COMPARISON OF LOW-FREQUENCY DATA FROM CO-LOCATED RECEIVERS USING FREQUENCY DEPENDENT LEAST-SQUARES-SUBTRACTION SCALARS

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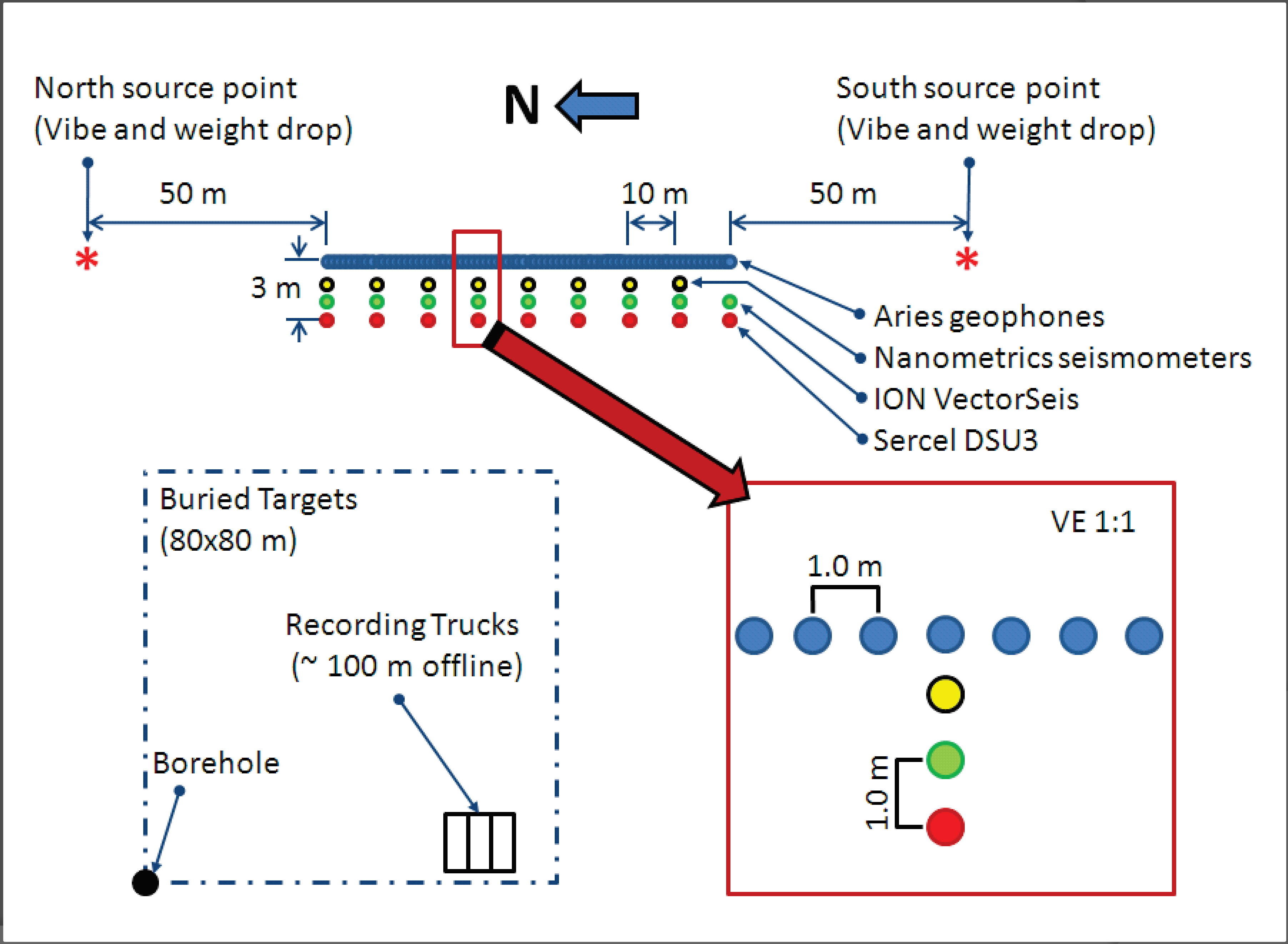
Why?

