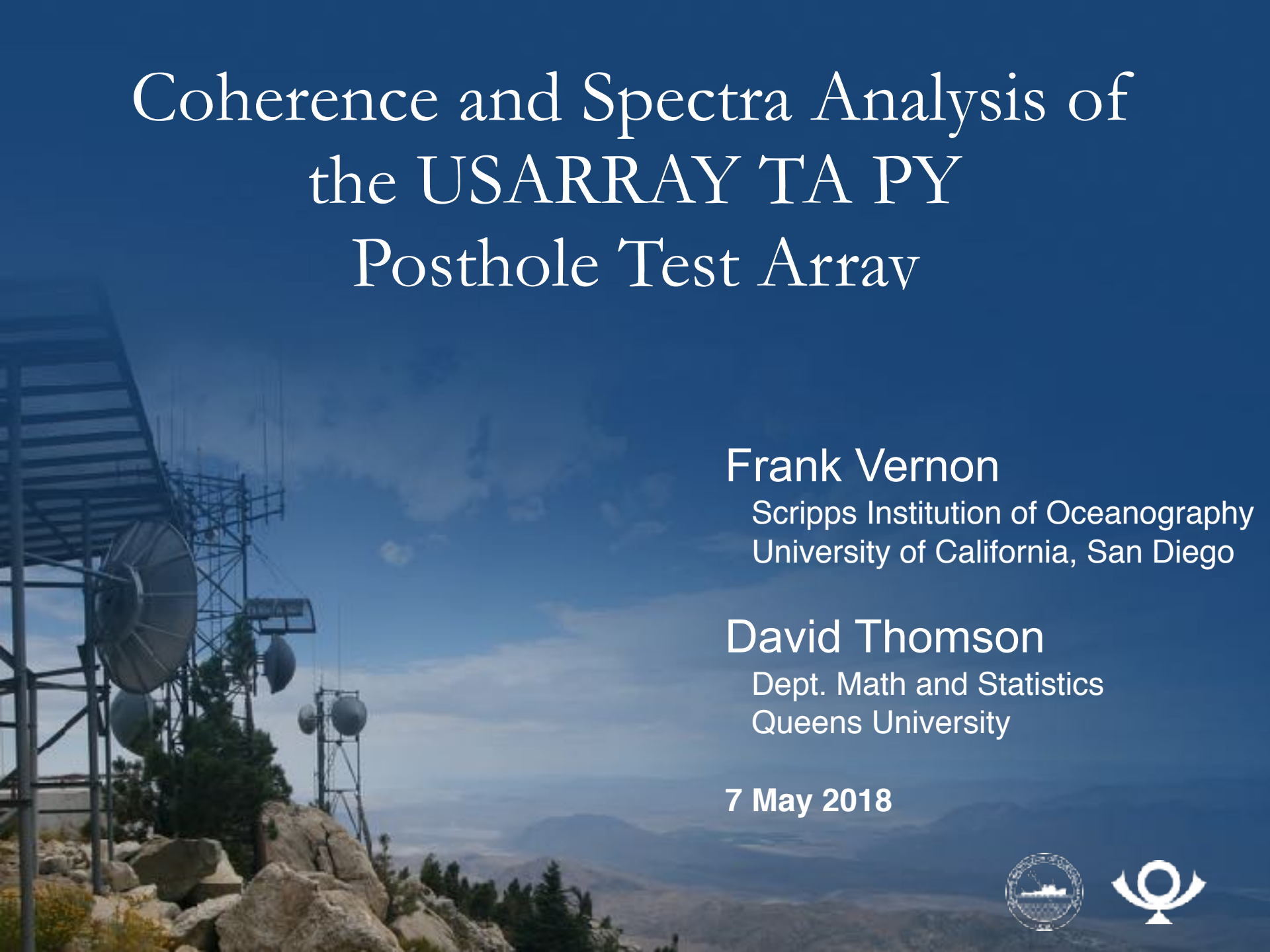
Coherence and Spectra Analysis of the USARRAY TA PY Posthole Test Array



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Dept. Math and Statistics
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7 May 2018

Outline

- USArray Alaska Deployment Motivation
- PFO Testbed
- IRIS PSD results
- Spectra and Coherences
- Event data
- Conclusions

TA Alaska Sensor Emplacement

The Lund-Drill is designed for TA in Alaska:

- 1600 lbs Sling load weight
- 28% Augering
- 3% Backhoe
- 69% Downhole Hammer

NEED: a hole in rock, frozen ground or up to 5M into soils.

Drill in Skyvan, bound for Middleton Island

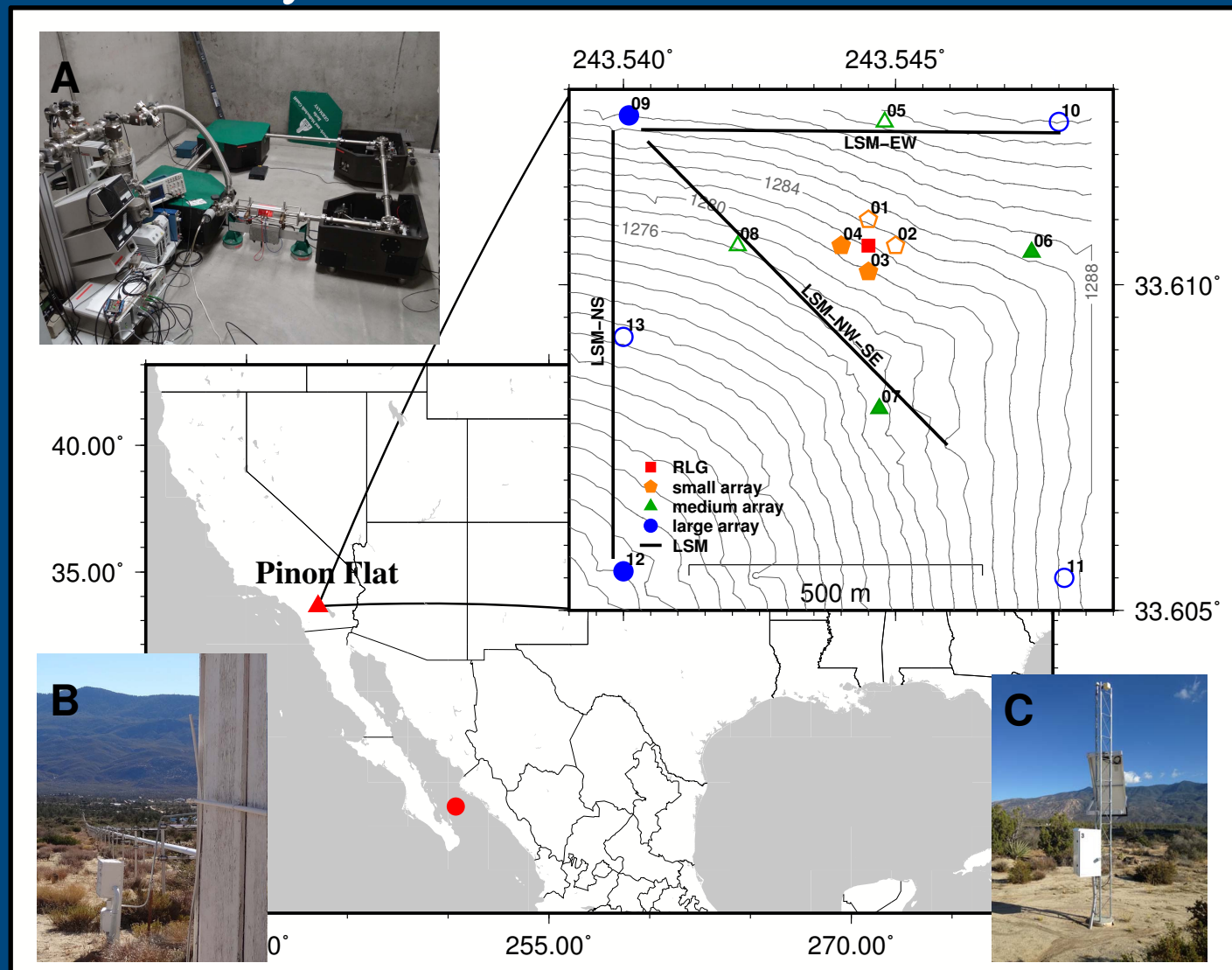
Hammer Drilling, AK.SCRK

Hammer drill, N25K

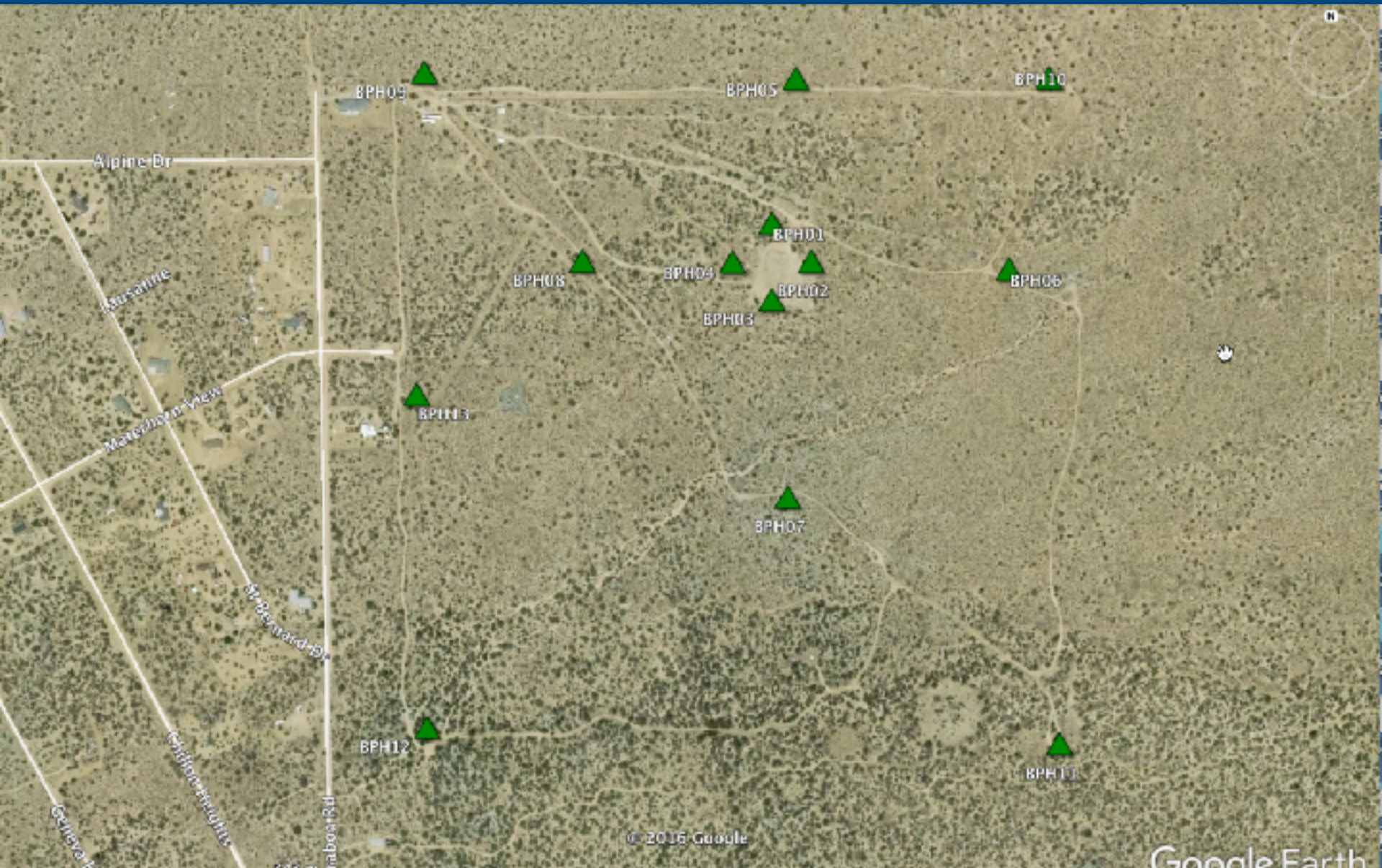
Mike Lundgren auger in Palmer AK

PFO PY Posthole Installation

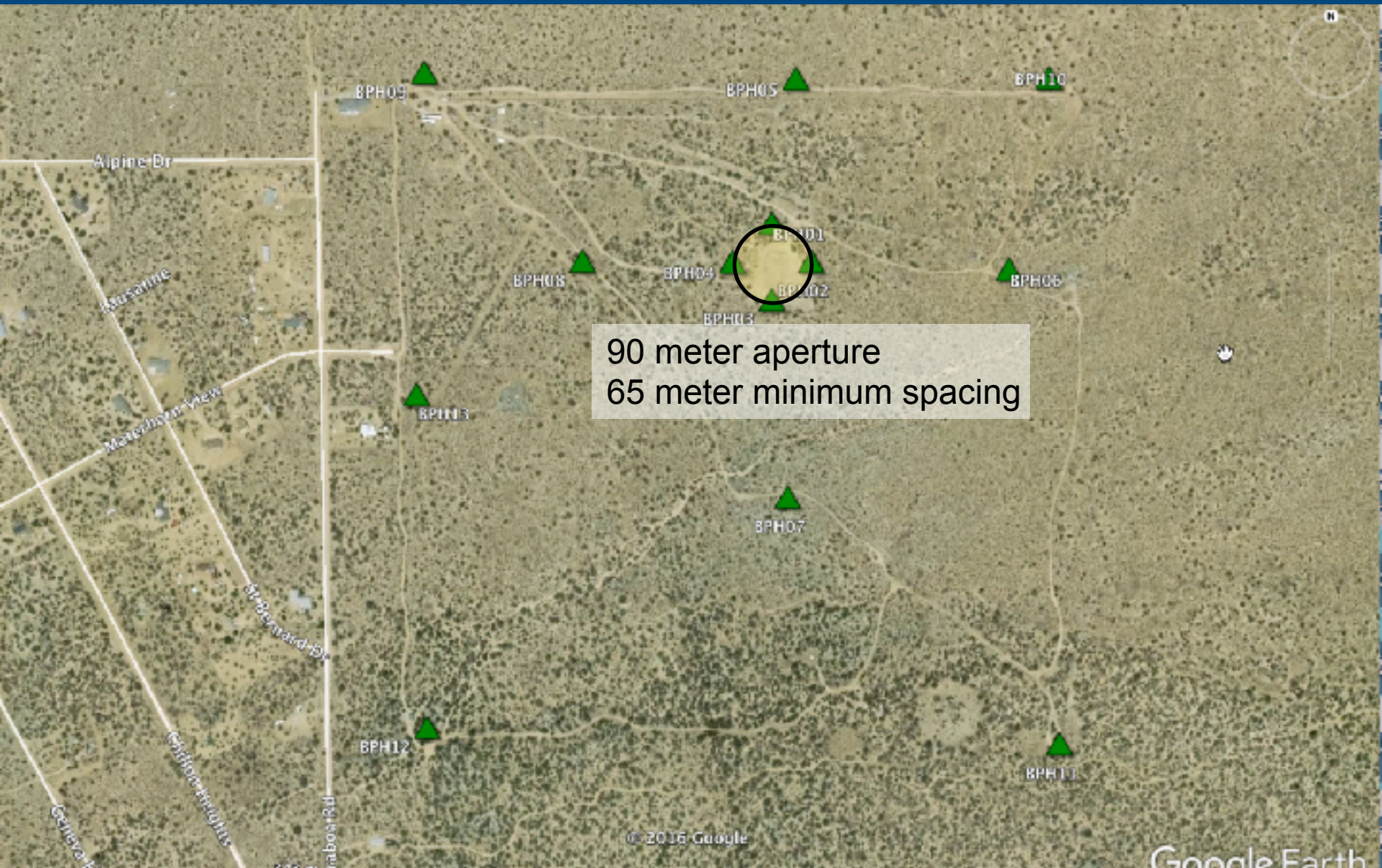
PY Array - Piñon Flat Observatory



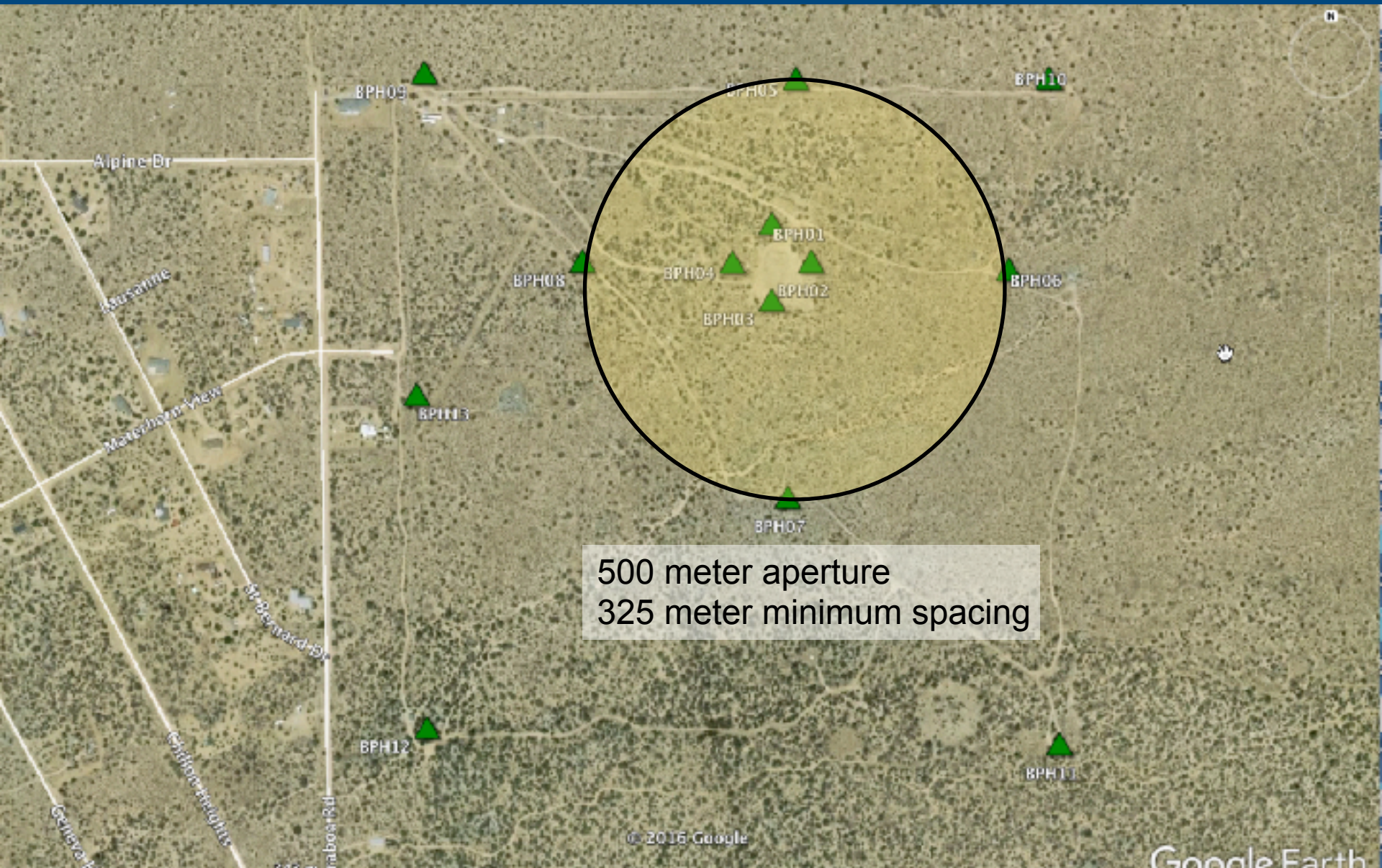
Piñon Flat PY Array



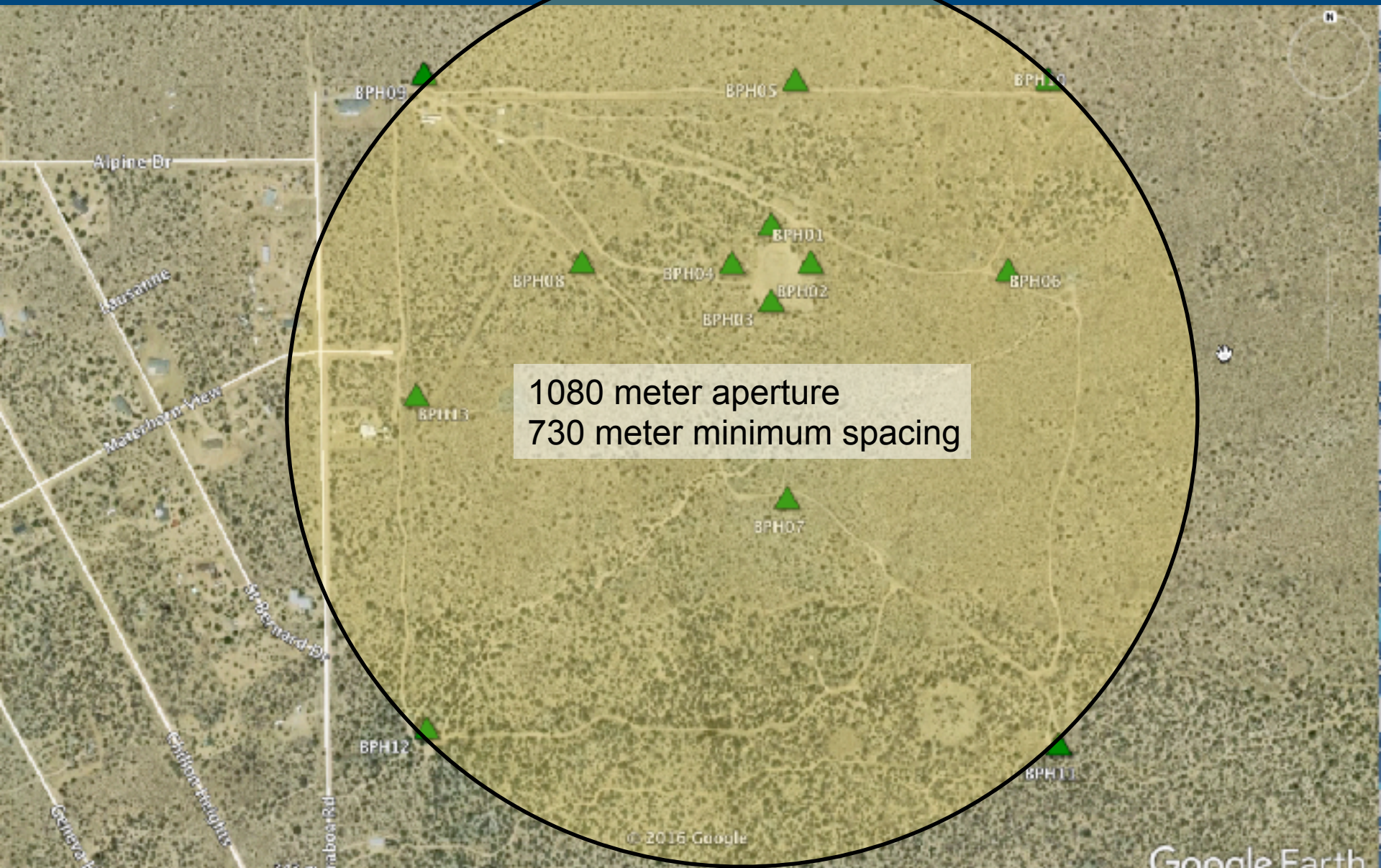
Piñon Flat PY Array



Piñon Flat PY Array

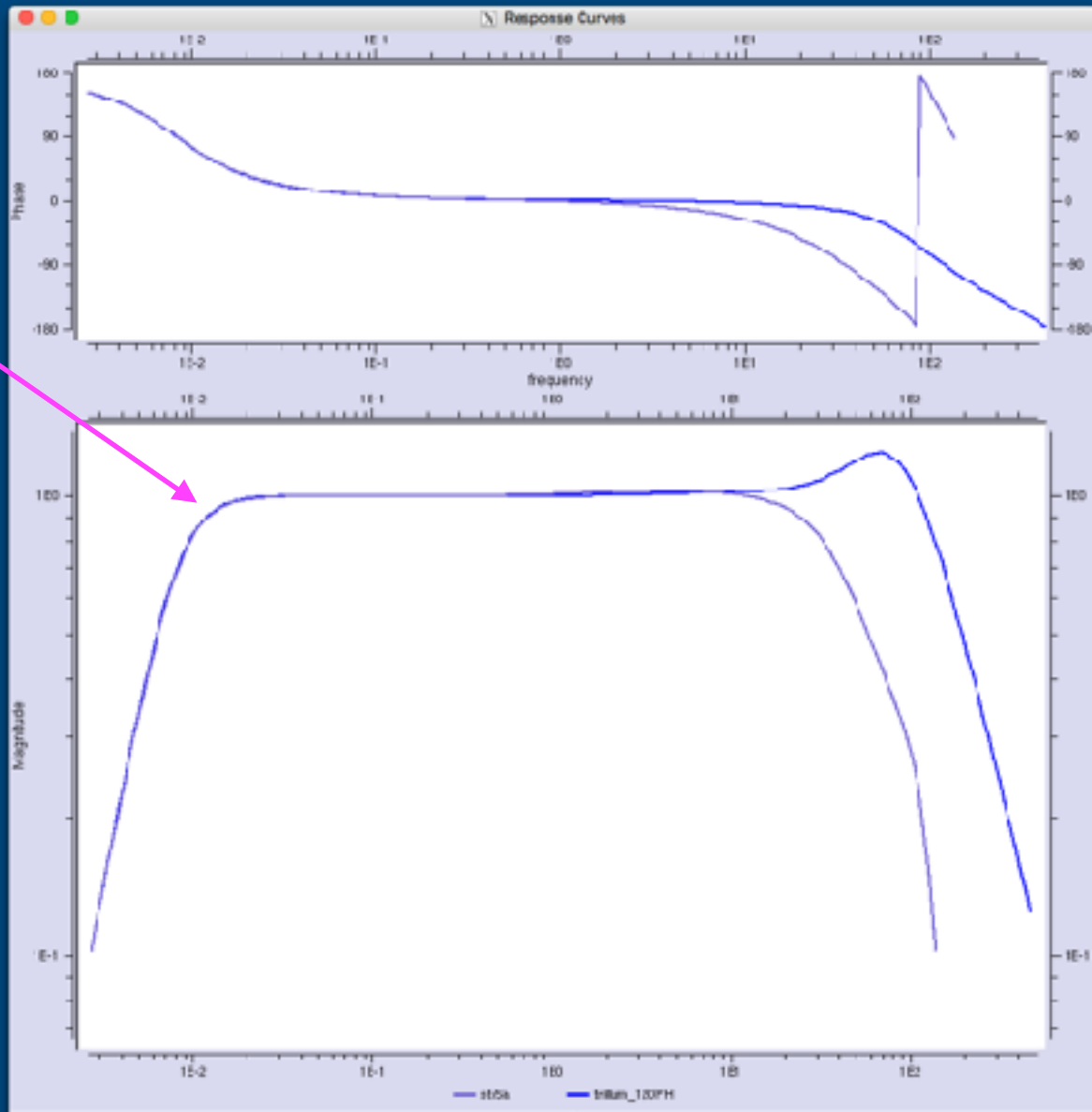


Piñon Flat PY Array



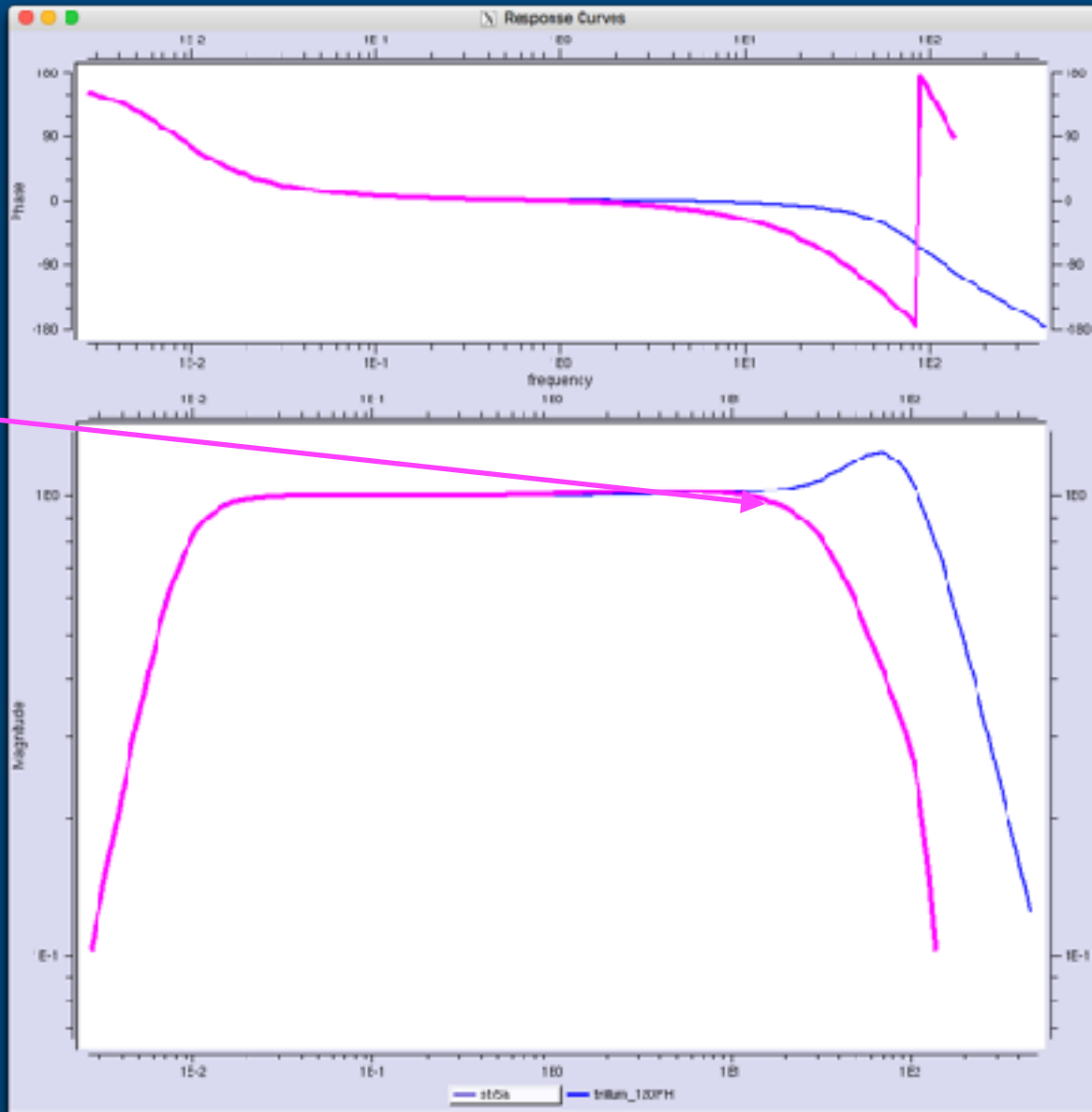
Nominal STS5 and Trillium 120 PH Responses

