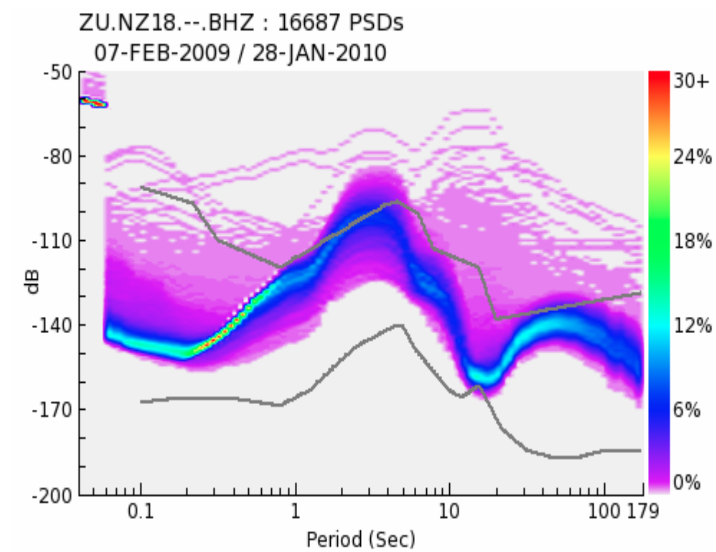
The MOANA OBS Experiment or:
How I learned to stop worrying and love the noise

Anne Sheehan, University of Colorado at Boulder
With input from Josh Stachnik, John Collins, Justin Ball, Dan Zietlow, Fan-Chi Lin, Zhaohui Yang, Martha Savage, Peter Molnar, Oleg Godin, Nikolay Zabotin

Noise!
- Study it
- Use it
- Get rid of it
- Deal with it



OUTLINE

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1. MOANA OBS experiment offshore New Zealand
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   QA/QC
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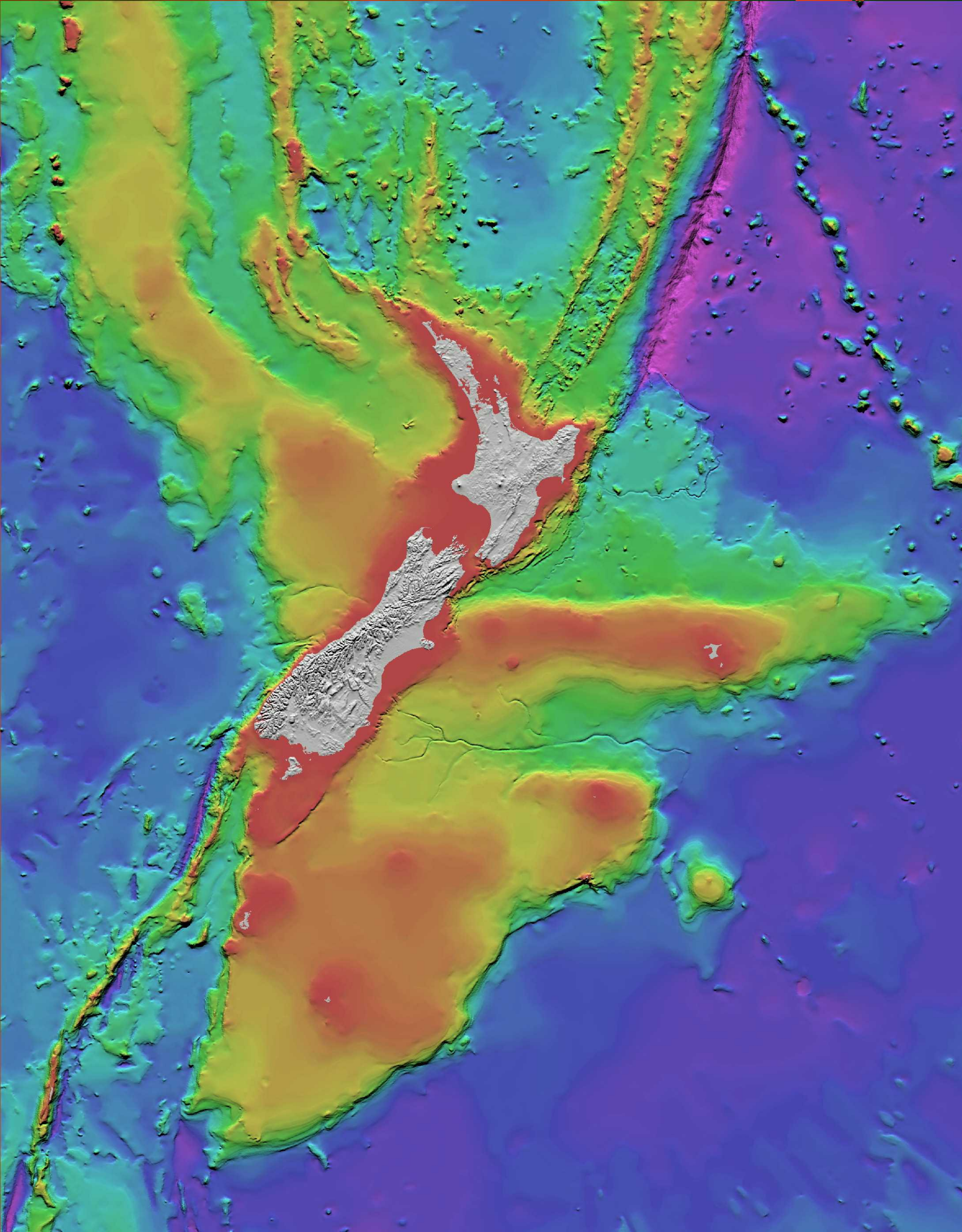
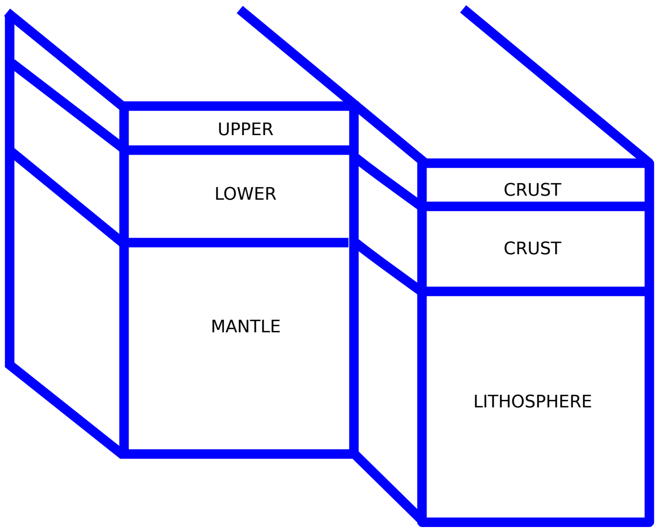
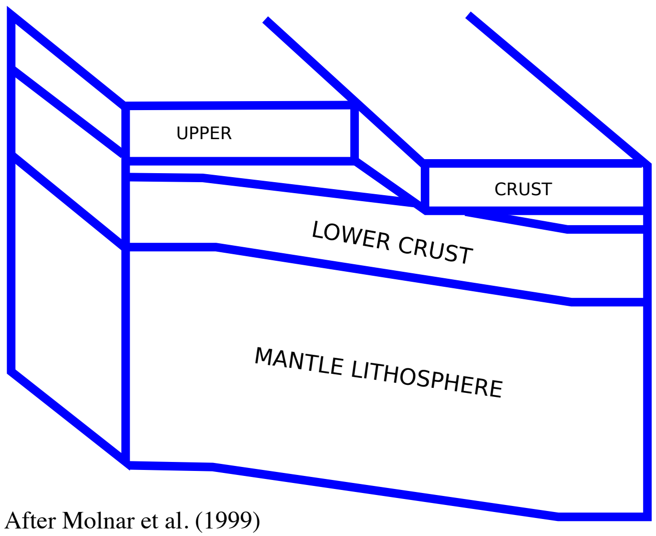
   Improve SNR on vertical in surface wave band
   Some surface wave results
5. Deal with noise – shear wave splitting, receiver functions



170° E
175° E
180° E
165° E
35° S
40° S
45° S
New Caledonia Basin
2000
Kaitaia
Whangarei
Auckland
Waikato
Raukumara
47 mm/yr
Challenger Plateau
Taranaki Basin
Taranaki
Australian Plate
Nelson
Wairarapa
Hikurangi Trough
41 mm/yr
Pacific Plate
Greymouth
Alpine Fault
38 mm/yr
Christchurch
Haast
Aoraki
Chatham Rise
Waitaki
Fiordland
Puysegur Trench
37 mm/yr
Murihiku
Dunedin
Bounty Trough
Campbell Plateau
0
100
200
Kilometres

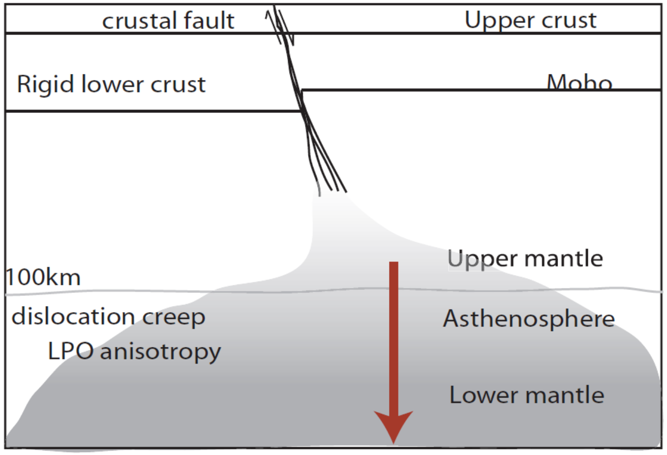
What is the nature of mantle deformation at a transform plate boundary?





After Molnar et al. (1999)

