

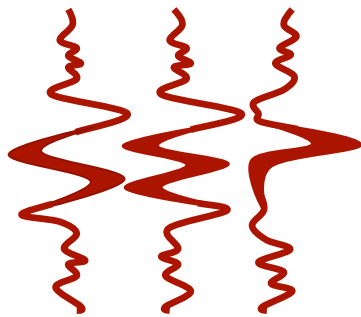
Correlation energy between surface and borehole stations at the Valhall field

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SEP Sponsor Meeting

SEP 147-213



**Stanford
Exploration
Project**



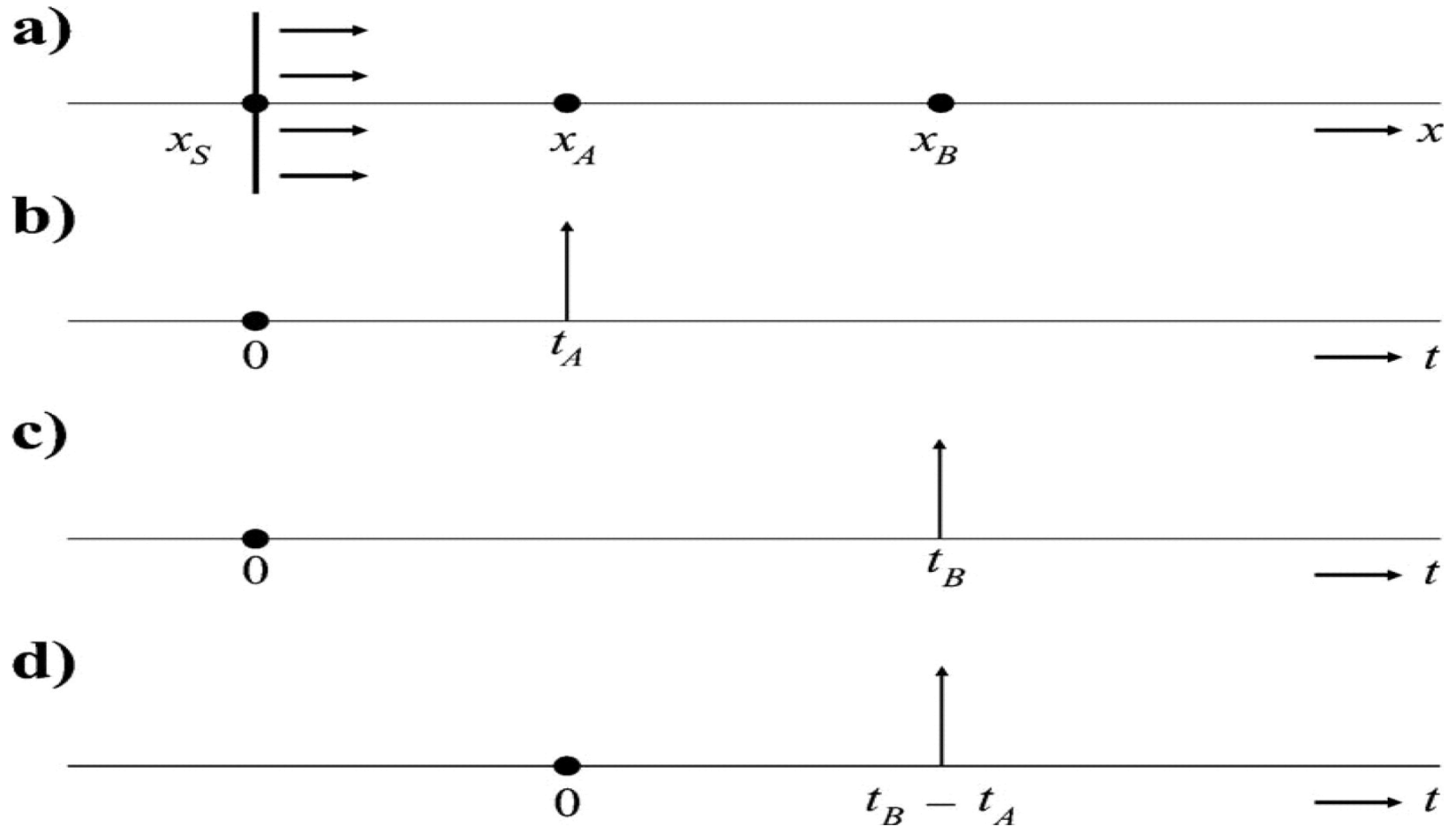
Agenda

- Seismic interferometry
- Project overview
- Spectrogram comparisons
- Surface to borehole cross-correlation results
- Discussion

Seismic interferometry

- Cross-correlate responses of two receivers to obtain the Green's function between receivers
- In other words: change a receiver-receiver pair into a virtual source-receiver pair

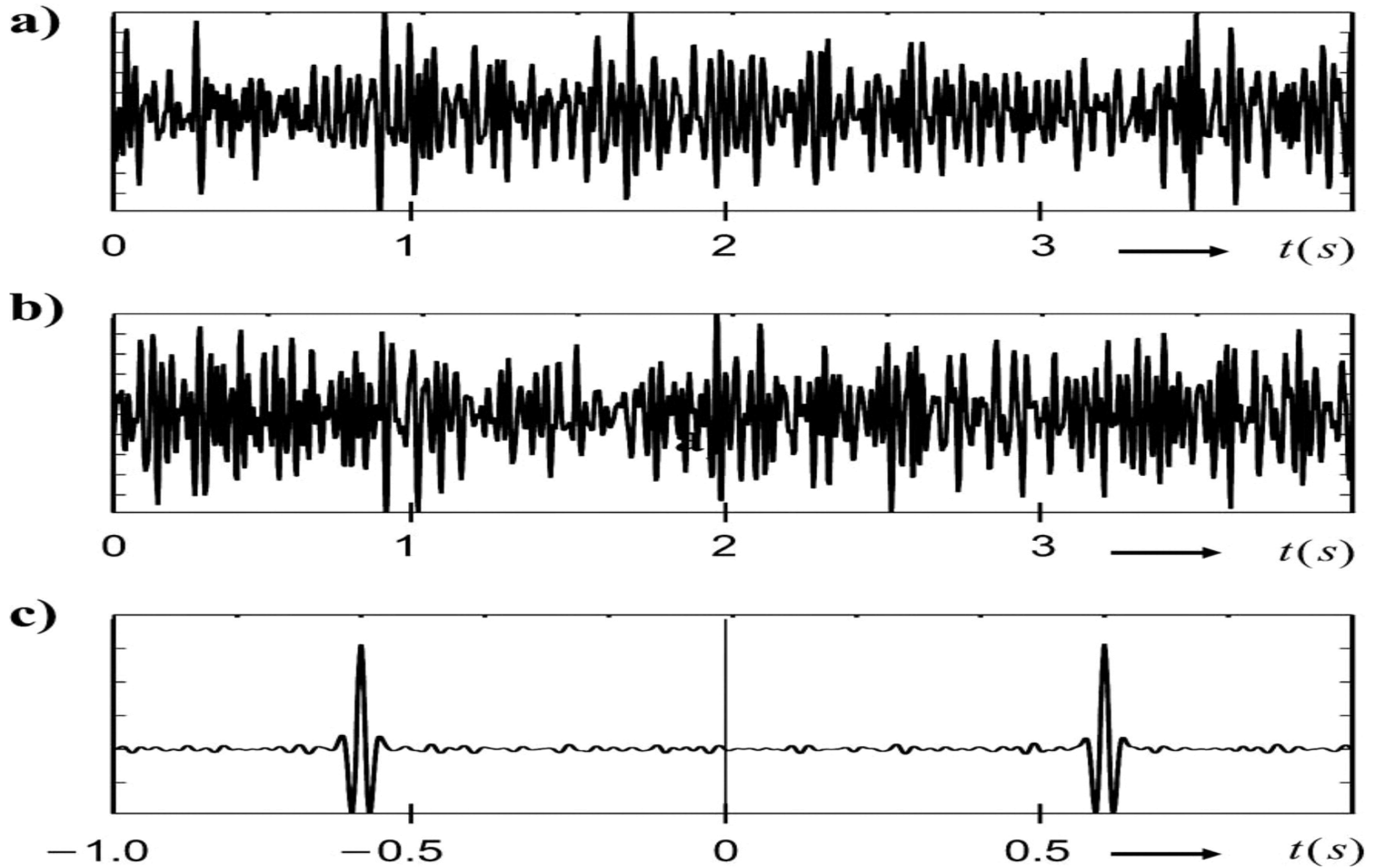
Seismic interferometry: plane wave



Seismic interferometry

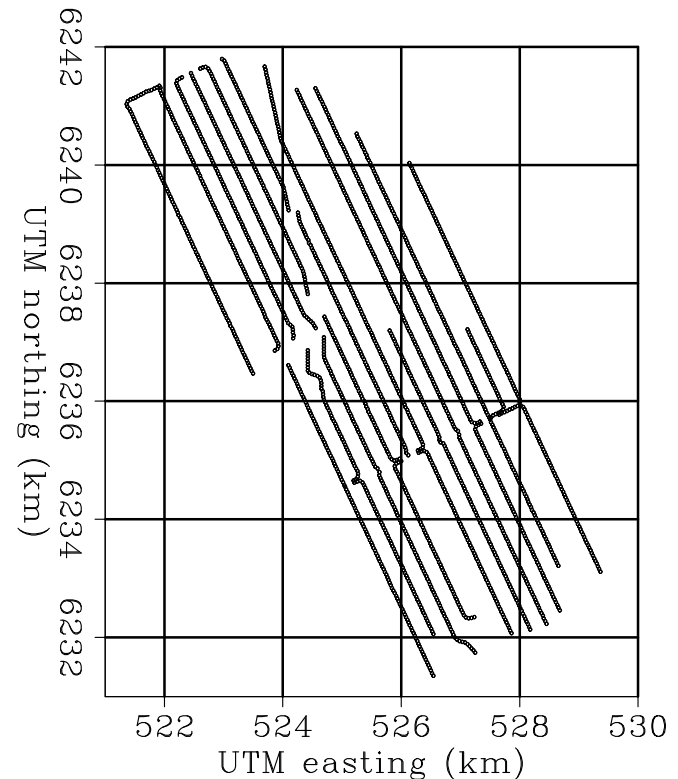
- With obtained travel time and distance between two receivers, we can potentially estimate propagation velocity
- This could be used with passive seismic noise

