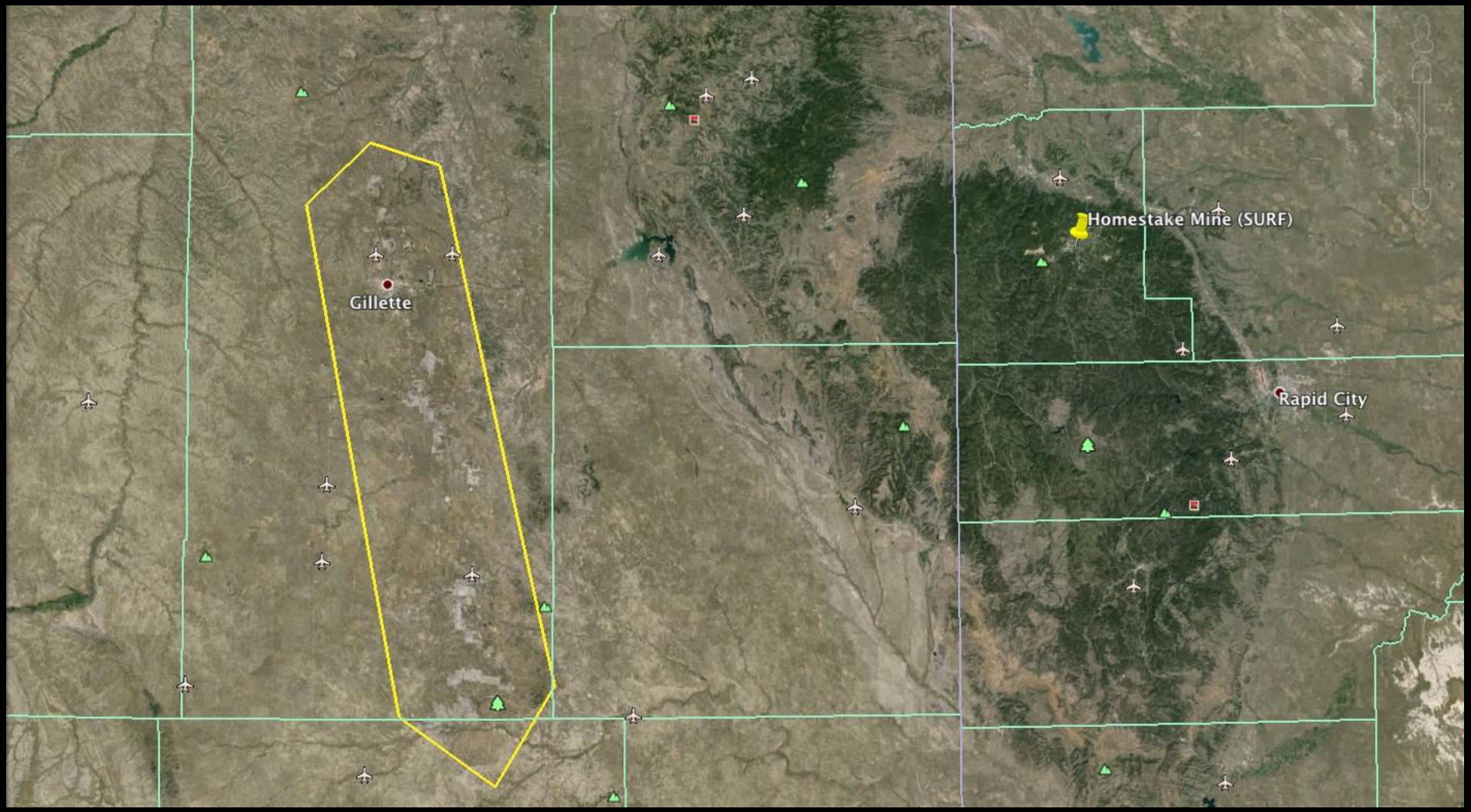
Dispersion of Surface Waves in the Black Hills, SD

Presented by Ross Caton

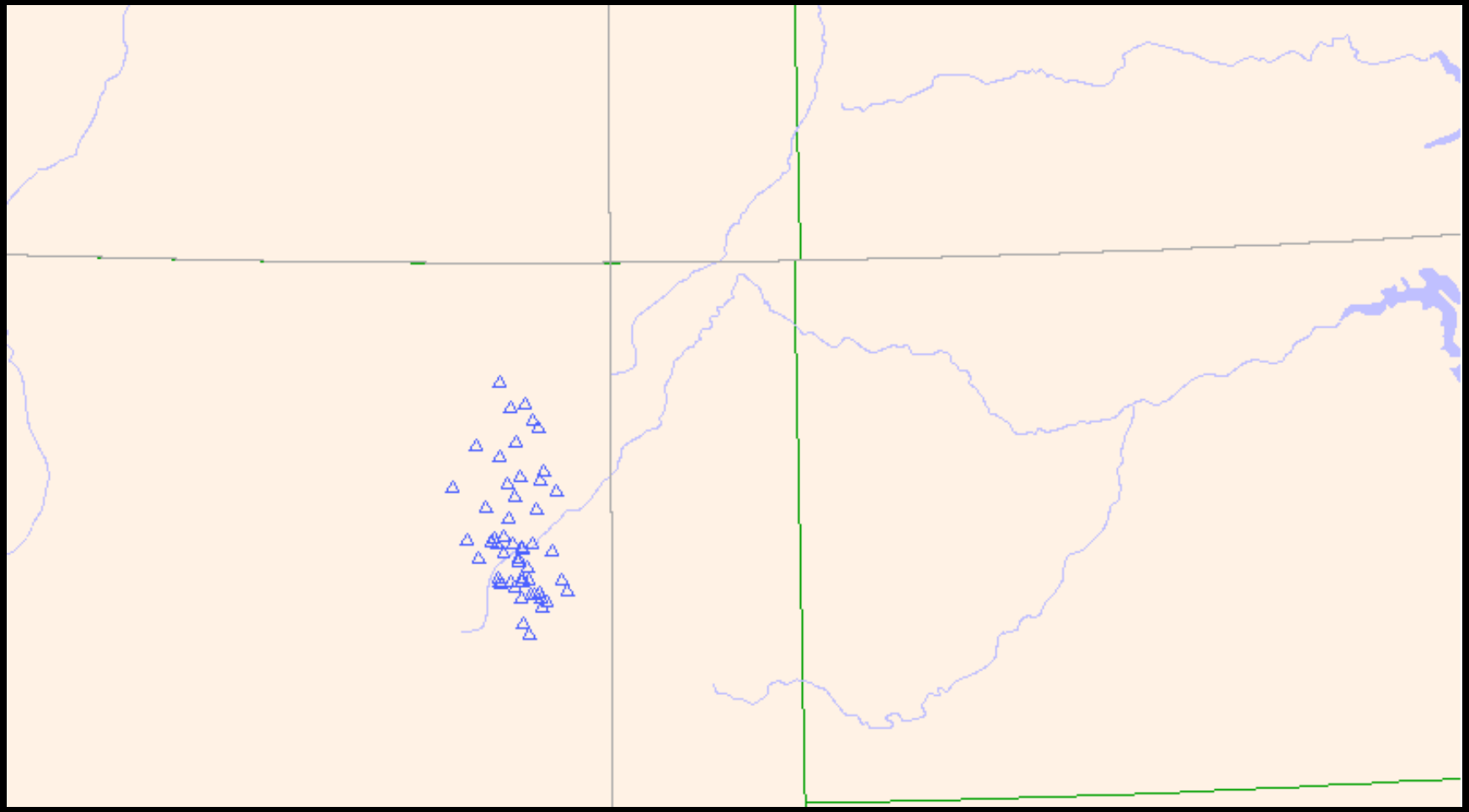
Data

- 5 mining blasts from coal mines to the west, in Wyoming
- Blasts produced strong surface waves in ~1-10 seconds period band, predominantly 2-5 seconds
- Chose seismometers at various depths in the mine