ii. Localized Deformation/ Fan shape model



i. Distributed Deformation/ Thin viscous sheet model

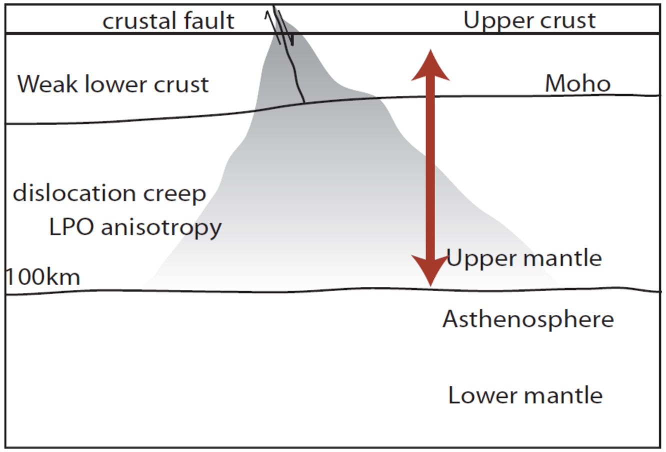
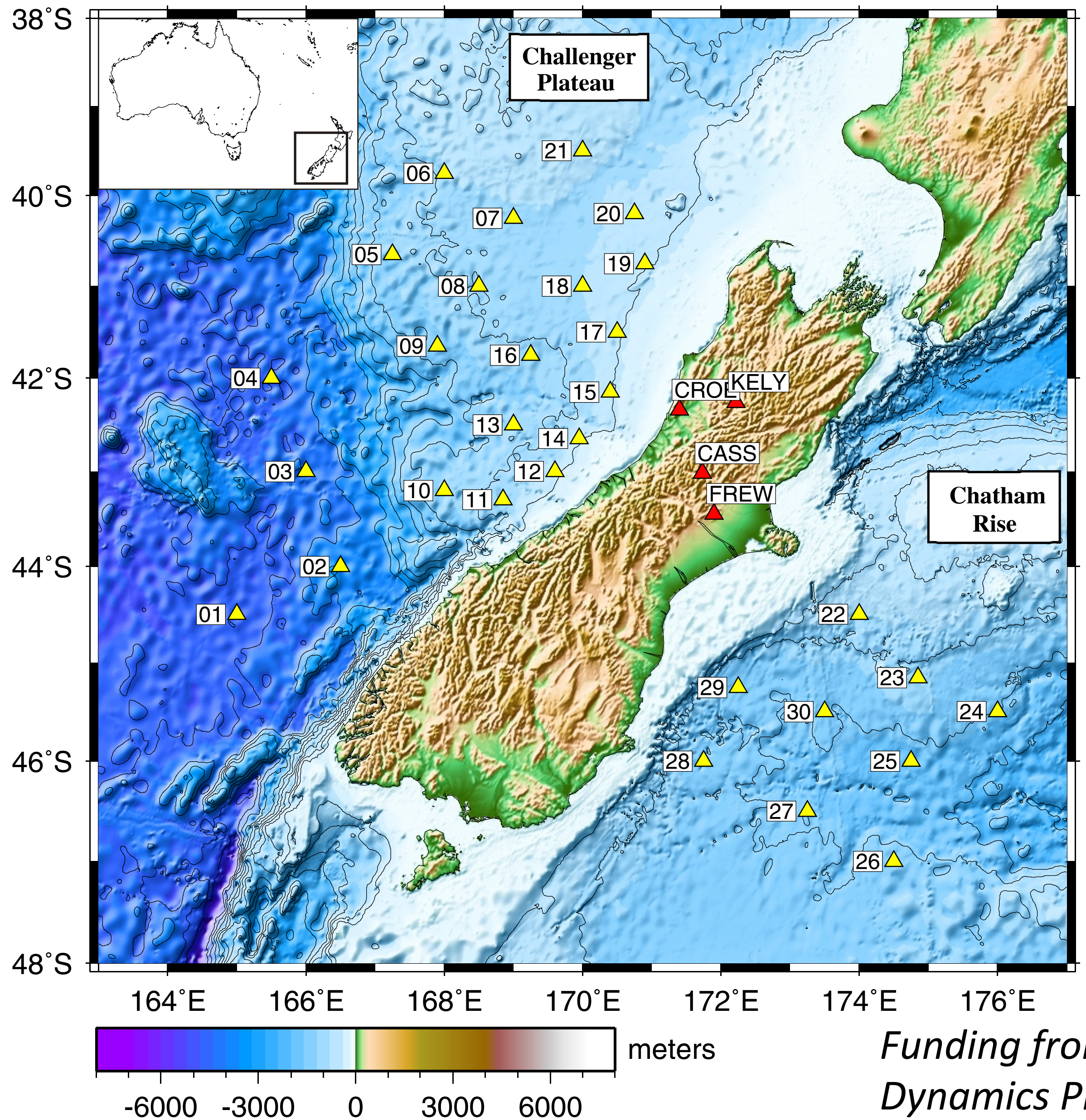


Figure by Sapthala Karalliyadda (U. of Wellington)

MOANA OBS Seismic Experiment, New Zealand

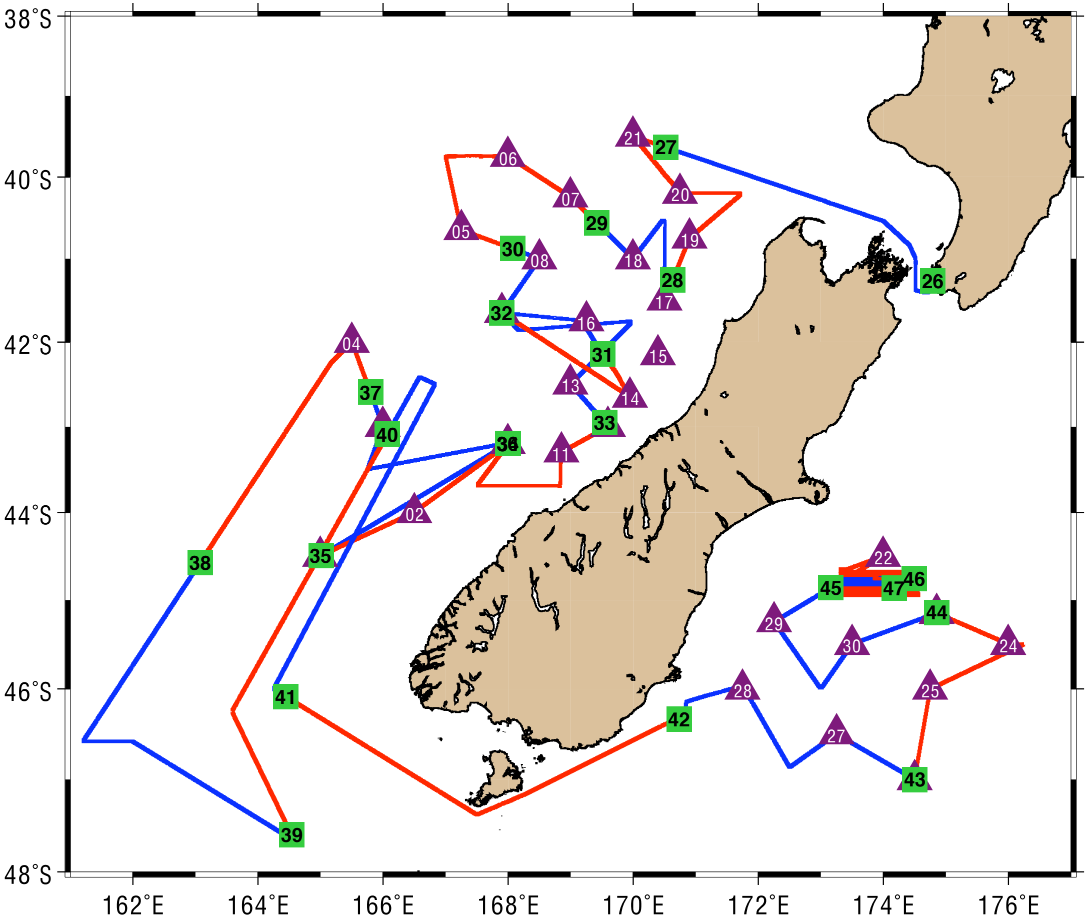
Marine **O**bservations of **A**nisotropy **N**ear **A**otearoa



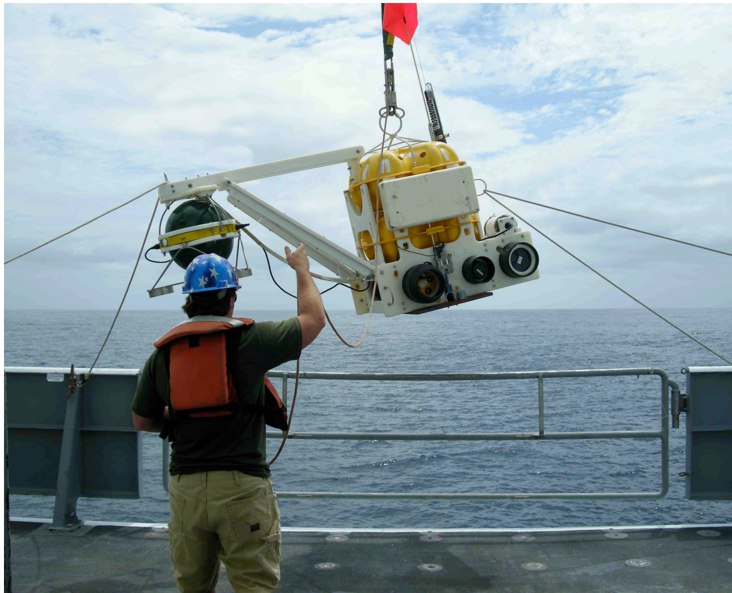
Funding from NSF Continental Dynamics Program

MOANA OBS Seismic Experiment, New Zealand

Marine **O**bservations of **A**nisotropy **N**ear **A**otearoa



- January 2009 – February 2010
- 30 SIO OBSIP Broadband OBS
- 50 sps sample rate
- Water depths 550 m – 4700 m
- Recovery: 28 by R/V Revelle (2 lassoed), 1 by trawler, 1 washed ashore
- DPG data fine for all, 1 bad OBS