Seismic interferometry: noise

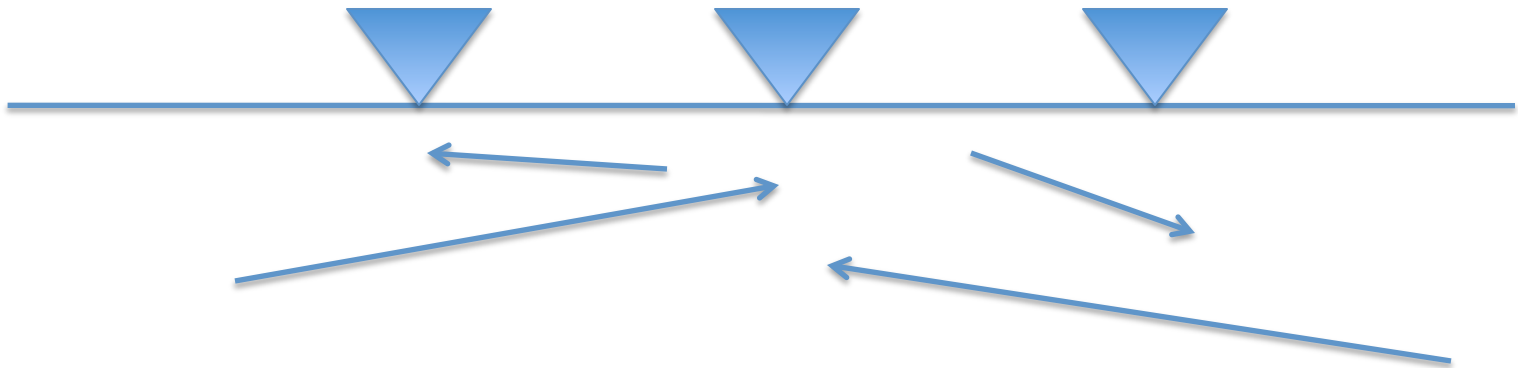


Valhall, Norway

- Oil field in the North Sea
- 2224 receivers recording continuously for over 5 days



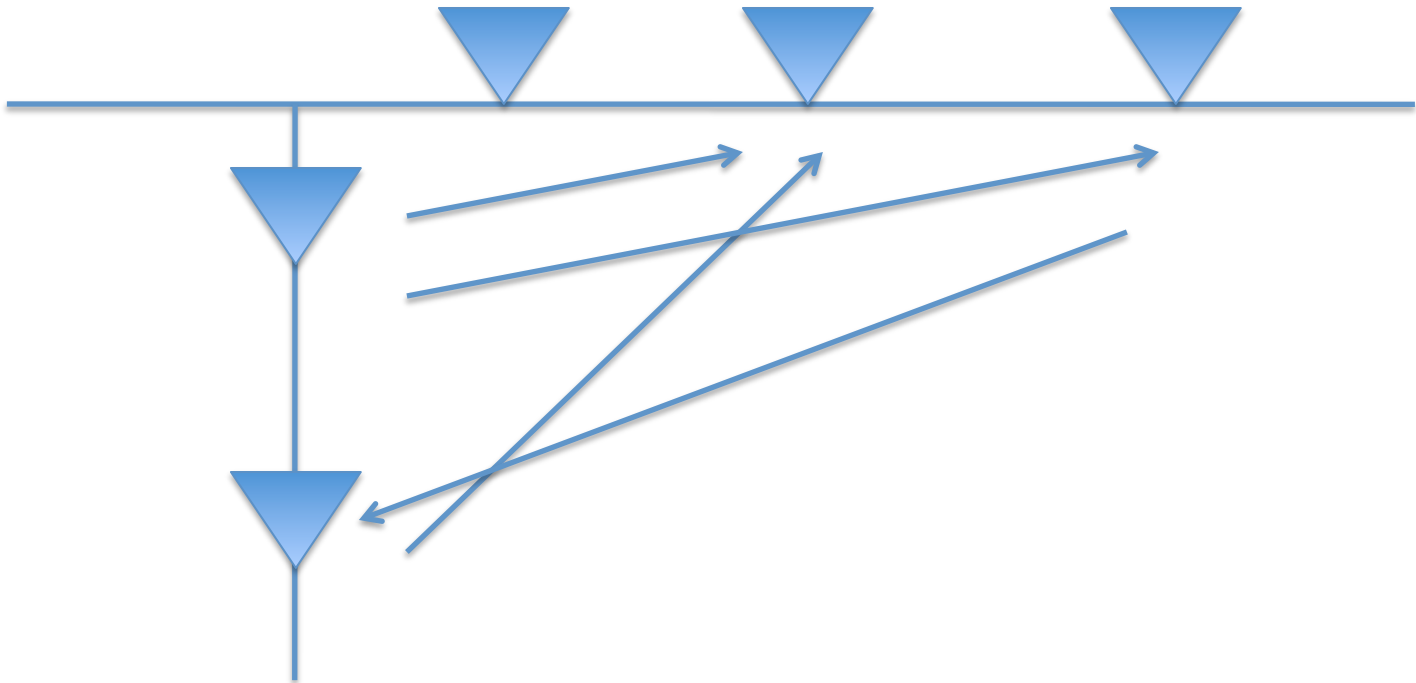
Previous Valhall studies



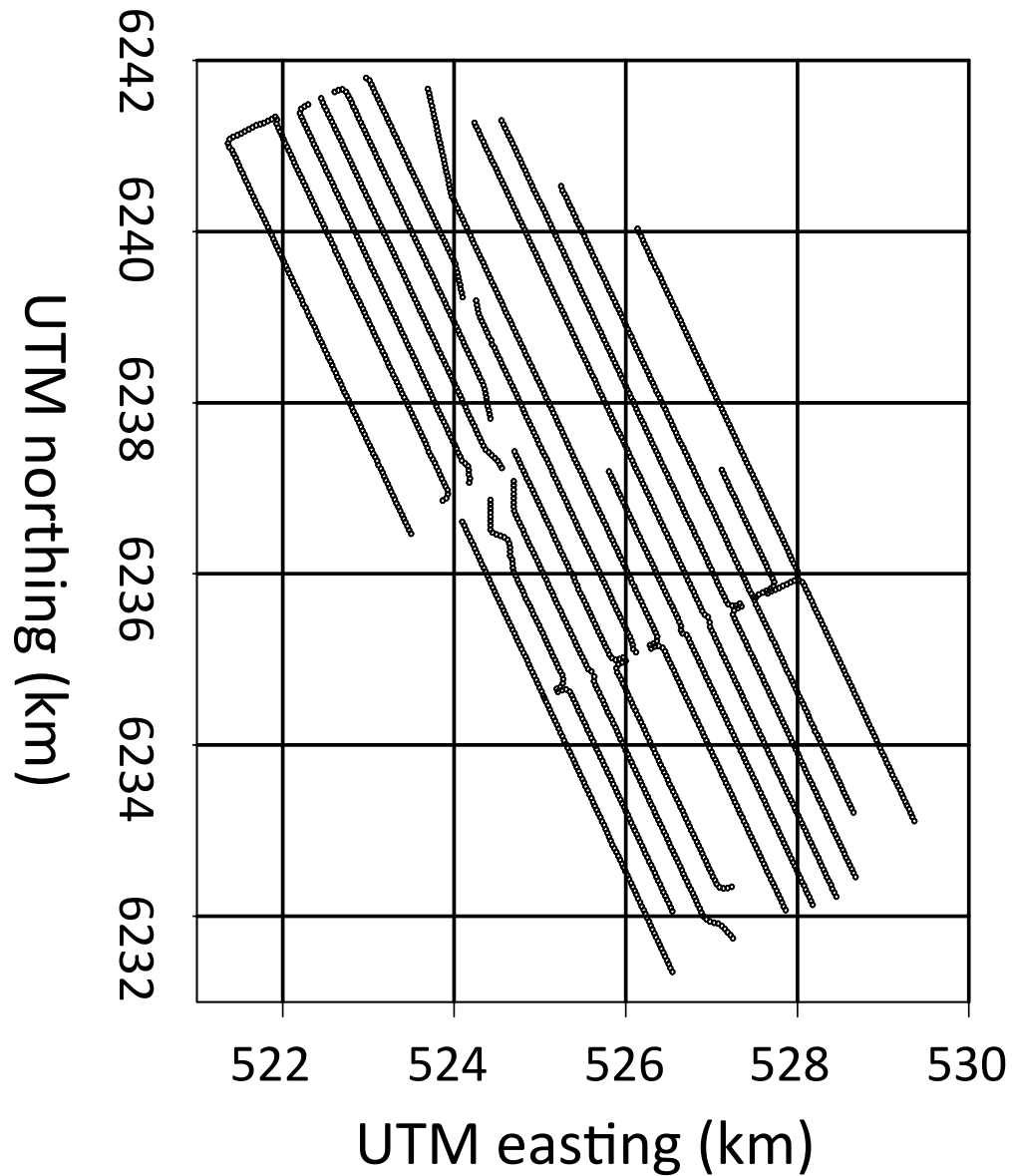
- Artman, 2007
- de Ridder and Dellinger, 2011

Our goal

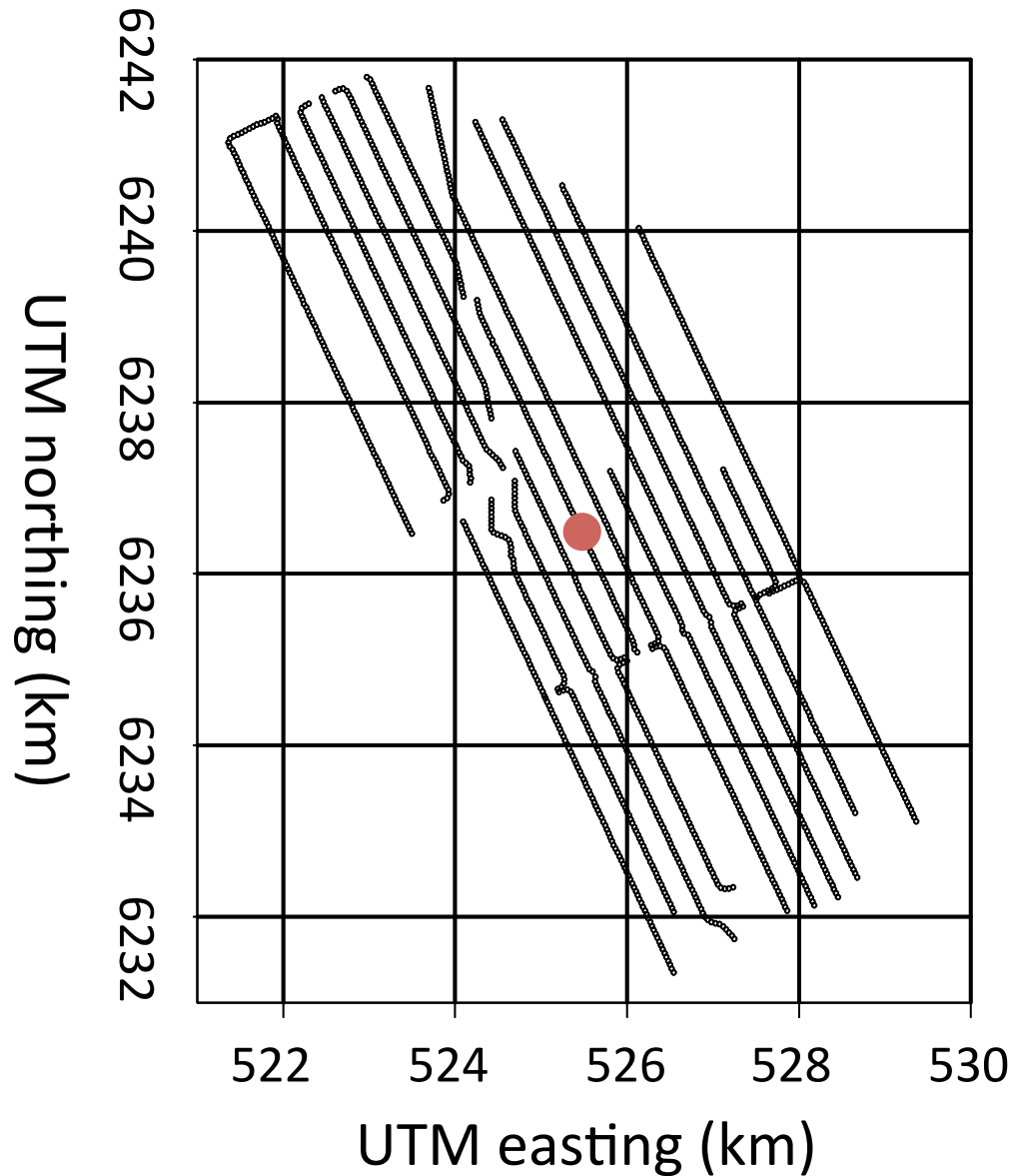
- See if there is correlating energy between borehole and surface stations at low frequencies
 - This concept has not been studied