Data



Data



Methods

- Used do_mft for multiple filter analysis
- MFT uses narrowband filters of the form

$$H_n(\omega) = \exp\{-\alpha[(\omega-\omega_n)/\omega_n]^2\}$$

- Amplitudes are calculated by the equation

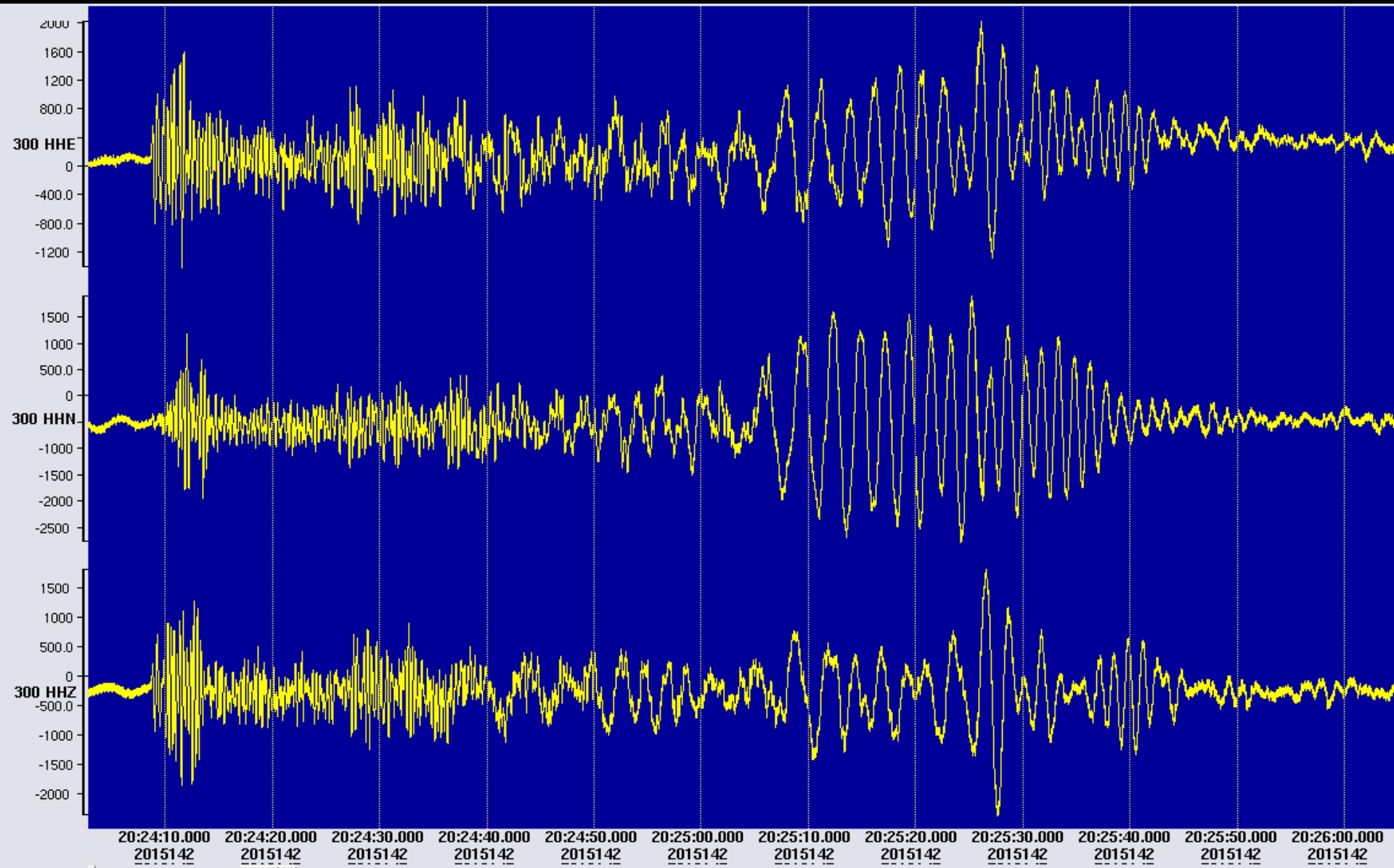
$$A_n(t)=(h_n^2(t) + q_n^2(t))^{1/2}$$

- $q_n(t)$ is the inverse Fourier transform of

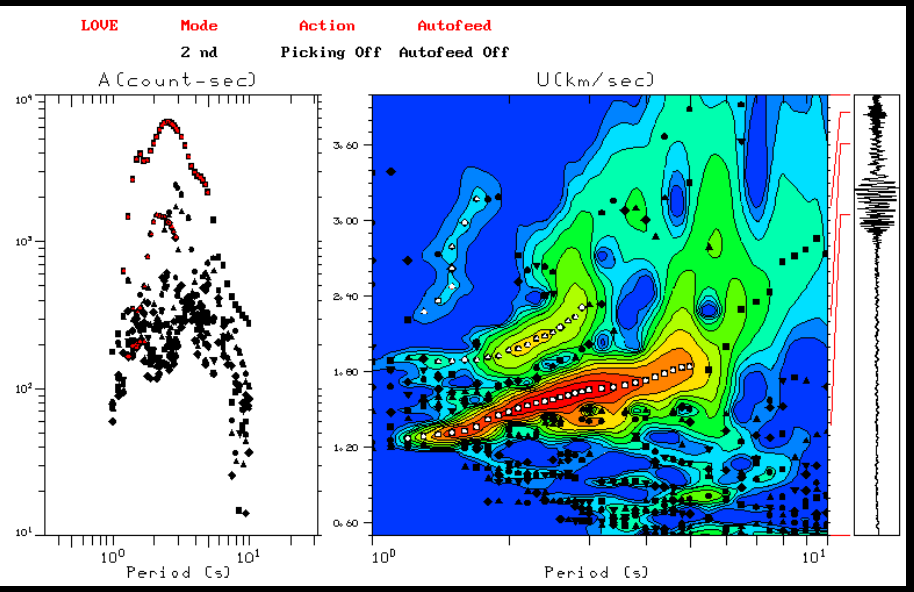
$$Q_n(\omega) = H_n(\omega)F(\omega)\exp(i\pi/2)$$

- First published by Dziewonski et al. (1969)