- Broadband Sensors
- 120 Sec Long Period Corner



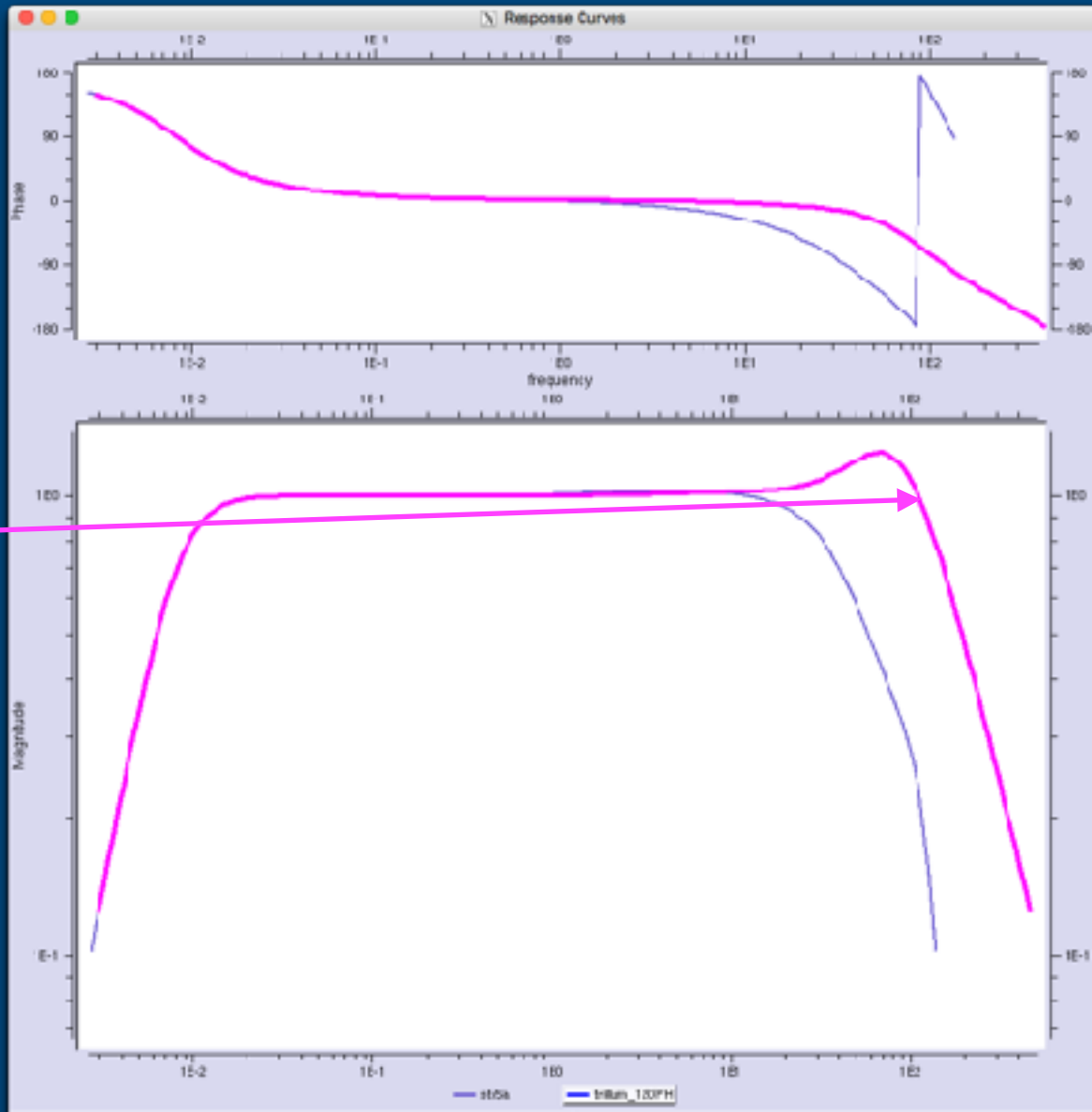
Nominal STS5 and Trillium 120 PH Responses

- Broadband Sensors
- 120 Sec Long Period Corner
- STS5 - ~40 Hz



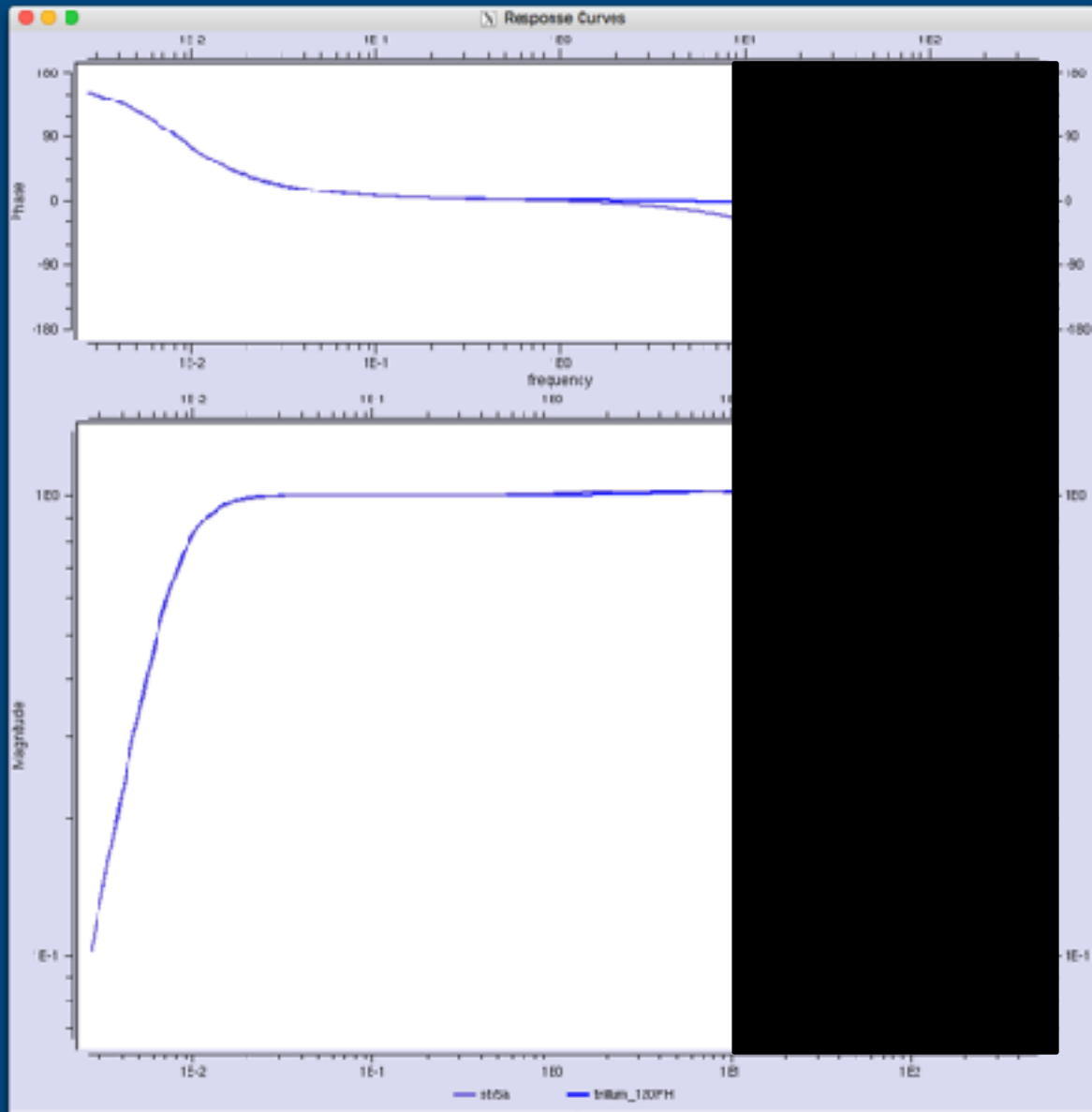
Nominal STS5 and Trillium 120 PH Responses

- Broadband Sensors
- 120 Sec Long Period Corner
- STS5 - ~40 Hz
- T120PH - ~200 Hz



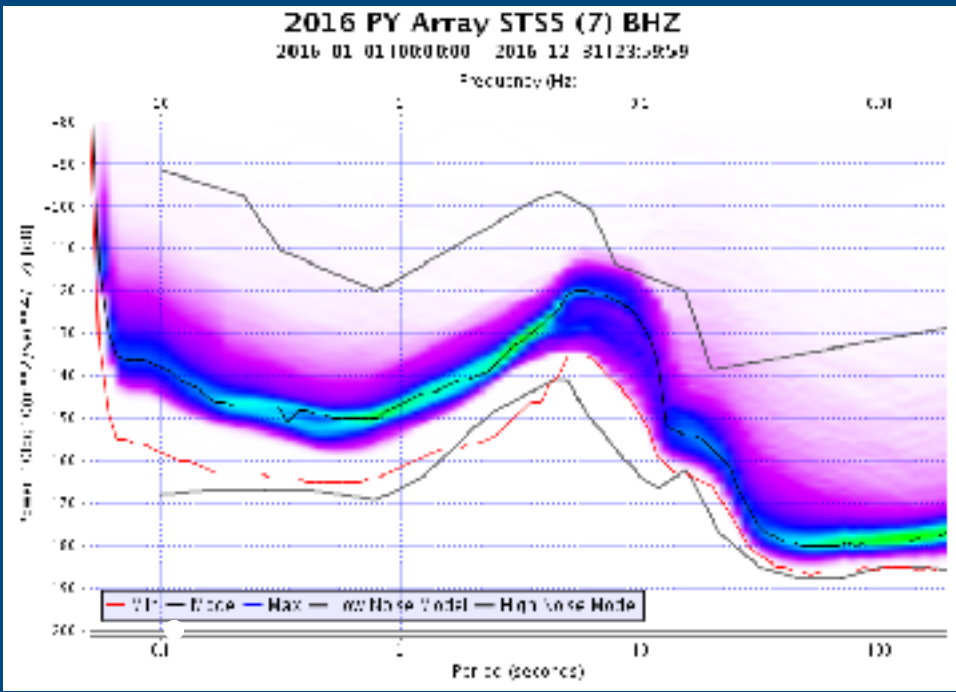
Nominal STS5 and Trillium 120 PH Responses

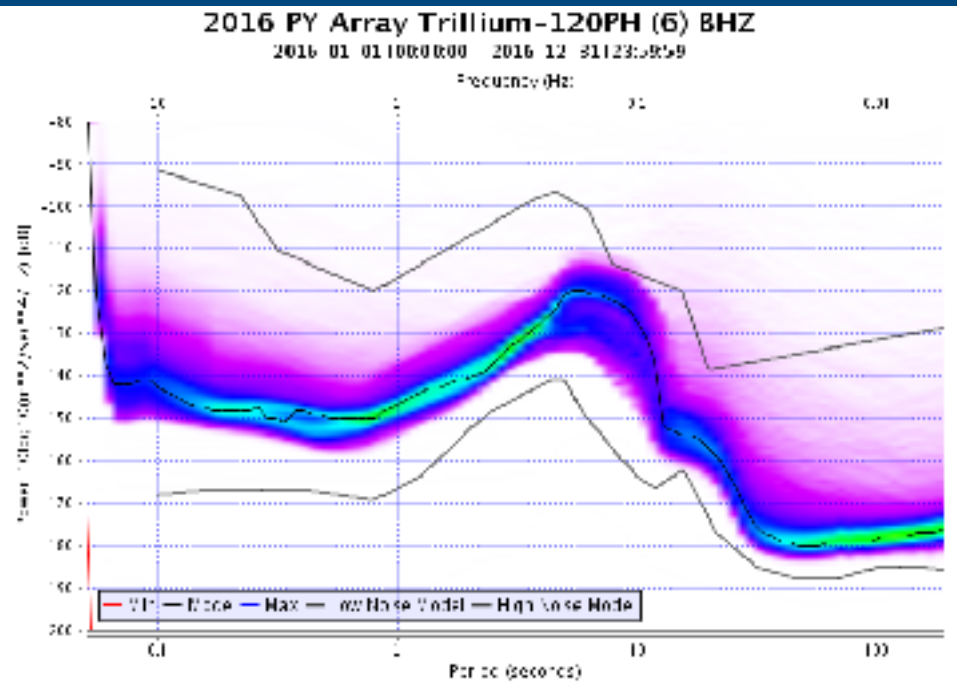
- Broadband Sensors
- 120 Sec Long Period Corner
- STS5 - ~40 Hz
- T120PH - ~200 Hz
- Similar response < 10 Hz



BHZ Sensor Comparison PDFs

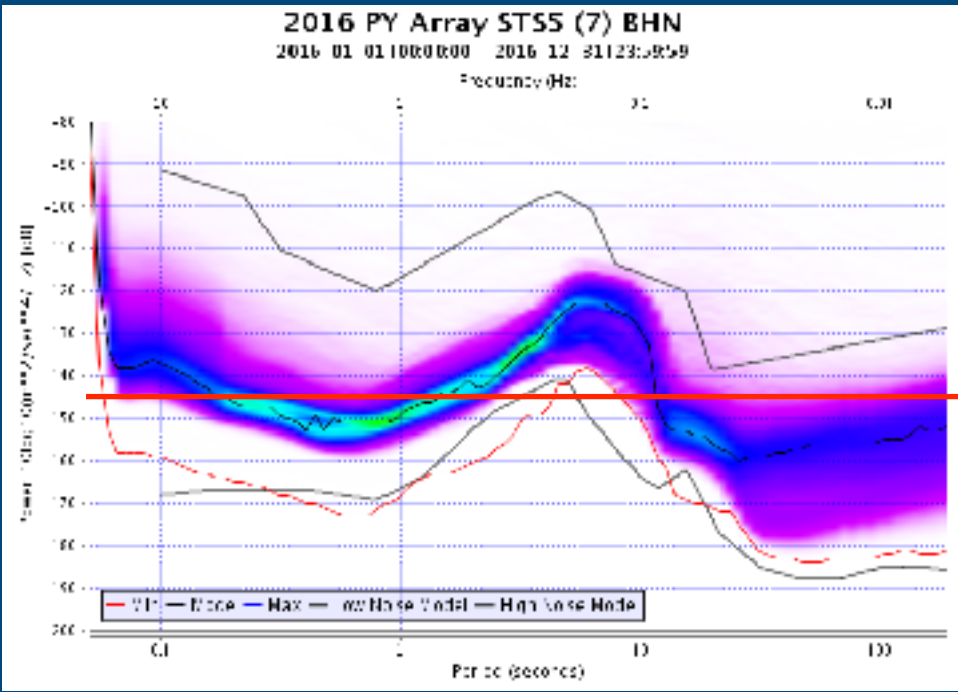
- 1 Jan - Dec 31 2016
- Nearly identical PDFs for both sensors

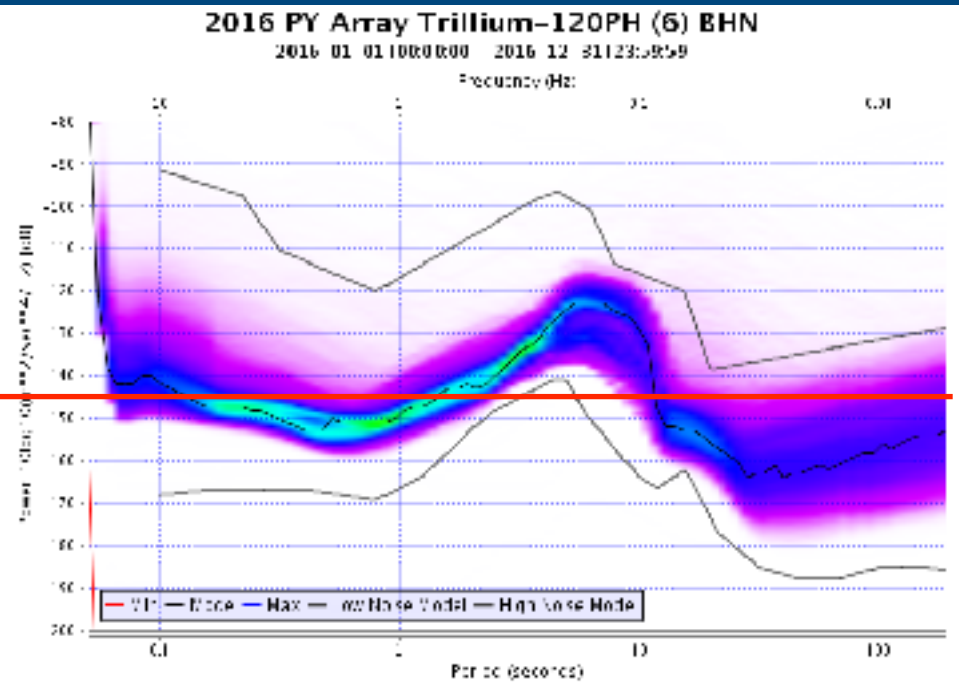




BHN Sensor Comparison PDFs

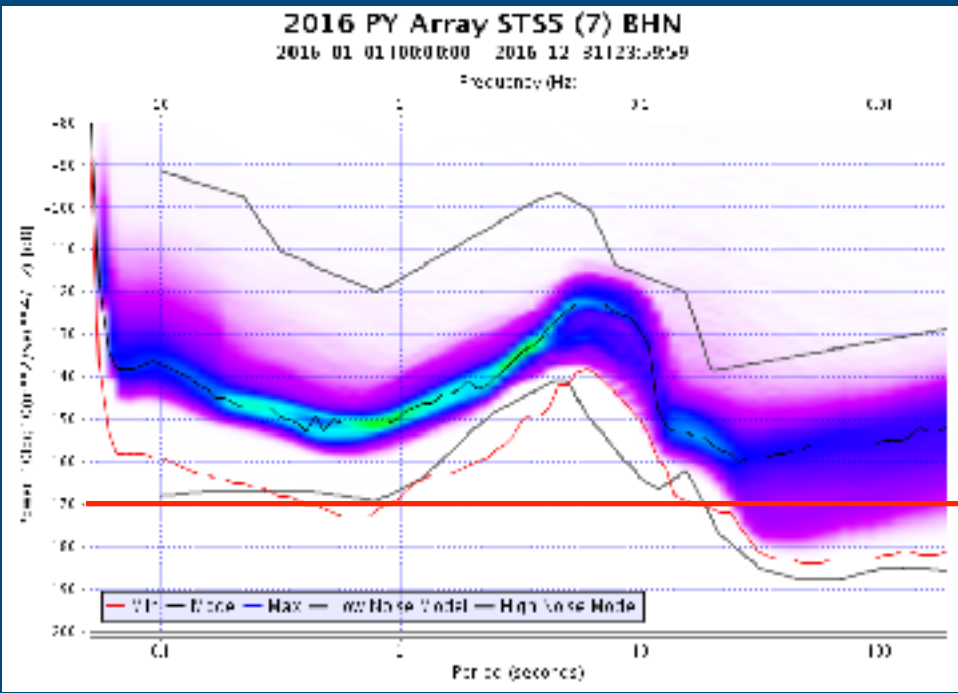
- 1 Jan - Dec 31 2016
- Slightly more long period noise on Trillium

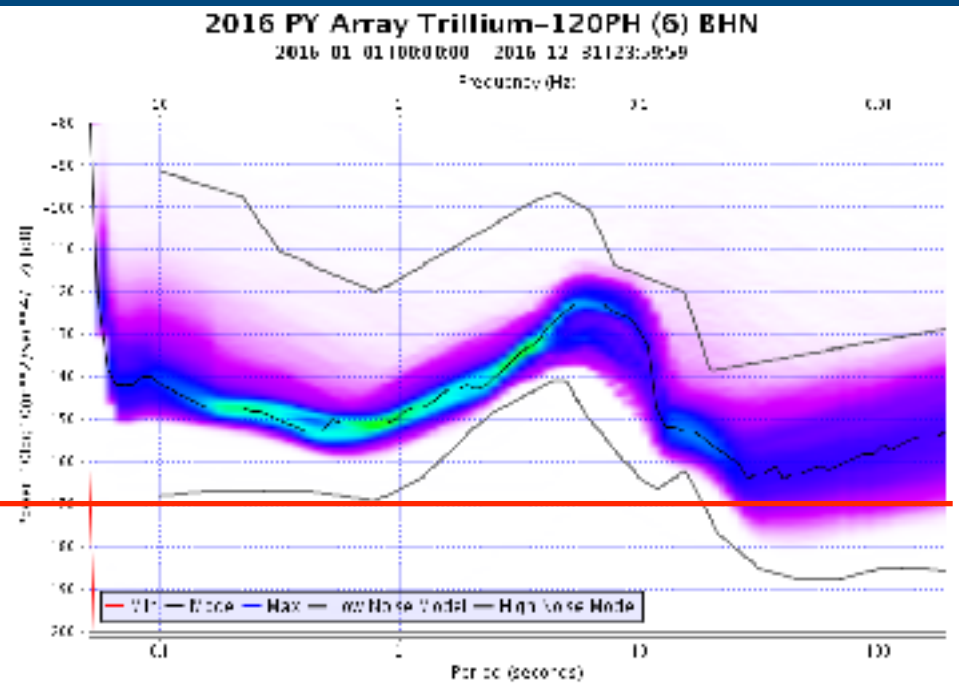




BHN Sensor Comparison PDFs

- 1 Jan - Dec 31 2016
- Slightly more long period noise on Trillium

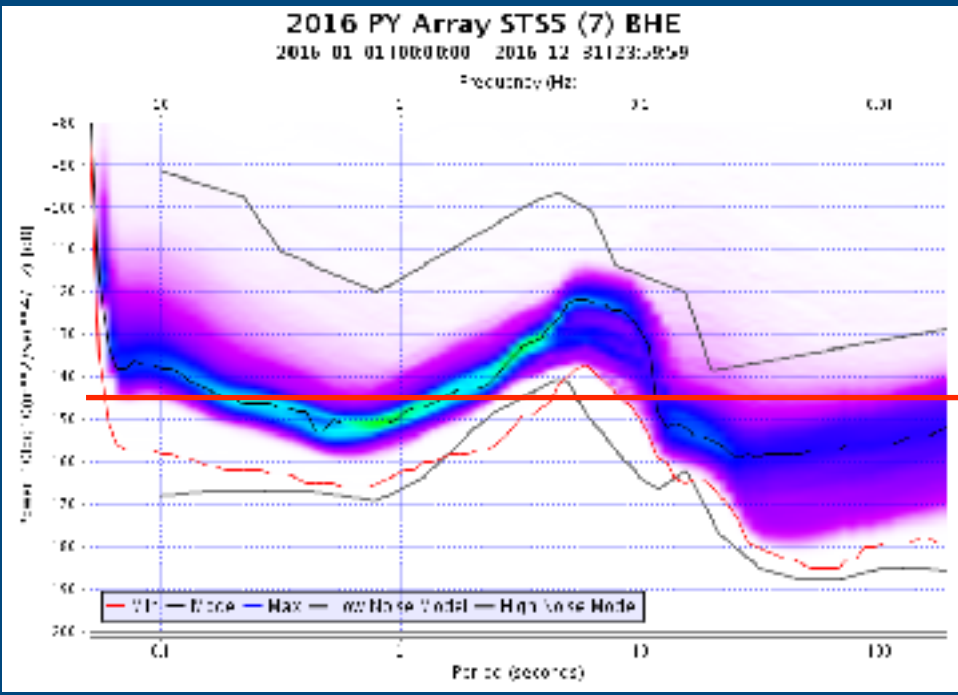


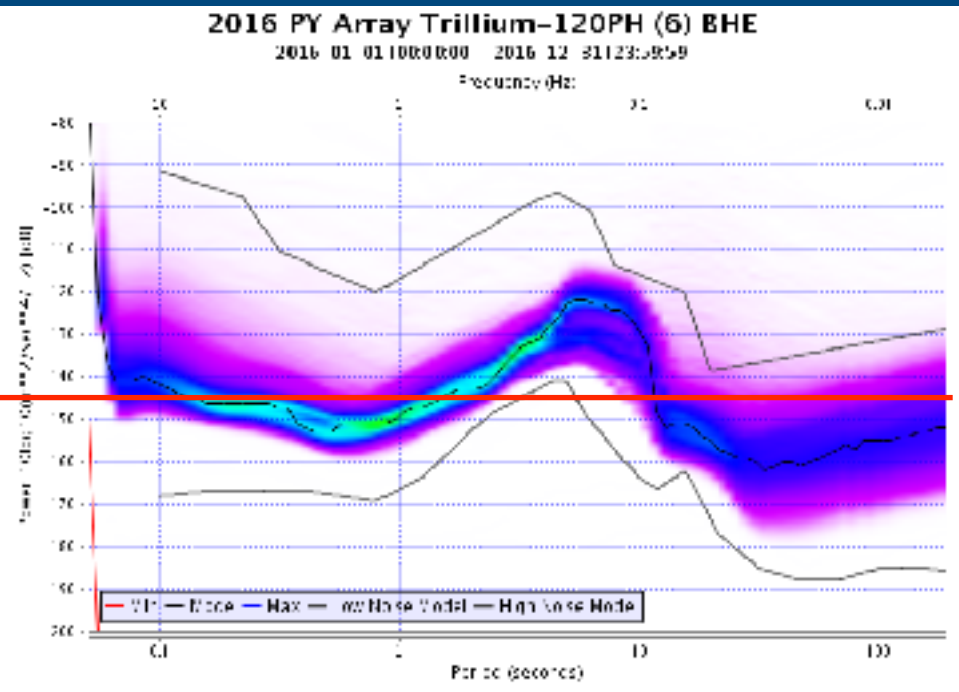


- Slightly quieter long period noise on STS5

BHE Sensor Comparison PDFs

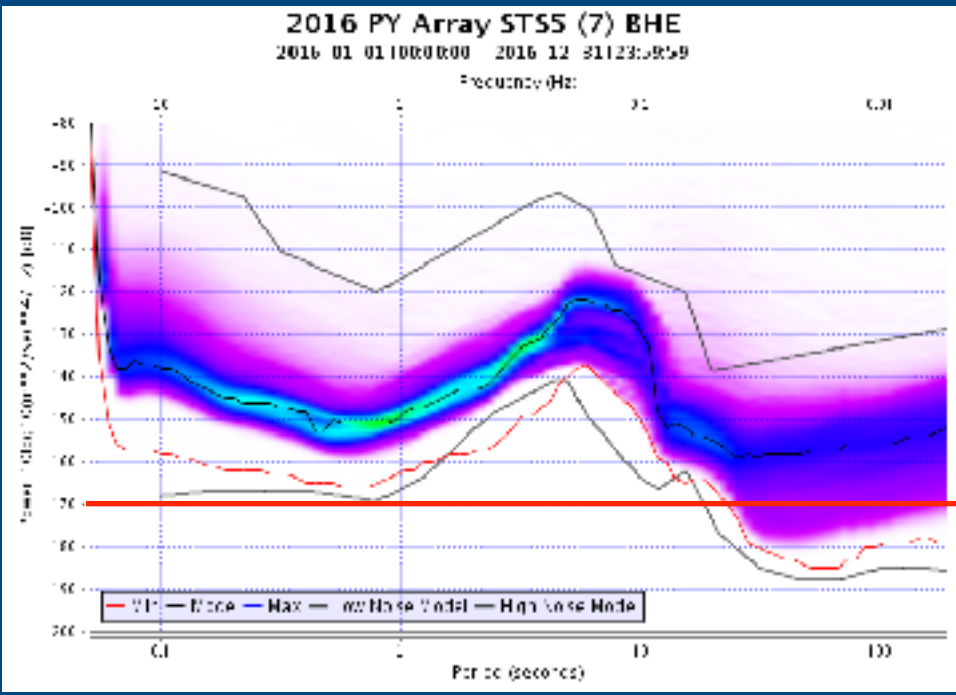
- 1 Jan - Dec 31 2016
- Slightly more long period noise on Trillium

