Optimal towing depth for streamer data to minimize normal mode noise

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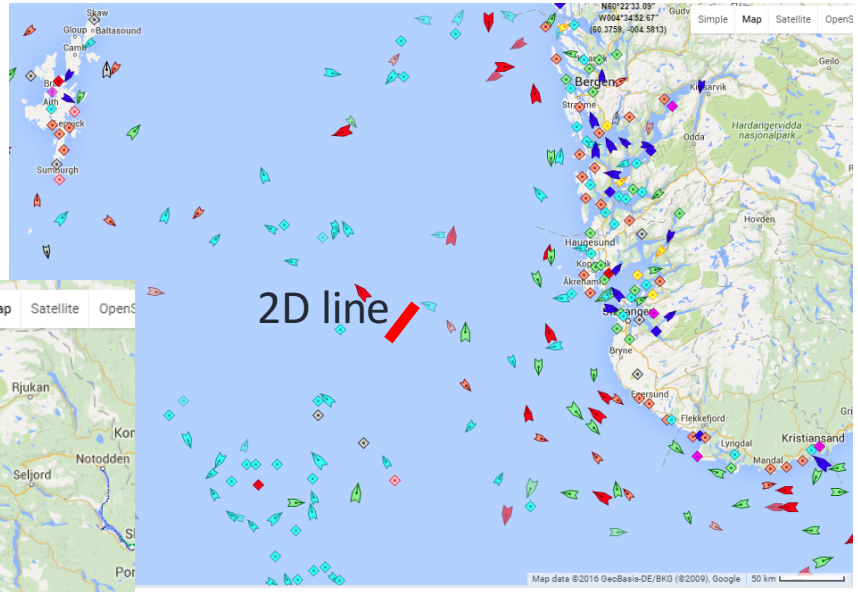
Outline

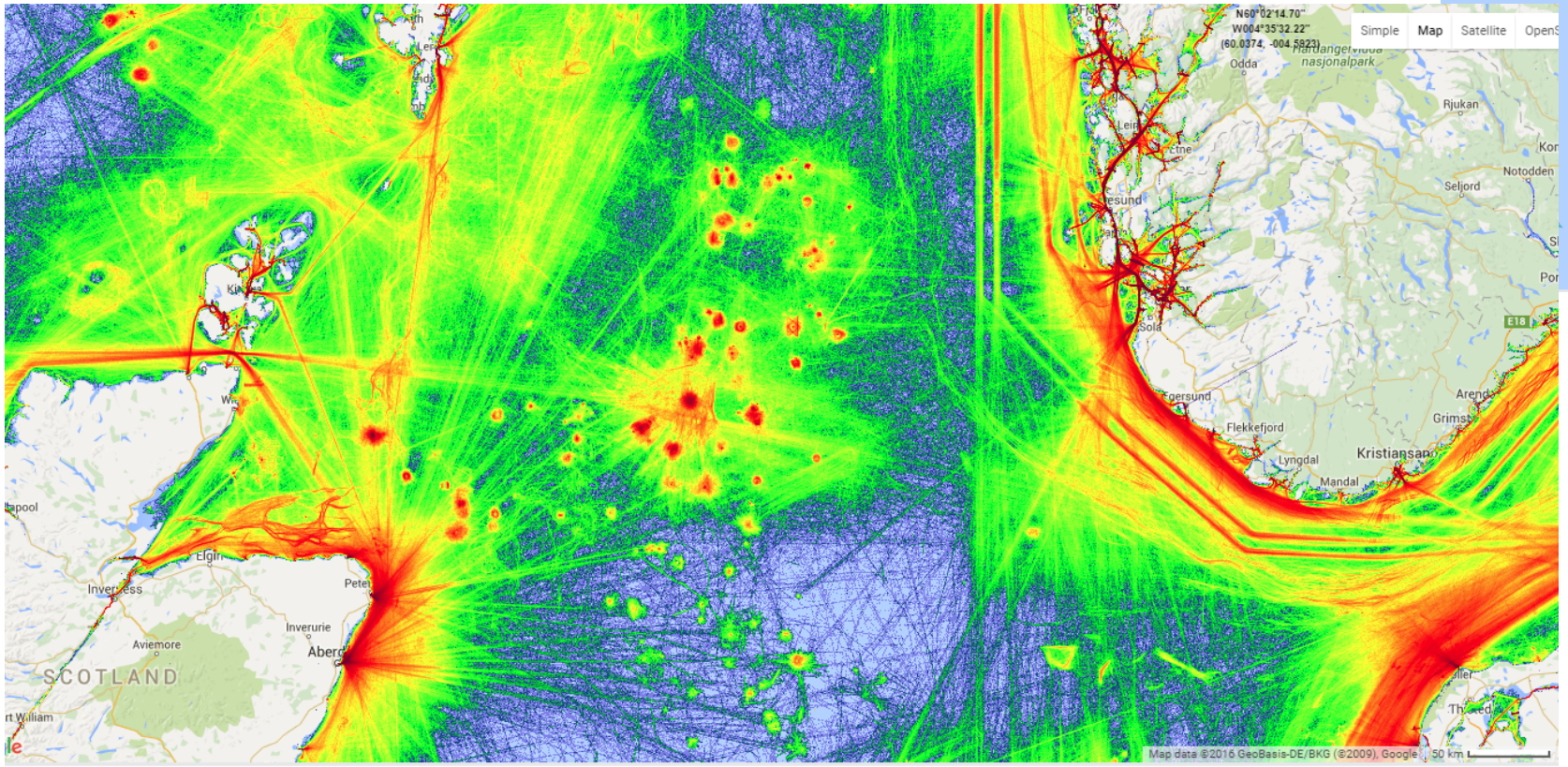
- Introduction
- Normal mode theory
- Forward modeling
- Field data
  - 8m and 60m streamer data: with and without airgun signal
- Conclusion

Introduction

Traffic in North Sea



Average traffic density of 2013



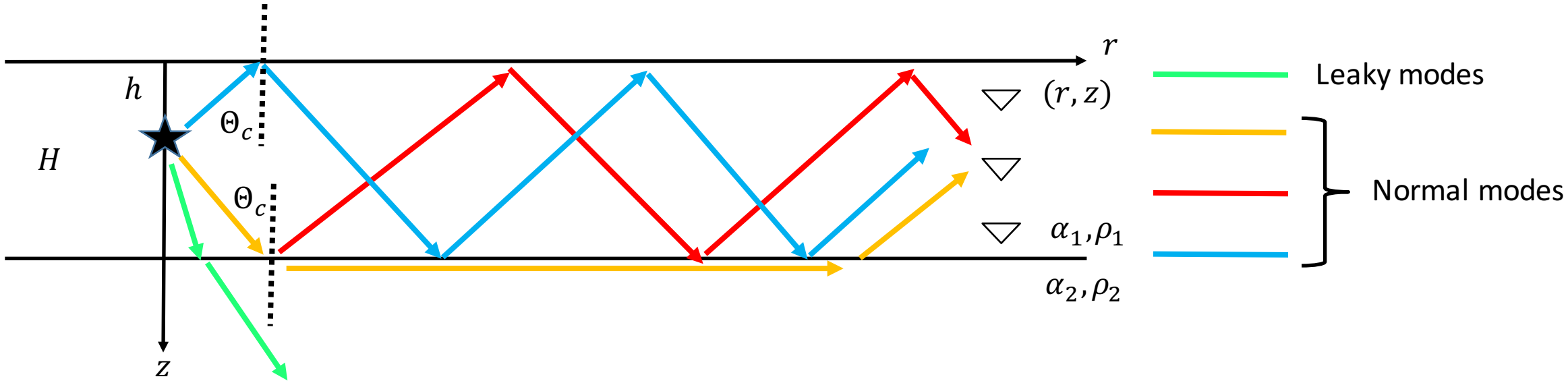
http://www.marinetraffic.com/

Introduction

- Ship noise:
  - dominant noise source below 200 Hz, coincides with seismic band
  - can be very loud, travel long distance
    - Tankers: 196+ dB re $\mu Pa^2/Hz$ @ 1 m
    - Fishing vessels: 140+ dB re $\mu Pa^2/Hz$ @ 1 m
    - 250 Hz (6m wavelength) 0.005 dB/km → 1 order of magnitude decreased after 200 km offset
- Marine seismic noise:
  - often uncontrollable
  - best to find a quiet depth
- Shallow water:
  - a few acoustic wavelength in depth
  - normal mode description of the sound field is efficient.

Normal mode theory

Normal mode theory



Normal mode theory

- Acoustic wave-equation for displacement potential p:
  - $(\nabla^2 - k^2)p(r,\omega) = -\frac{\delta(r)\delta(z-h)}{2\pi r}$
  - Total wavefield: $p(r,z) = \sum_n \mathrm{S}(\omega)\mathrm{a}_n(r)\varphi_\mathrm{n}(\omega,z)$.

