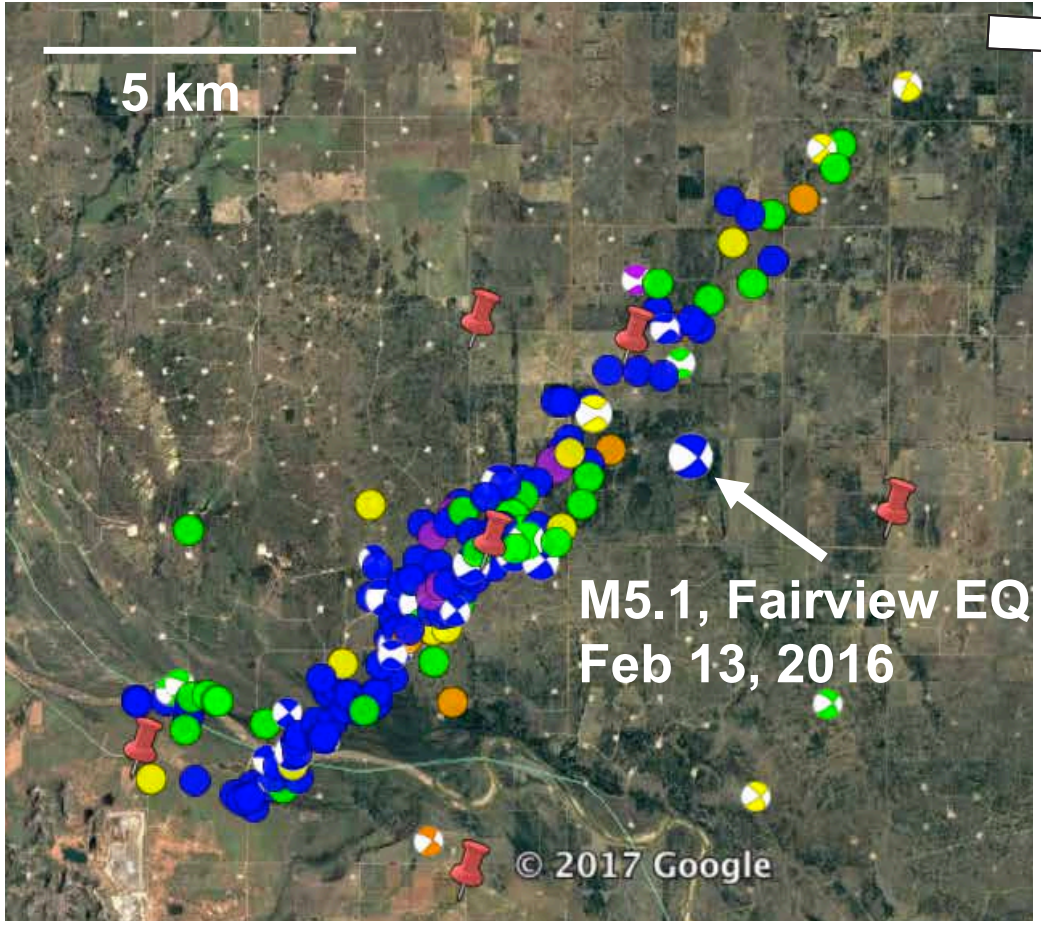
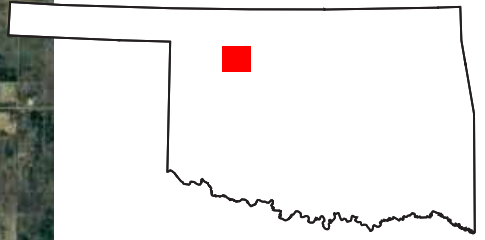
Characterization of earthquake ground motion and ambient-noise correlation using a rotational seismometer and an array-based rotational motion

1. Single-station 6C beamforming
2. 36C ambient noise correlation

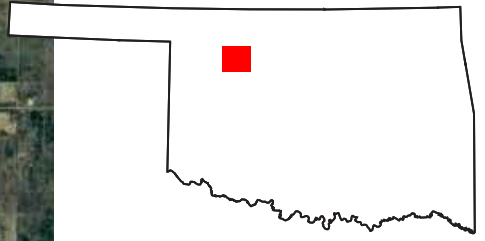
Nori Nakata (MIT)

Oklahoma rotational data





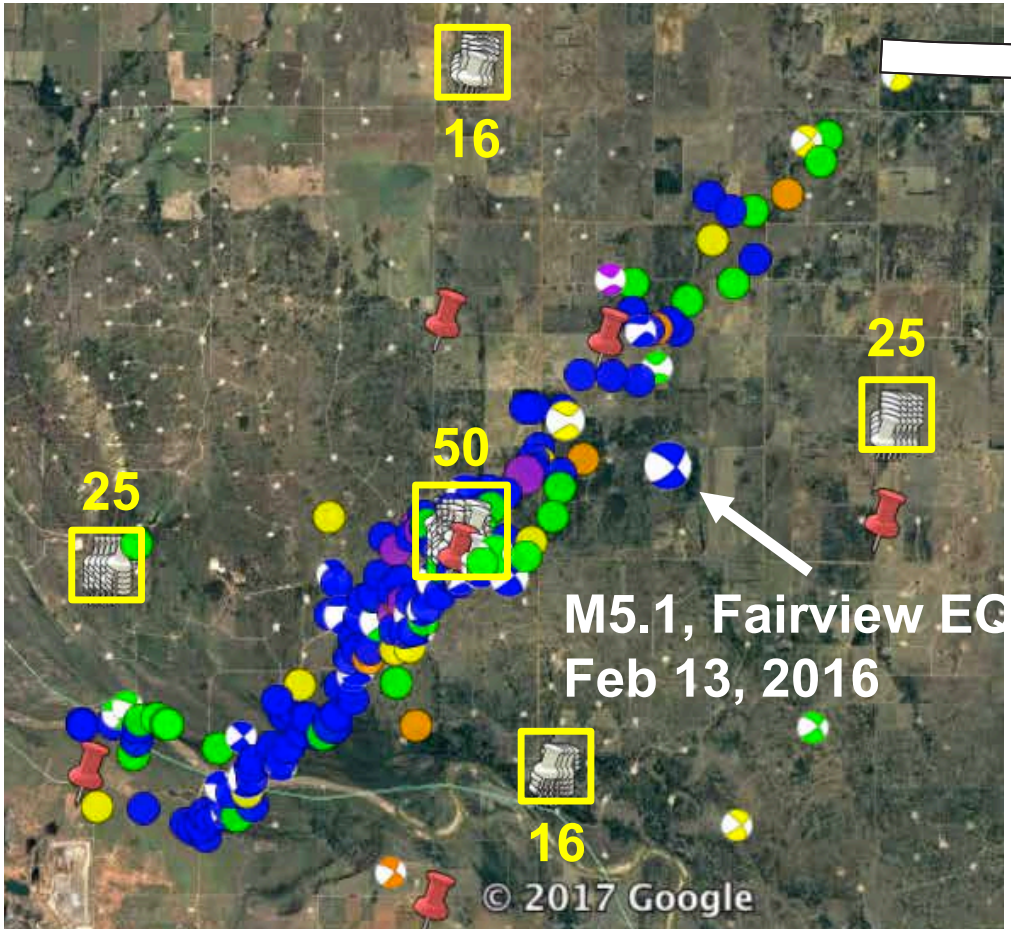
Oklahoma rotational data



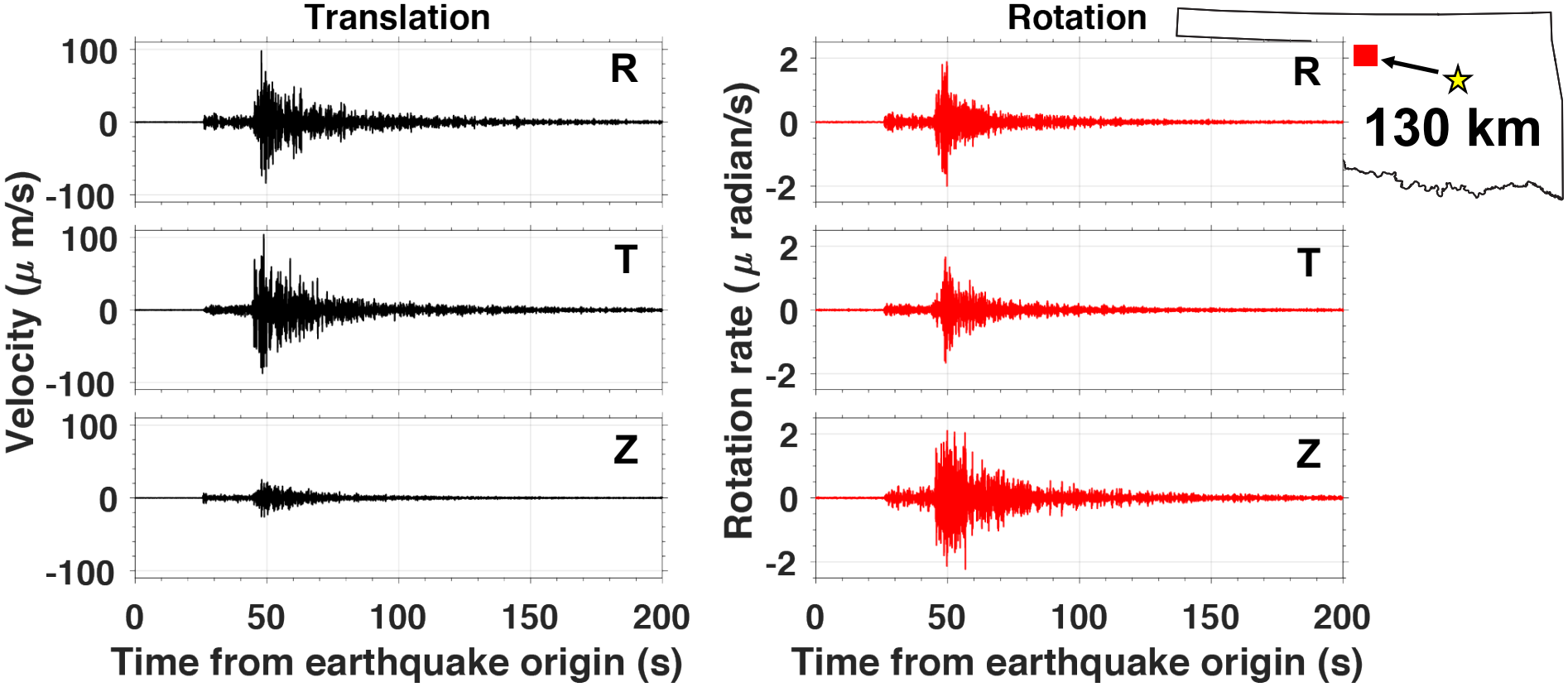
6C station
GS.OK038
GS.OKR1
(ATA sensor)

Geophone arrays

- Fairfield 5Hz, 3C
- 132 receivers
- 80-m spacing
- Total 2 months in 2017

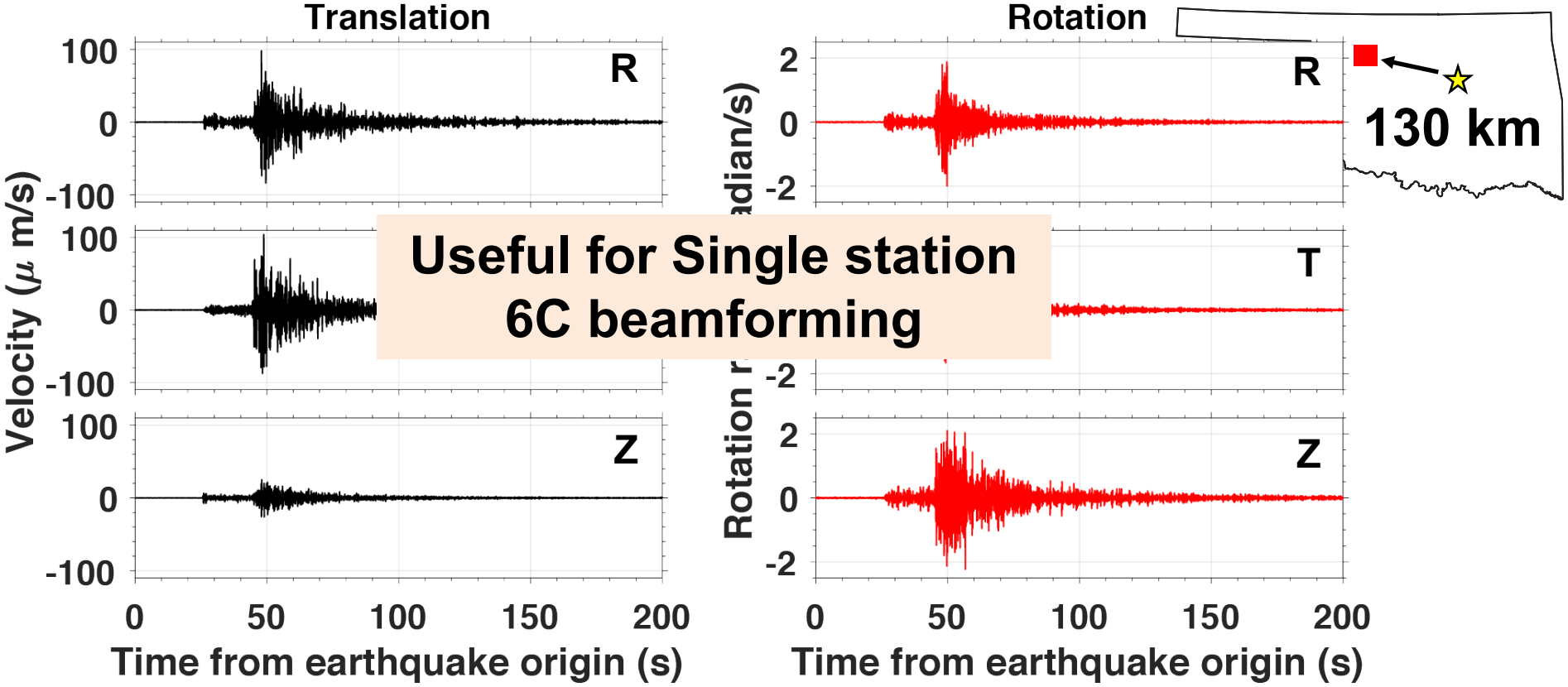


Example of observed data



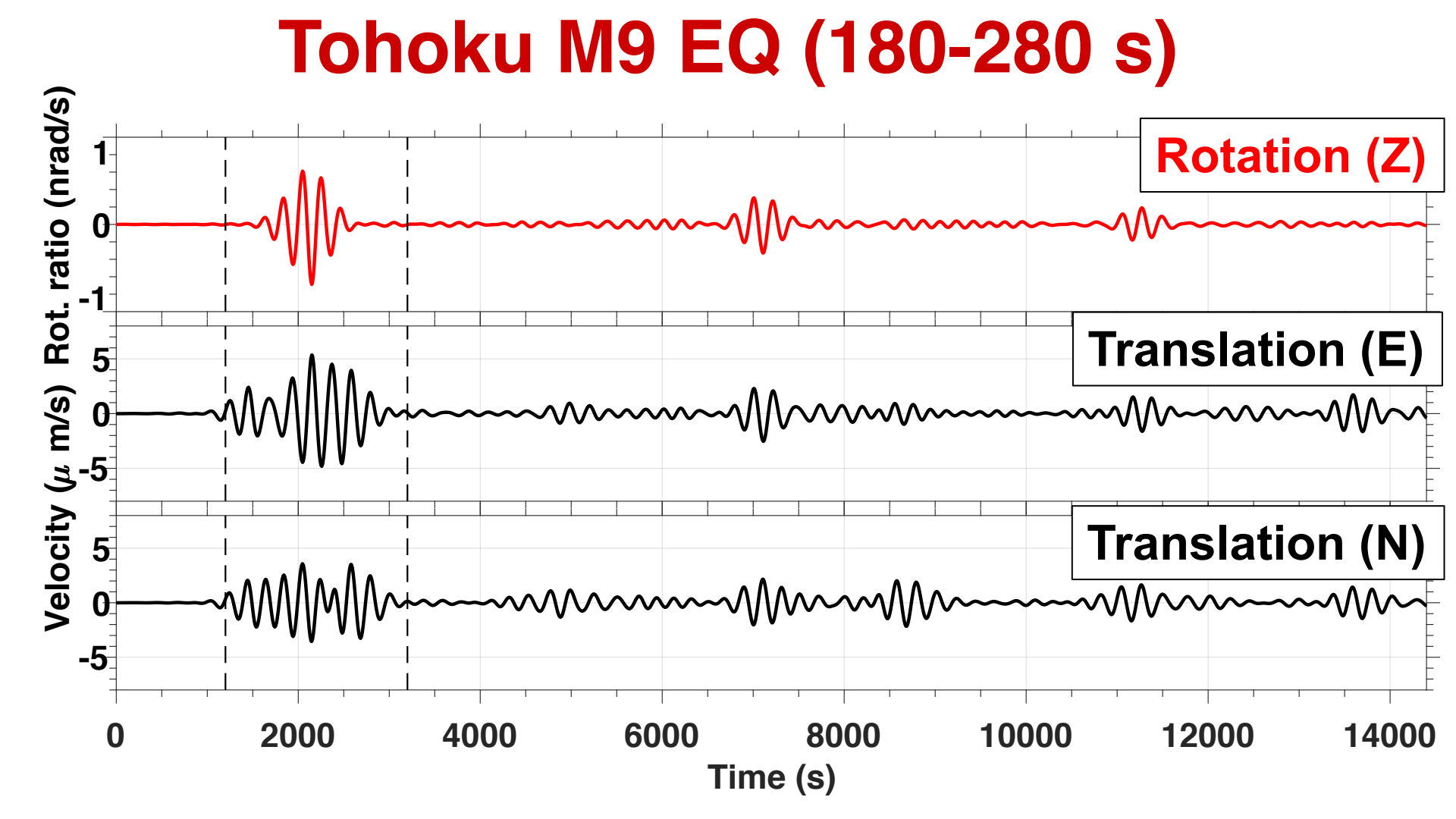
Acknowledgment: Adam Ringler (USGS), Bob Pierson (ATA)