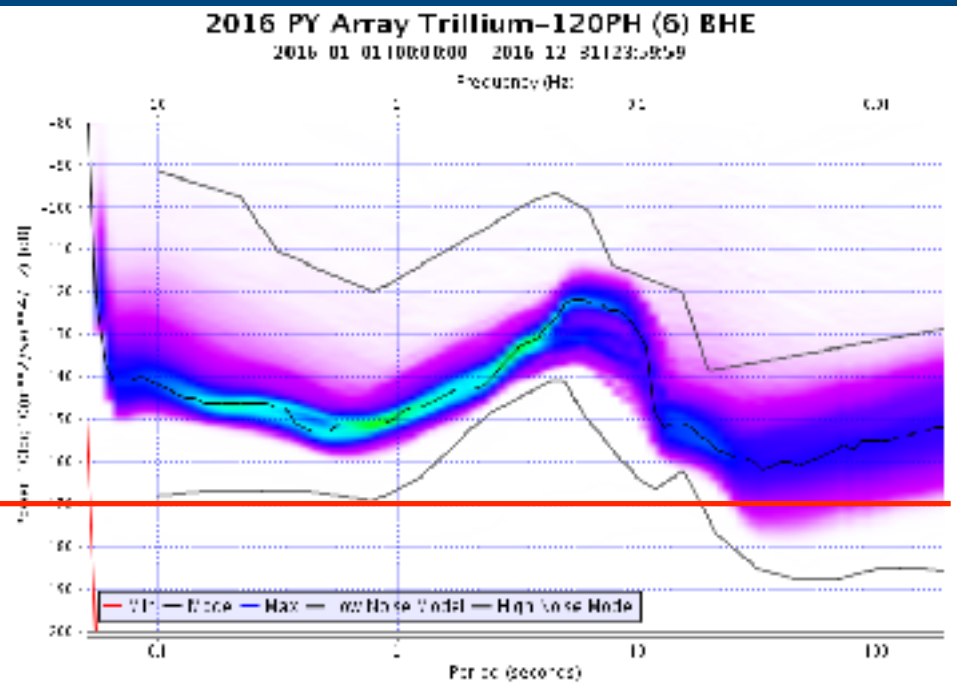




BHE Sensor Comparison PDFs

- 1 Jan - Dec 31 2016
- Slightly more long period noise on Trillium

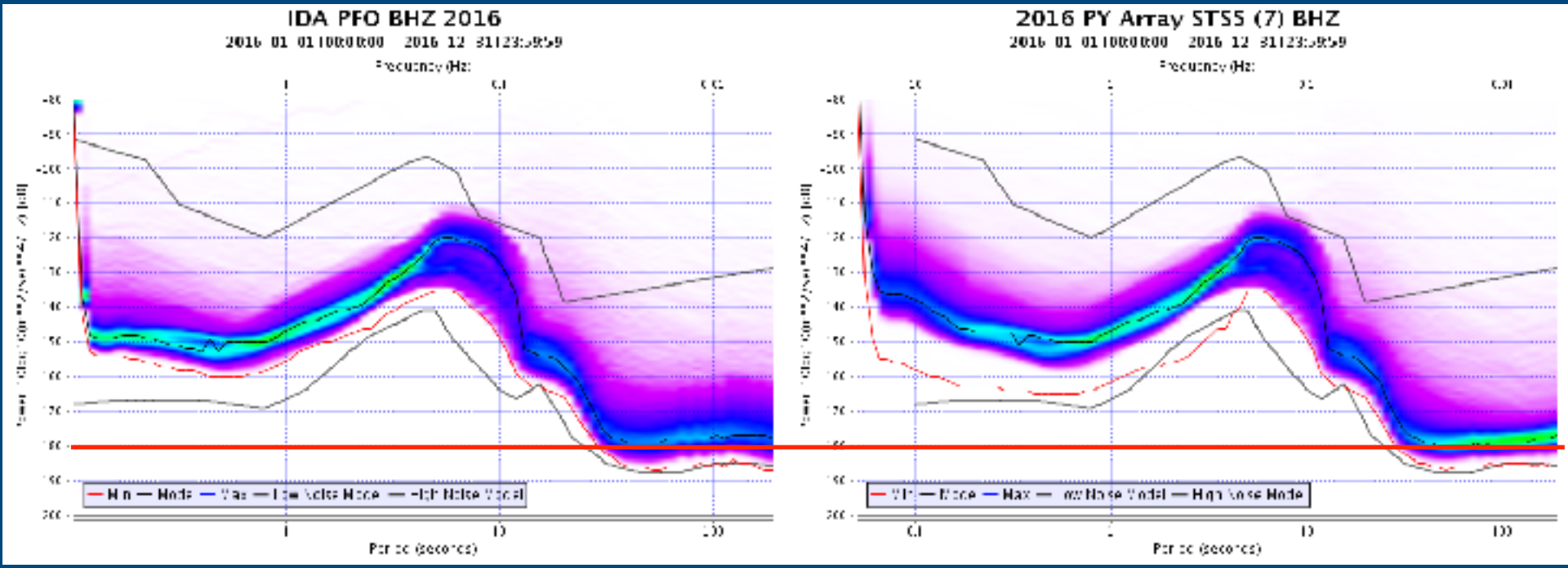




- Slightly quieter long period noise on STS5

GSN-PY BHZ Sensor Comparison

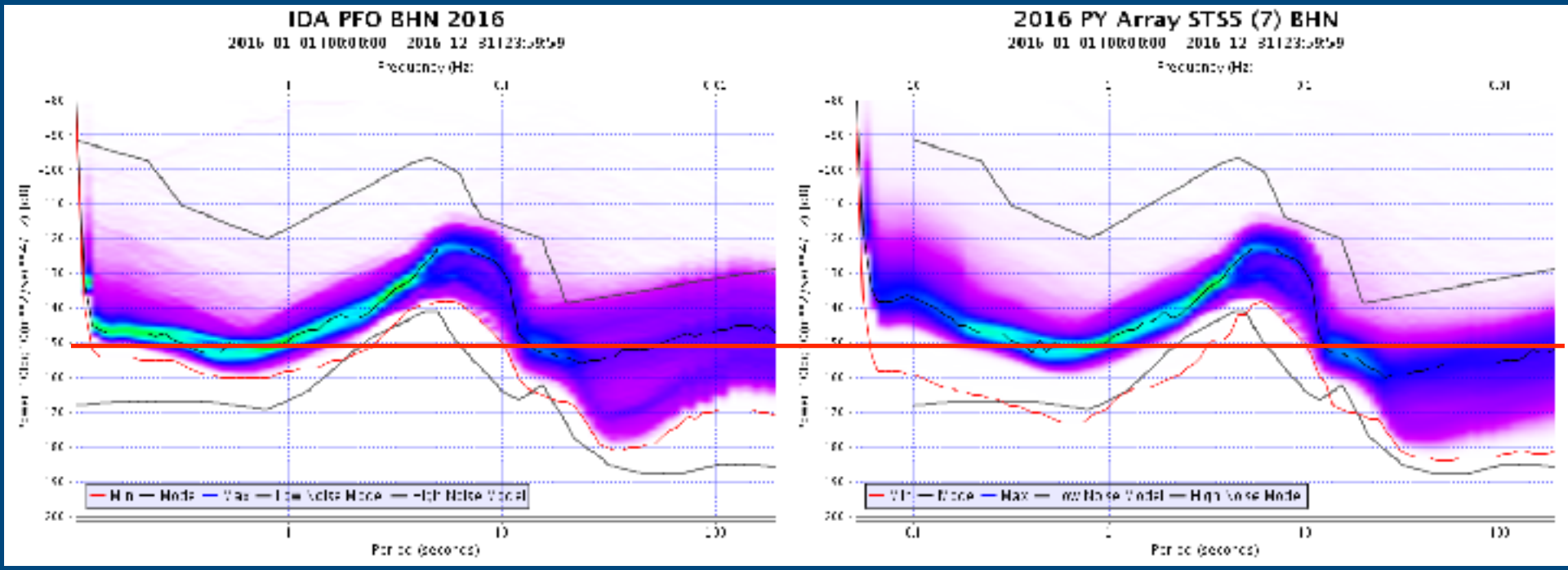
- 1 Jan - Dec 31 2016



Similar performance between STS-5 Posthole and STS-1

GSN-PY BHN Sensor Comparison

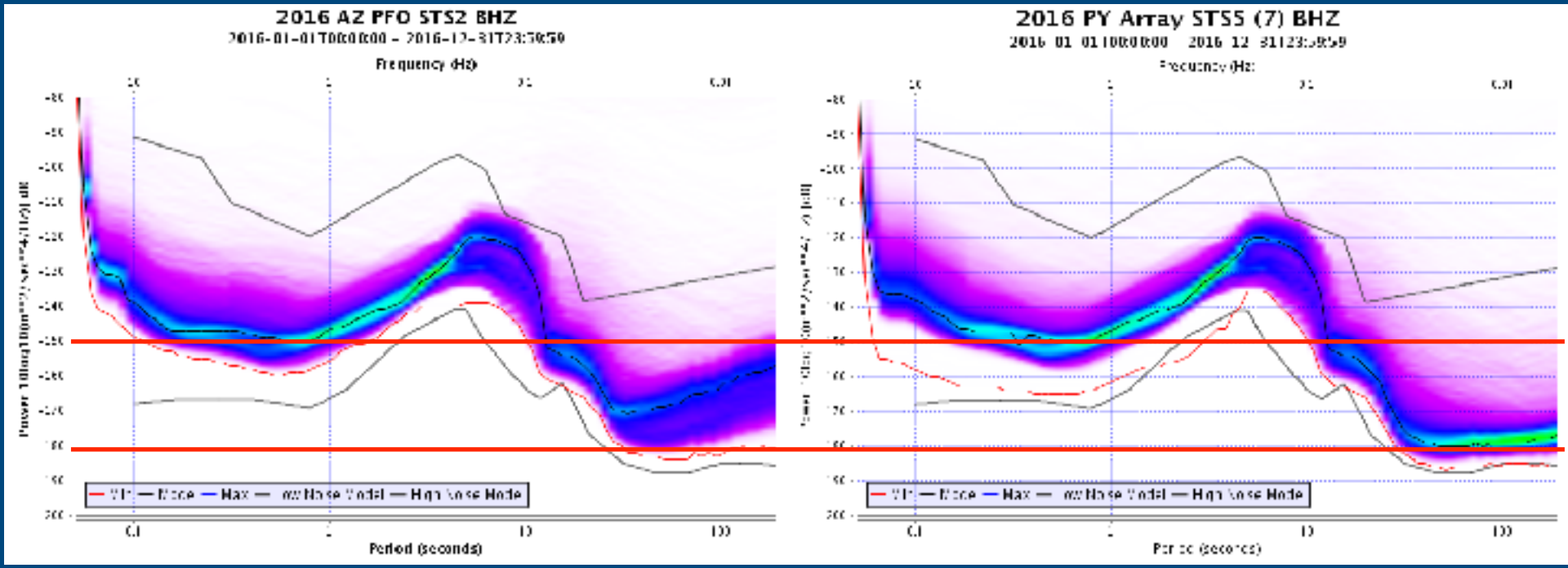
- 1 Jan - Dec 31 2016



Improved performance of STS-5 Posthole over STS-1

AZ-PY BHZ Sensor Comparison

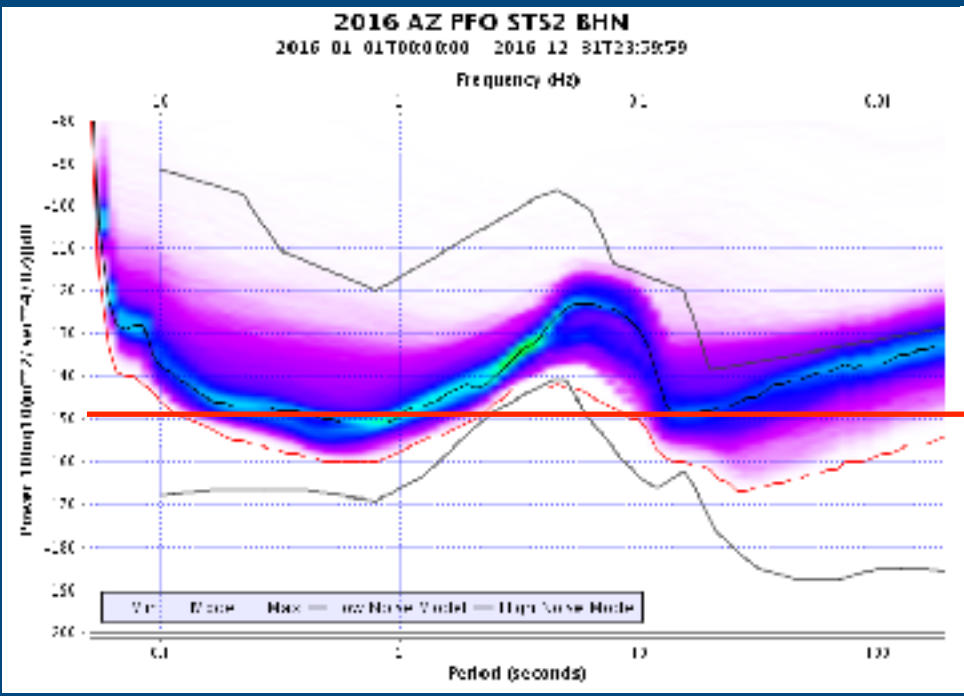
- 1 Jan - Dec 31 2016

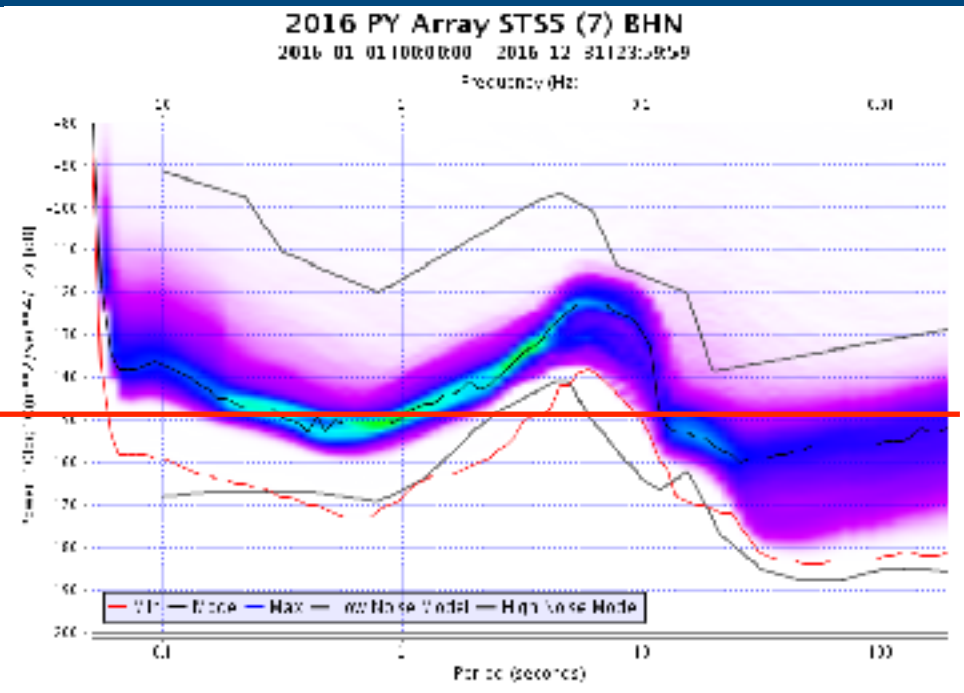


Improved performance of STS-5 Posthole over surface STS-2

AZ-PY BHN Sensor Comparison

- 1 Jan - Dec 31 2016

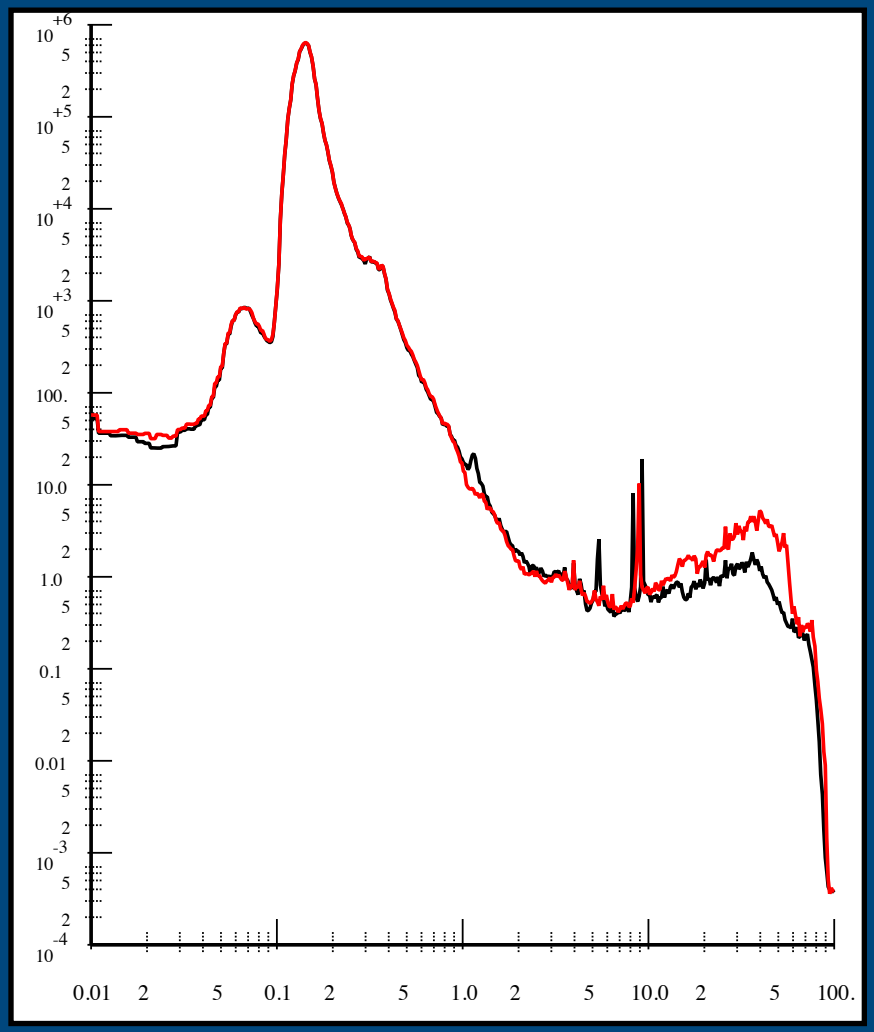




Improved performance of STS-5 Posthole over surface STS-2

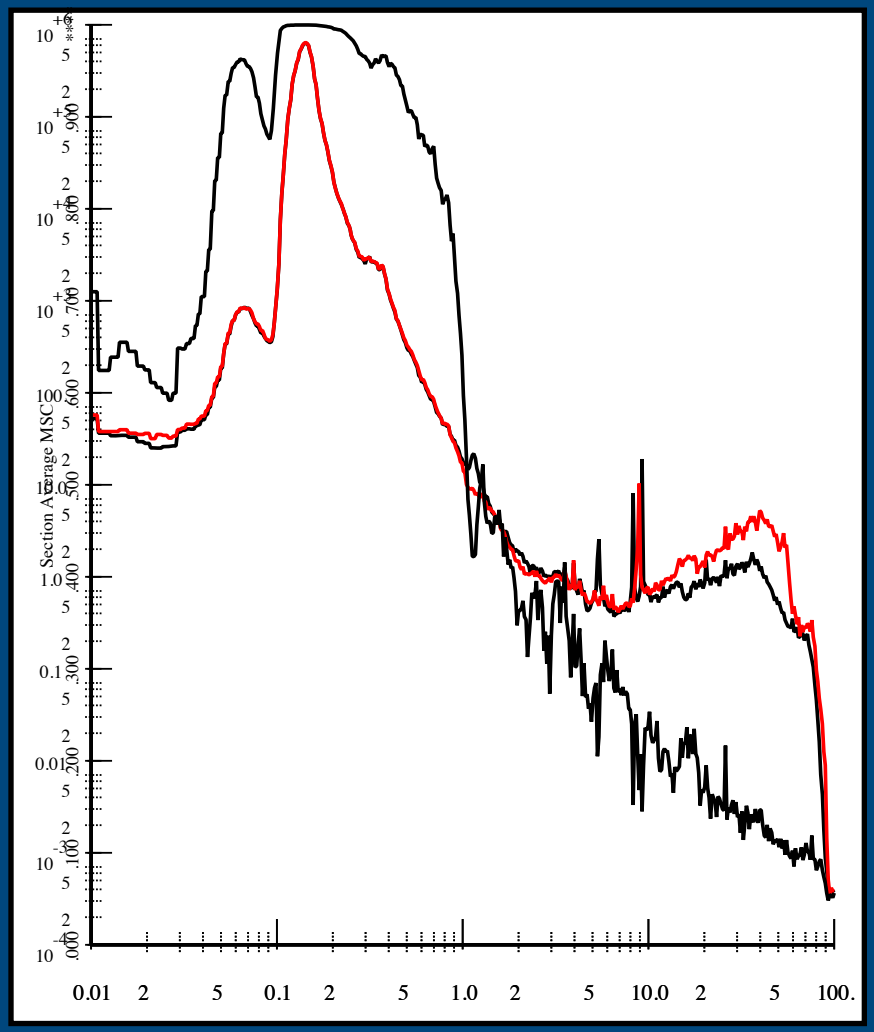
STS5 HHZ
BPH01-BPH02 65 Meter Separation

- multi taper spectra
  - 200 sps
  - 600 sec windows
  - 600 sec offset
  - 140 windows
  - 10 tapers
  - 6 NW (time bandwidth product)



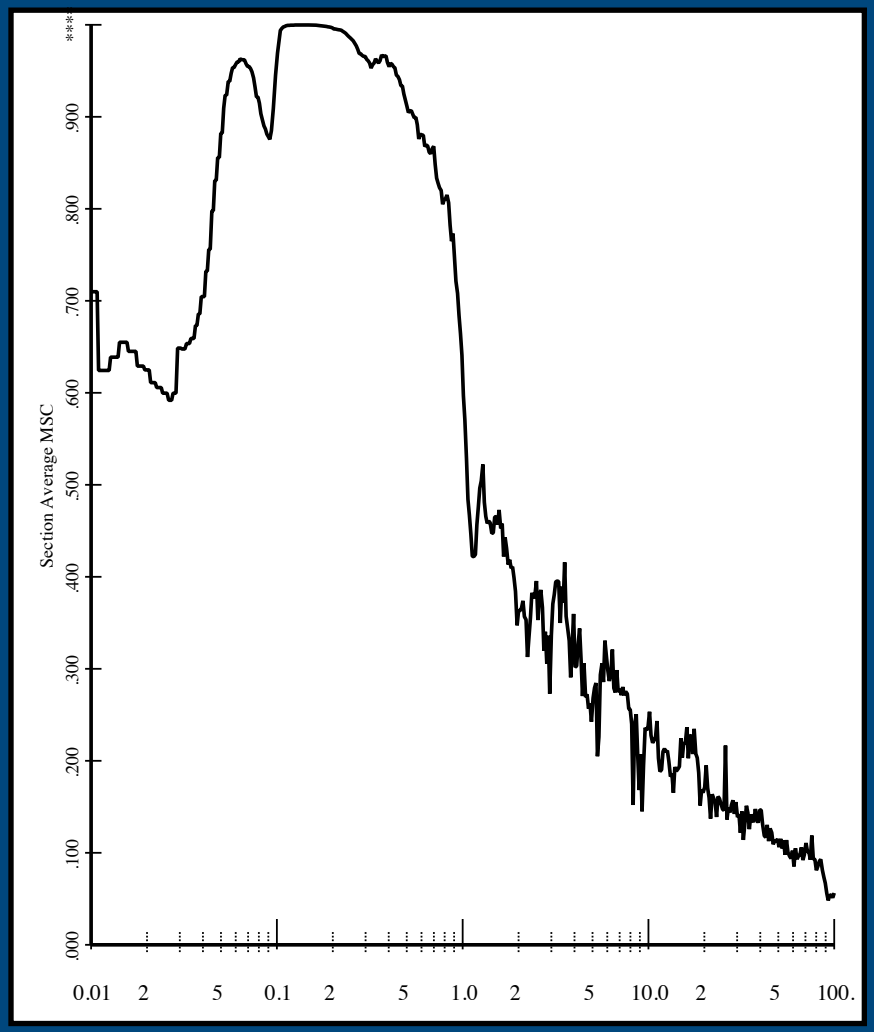
STS5 HHZ
BPH01-BPH02 65 Meter Separation

- multi taper spectra
  - 200 sps
  - 600 sec windows
  - 600 sec offset
  - 140 windows
  - 10 tapers
  - 6 NW (time bandwidth product)
- multi taper coherence



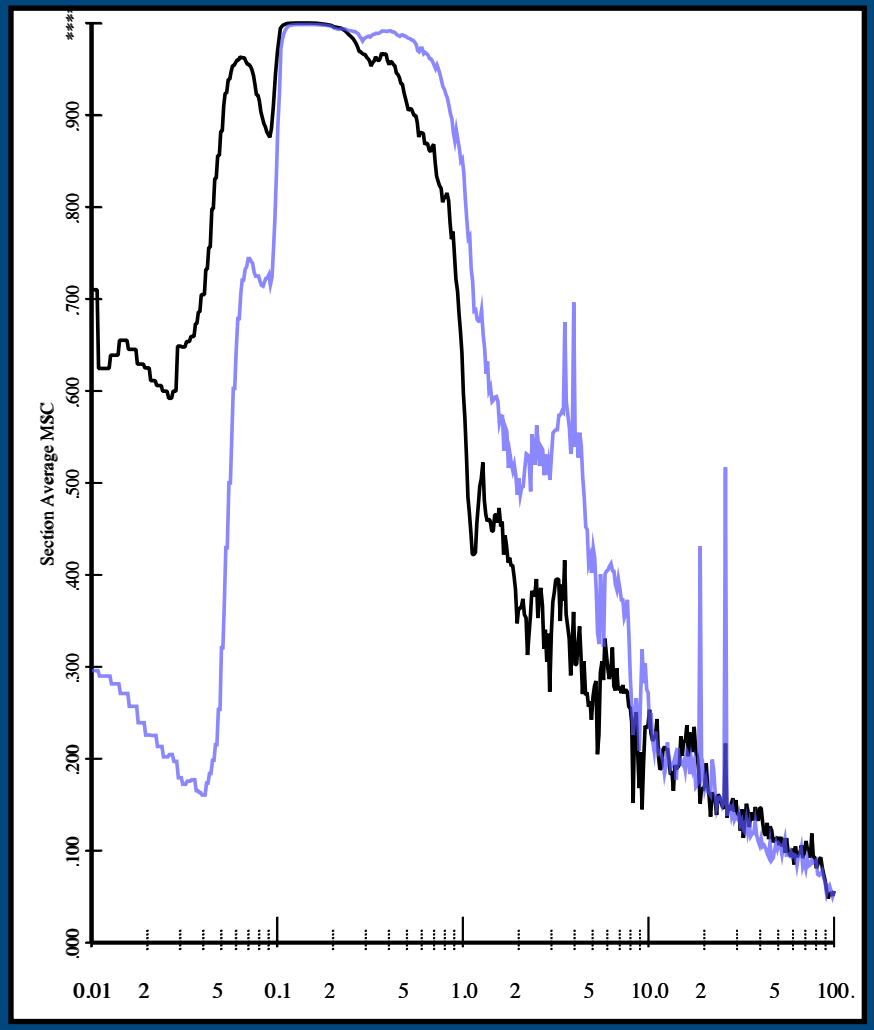
STS5 Coherence
BPH01-BPH02 65 Meter Separation