Source — Eigenvalue

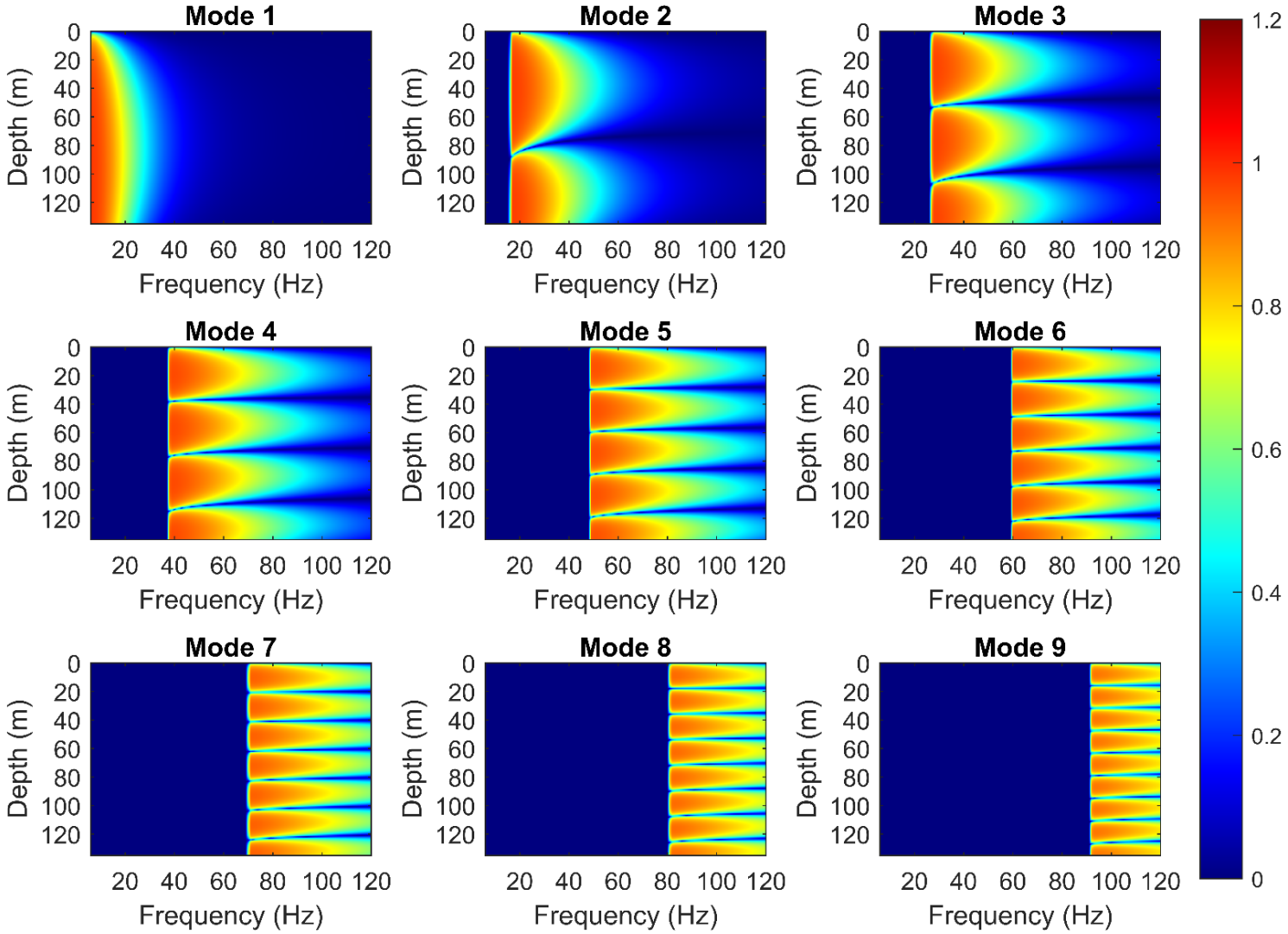
- Normal mode
- Depend only on depth

Displacement potential

$v_p = 1500, \rho = 1.0$

$v_p = 1600, \rho = 1.7$

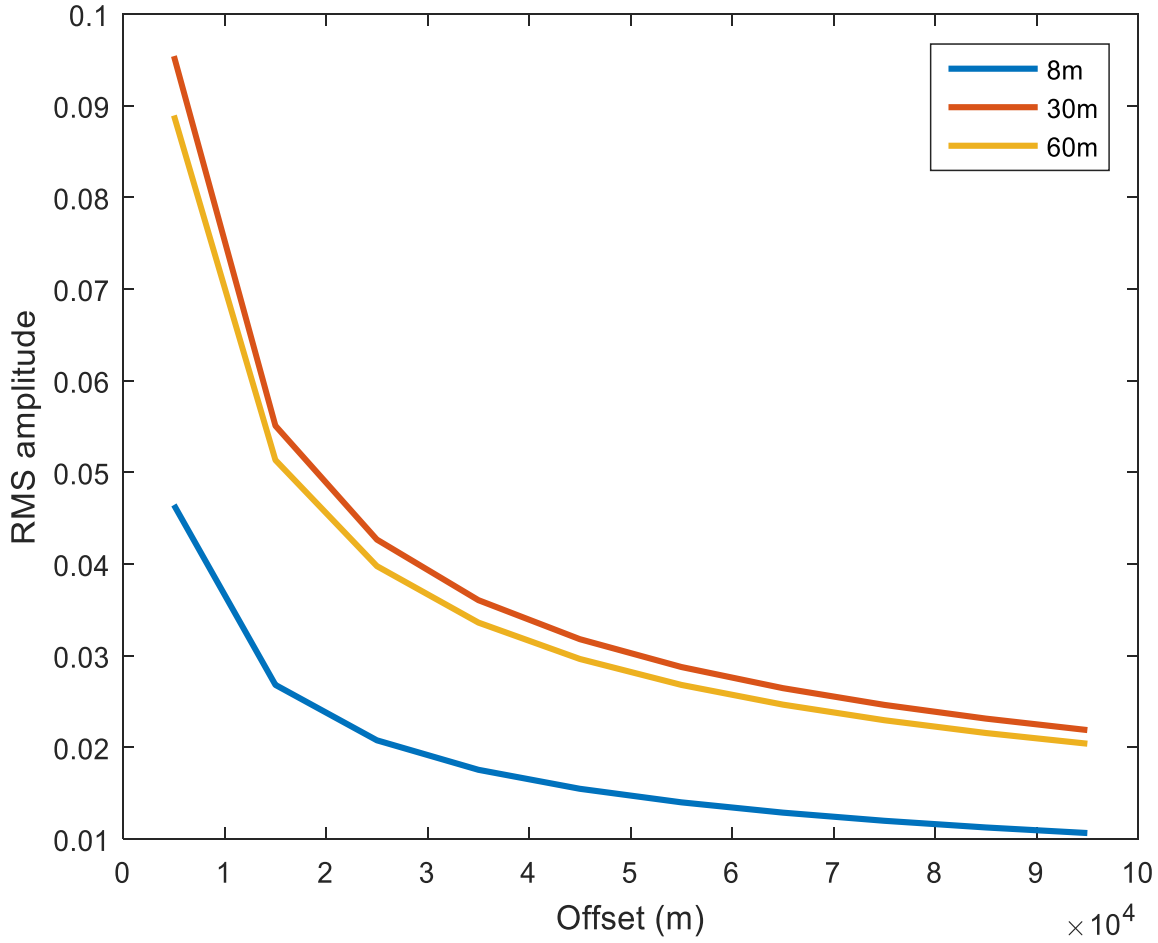
$Water\ depth = 130\ m$



Theoretical normal mode amplitude

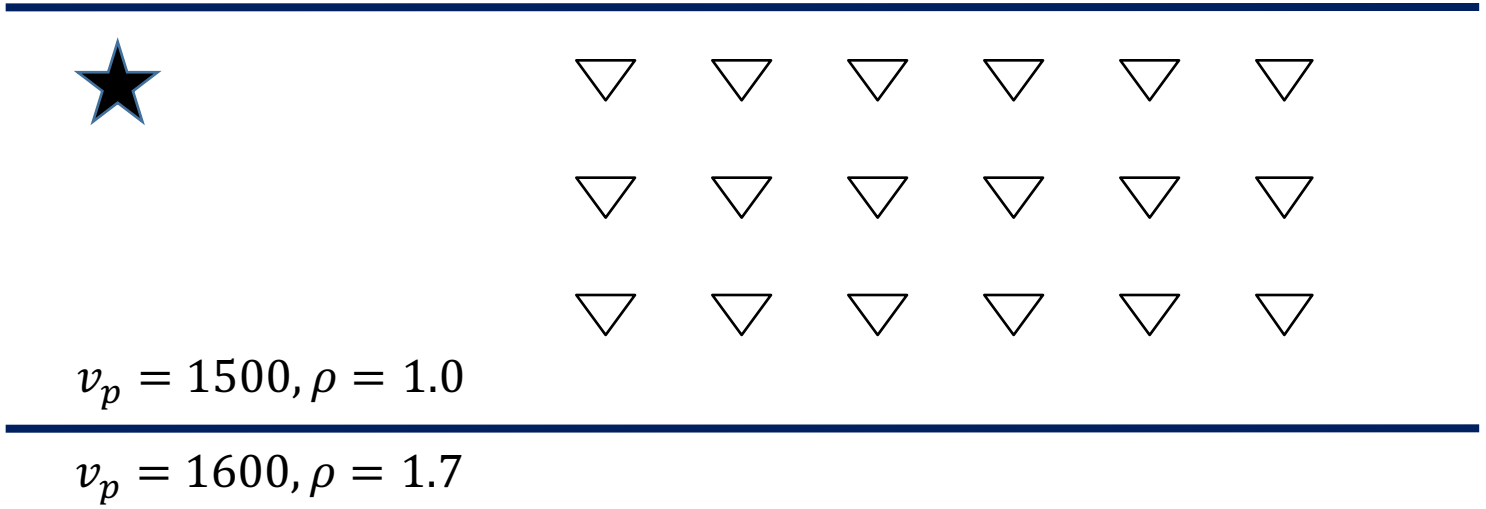
- Shallow source

- Seismic frequency band from 6 Hz

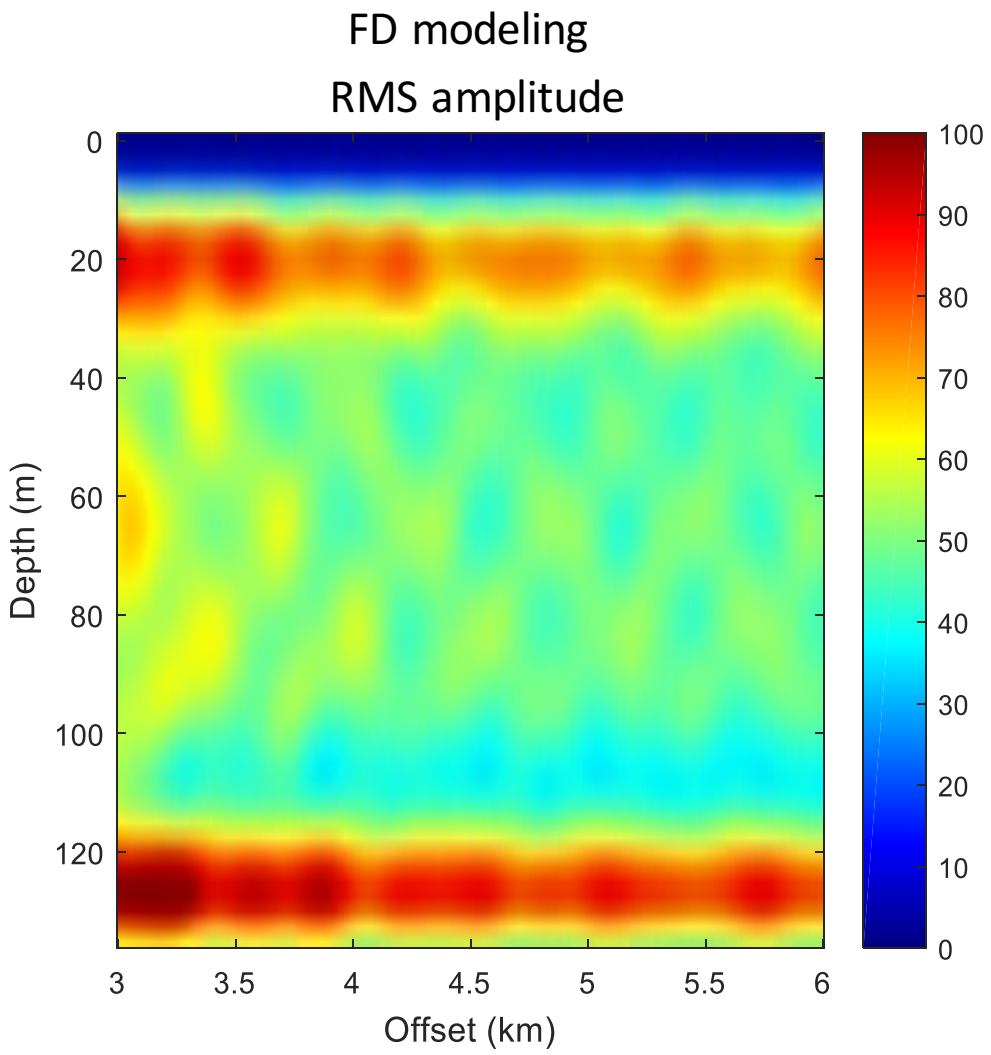


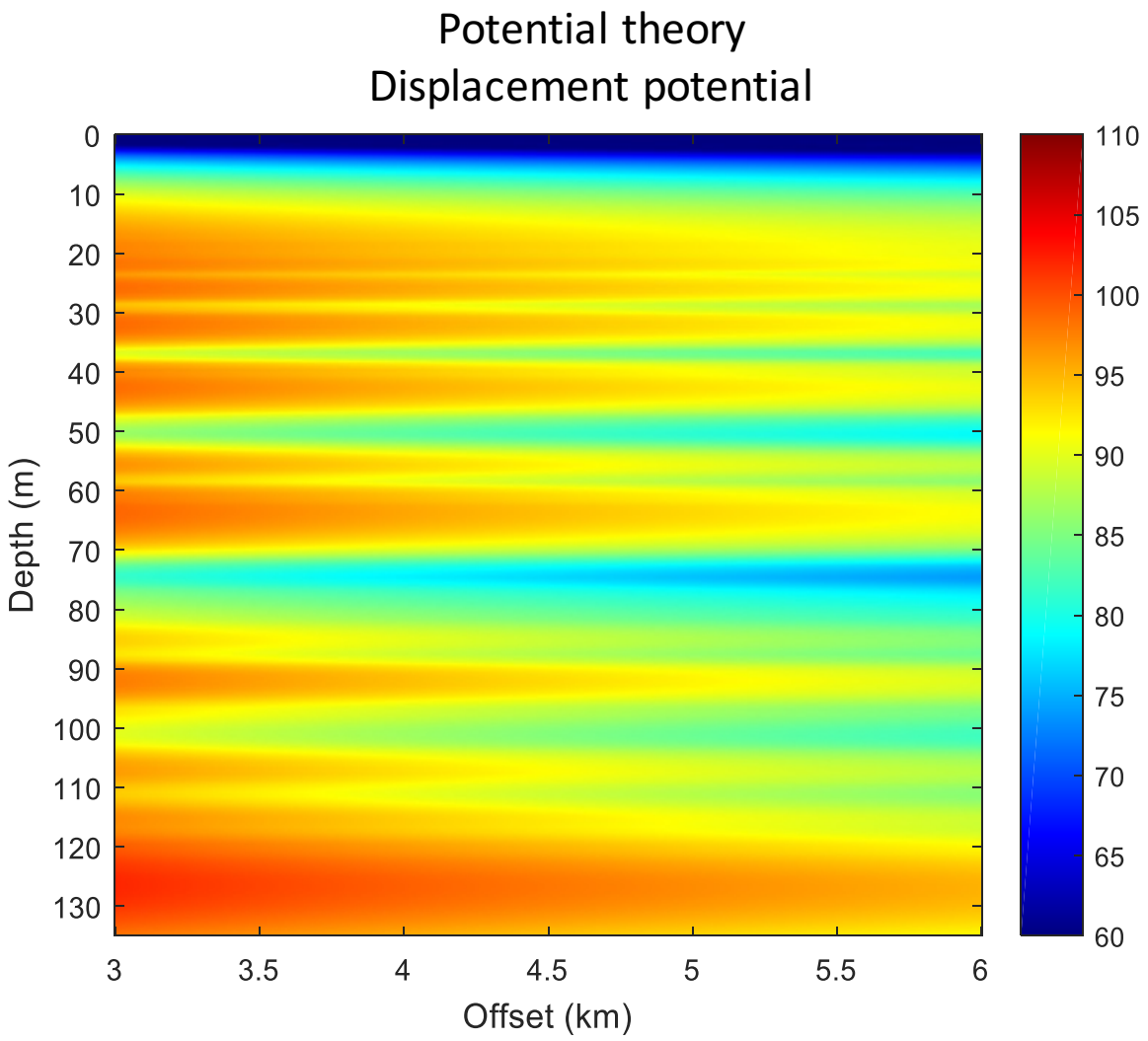
Finite-difference modeling

Different source wavelets