Example of observed data

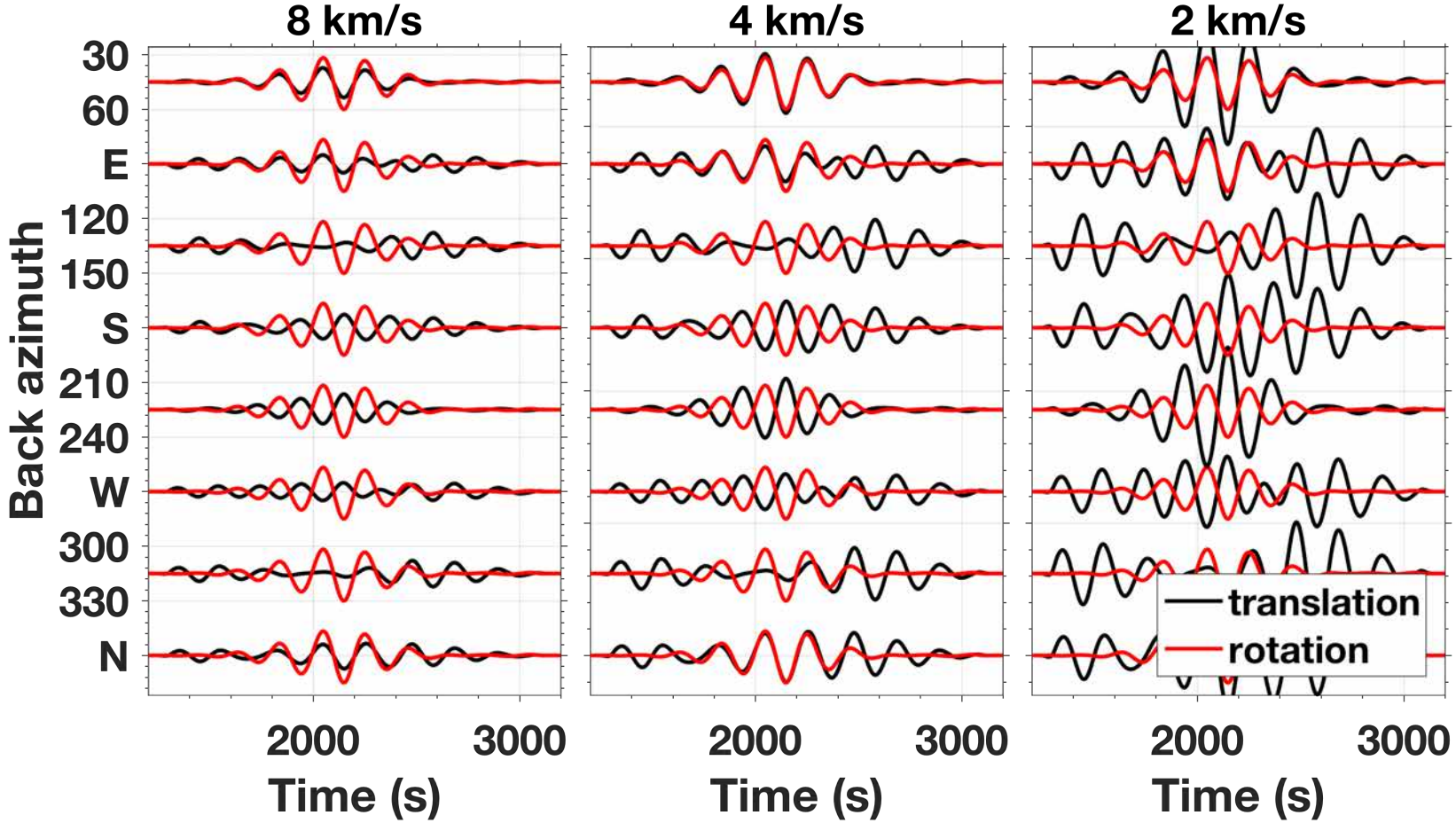


Useful for Single station 6C beamforming

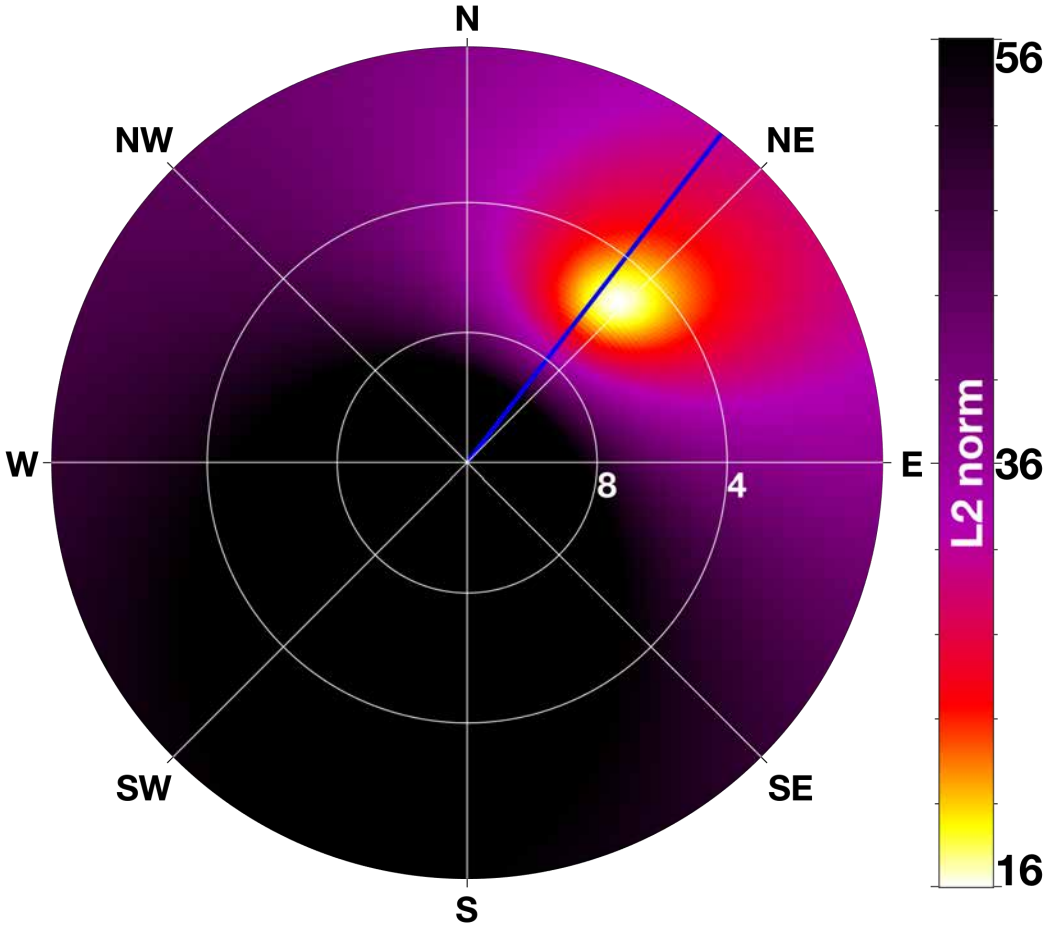
Acknowledgment: Adam Ringler (USGS), Bob Pierson (ATA)

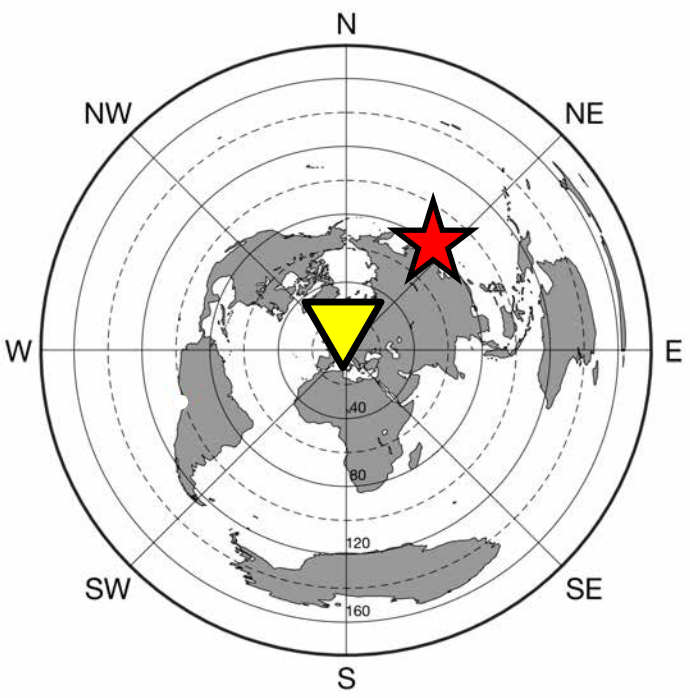

Tohoku M9 EQ (180-280 s)
Rotation (Z)
Translation (E)
Translation (N)
Rot. ratio (nrad/s)
Velocity (μ m/s)
1
0
-1
5
0
-5
5
0
-5
0
2000
4000
6000
8000
10000
12000
14000
Time (s)

Grid search

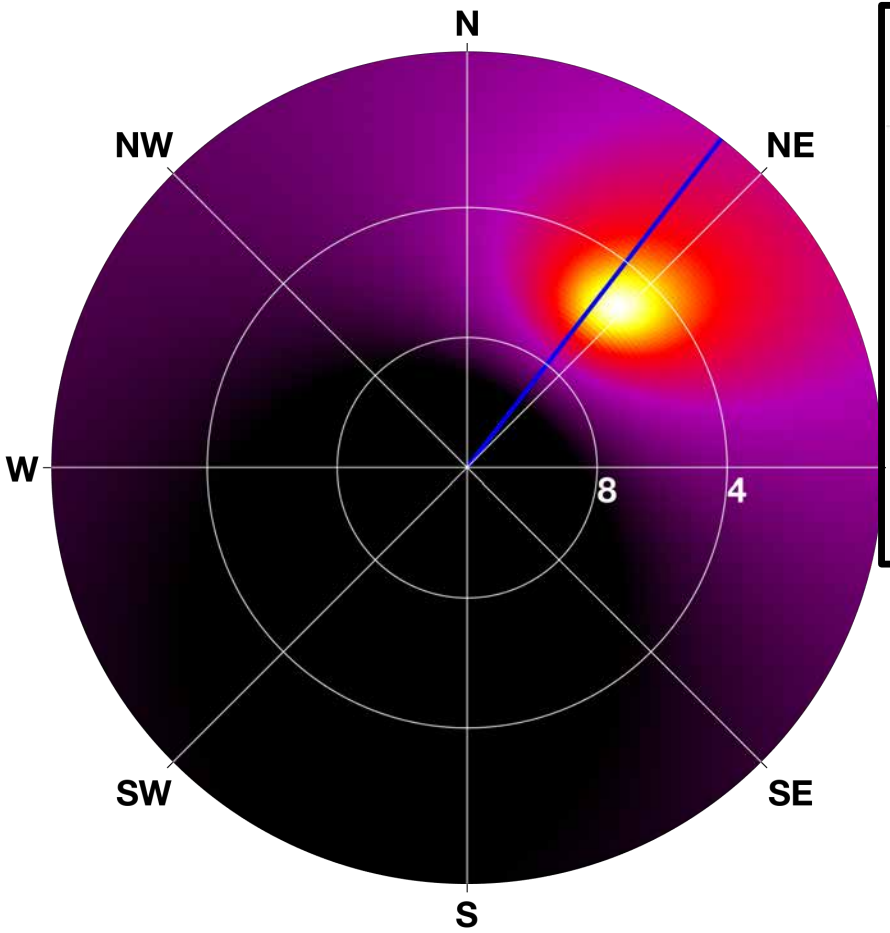

8 km/s
4 km/s
2 km/s
Back azimuth
30
60
E
120
150
S
210
240
W
300
330
N
translation
rotation
2000
3000
Time (s)