1. Multichannel analysis of surface waves (MASW)

2. Relate geophone/accelerometer response directly to ground motion based on calibrated seismometer response

3. Compare character of geophone/accelerometer response to seismometer response.



North source point
(Vibe and weight drop)
N
South source point
(Vibe and weight drop)
50 m
10 m
50 m
3 m
Aries geophones
Nanometrics seismometers
ION VectorSeis
Sercel DSU3
Buried Targets
(80x80 m)
Recording Trucks
(~ 100 m offline)
Borehole
VE 1:1
1.0 m
1.0 m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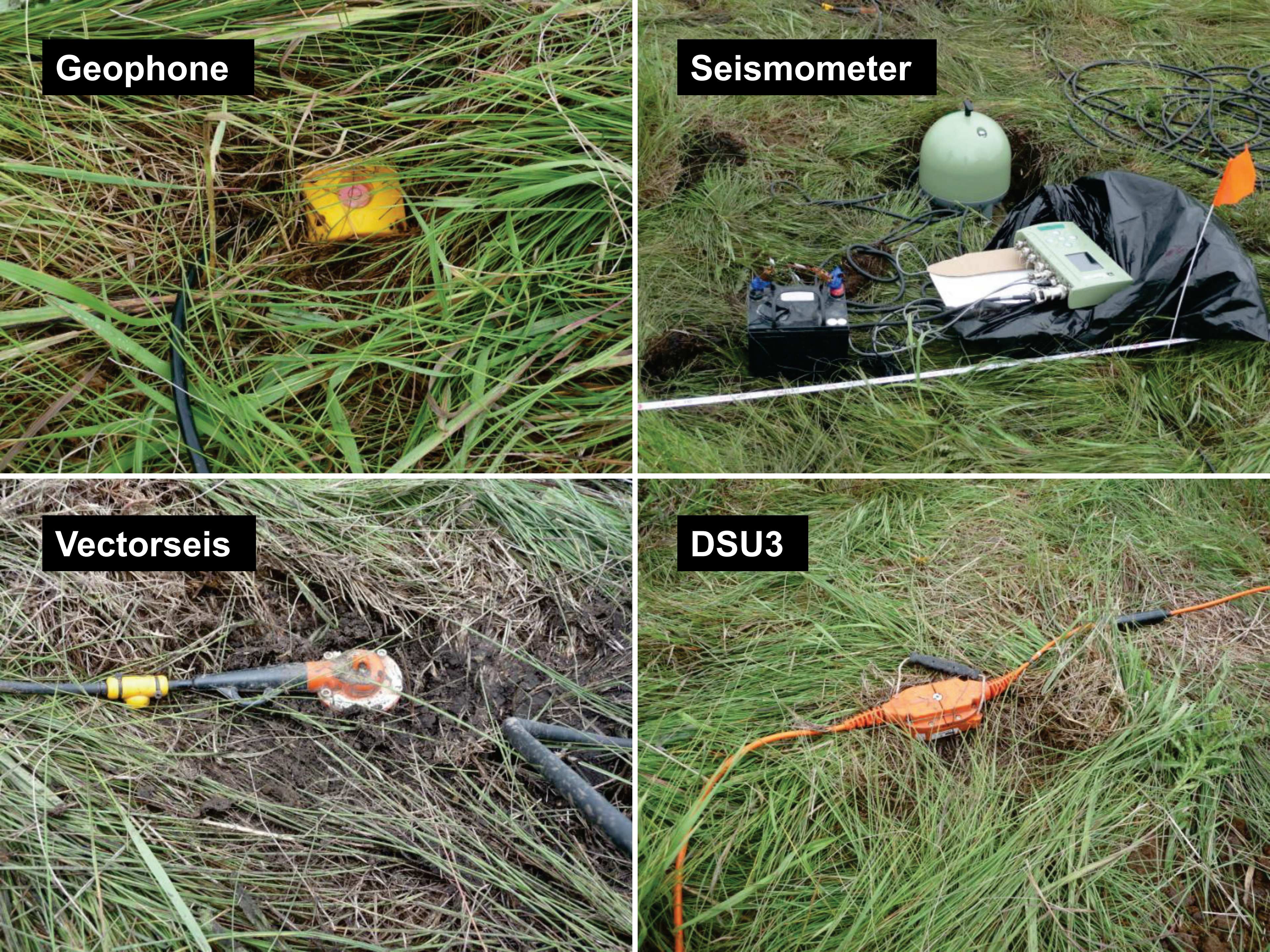
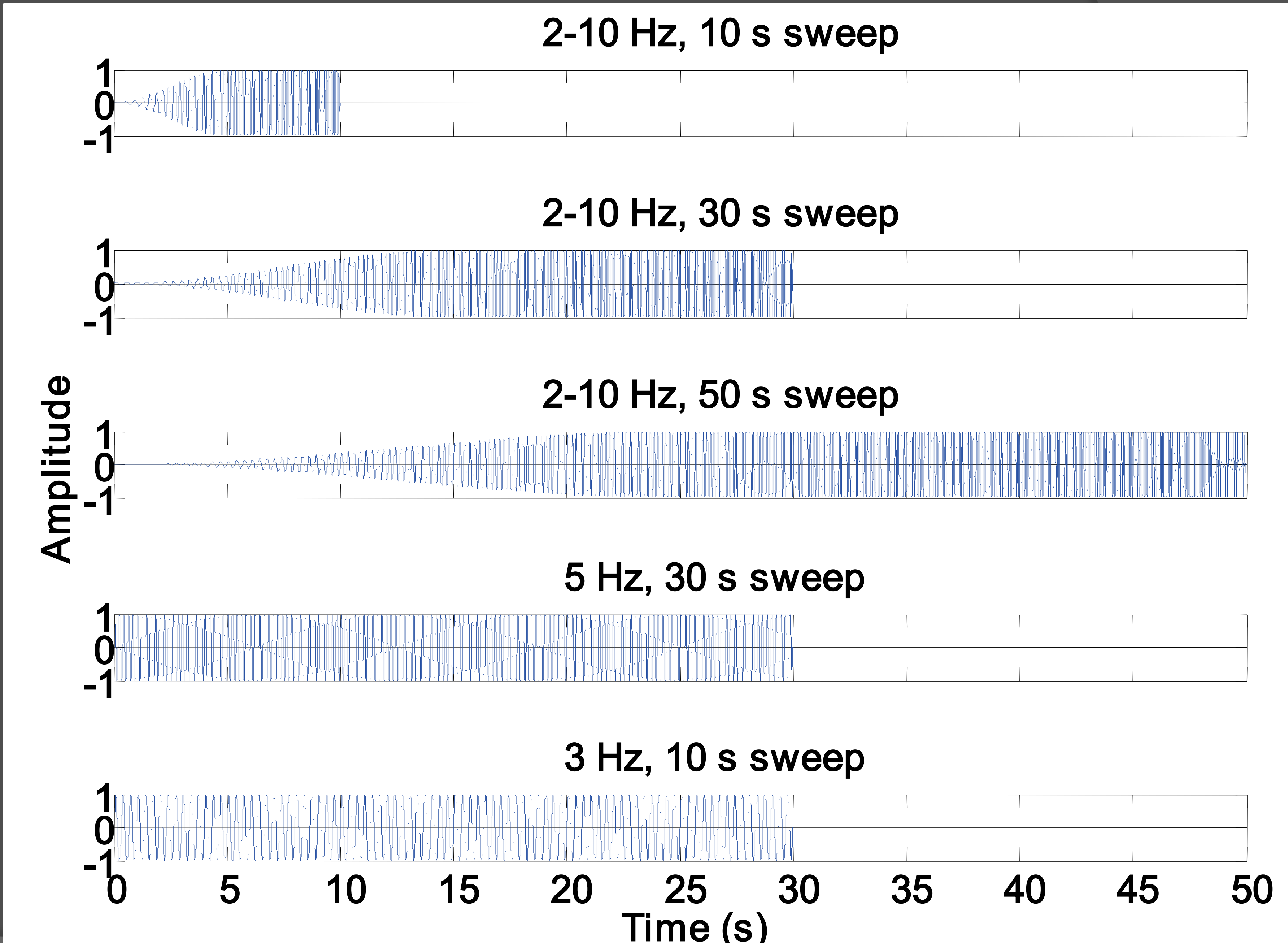
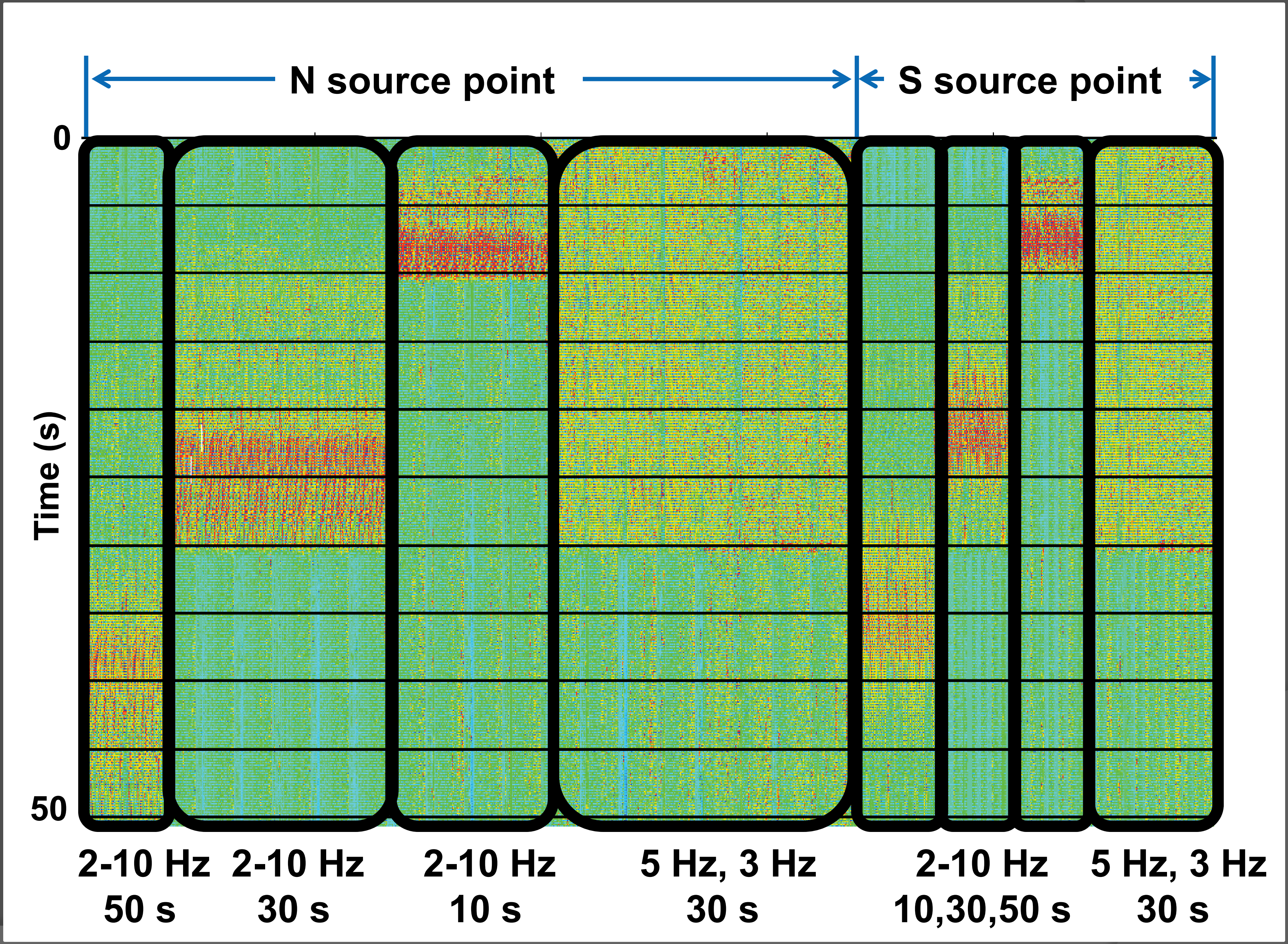
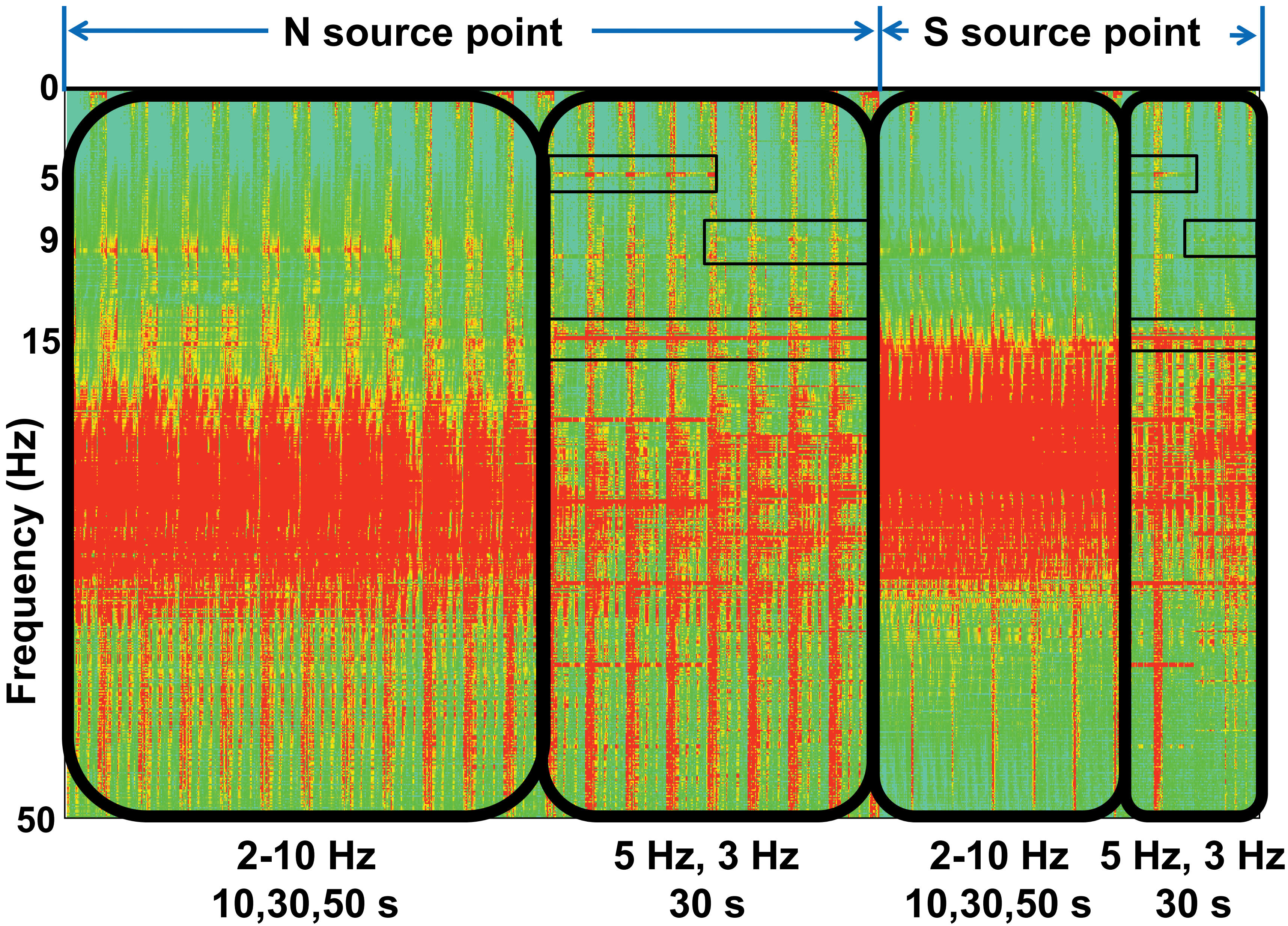
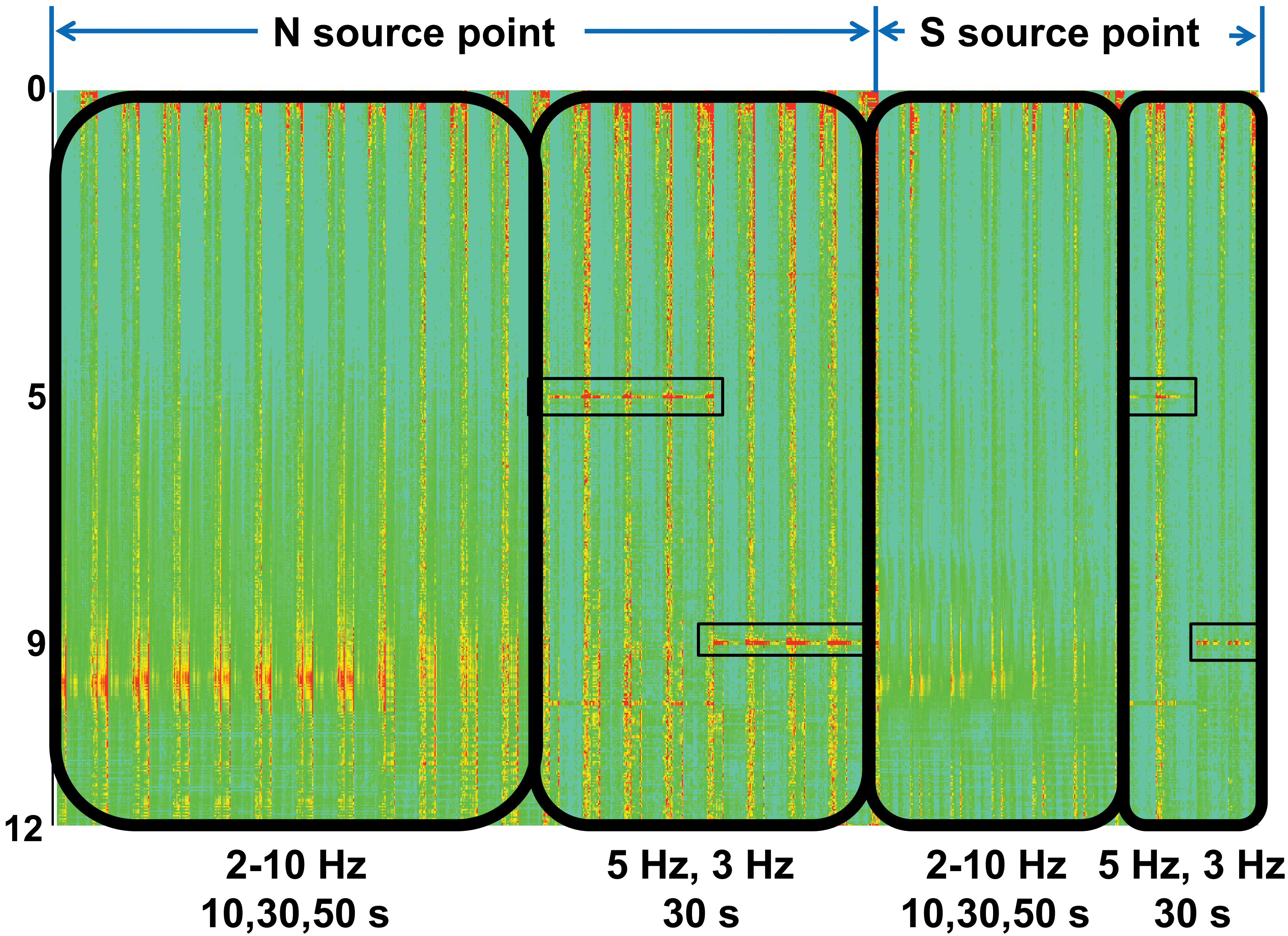