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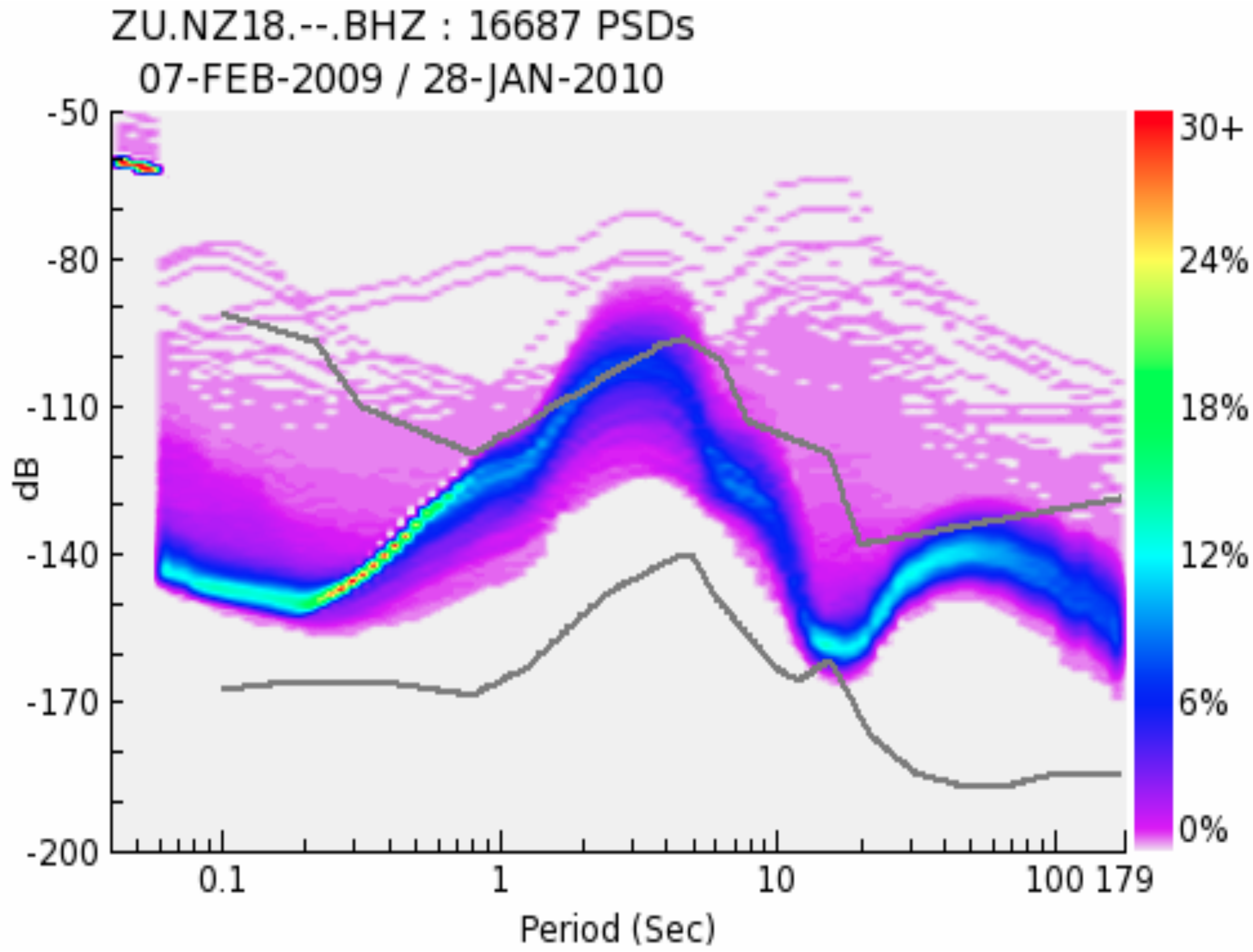
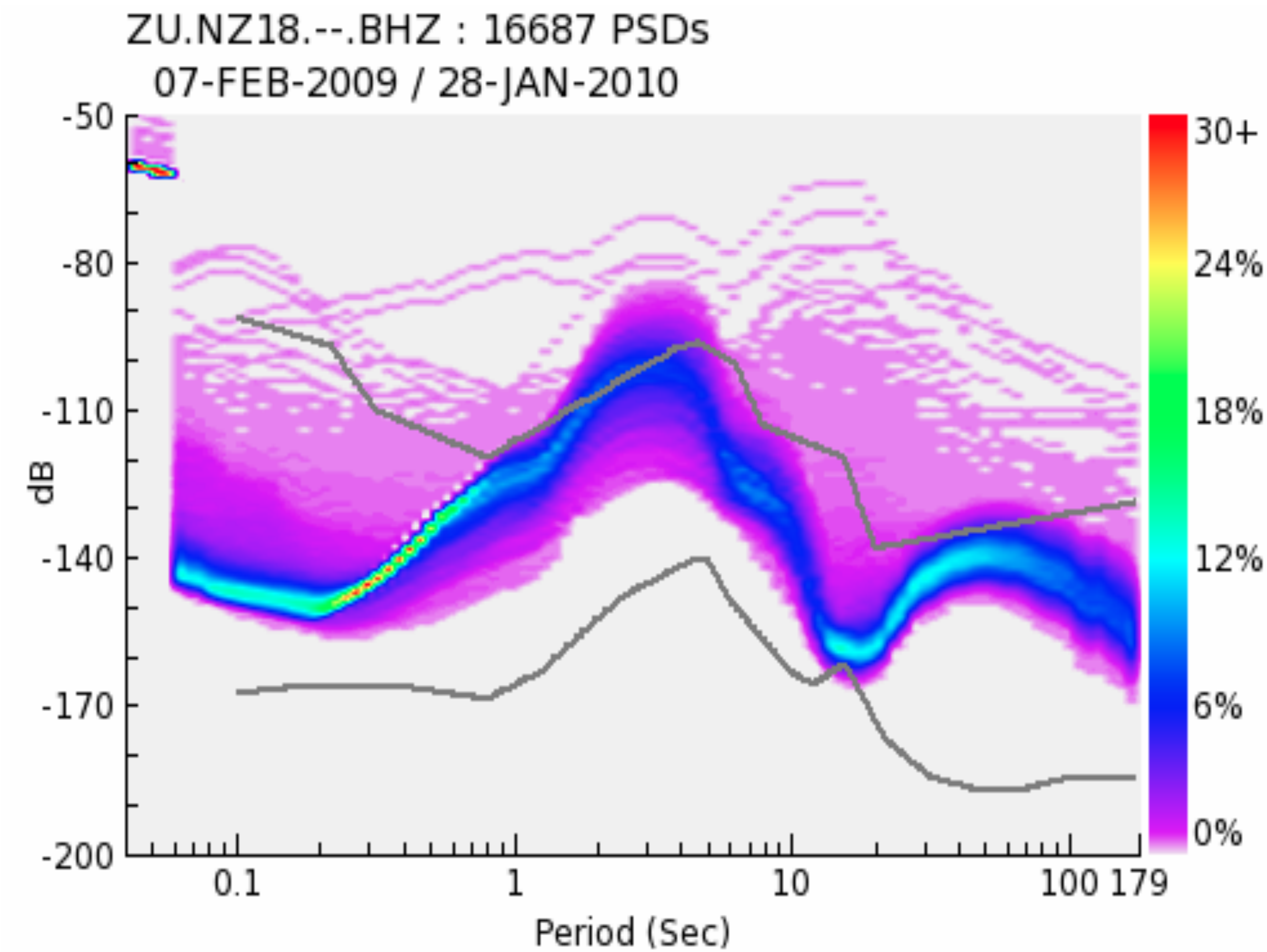
Display of background noise spectra via PQLX

- Plots made using the program PQLX (PASSCAL Quick Look eXtended)
- http://www.iris.edu/software/pqlx/
- Based on algorithm of McNamara and Buland, BSSA, 2004

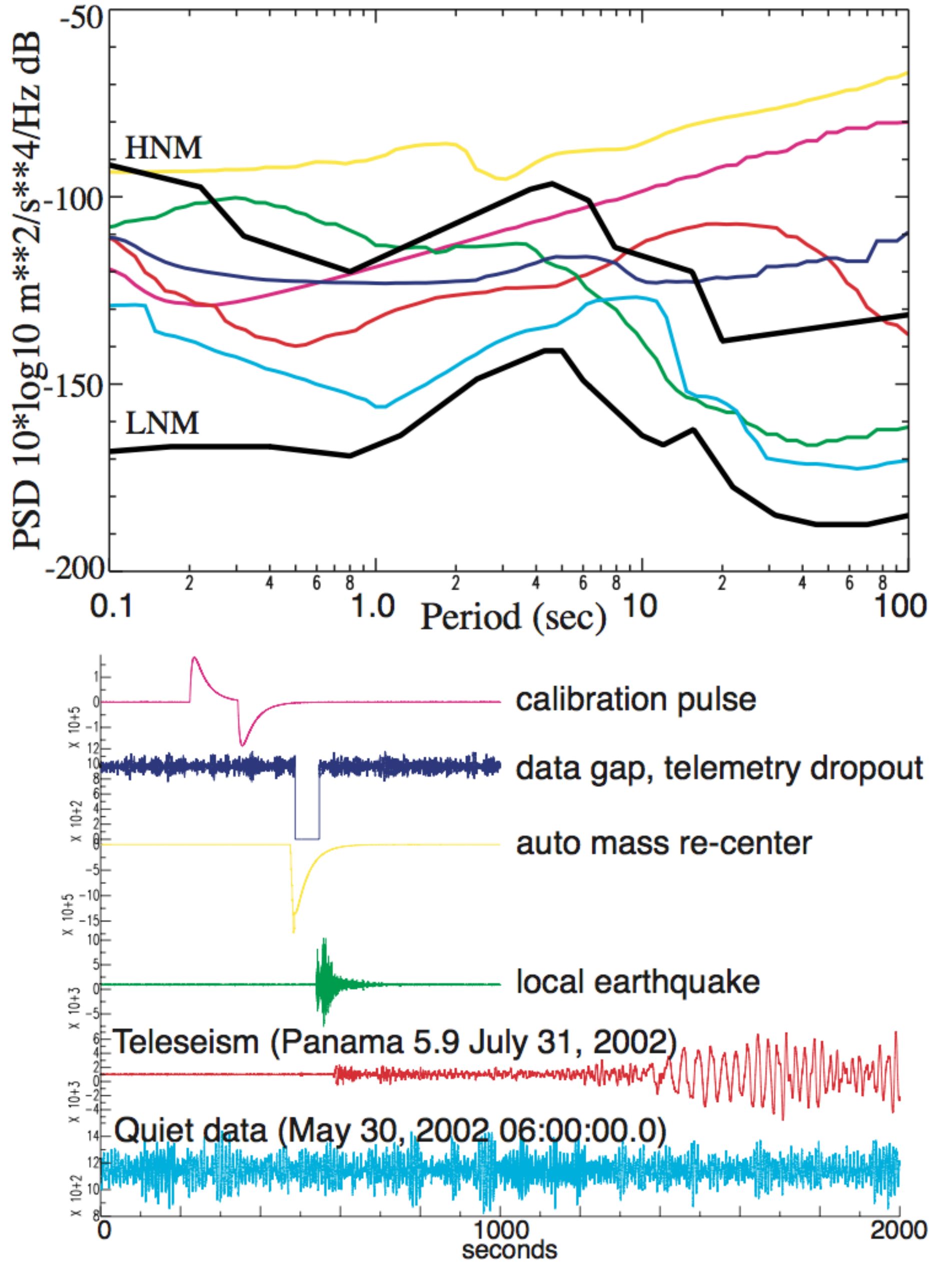


Display of background noise spectra via PQLX

- Power spectra determined for one-hour segments of the entire year of data
- Probability density function used to display the thousands of spectra
- Blues and greens represent frequent values, light purple represents less frequent values