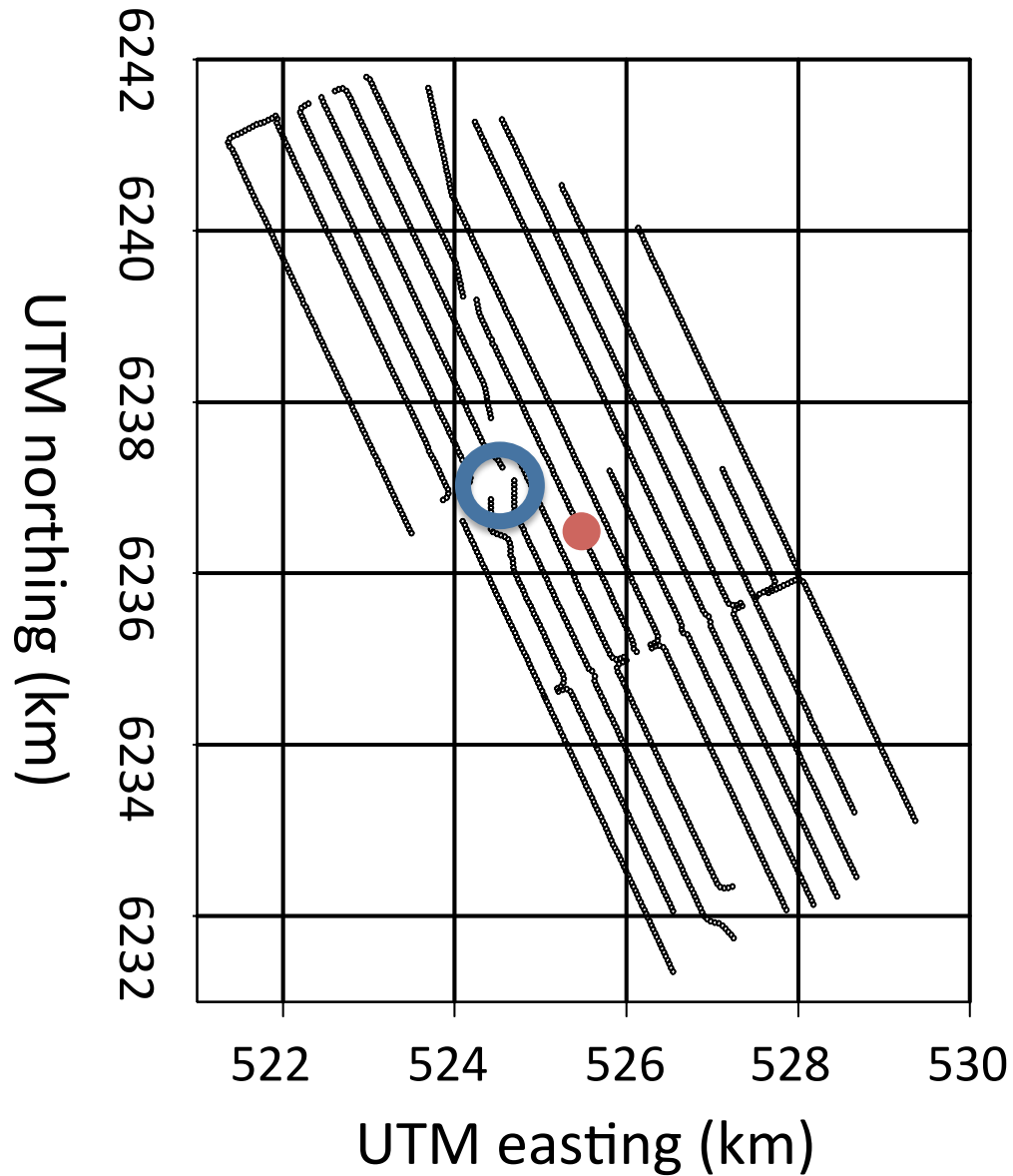
OBC network



Borehole stations locations



Platform location

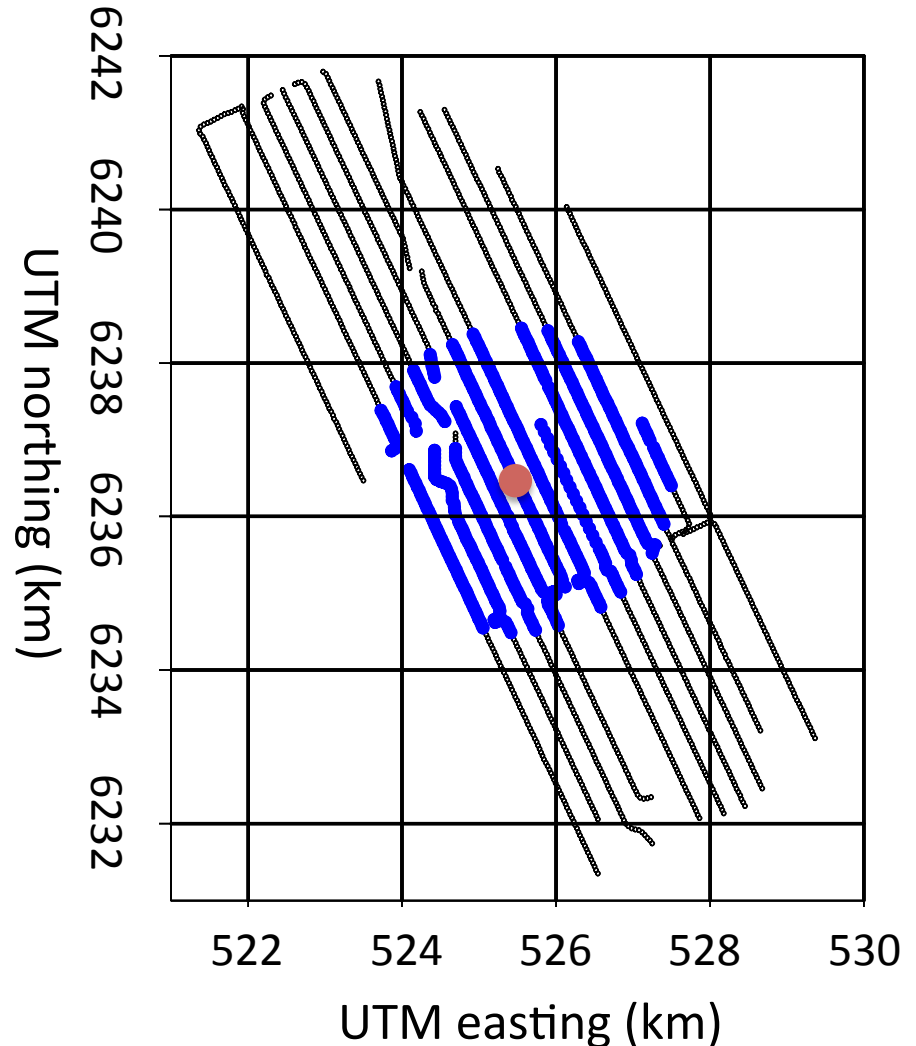


Spectrograms

- Look at spectrograms (spectra vs. time) to compare spectral content of different groups of stations
- Here: only vertical components
 - Surface stations within 2km of the shallowest borehole station's surface location
 - 5 surface stations nearest to the platform
 - 4 of 5 borehole stations

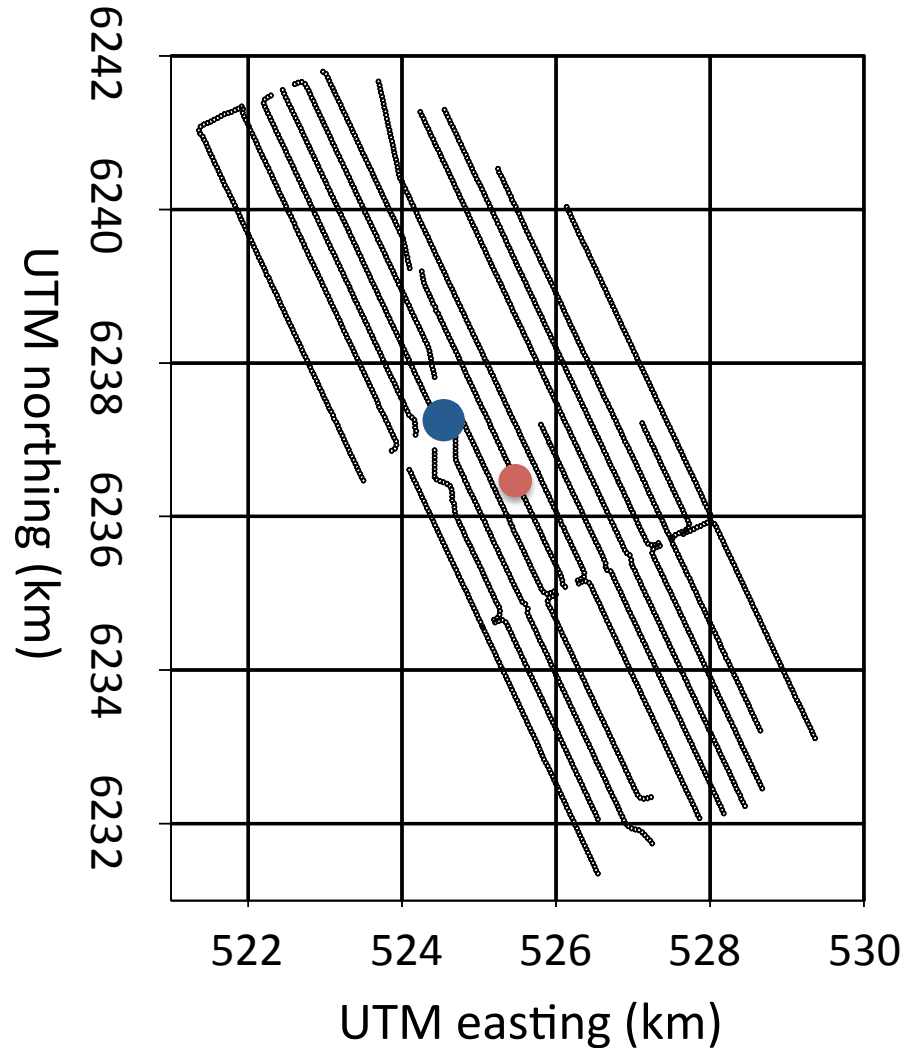
Stations within 2 km

- Compare signals in the borehole and those at a lateral distance comparable to the depth of the borehole stations