Geophone
Seismometer
Vectorseis
DSU3



2-10 Hz, 10 s sweep
2-10 Hz, 30 s sweep
2-10 Hz, 50 s sweep
5 Hz, 30 s sweep
3 Hz, 10 s sweep
Amplitude
1
0
-1
0
5
10
15
20
25
30
35
40
45
50
Time (s)


N source point
S source point
0
50
Time (s)
2-10 Hz
50 s
2-10 Hz
30 s
2-10 Hz
10 s
5 Hz, 3 Hz
30 s
2-10 Hz
10,30,50 s
5 Hz, 3 Hz
30 s


N source point
S source point
0
5
9
15
50
Frequency (Hz)
2-10 Hz
10,30,50 s
5 Hz, 3 Hz
30 s
2-10 Hz
10,30,50 s
5 Hz, 3 Hz
30 s



N source point
S source point
0
5
9
12
2-10 Hz
10,30,50 s
5 Hz, 3 Hz
30 s
2-10 Hz
10,30,50 s
5 Hz, 3 Hz
30 s

Least-squares-subtraction of two traces *s1* and *s2*

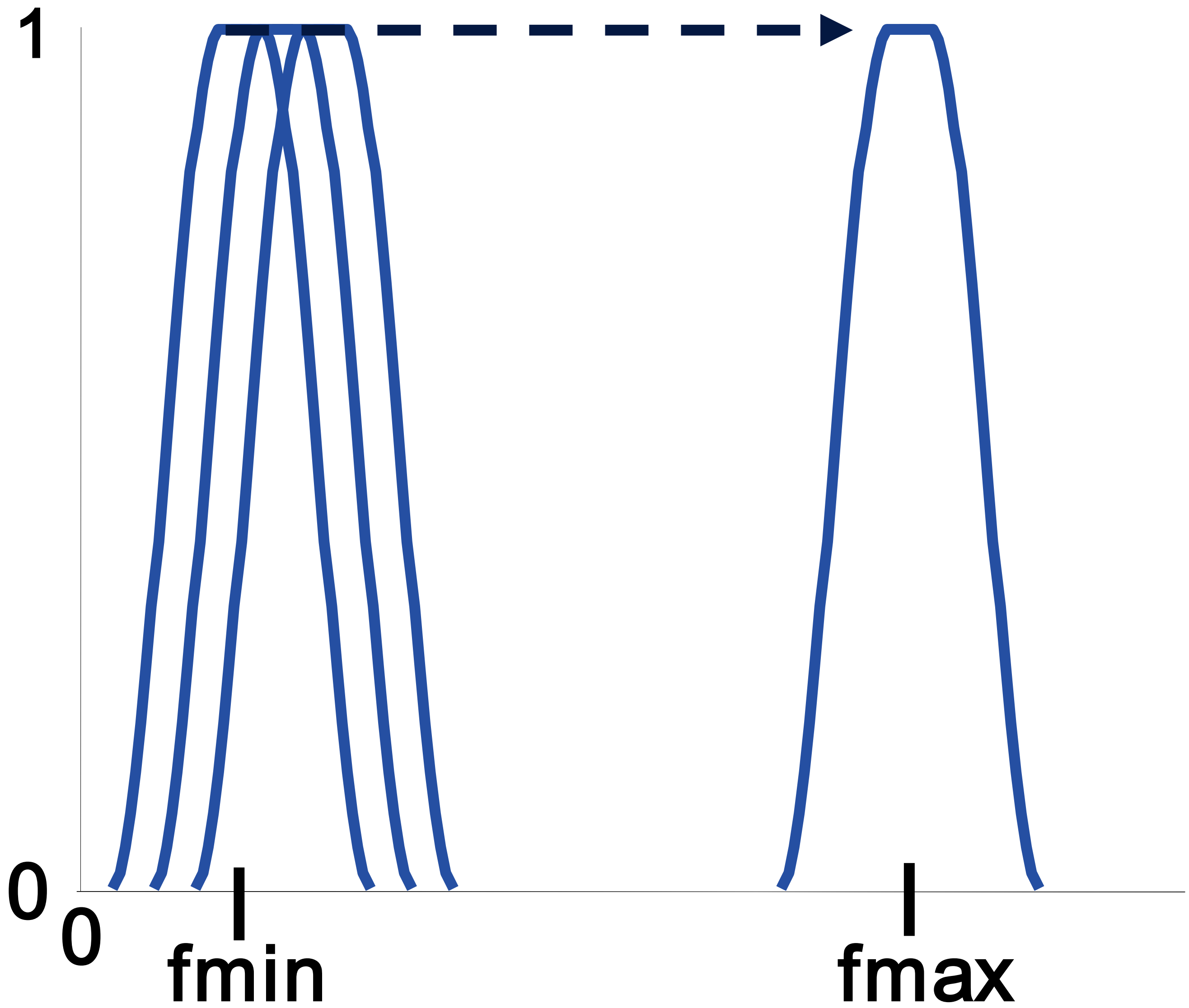
$$\varepsilon = \sum_k (S_{1k} - aS_{2k})^2$$

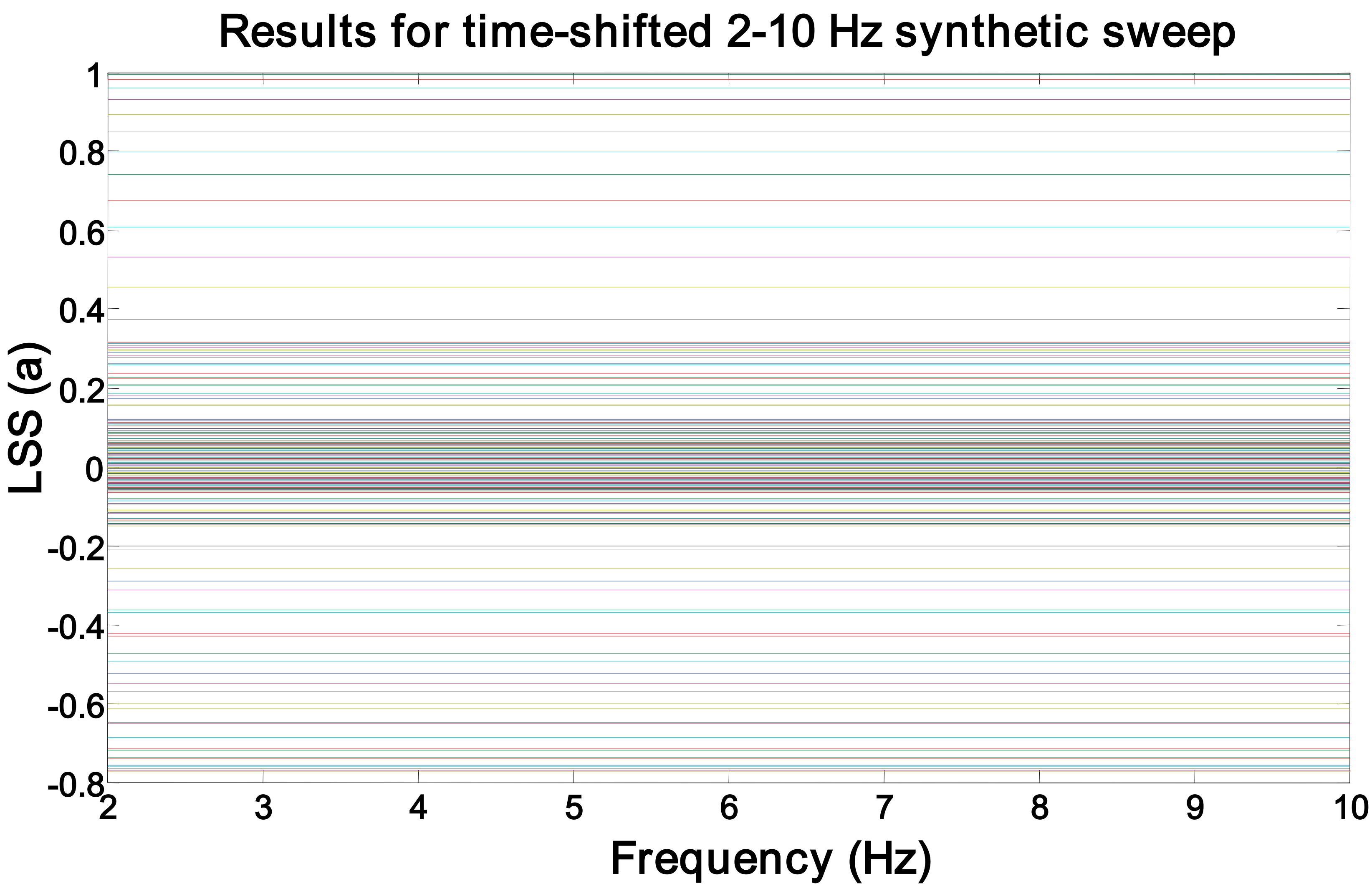
can be solved for a (least-squares-subtraction scalar) by differentiating and requiring that the result be equal to zero:

$$\frac{1}{2}\frac{\partial \varepsilon}{\partial a} = \sum_k S_{1k}S_{2k} - a\sum_k S_{2k}^2 = 0,$$

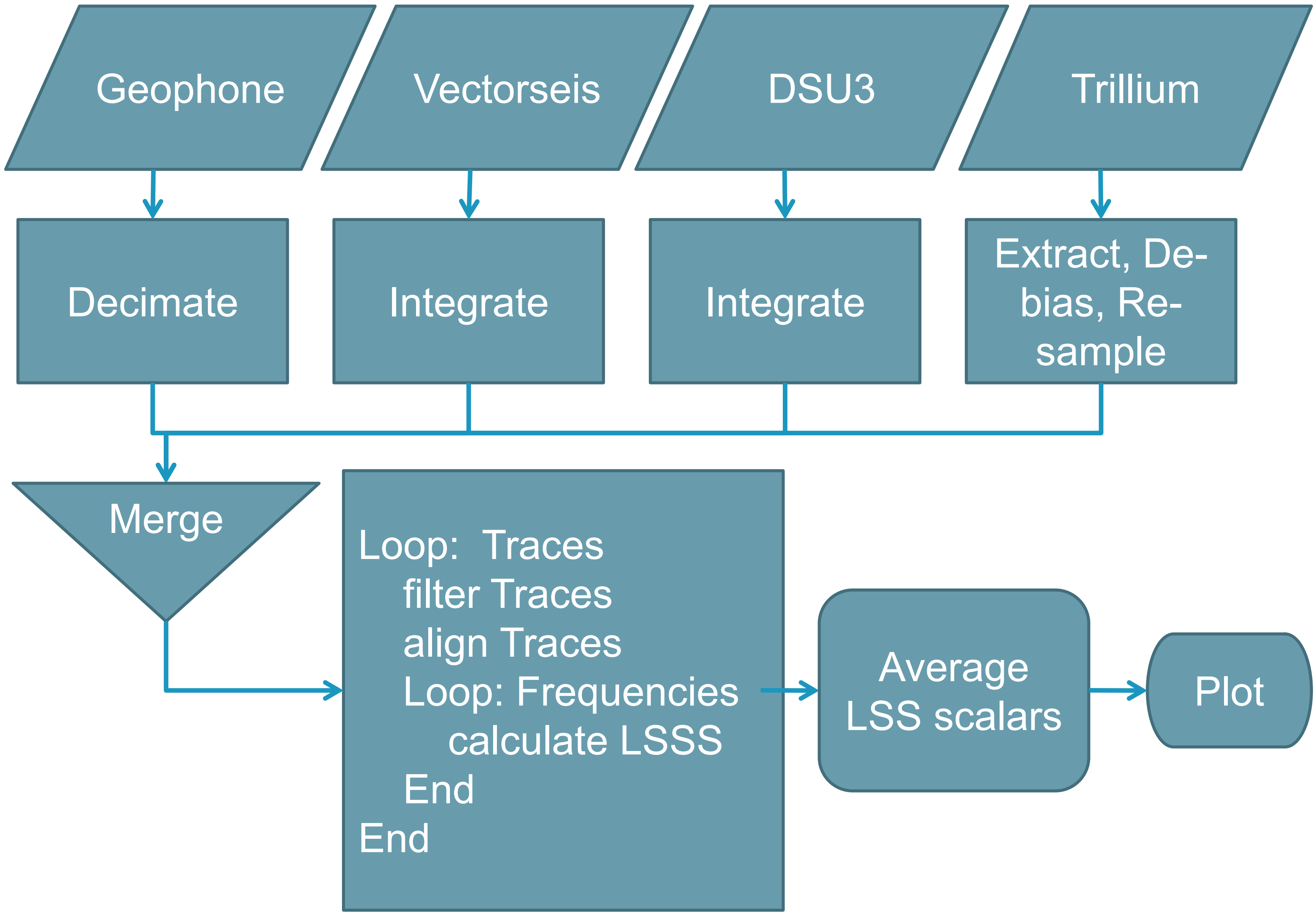
$$a = \frac{\sum_k S_{1k}S_{2k}}{\sum_k S_{2k}^2}$$

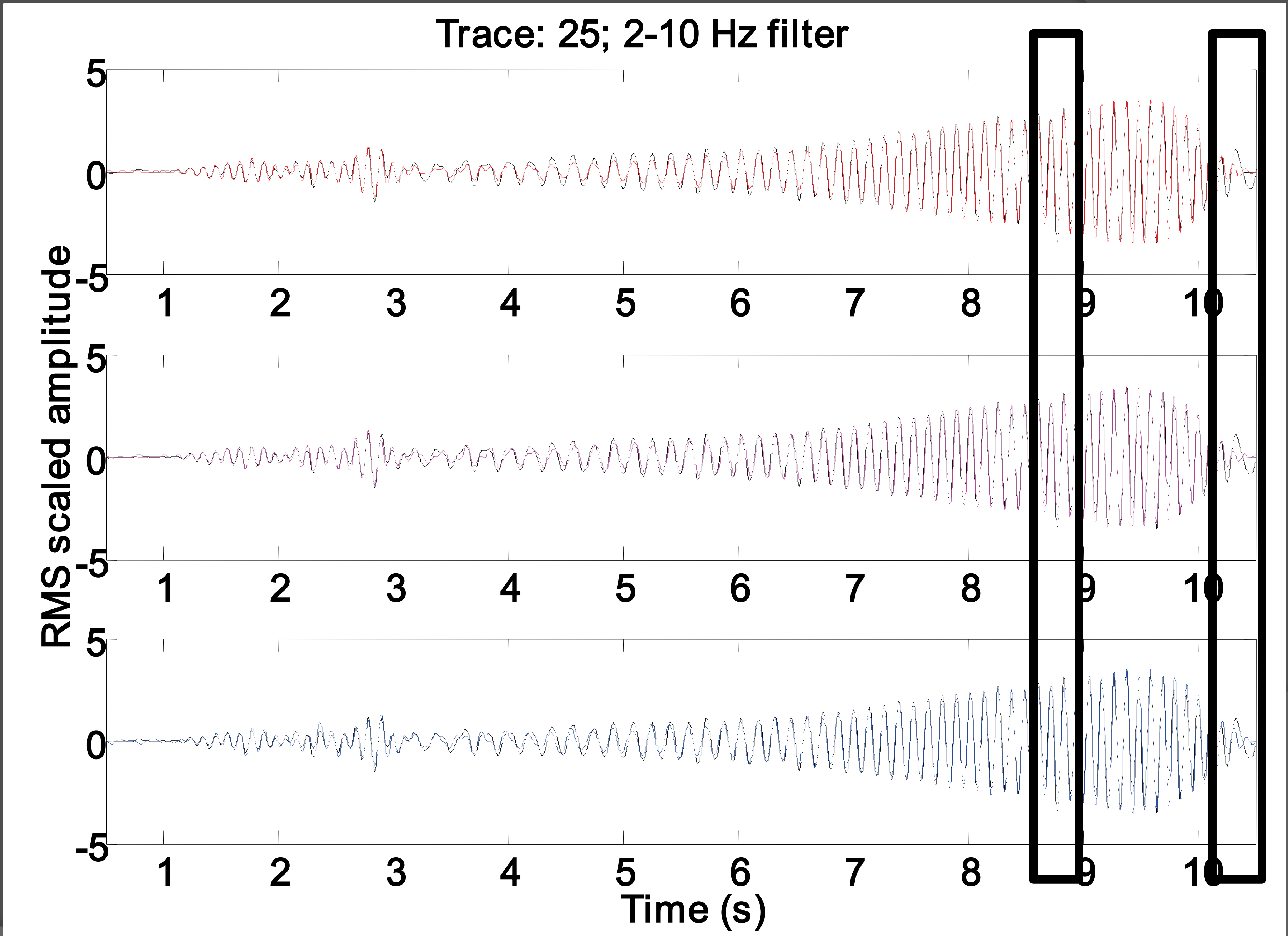
So: a is equivalent to the zero-lag cross-correlation divided by the zero-lag auto-correlation