- HHZ MSC



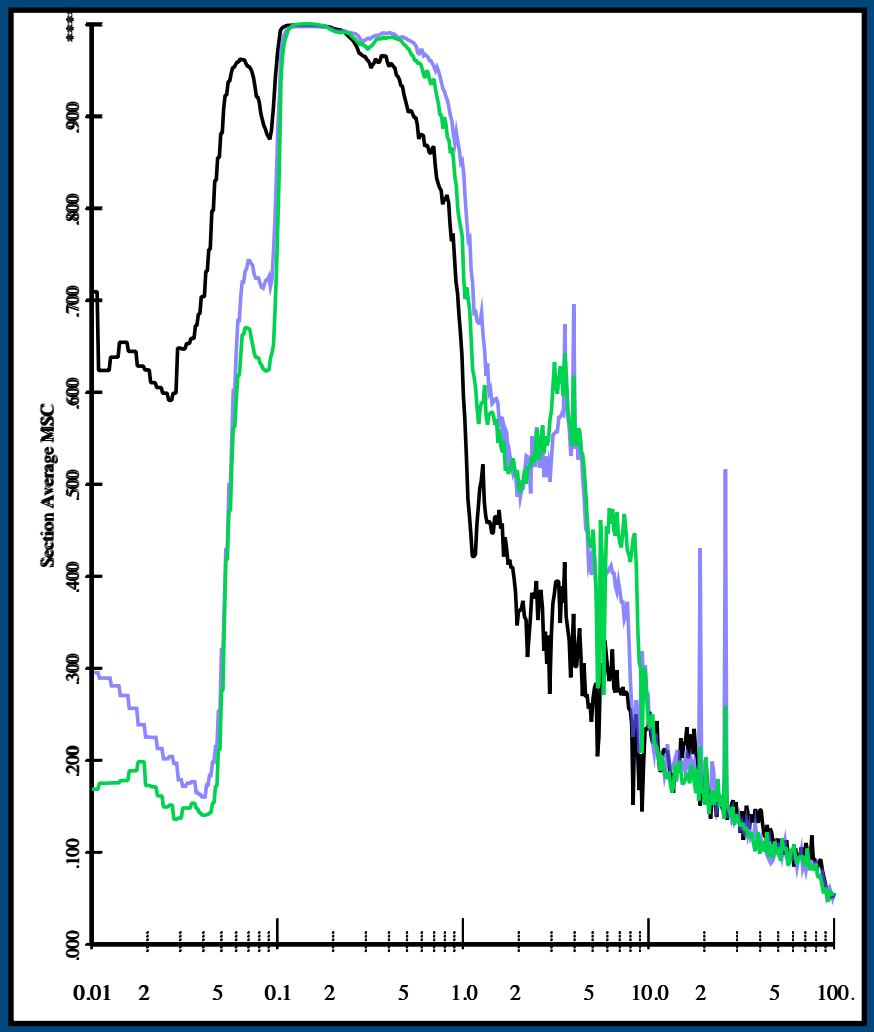
STS5 Coherence
BPH01-BPH02 65 Meter Separation

- HHZ MSC
- HHN MSC
  - << HHZ
    0.01 Hz to 0.1 Hz
  - > HHZ
    1 Hz to 10 Hz



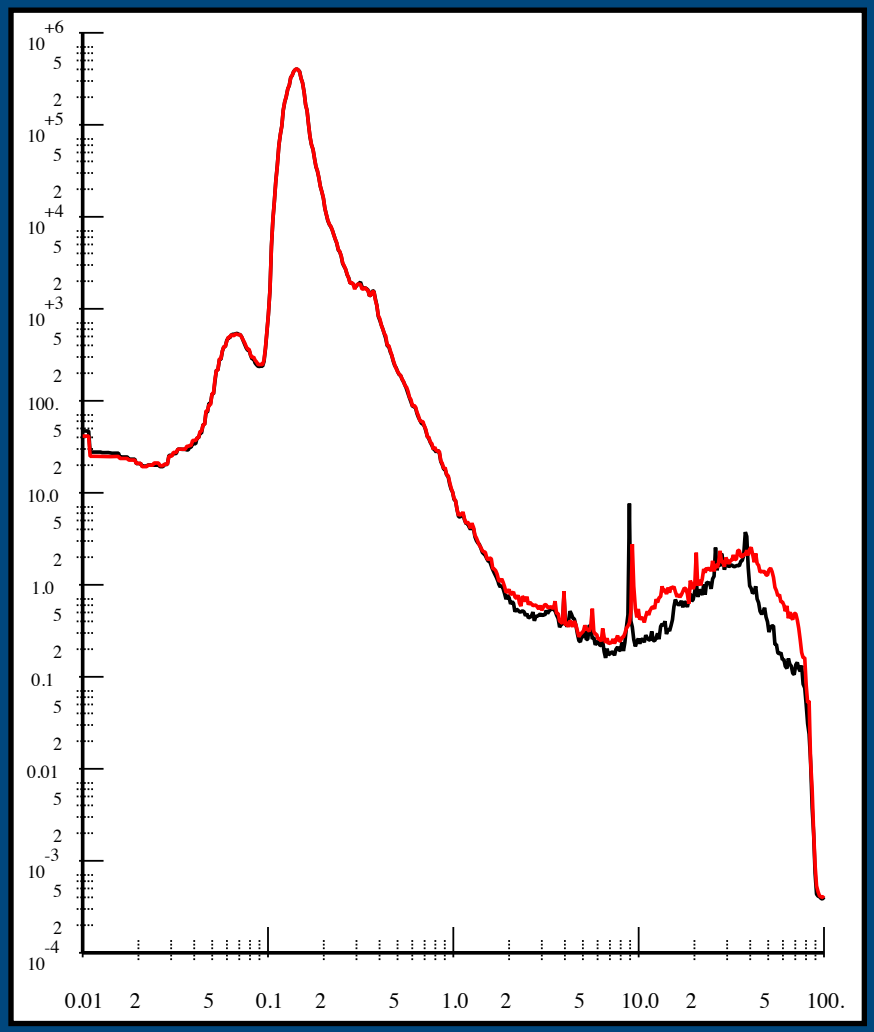
STS5 Coherence
BPH01-BPH02 65 Meter Separation

- HHZ MSC
- HHN MSC
  - << HHZ
    0.01 Hz to 0.1 Hz
  - > HHZ
    1 Hz to 10 Hz
- HHE MSC
  - Similar to HHN



Trillium 120 PH HHZ
BPH03-BPH04 65 Meter Separation

- multi taper spectra
  - 200 sps
  - 600 sec windows
  - 600 sec offset
  - 140 windows
  - 10 tapers
  - 6 NW
- multi taper coherence



Trillium 120 PH HHZ
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- multi taper spectra
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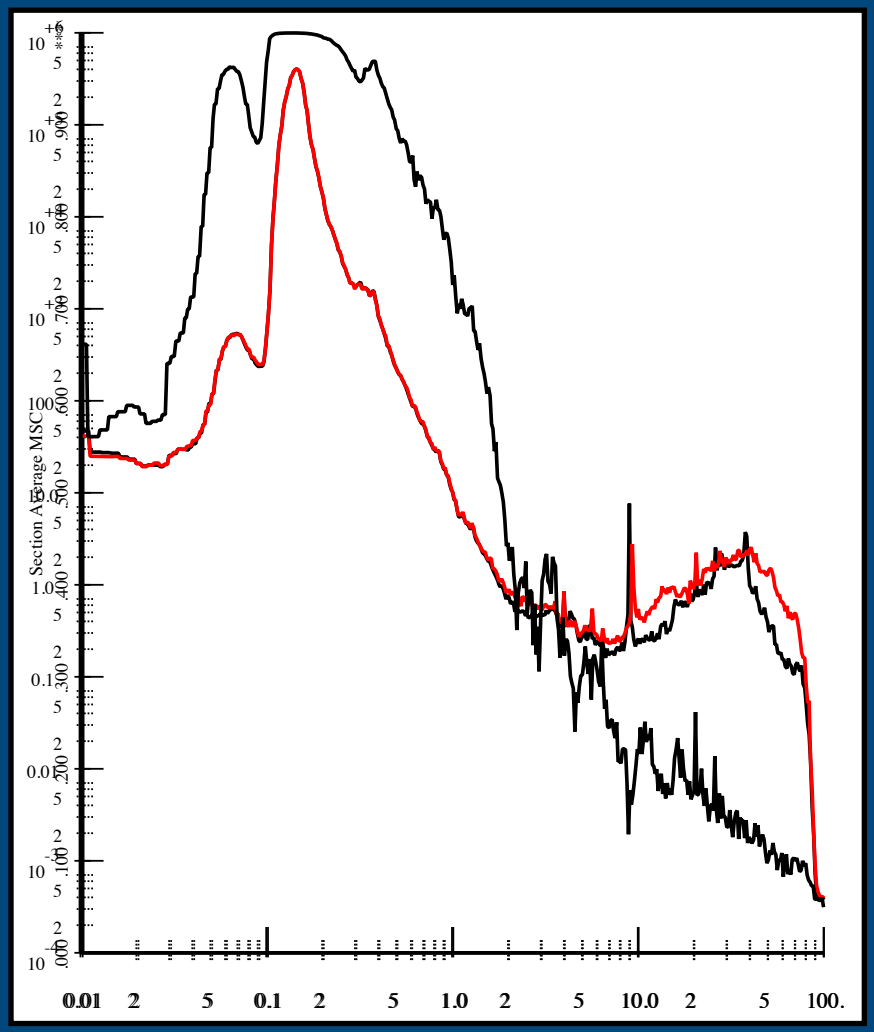
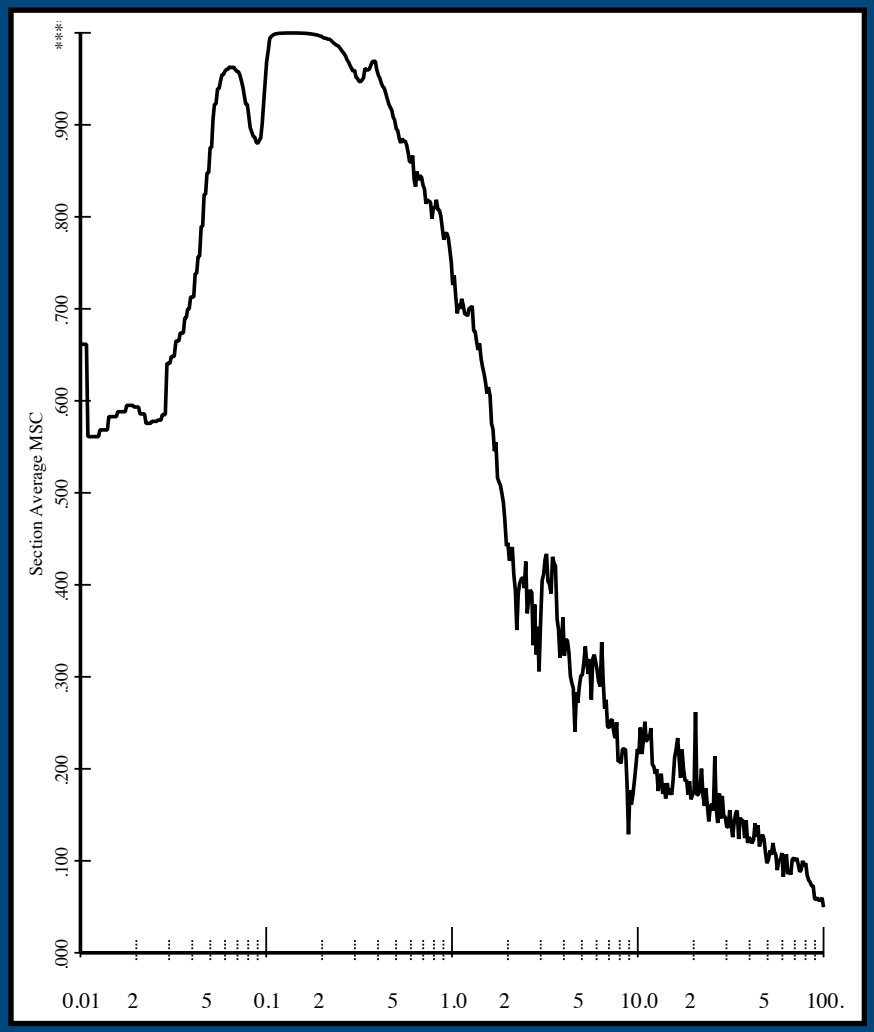


Trillium 120 PH Coherence
BPH03-BPH04 65 Meter Separation

- HHZ MSC
- HHN MSC
  - << HHZ
    0.01 Hz to 0.1 Hz
  - > HHZ
    1 Hz to 10 Hz
- HHE MSC
  - Similar to HHN



Trillium 120 PH Coherence
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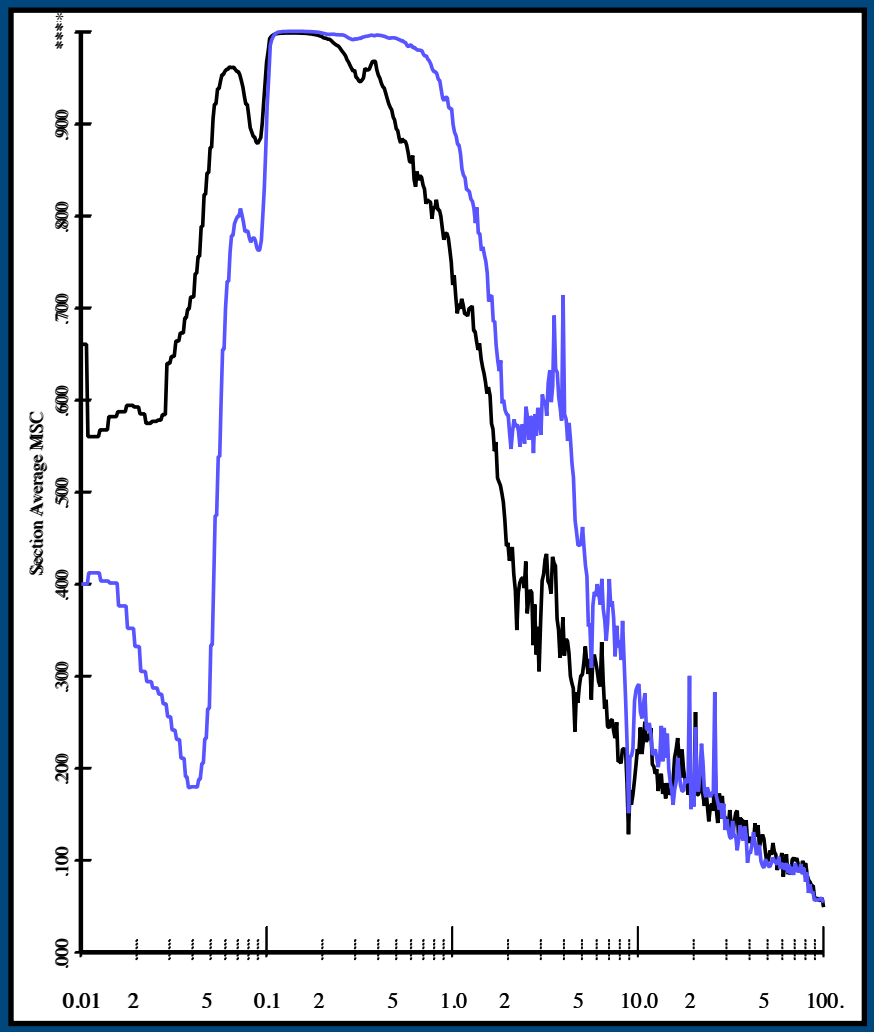

Trillium 120 PH Coherence
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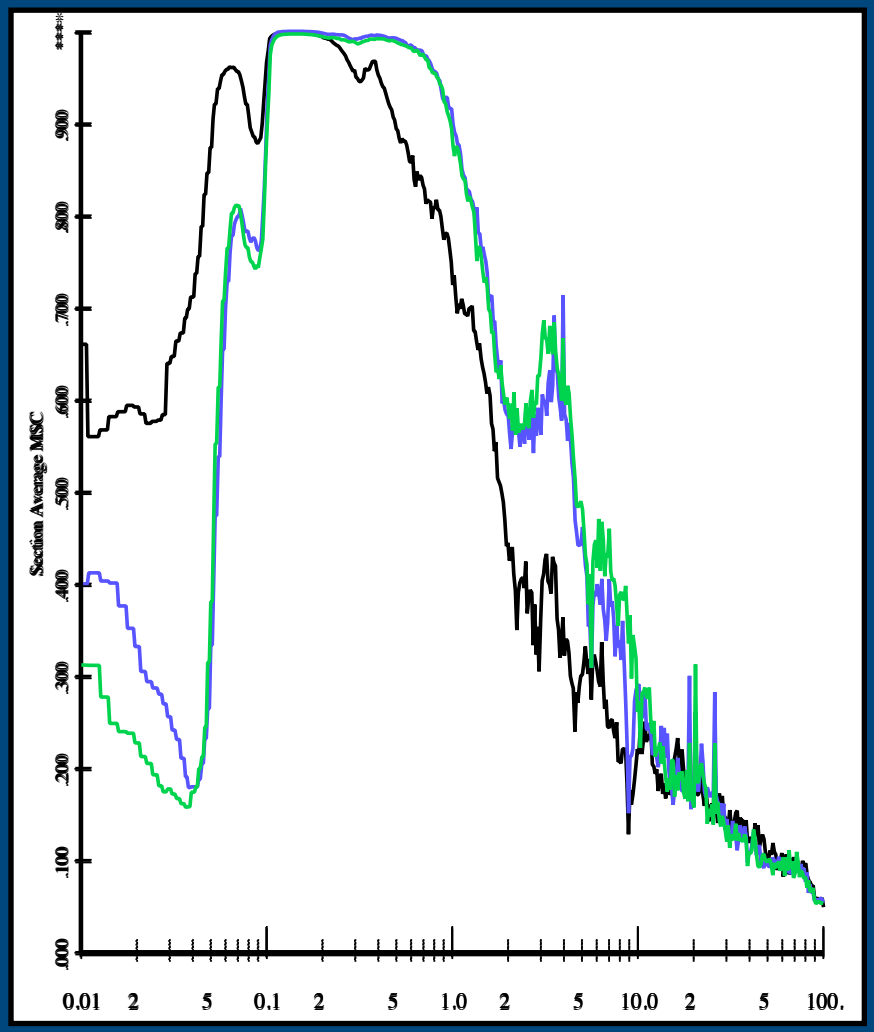
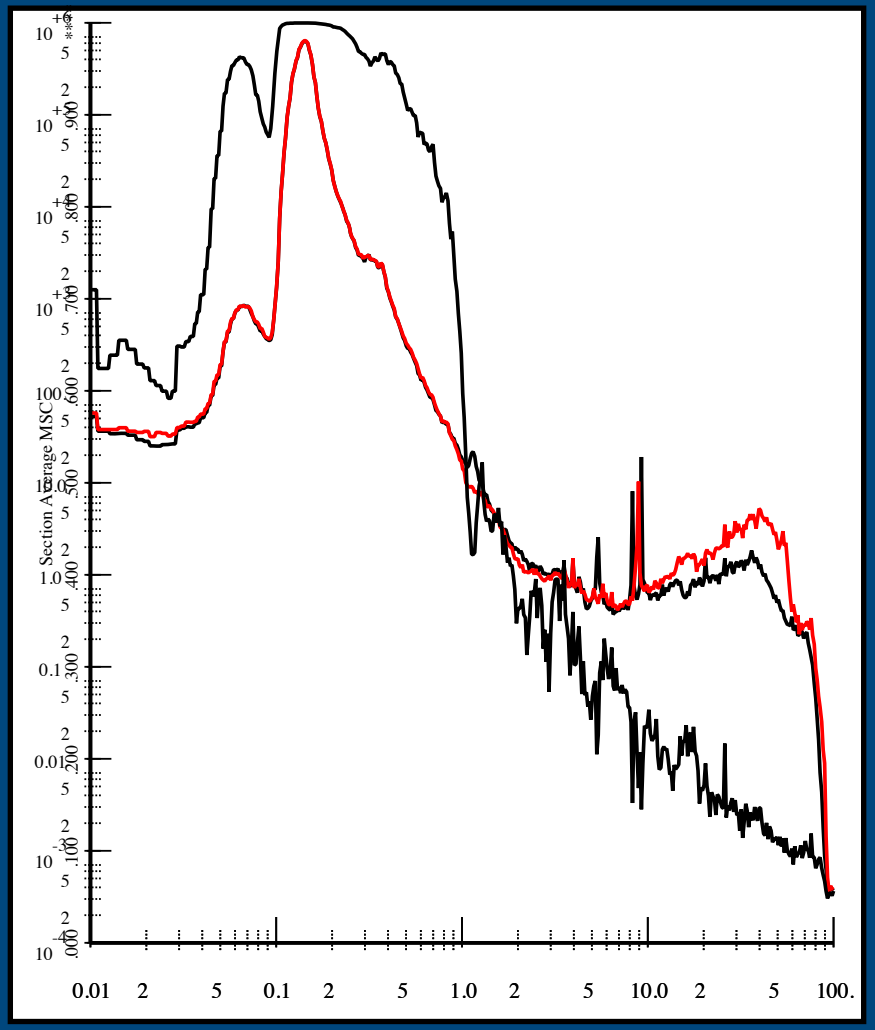
  - << HHZ
    0.01 Hz to 0.1 Hz
  - > HHZ
    1 Hz to 10 Hz
- HHE MSC
  - Similar to HHN