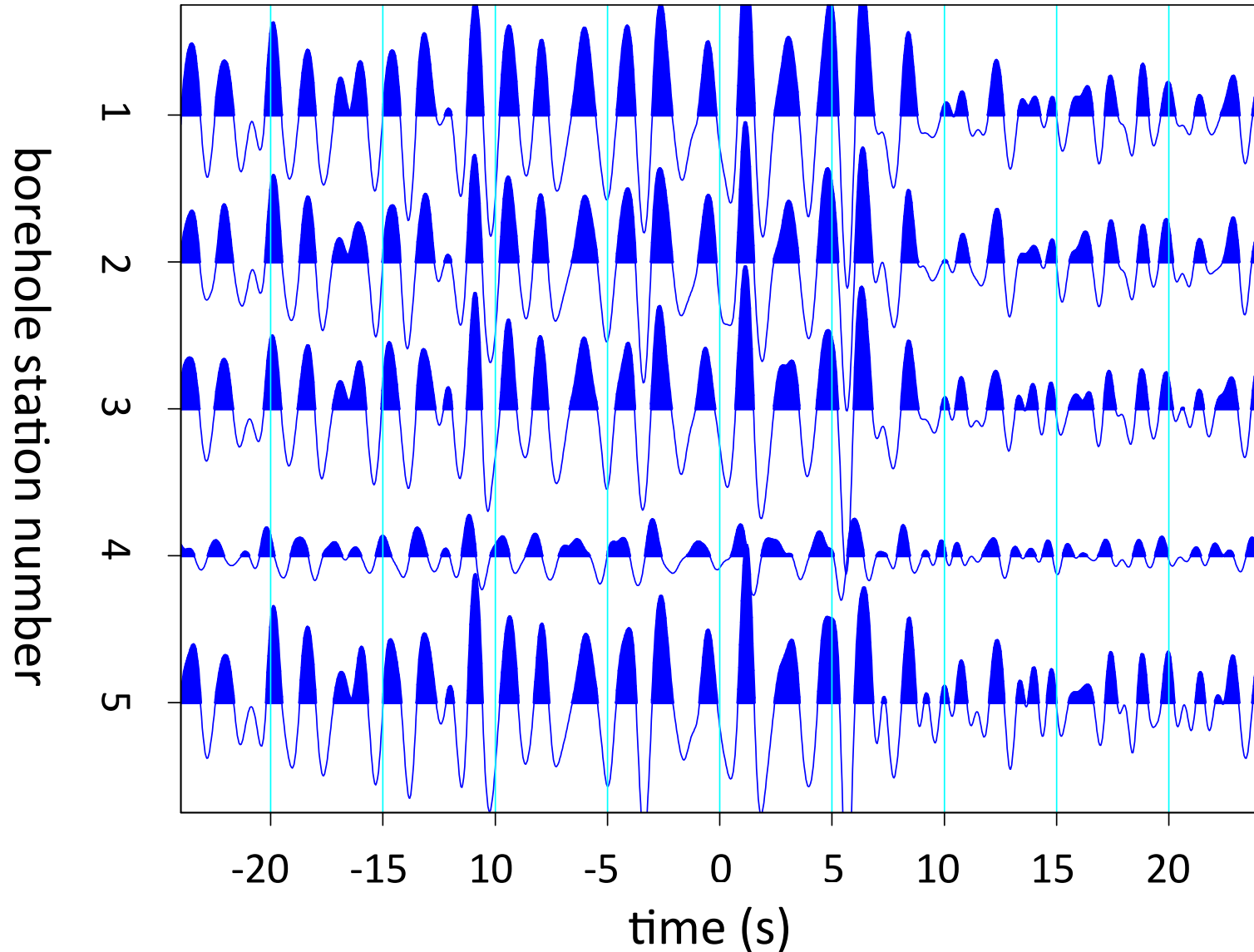


5 stations nearest the platform

- Borehole entrance is at the platform
- Compare signals in the borehole and at the entrance of the borehole