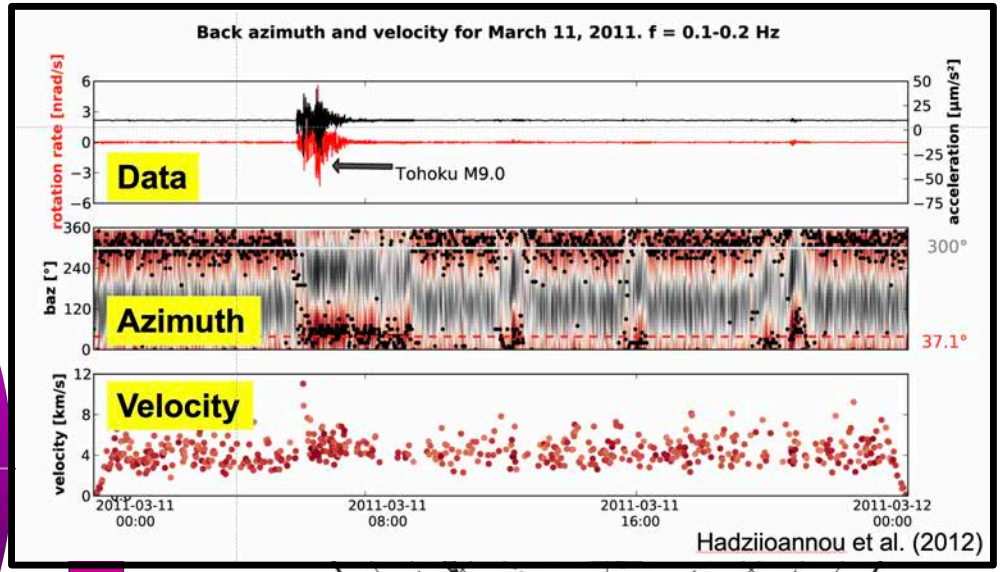
Measure distance of Rot and Tra

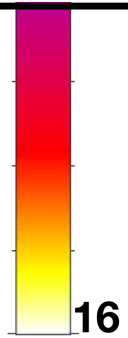


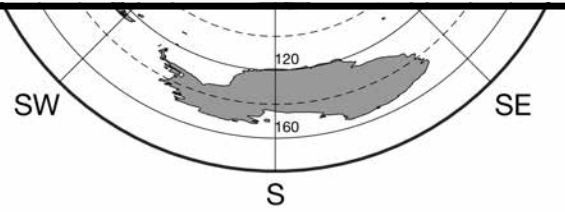


Measure distance of Rot and Tra

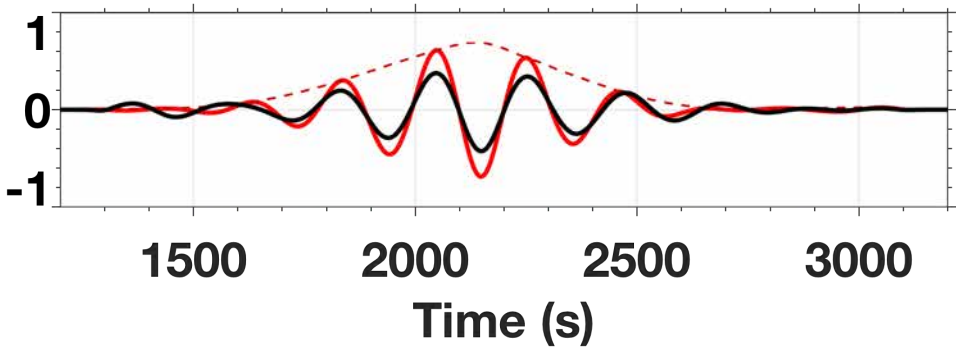




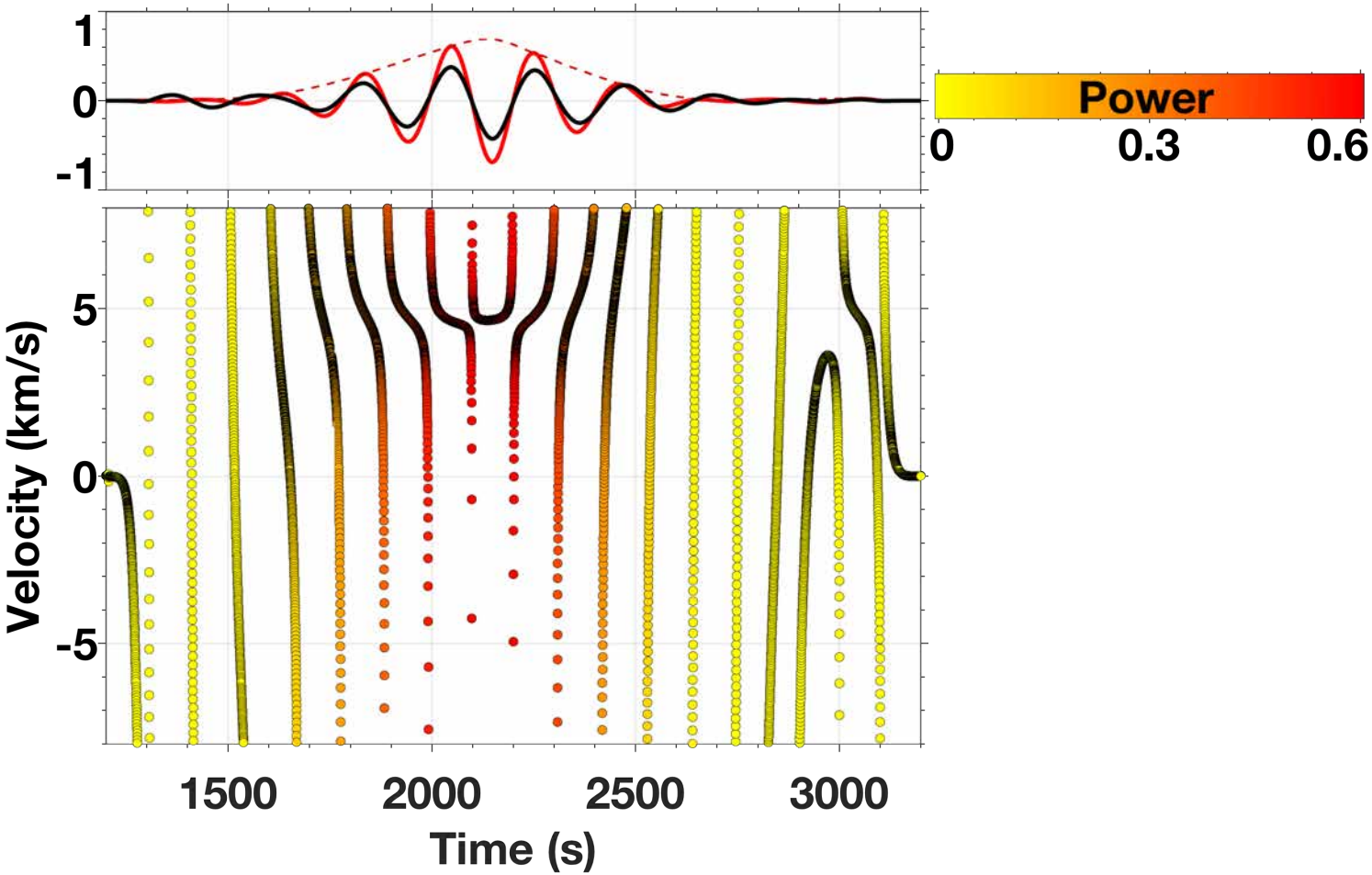




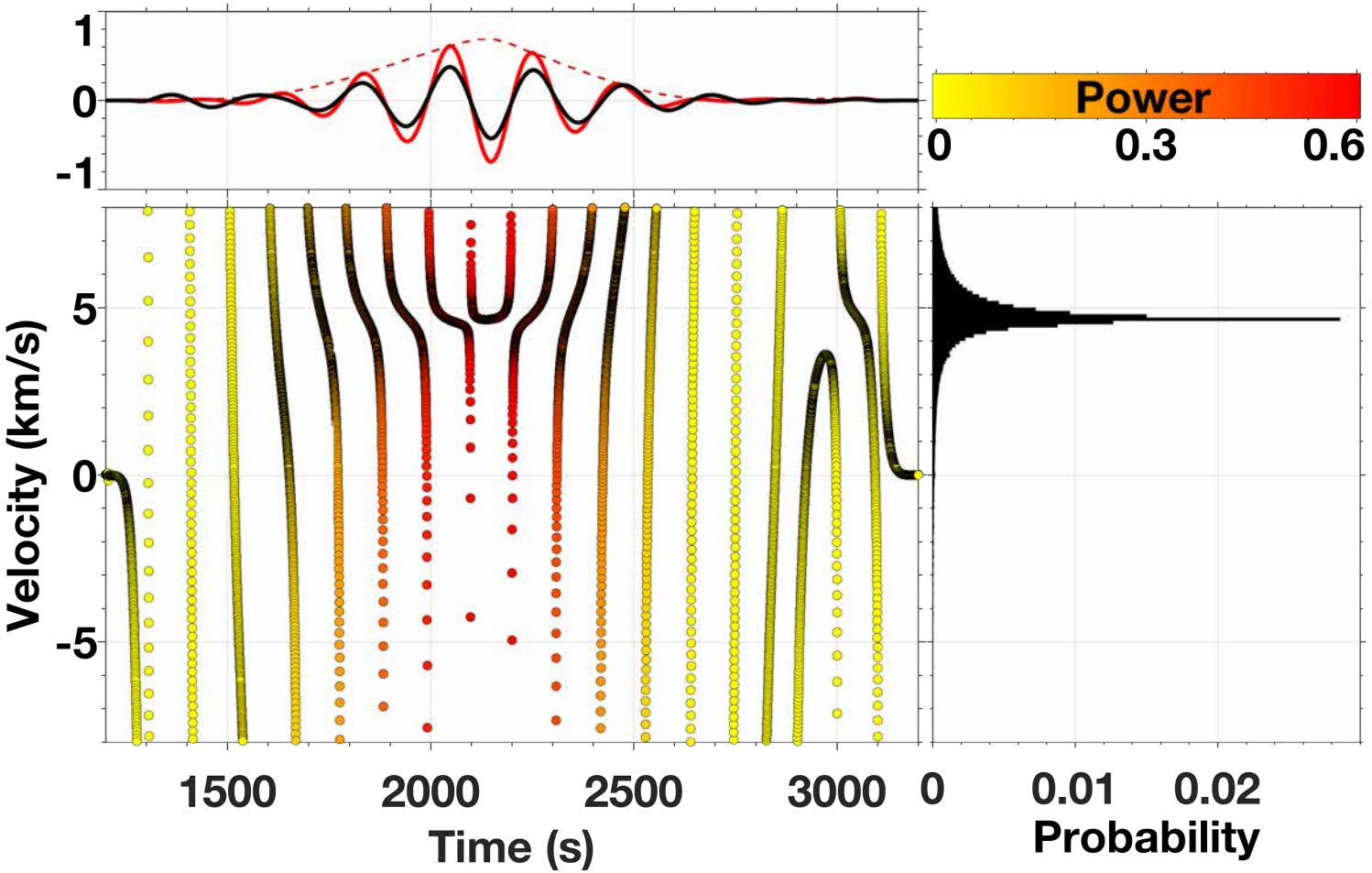
Probability analysis



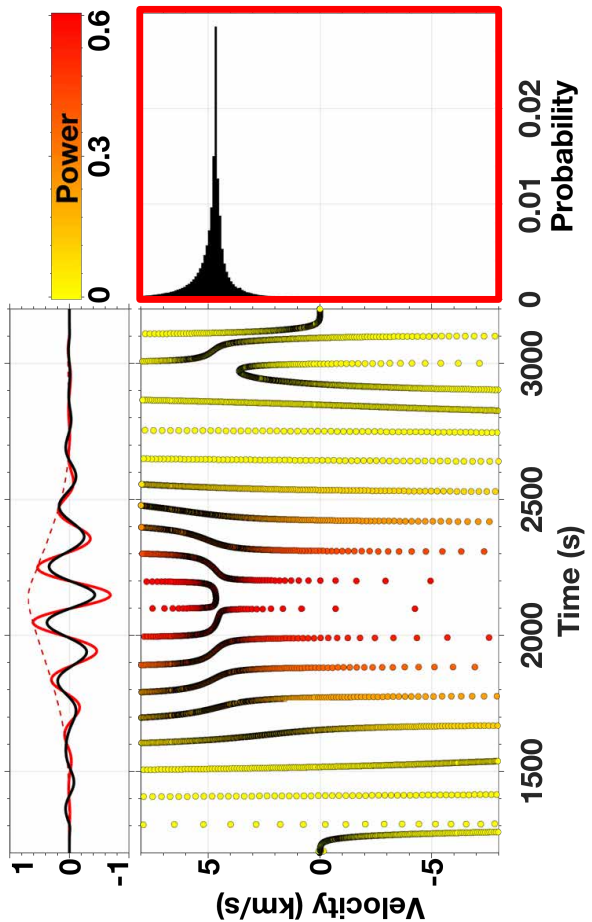
Probability analysis



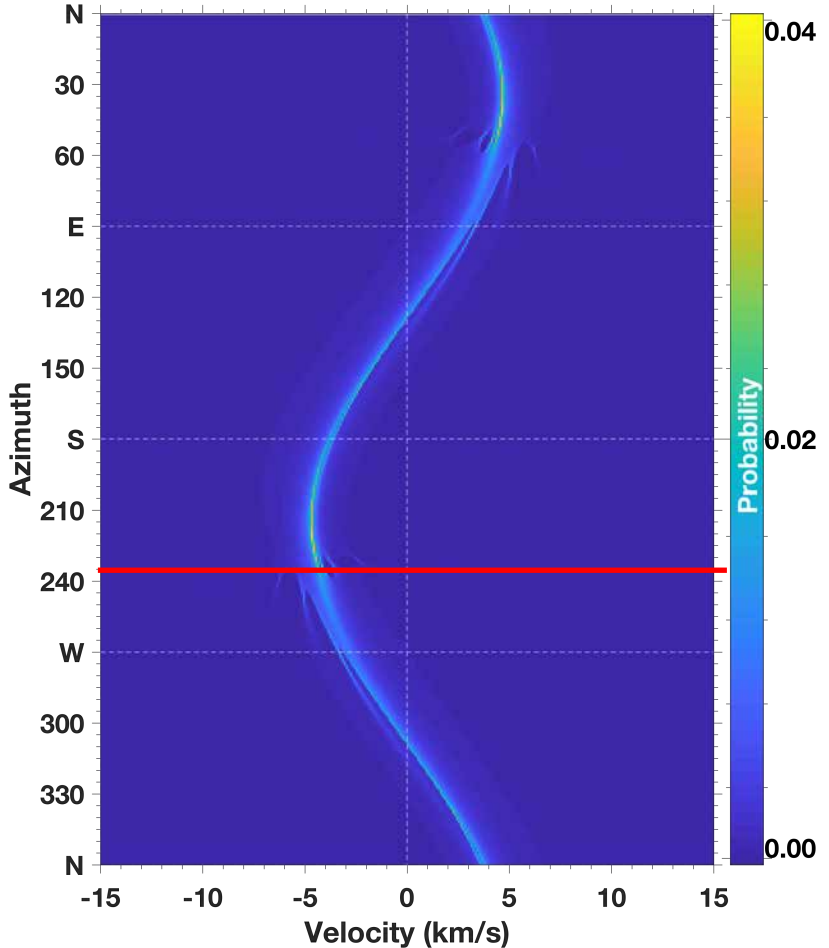
Probability analysis



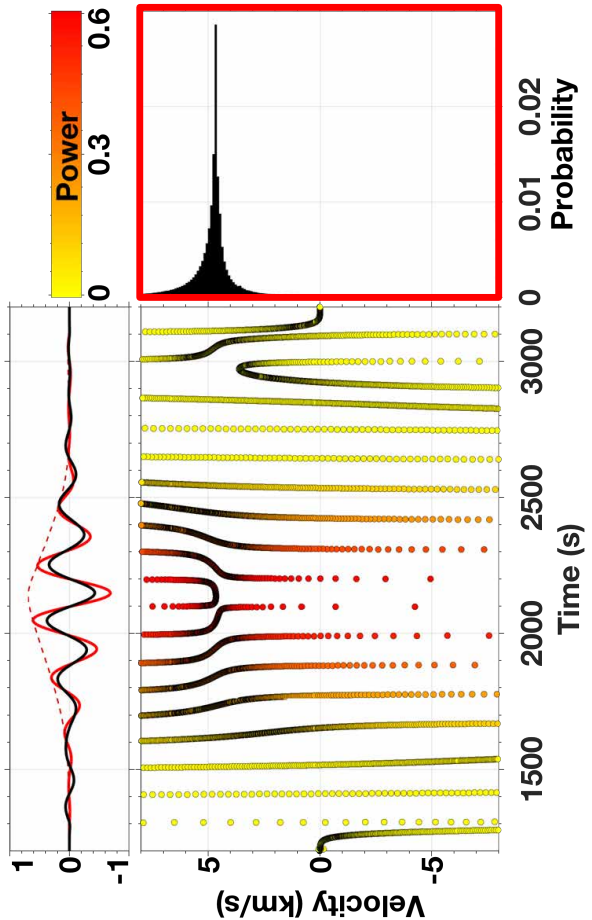
Probability analysis



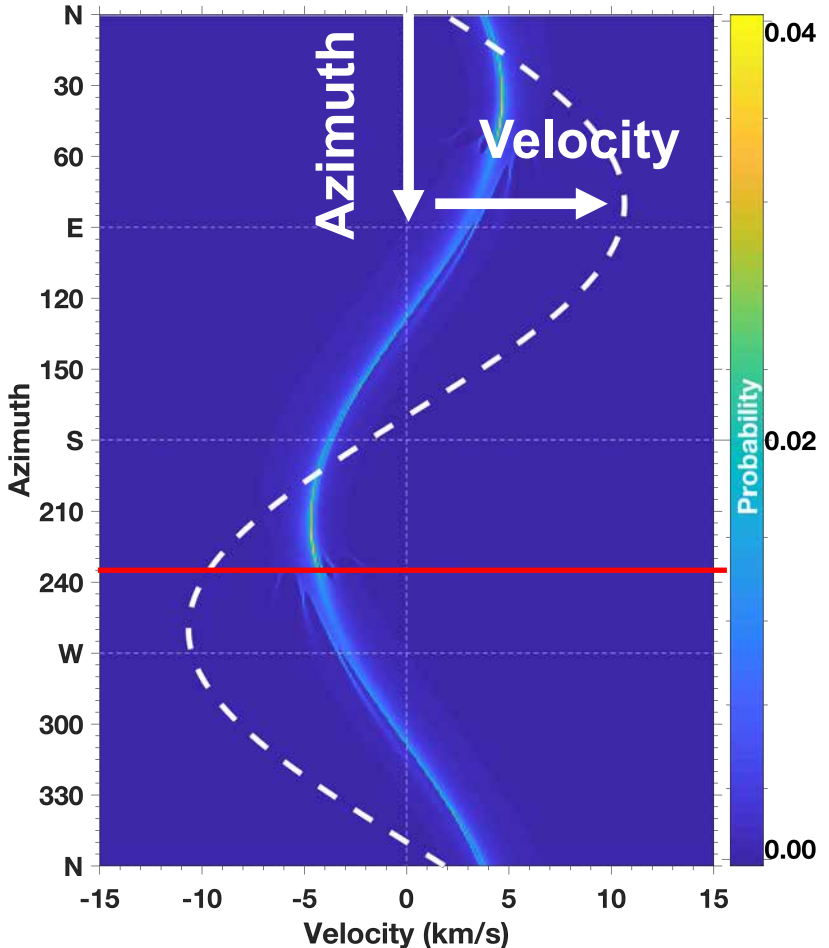
For
all azimuths



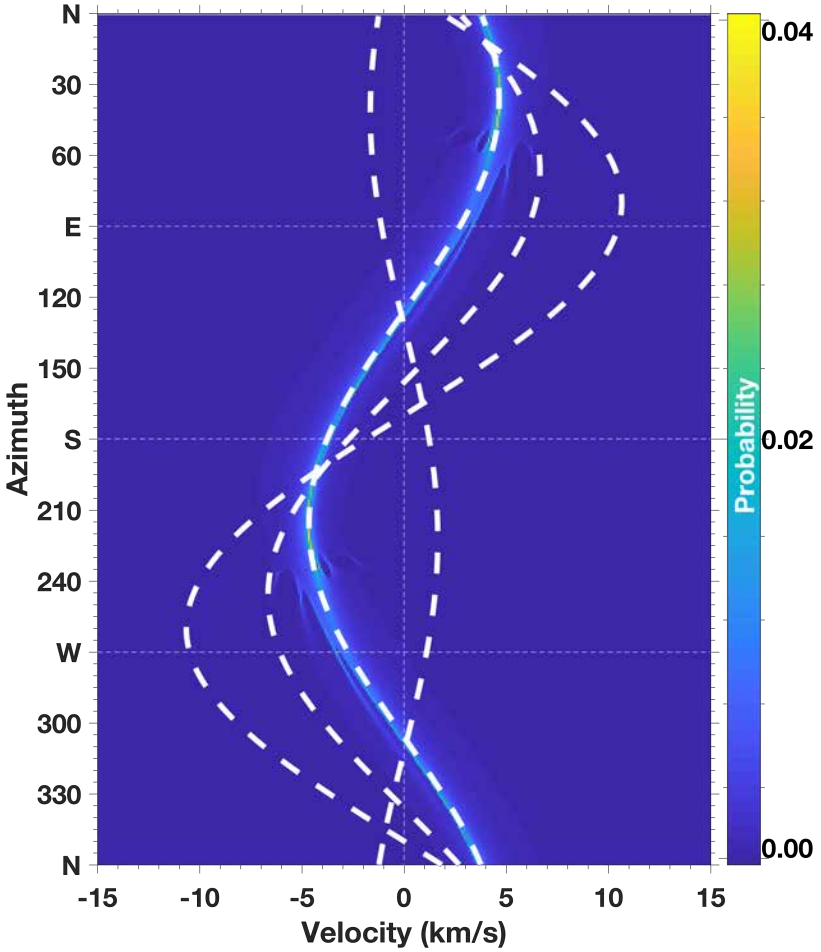
Probability analysis



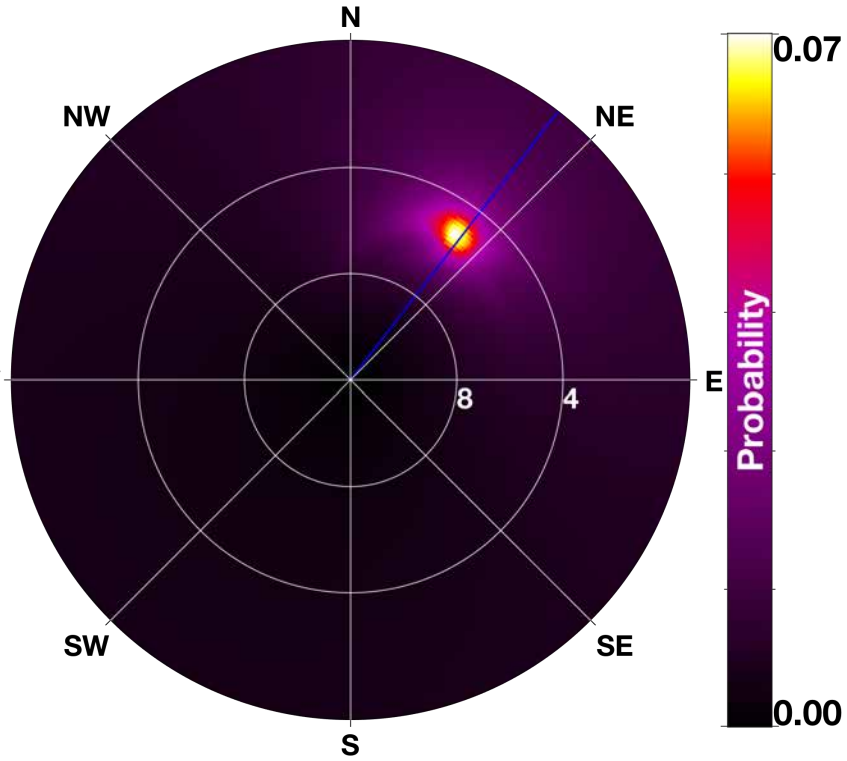
For all azimuths



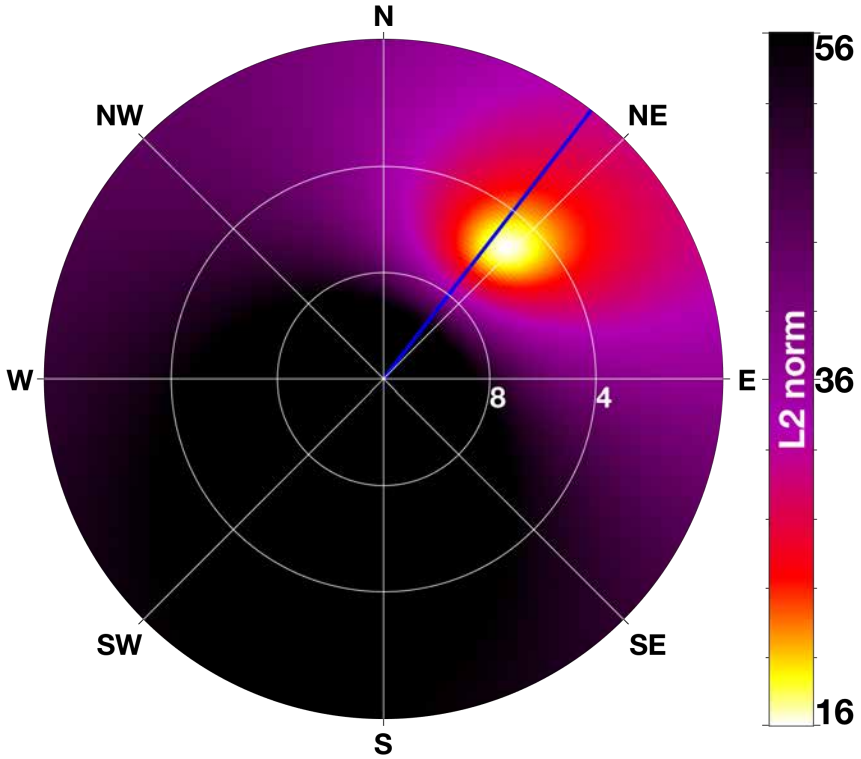
Transform



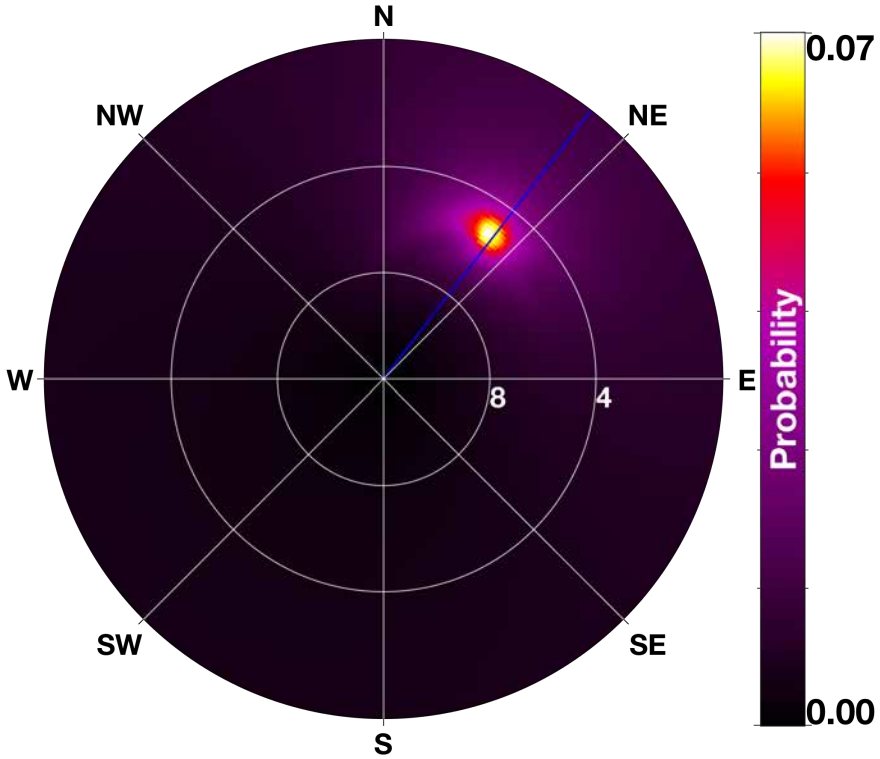
Grid search



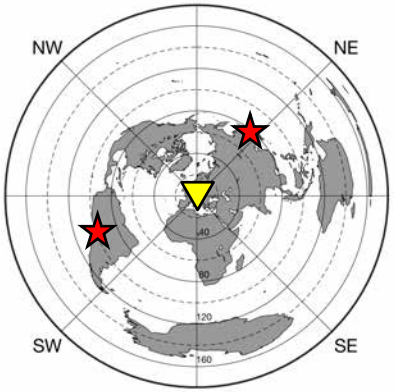
L2 norm between Rot & Tra



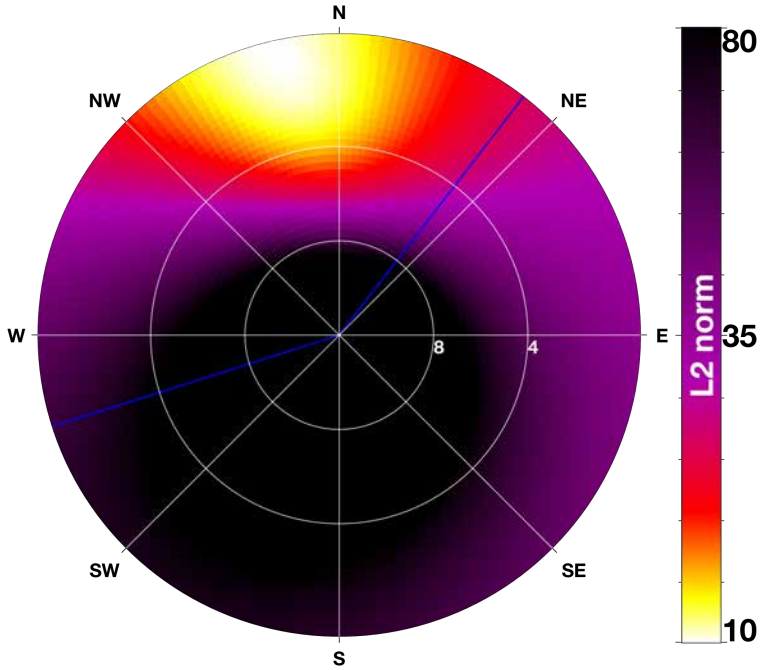
Probability-based approach (proposed approach)



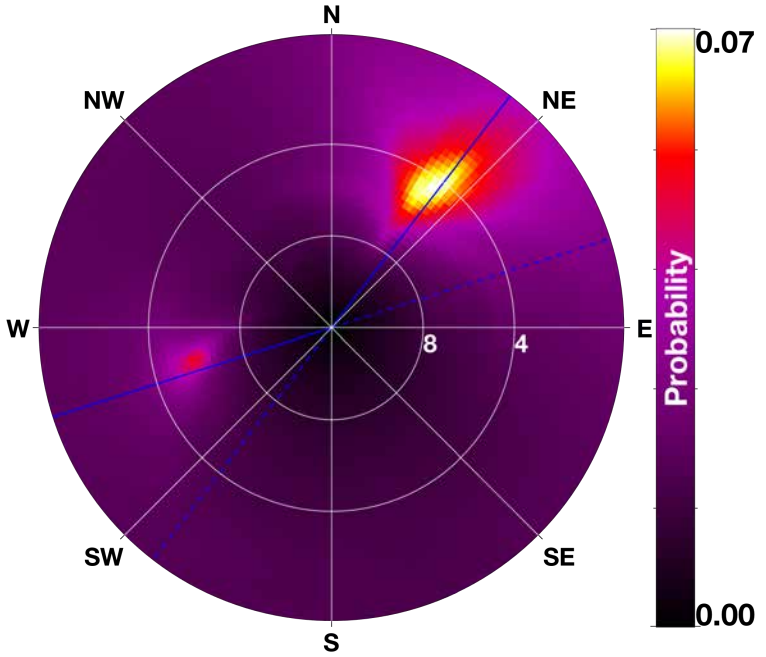
Two waves arrive at same time
(Synthetic data by adding two EQ data)