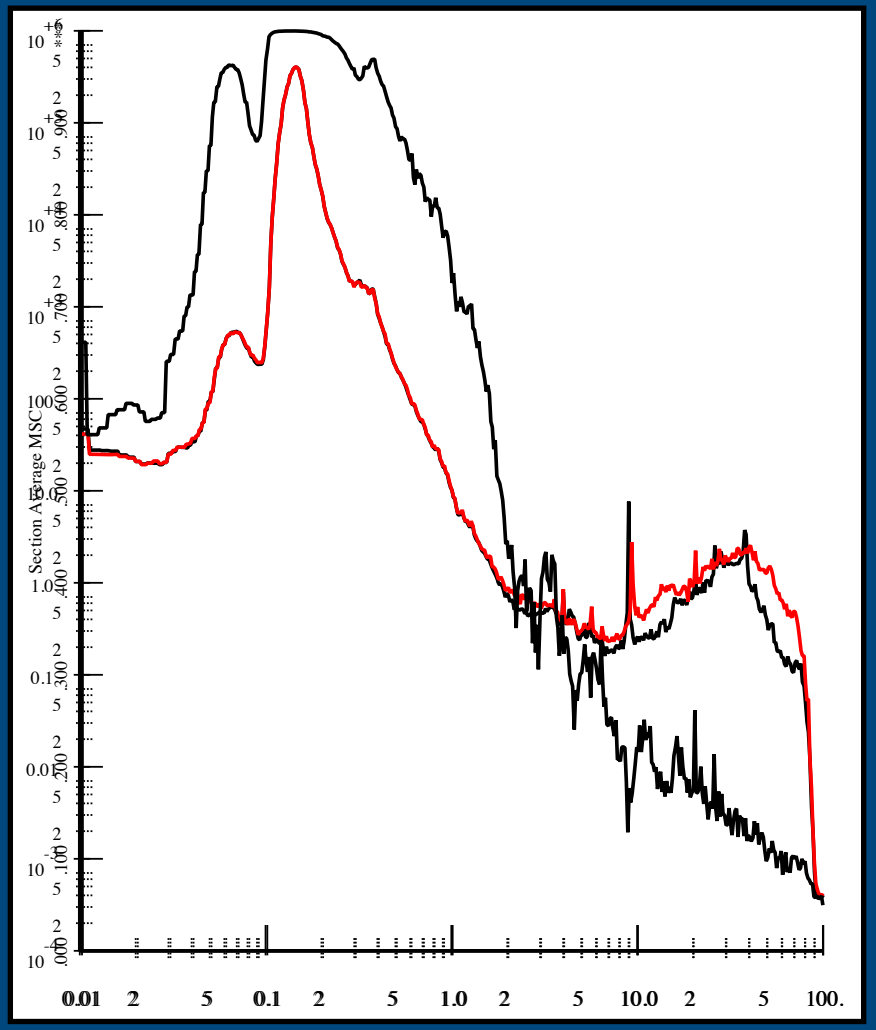


HHZ 65 Meter Separation

BPH01-BPH02 STS5

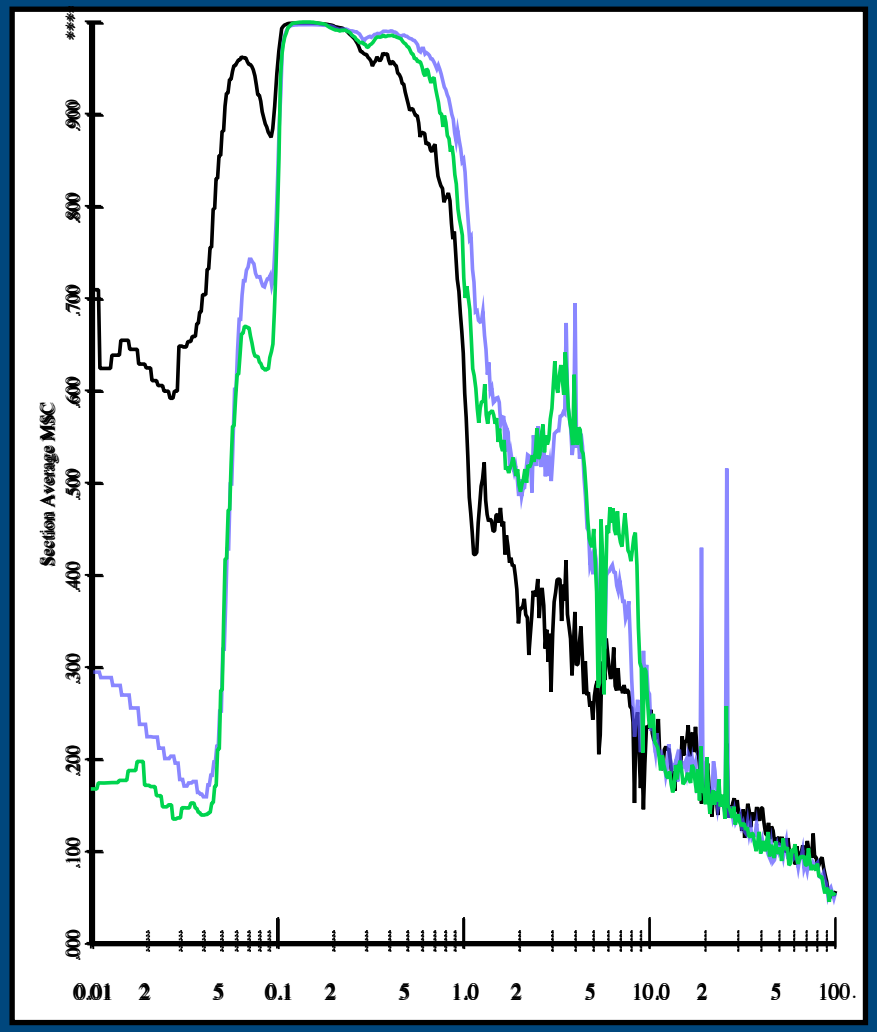


BPH03-BPH04 Trillium 120 PH

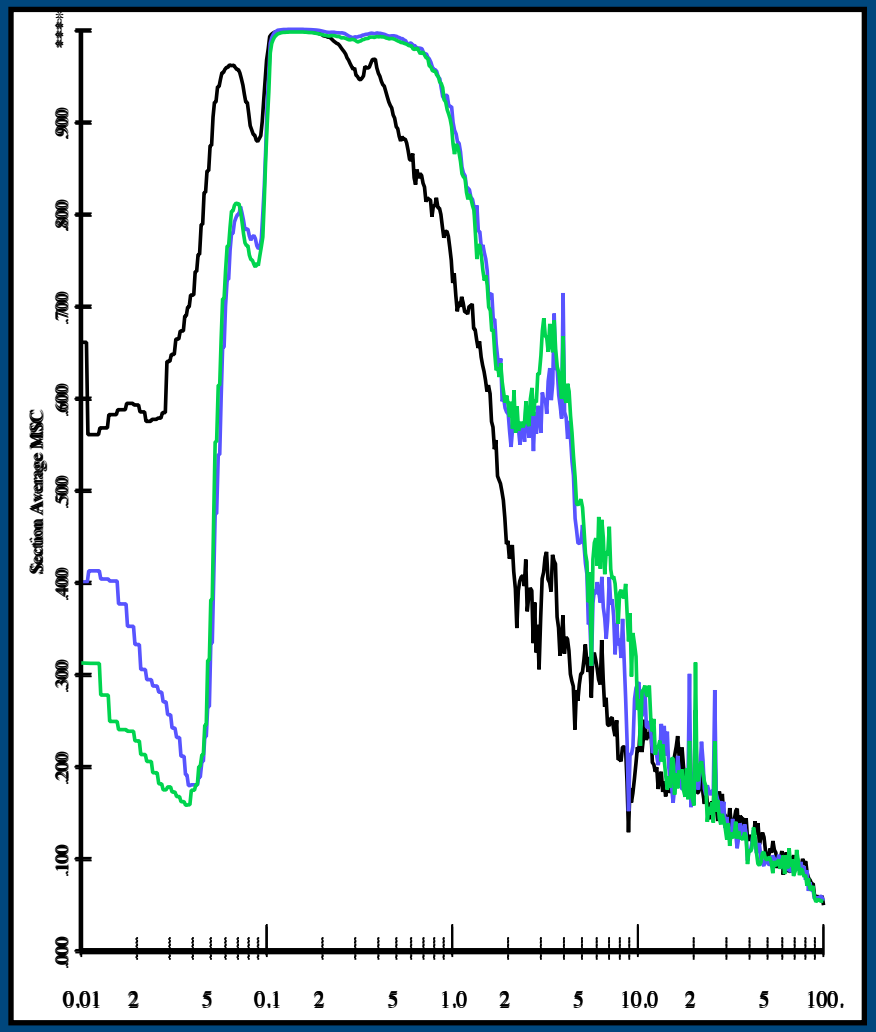


MSC 65 Meter Separation

BPH01-BPH02 STS5

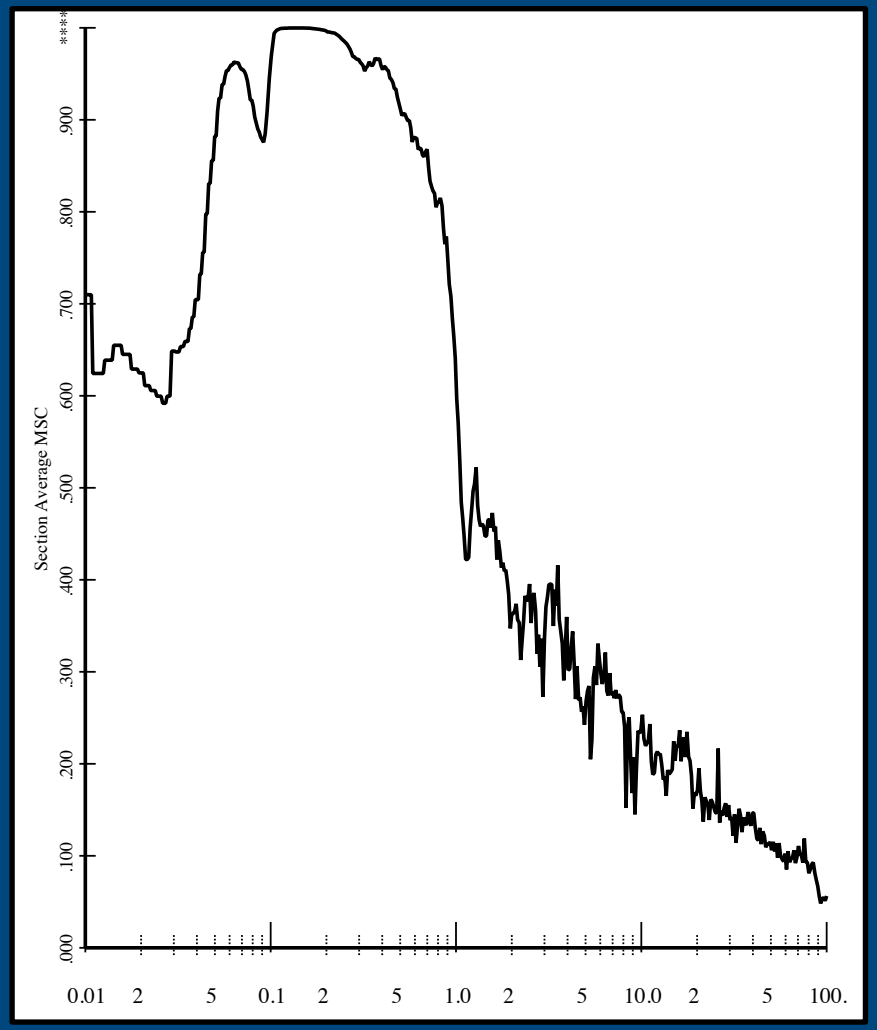


BPH03-BPH04 Trillium 120 PH

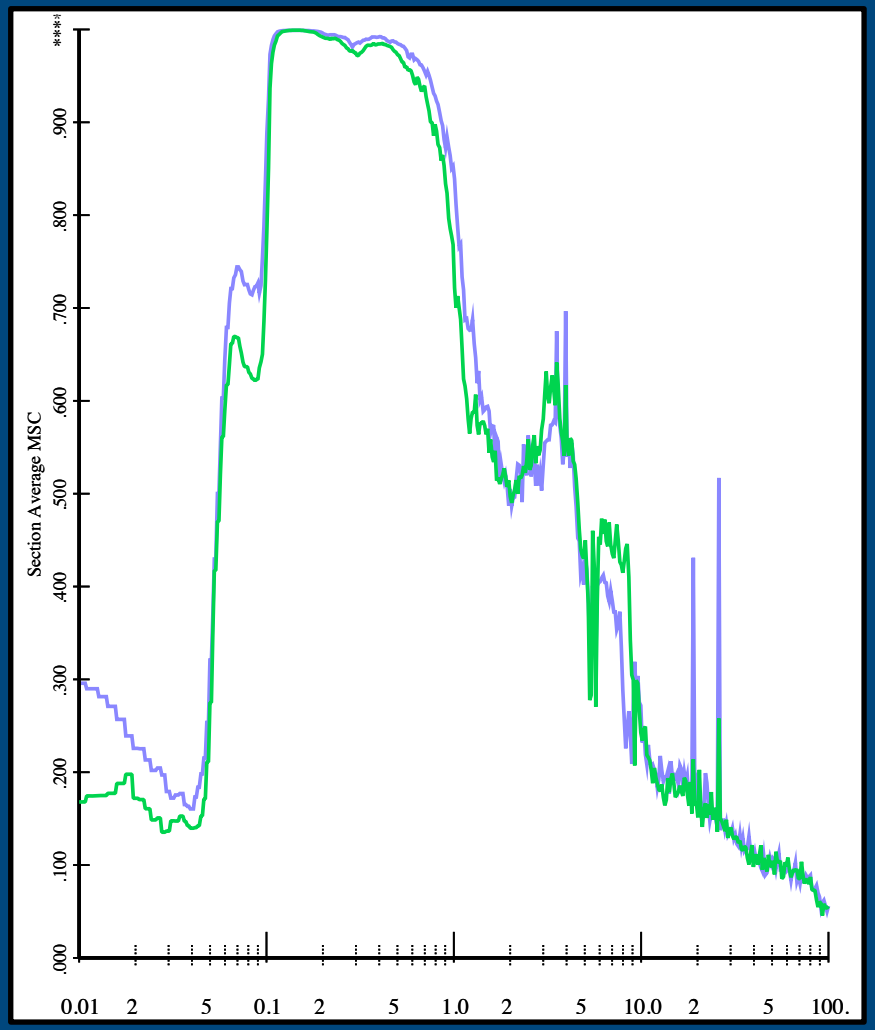


STS5 Coherence - 65 meters vs 870 meters

BHZ

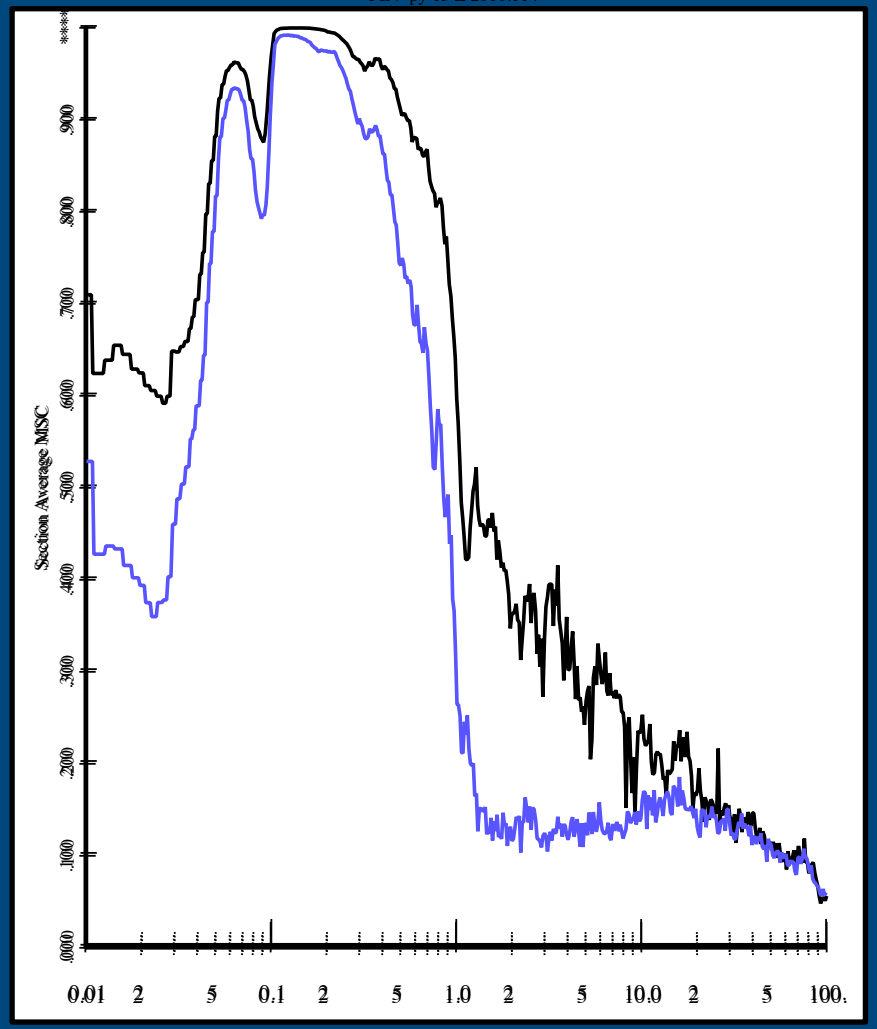


BHN BHE

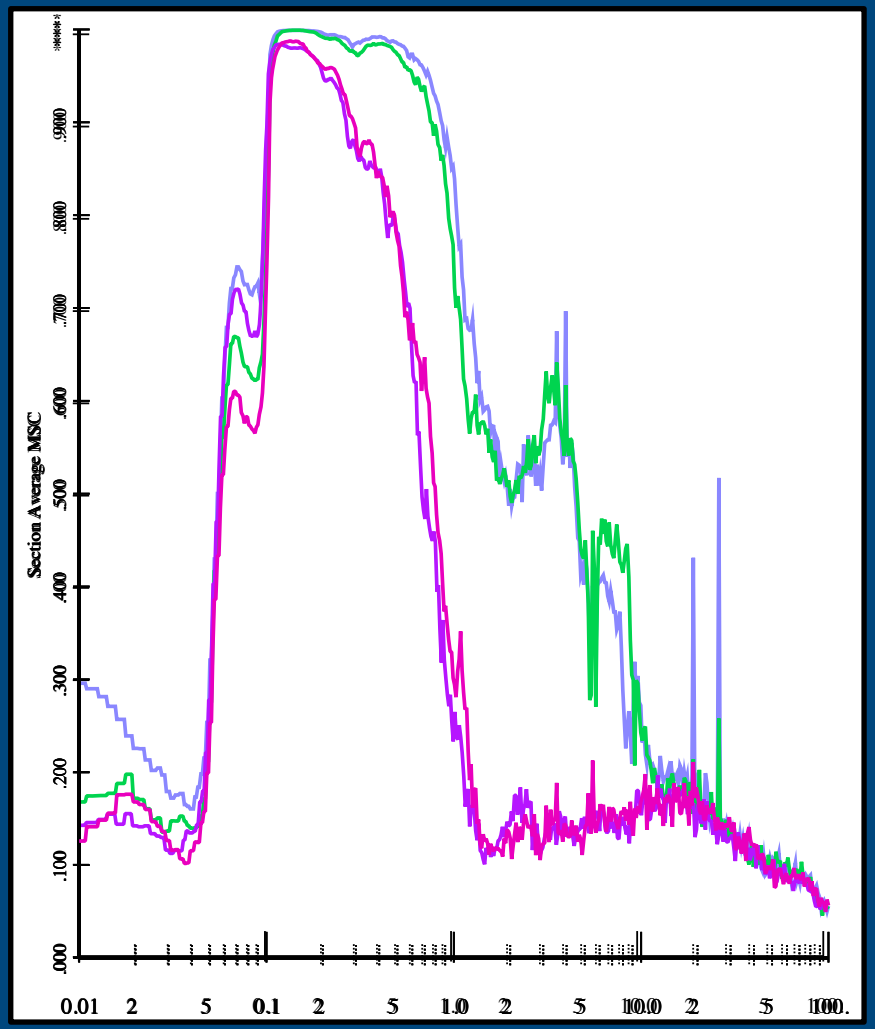


STS5 Coherence - 65 meters vs 870 meters

BHZ

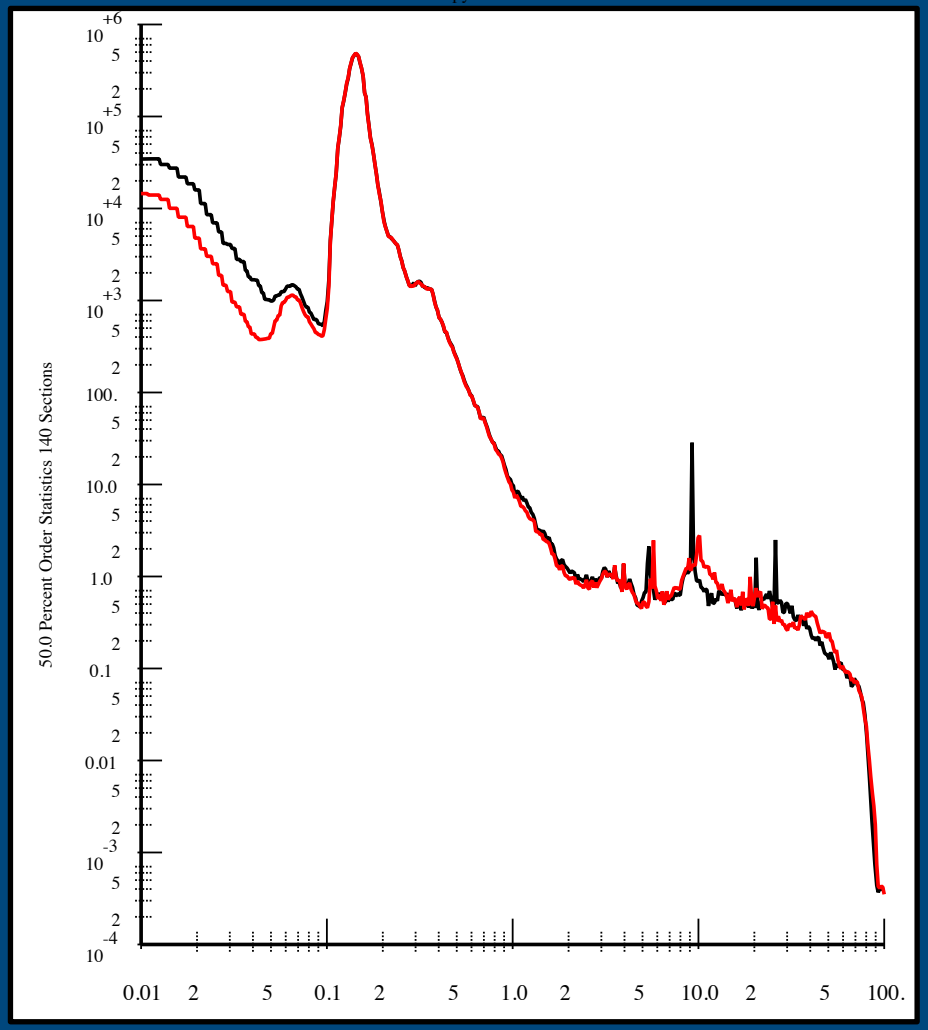


BHN BHE

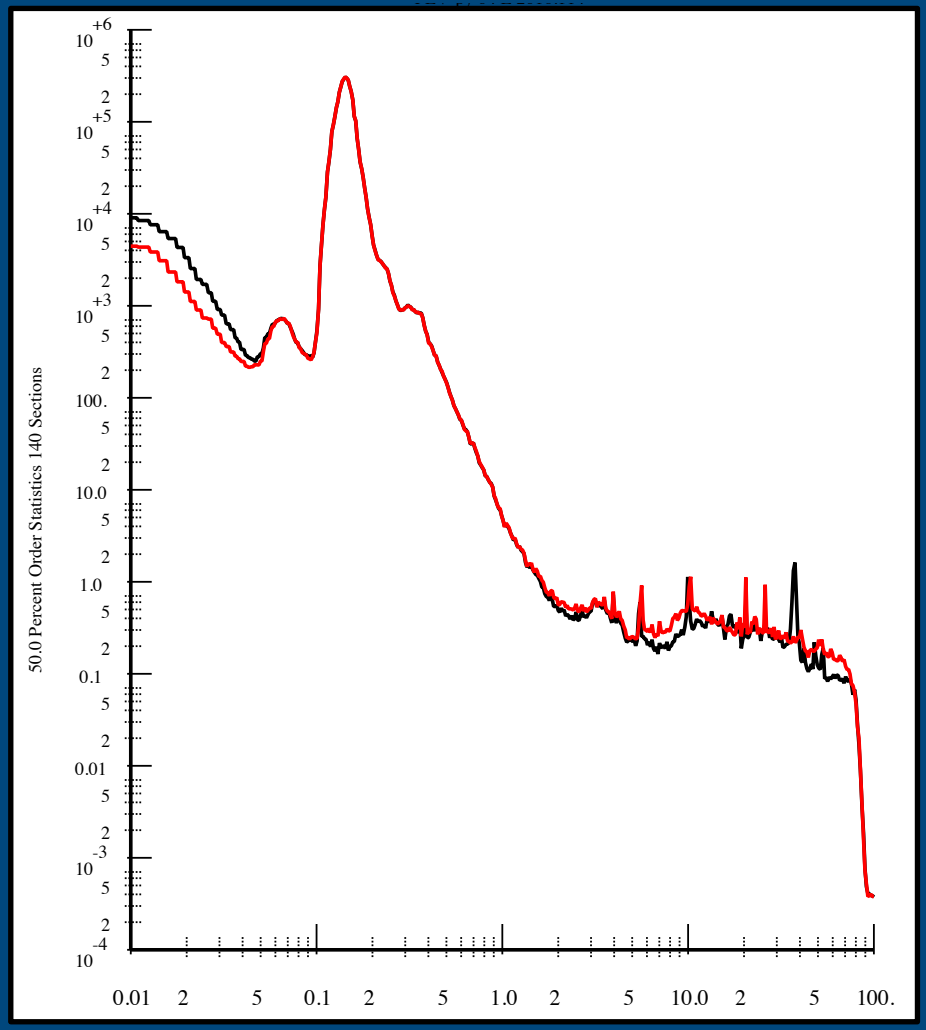


Potential Horizontal Response Issues

BPH01-BPH02 STS5

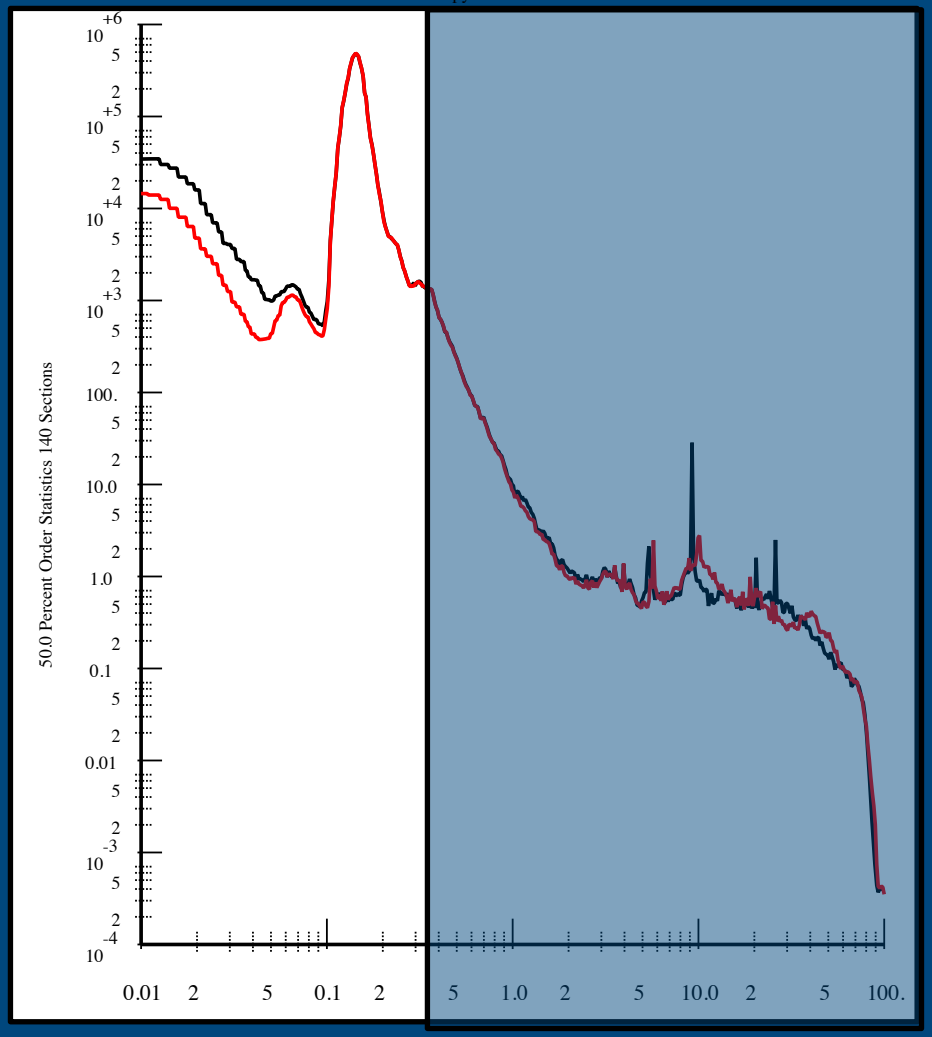


BPH03-BPH04 Trillium 120 PH

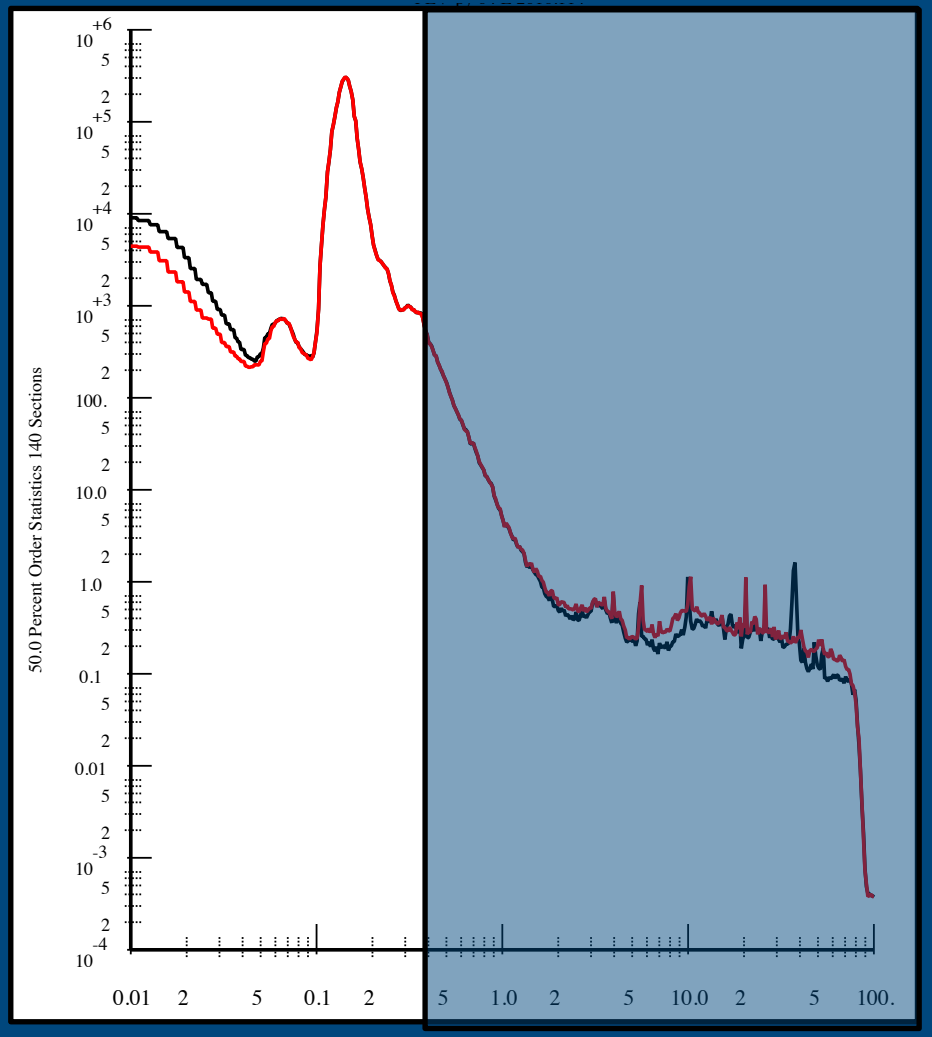


Potential Horizontal Response Issues

BPH01-BPH02 STS5

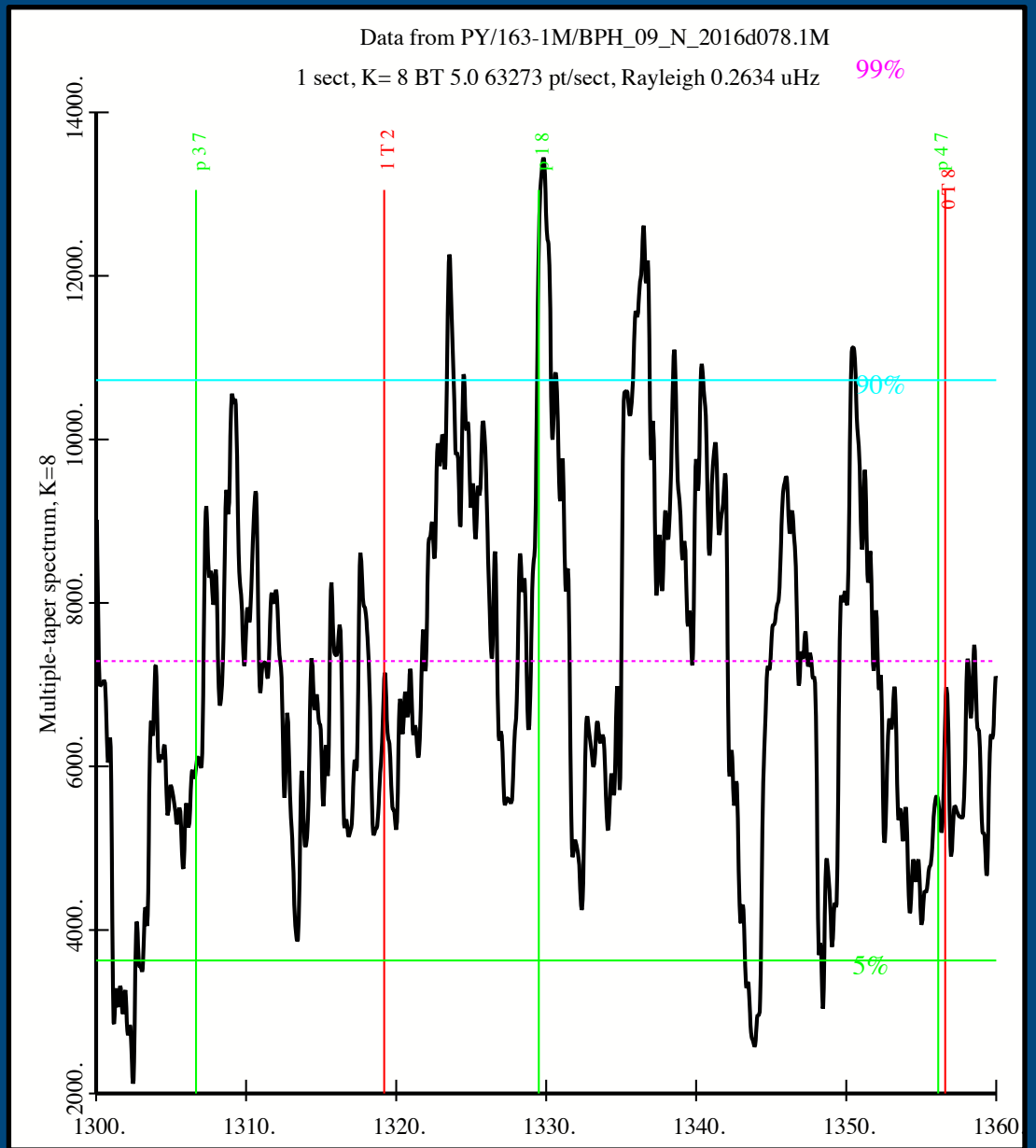


BPH03-BPH04 Trillium 120 PH

