krischer, L., Megies, T., Behrd, Y., and Wassermann, J., 2010,ObsPy: A python tool for seismology: Seismol. Res. Lett., v. 81, p. 530-533.
- Crotwell, H.P. , Owens, T.J., and Ritsema, J., 1999, The TauP toolkit: Flexible seismic travel-time and raypath utilities, Seism. Res. Lett., v. 70, p. 154-160.
- Lomax, A., Satriano, C. and Vassallo, M., 2012, Automatic picker developments and optimization:FilterPicker - a robust, broadband picker for real-time seismic monitoring and earthquake early-warning, Seism. Res. Lett. ,v. 83, p. 531-540.

Another Example



Another Example



Abstract

We developed a robust method for automatic phase arrival and event association applicable to real-time monitoring or archived data processing. This system consists of two main components FBpicker and Associator. These two modules could work separately or jointly depending on users' requirements, providing users flexibility to process data in term of their own priorities. Our system uses the statistical concept of characteristic function from Lomax et al. (2012) and in Python. The algorithm takes advantage of existing seismological and scientific Python libraries such as ObsPy (Beyreuther et al., 2010). The system is designed to work on a variety of instrumentation automatically adapting to different sampling rates and instrument gains. The time series signals are octave filtered for each band. We take band-pass filtered energy as characteristic function to detect changes of energy at phase onset. By simply taking the maximum statistics of all bands of each sample, we summarize the statistics. We trigger potential picks with a dynamic threshold based on the summary statistics. This has the advantage that the picker does not have channel specific configurations when processing data from a wide variety of instrumentation with different response characteristics. The algorithm also contains a method to determine the first motion direction associated with a pick. As with any automatic phase identification system false picks can and do occur. A few simple algorithms are implemented to avoid false-picks, and are highly configurable. These algorithms remove picks that occur very close in time and picks for which a phase has a smaller signal immediately after the pick than preceding the pick. The algorithm also uses techniques within Numpy to improve computation efficiency. Moreover, we implemented an Associator to associate the picks from FBpicker to events and assign phases.