L2 norm between Rot & Tra



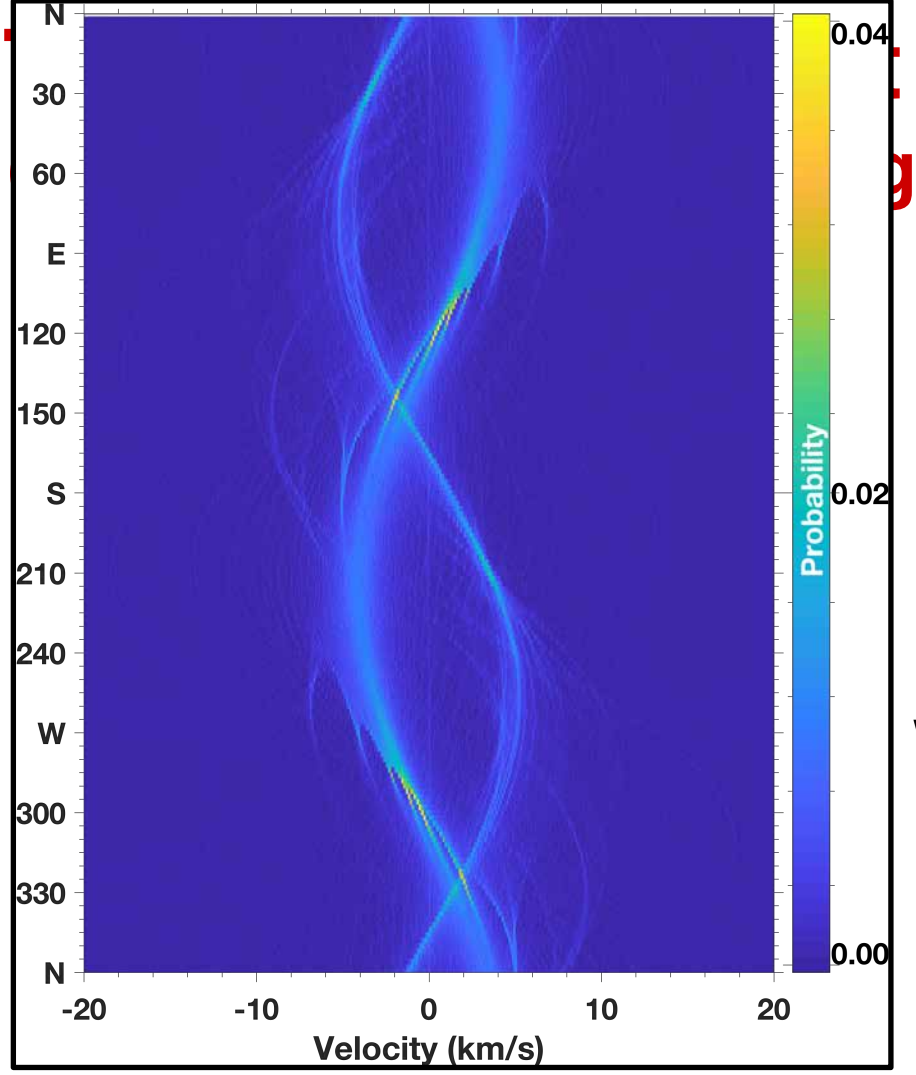
Probability-based approach

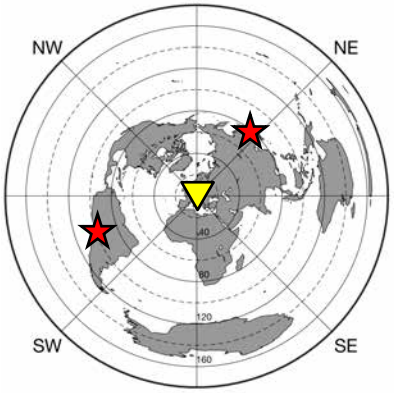


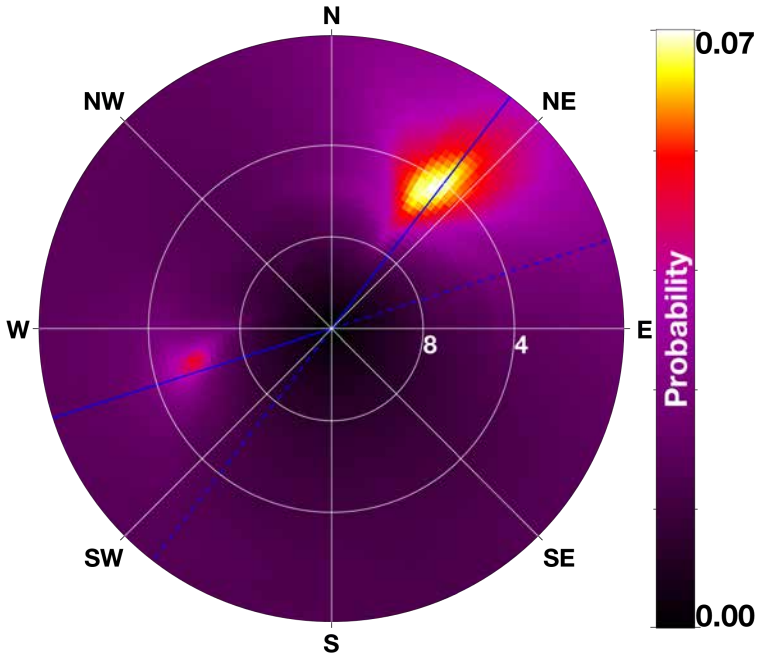
same time

g two EQ data)

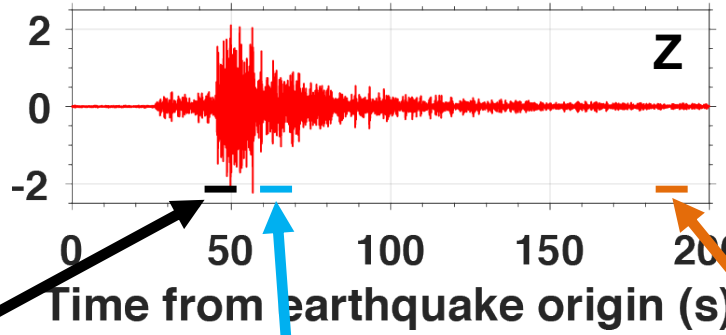
Probability-based approach

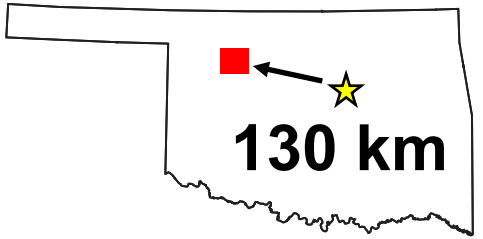




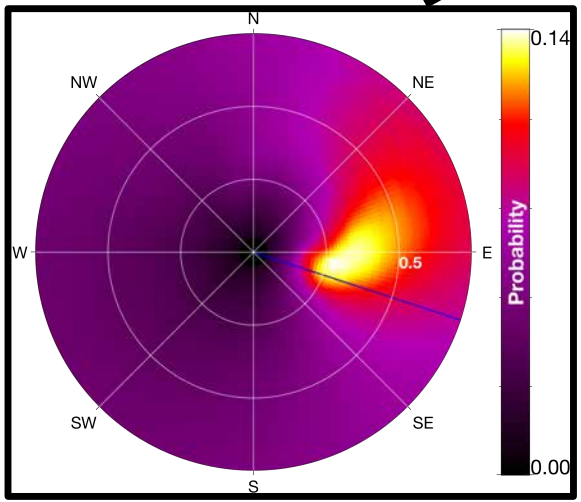


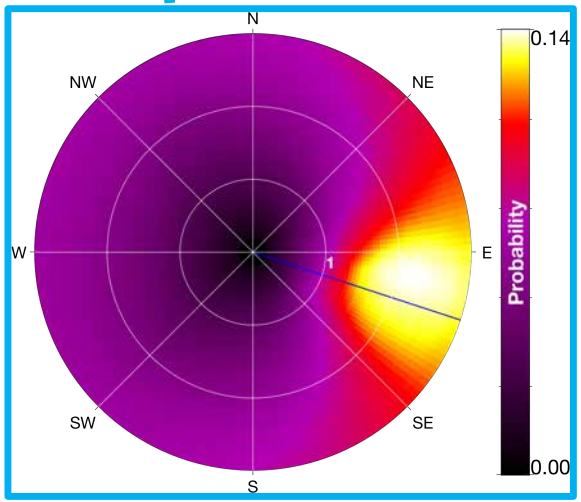
6C beamforming (back to OK data)

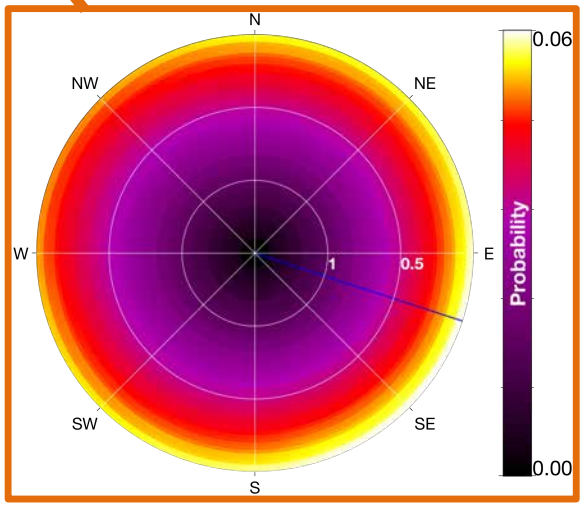




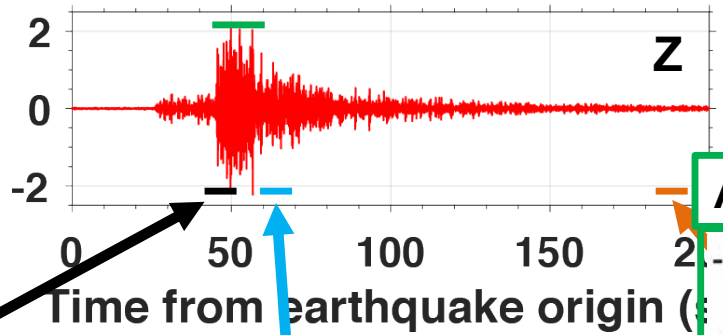
1.0-1.5 Hz

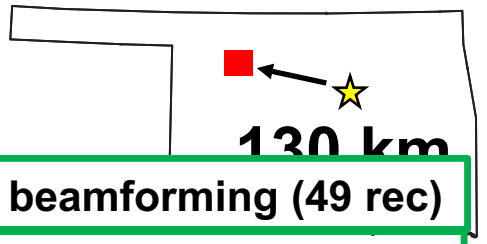




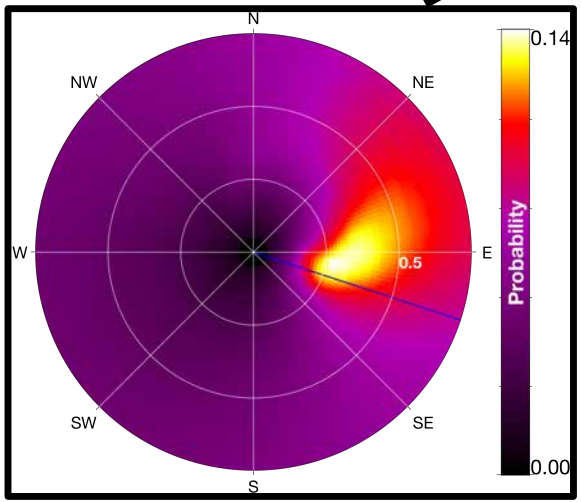


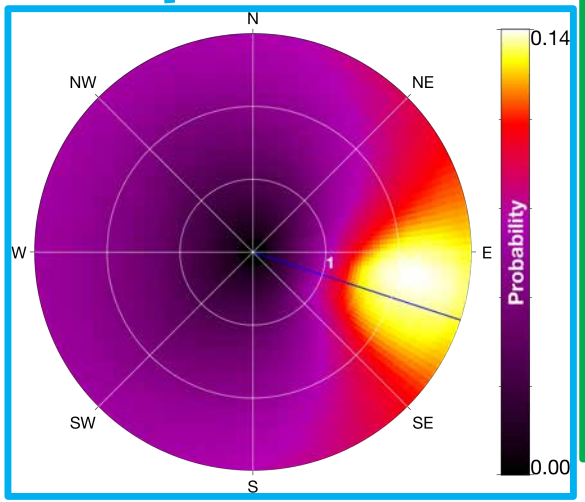
6C beamforming

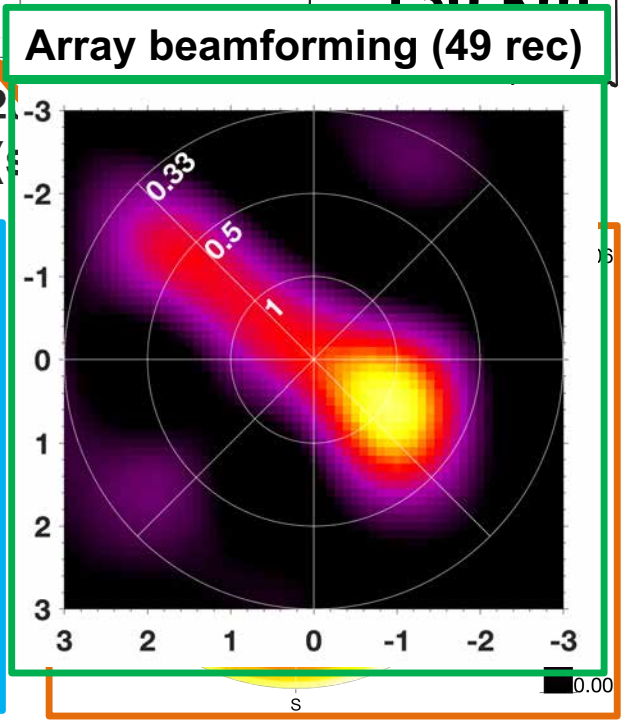




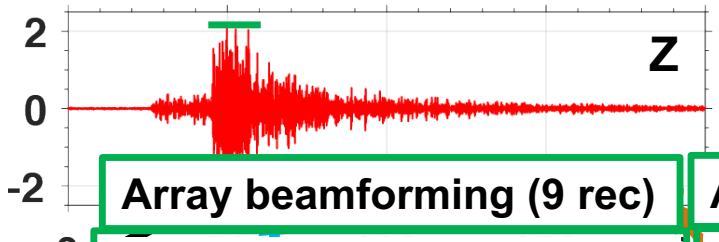
1.0-1.5 Hz

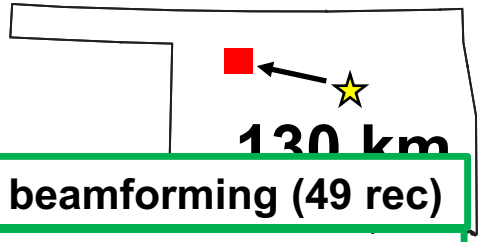




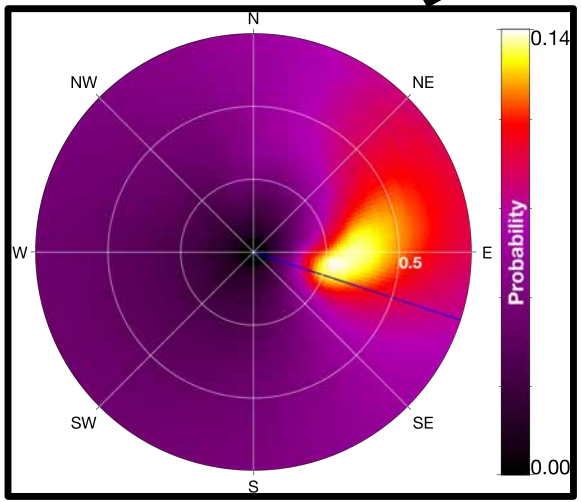


6C beamforming

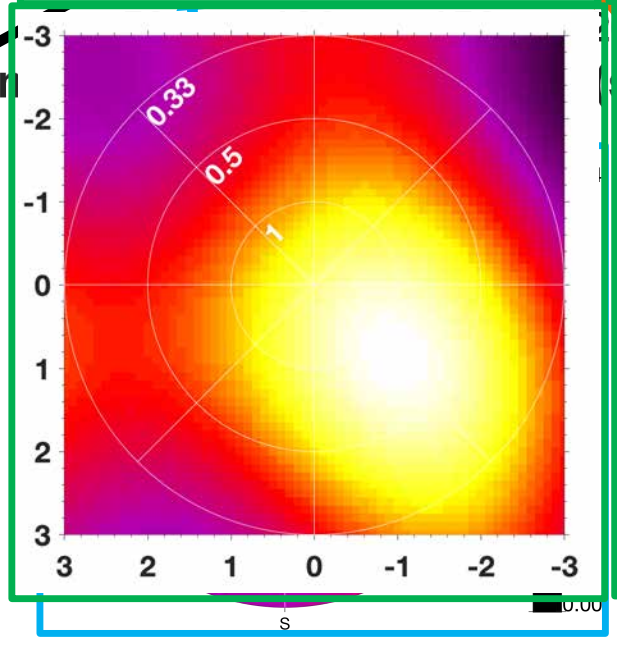




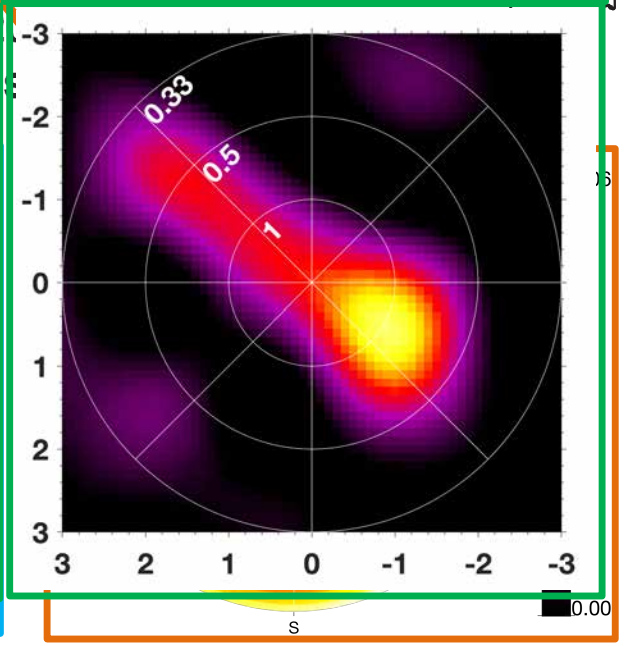
1.0-1.5 Hz



Array beamforming (9 rec)

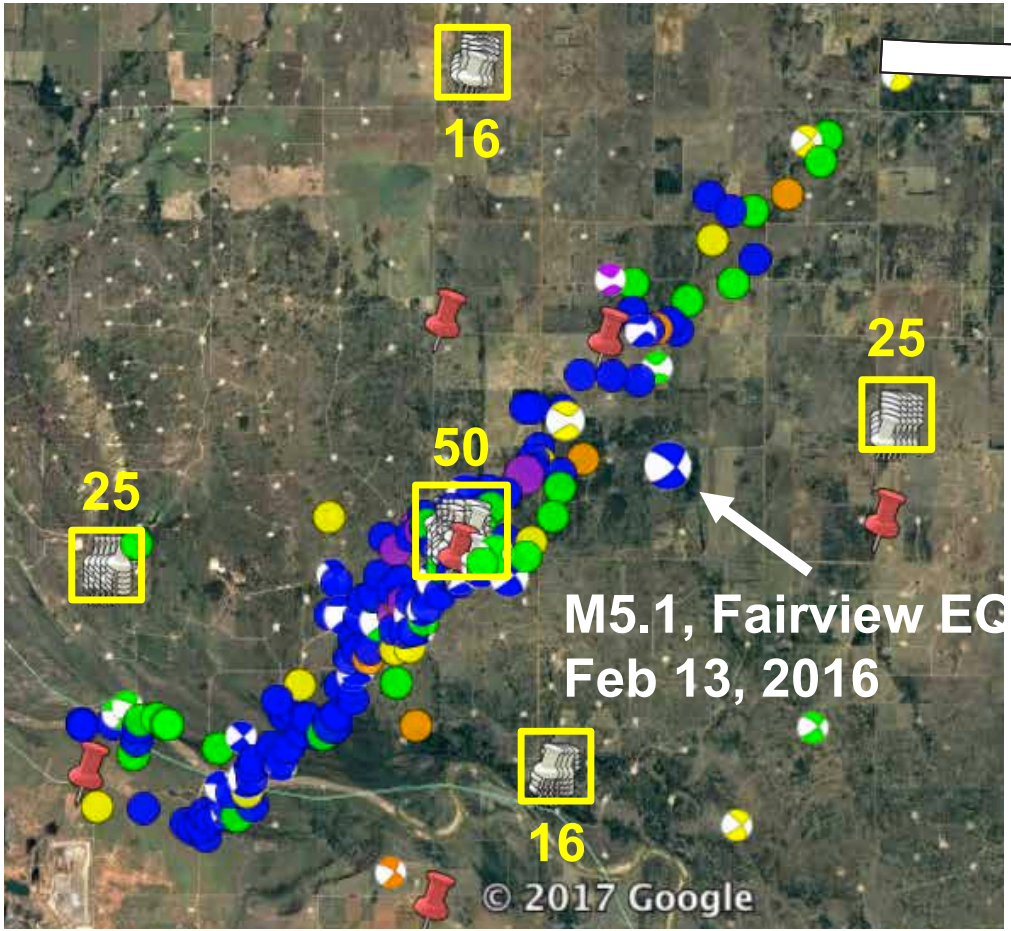


Array beamforming (49 rec)