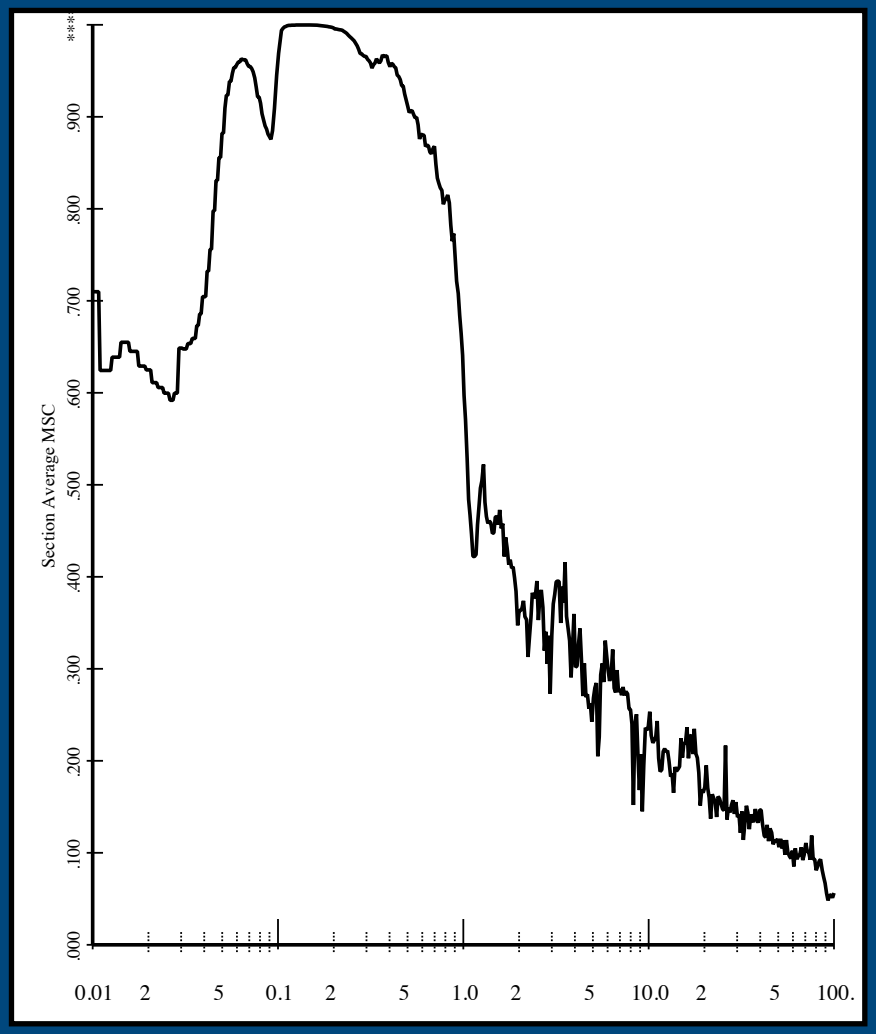


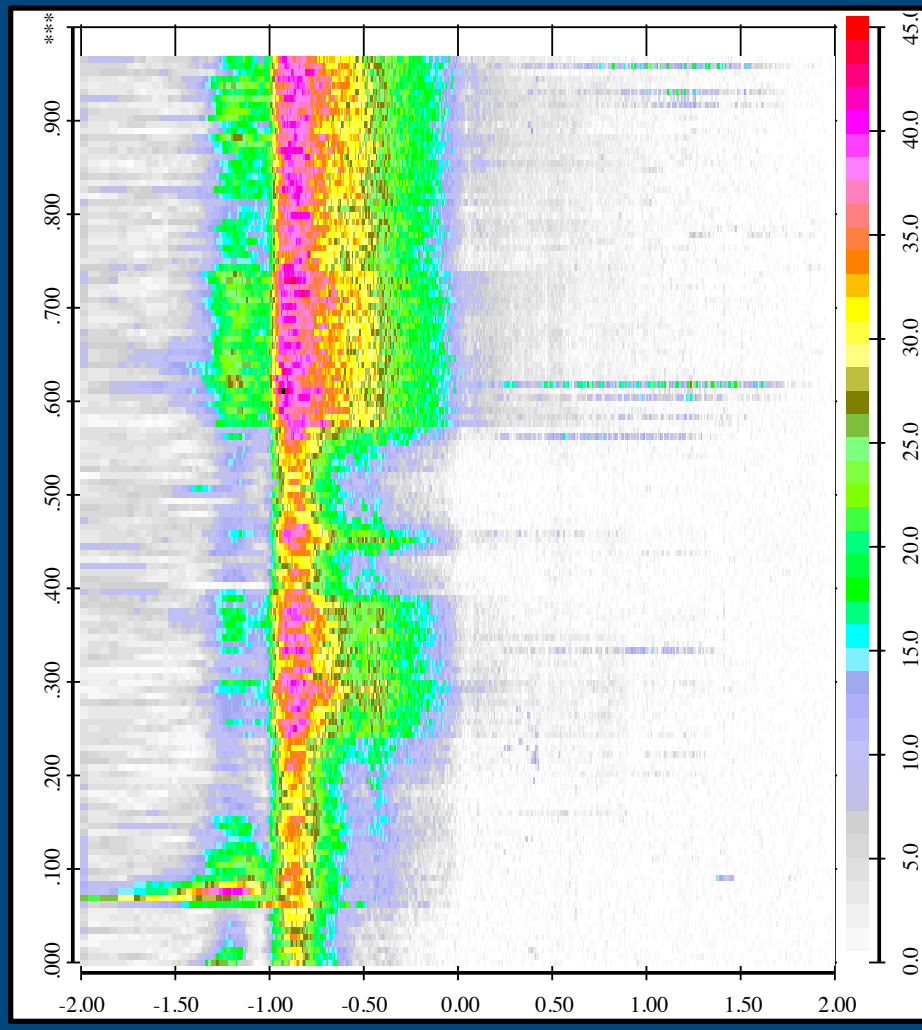
Signatures of Solar modes in BPH09 N Spectra

- Solar Mode Refs
- 2007 PIEEE07 Thomson et al
- 2015 GJI Thomson and Vernon
- 2016 IEEE Thomson and Vernon

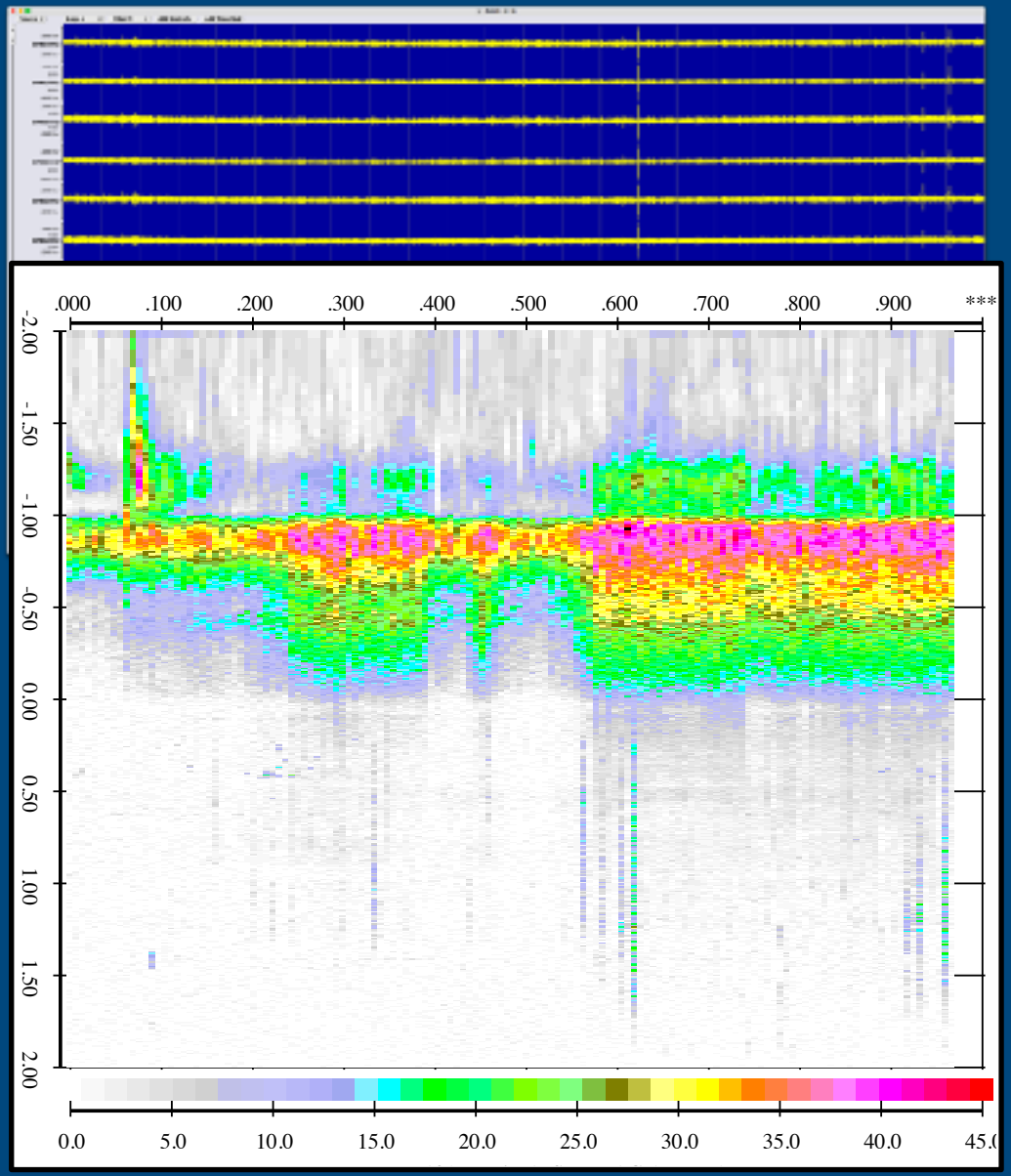


STS5 HHZ
BPH01-BPH02 "Coherogram"





“Coherogram”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.100
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.400
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.700
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.900
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-1.50
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-0.50
0.00
0.50
1.00
1.50
2.00
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5.0
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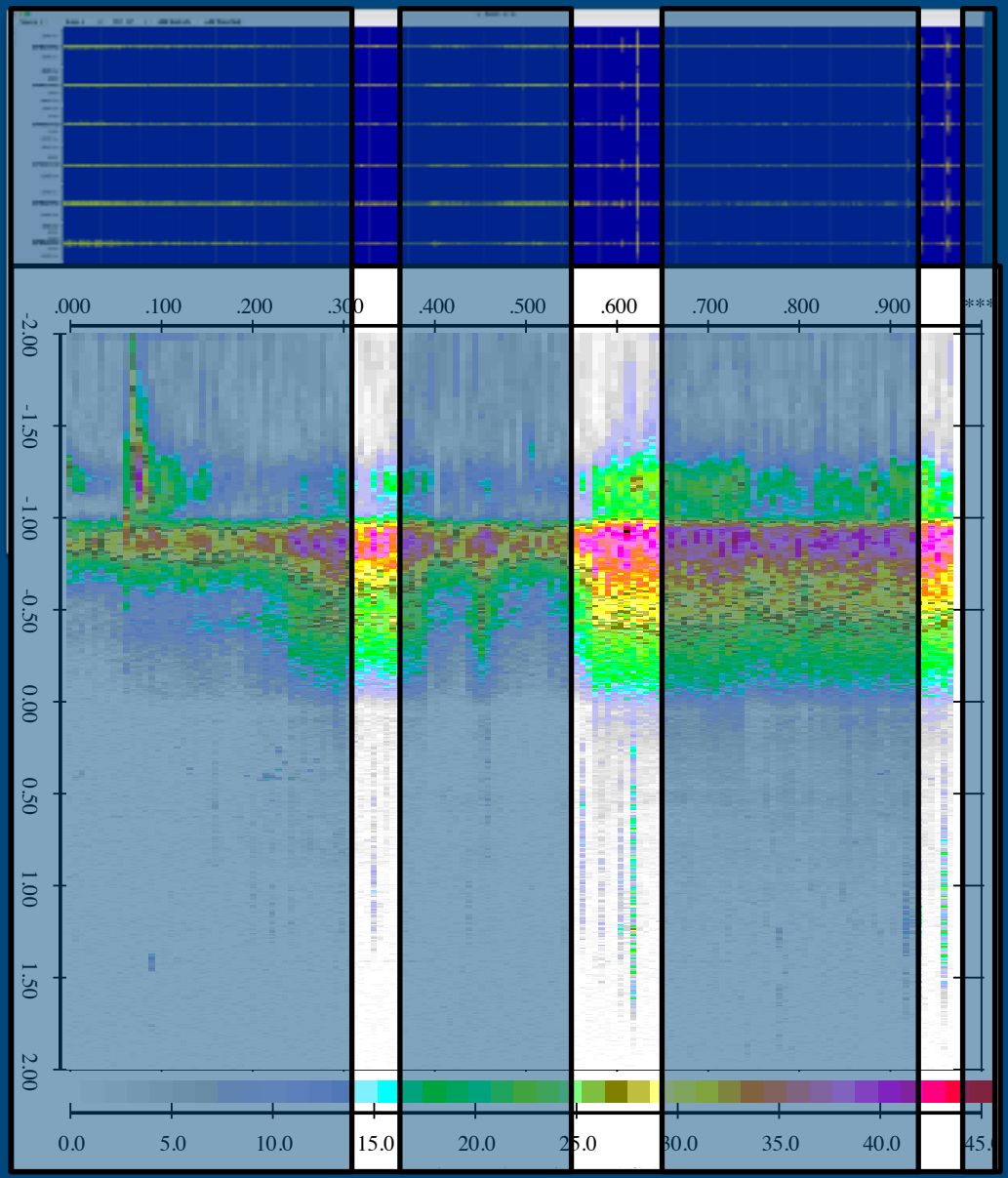
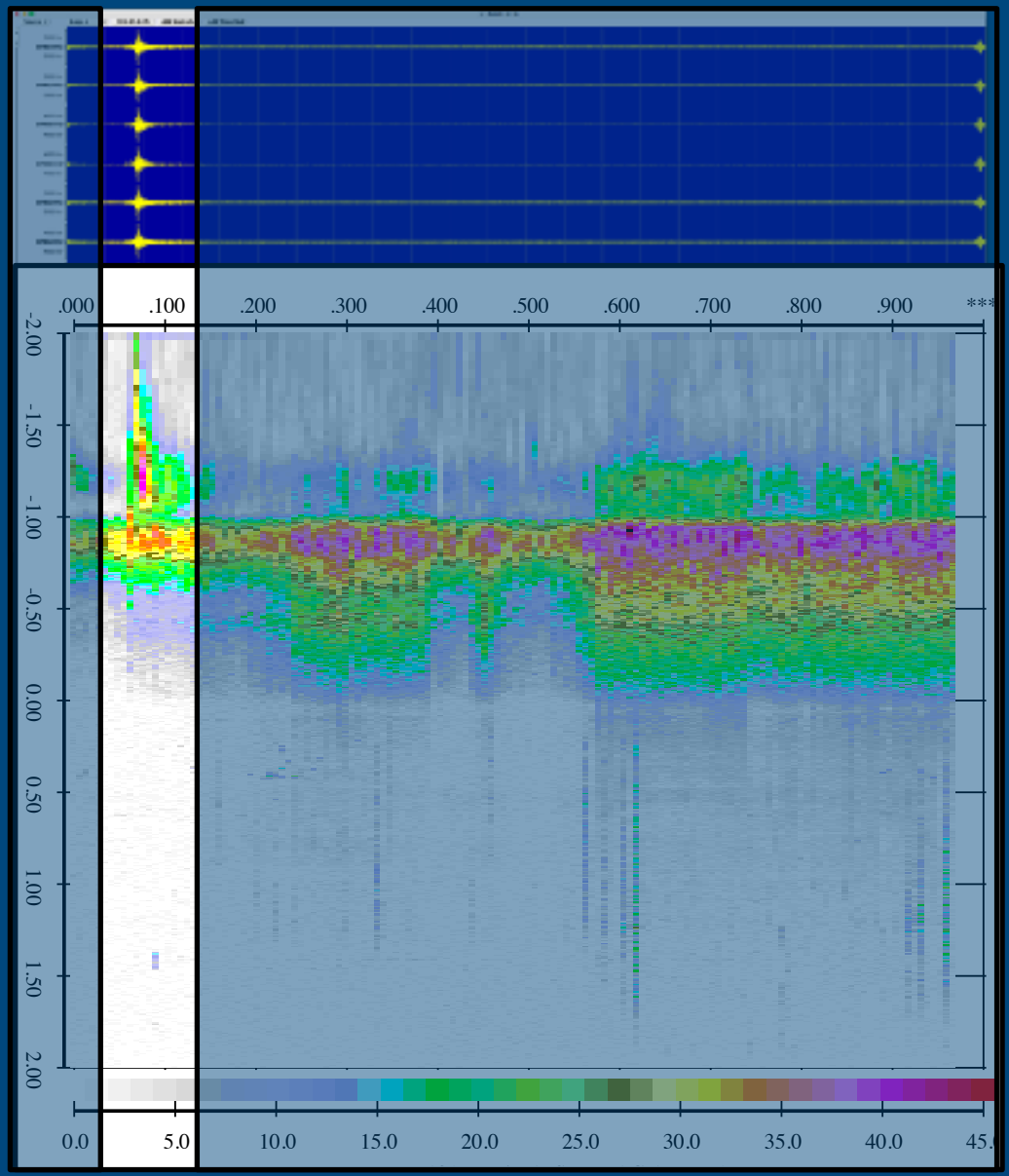
15.0
20.0
25.0
30.0
35.0
40.0