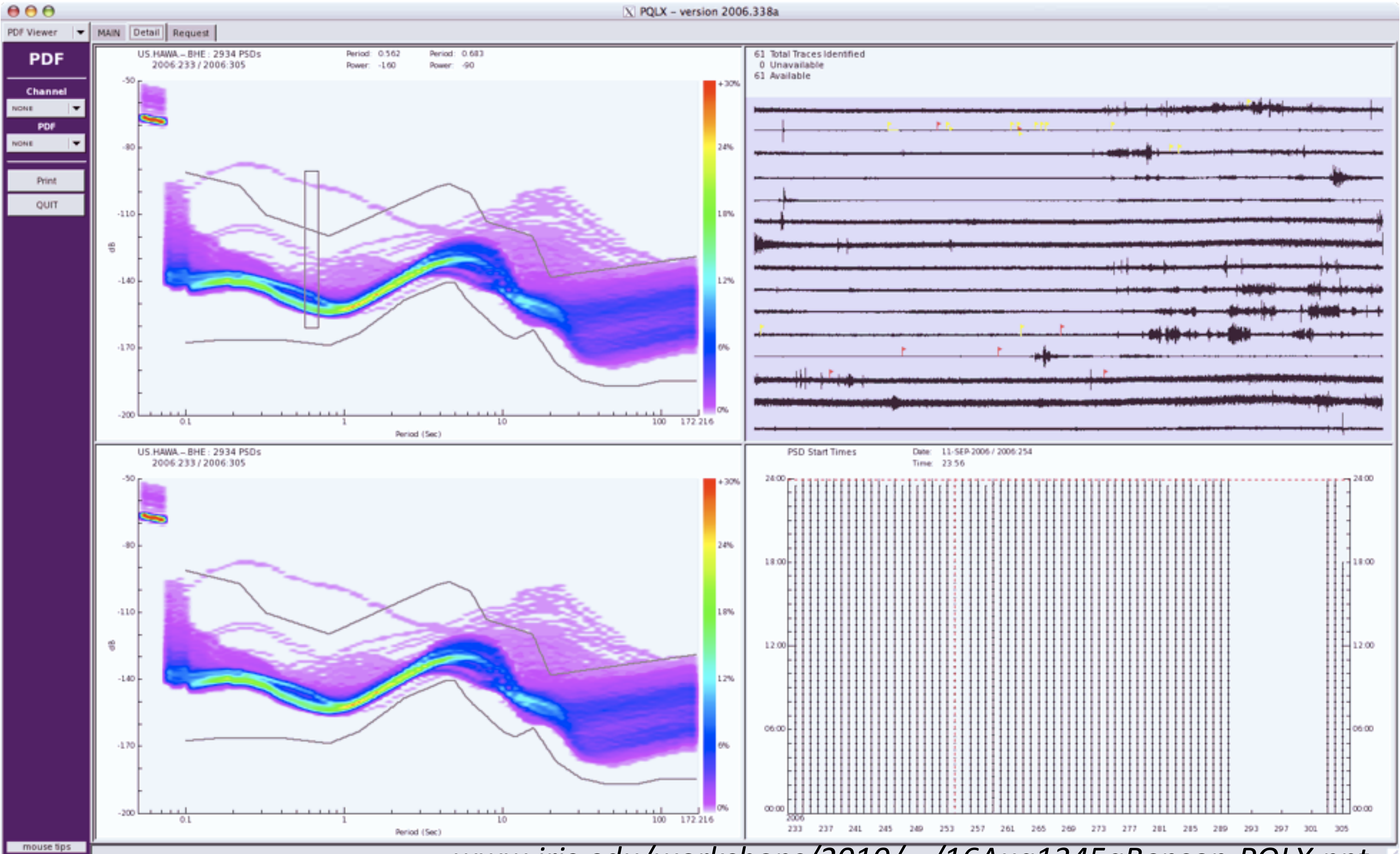


Background Noise Spectra as Tool for Quality Control



McNamara and Buland, BSSA, 2004

PDF detail view

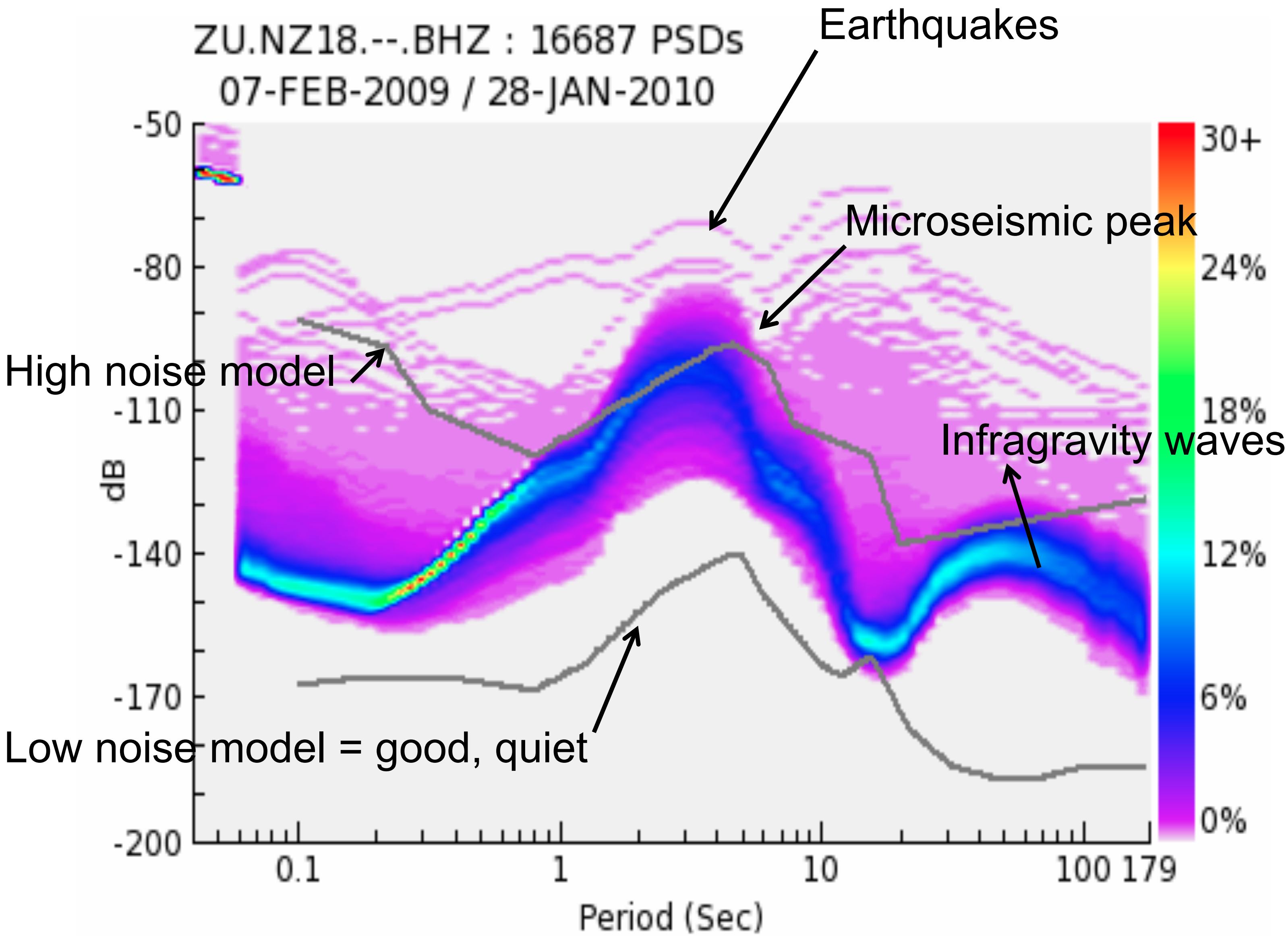


www.iris.edu/workshops/2010/.../16Aug1345aBenson-PQLX.ppt

Background noise spectra

Power spectral density PSD

Probability density function PDF



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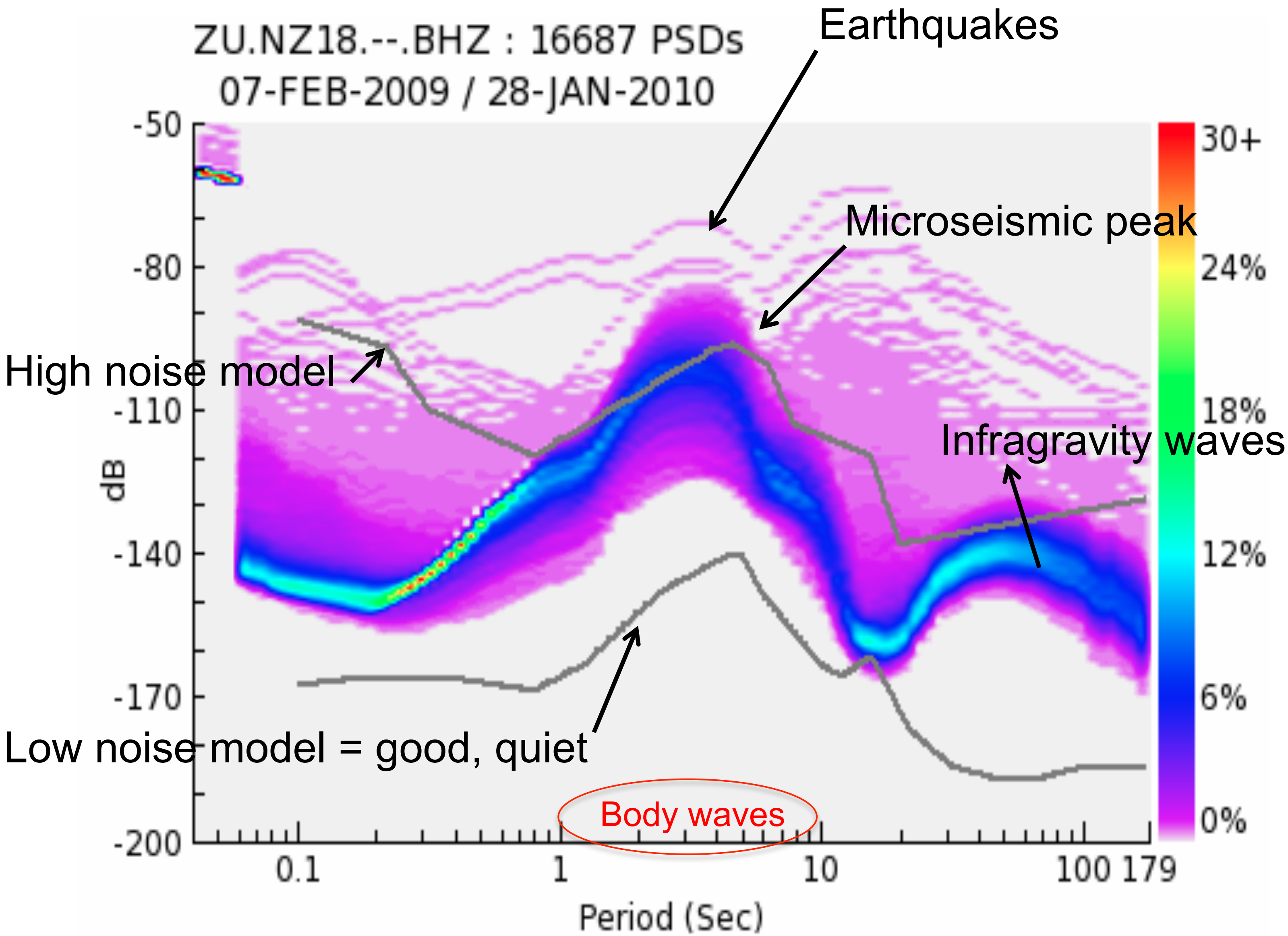