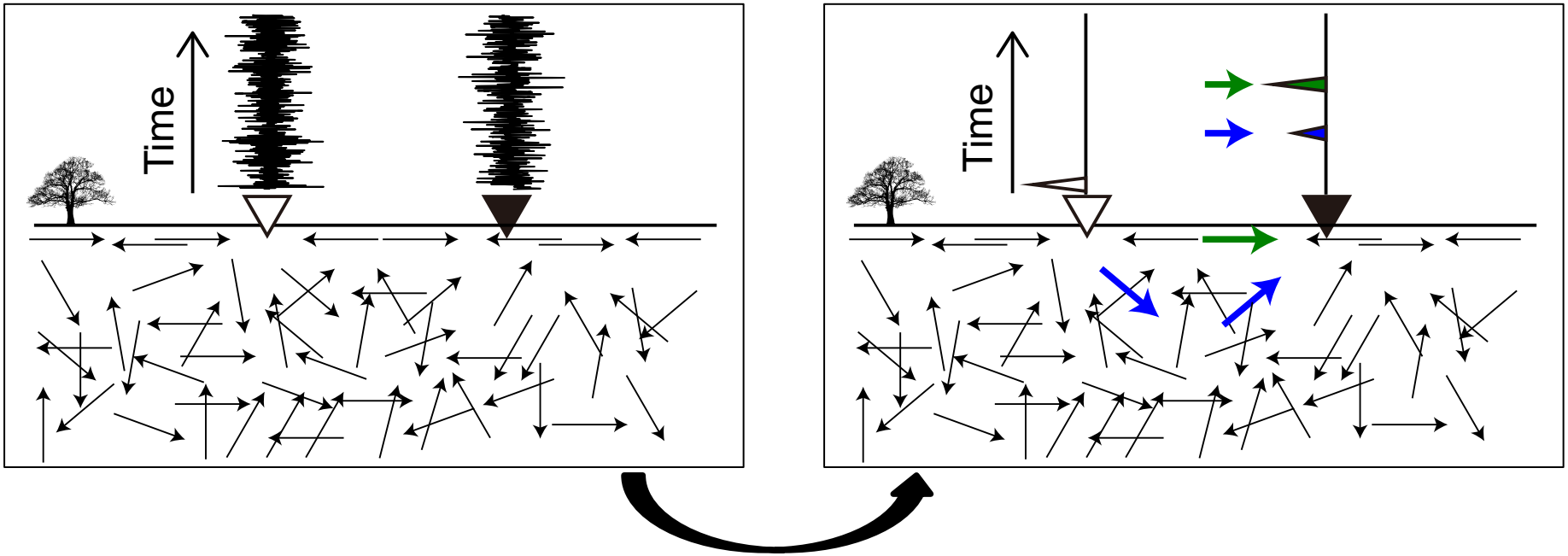


Geophone arrays

- Fairfield 5Hz, 3C
- 132 receivers
- Total 2 months in 2017



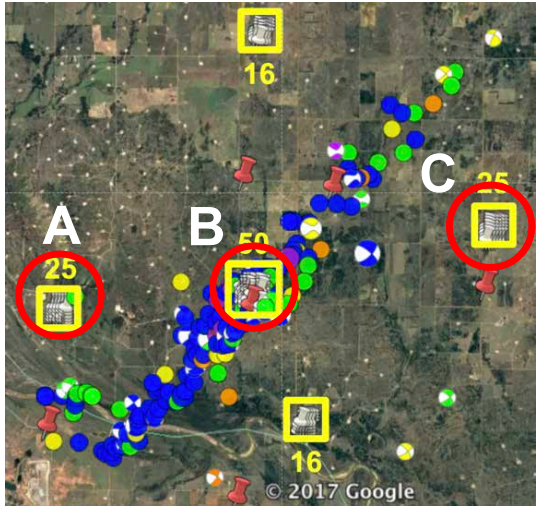
Ambient-noise correlation

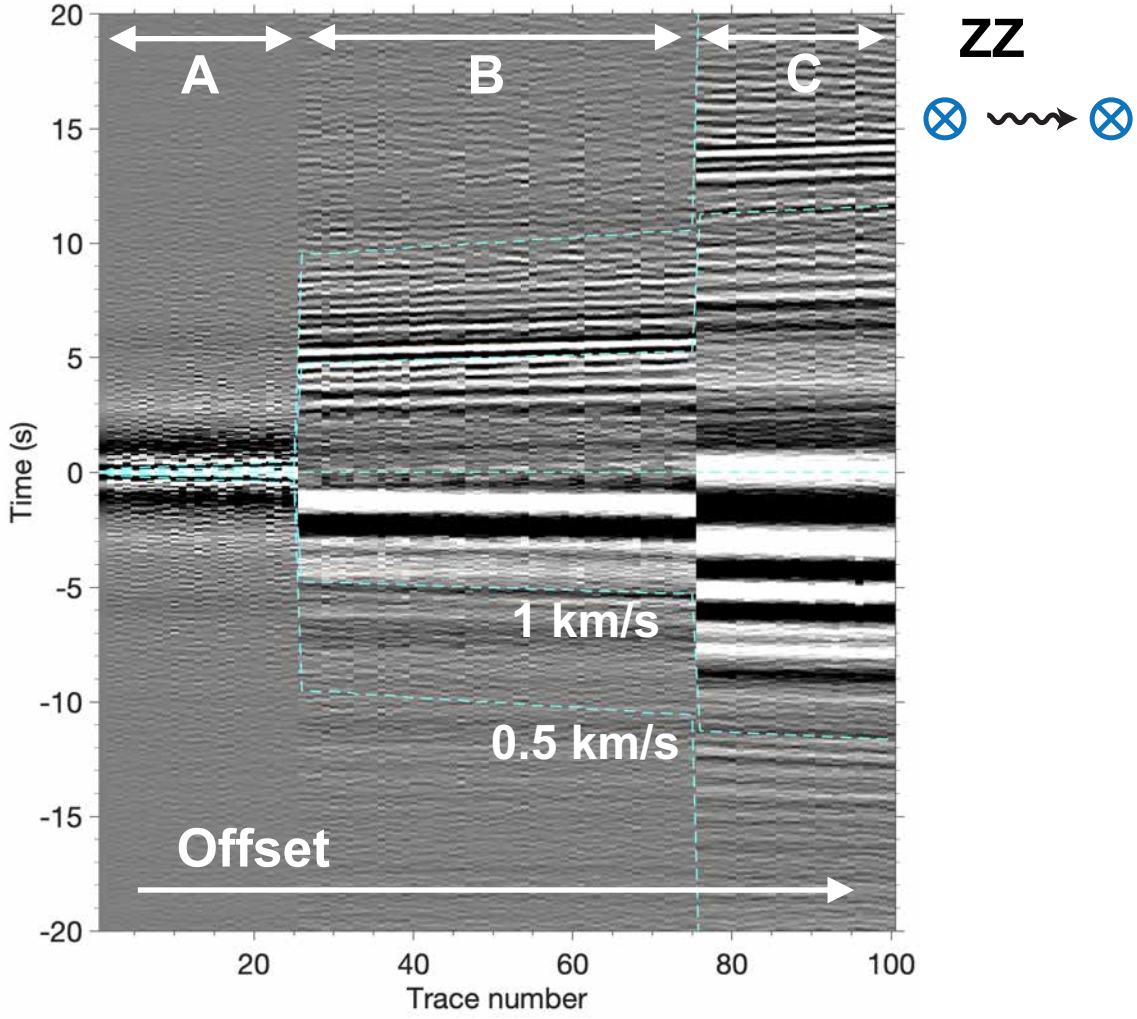


Processing

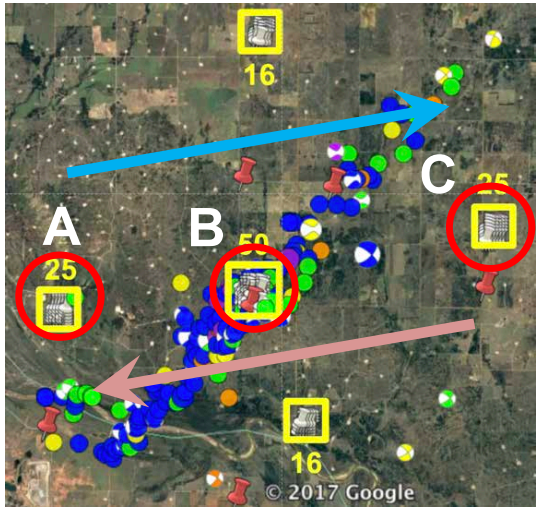
Crosscorrelation & more

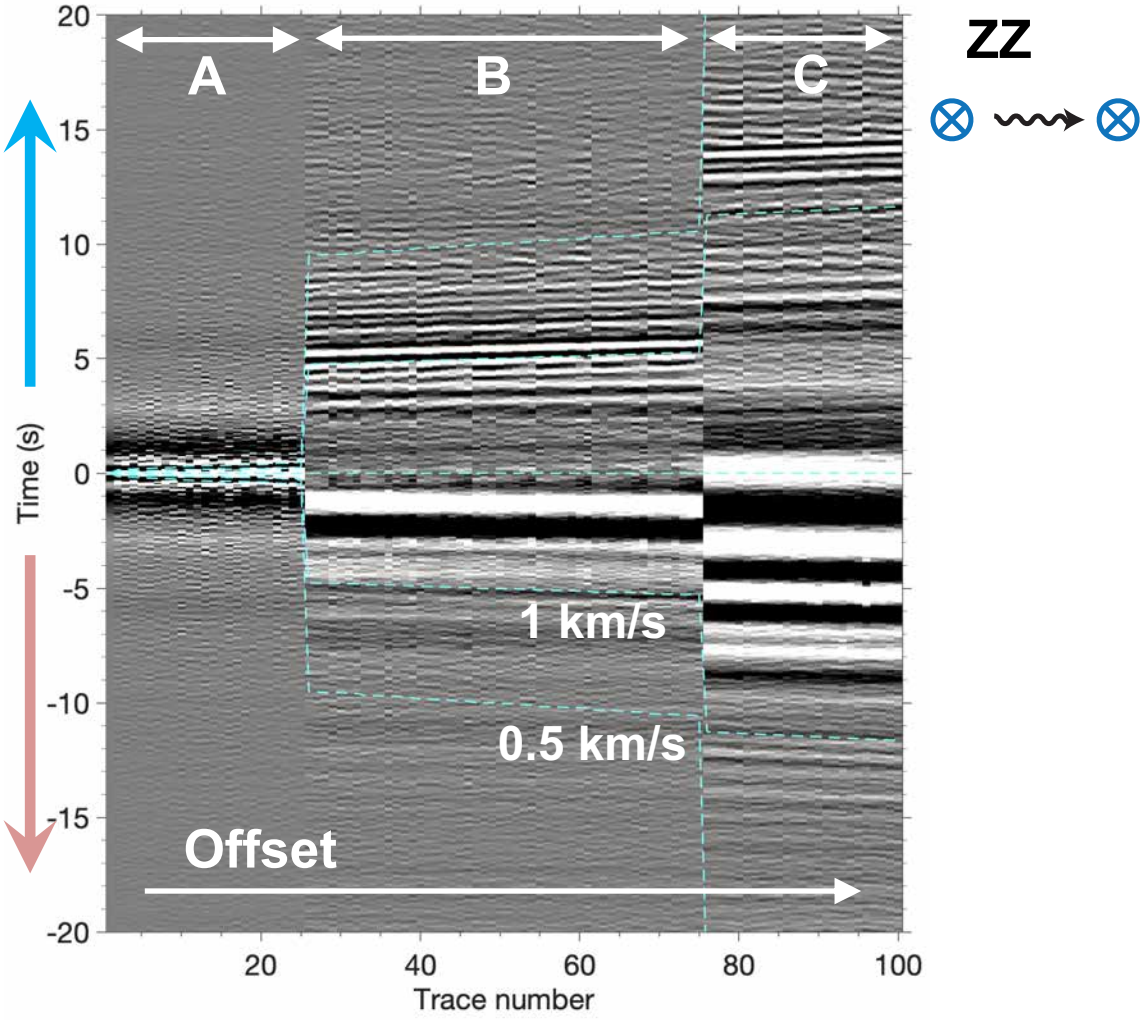
Ambient noise correlation



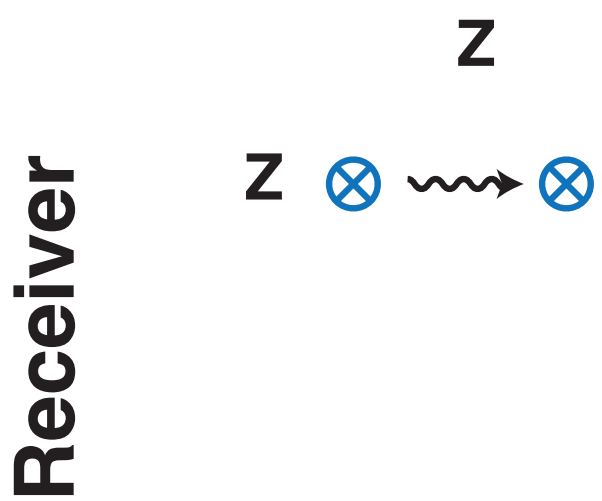


Ambient noise correlation

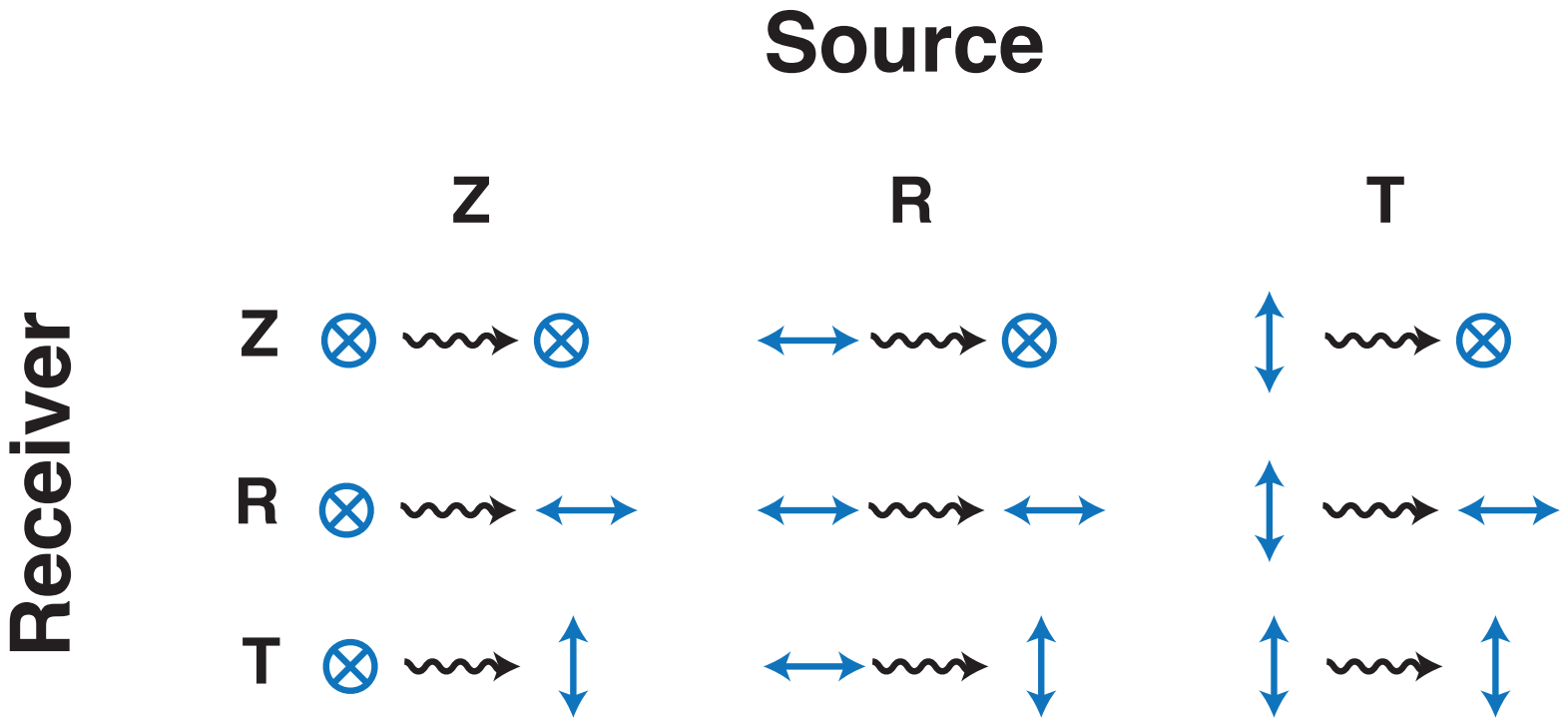




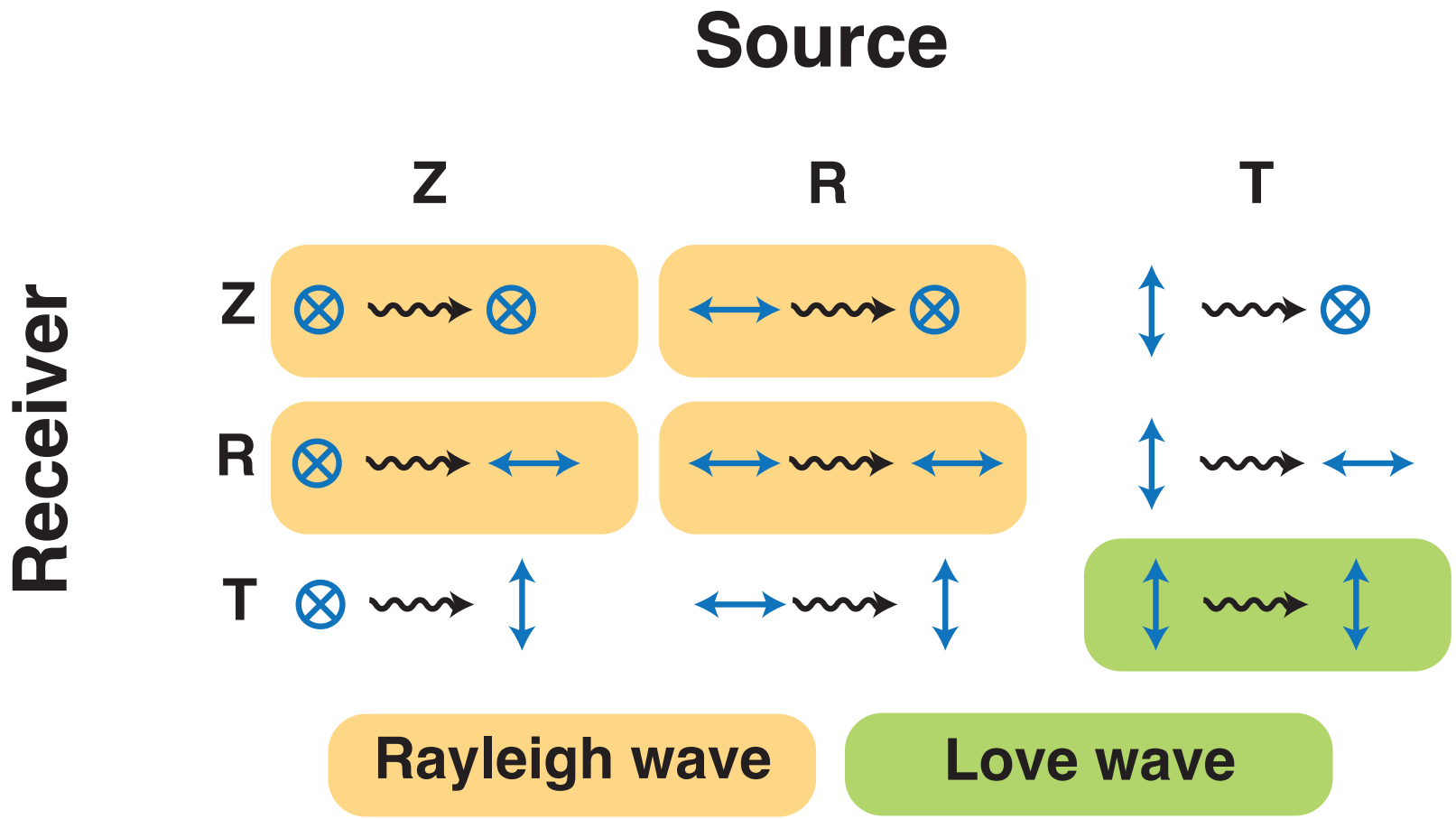
1C ambient-noise correlation

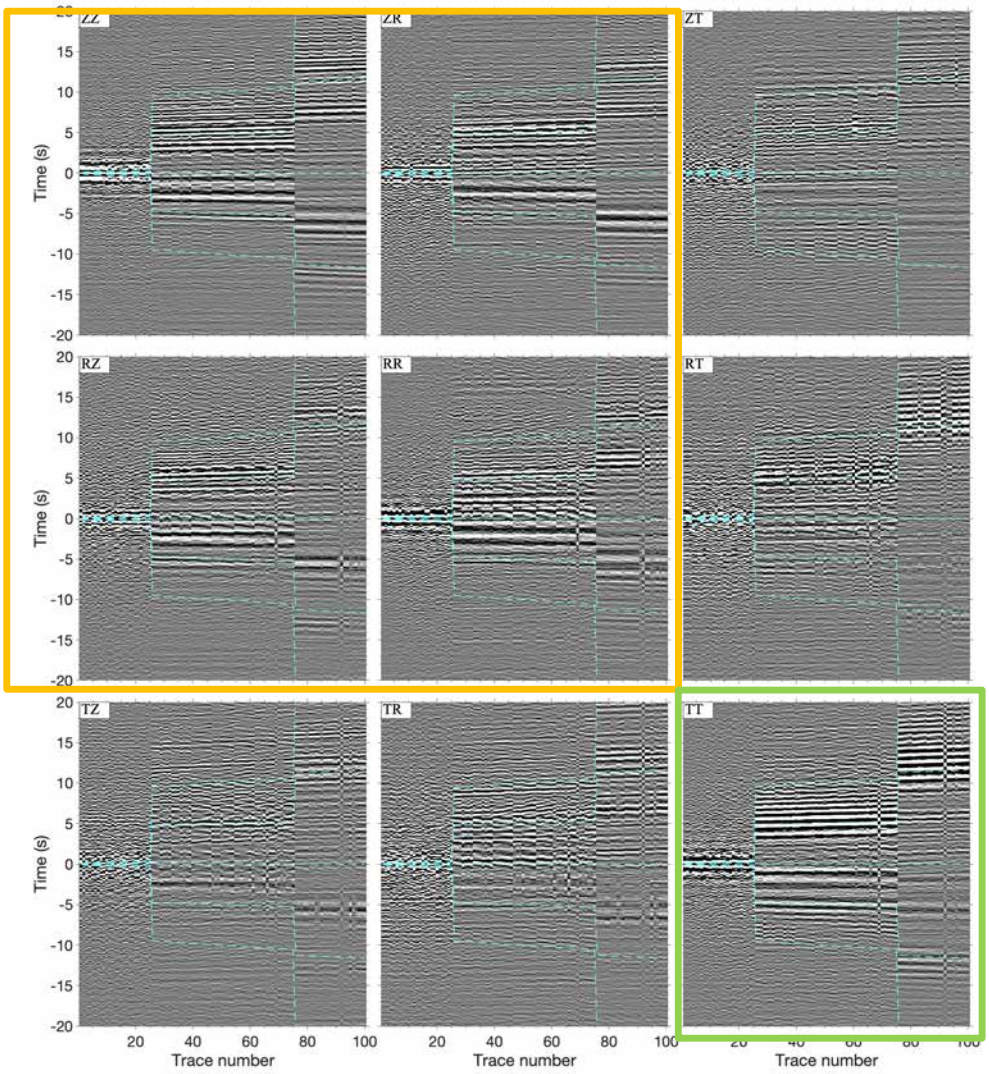