First Event

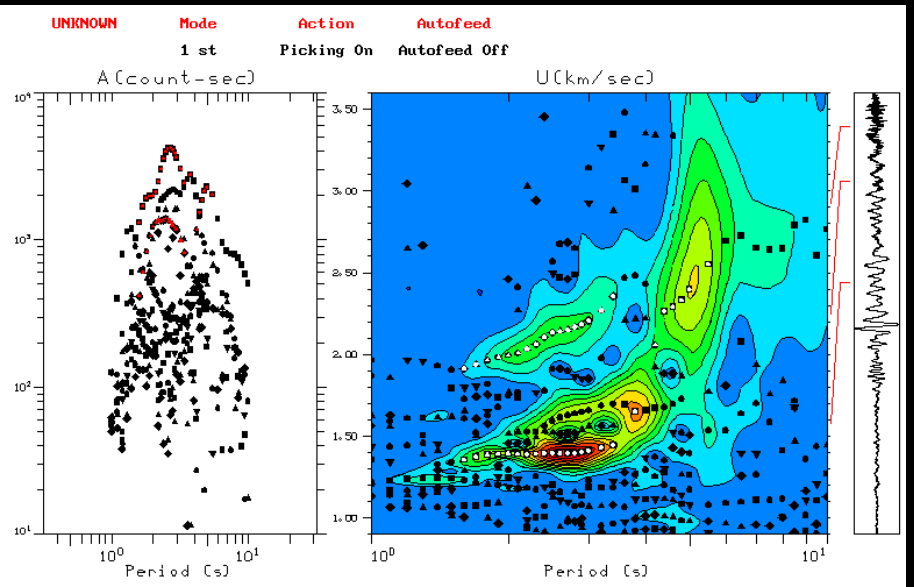

2000
1600
1200
800.0
300 HHE
0
-400.0
-800.0
-1200
1500
1000
500.0
0
300 HHN
-1000
-1500
-2000
-2500
1500
1000
500.0
0
300 HHZ
-500.0
-1000
-1500
-2000
20:24:10.000
2015142
20:24:20.000
2015142
20:24:30.000
2015142
20:24:40.000
2015142
20:24:50.000
2015142
20:25:00.000
2015142
20:25:10.000
2015142
20:25:20.000
2015142
20:25:30.000
2015142
20:25:40.000
2015142
20:25:50.000
2015142
20:26:00.000
2015142

First Event

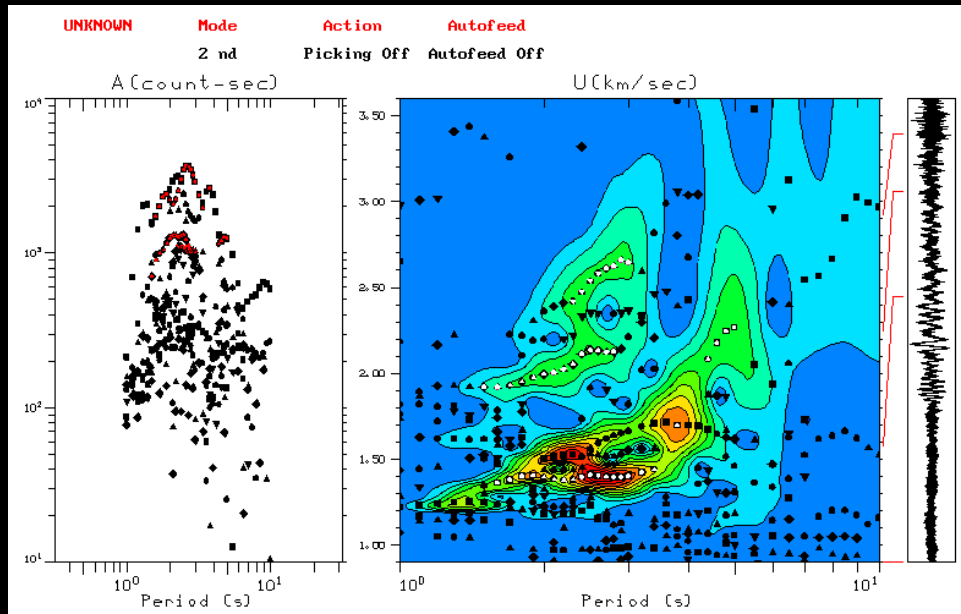


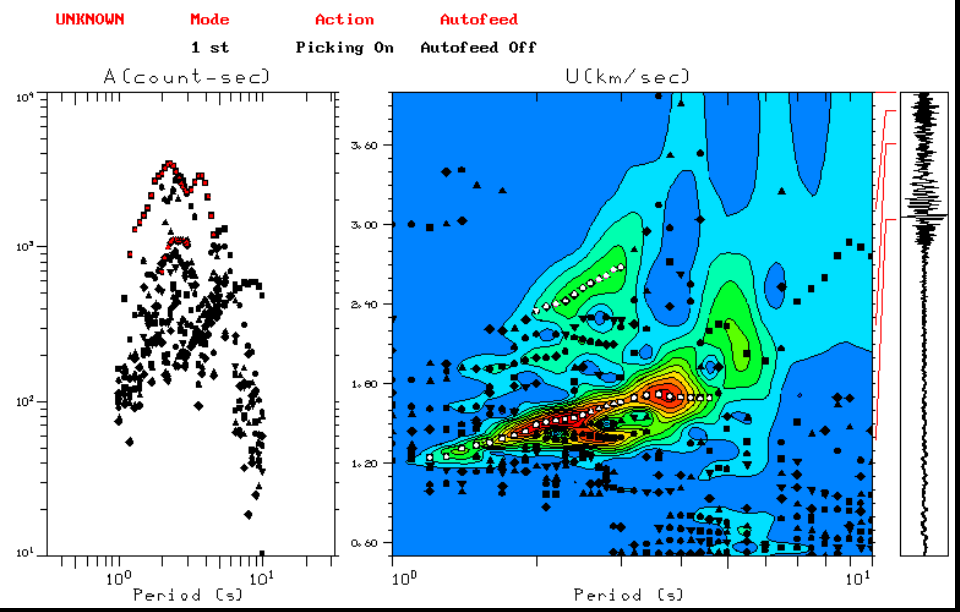
E2000, N (above) & C4850 Z (below)

- Moderate 1st overtone
- Possible 2nd overtone on E2000
- Branched fundamental on E & somewhat on Z (Rayleigh wave)
- E channel fundamental changes with depth