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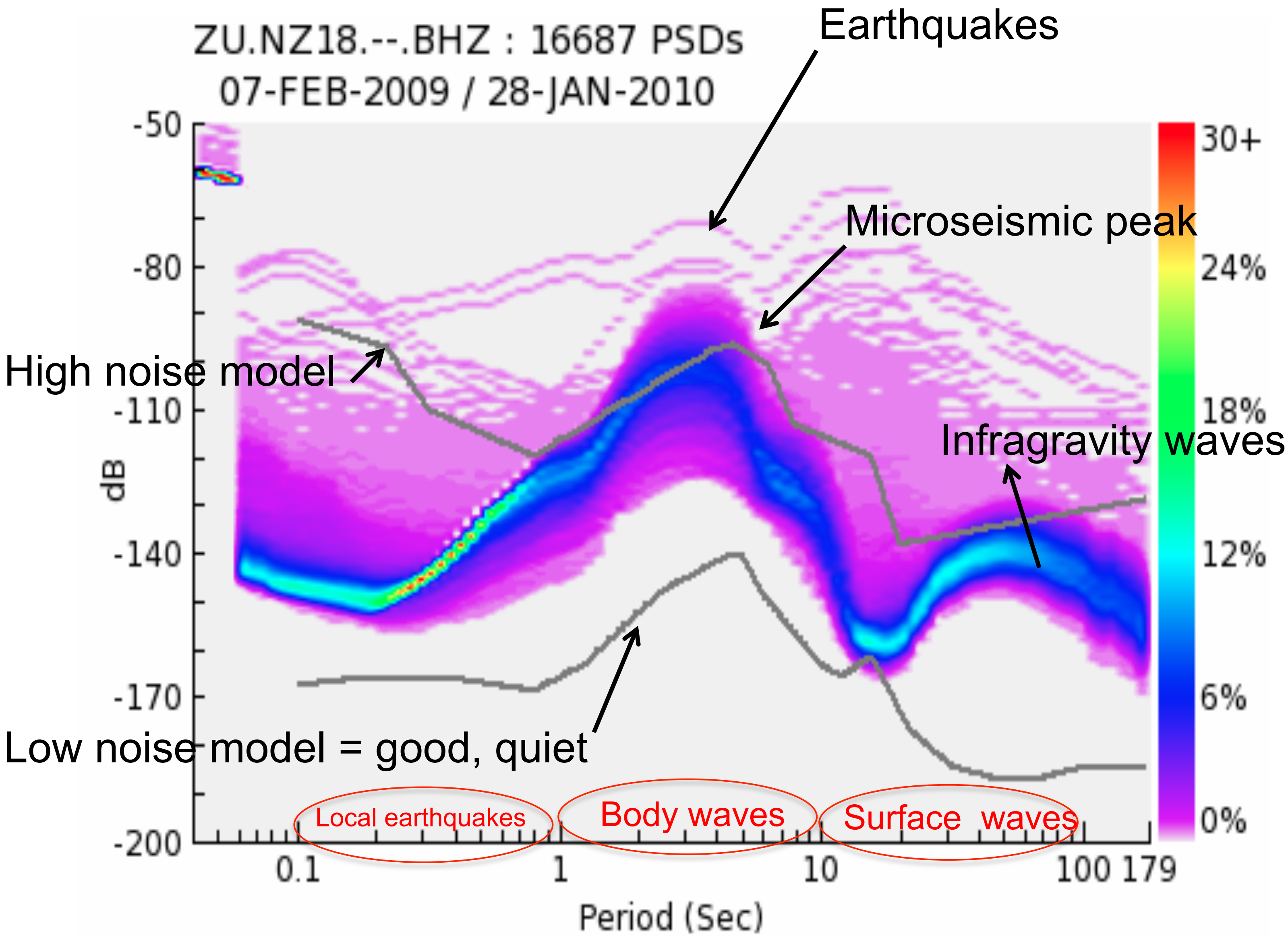
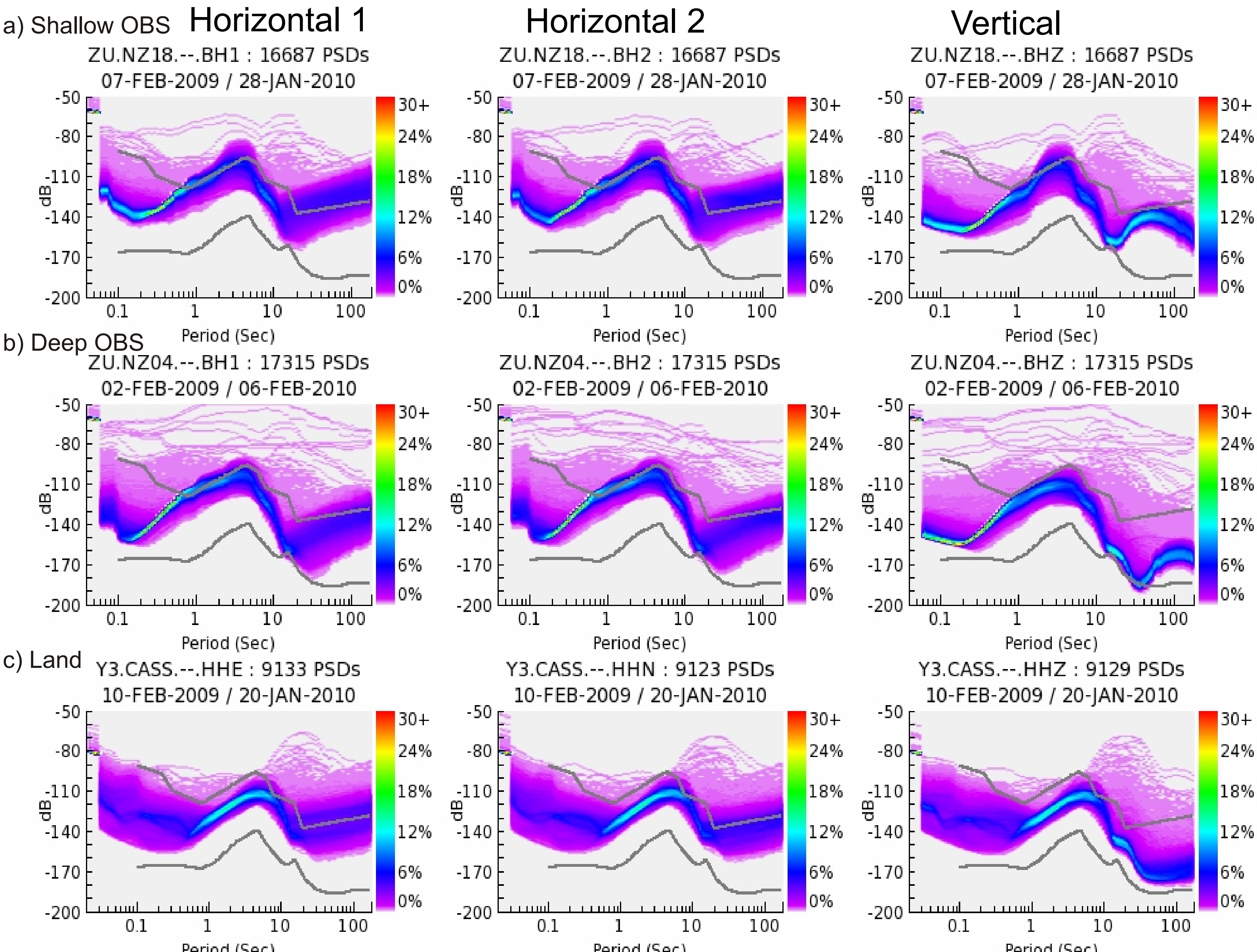


Comparison of spectra from deep water, shallow water, and land



Shallow OBS < 1 km water depth

Deep OBS > 4 km water depth

Land Station, New Zealand

Yang et al., G-cubed, 2013

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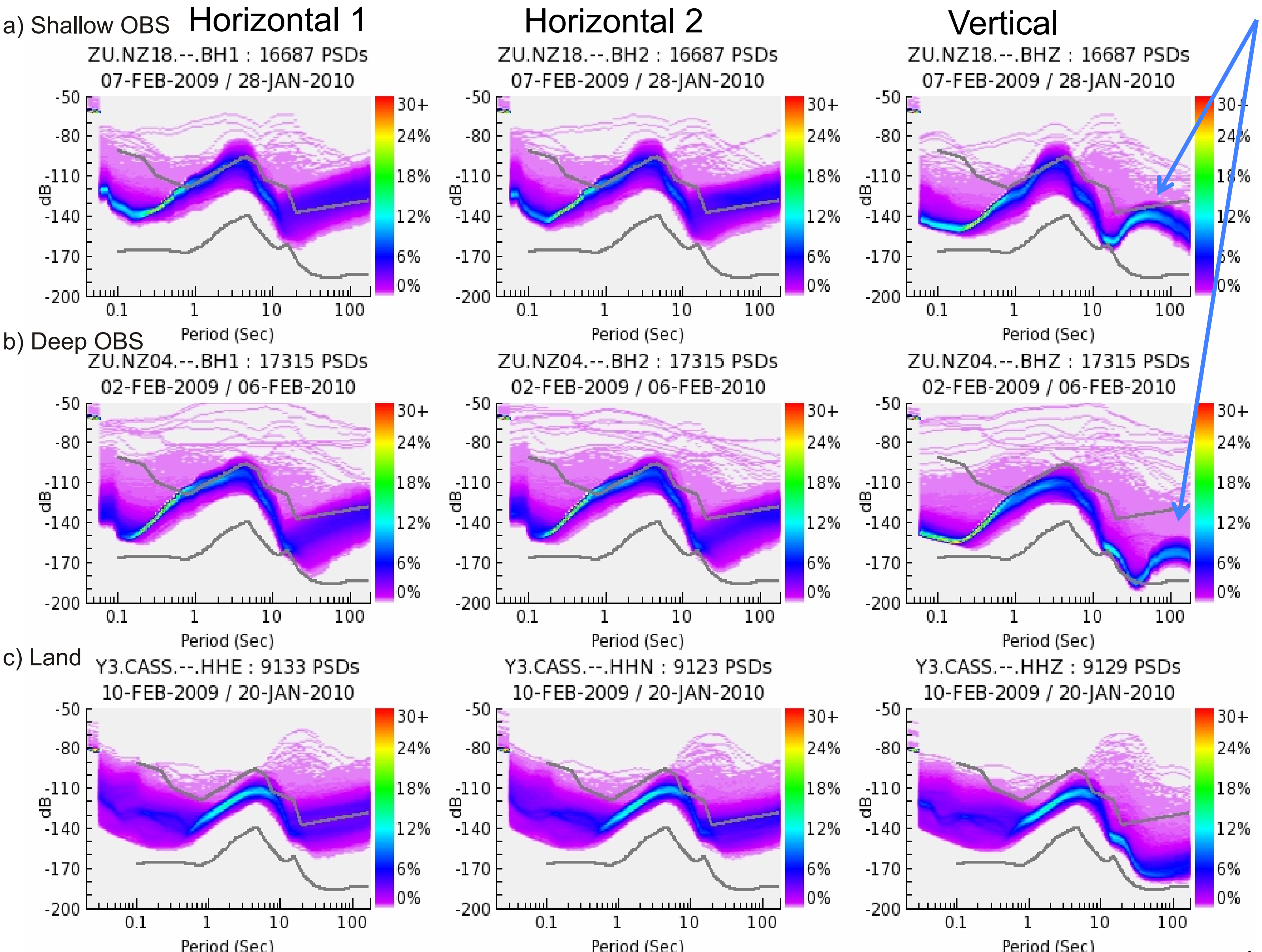

Infragravity wave peak is depth dependent

Shallow OBS < 1 km water depth

Deep OBS > 4 km water depth

Land Station, New Zealand

Yang et al., G-cubed, 2013

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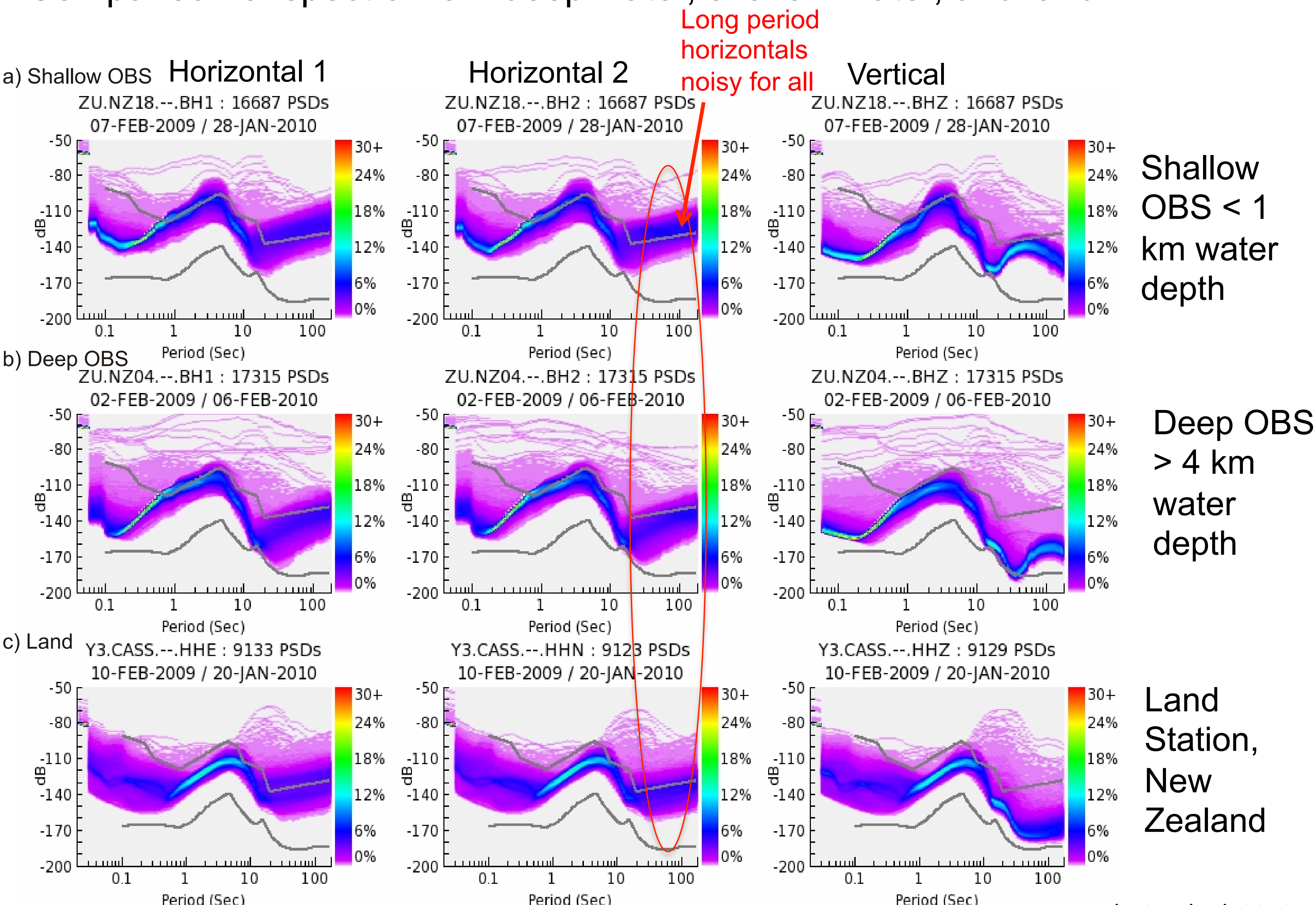