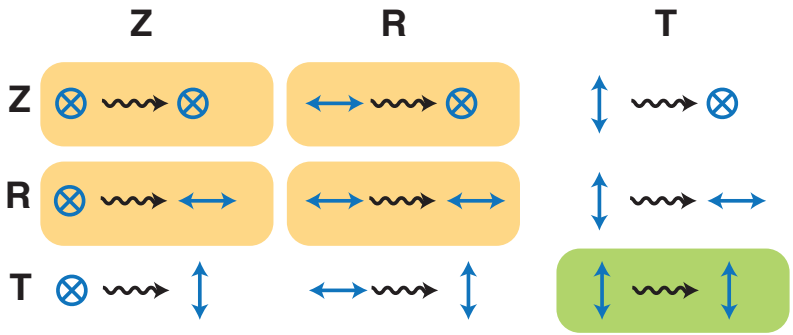
9C ambient-noise correlation



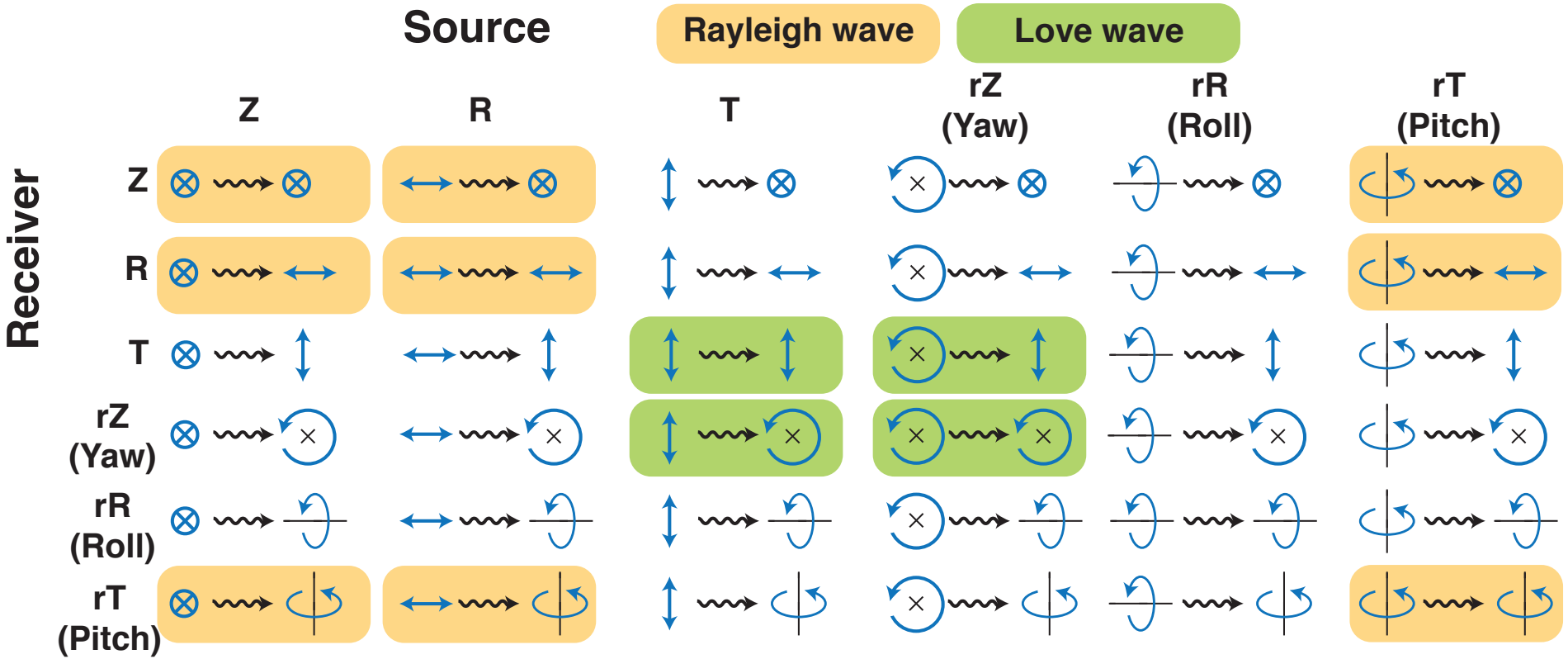
9C ambient-noise correlation



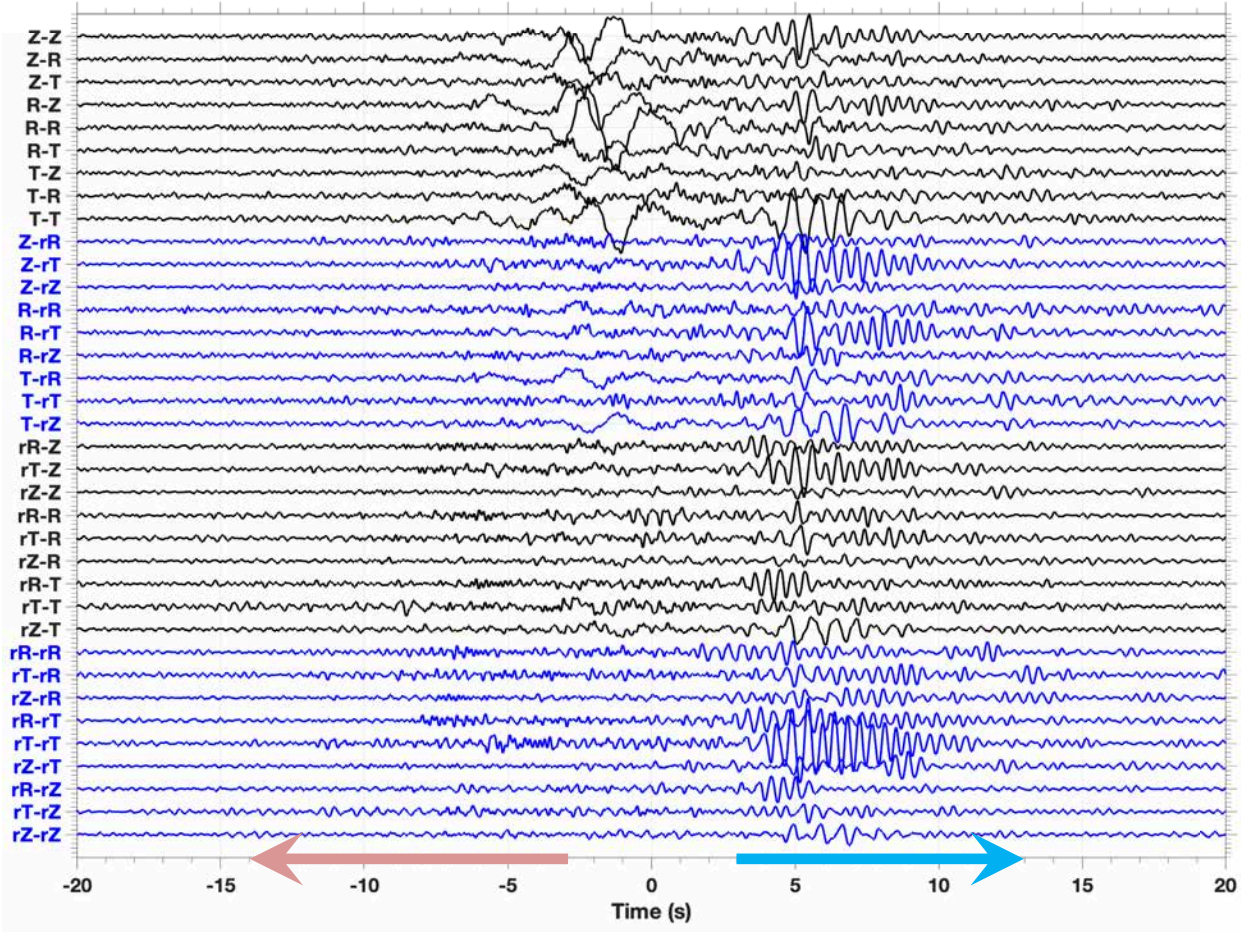

ZZ
ZR
ZT
RZ
RR
RT
TZ
TR
TT
Time (s)
Trace number

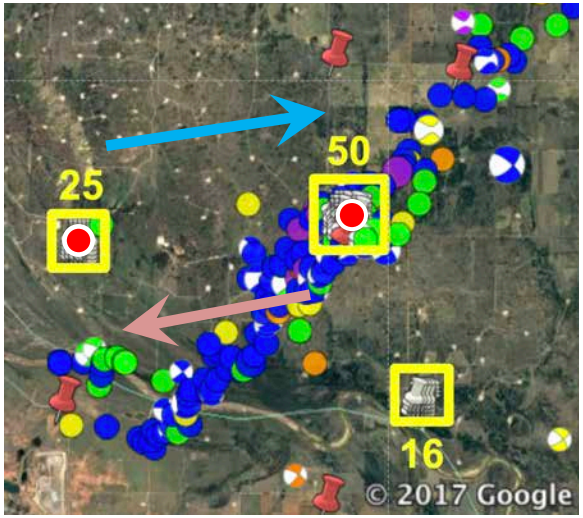

Z
R
T
Z
R
T

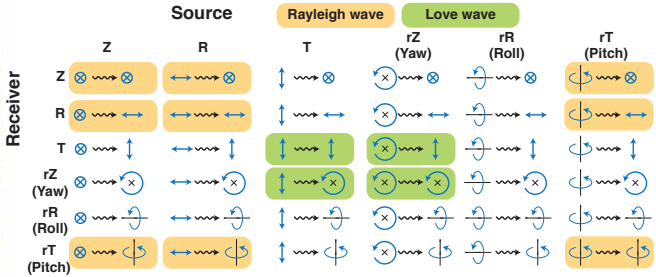
36C ambient-noise correlation



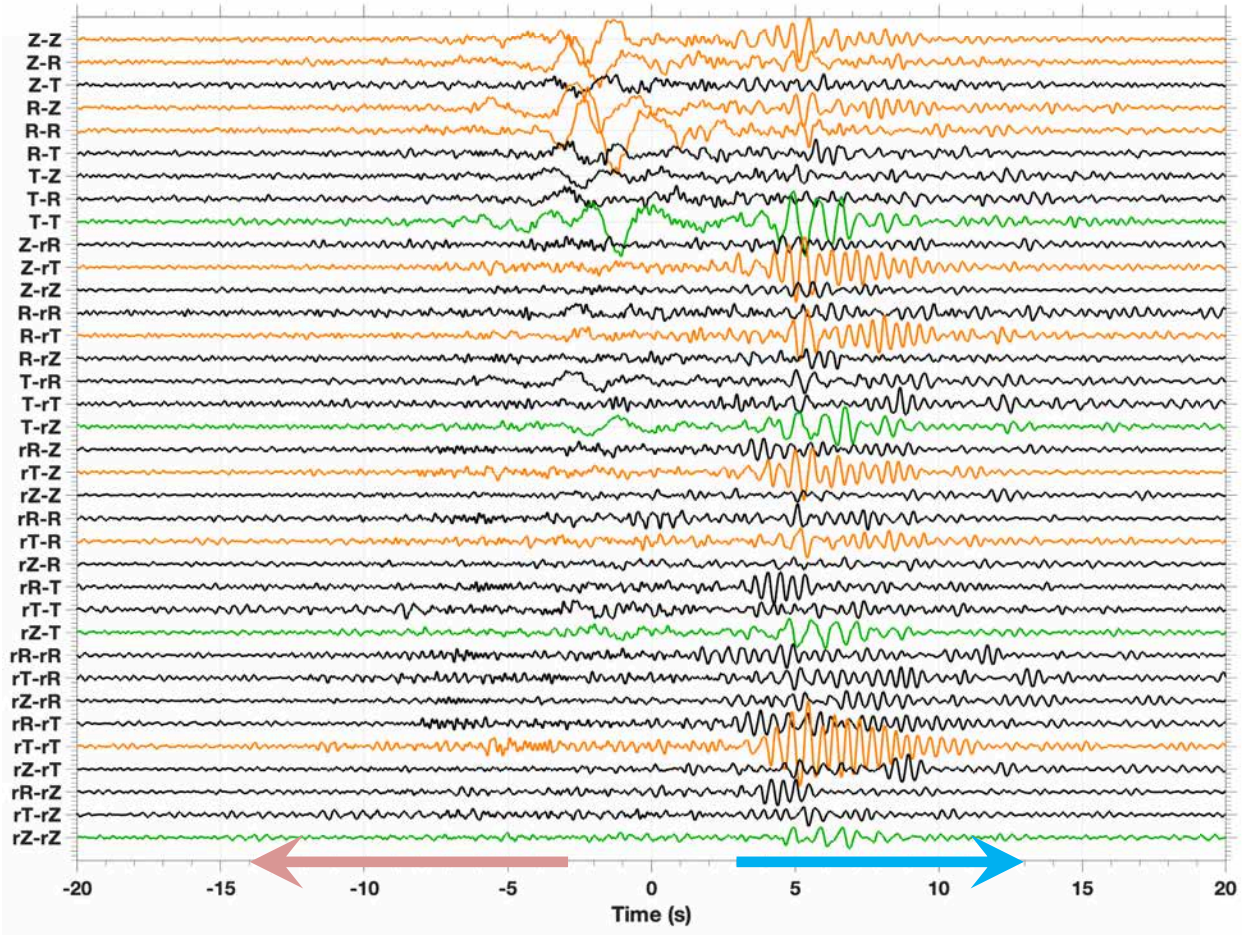
36C (two stations)

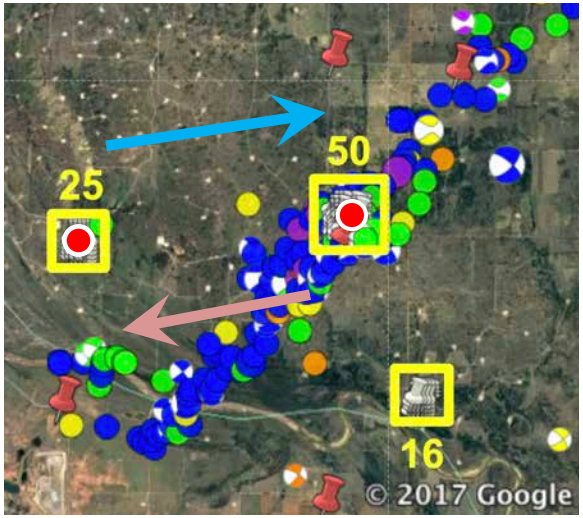


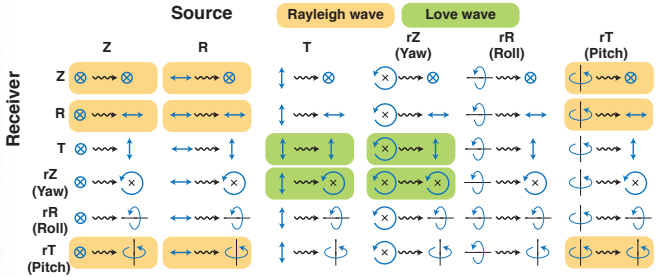




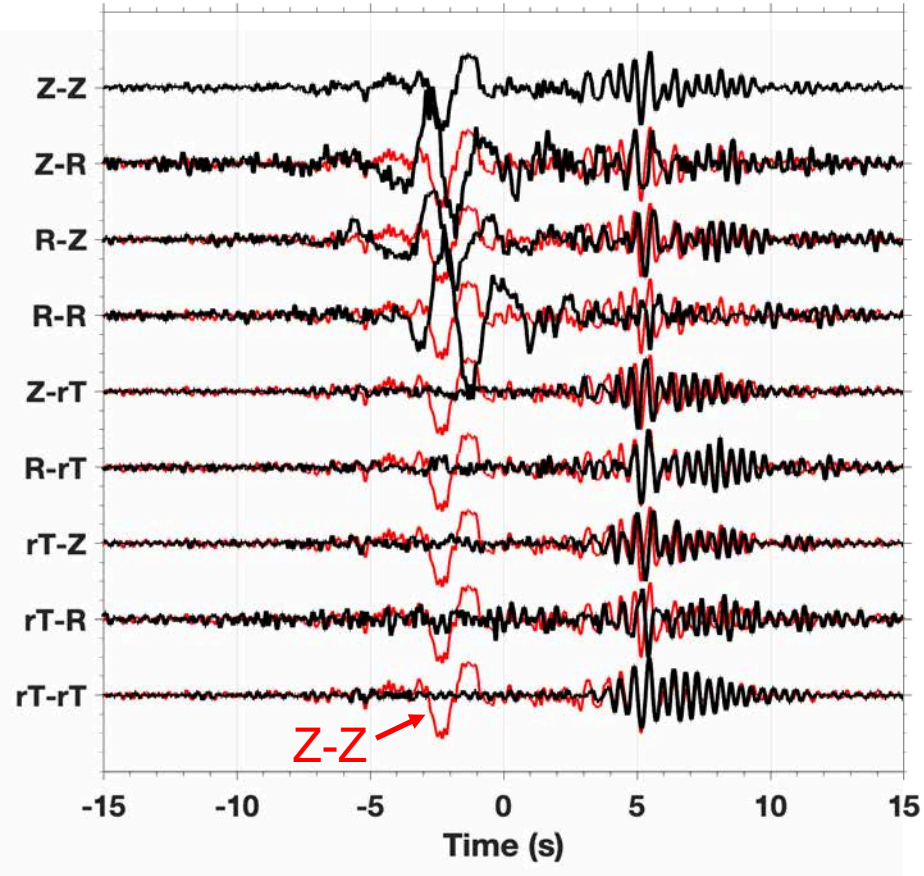
36C (two stations)



