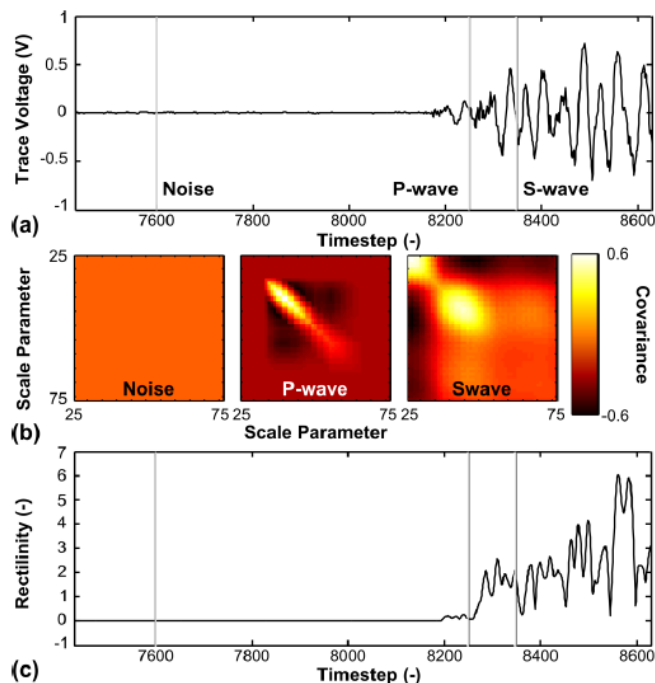


# Using wavelet covariance models for simultaneous picking of overlapping P- and S-wave arrival times in noisy single-component seismic data

## Theme 1. Fluid-Driven Geomechanics Challenge 3. Controlling Emergence



Acoustic event from laboratory fracture test with (a) detected signal; (b) covariance matrices in noise interval, P-wave coda and S-wave coda; and de-noised rectilinearity values

Alex J. Rinehart, Sean A. McKenna, and Thomas A. Dewers, 2016, Using wavelet covariance models for simultaneous picking of overlapping P- and S-wave arrival times in noisy single component data, *Seismological Research Letters*, v. 87, no. 4, p. 1-9, doi: 10.1785/0220150130

## Scientific Achievement

Developed robust and efficient method for determining arrival times of overlapping P- and S- wave arrivals in noisy seismic signals

## Significance and Impact

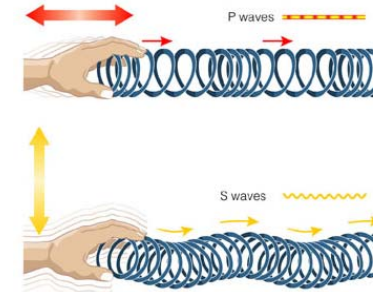
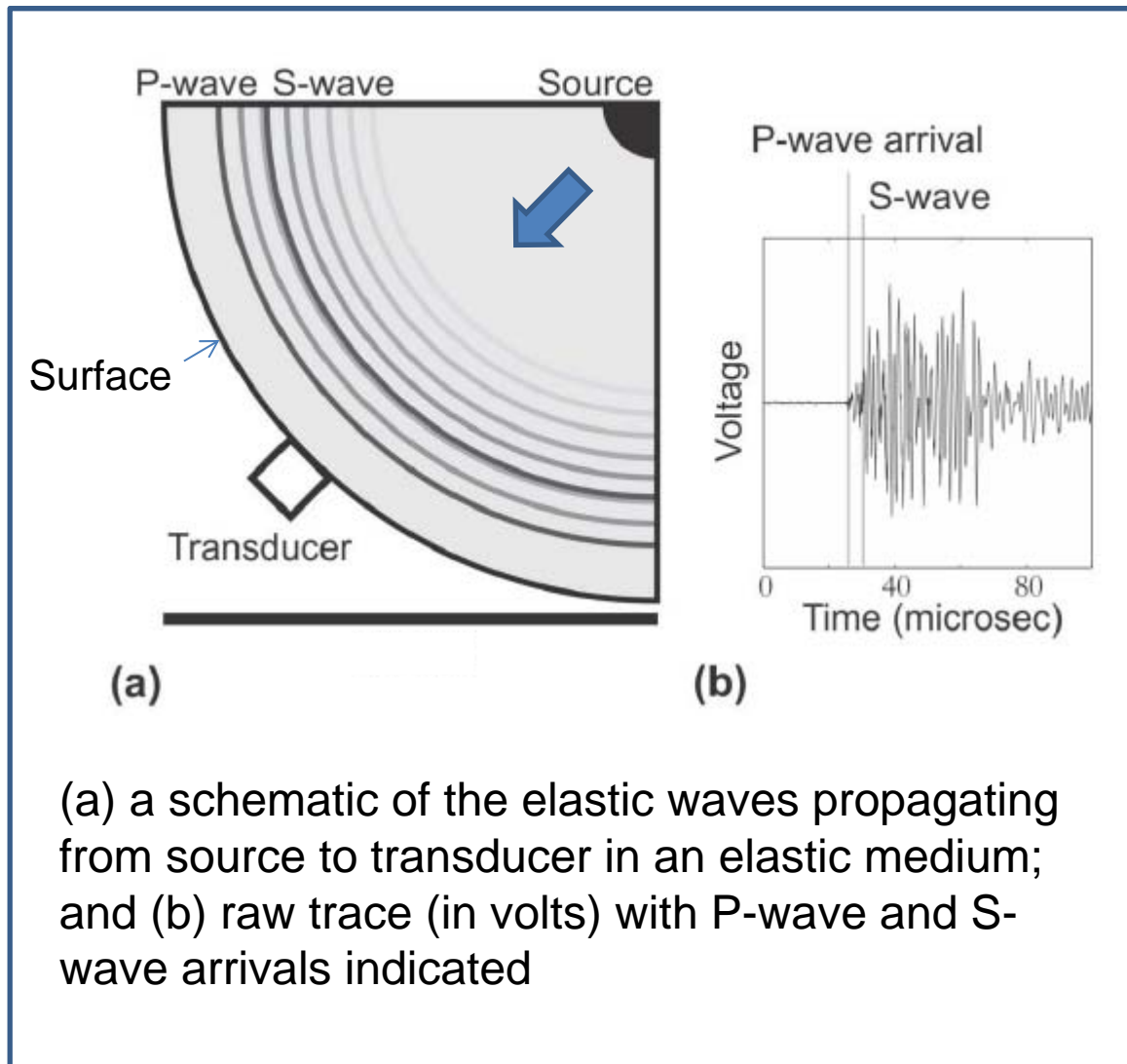
By automating arrival picking, method can be used for machine learning for discerning CO2 plume tomography and possibly fracture propagation during subsurface injection