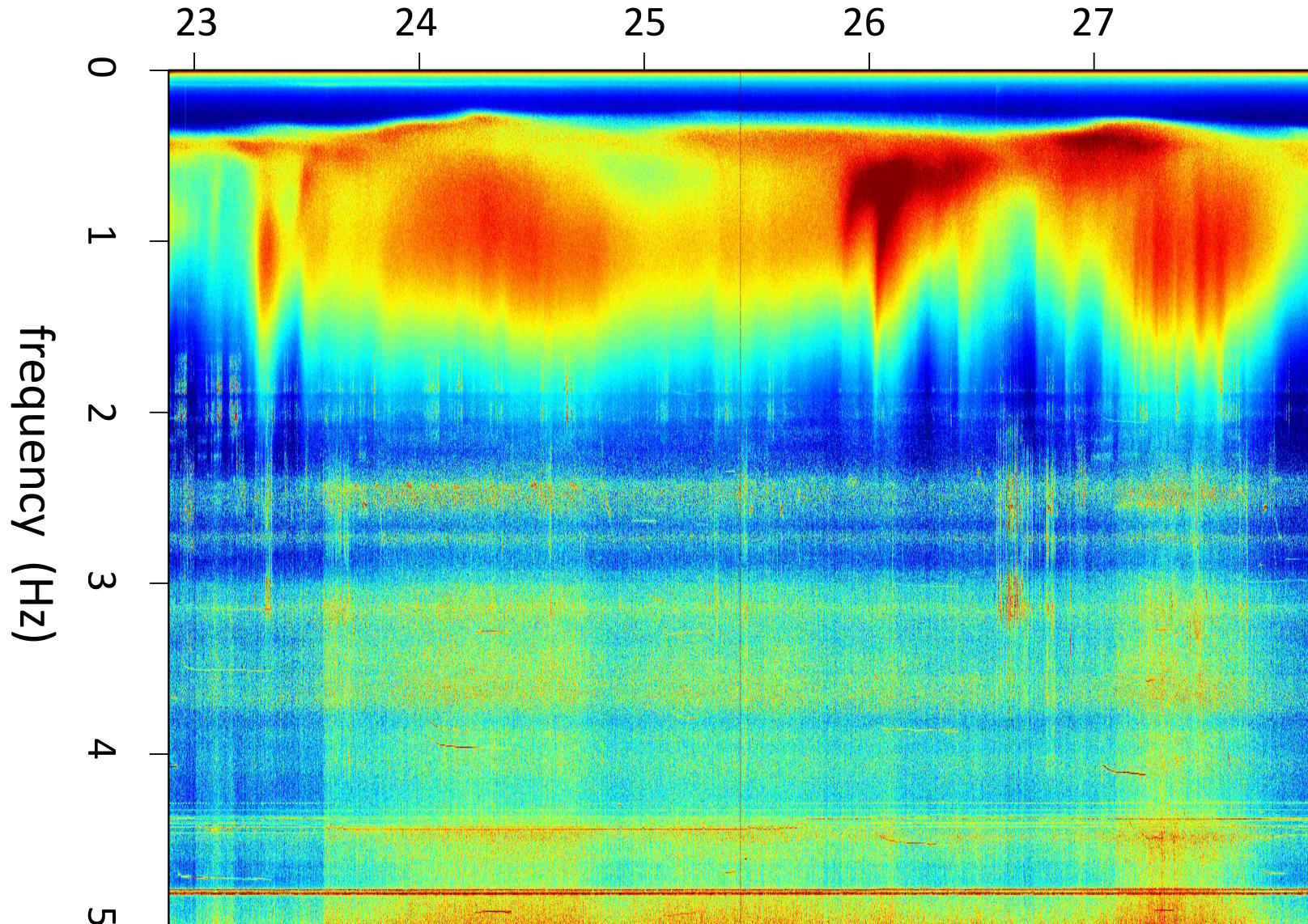


4 of 5 borehole stations

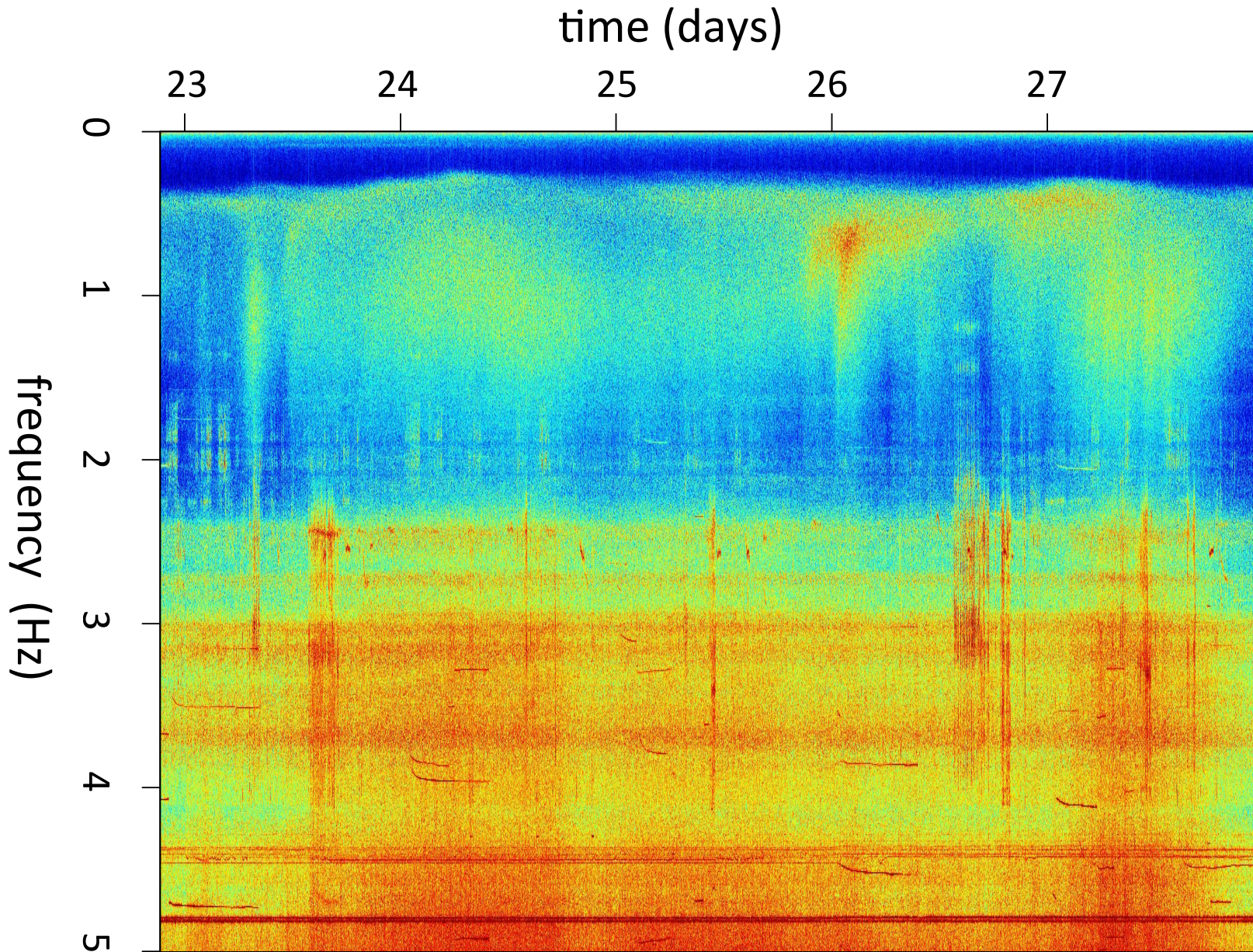


Averaged spectra within 2km

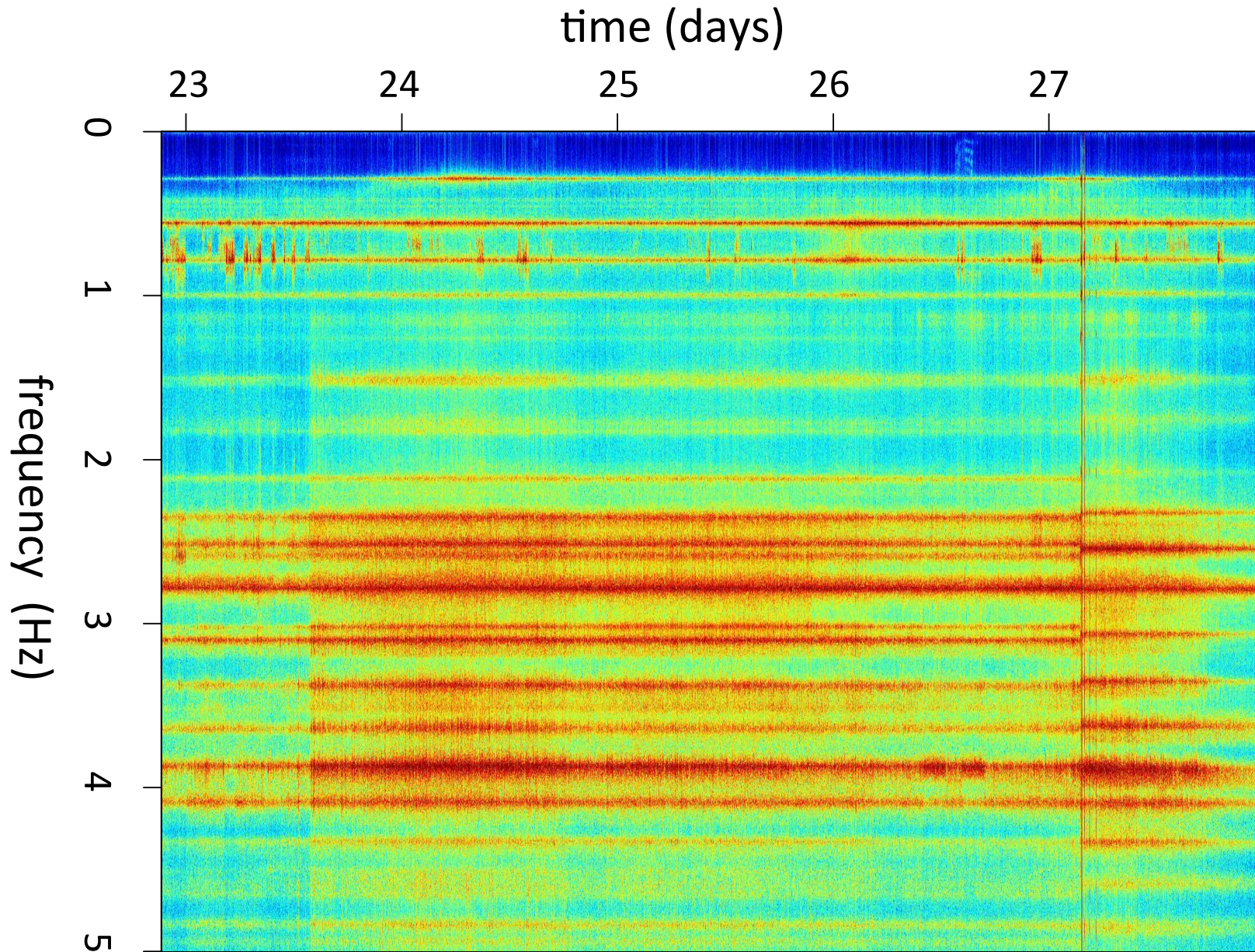
time (days)



Averaged spectra near platform



Averaged spectra in borehole



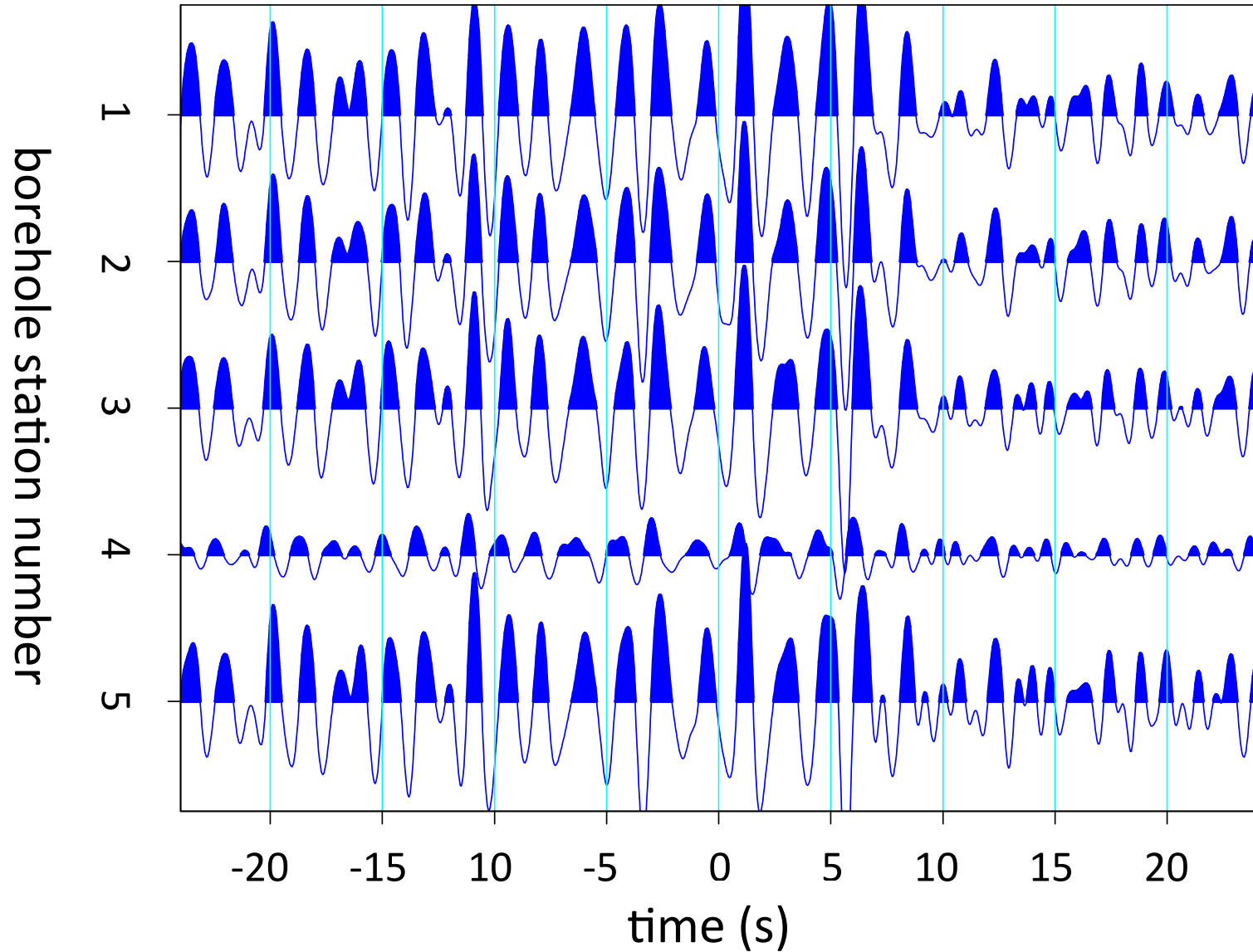
Observations

- Spectrograms for the surface stations within 2km are quite different from that for the borehole stations
- Spectrograms for the surface stations near the platform better match that for the borehole stations
- Borehole energy in the low-frequencies might be covering up the correlating energy

Correlation details

- Band-passed for .175Hz to 1.75Hz
 - Comparable to Scholte-wave frequencies investigated in previous studies
- Cross-correlated each borehole station with all surface stations
 - Results were similar
- Only vertical components