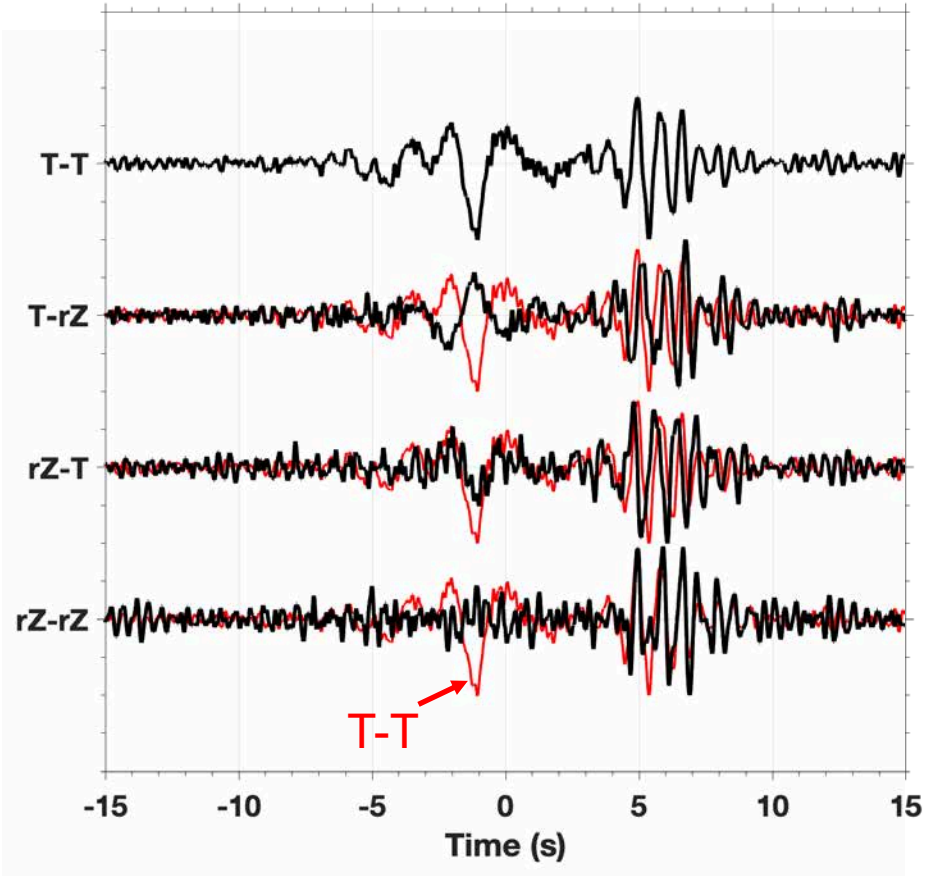




Rayleigh wave

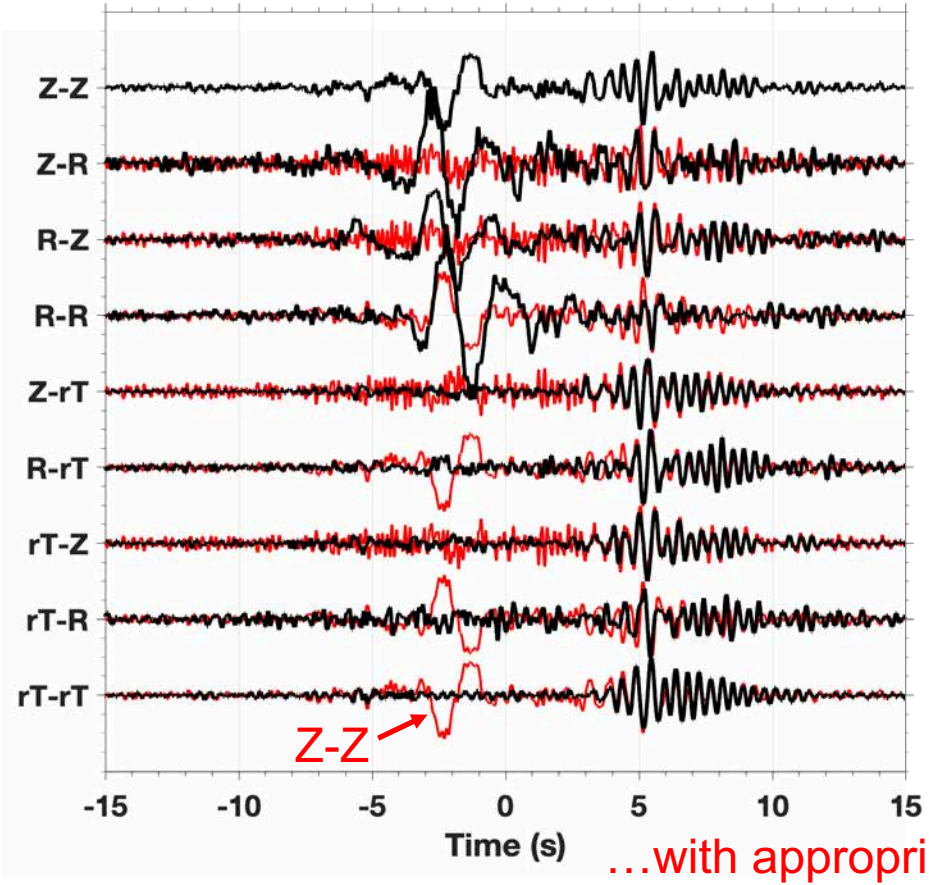


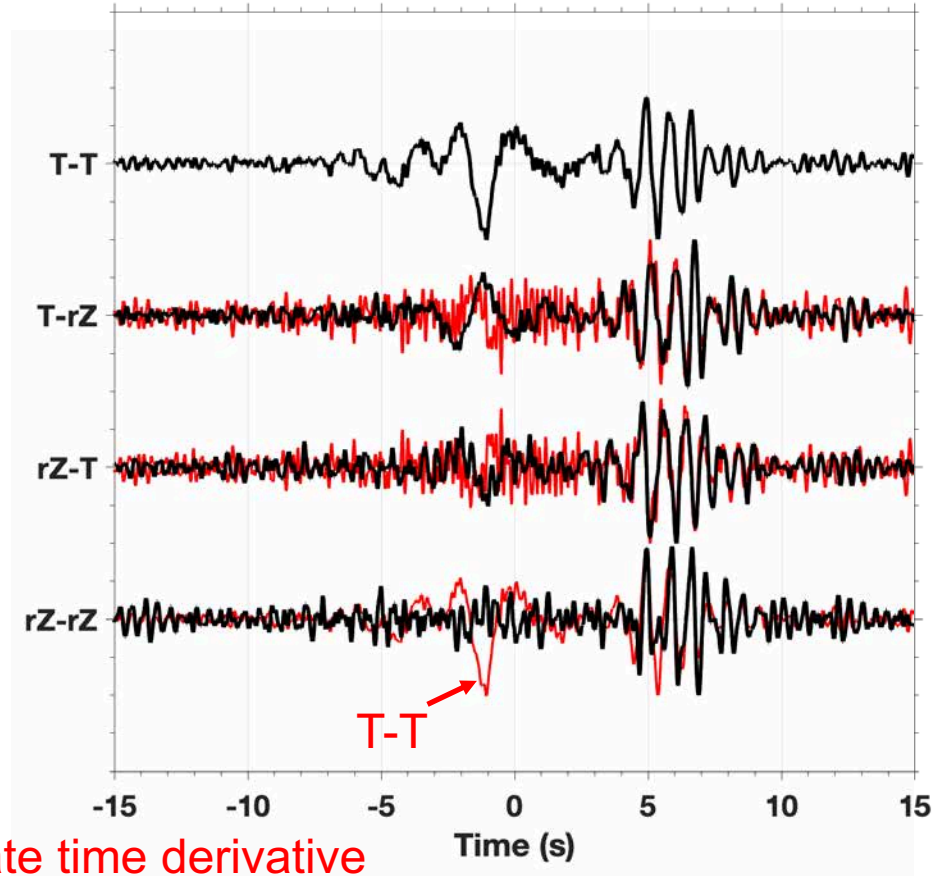
Love wave



Rayleigh wave

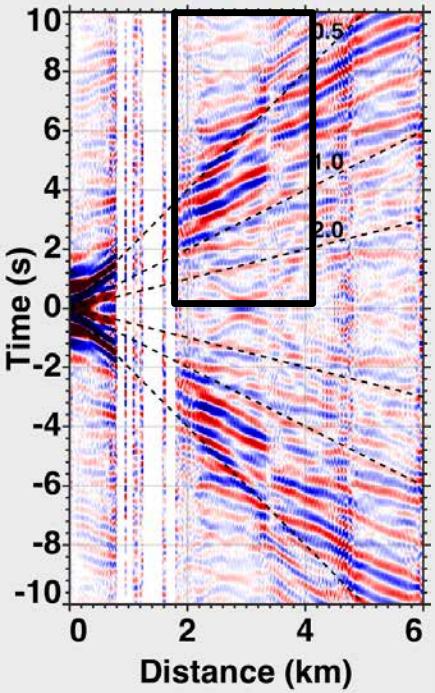
Love wave

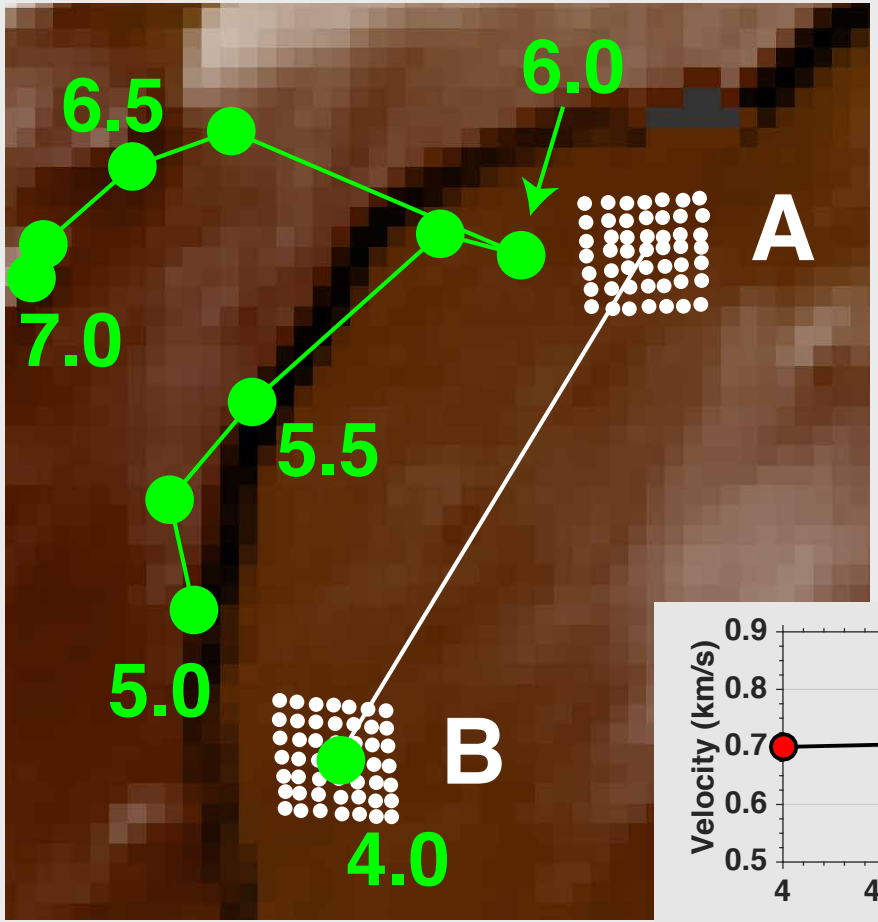


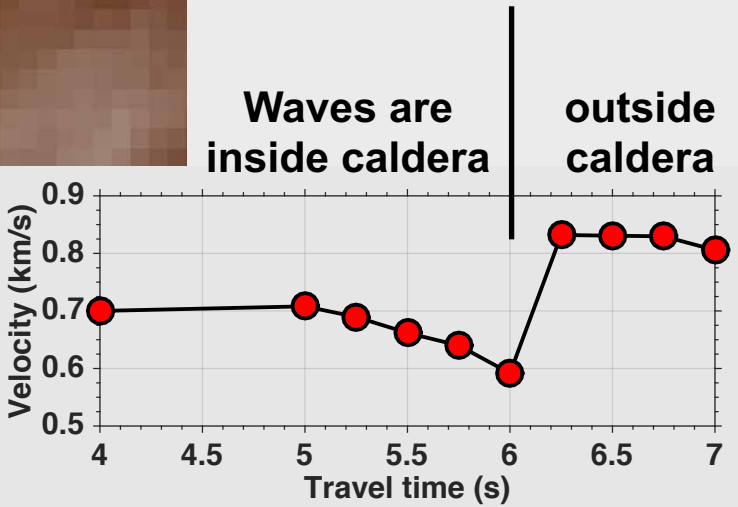


…with appropriate time derivative

Potential application: Reflected waves imaging



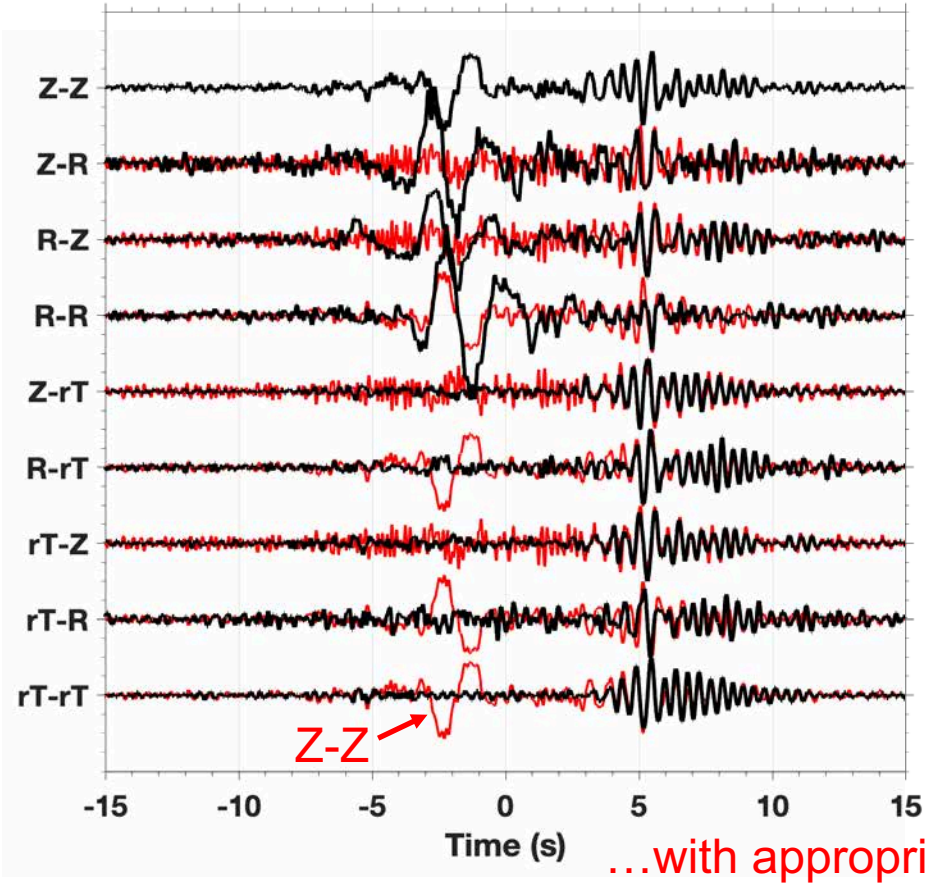


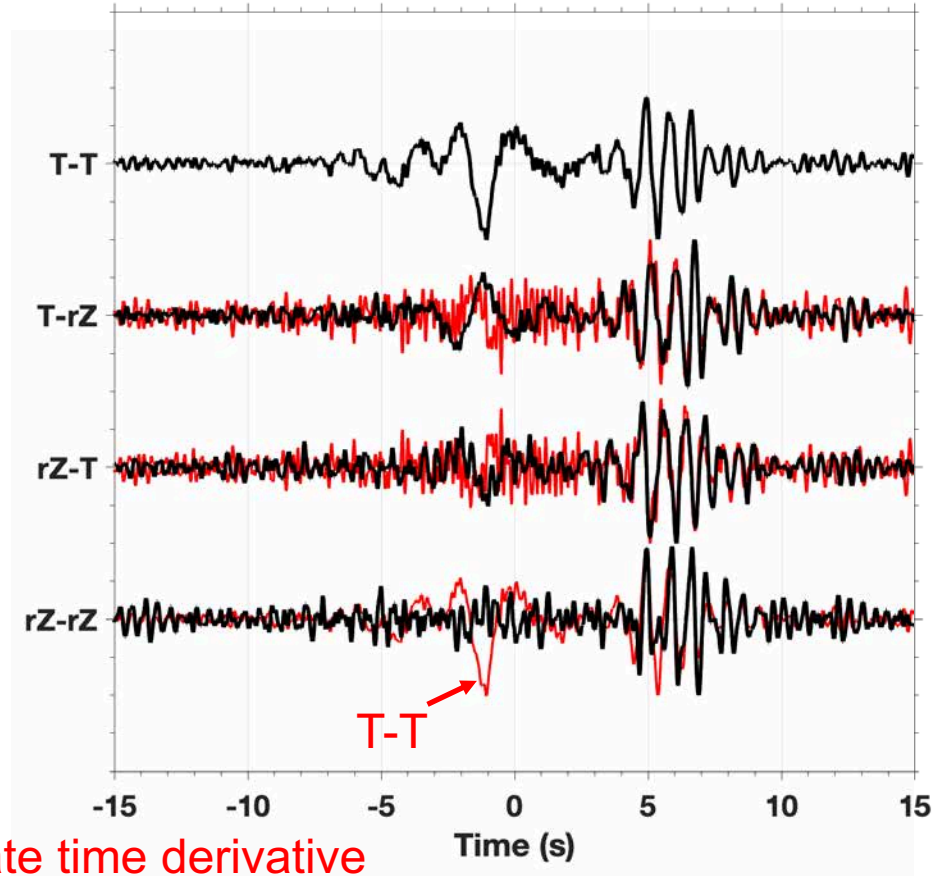


Nakata et al. (GRL, 2016)