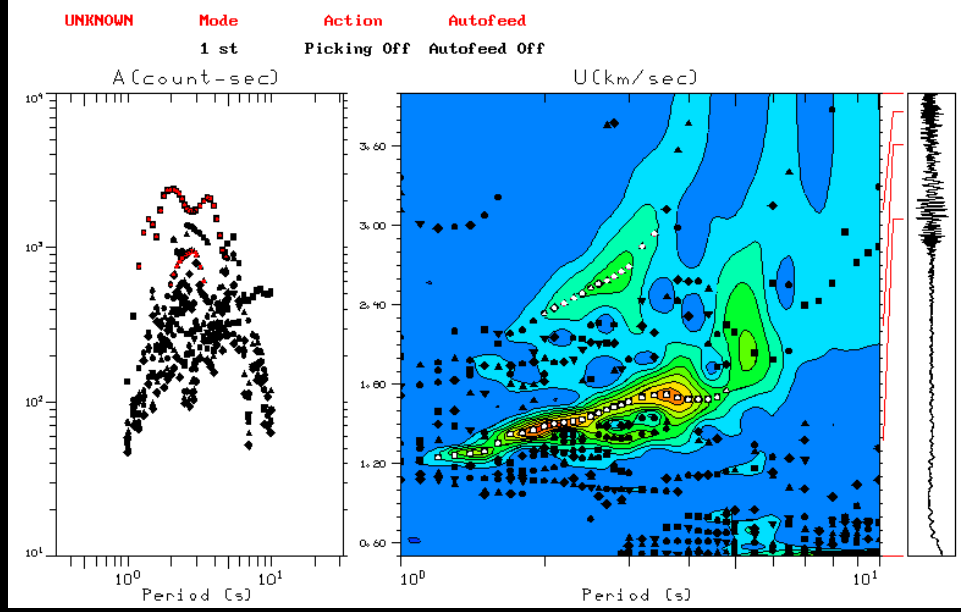


YATES, E



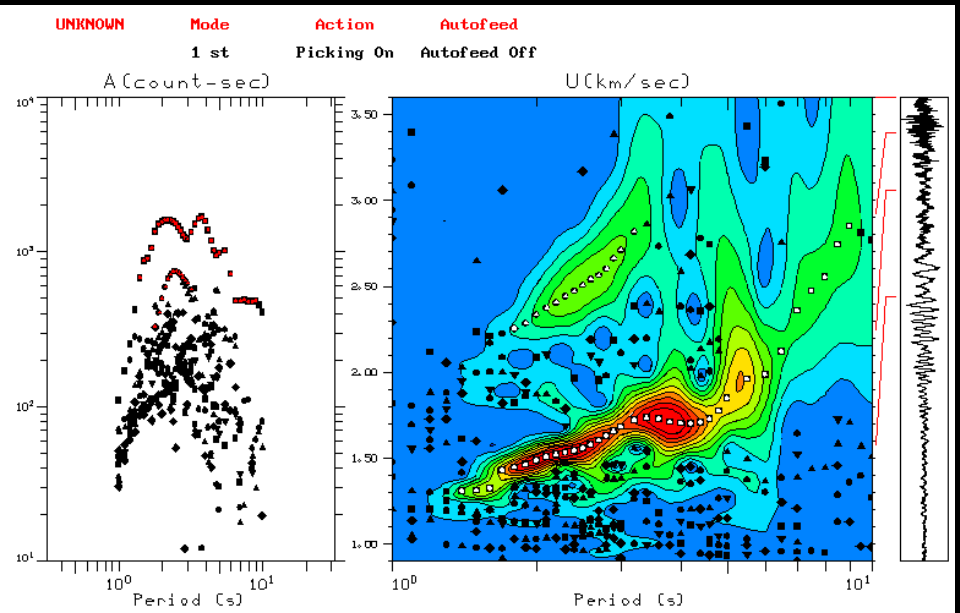


300, E

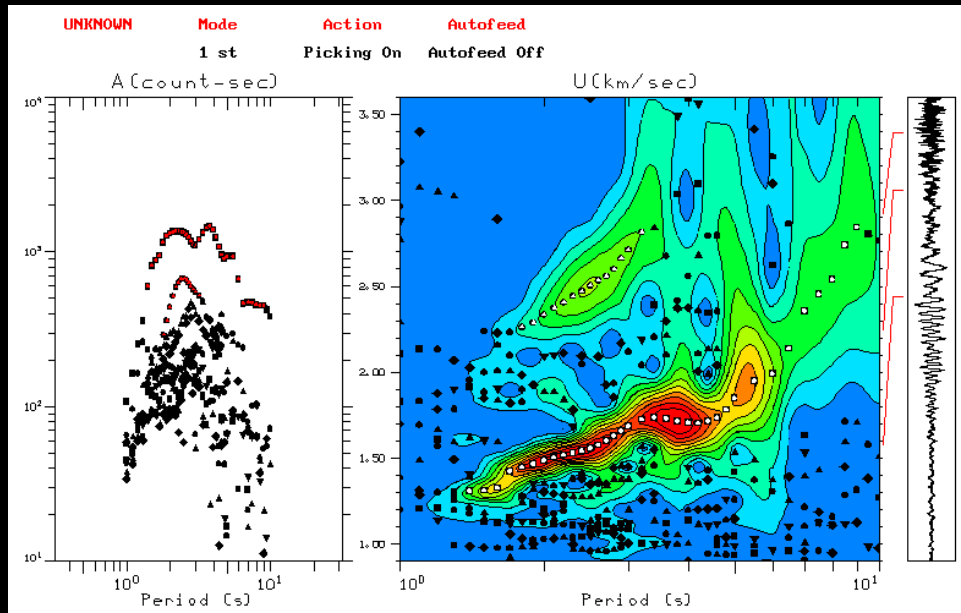


E2000, E

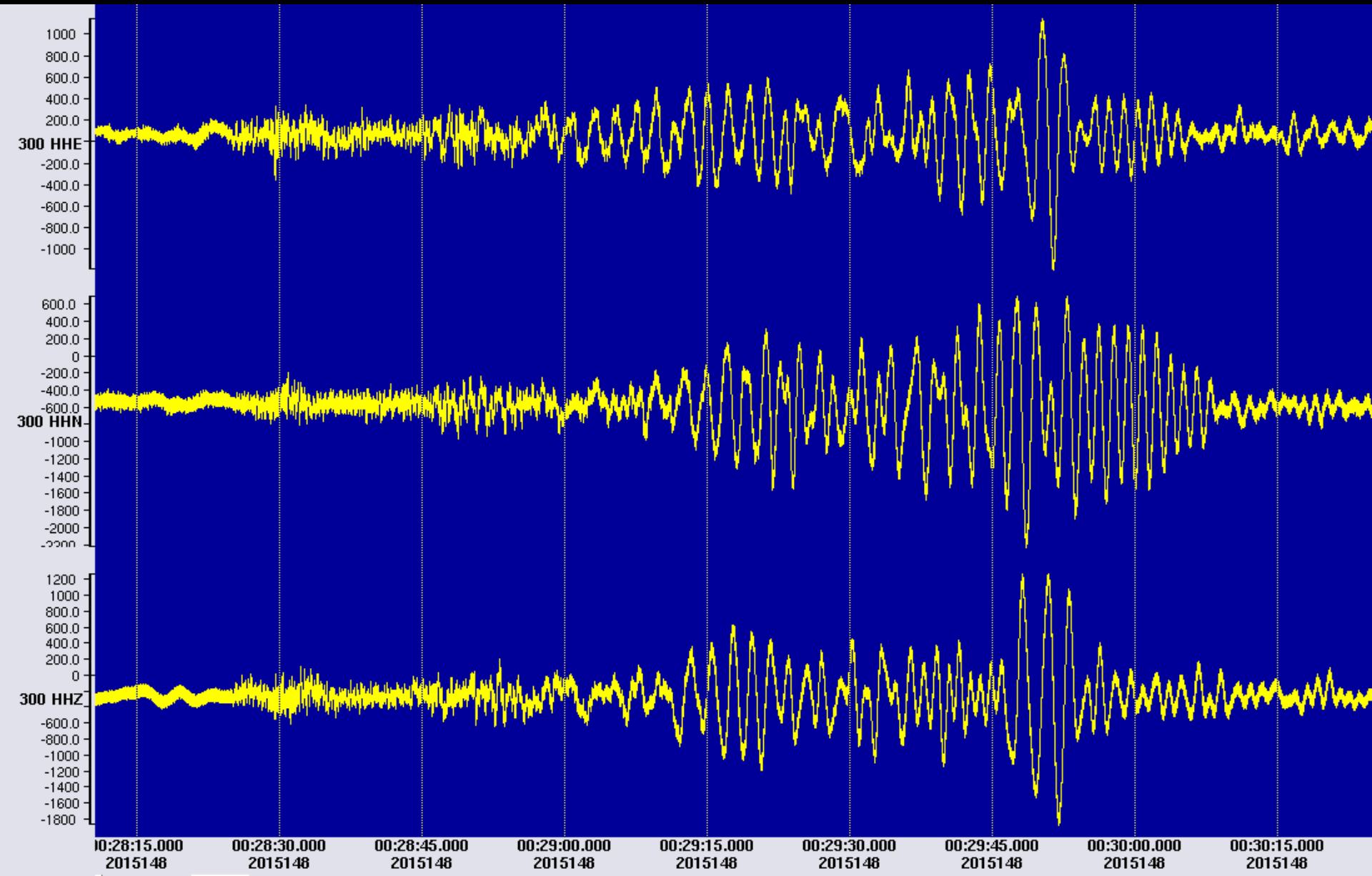