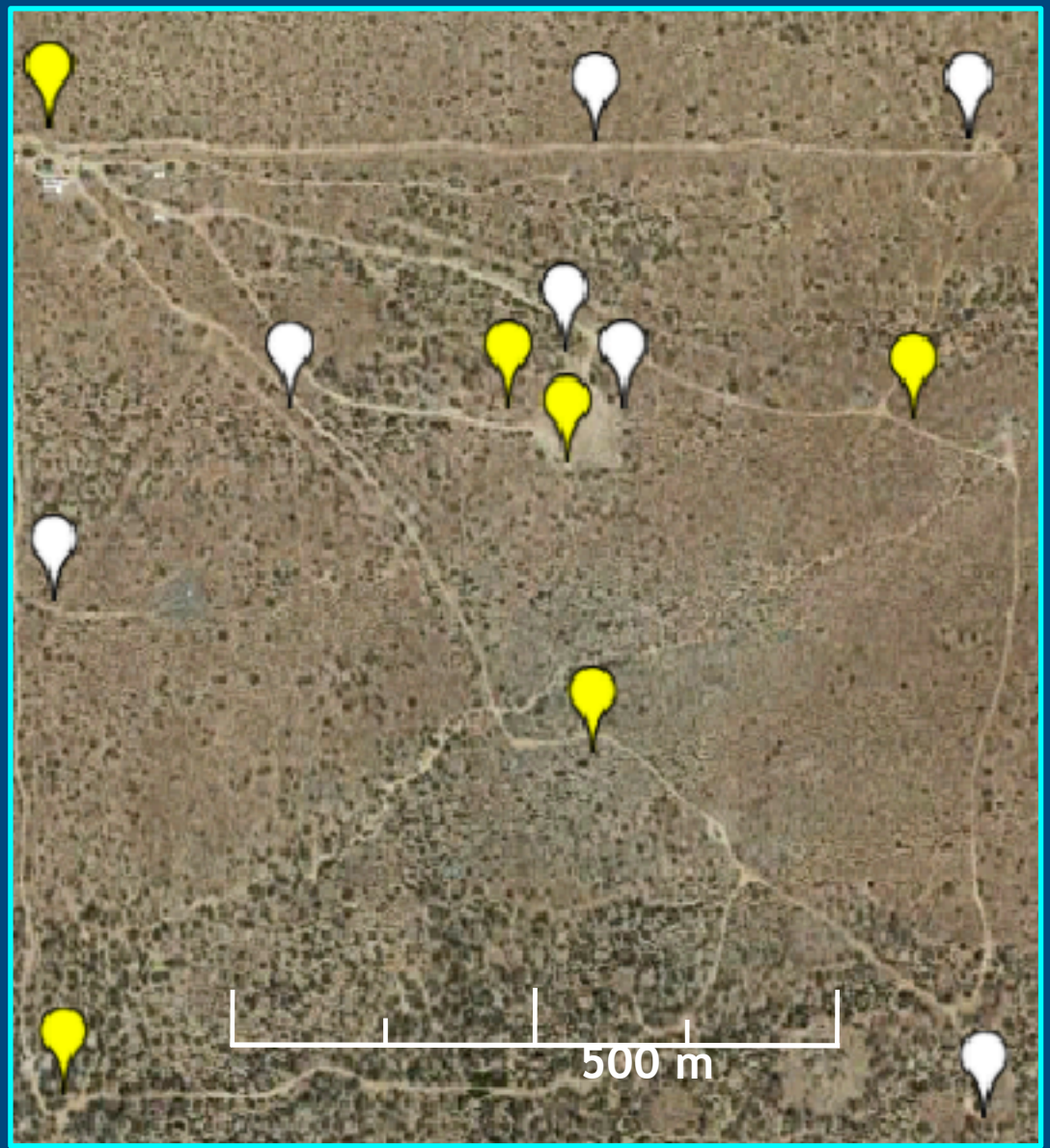
Coherogram Local Events



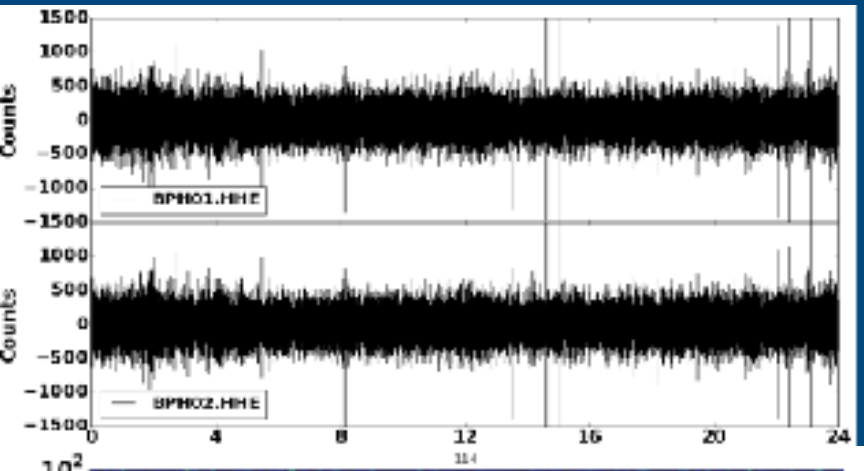
Coherogram Teleseismic Event

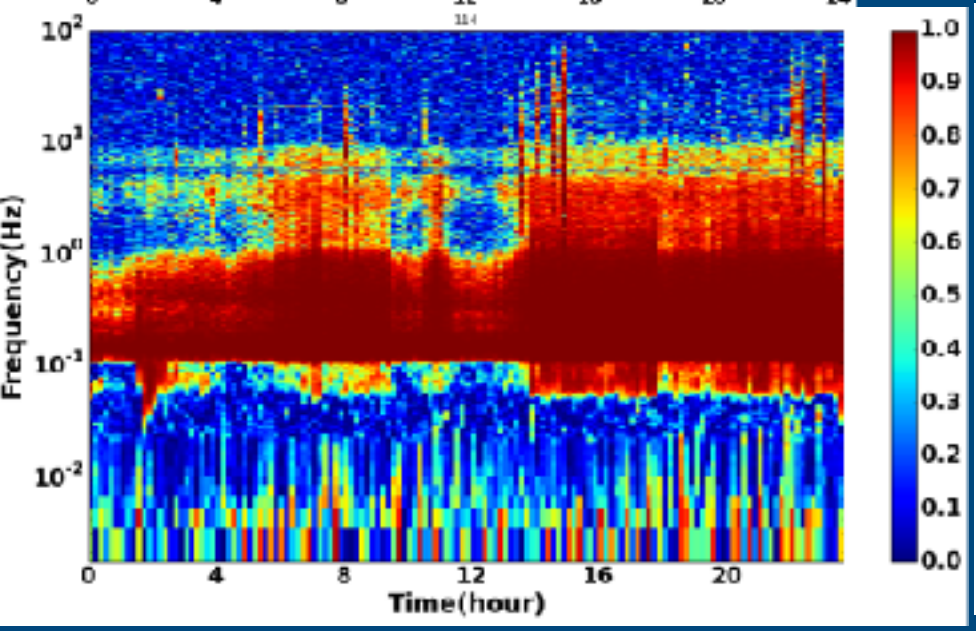


PY STS-5, Trillium 120BH

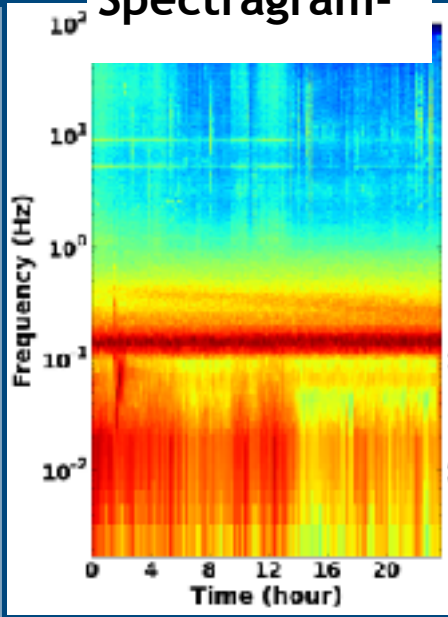


2016 114 Cohero and Spectragrams

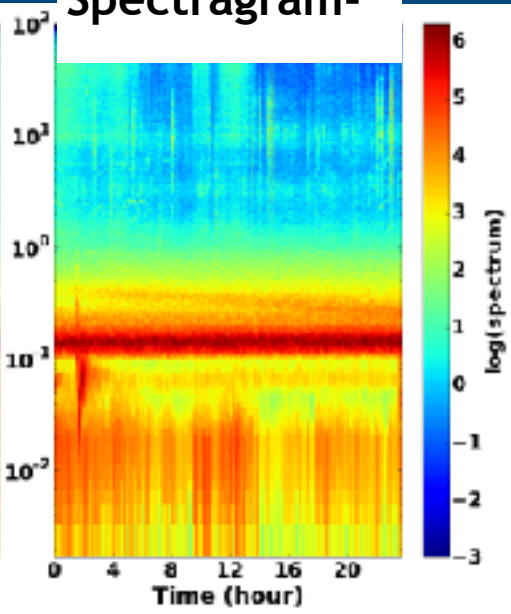




Spectragram-

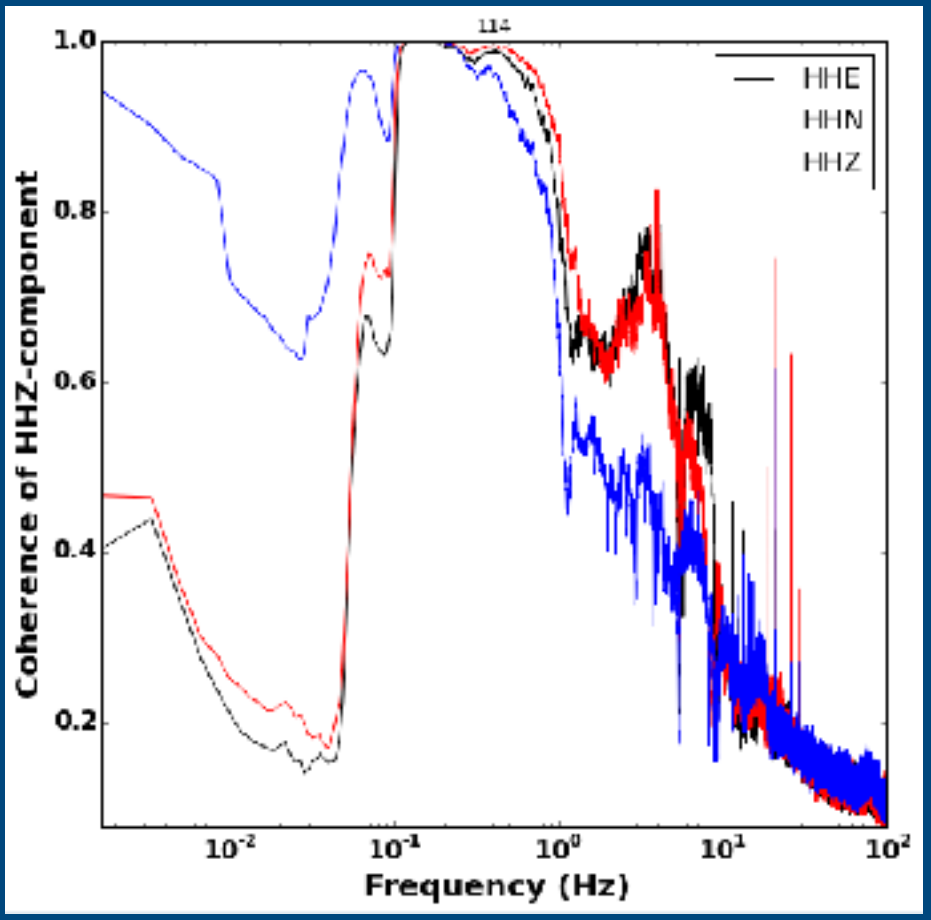


Spectragram-

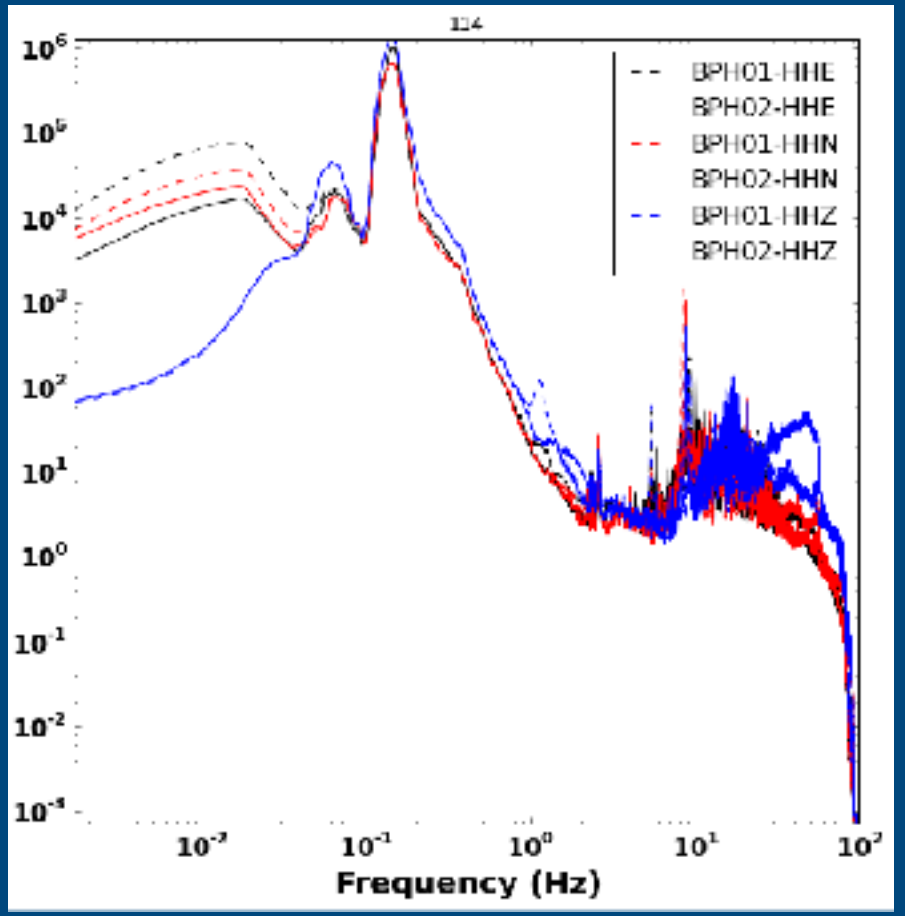


2016 114 Coherence and Spectra

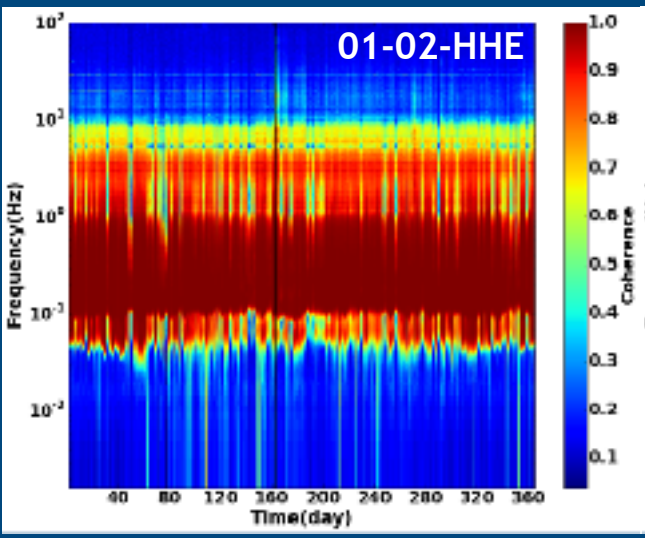
One-day average coherence

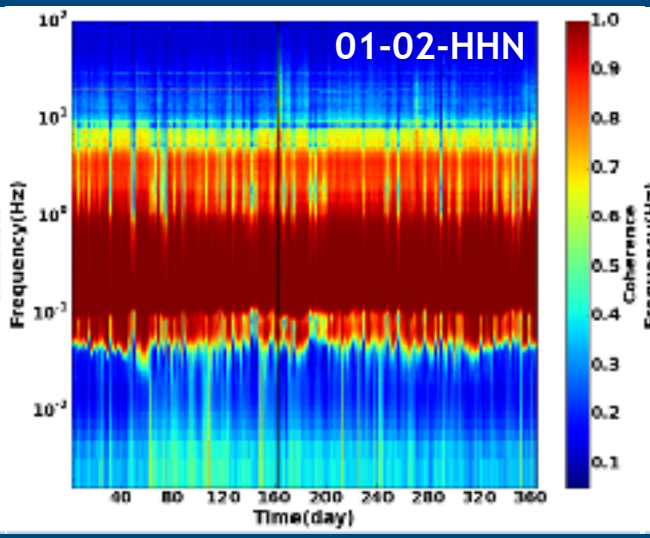


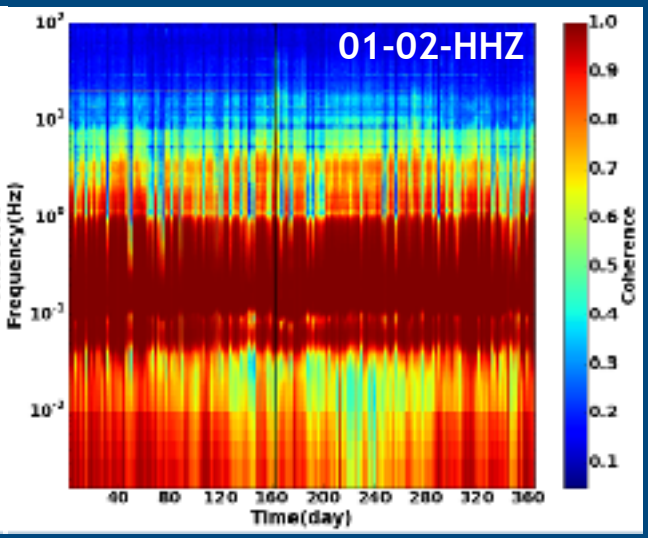
One-day average spectra

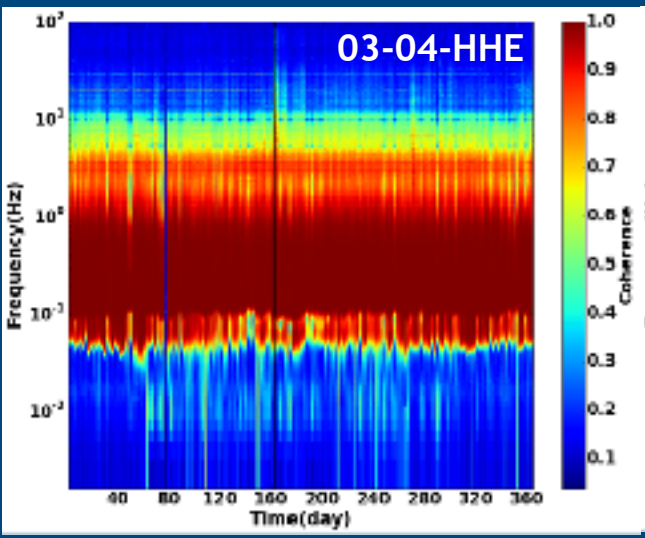


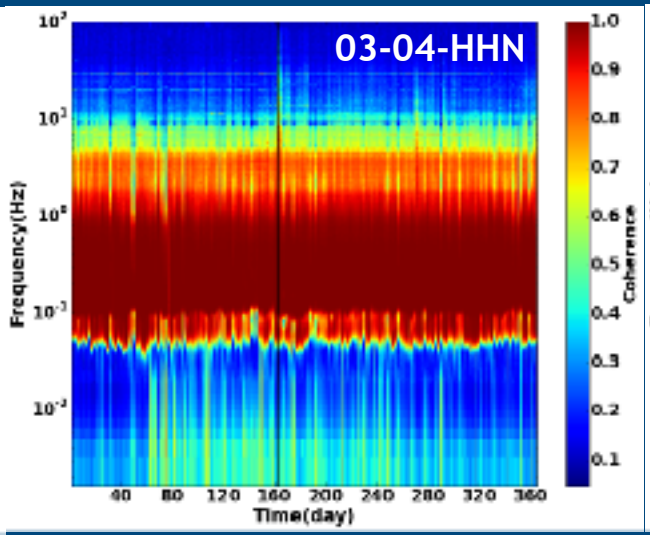
2016 Year Long 65 meter Coherogram

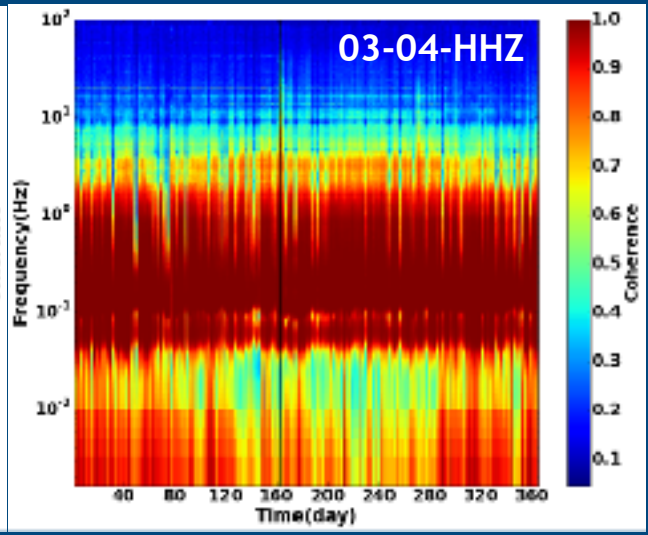




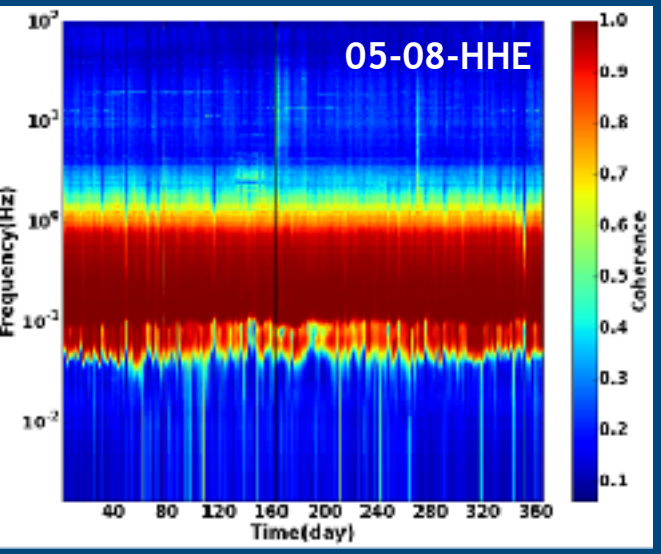


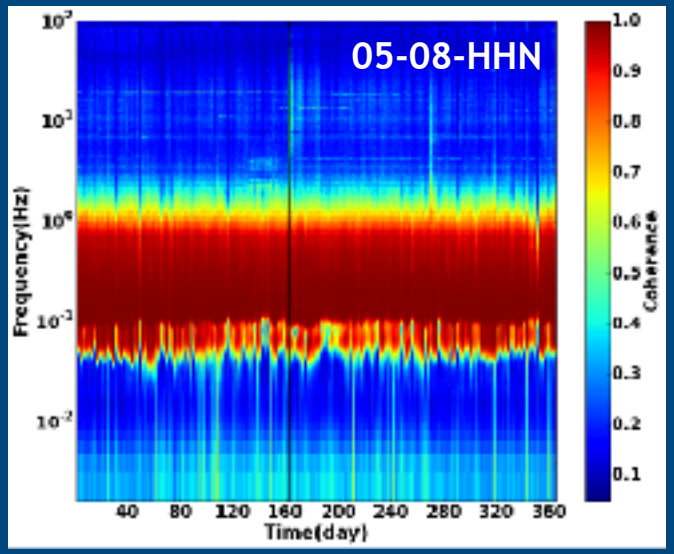


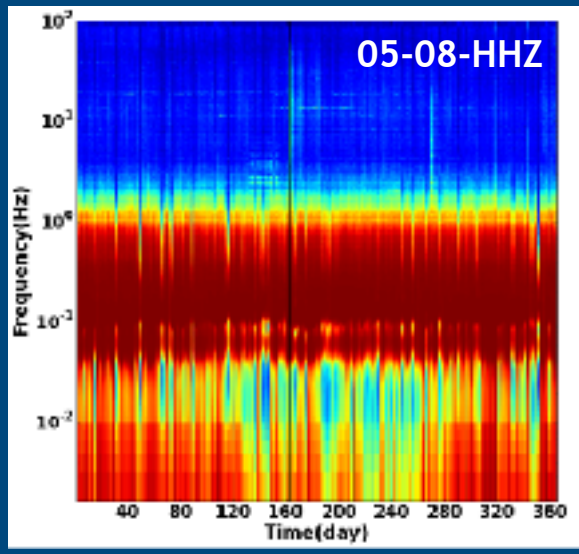




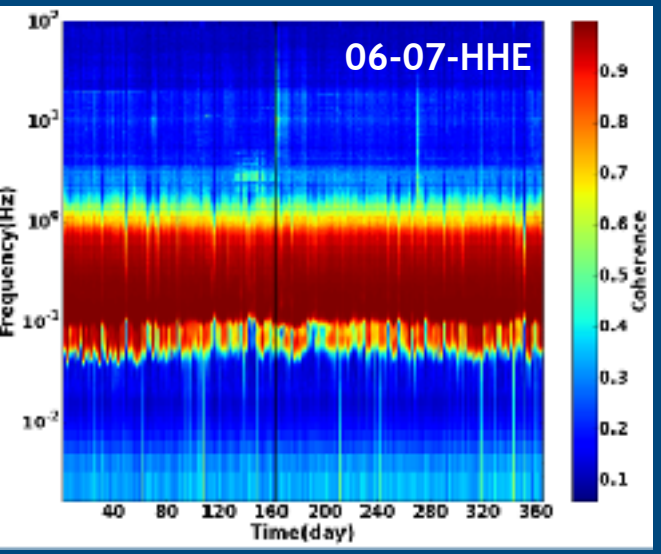
2016 Year Long 330 meter Coherogram

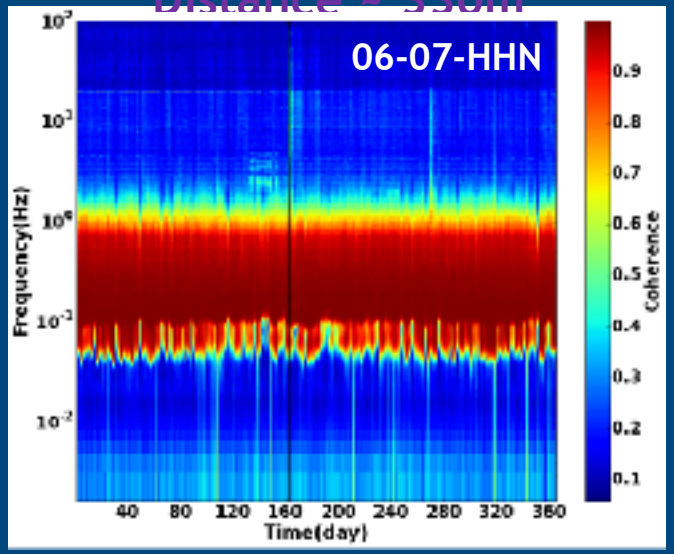


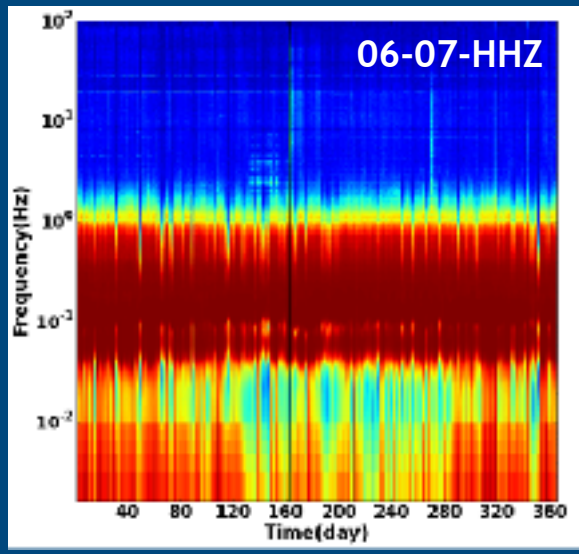




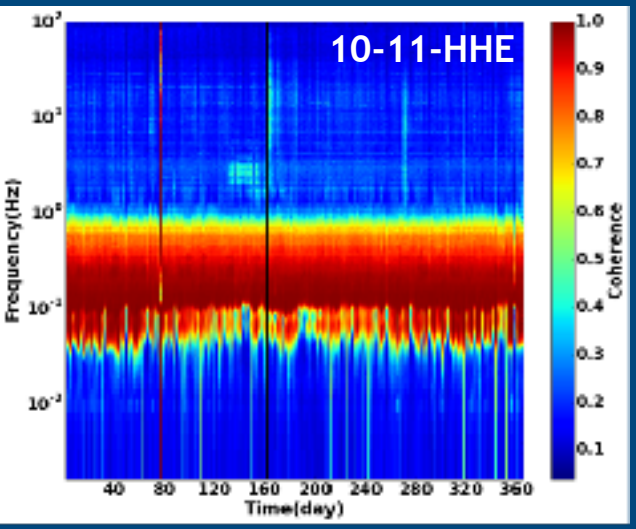
Distance ~ 330m

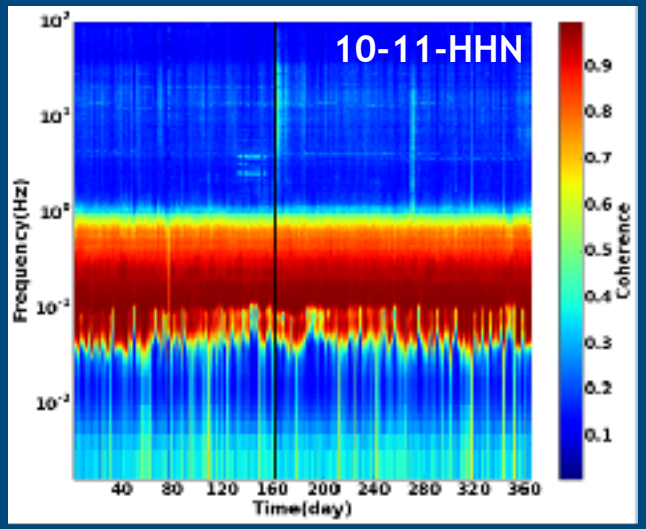


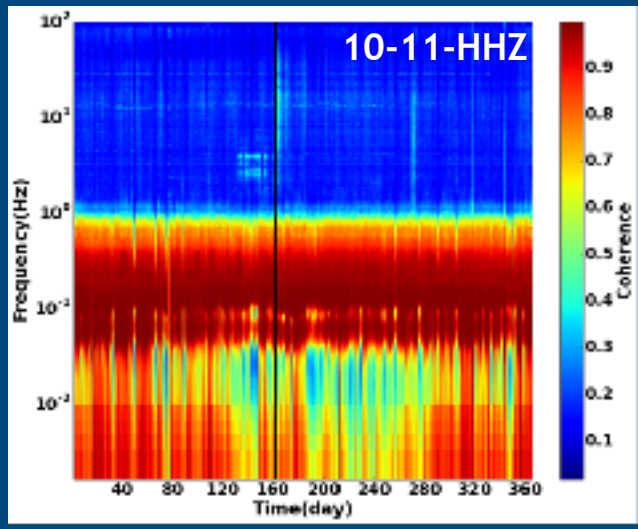


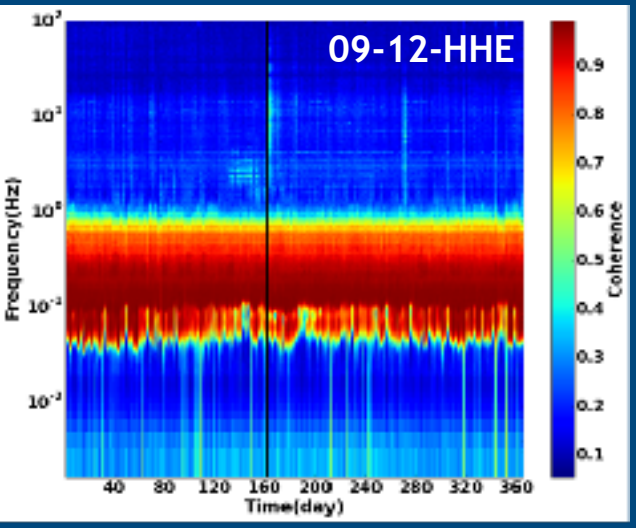


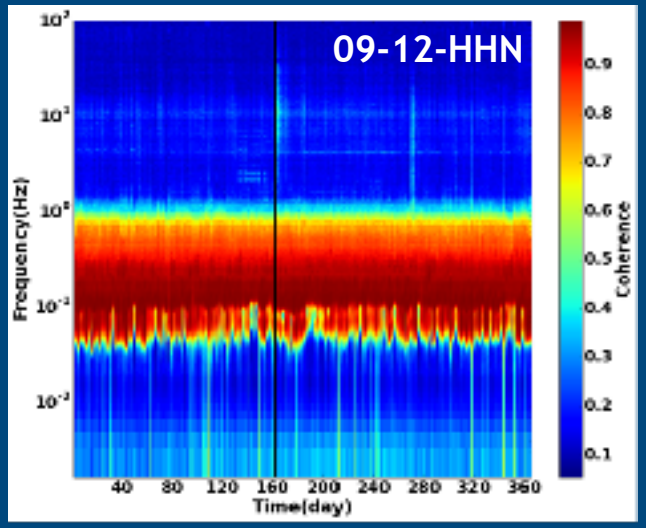
2016 Year Long 780 meter Coherogram

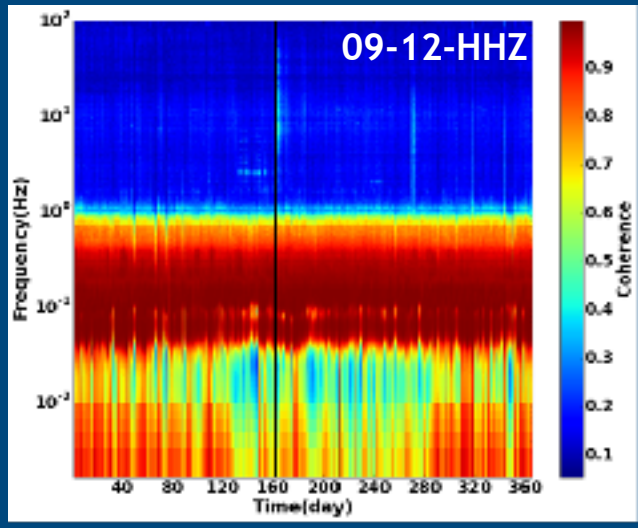




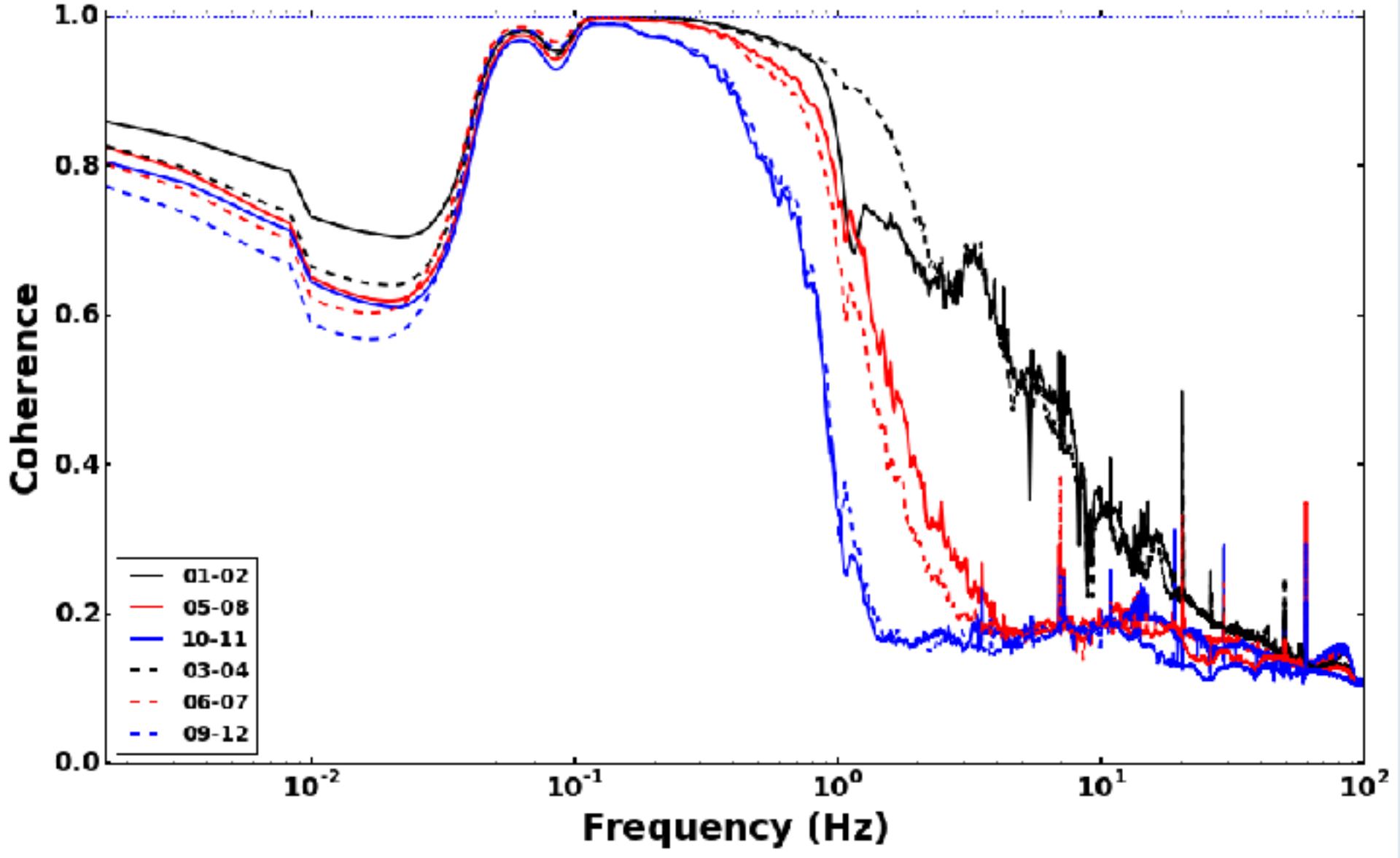




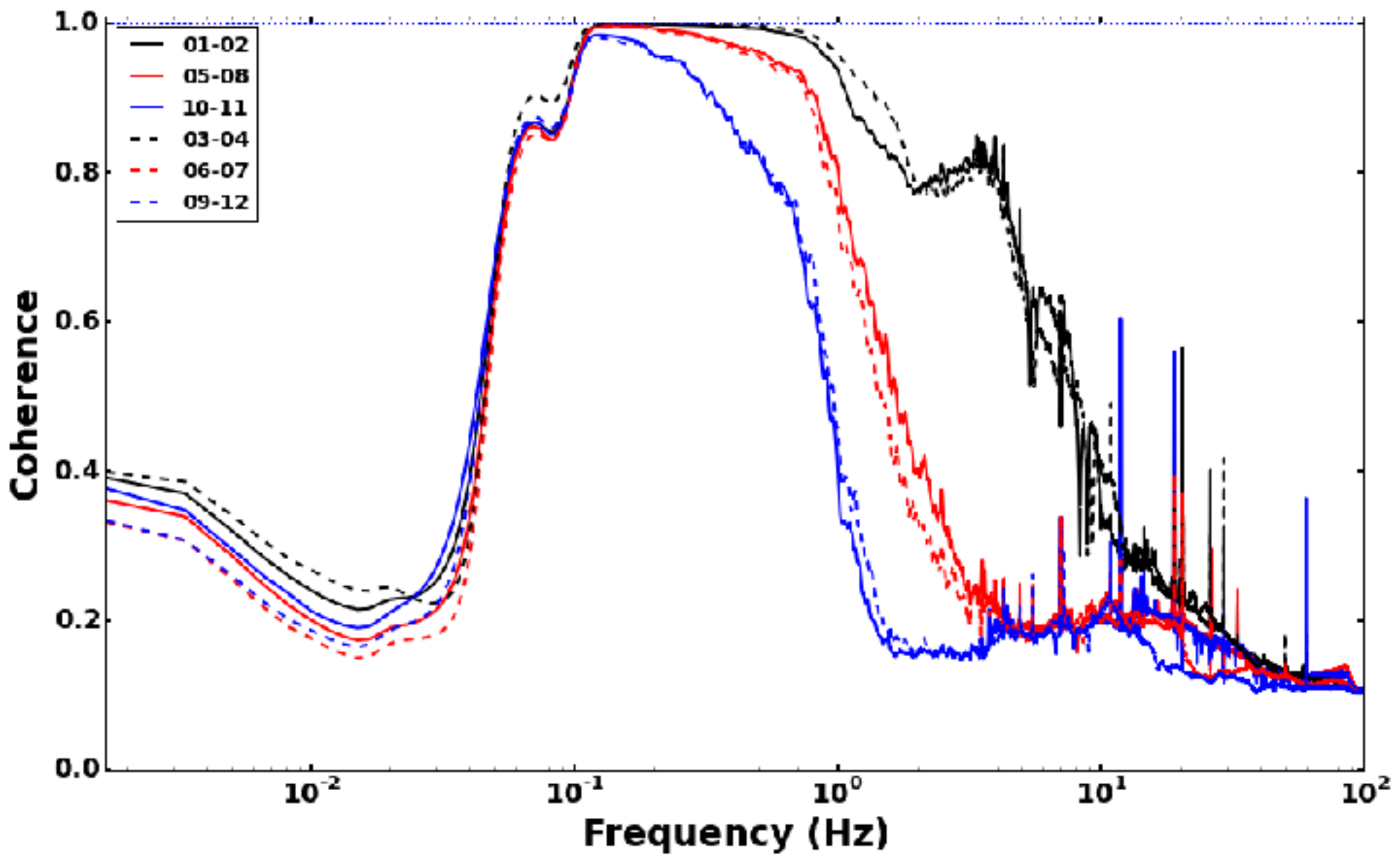