Finite-difference modeling – 35Hz wavelet

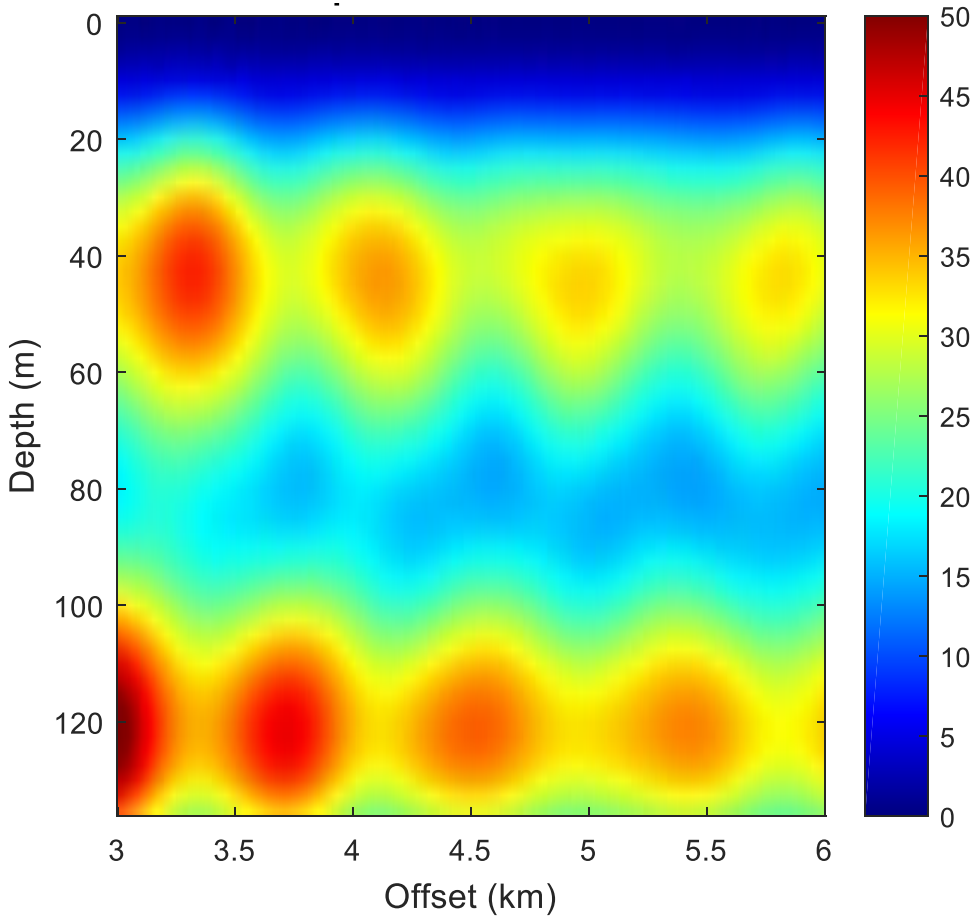




Finite-difference modeling – 15Hz wavelet

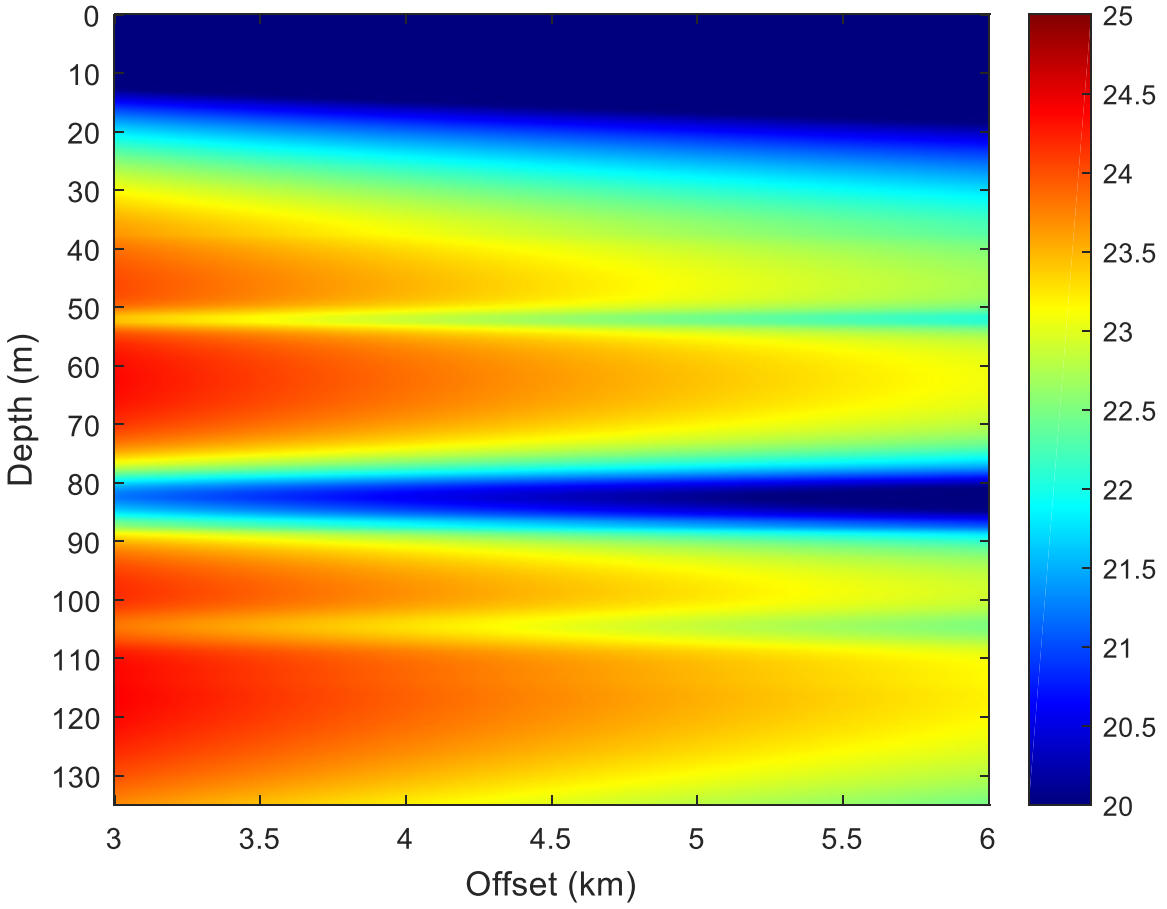
FD modeling

RMS amplitude



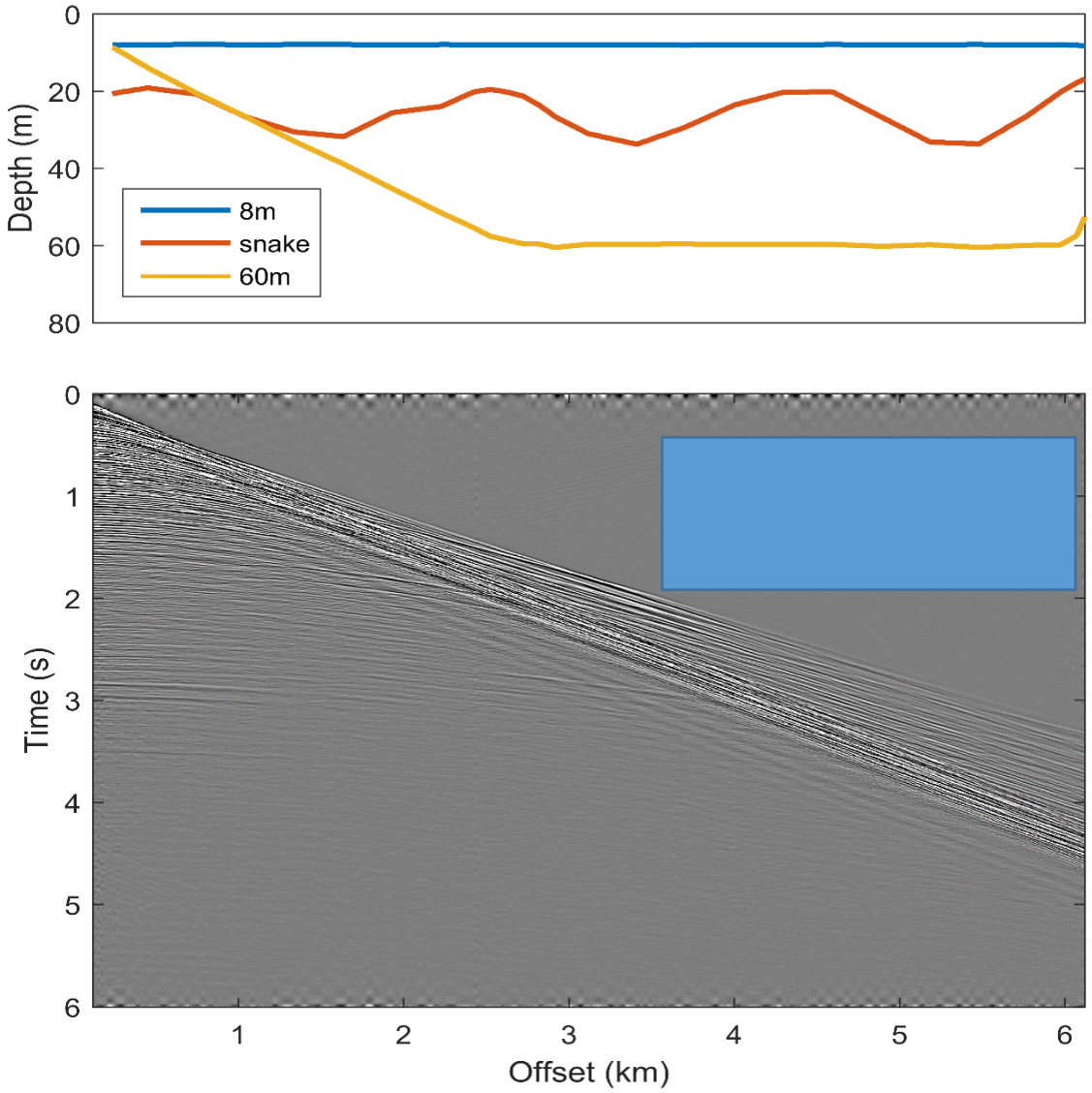
Potential theory

Displacement potential

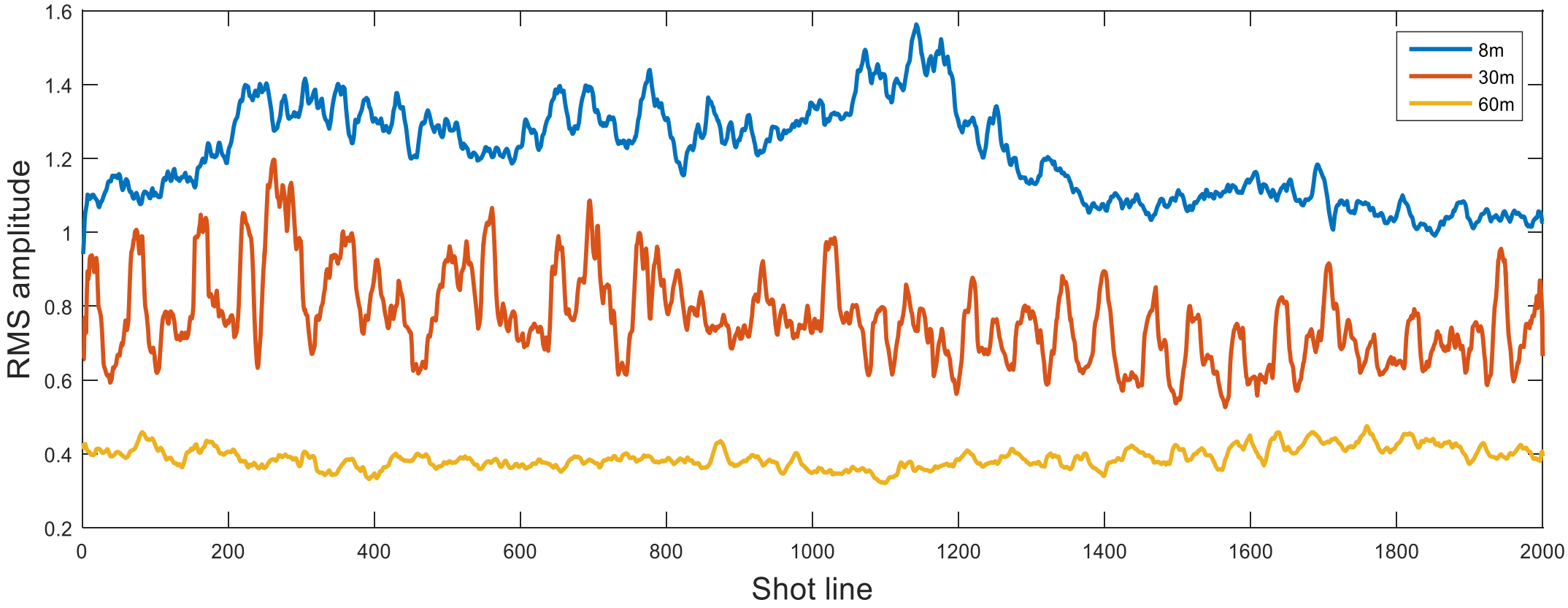


Data with airgun signal

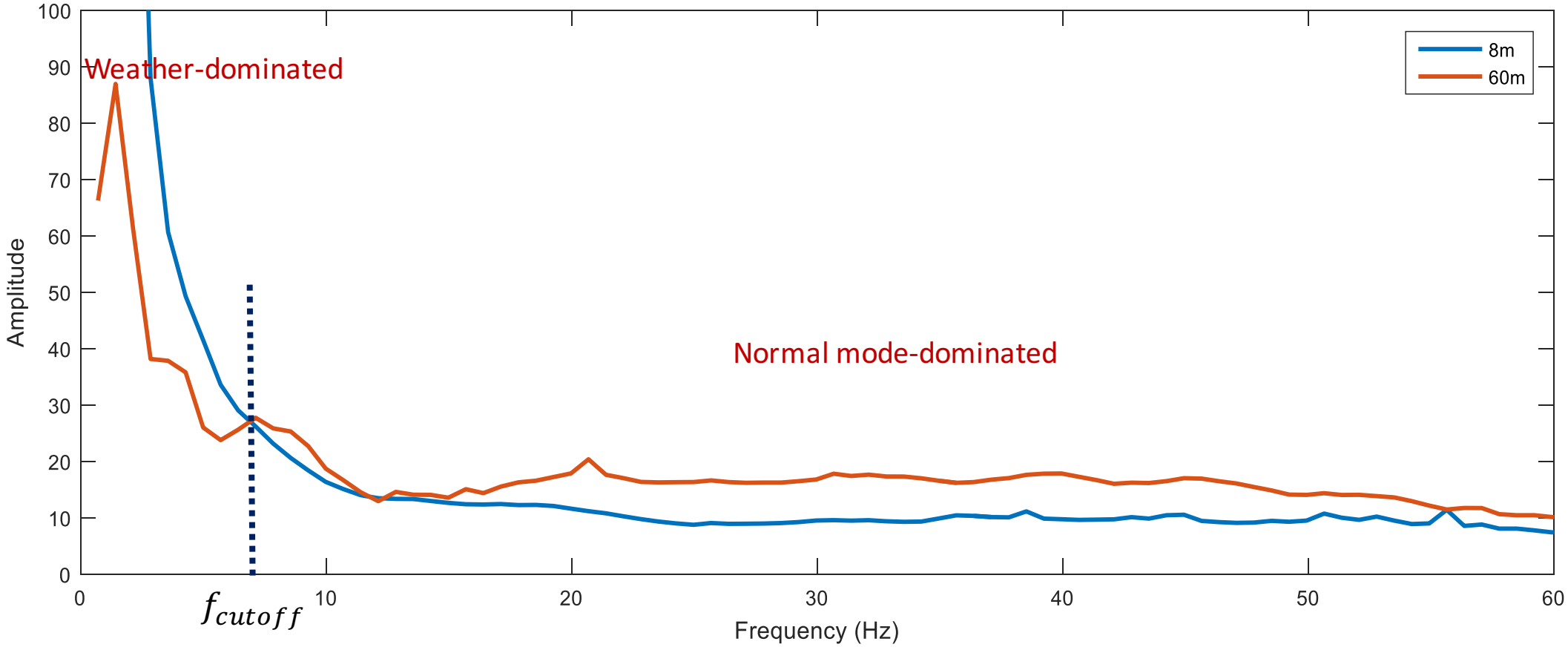
Streamer configurations



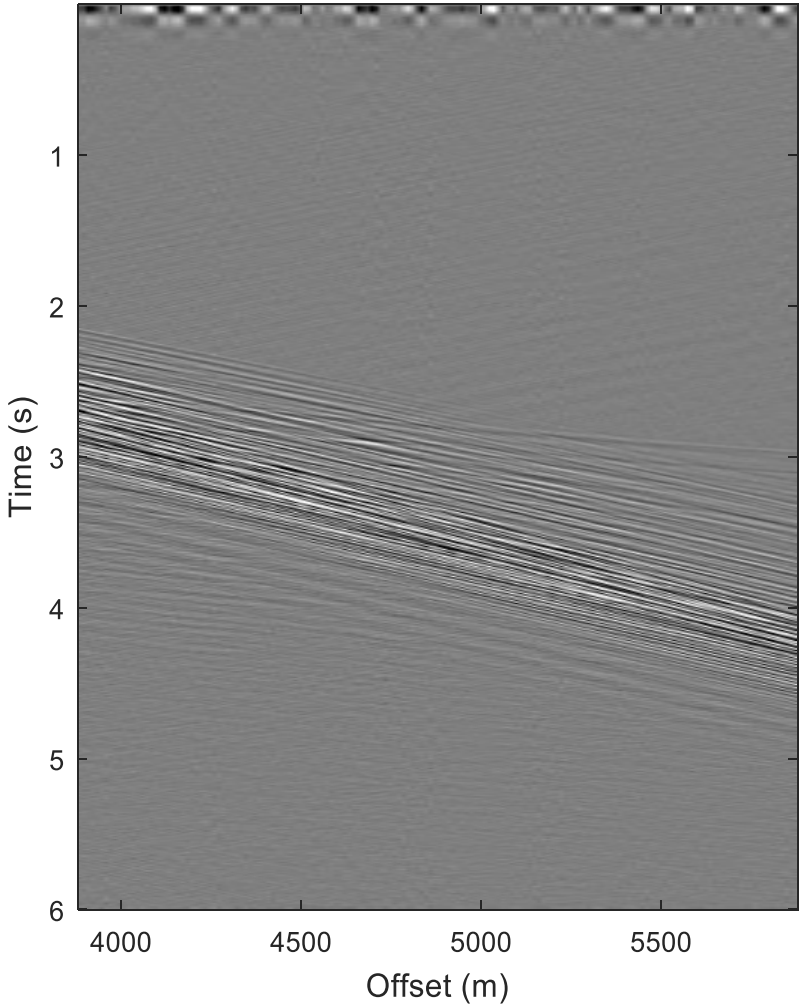
Weather-dominated noise below f_{cutoff} = 6 Hz