A4100, E



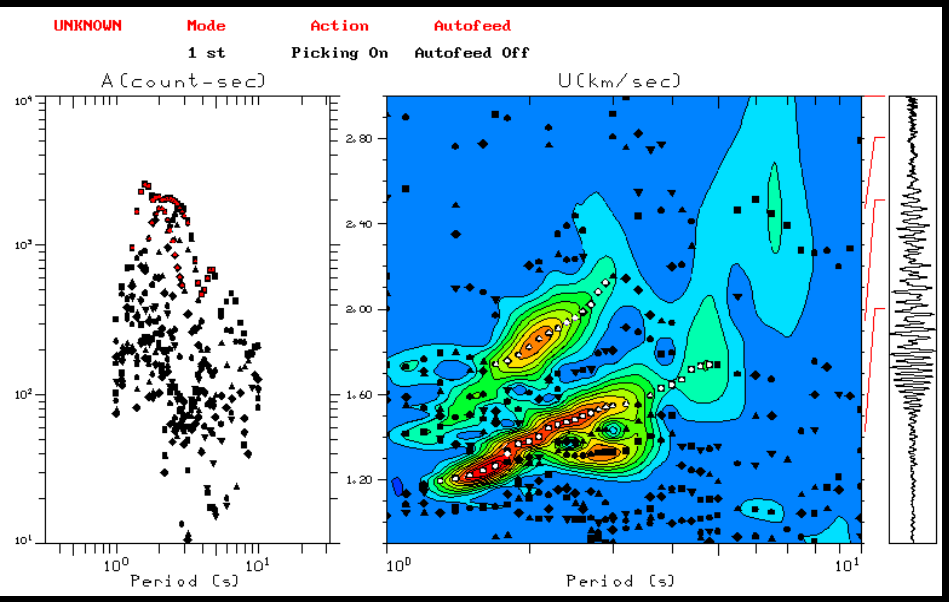
C4850, E



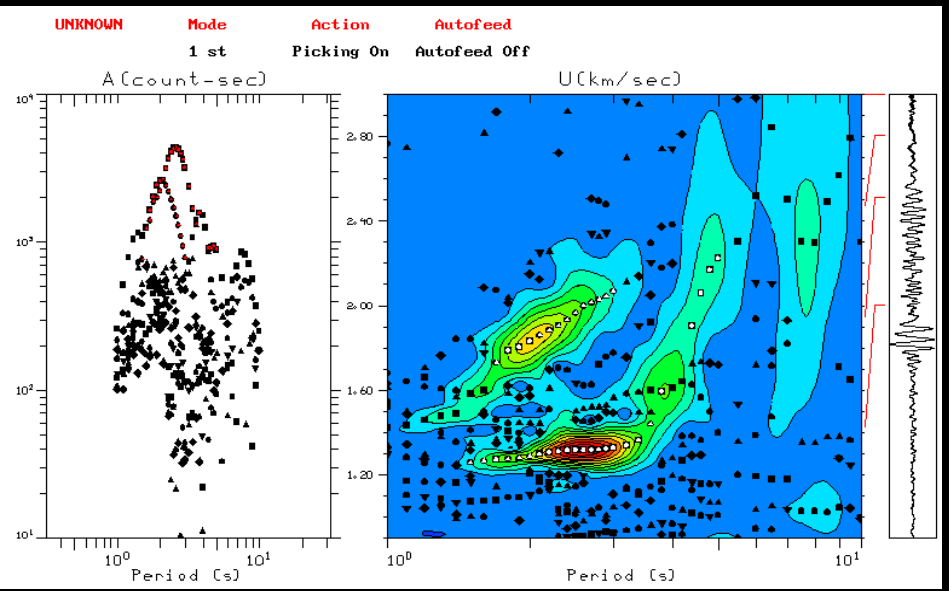
Second event



Second event



E2000, Z (below) & N (above)