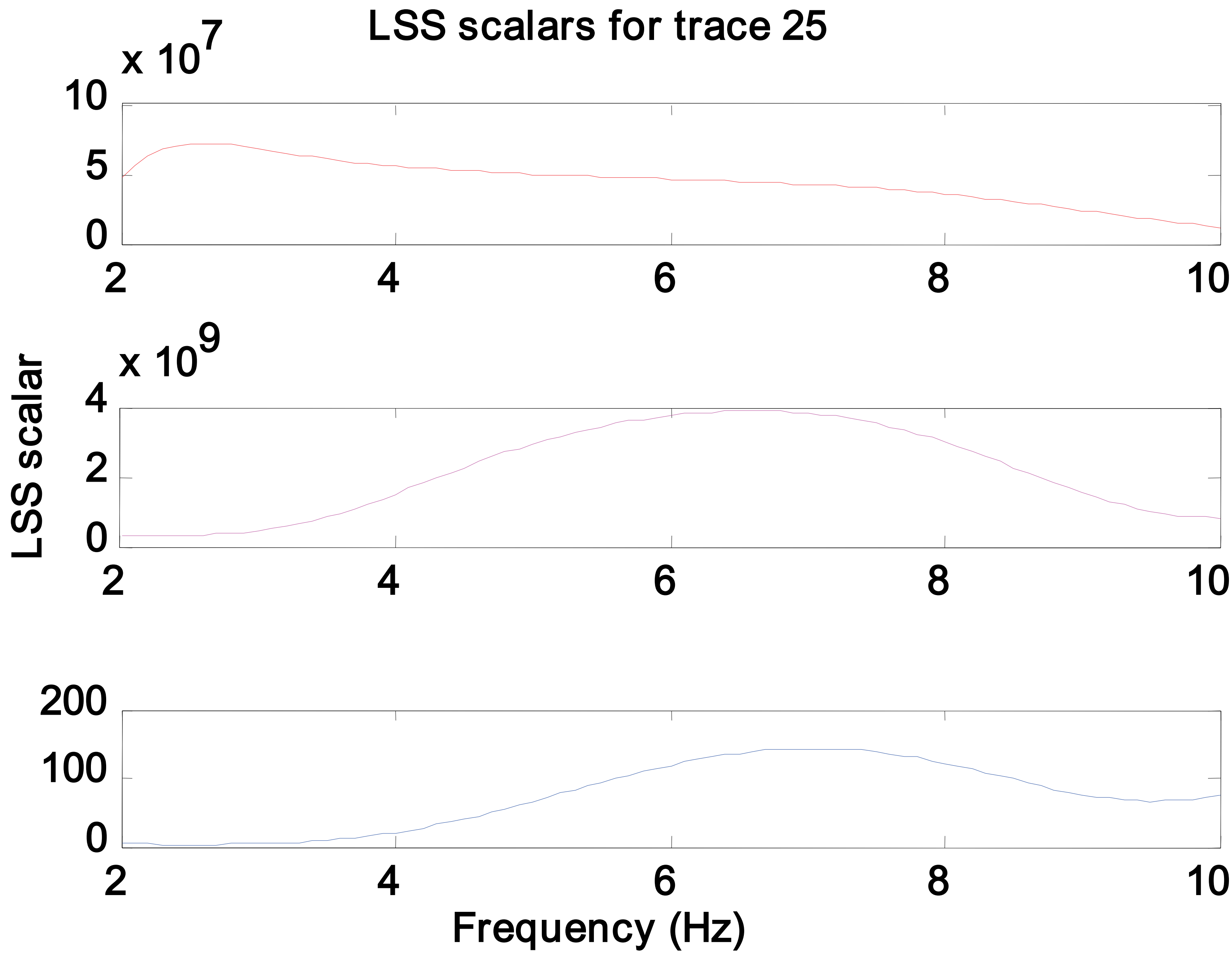

1
0
0
fmin
fmax

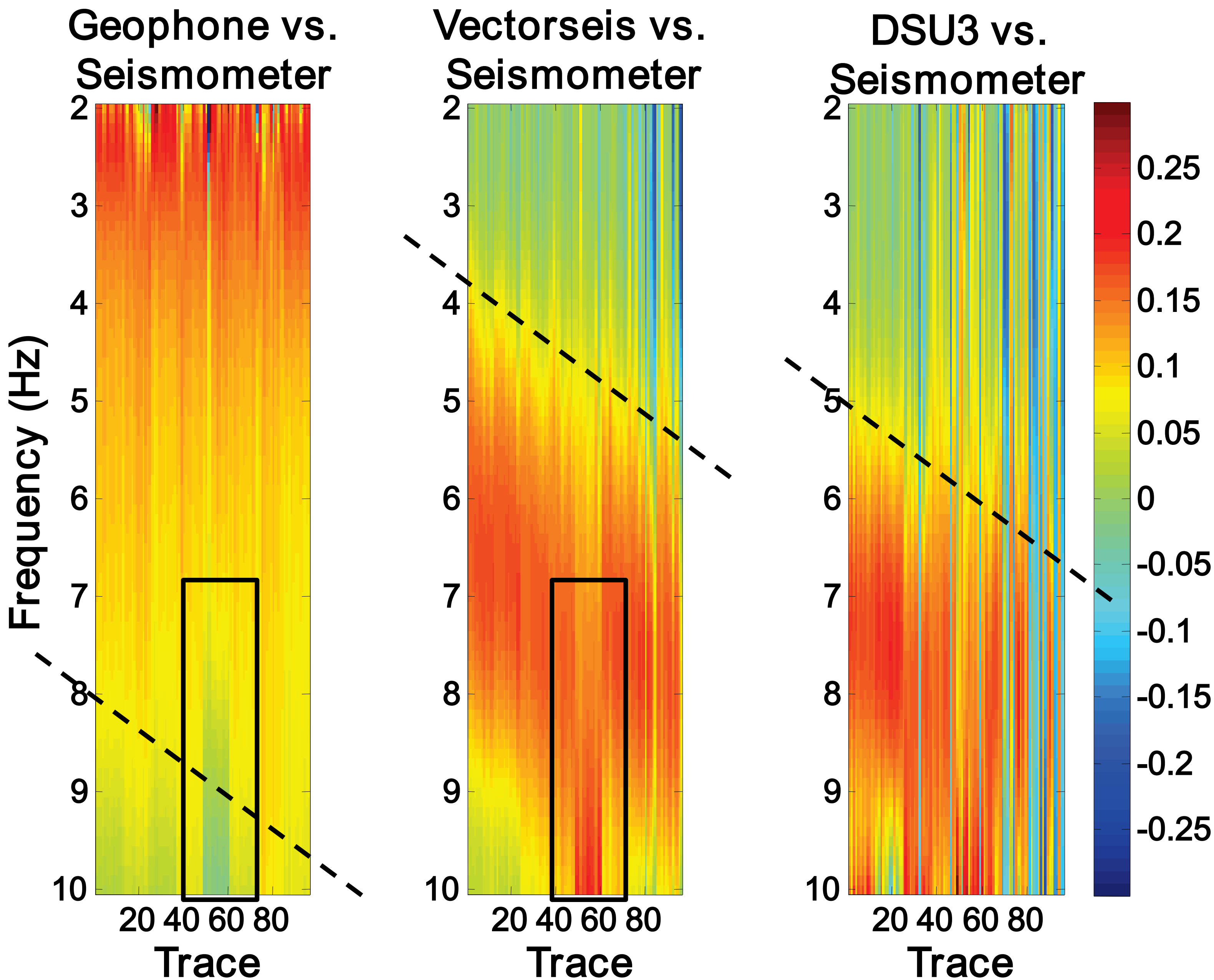


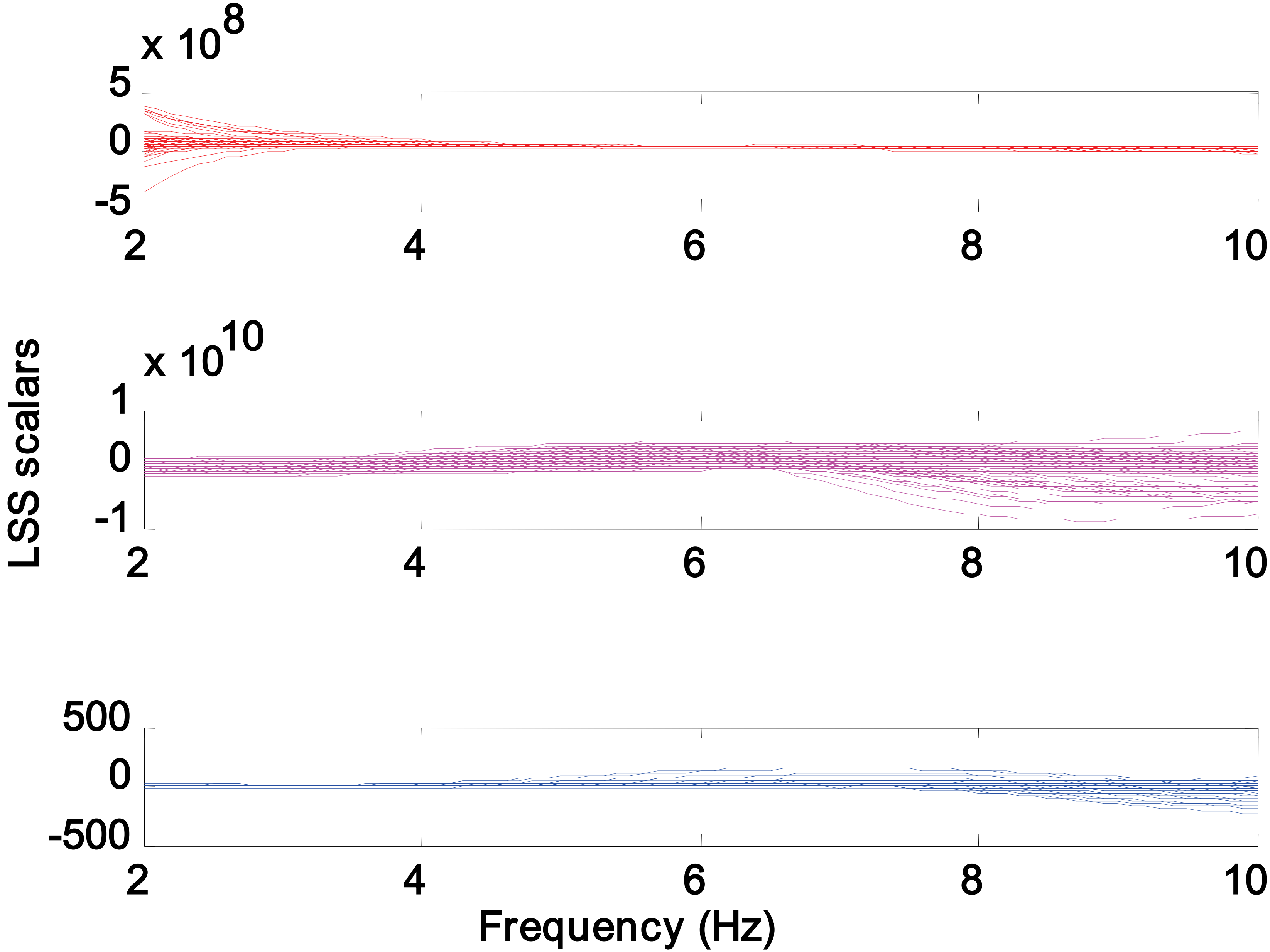
Results for time-shifted 2-10 Hz synthetic sweep
LSS (a)
Frequency (Hz)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
2
3
4
5
6
7
8
9
10