Correlation results



surface station number

400

800

1200

1600

2000

-20

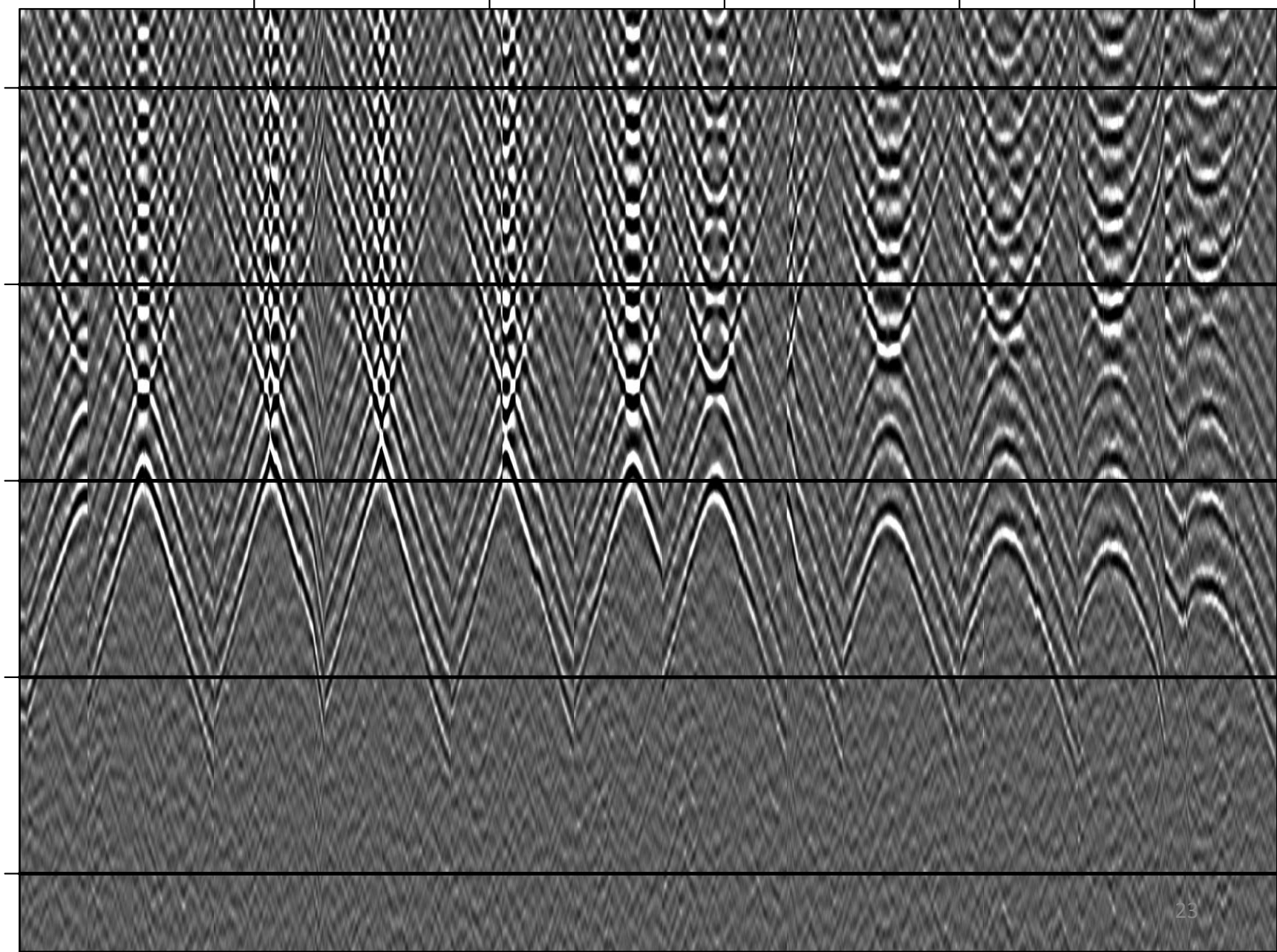
-10

0

10

20

time (s)



surface station number

400

800

1200

1600

2000

-20

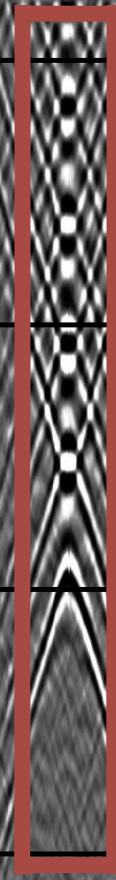
-10

0

10

20

time (s)



not time-symmetric

surface station number

400

800

1200

1600

2000

-20

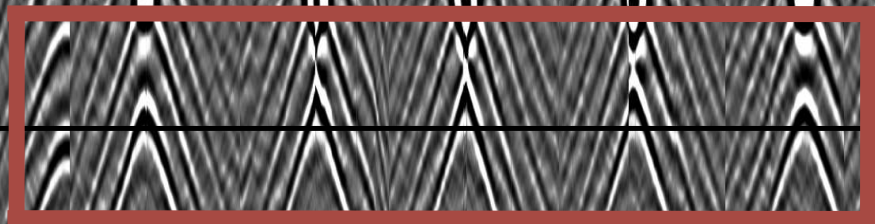
-10

0

10

20

time (s)



apexes of causal events
are at negative time lags

surface station number

400

800

1200

1600

2000

-20

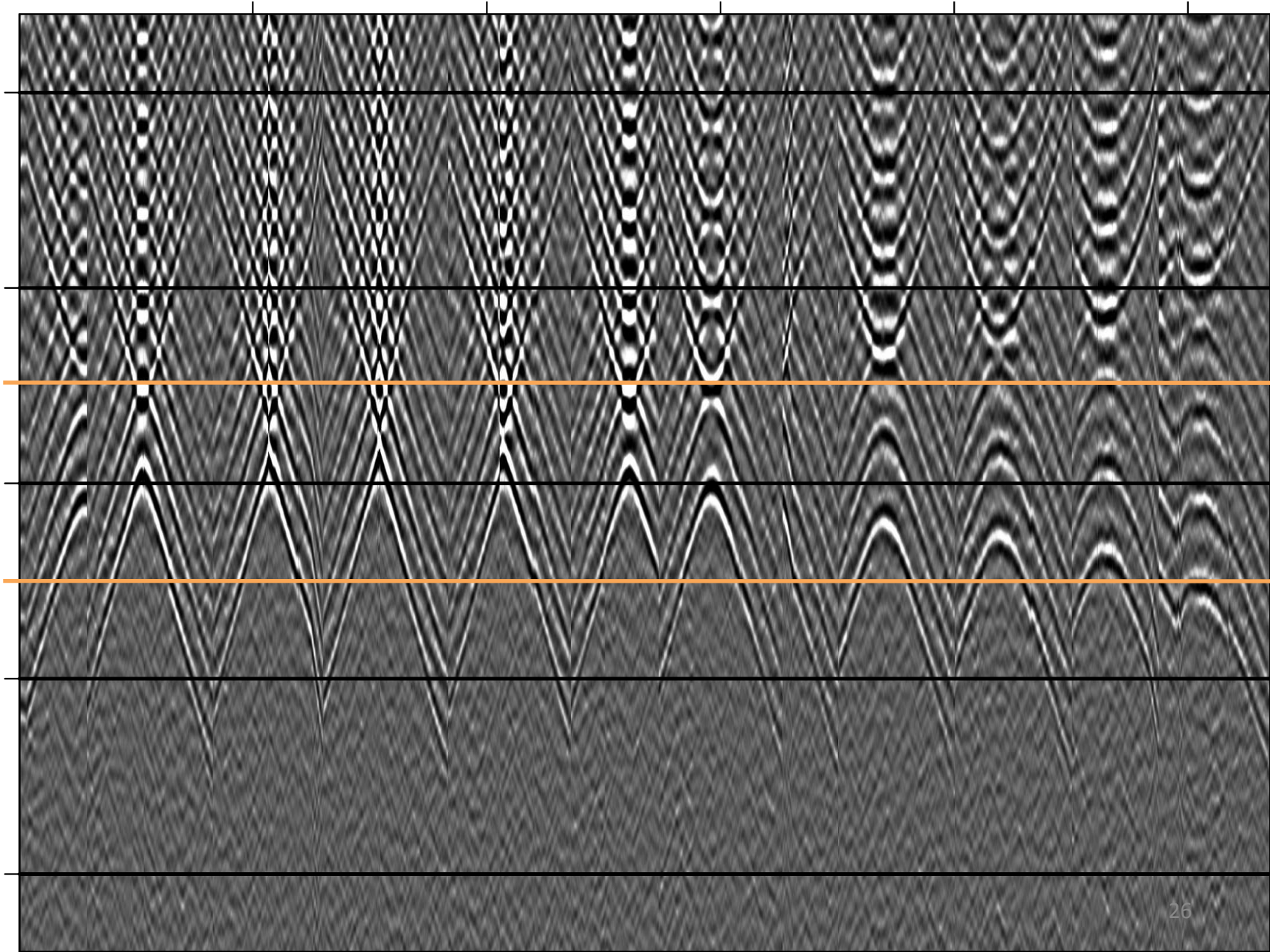
-10

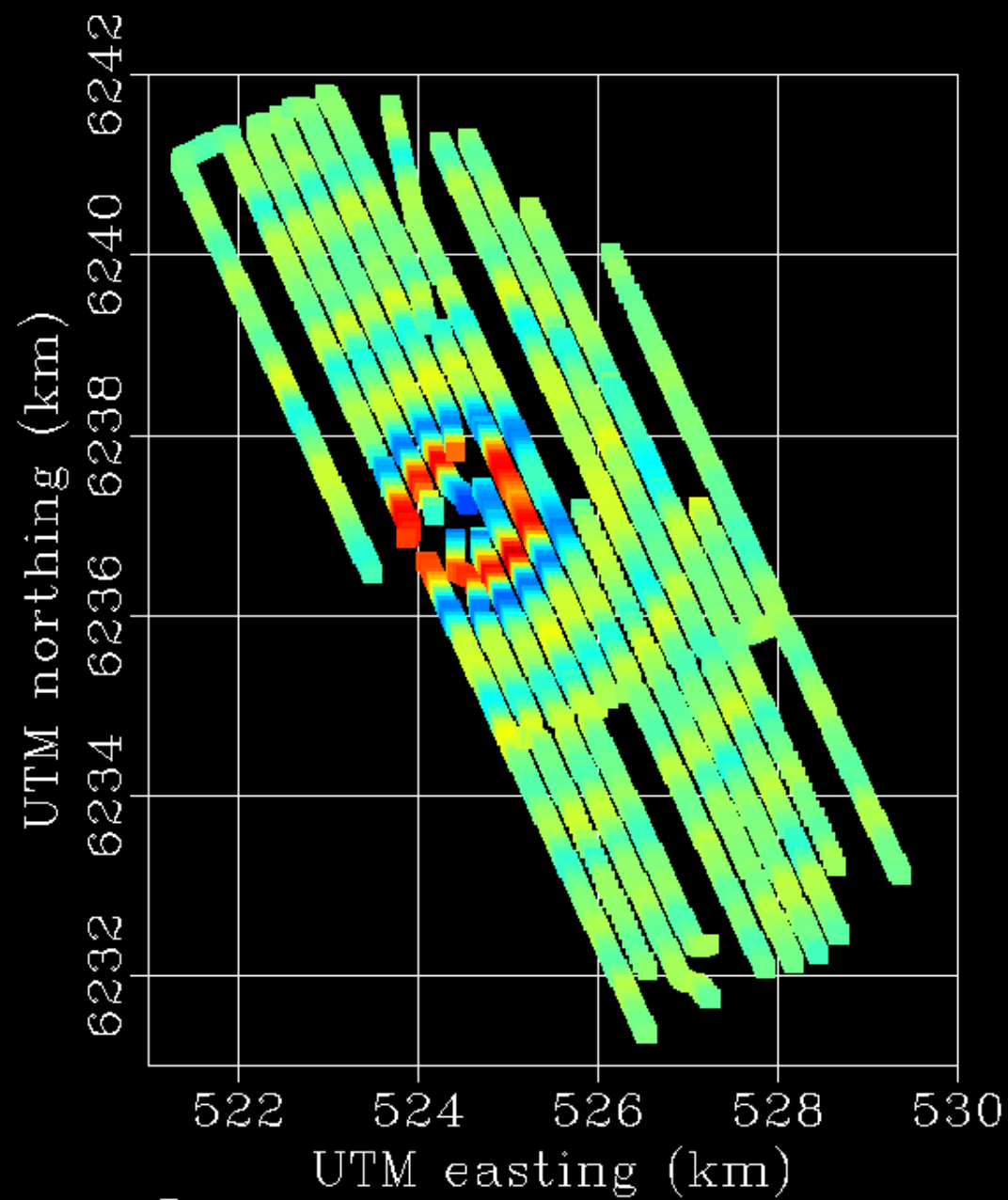
0

10

20

time (s)