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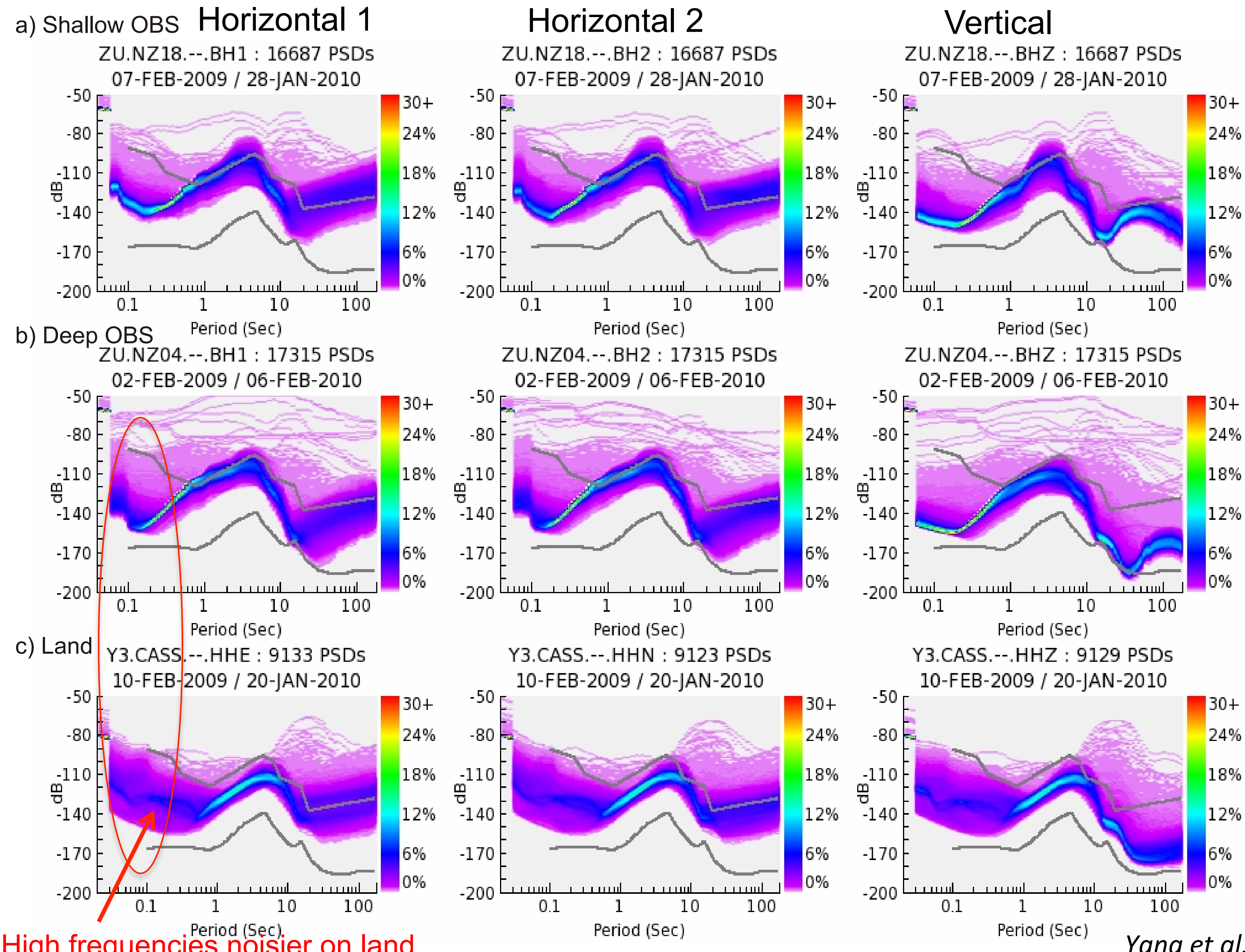

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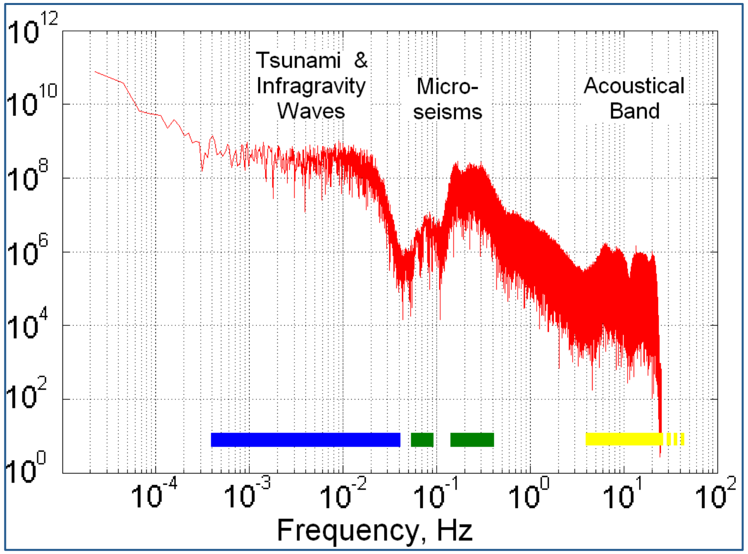
Yang et al., G-cubed, 2013

Infragravity waves

DPG spectra



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Directionality

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O. Godin and N. Zabotin
CIRES and NOAA

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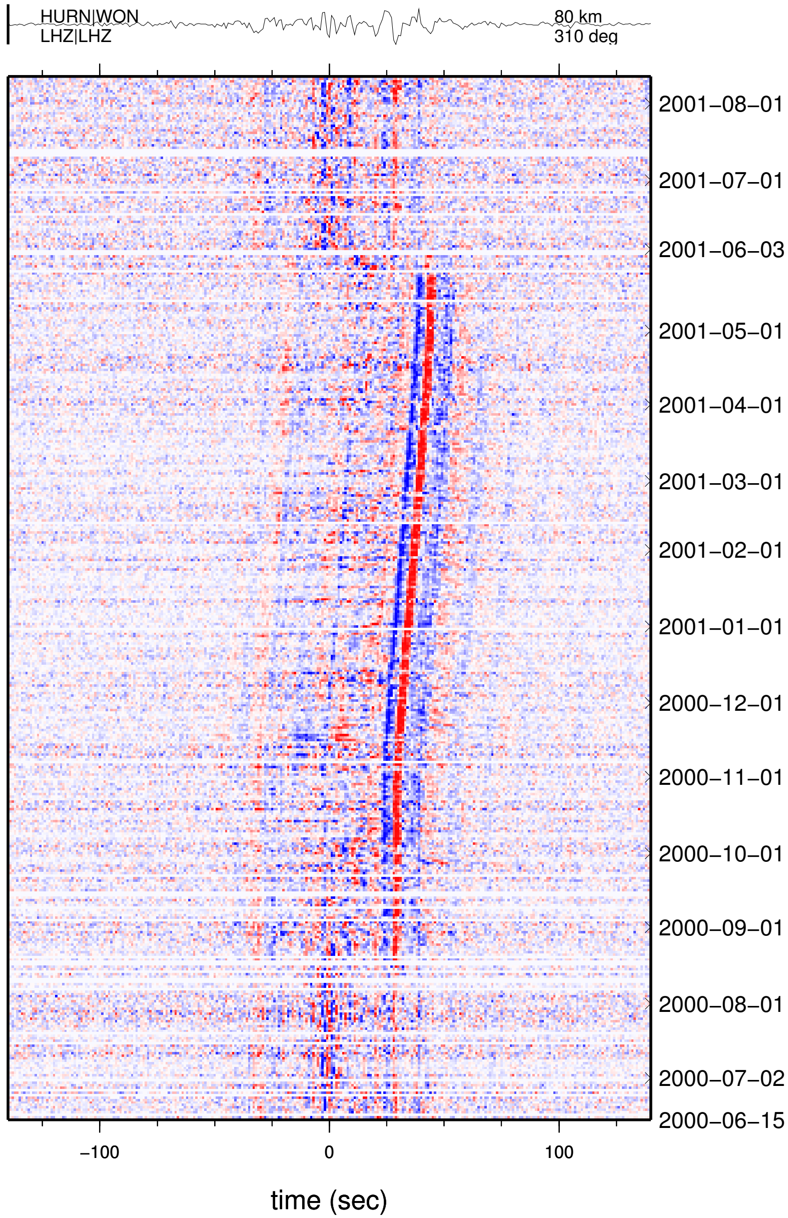
Ambient noise cross correlations:
Can be used to check clock drift

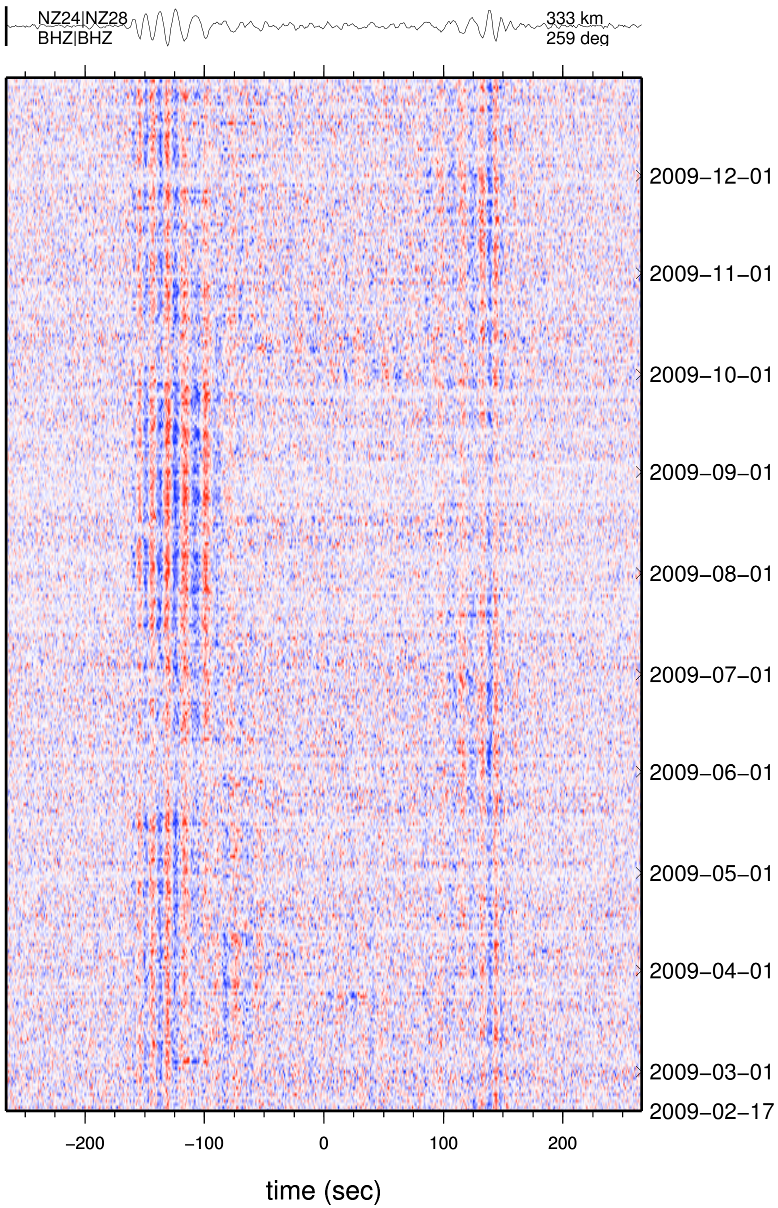


Example from BEAAR PASSCAL experiment in Alaska, 1999-2000

One year of cross correlations beween BEAAR stations HURN and WCN

J. Stachnik

Ambient noise cross correlations:
Can be used to check clock drift



One year of cross correlations beween MOANA OBS stations NZ24 and NZ28

J. Stachnik

Ambient noise cross correlations:
Can be used to orient horizontal components

GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 1–6, doi:10.1002/grl.50698, 2013

Determining the orientations of ocean bottom seismometers using ambient noise correlation

Yang Zha,[1] Spahr C. Webb,[1] and William Menke[1]

Received 25 April 2013; revised 16 June 2013; accepted 24 June 2013.