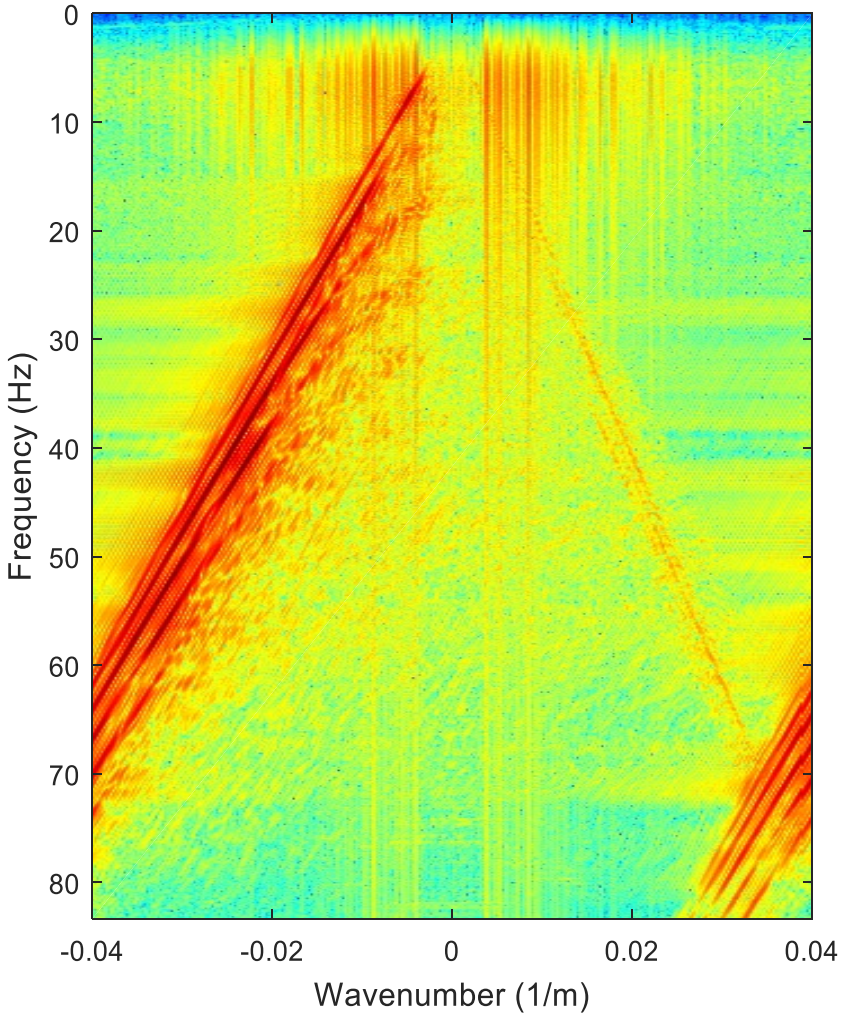


Noise data spectra before fan filter

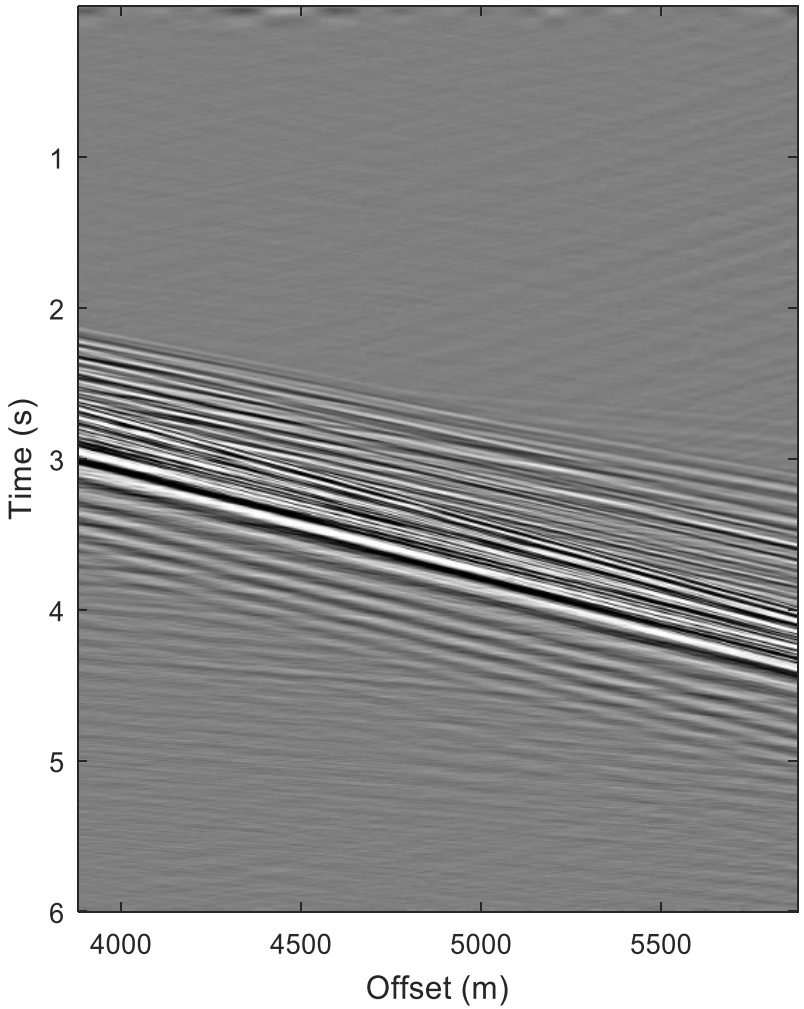


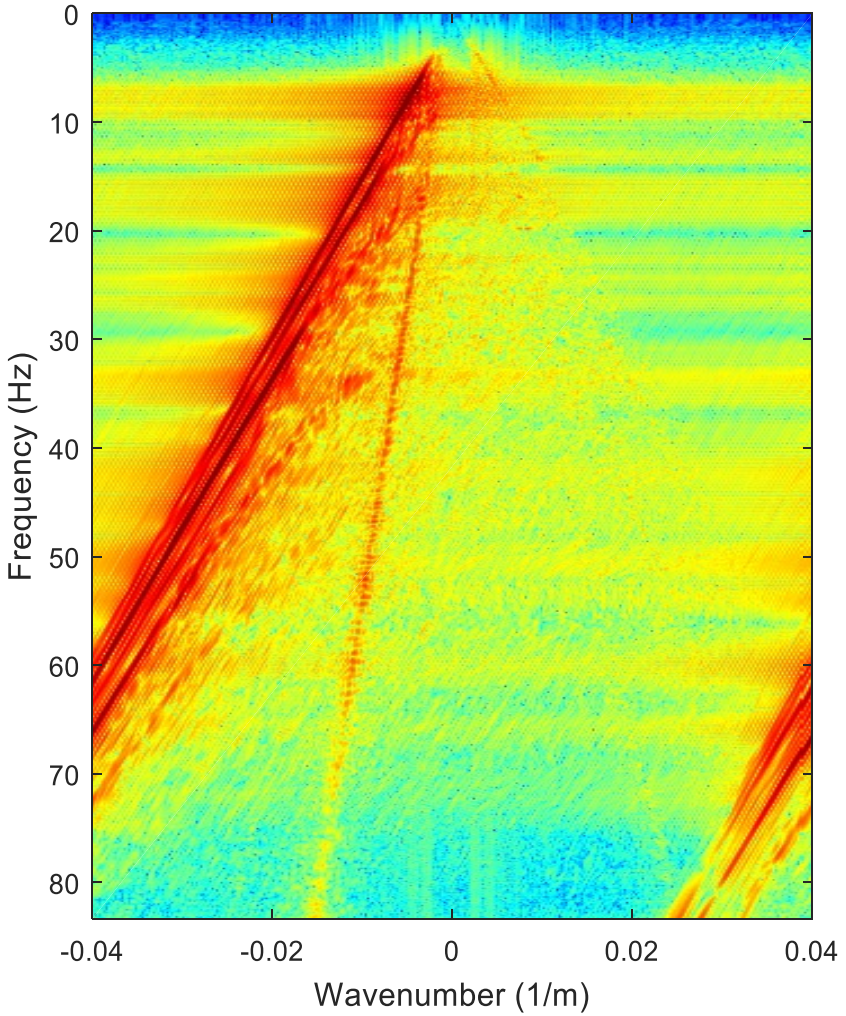
Far-offset data – 8m





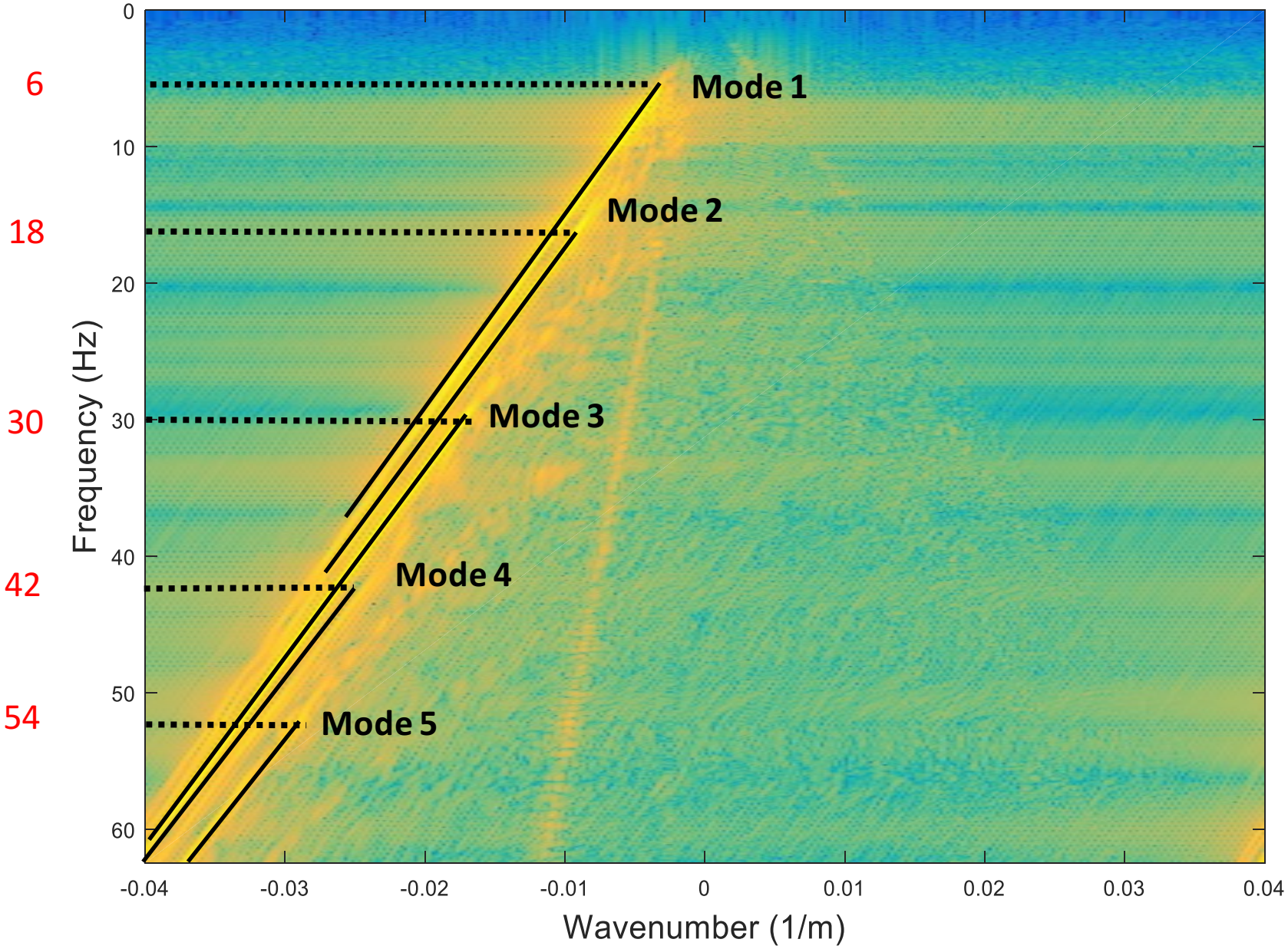
Far-offset data – 60m



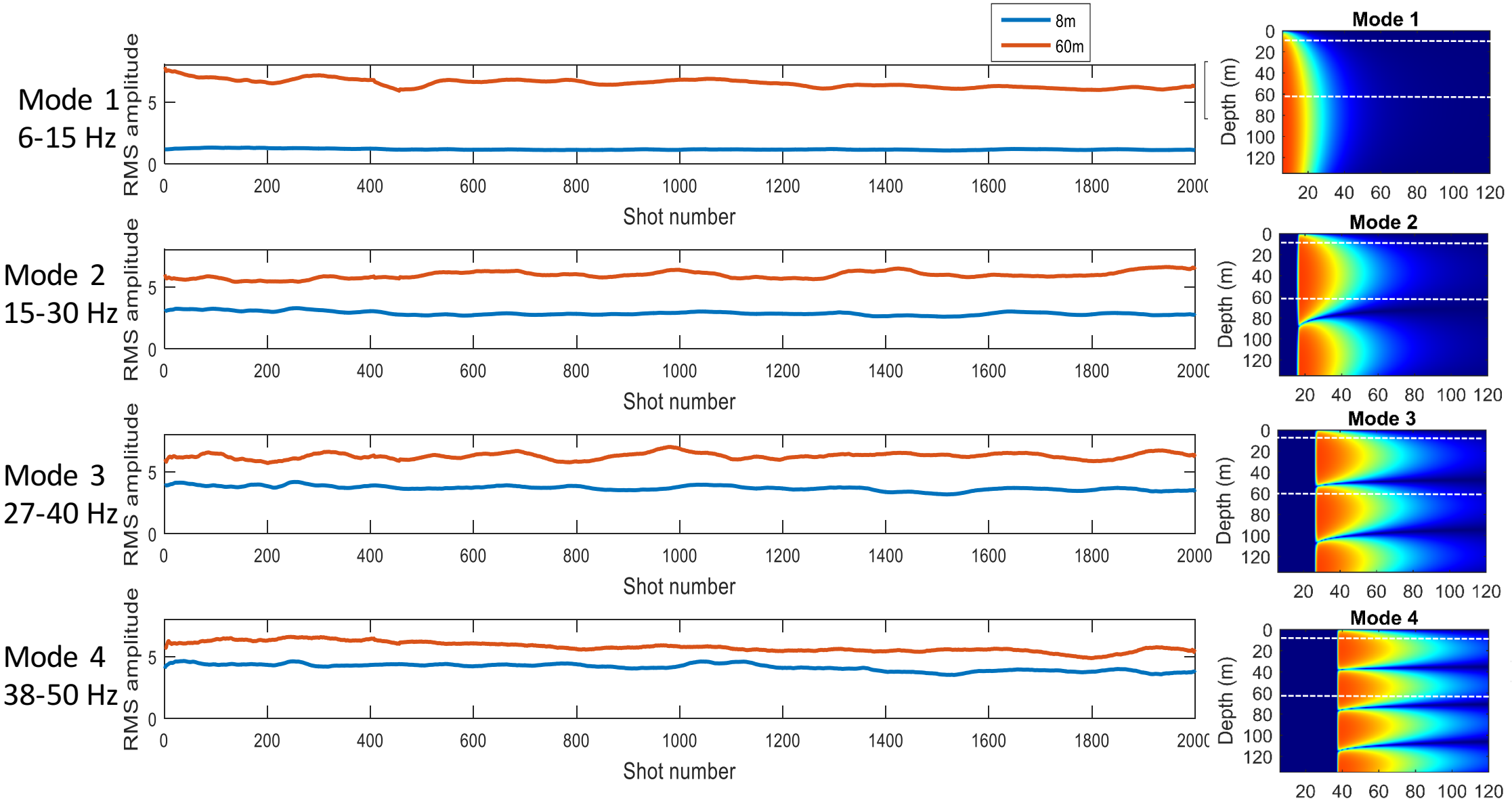


60m signal is stronger than 8m signal

Identifying normal modes from f-k-plot

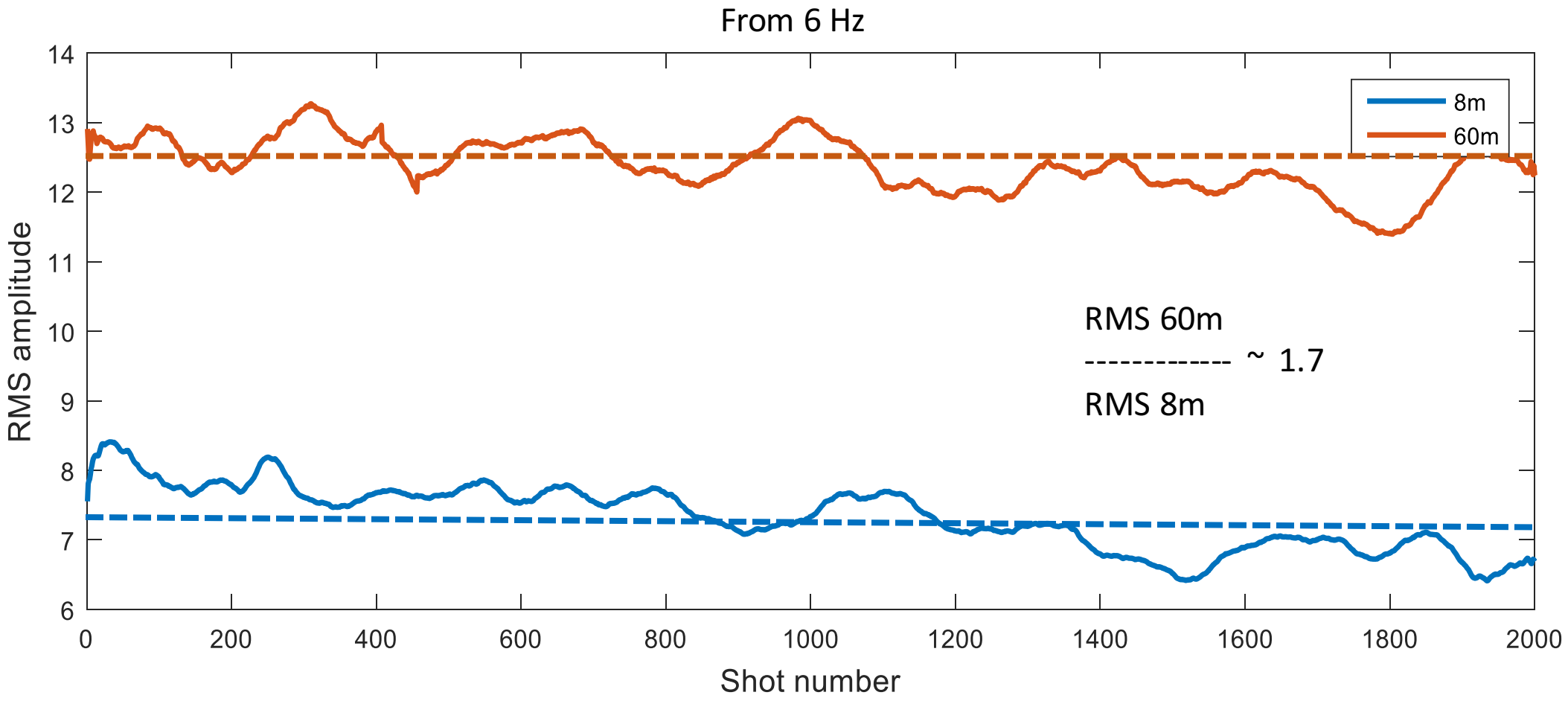


Far-offset data



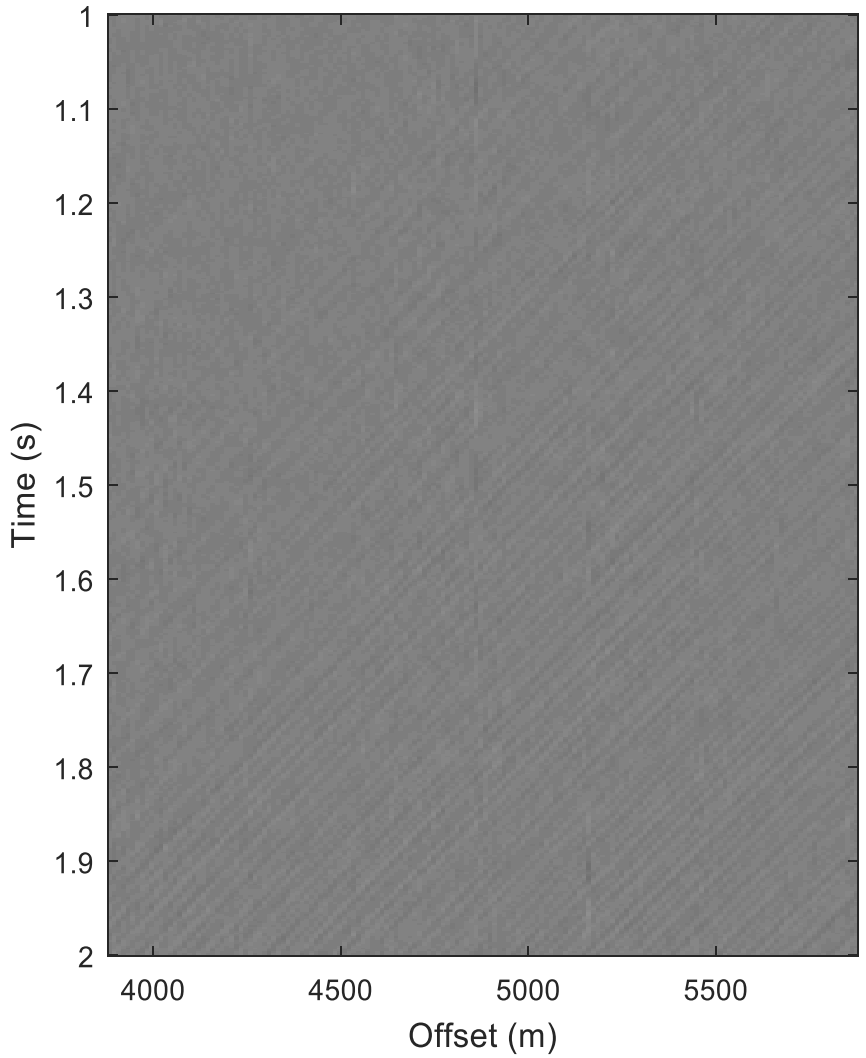
Good correlation between potential normal mode theory and field data