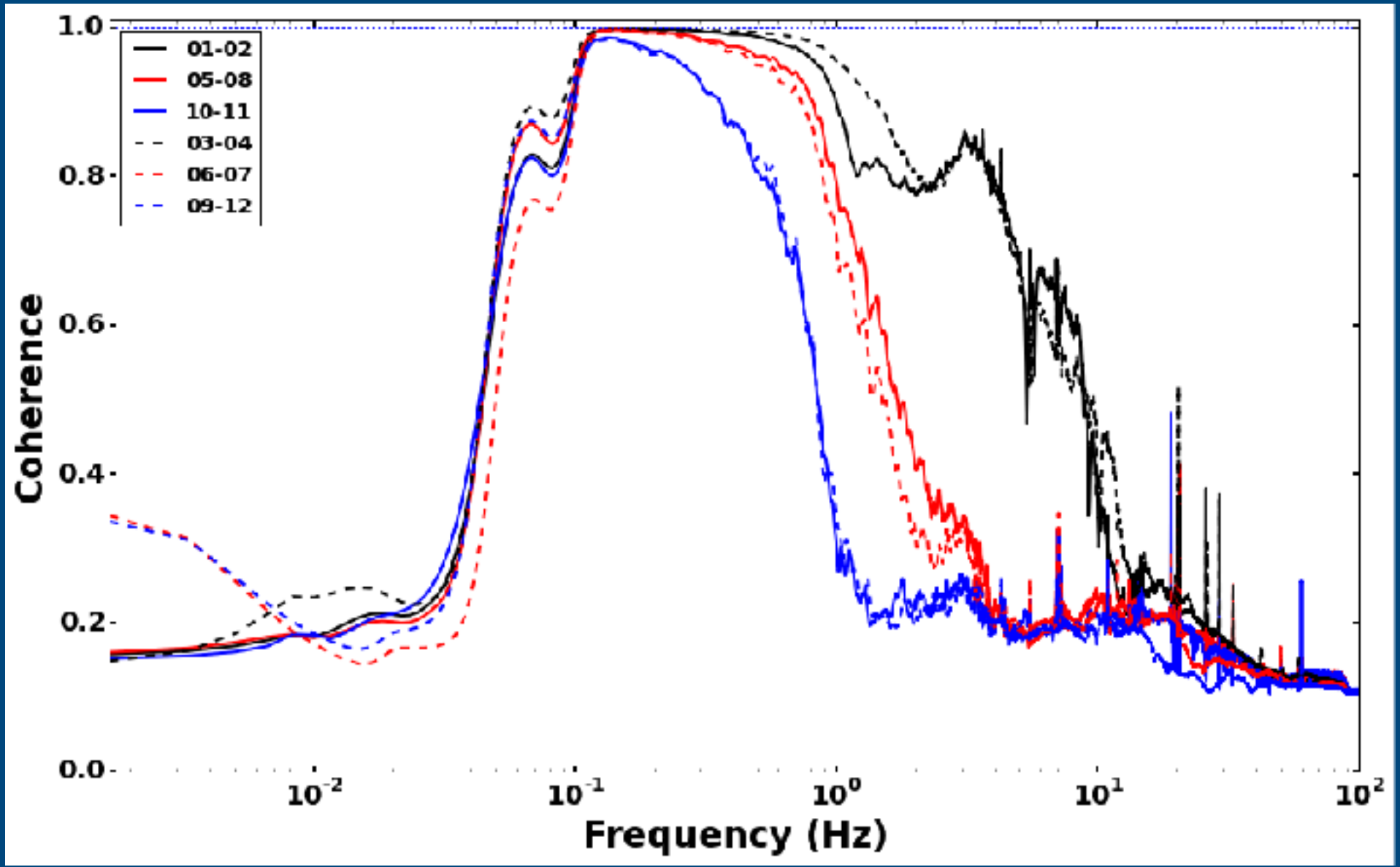
2016 BHZ Coherence



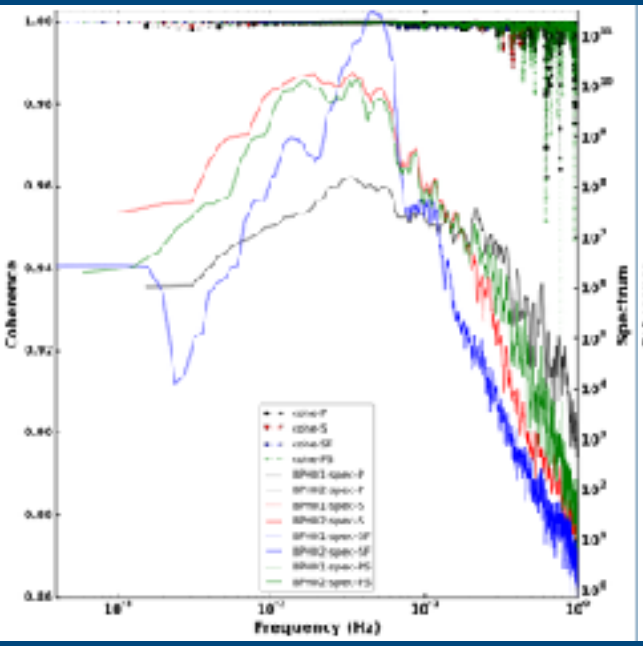
2016 BHN Coherence

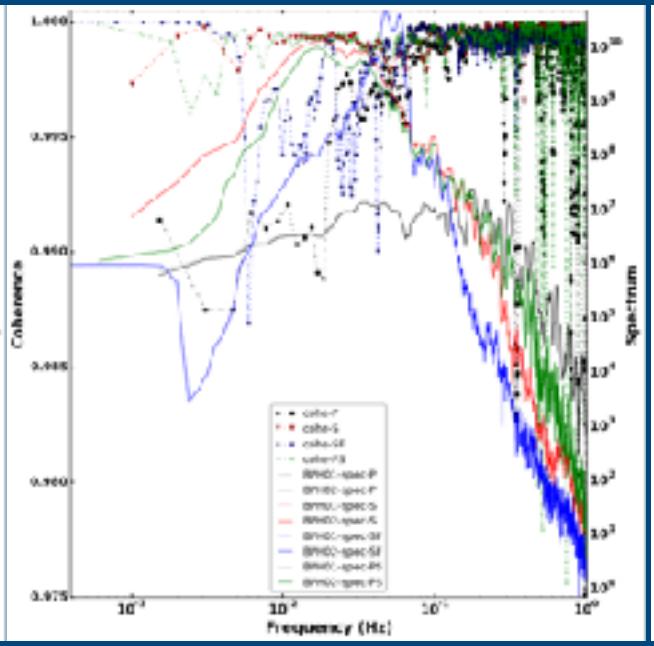


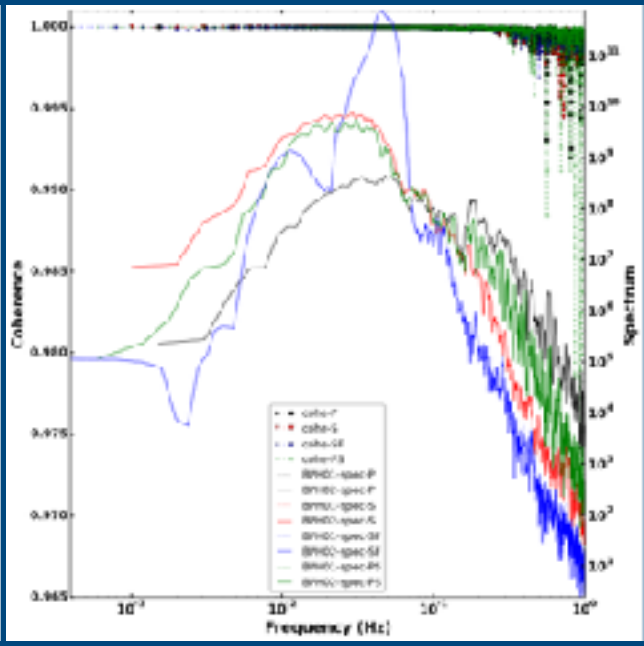
2016 BHE Coherence

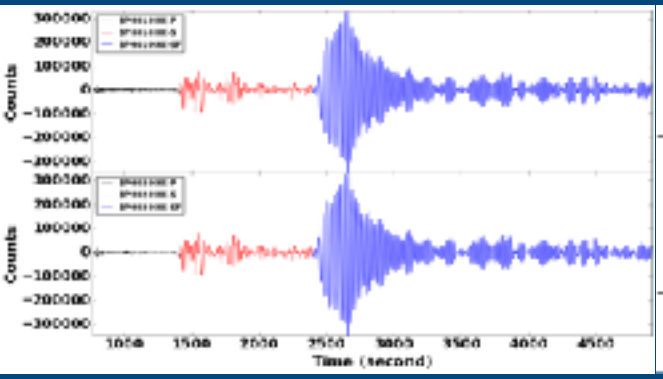


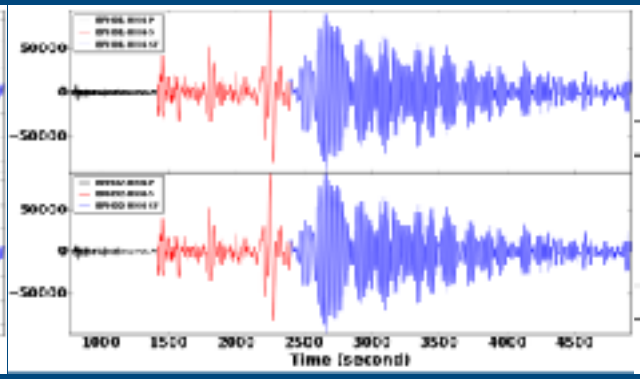
Three Teleseisms

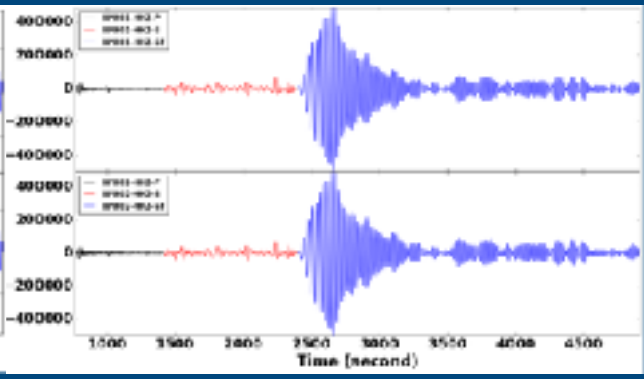




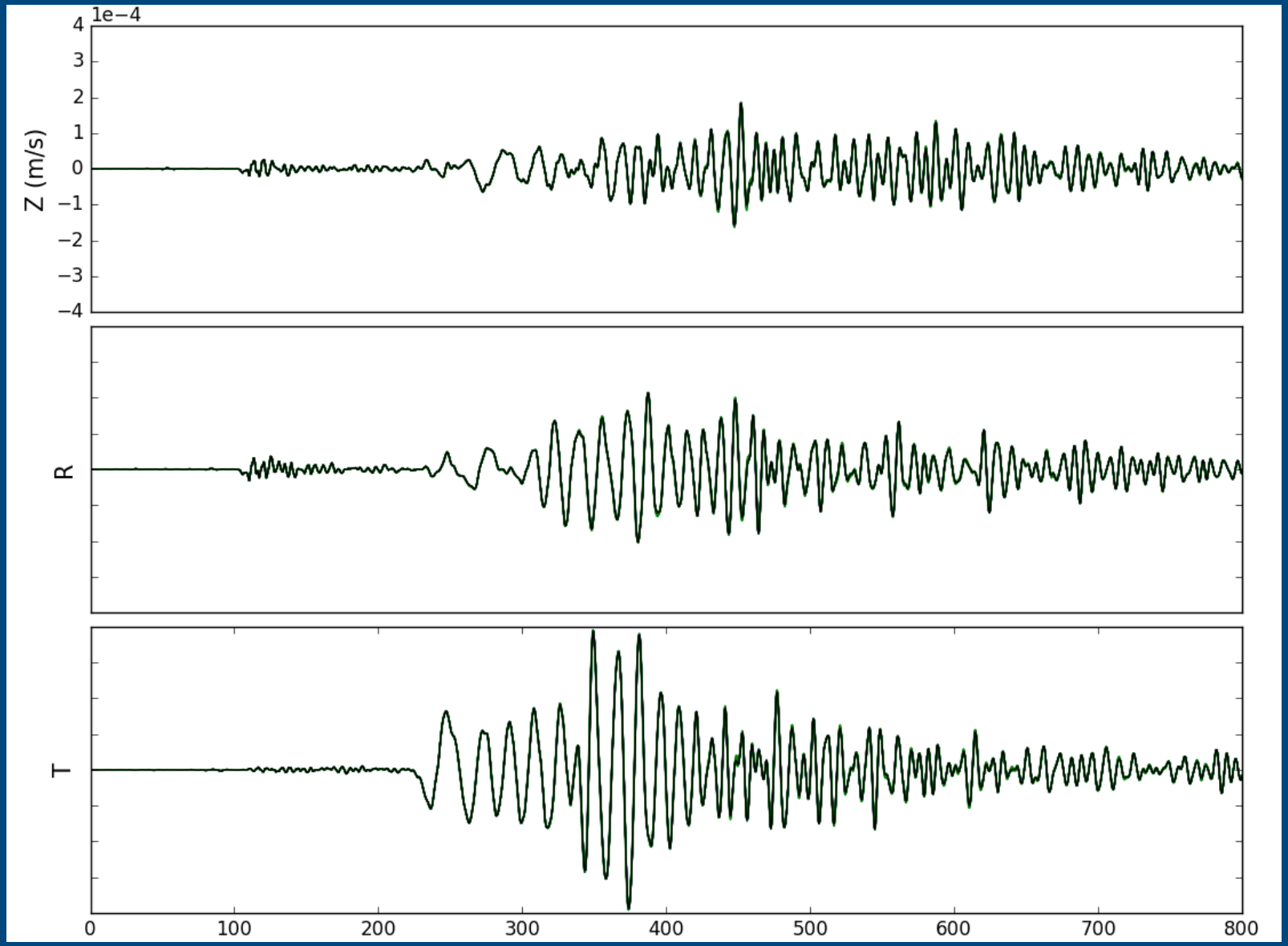








2015 09 13 Mw 6.7 Gulf of California
2017 SRL Donner et al



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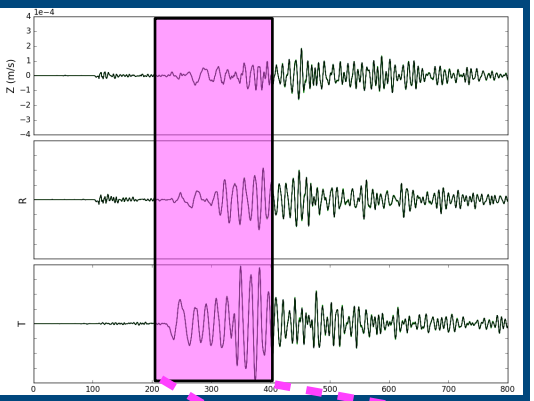
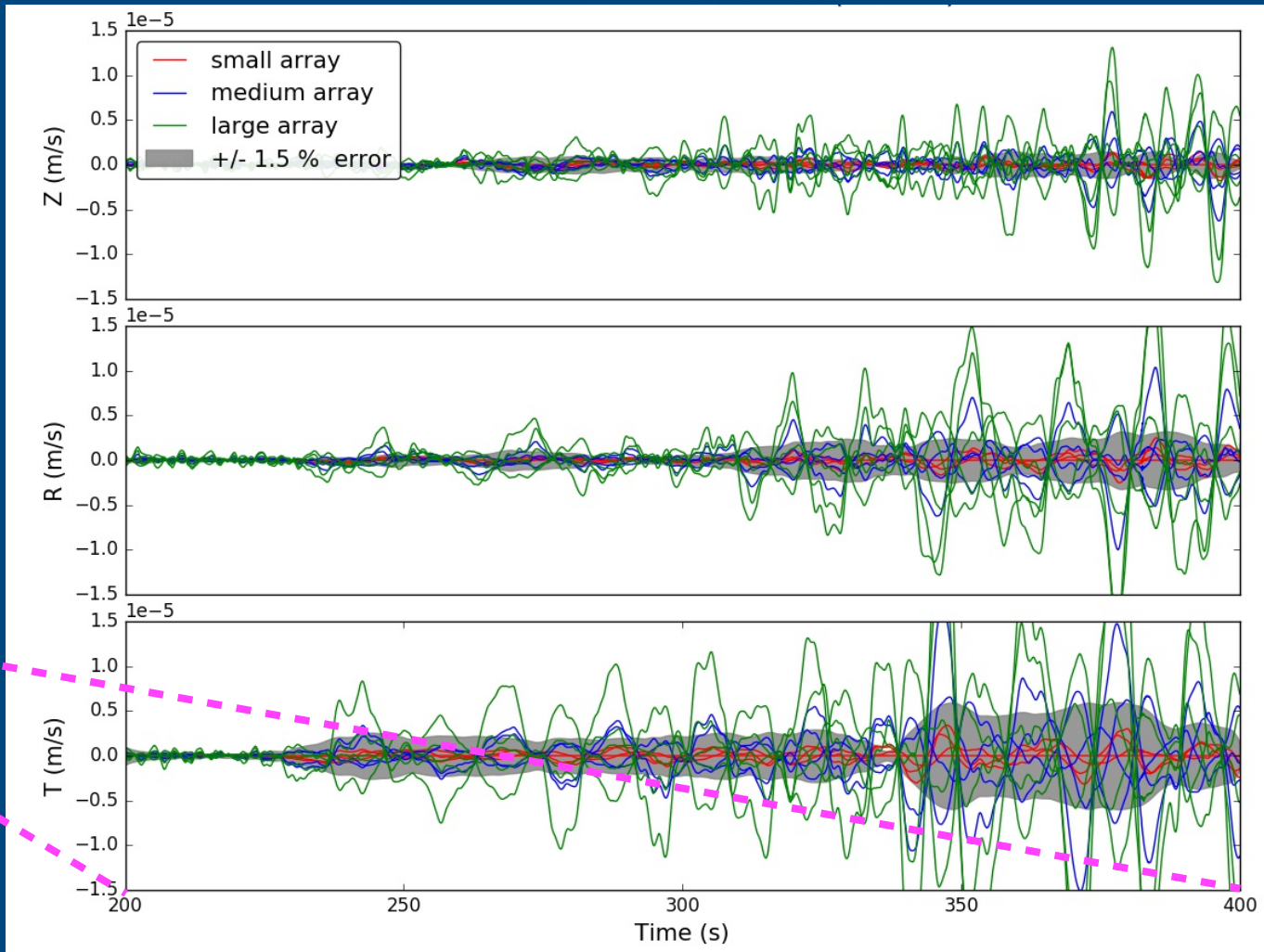
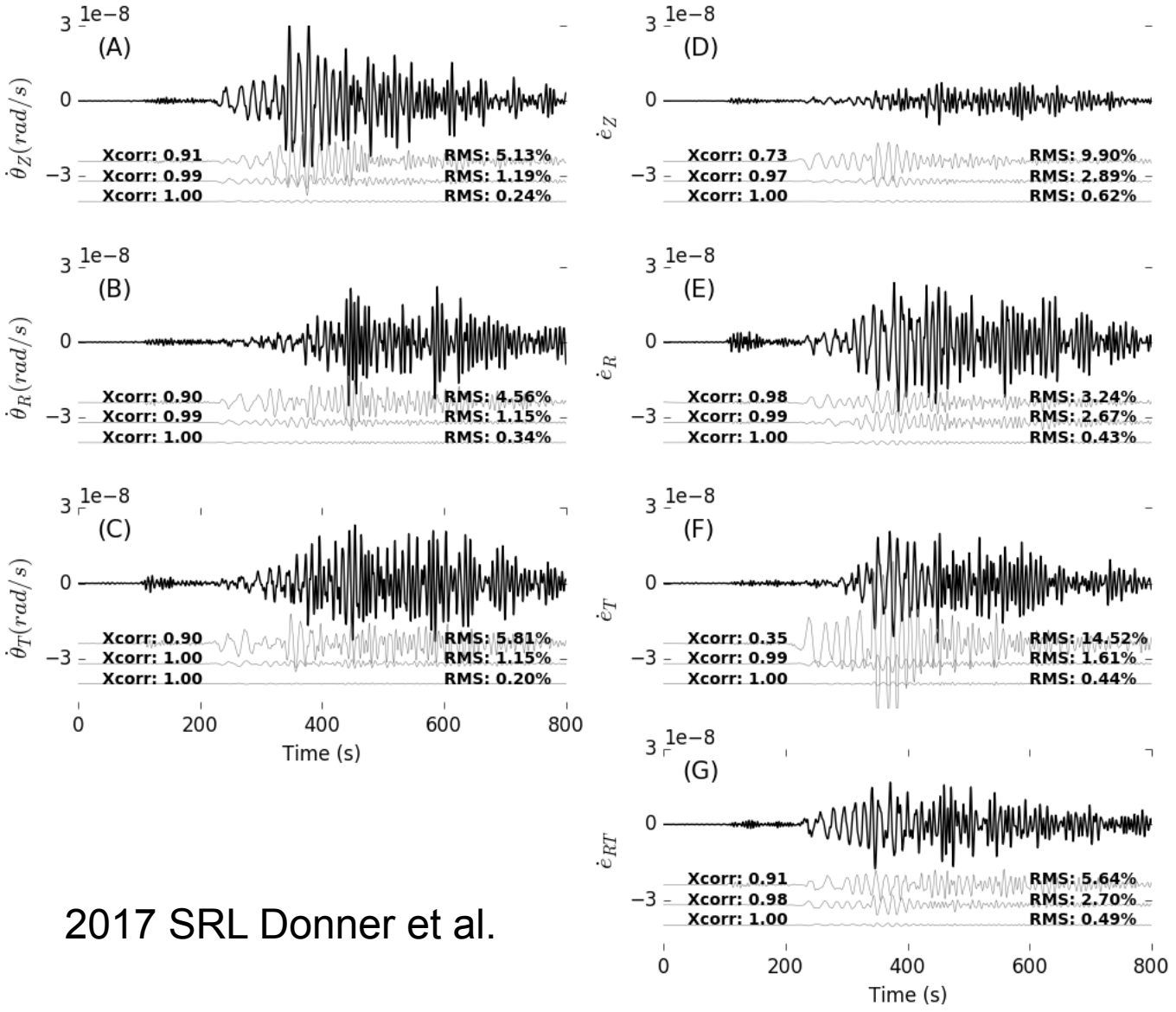
2017 SRL Donner et al





2015 09 13 Mw 6.7 Gulf of California Array Derived Rotation and Strain



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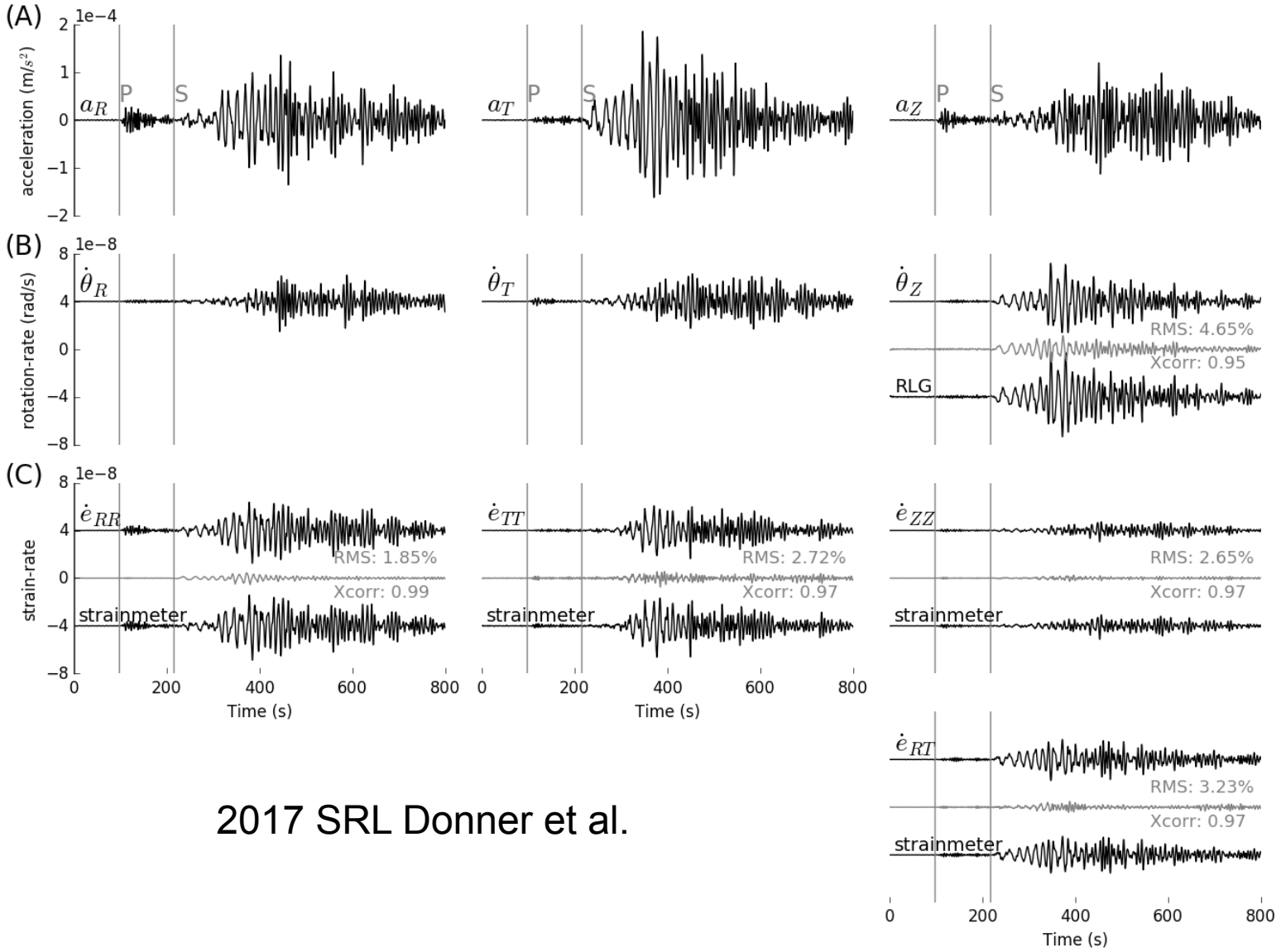
2015 09 13 Mw 6.7 Gulf of California Comparison with PFO Strain and Rotation



2017 SRL Donner et al.

Summary

- USArray Posthole Deployment provides consistent high quality data
- STS5 and Trillium 120 PH show similar performance
- All array elements with the same orientation are have highly coherent ground noise in the microseism band
- Outside the microseism band the coherence of ground noise drops significantly as a function of distance.
- Earthquake signals exhibit higher coherence across a wider bandwidth
- Small Aperture Arrays of posthole broadband sensors can effectively measure strain and rotation of earthquakes.