## Research Details

- Use statistics of temporal covariance to discern arrivals in low signal-to-noise waves as are common in near-source micro- and pico-seismicity monitoring, e.g. injection sites
- Acoustic emissions during lab fracture test (worst case) used to develop and demonstrate proof-of-concept

Work was performed at Sandia National Laboratories with help from UT

# Common Problems in Seismic Wave Detection and Analysis



## Challenges associated with estimating both P-wave and S-wave arrival times in near-source acoustic signals:

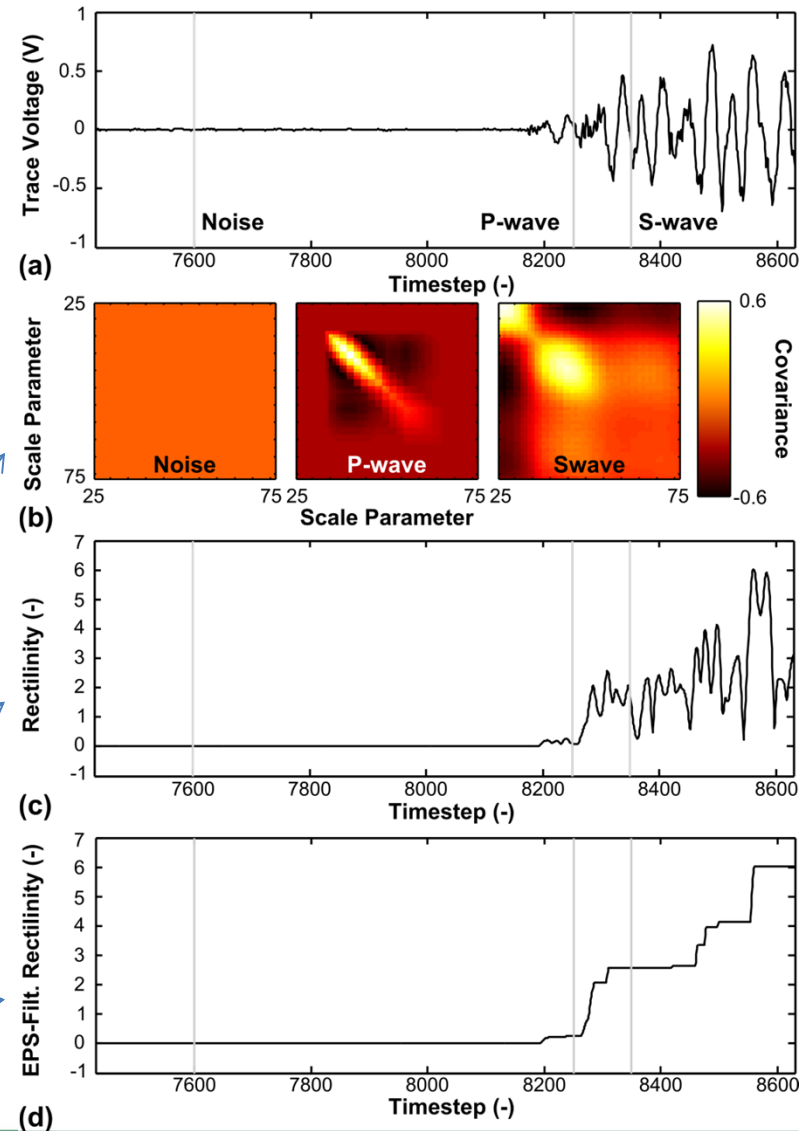
- S-waves (shear) travel more slowly than P-waves (compressional)
- Over large distances there is a clear separation, e.g. for earthquake seismology
- Near source, S-wave signatures are lost in the p-wave “coda” & noise
- Huge amounts of data typical