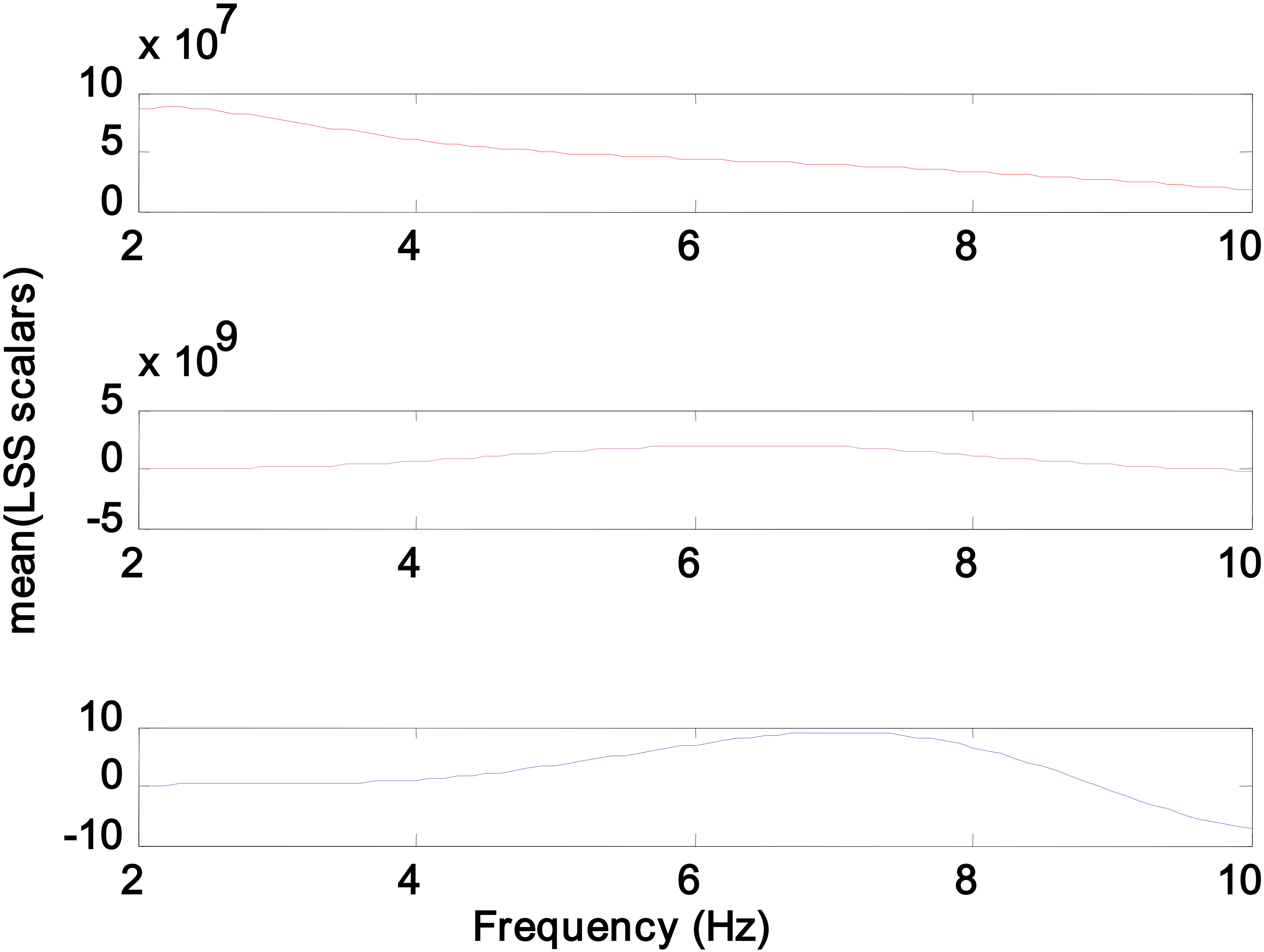

Geophone
Vectorseis
DSU3
Trillium
Decimate
Integrate
Integrate
Extract, De-bias, Re-sample
Merge
Loop: Traces
filter Traces
align Traces
Loop: Frequencies
calculate LSSS
End
End
Average LSS scalars
Plot

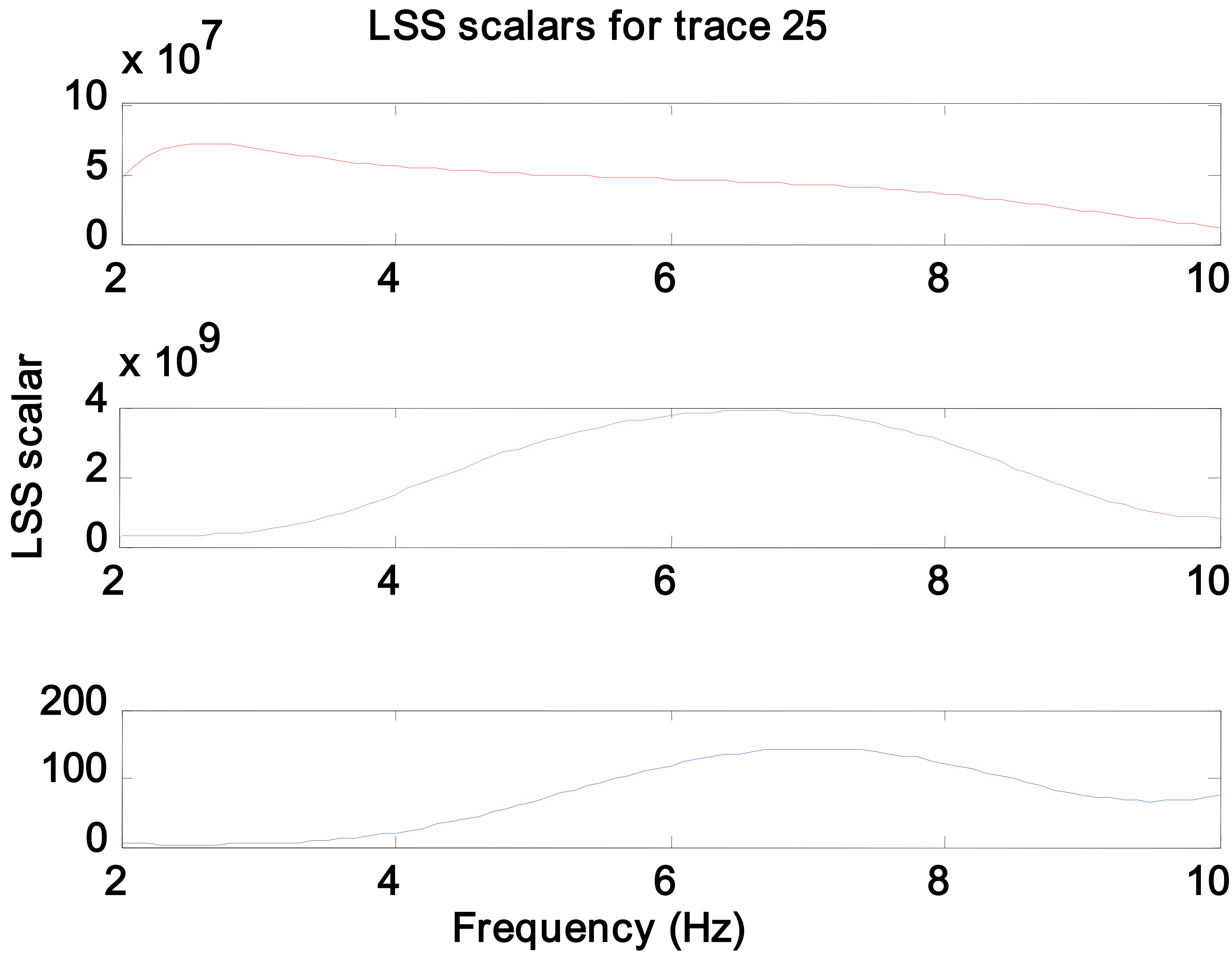

Trace: 25; 2-10 Hz filter
RMS scaled amplitude
5
0
-5
1
2
3
4
5
6
7
8
9
10
Time (s)


LSS scalars for trace 25
x 10^7
10
5
0
2
4
6
8
10
x 10^9
4
2
0
2
4
6
8
10
LSS scalar
200
100
0
2
4
6
8
10
Frequency (Hz)


Geophone vs. Seismometer
Vectorseis vs. Seismometer
DSU3 vs. Seismometer
Frequency (Hz)
2
3
4
5
6
7
8
9
10
20 40 60 80
Trace
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25


x 10^8
5
0
-5
2
4
6
8
10
LSS scalars
x 10^10
1
0
-1
2
4
6
8
10
500
0
-500
2
4
6
8
10
Frequency (Hz)


x 10^7
10
5
0
2
4
6
8
10
x 10^9
5
0
-5
2
4
6
8
10
10
0
-10
2
4
6
8
10
mean(LSS scalars)
Frequency (Hz)



LSS scalars for trace 25
x 10^7
10
5
0
2
4
6
8
10
x 10^9
4
2
0
2
4
6
8
10
200
100
0
2
4
6
8
10
LSS scalar
Frequency (Hz)

Discussion 1/2

1. Least-squares-subtraction scalar depends on amplitude, phase, frequency, quality of sensor placement and source-receiver offset

2. Geophone amplitudes are 10^7 less than seismometer

3. Vectorseis amplitudes are 10^9 less than seismometer

4. DSU3 amplitudes are 10^2 less than the seismometer

Discussion 2/2

1. Accelerometer LSSS curves are similar to each other, aside from magnitude

2. Geophone LSSS curve is different than the accelerometer curves

Acknowledgements

We would like to thank the field crew, which included CREWES faculty, staff and students, as well as Kris Dash from ARAM Systems, Tom Preusser and Aaron Kennedy from CGGVeritas (Sercel/DSU3), Brett Frederickson from ION (Scorpion/Vectorseis), and Waled Bin Merdhah from ERCB/Alberta Geological Survey (Nanometrics/Trillium). We would also like to thank Dave Eaton for allowing the use of his seismometers for this experiment.