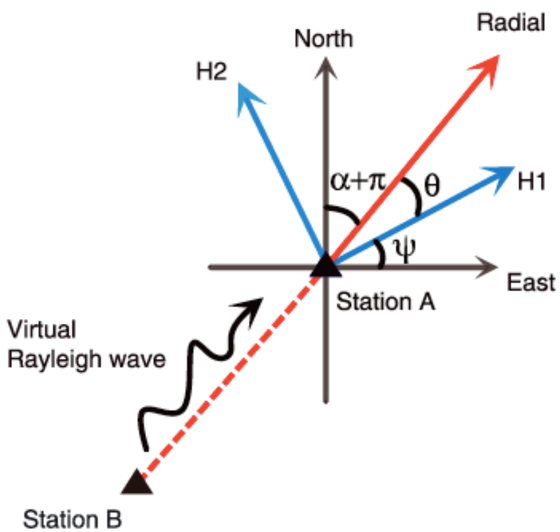
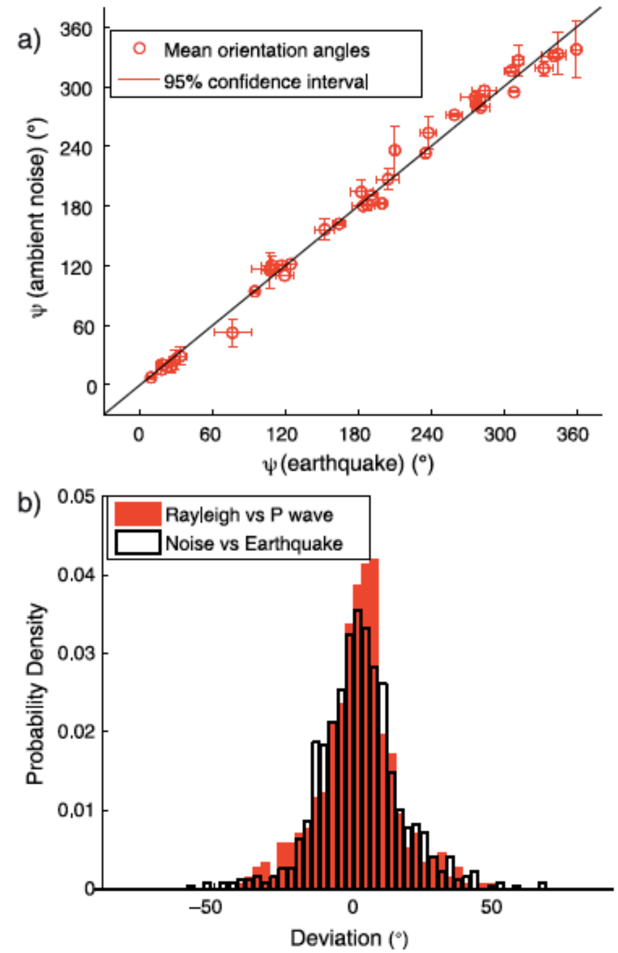


Figure 1. Illustration of the coordinate systems and virtual Rayleigh wave propagating from station B to A used to calculate orientation angle for A. H_1 and H_2: orthogonal OBS components of unknown direction; ψ : orientation angle for A; α: back azimuth from A to B; θ: correction angle to rotate H_1 and H_2 component to radial and transverse direction.



Ambient noise cross correlations:
For dispersion measurements and structural studies

Ambient Noise Group Velocities (6 s – 27 s)

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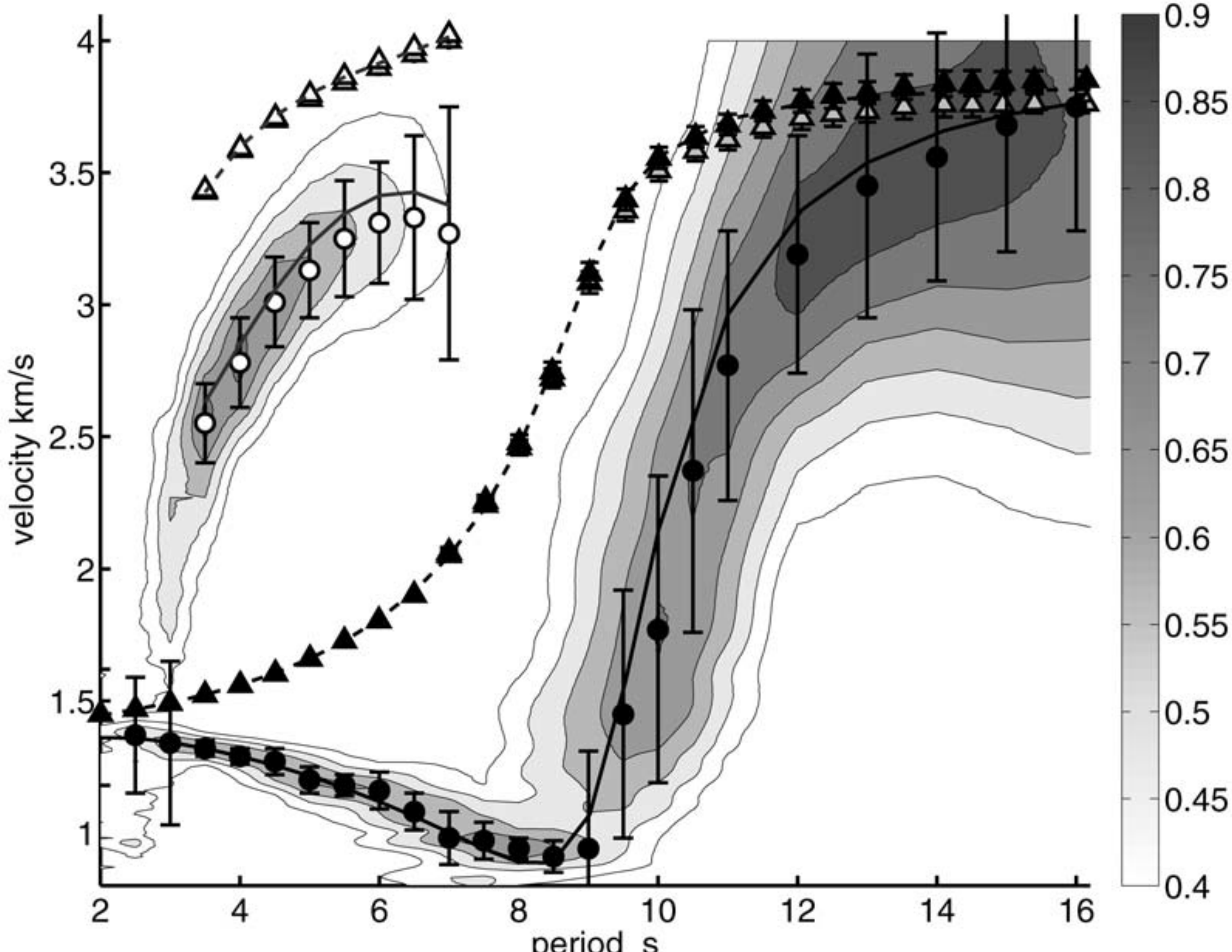
J. Stachnik

Ambient noise cross correlations:
For dispersion measurements and structural studies

Caution – very slow velocities at short periods



Harmon et al., BSSA, 2007

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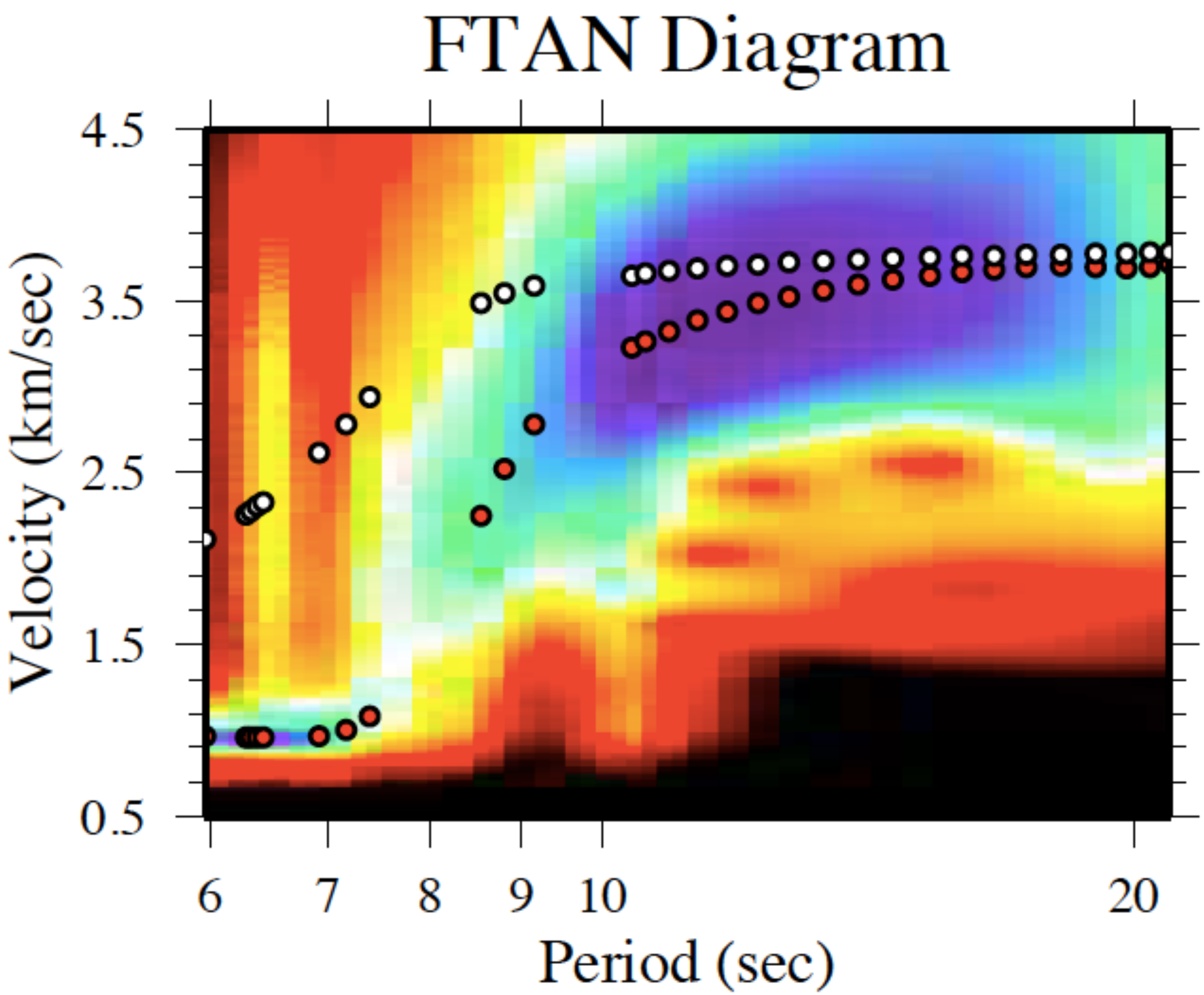