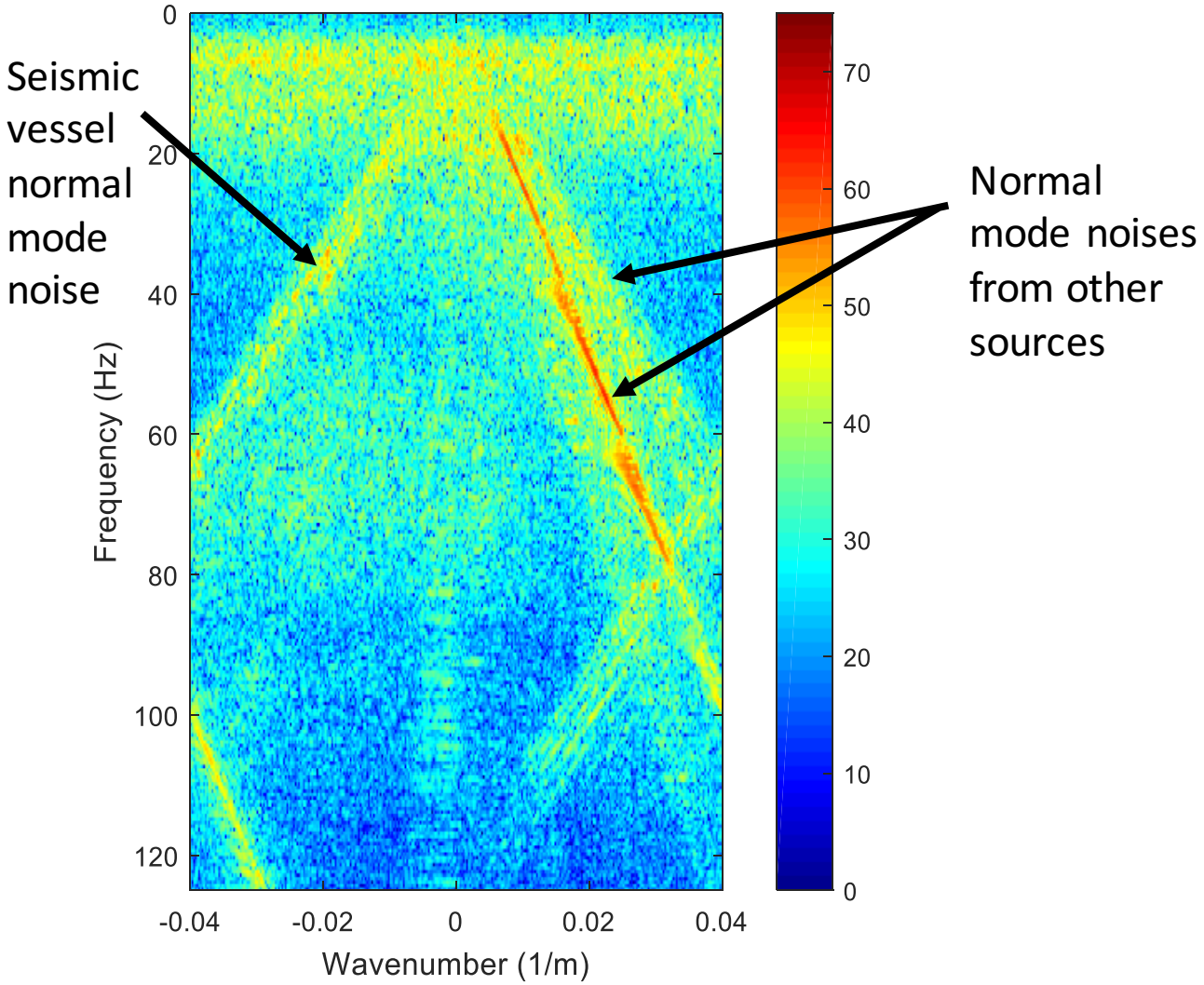
Far-offset data



Data without airgun signal

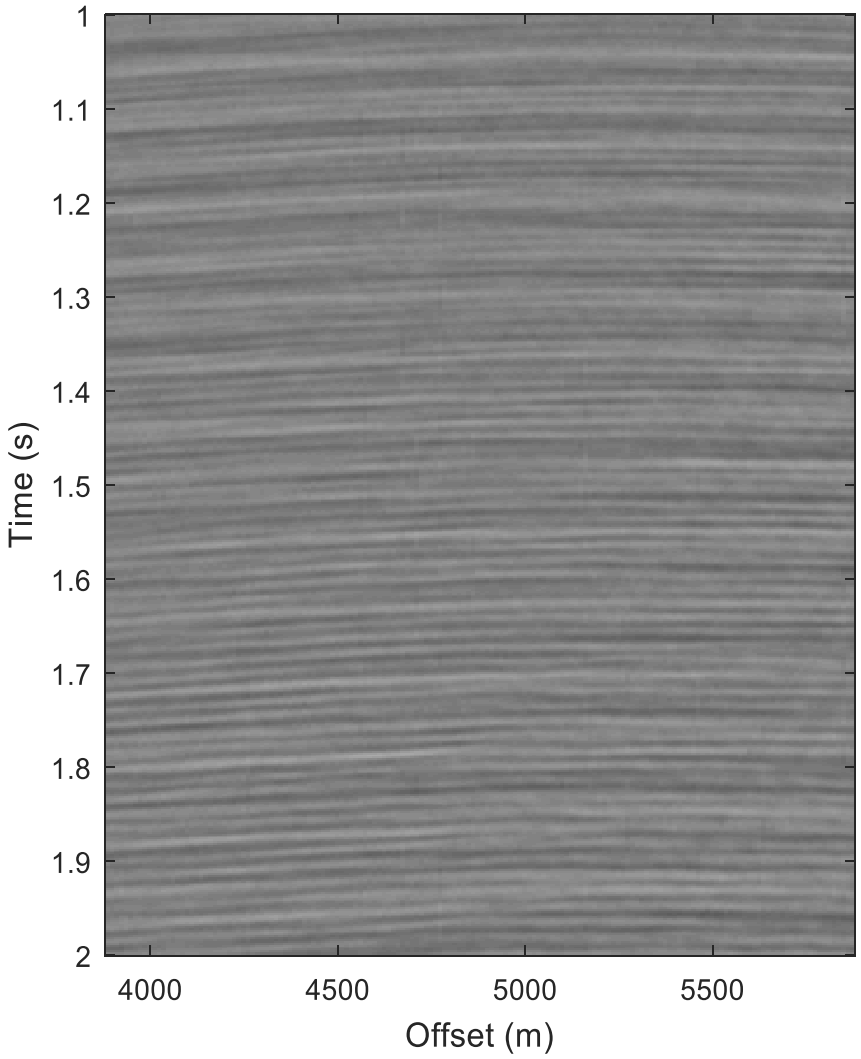
FK spectra of noise

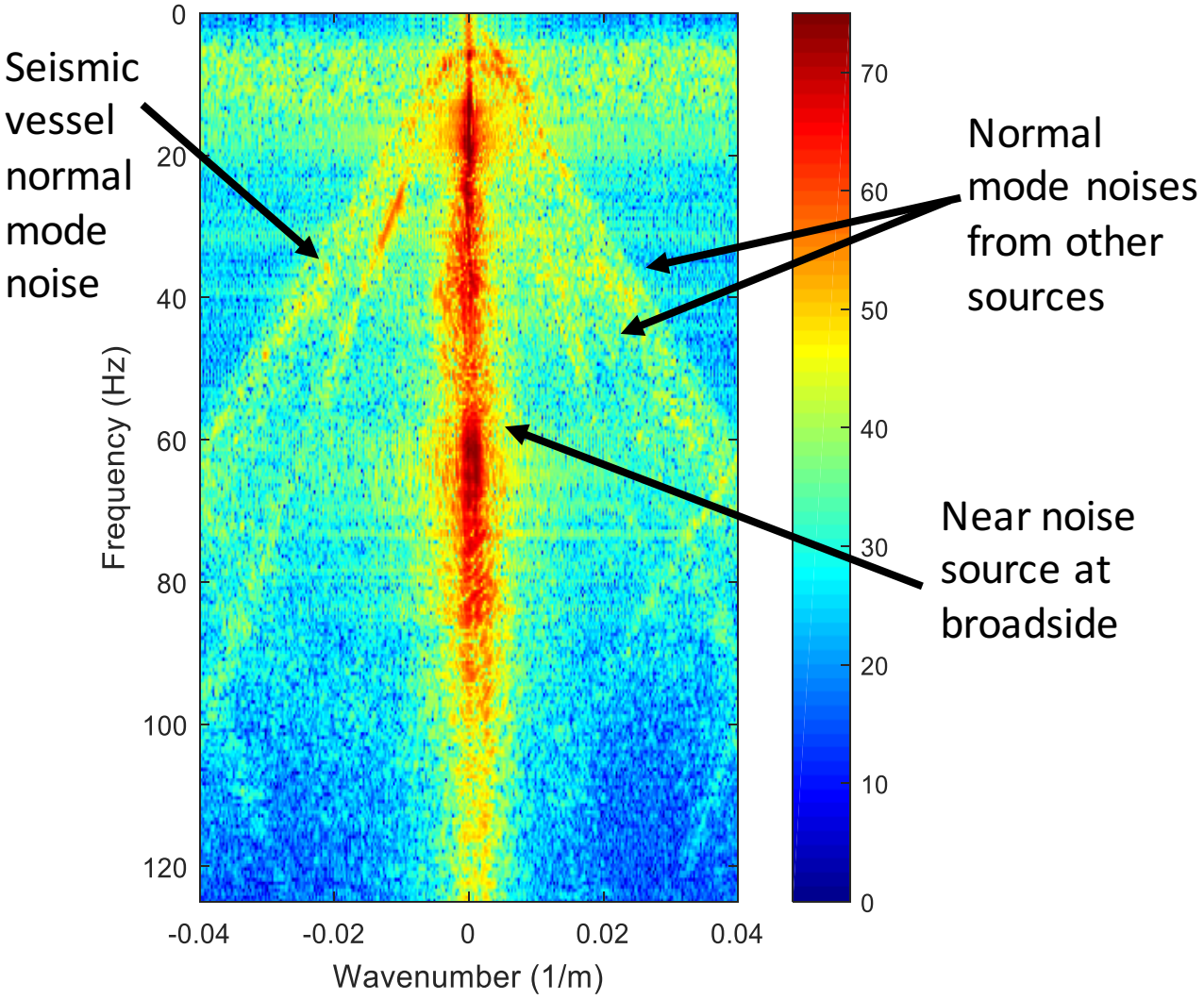




Linear events indicate the noise source is far away.
This noise is normal mode dominated

FK spectra of noise

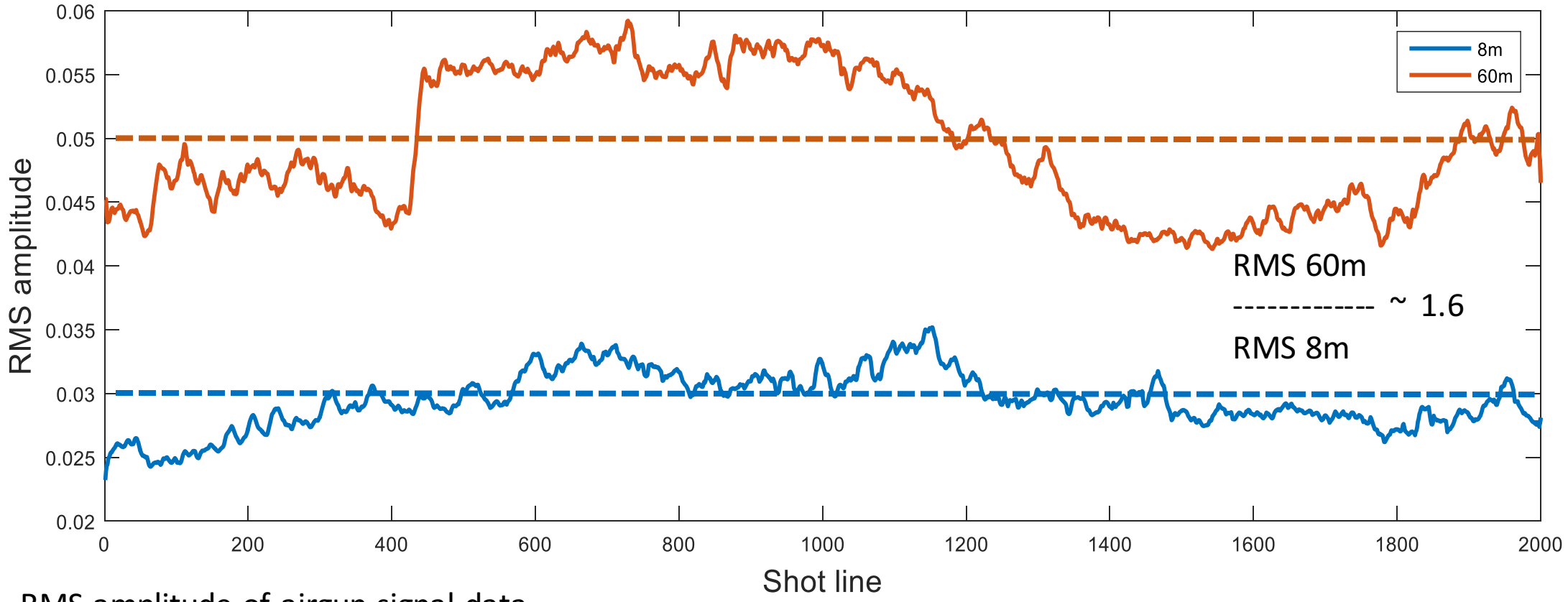




Curved events indicate the noise source is near.
This noise is not normal mode dominated

Noise data after fk-filter to enhance the seismic vessel noise

RMS amplitude of the seismic vessel noise (FK filtered noise) from 6 – 60 Hz



RMS amplitude of airgun signal data

---------- ~ 50 dB for both 8m and 60m, equivalent to 260 times stronger!!

RMS amplitude of the seismic vessel noise

Conclusions

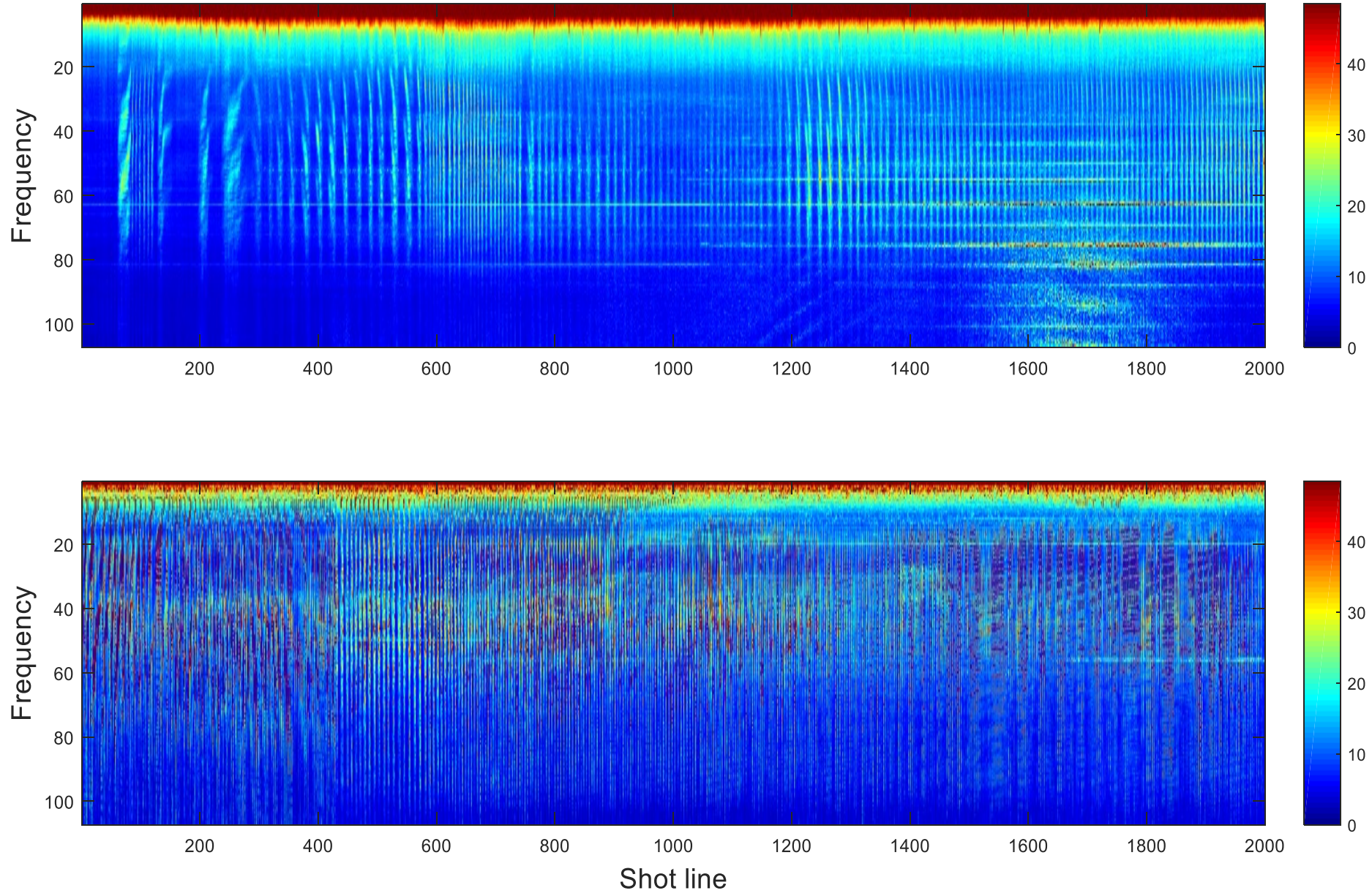
- 8 m data more noisy than 60 m data for low frequencies < 6 Hz
- 8 m data less noisy than 60 m data for frequencies above 6 Hz by a factor of 1.7
- Normal mode noise vary strongly with streamer depth, and an optimal streamer depth can be determined prior to acquisition
- Normal mode noise caused by several sources: the seismic vessel, other vessels far away
- In this field test, the noise from the shooting vessel and other vessels are typically 50 dB weaker than the normal mode signal created by the source array. 8m is more quiet than 60m to minimize the impact of marine traffic noise on seismic data.

Acknowledgments

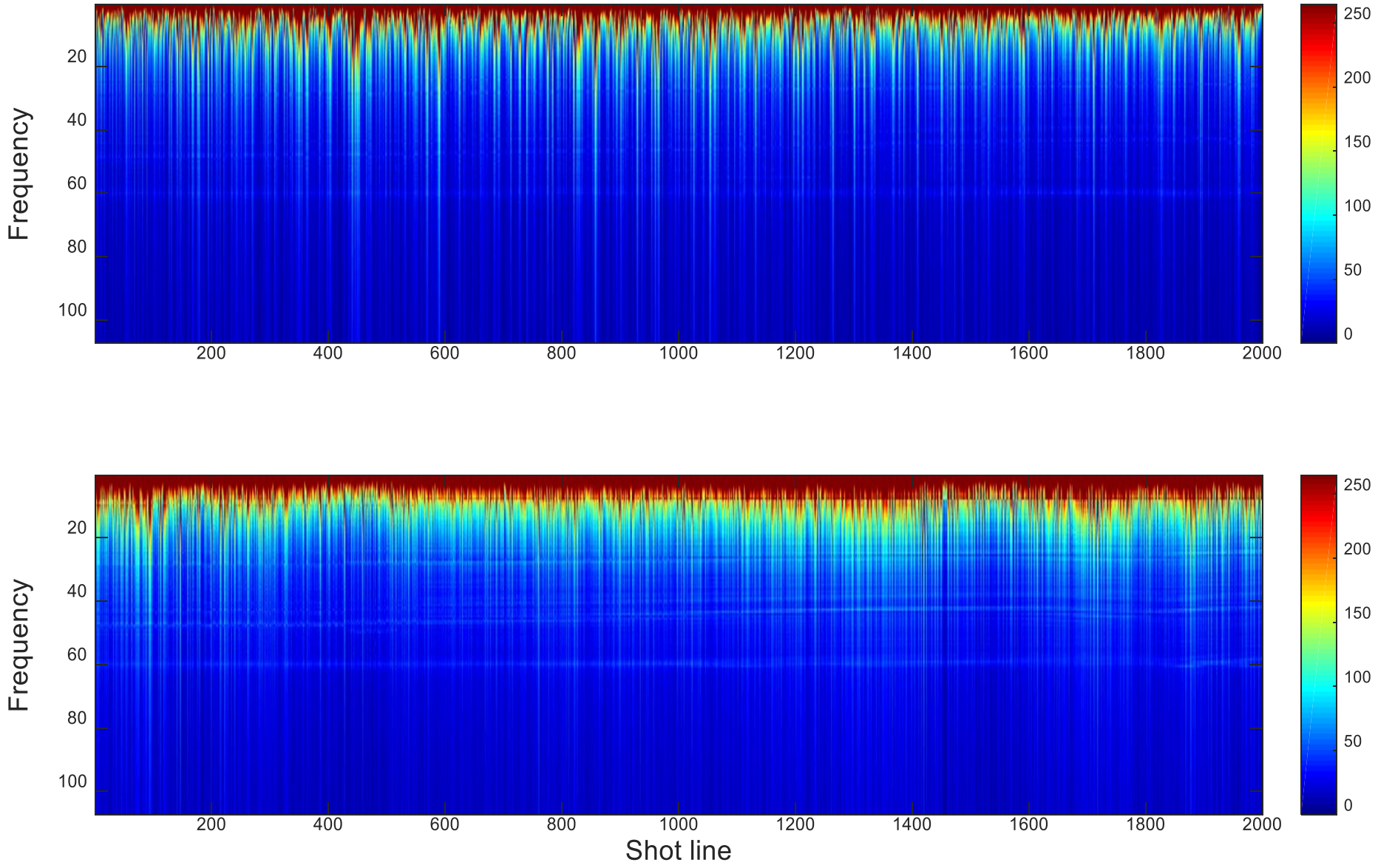
- Lundin Norway for providing the data for this analysis
- The Norwegian Research Council and the ROSE sponsors for financial support to my PhD
- Wiktor Weibull and Espen Birger Raknes for helping with FD modeling