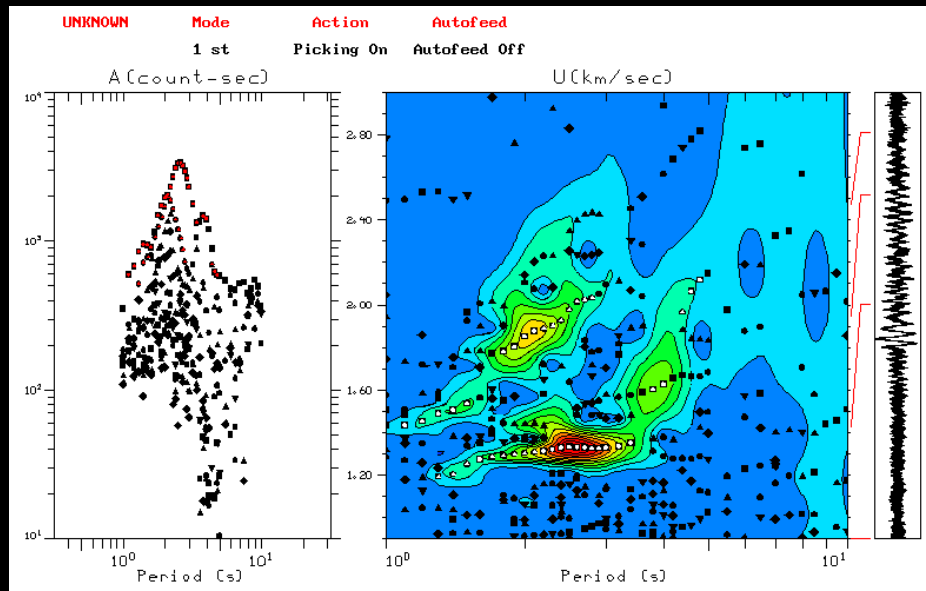


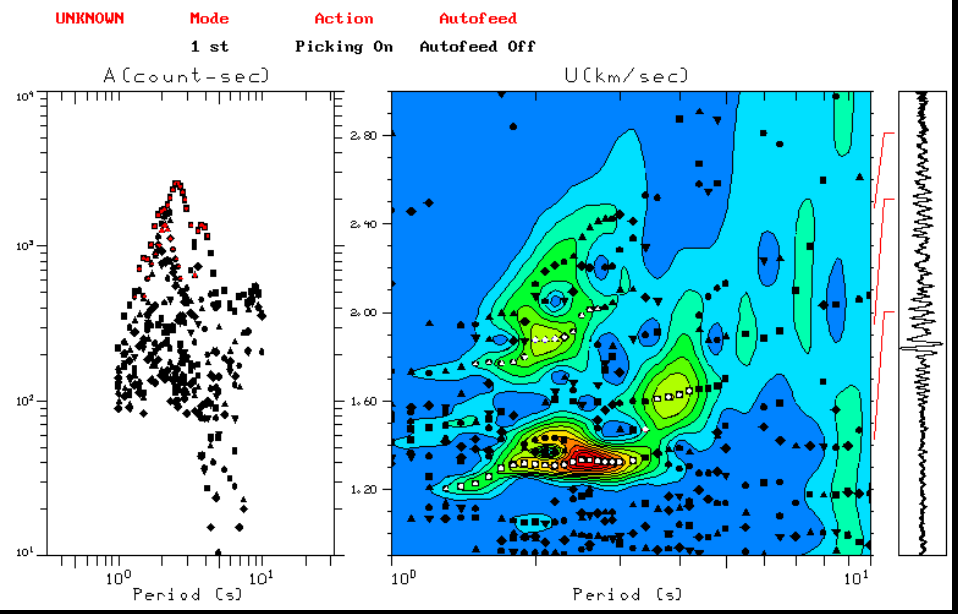
Second event (May 28th, 00:27 UTC) shows only one branch on z components, but multiple branches on north components

Stronger 1st overtone

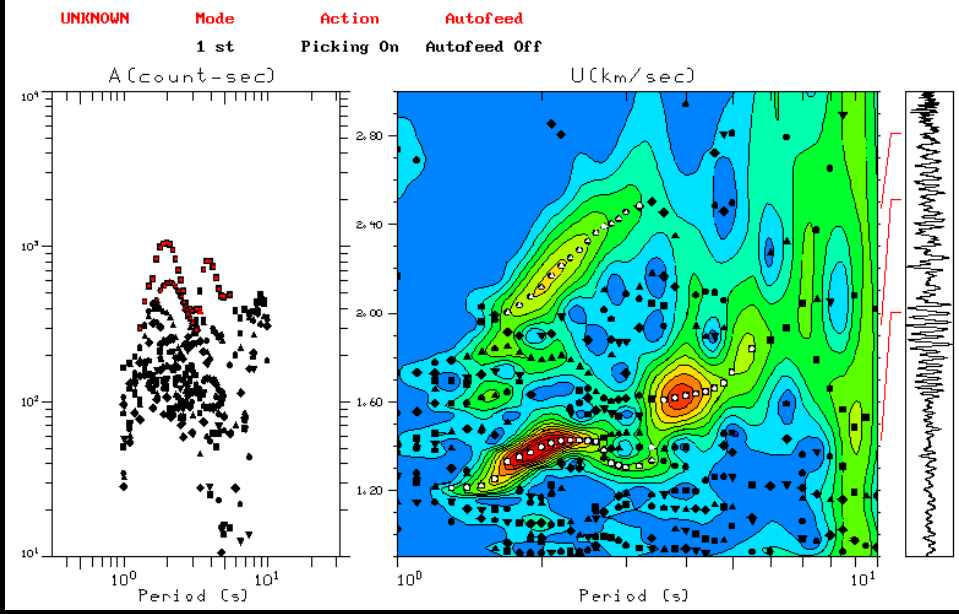
East component fundamental “migrates” with depth