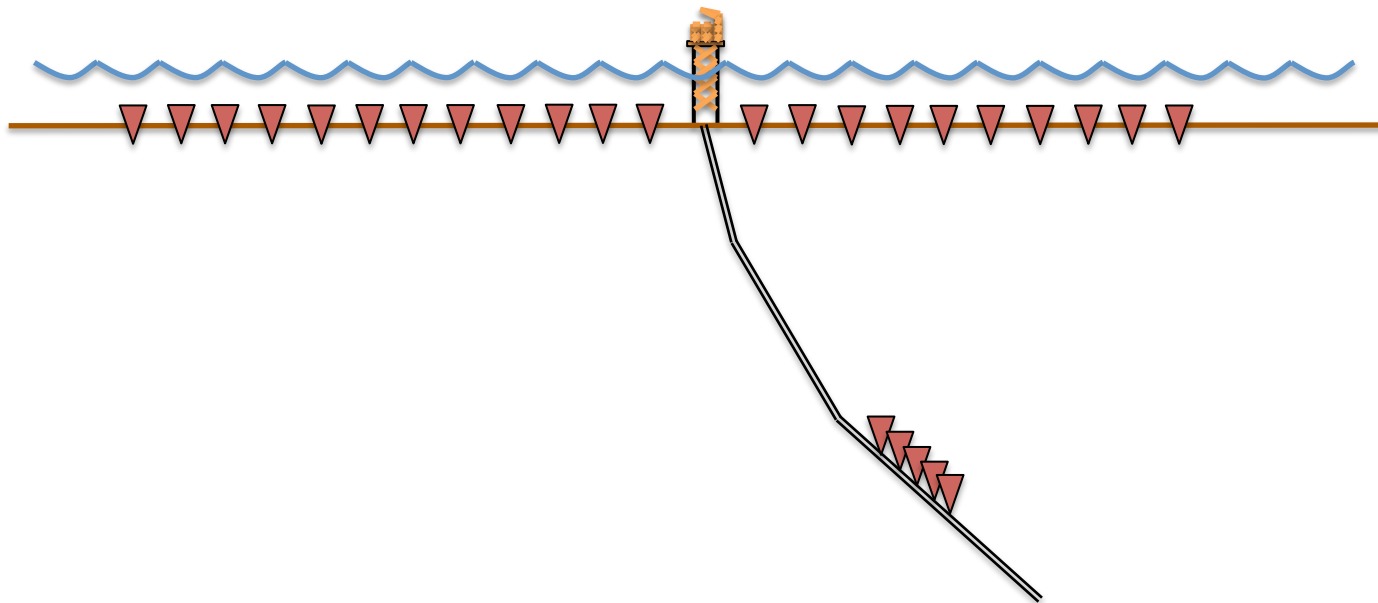


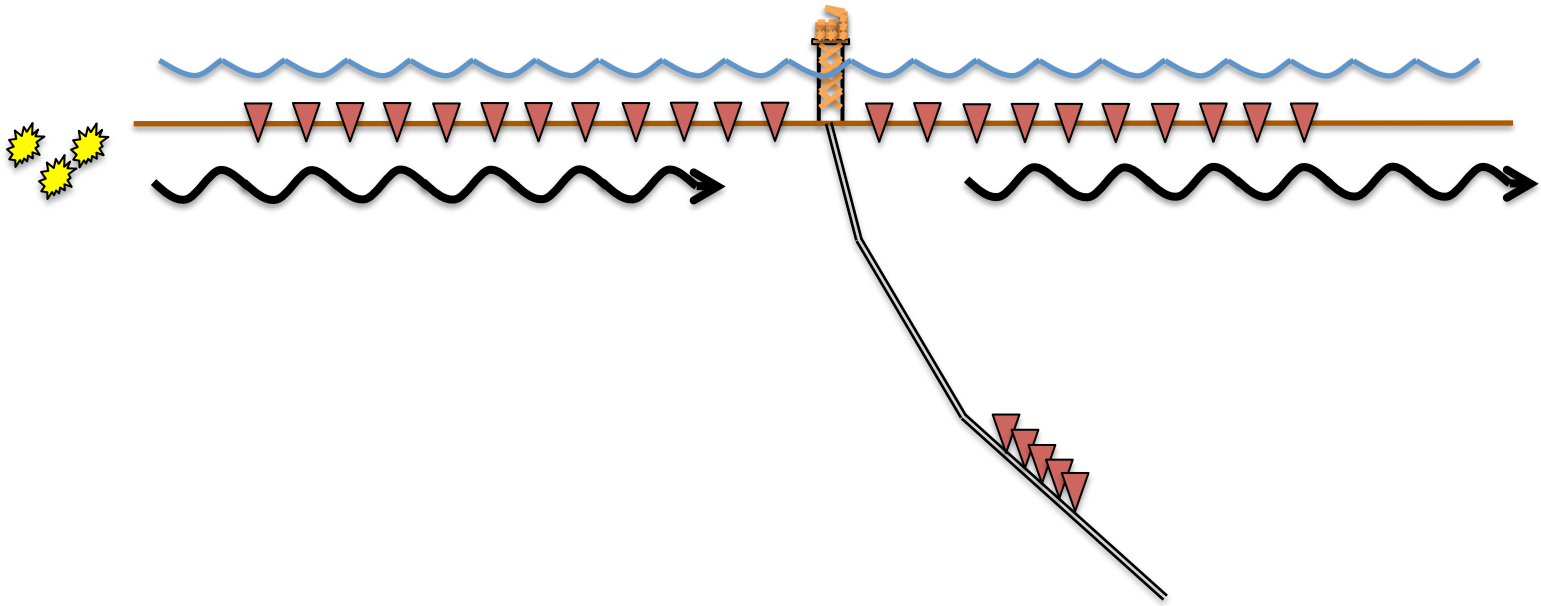


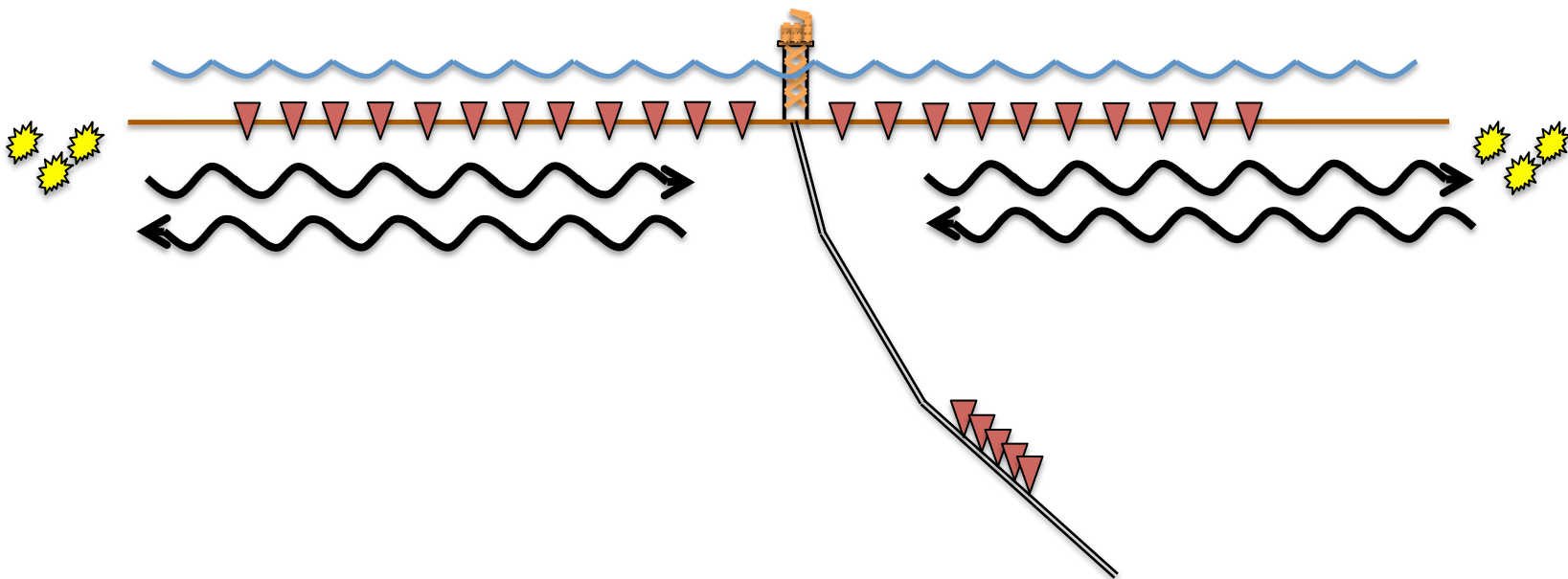
Observations

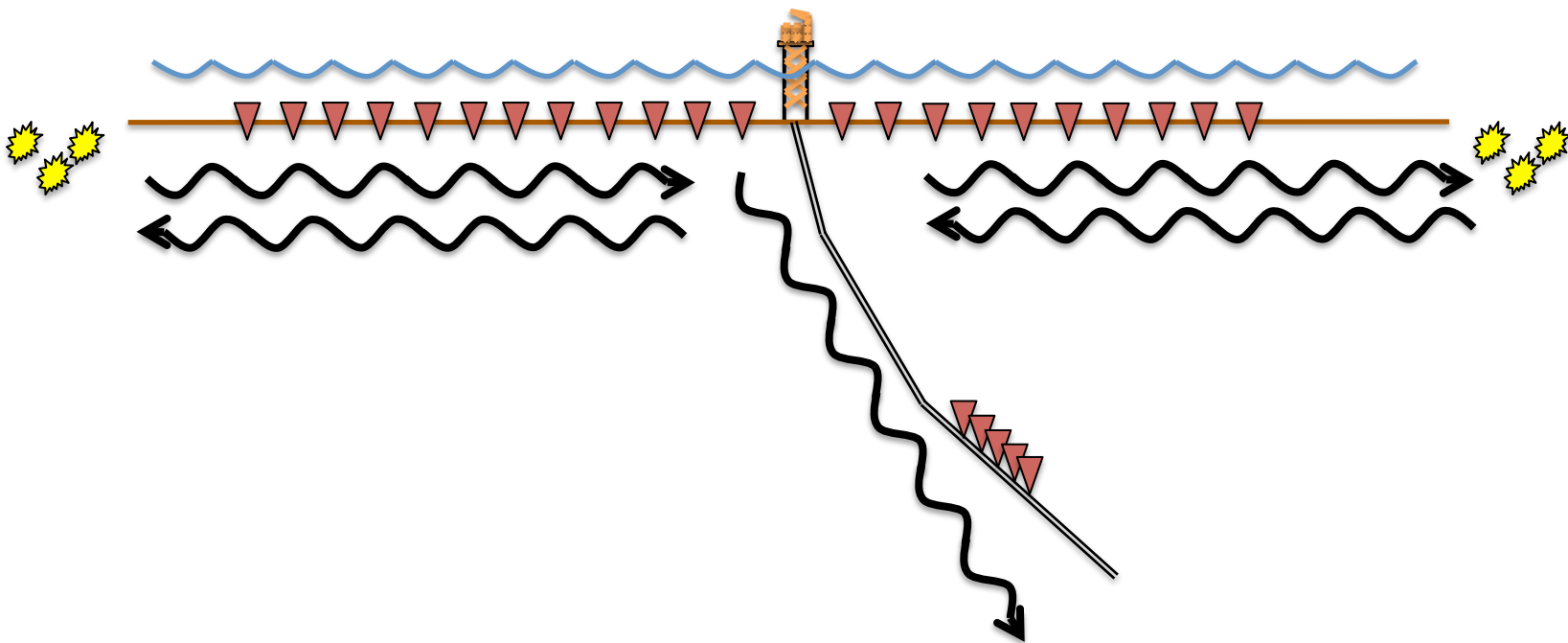
- Not a typical result for seismic interferometry
 - Not time symmetric, as there are multiple arrivals at acausal (negative) times
 - Apexes of causal events are at negative time lags rather than at zero time lag
- Virtual source appears to emanate from the platform rather than the borehole locations