Additional slides

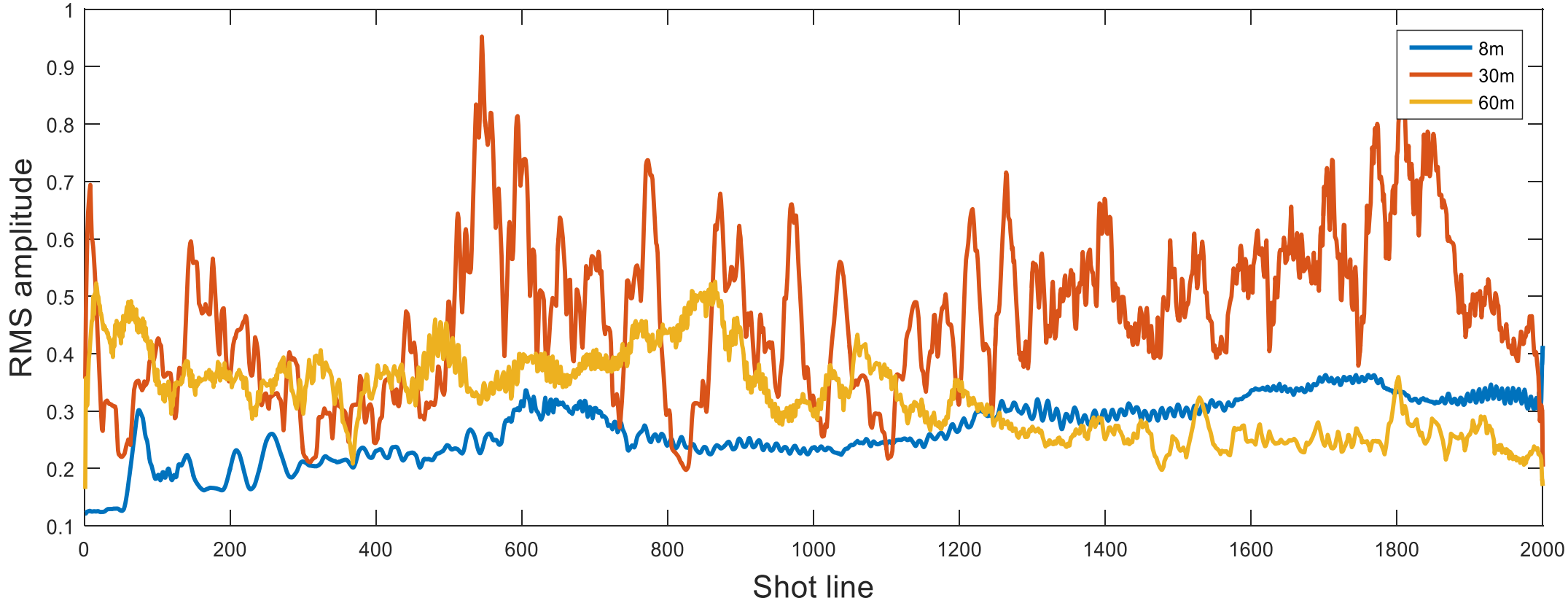
Spectra of noise data before filter



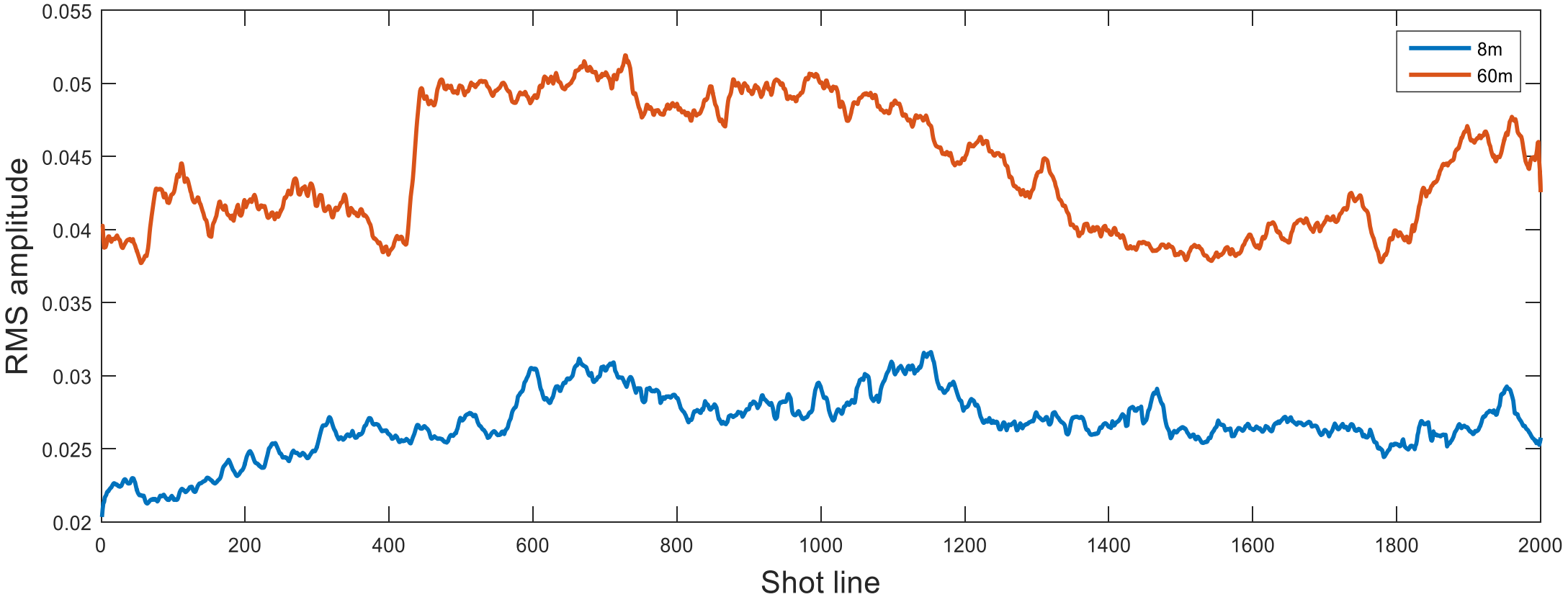
FX spectra of the vessel noise after FK filter



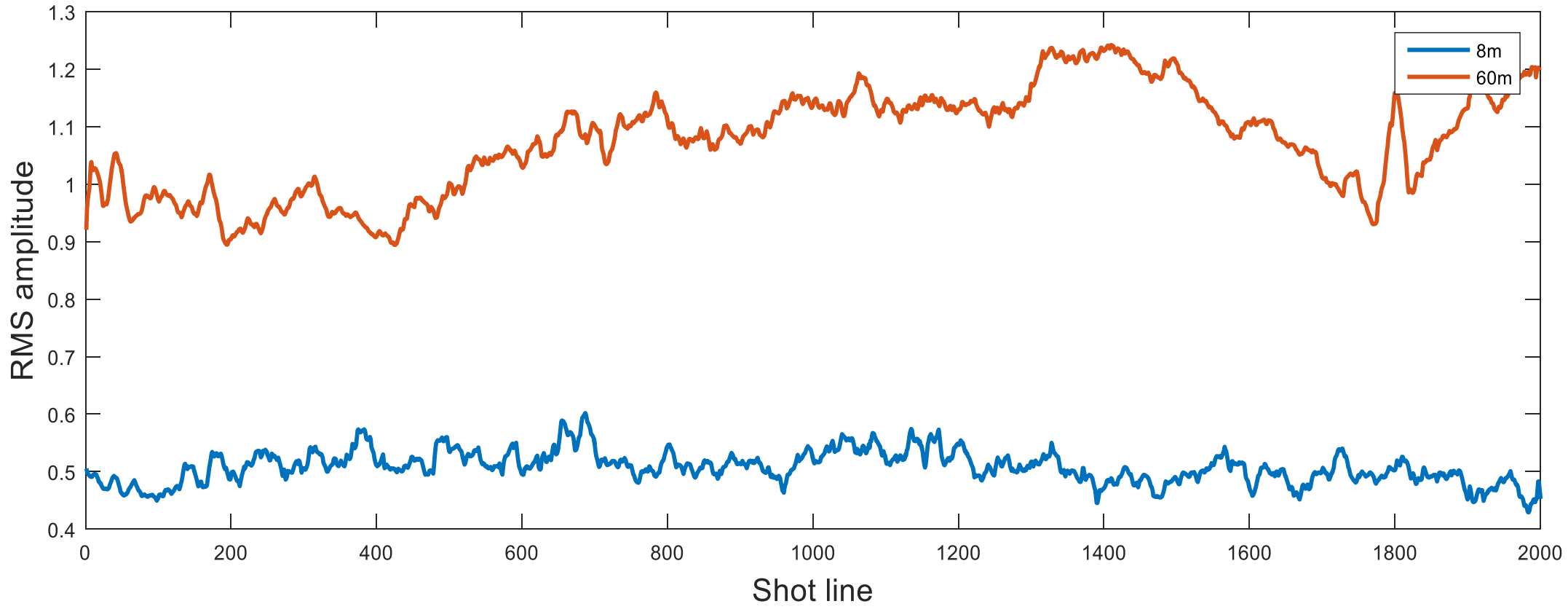
ALL Noise from 6 Hz



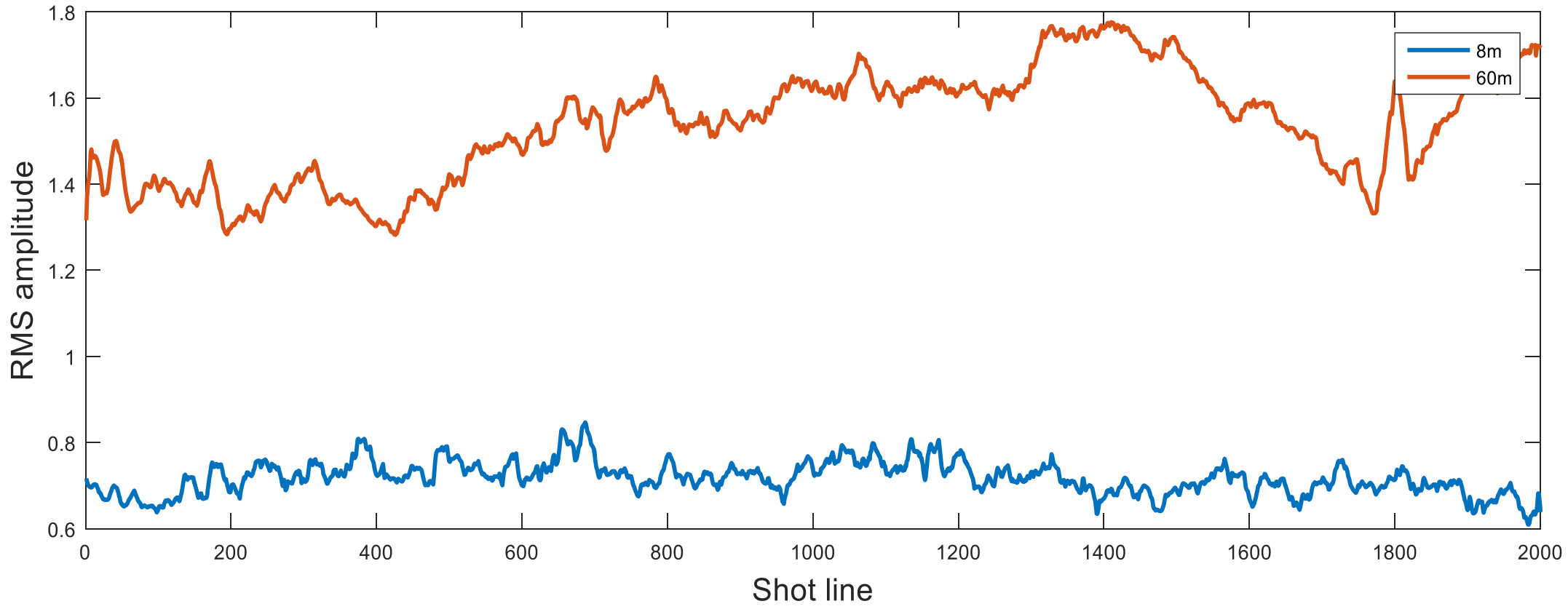
RMS amplitude of the seismic vessel noise (FK filtered noise) from 6 – 55 Hz



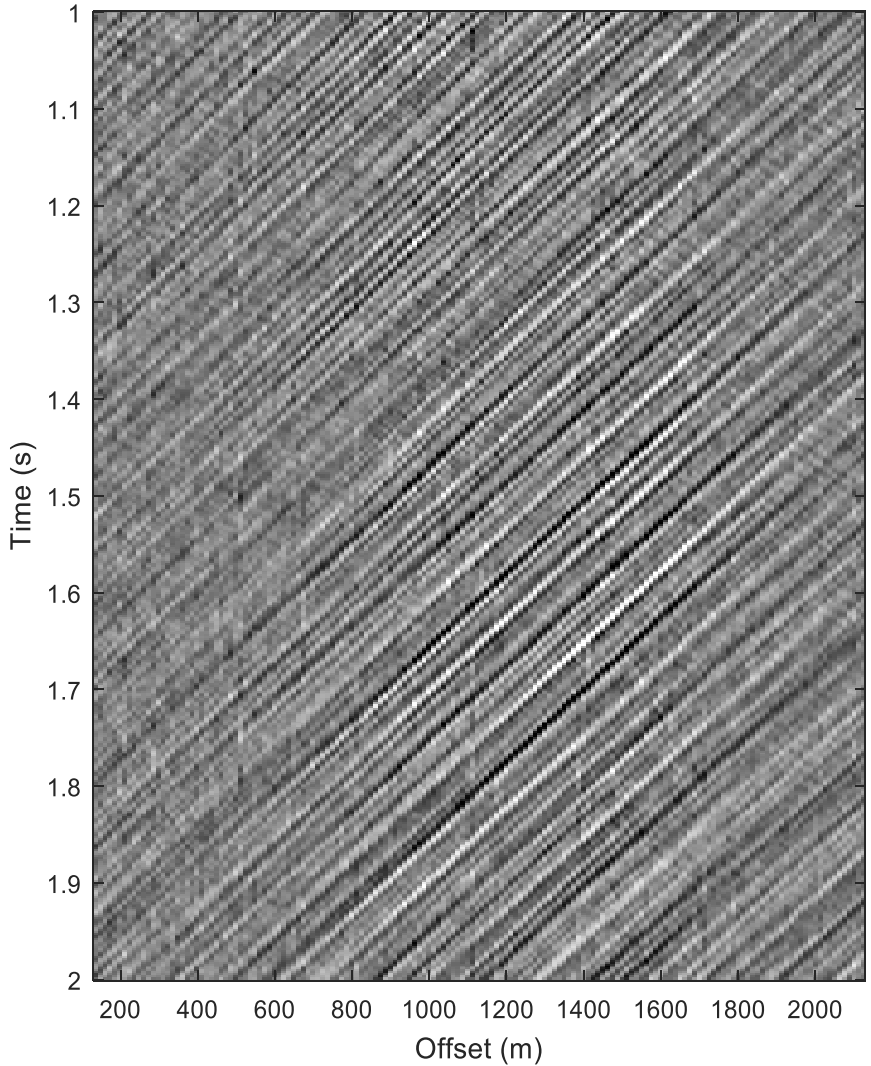
RMS amplitude of the seismic vessel noise (FK filtered noise) from 1 – 60 Hz