YATES, E



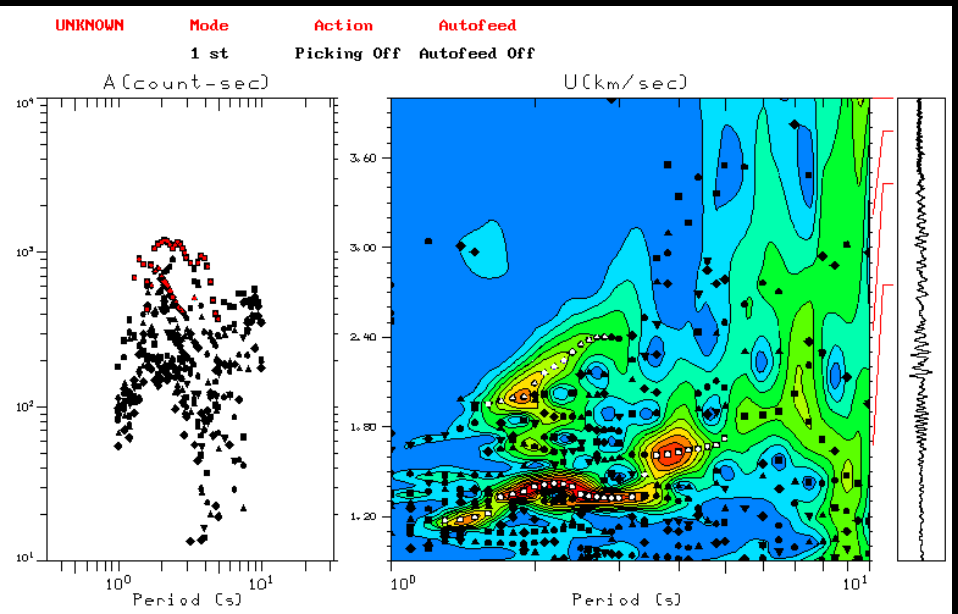


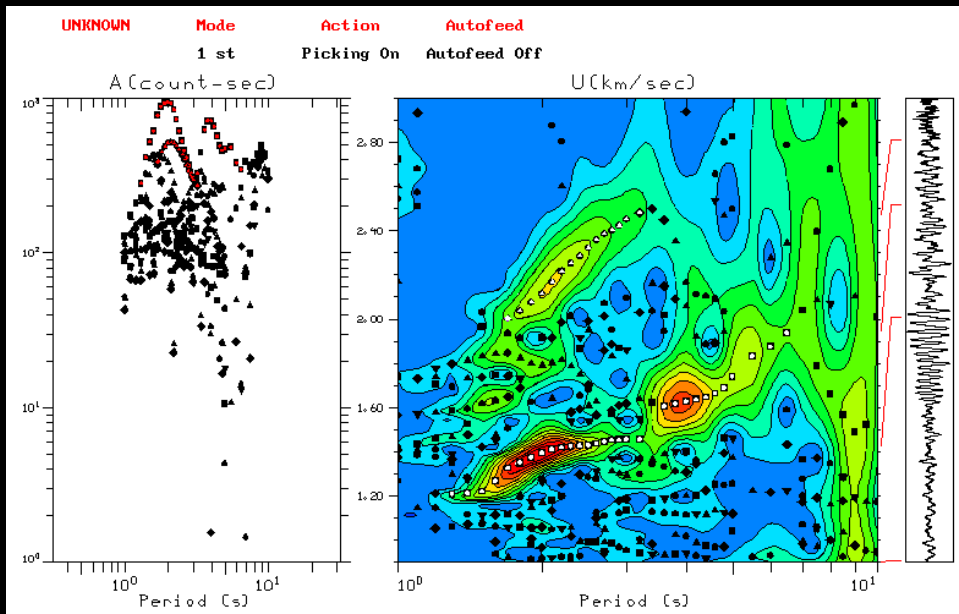
300, E



A4100, E

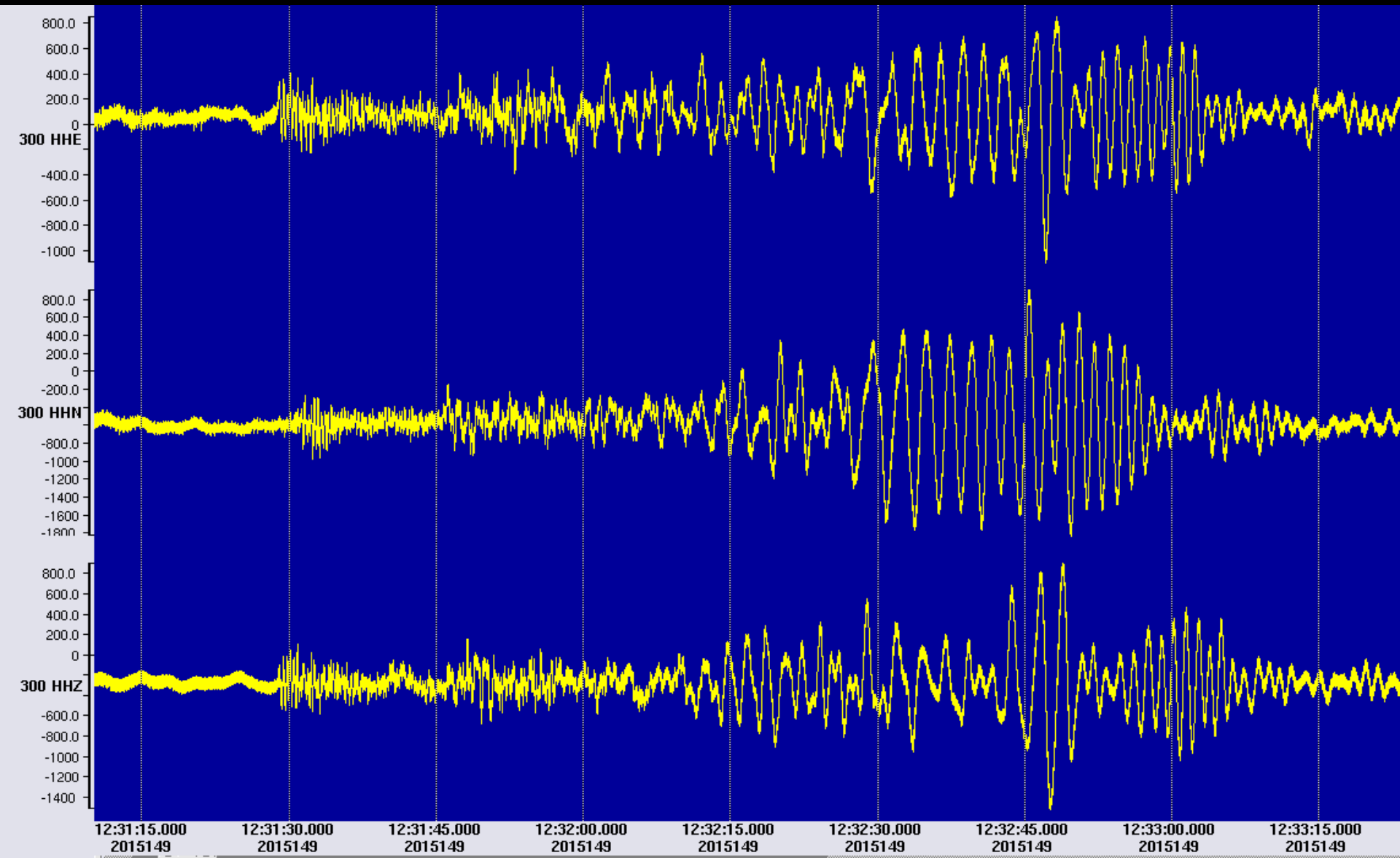
E2000, E





C4850, E

Fifth event


800.0
600.0
400.0
200.0
0
300 HHE
-400.0
-600.0
-800.0
-1000
800.0
600.0
400.0
200.0
0
-200.0
300 HHN
-800.0
-1000
-1200
-1400
-1600
800.0
600.0
400.0
200.0
0
300 HHZ
-600.0
-800.0
-1000
-1200
-1400
12:31:15.000
2015149
12:31:30.000
2015149
12:31:45.000
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2015149
12:32:15.000
2015149
12:32:30.000
2015149
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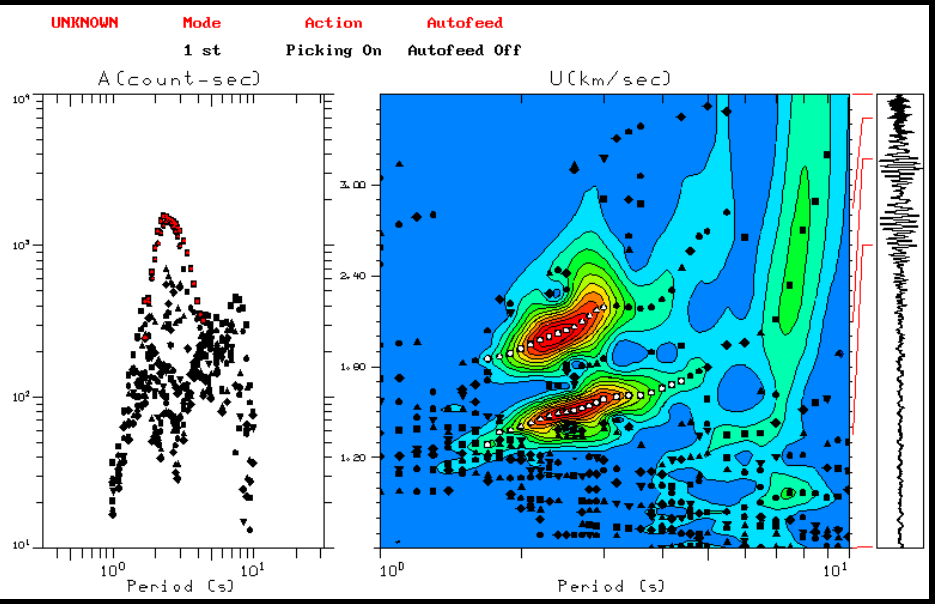
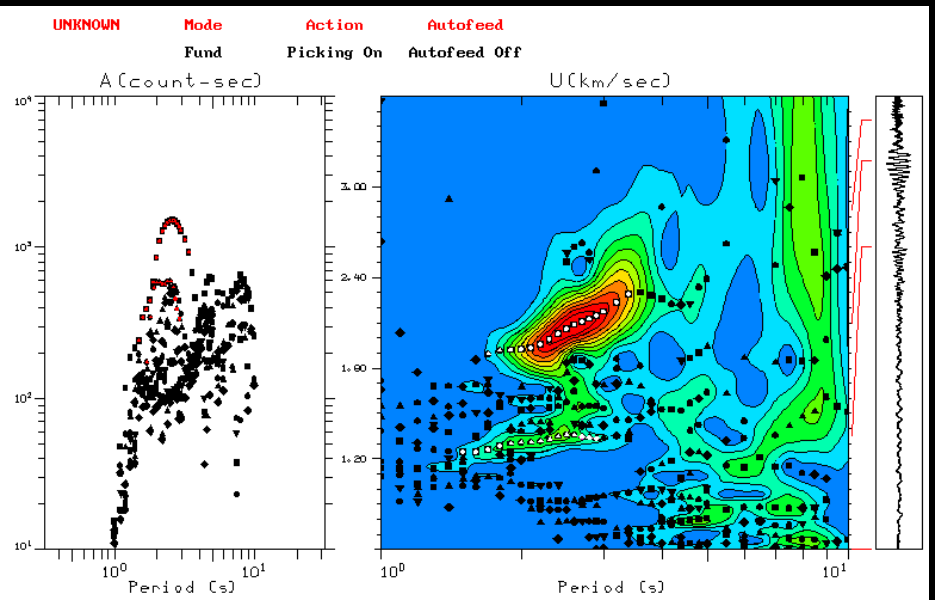
2015149
12:33:00.000
2015149
12:33:15.000
2015149