Rayleigh wave

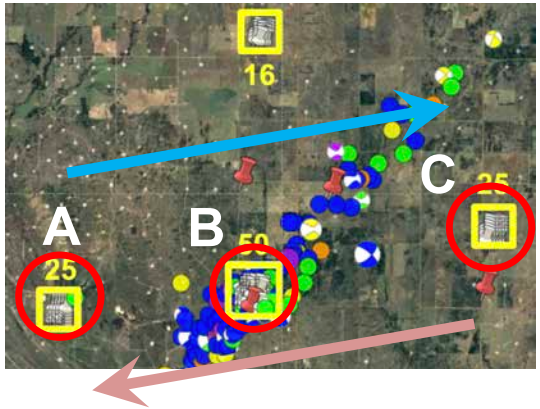
Love wave

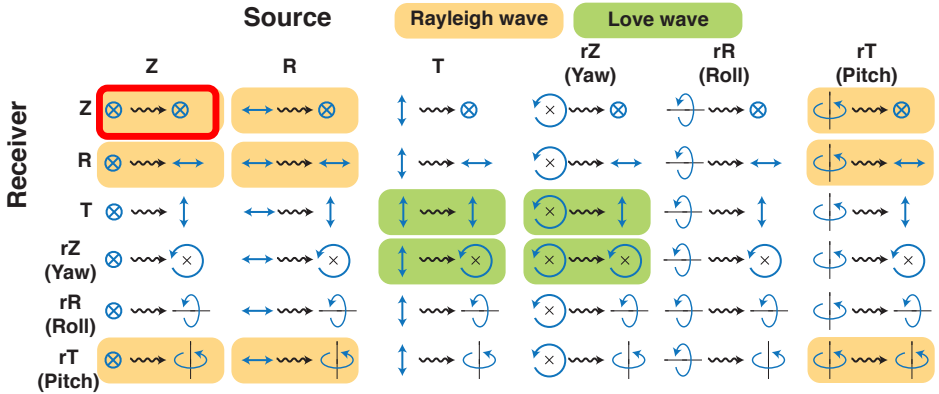


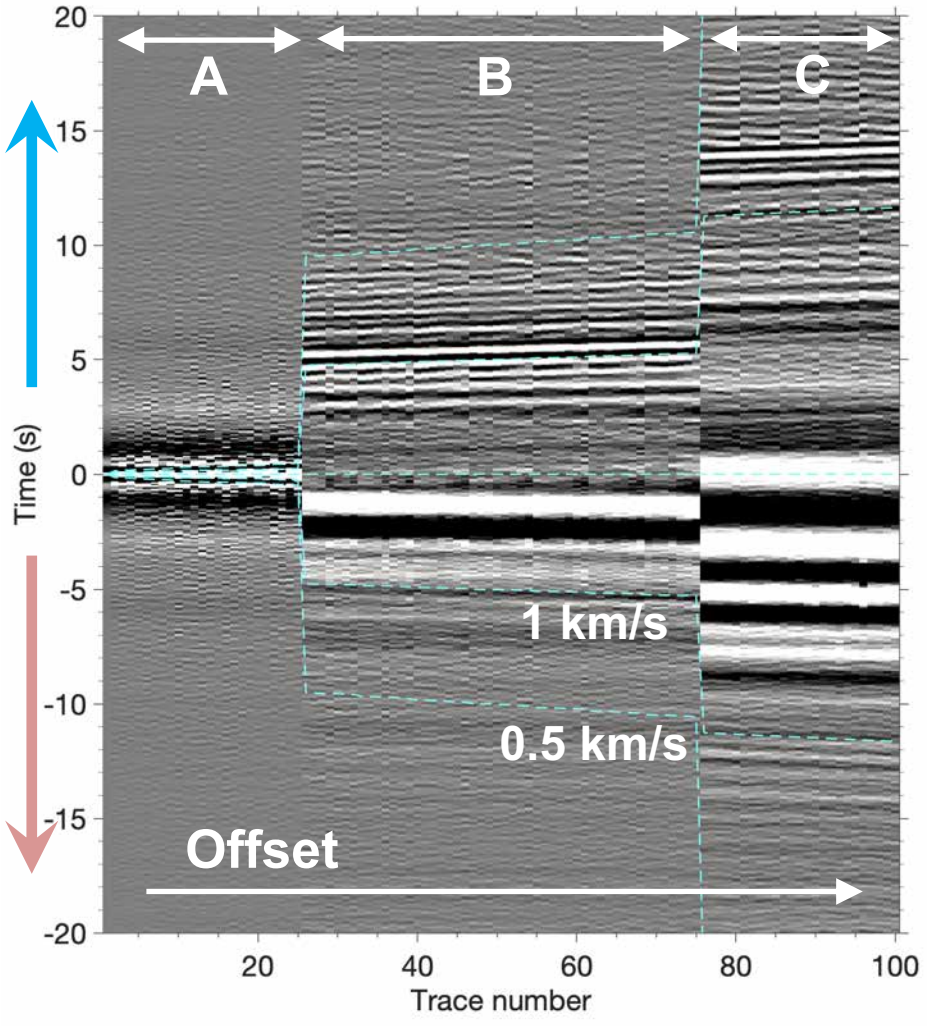


…with appropriate time derivative

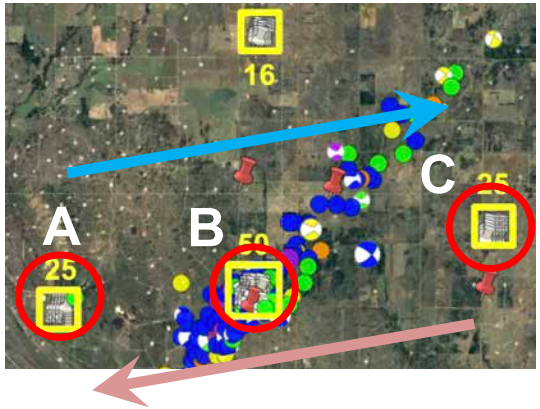
Ambient noise correlation

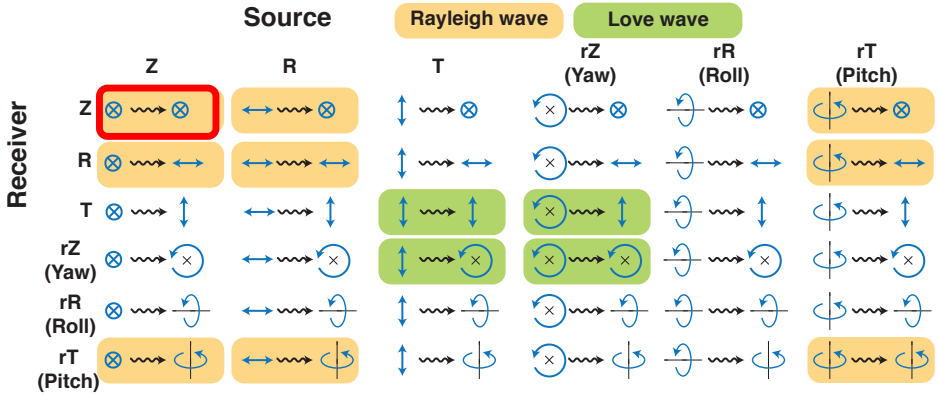


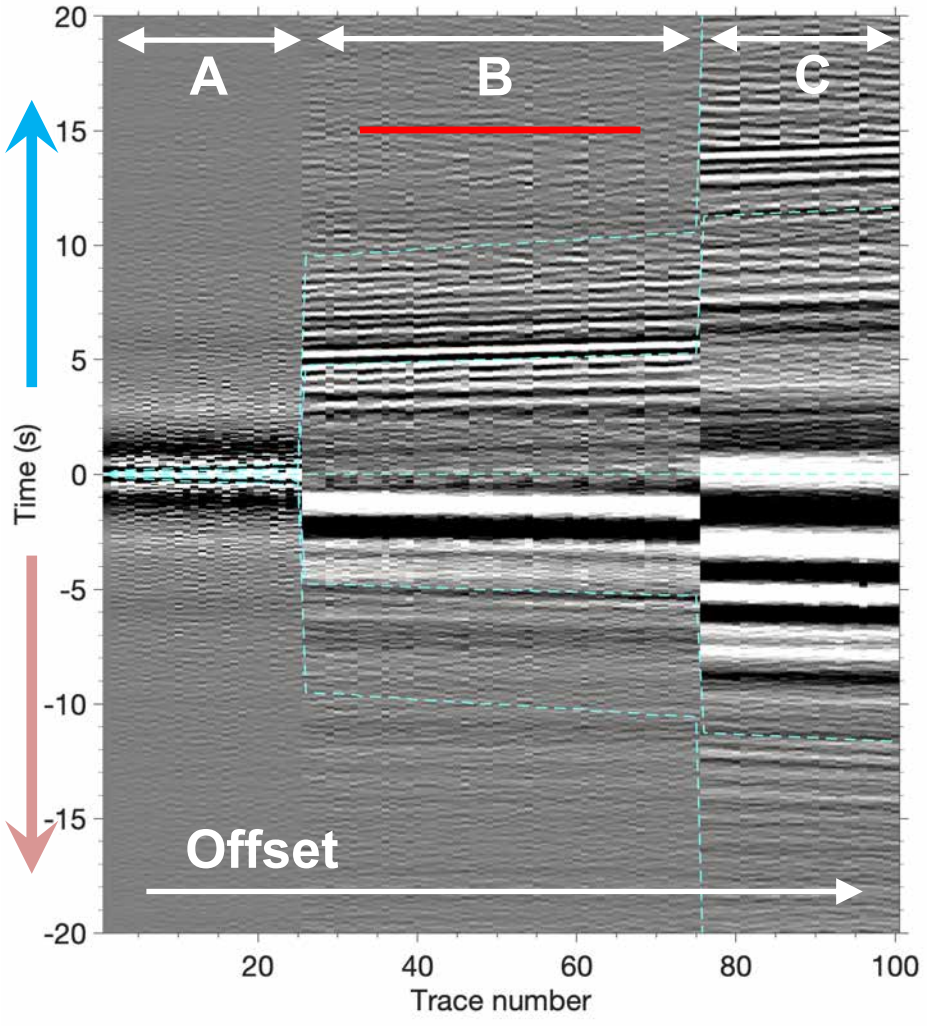




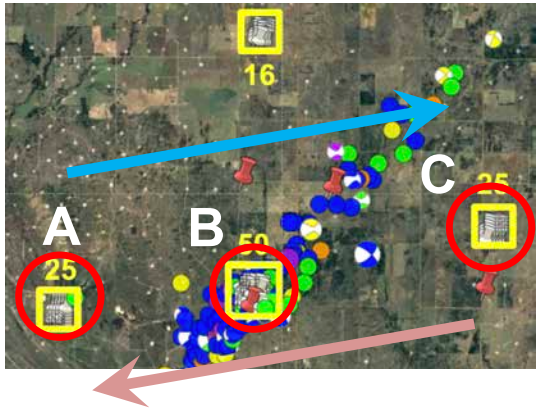
Ambient noise correlation

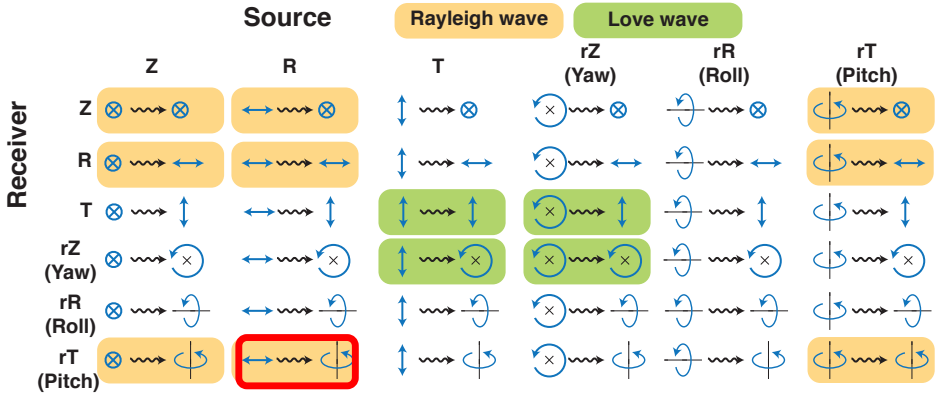


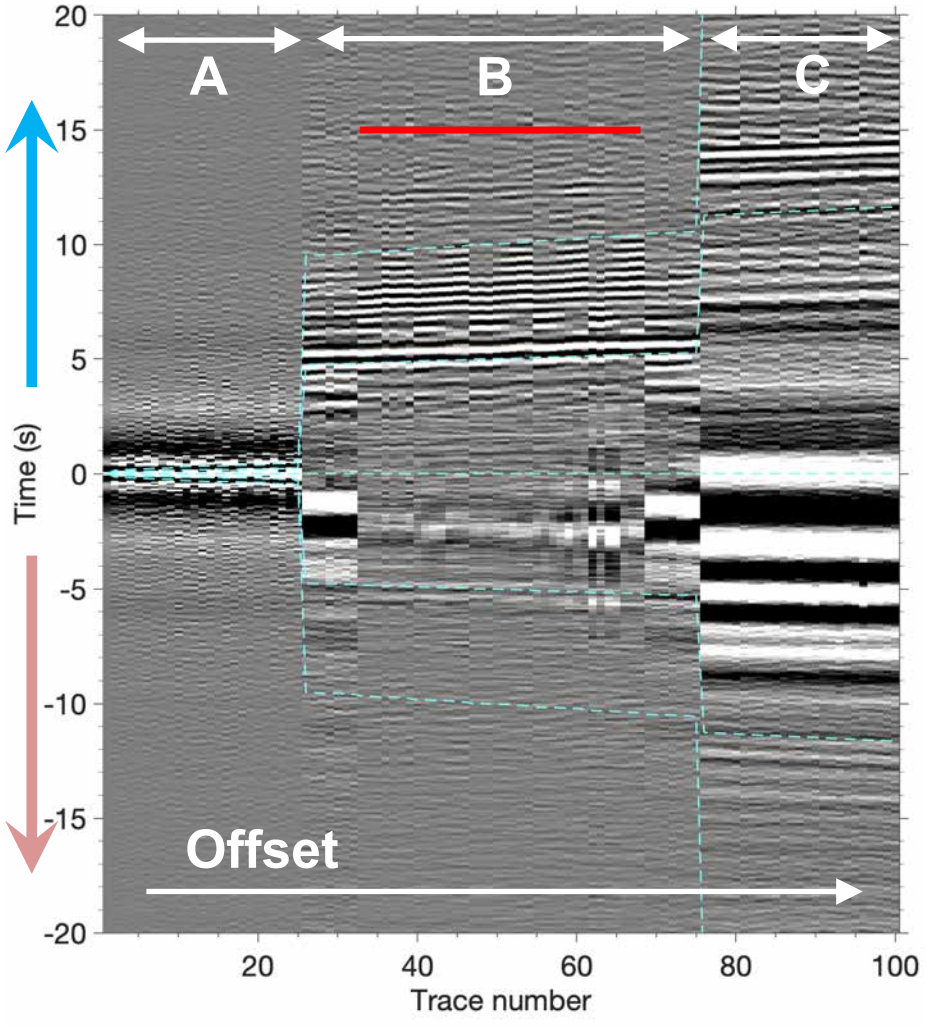




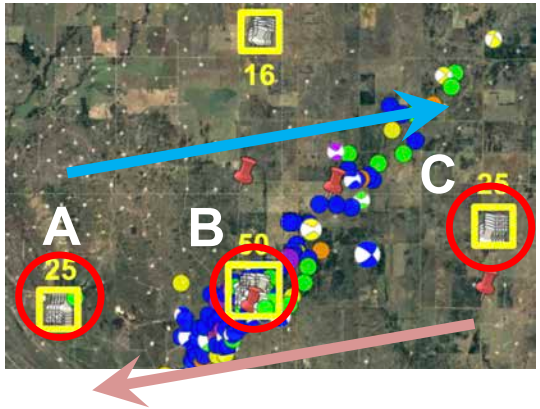
Ambient noise correlation

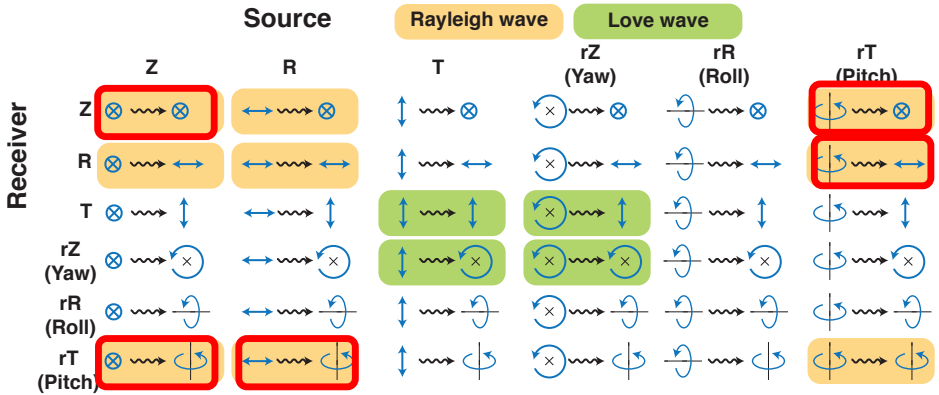


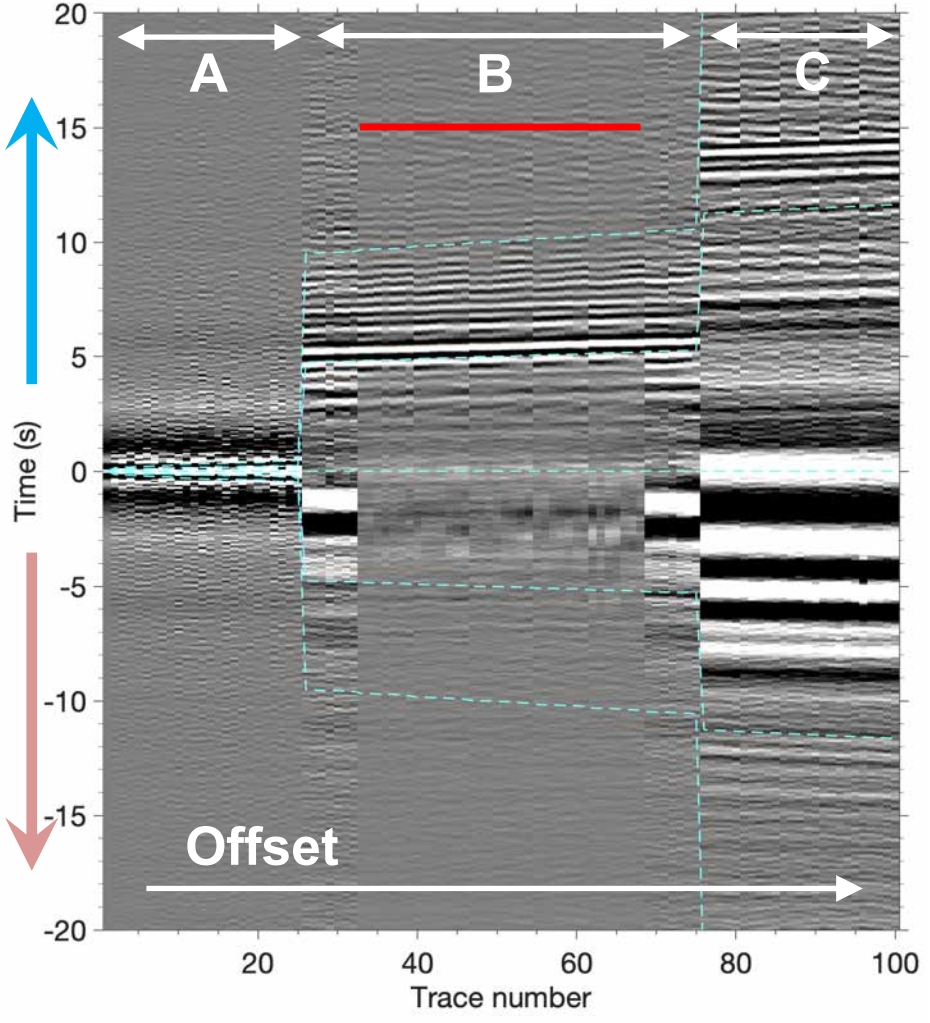




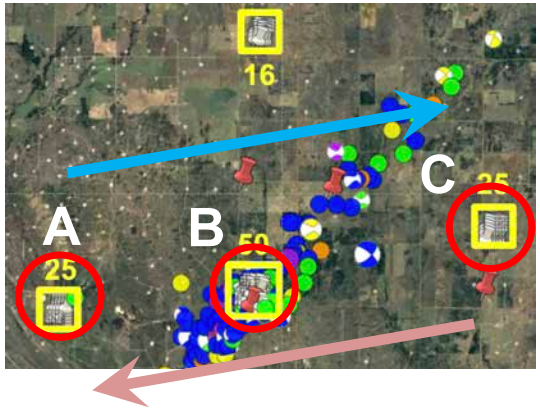
Ambient noise correlation

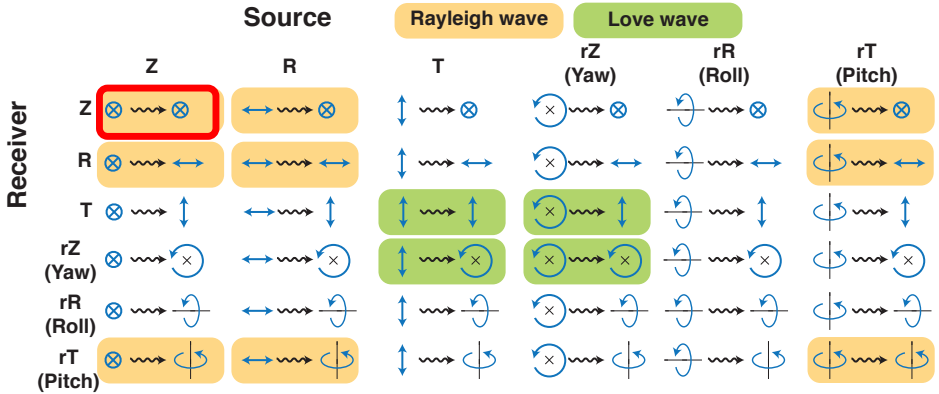


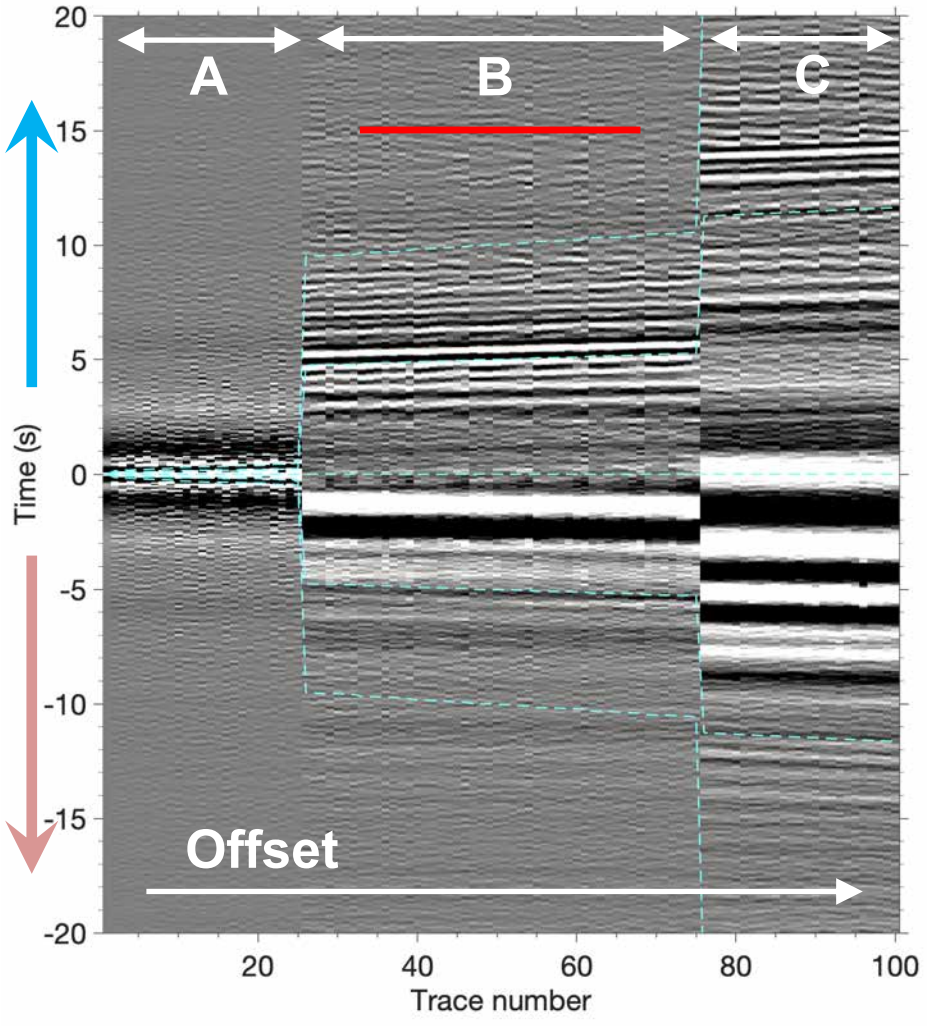




Ambient noise correlation

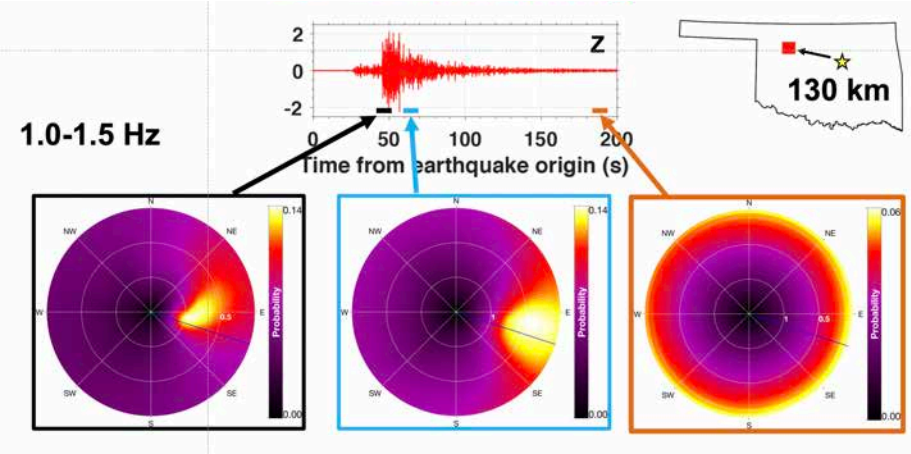






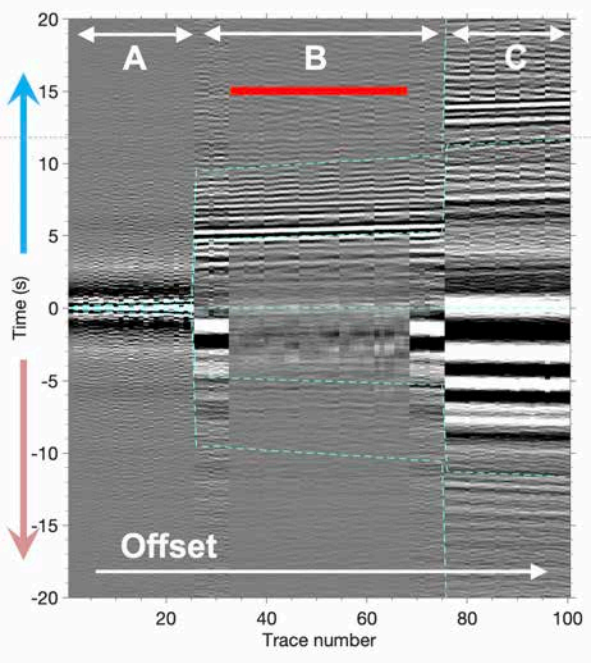
Conclusion

Single-station 6C beamforming



- Higher resolution
- Beamforming in shorter time window

36C ambient noise correlation



- Improve SNR
- Better stationary-phase approximation
- Etc.