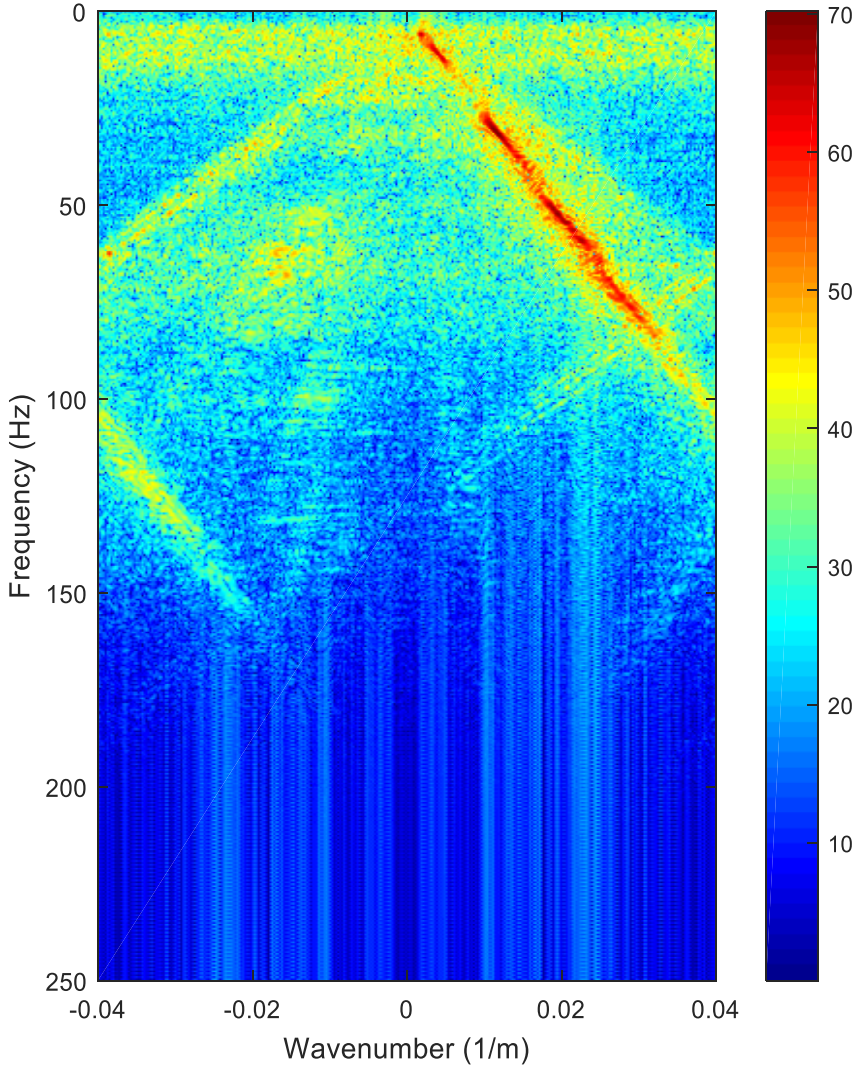


RMS amplitude of the seismic vessel noise (FK filtered noise) from 1-6 Hz

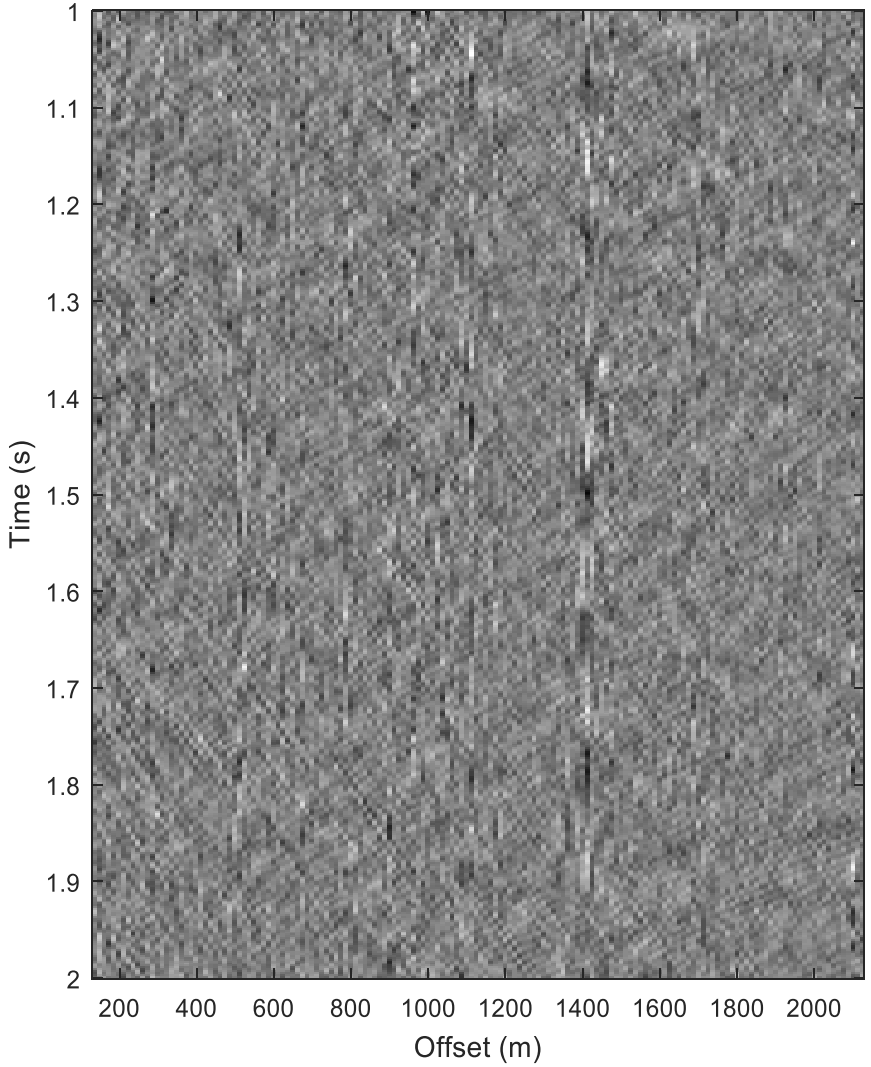


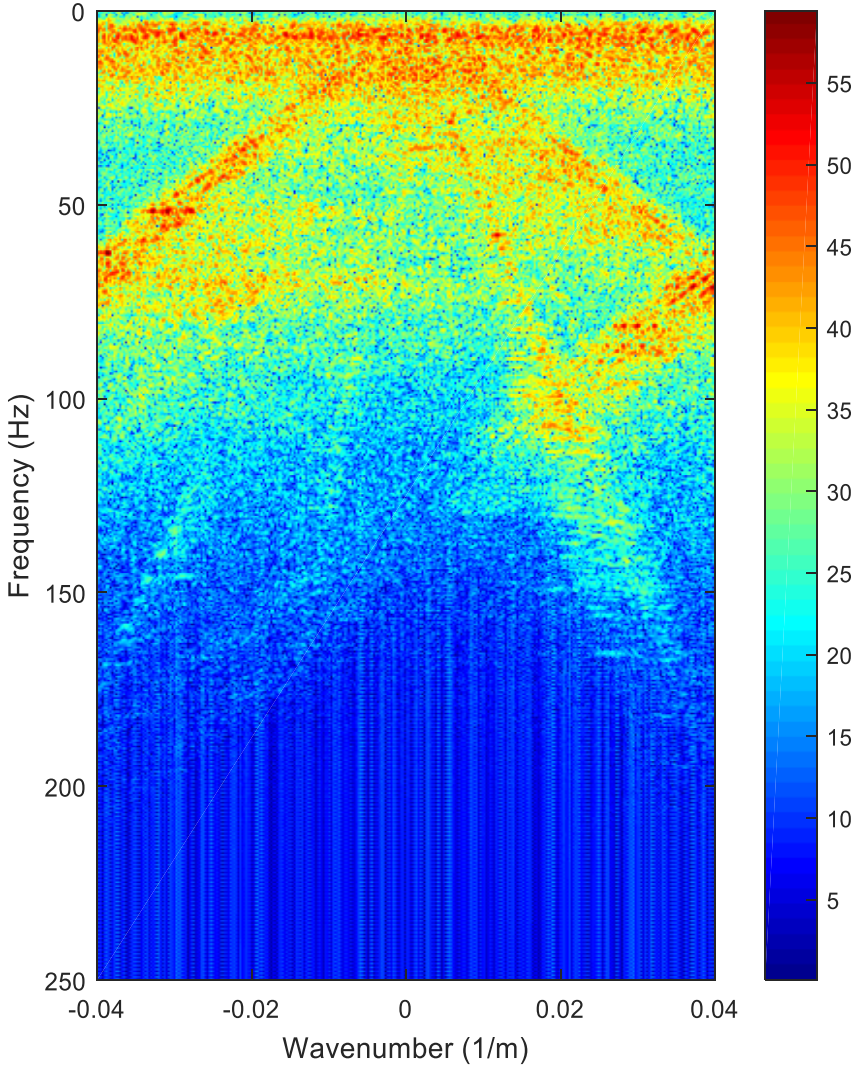
FK spectra of the noise – 8m data – shot 100



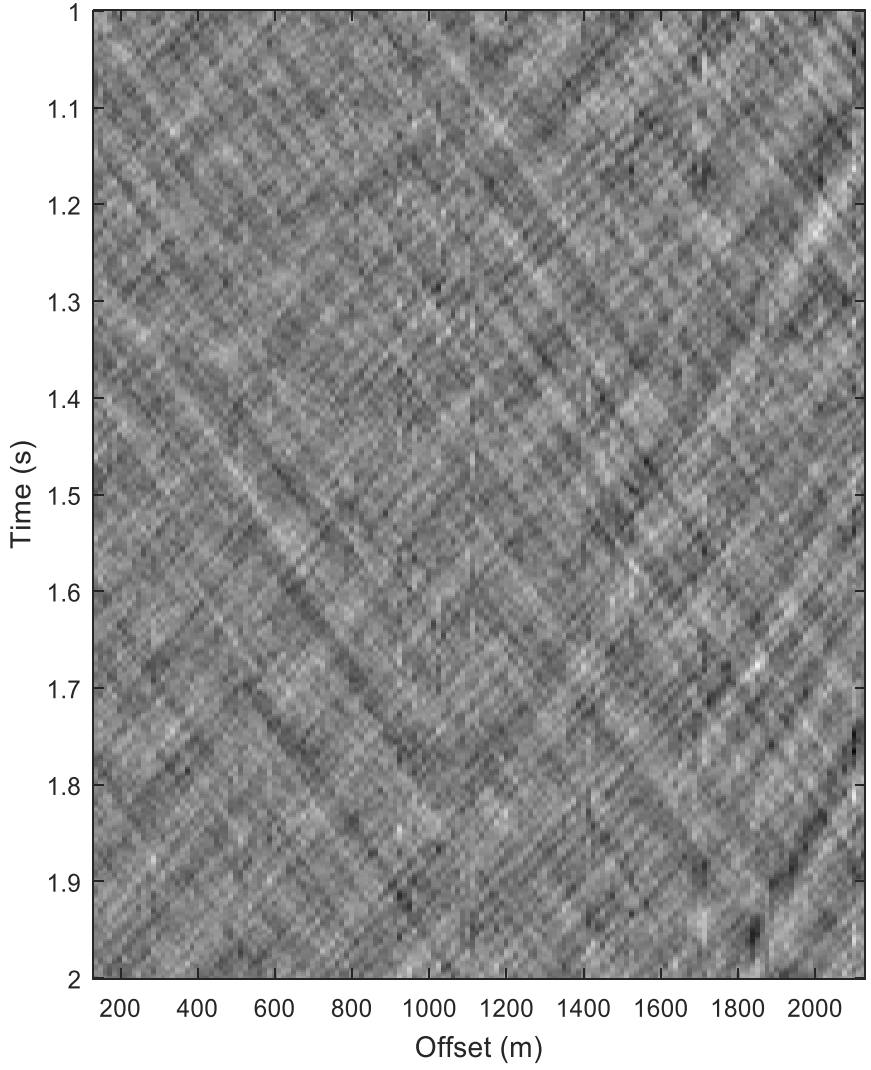


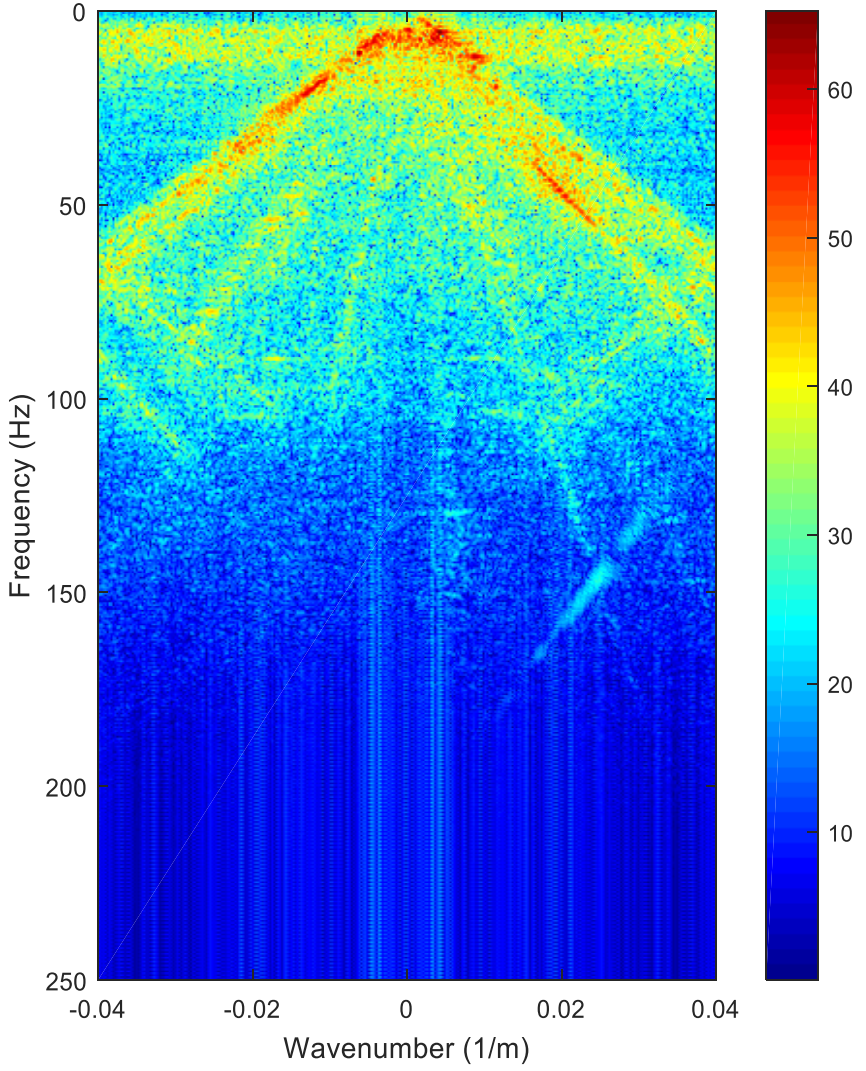
FK spectra of the noise – 8m data – shot 500



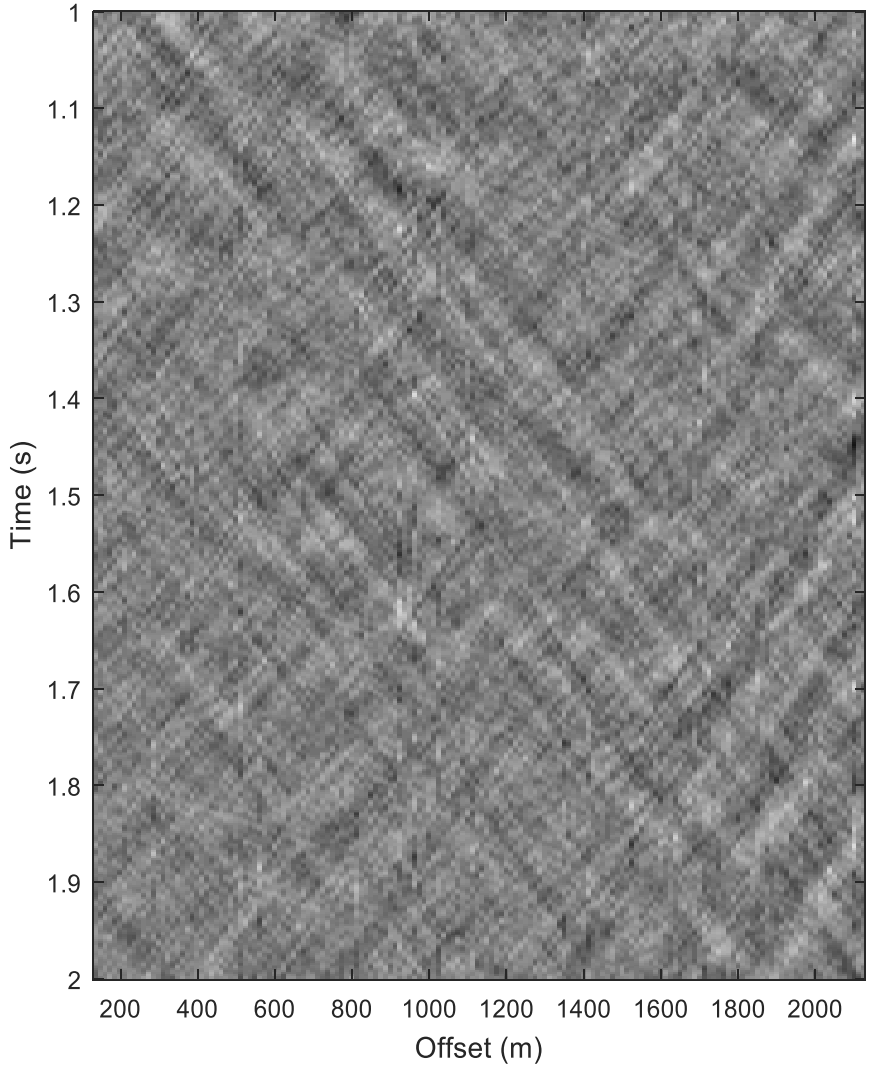


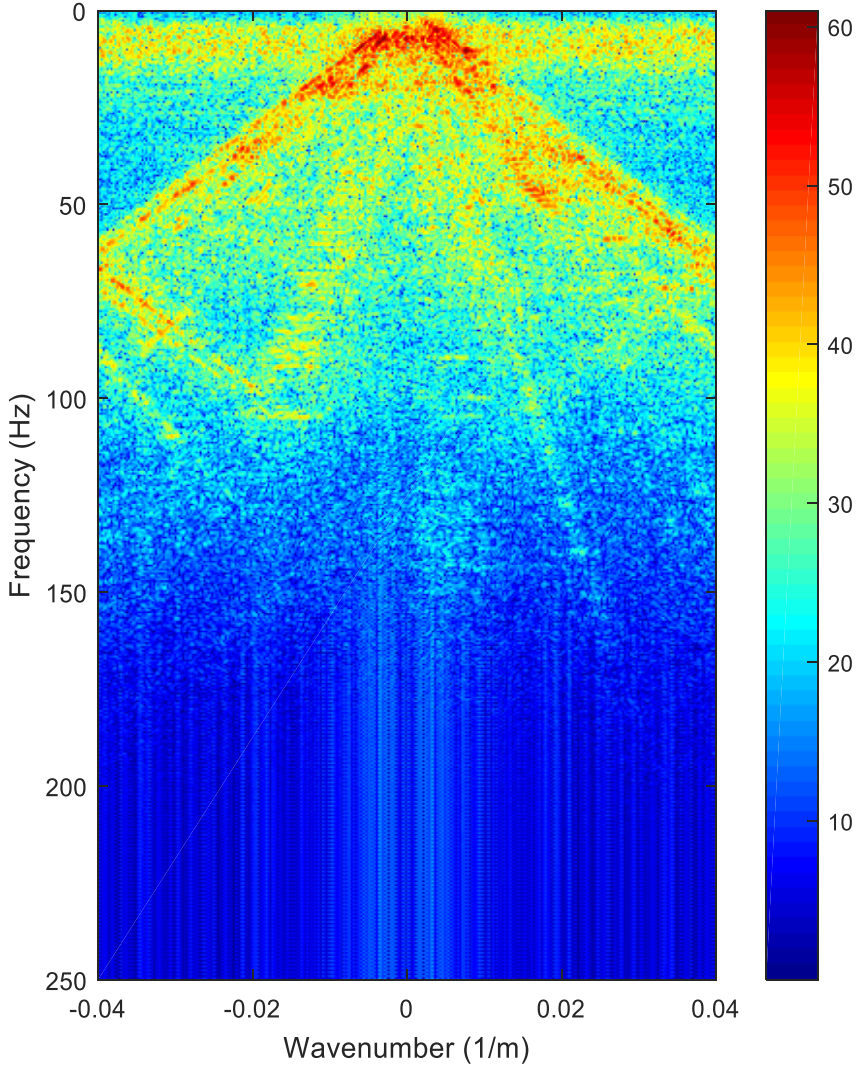
FK spectra of the noise – 60m data – shot 1