Fifth event

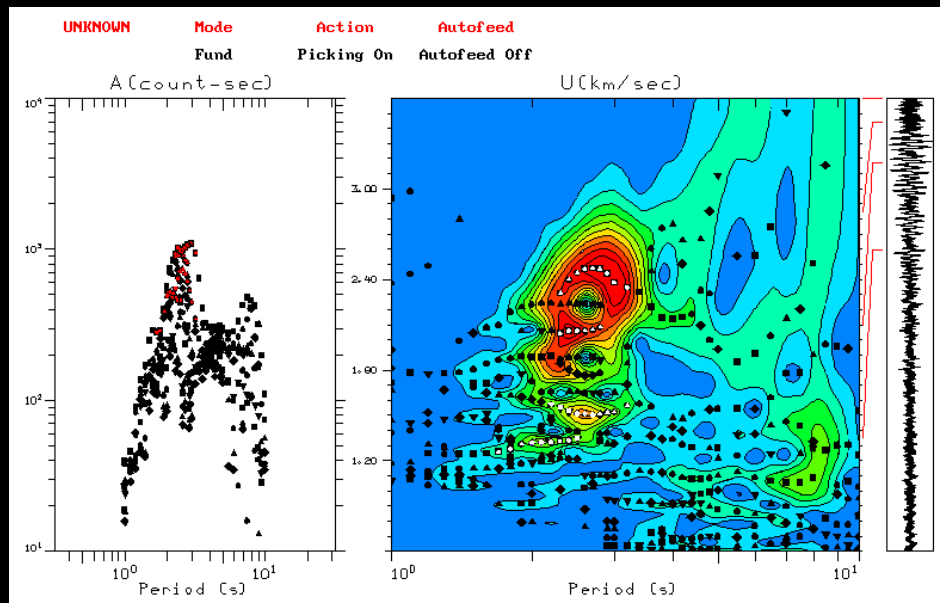


C4850, Z (below) & E2000 N (above)

- Nearly all Rayleigh energy in 1st overtone, very weak fundamental
- Spectral hole on east component
- Love has strong fundamental and first overtone



300, E



Discussion

- Branched fundamentals may indicate multipathing
- Since the N components almost never have branched fundamentals, this would suggest a P-velocity anomaly only
- Does not appear to be related to azimuth
  - Events 1 & 2 are 71^{o} and 70^{o}, but look different
  - 1 & 4 look very similar, but are 71^{o} and 79^{o}
  - 3 & 5 look very different, but are 64^{o} and 61^{o}

Discussion

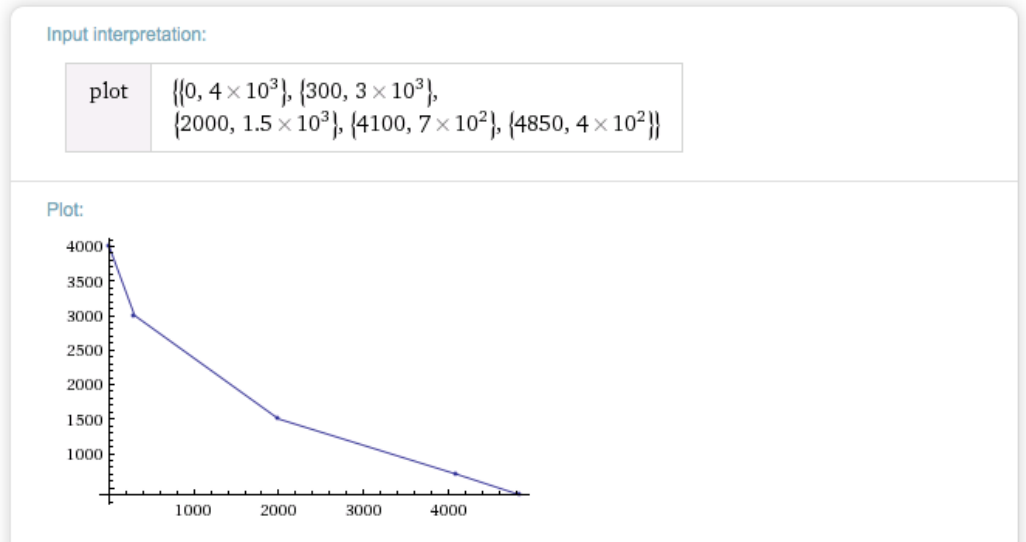
- We can also examine the decay of surface waves with depth
- From Stein & Wysession, we know that Rayleigh waves decay as $\exp(-k_x z)$ in a half-space

Discussion

- The vanishing branch from the first event decays in a manner expected from a half space
- It has c_x~1.4 km/s and T~2.5s, implying λ_x=3.5 km and k_x=1.8 km^{-1}
- Decays roughly as exp(-1.8 km^{-1} z)

Discussion

Depth (ft)	Observed amplitude (counts*s)	Predicted amplitude for half-space (counts*s)
0	4000	4000
300	3000	3200
2000	1500	1320
4100	700	400
4850	400	280



References

- Dziewonski, A., Bloch, S., & Landisman, M., 1969. A technique for the analysis of transient seismic signals, *Bull. Seism. Soc. Am.*, **59**, 427-444.
- Stein, S., & Wysession, M., 2003. *An Introduction to Seismology, Earthquakes, and Earth Structure*, Blackwell Publishing, Ltd., Malden, MA.

Questions?