Discussion

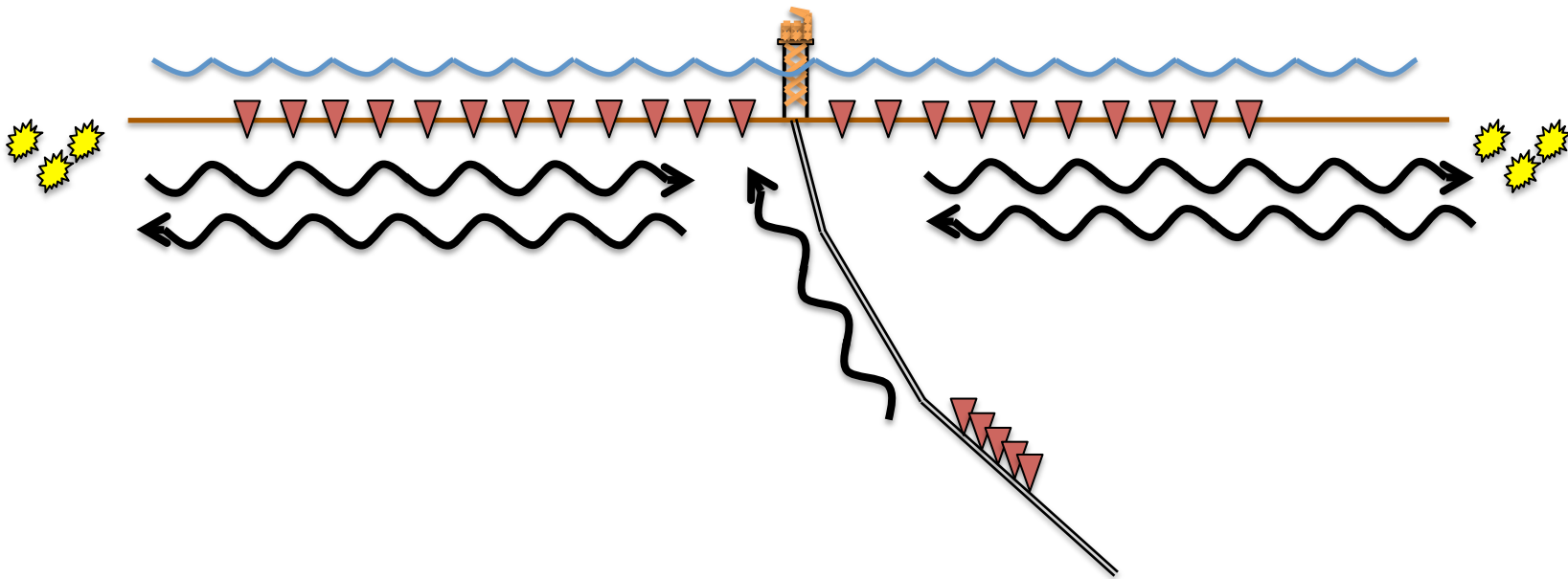




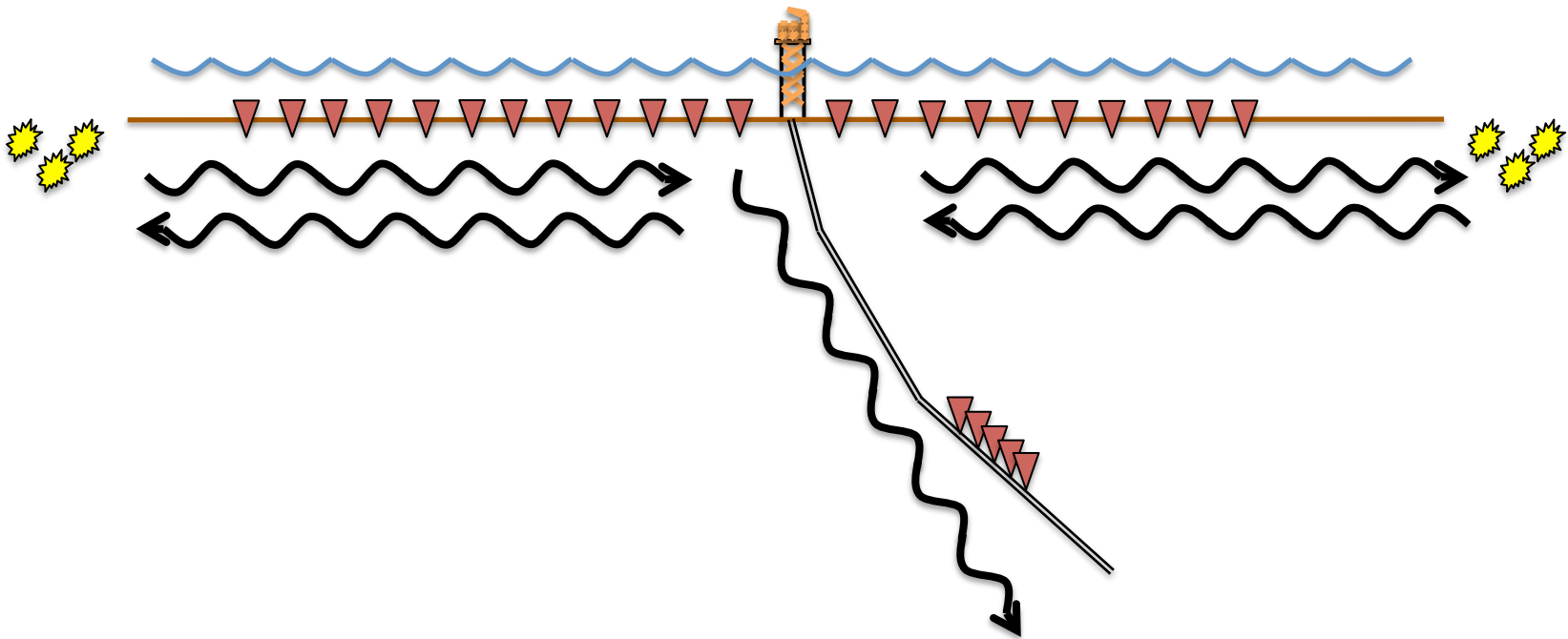




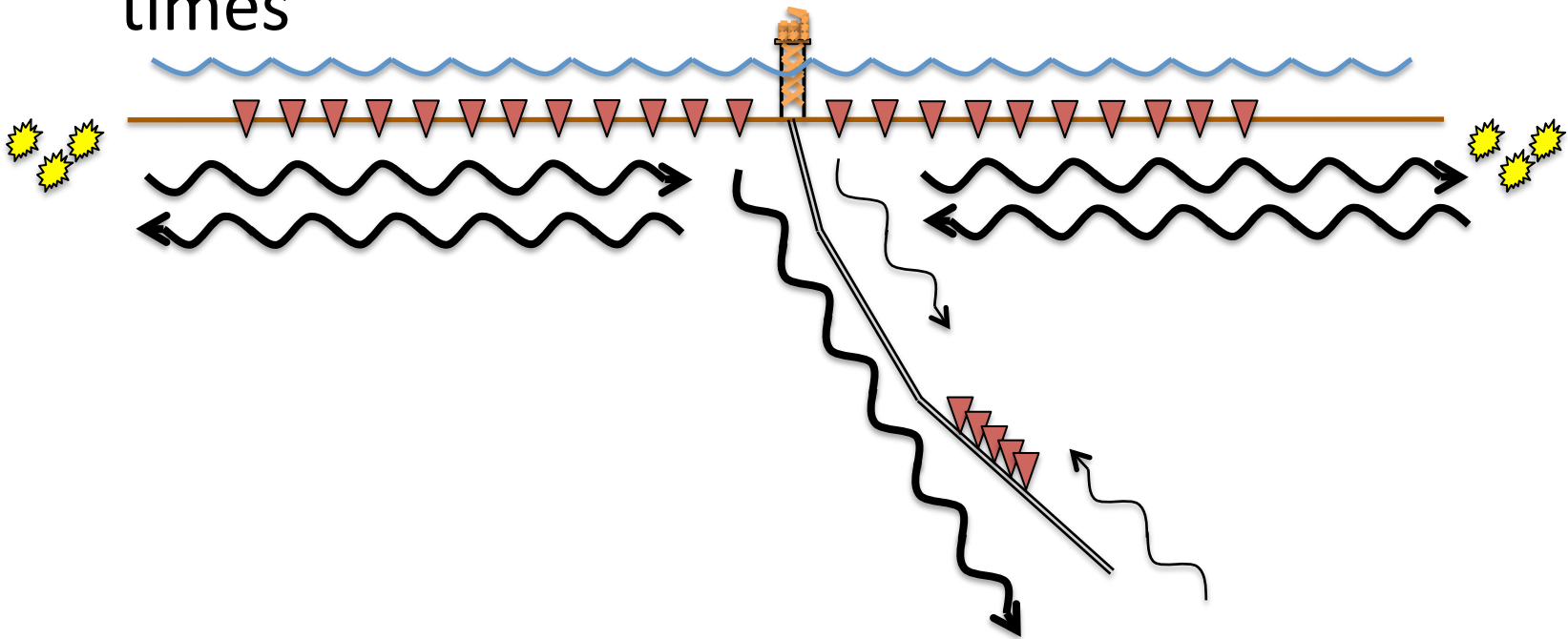
- Borehole acts as a waveguide
- Violates energy equipartition
- Virtual source created at the borehole must reach the surface at the platform



- Time it takes for signal to reach the borehole stations from the surface via the borehole accounts for the apexes of causal events being at negative time lags



- Wave generated at the surface bounce up and down in the borehole
- Accounts for the multiple arrivals at acausal times



Recap

- Virtual source appears to emanate from the platform due to the borehole acting as a waveguide

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- Apexes of causal events are at negative time lags due to energy from the surface having to travel in the borehole to reach stations at depth

Recap

- Virtual source appears to emanate from the platform due to the borehole acting as a waveguide
- Apexes of causal events are at negative time lags due to energy from the surface having to travel in the borehole to reach stations at depth
- Not time symmetric due to energy moving up and down the borehole

Conclusions

- The borehole acts as a waveguide
- This does not satisfy the conditions of seismic interferometry (energy equipartition)
- These cross-correlations cannot be interpreted as inter-station Green's functions

Acknowledgements

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Questions