# New Methodology

Upon analysis of multiple continuous wavelet transforms of acoustic events in benchtop testing, it was discovered that the **wavelet scale covariance** showed consistent changes at the arrival of P- and S- waves. This suggested the following methodology:

- Combine wavelet-based de-noising with filtered metrics based on the covariance of the continuous wavelet transform (b) of the signal (a)
- An edge-preserving rectilinearity function captures the variance and rate of decay of eigenvalues of the covariance matrices (c).
- P- and S-wave arrivals are found sequentially by thresholding (d)



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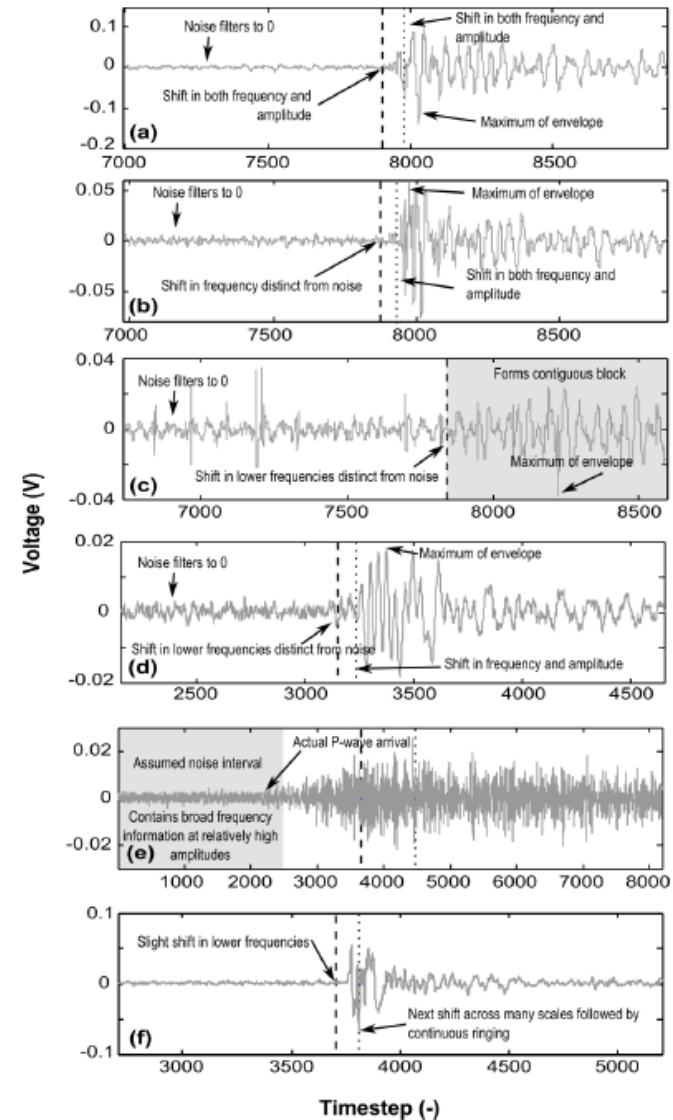
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# Robustness of the Method: Benchtop Proof of Concept

- High success rate in automated picking for P- and S-waves
- Not so good for low-magnitude “rumbling events” and with high electrical noise
- Low amplitude long term events could be discerned by further thresholding in amplitude

Examples of different event traces with P-wave arrival time (dashed) and S-wave arrival times from fracture toughness tests in aluminum (a-c) and more complicated events from Cranfield caprock failure tests (d-f).



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# Conclusions and On-Going Work

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- The novel parts of our approach are quantifying the covariance of scales of a continuous wavelet transform, then using a filtered non-normalized rectilineity function to have a usable quantification of these changes
- By using the *covariance* rather than the *correlation*, we capture both magnitude and correlation information
- Method is being adapted to near-real time imaging and velocity tomographic reconstructions of localized shear failure and fracture in lab tests
- Method is being applied to cross-borehole tomographic reconstruction of induced fracturing at field site in Socorro, NM (part of a DOE-SubTER “seedling” project)
- With modification, method could be tuned to detect P-to-S conversions at propagating fracture fronts (e.g. associated with injection stimulation or hydrofracturing), long wavelength low-magnitude “tremors” associated with fluid movement in fracture planes, and in near-real-time recognition of precursors to injection-induced seismic events

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