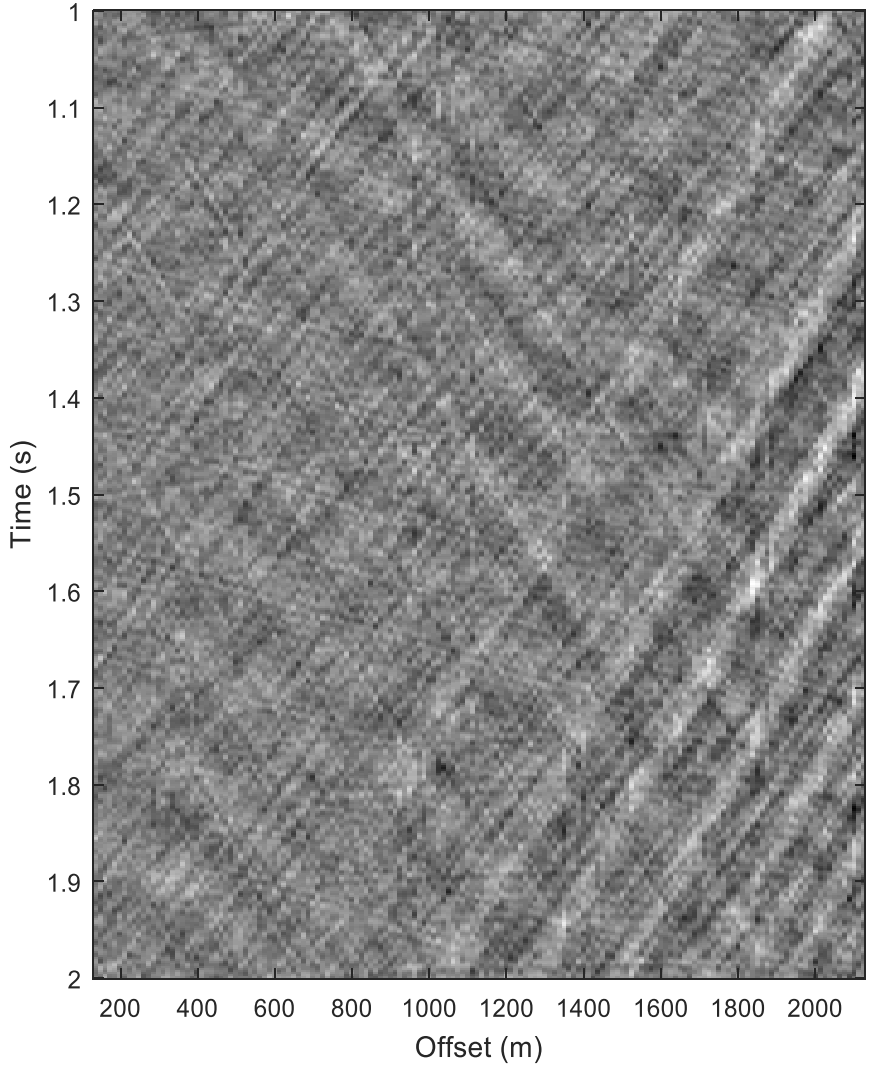


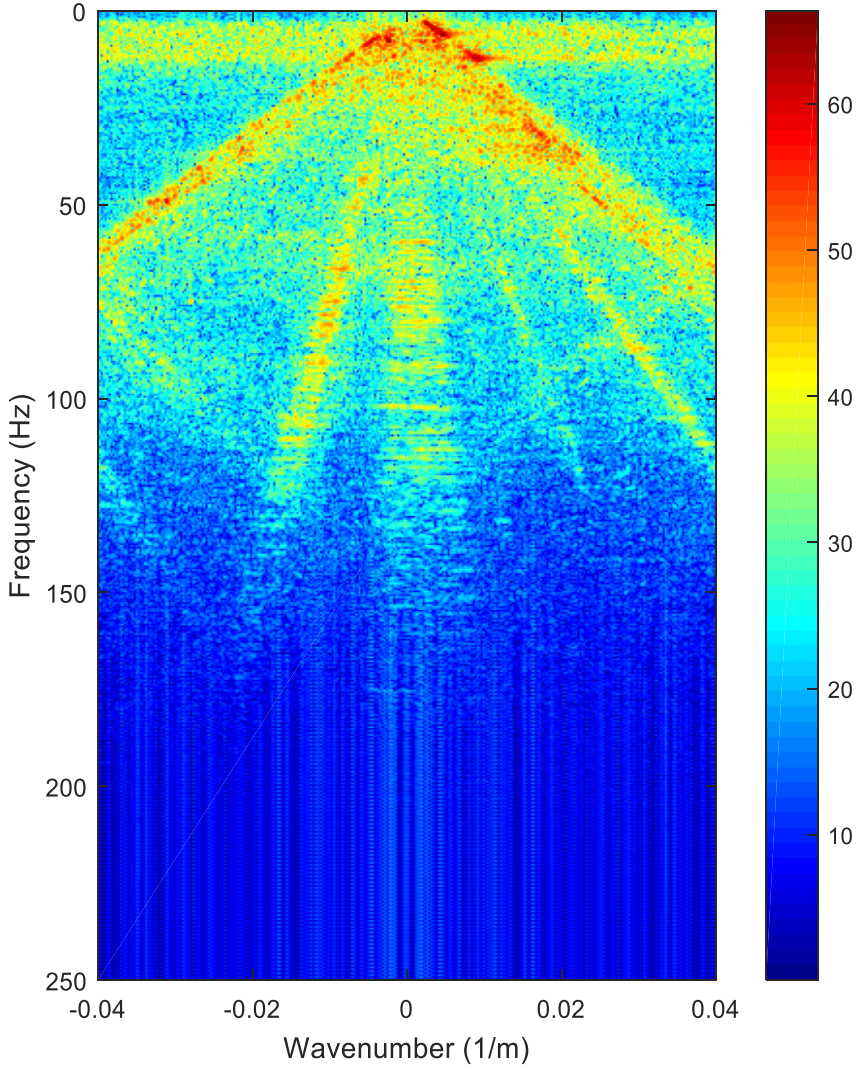
FK spectra of the noise – 60m data – shot 100



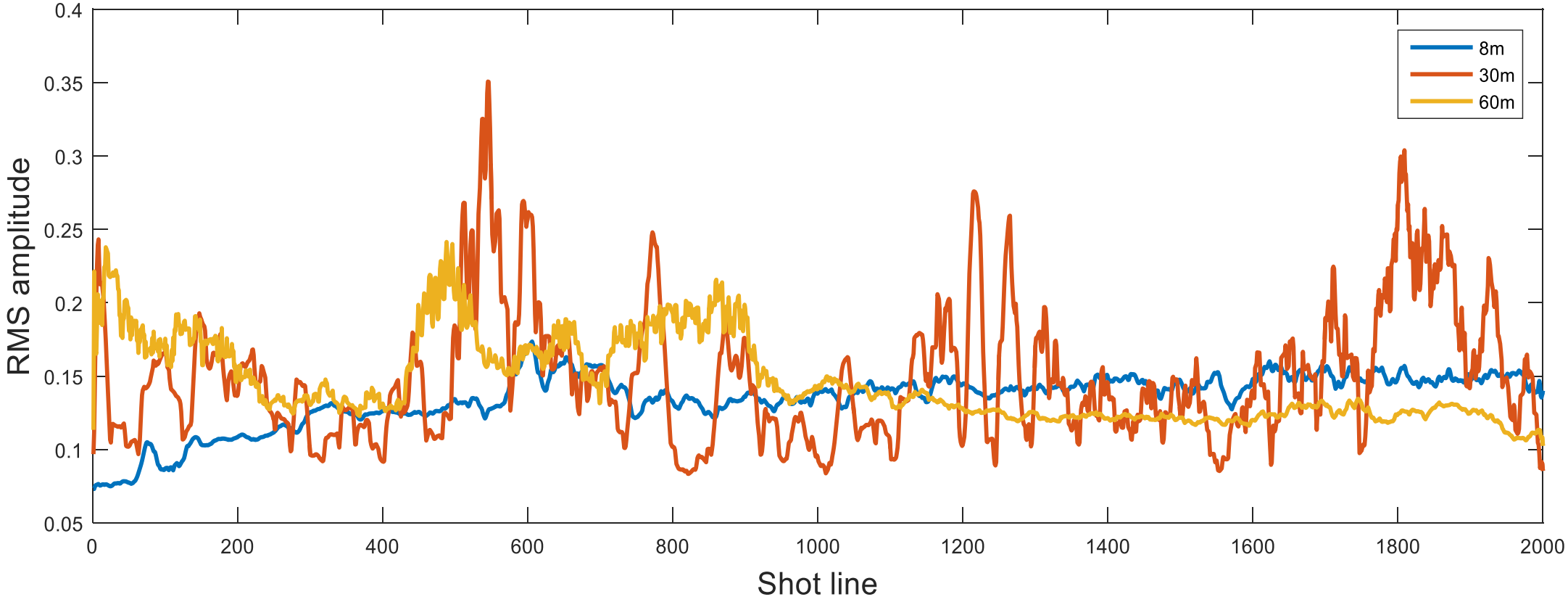


FK spectra of the noise – 60m data – shot 500

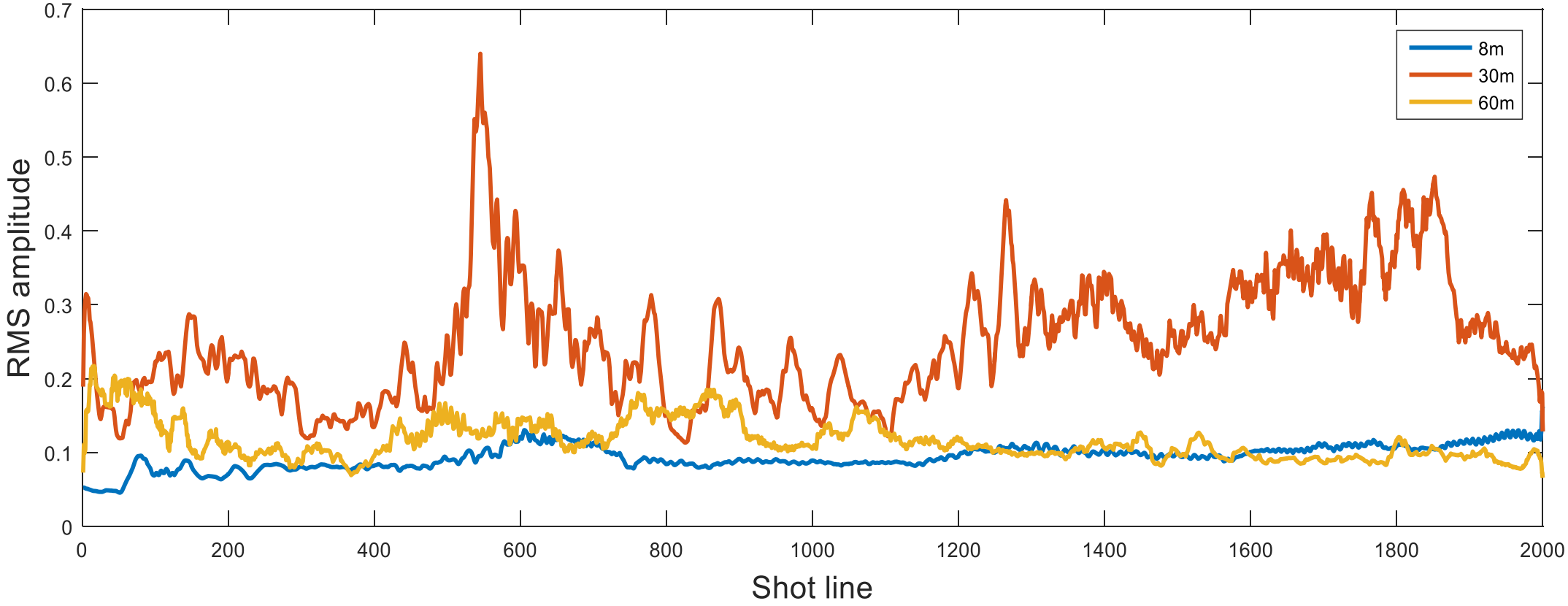




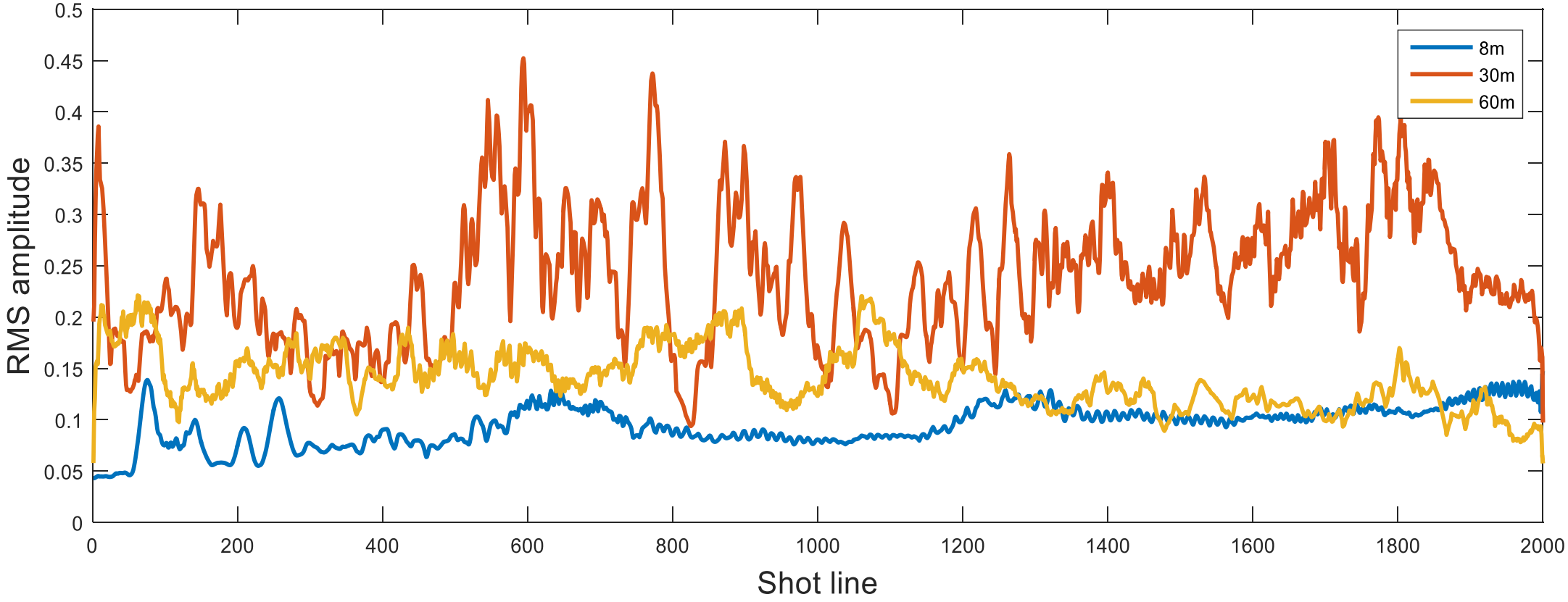
Normal mode-dominated noise (6 - 18 Hz)



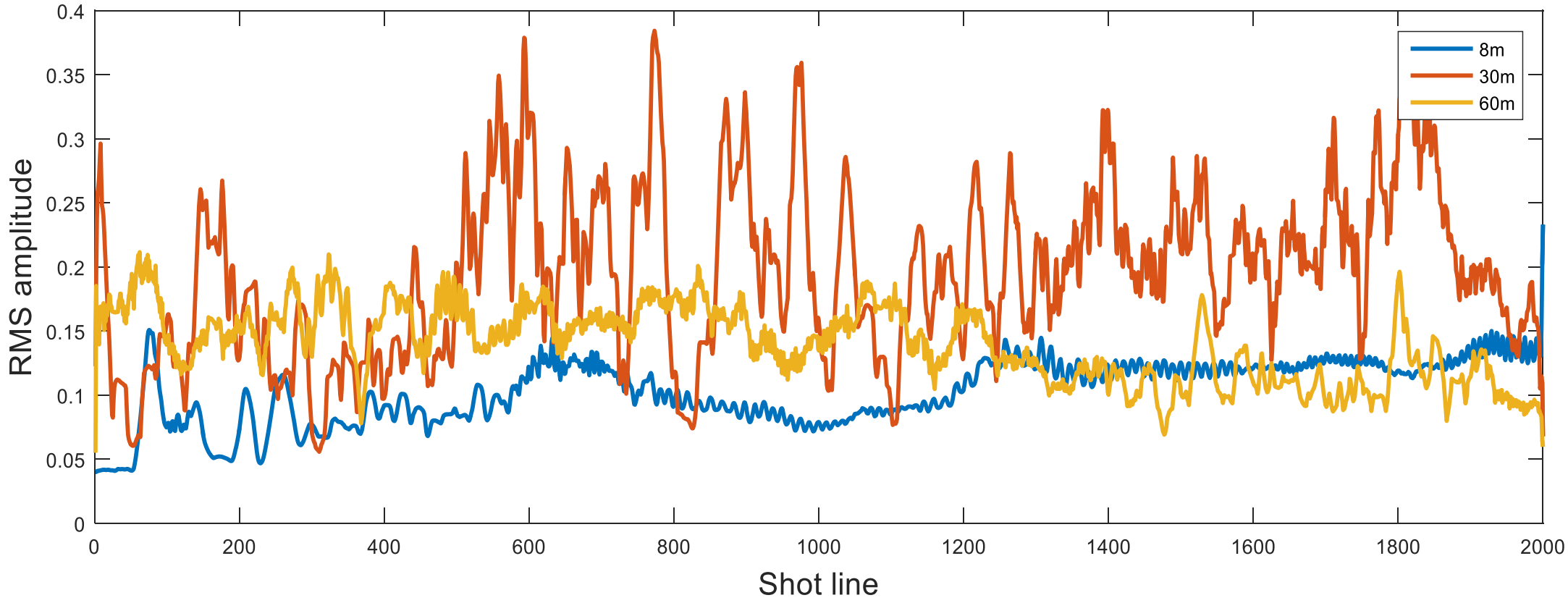
Normal mode-dominated noise (18 - 30 Hz)



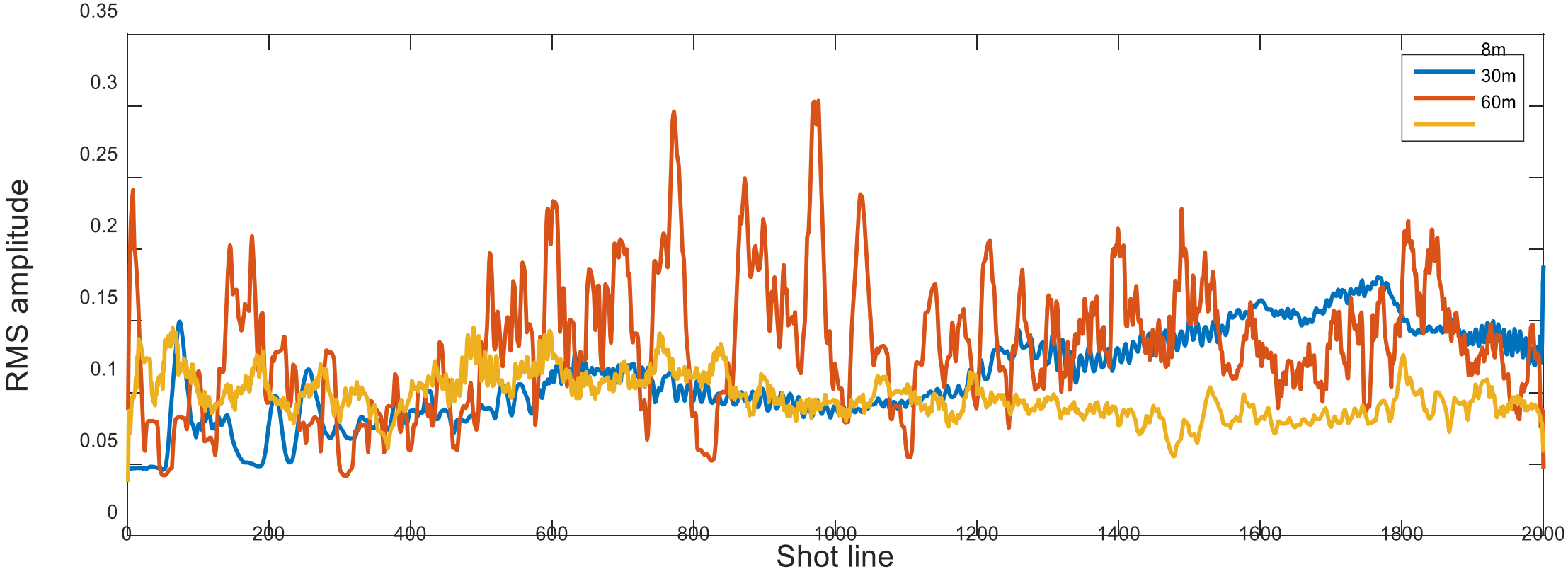
Normal mode-dominated noise (30 - 42 Hz)



Normal mode-dominated noise (42 - 54 Hz)



Normal mode-dominated noise (54 - 66 Hz)



Normal mode-dominated noise (66 - 78 Hz)