Ye, Ritzwoller, Shen, G-cubed, 2013

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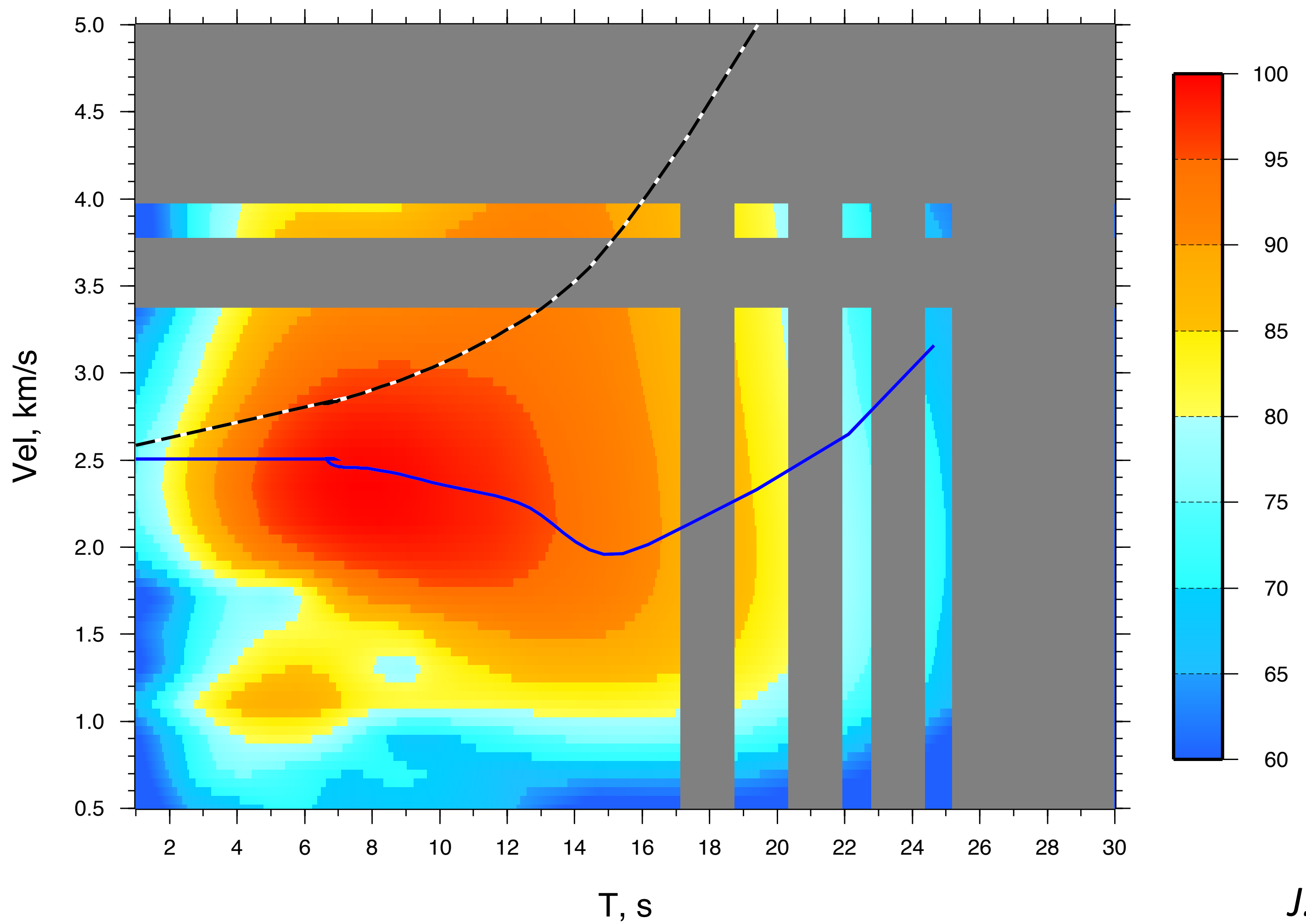
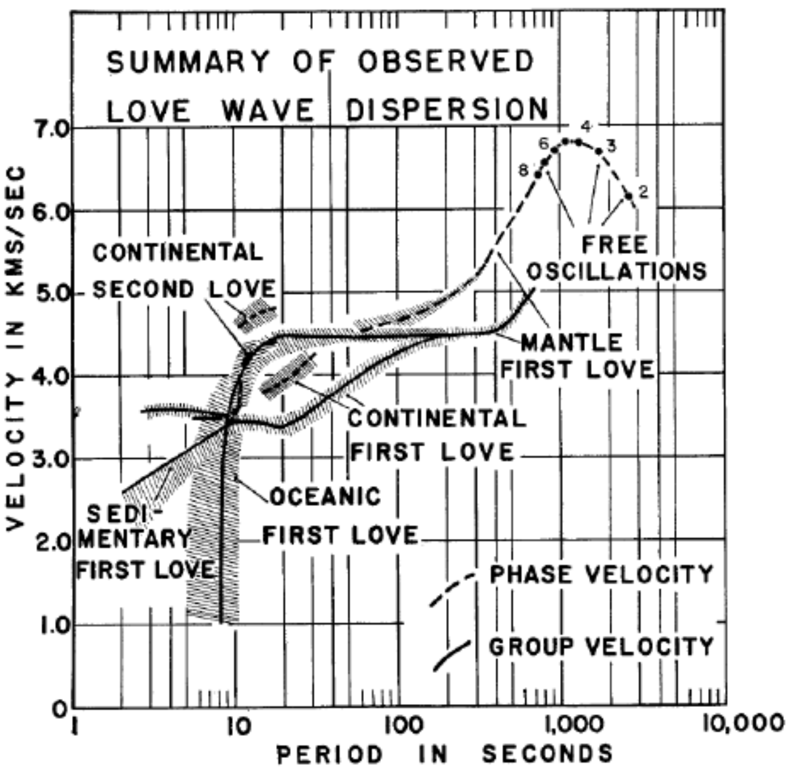
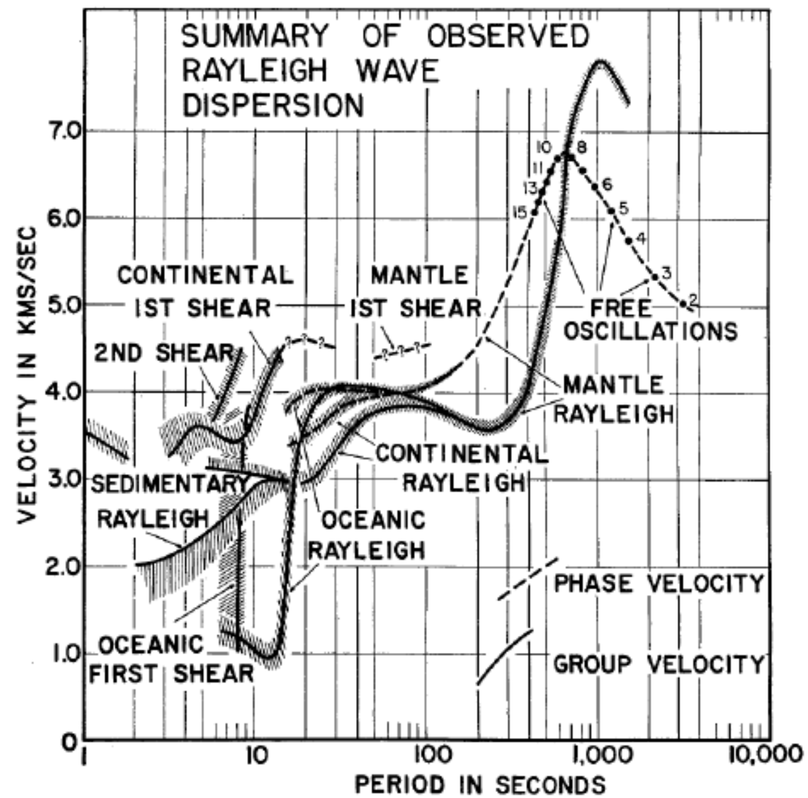


J. Stachnik

Surface wave studies have been around a long time in seismology





Oliver, 1962

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Can Improve SNR on vertical by removing compliance signal

Bulletin of the Seismological Society of America, 90, 4, pp. 952–963, August 2000

Identifying and Removing Tilt Noise from Low-Frequency (<0.1 Hz) Seafloor Vertical Seismic Data

by Wayne C. Crawford and Spahr C. Webb

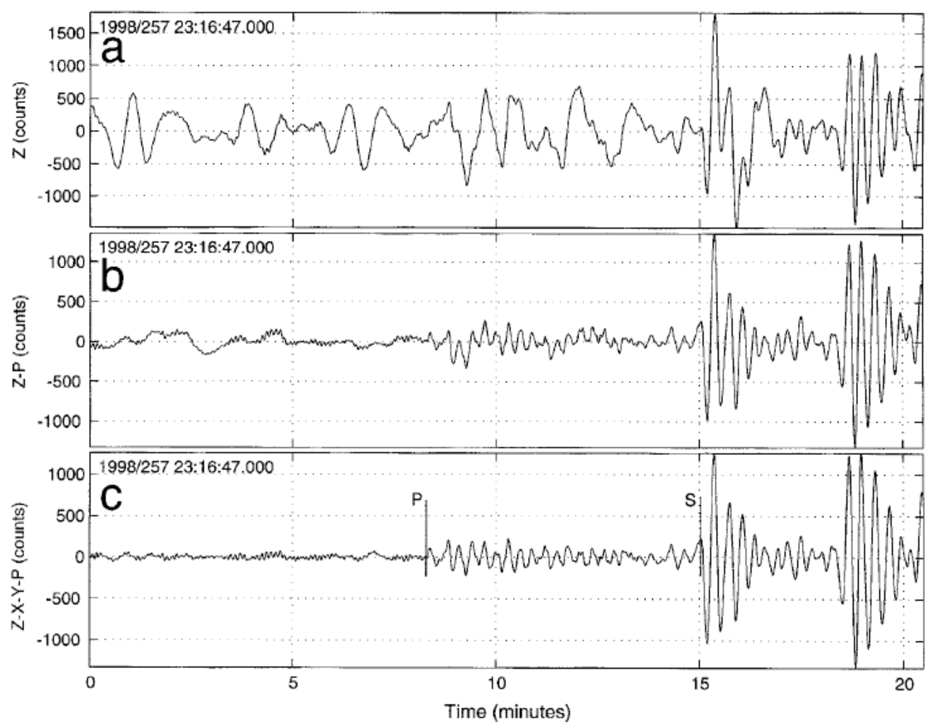
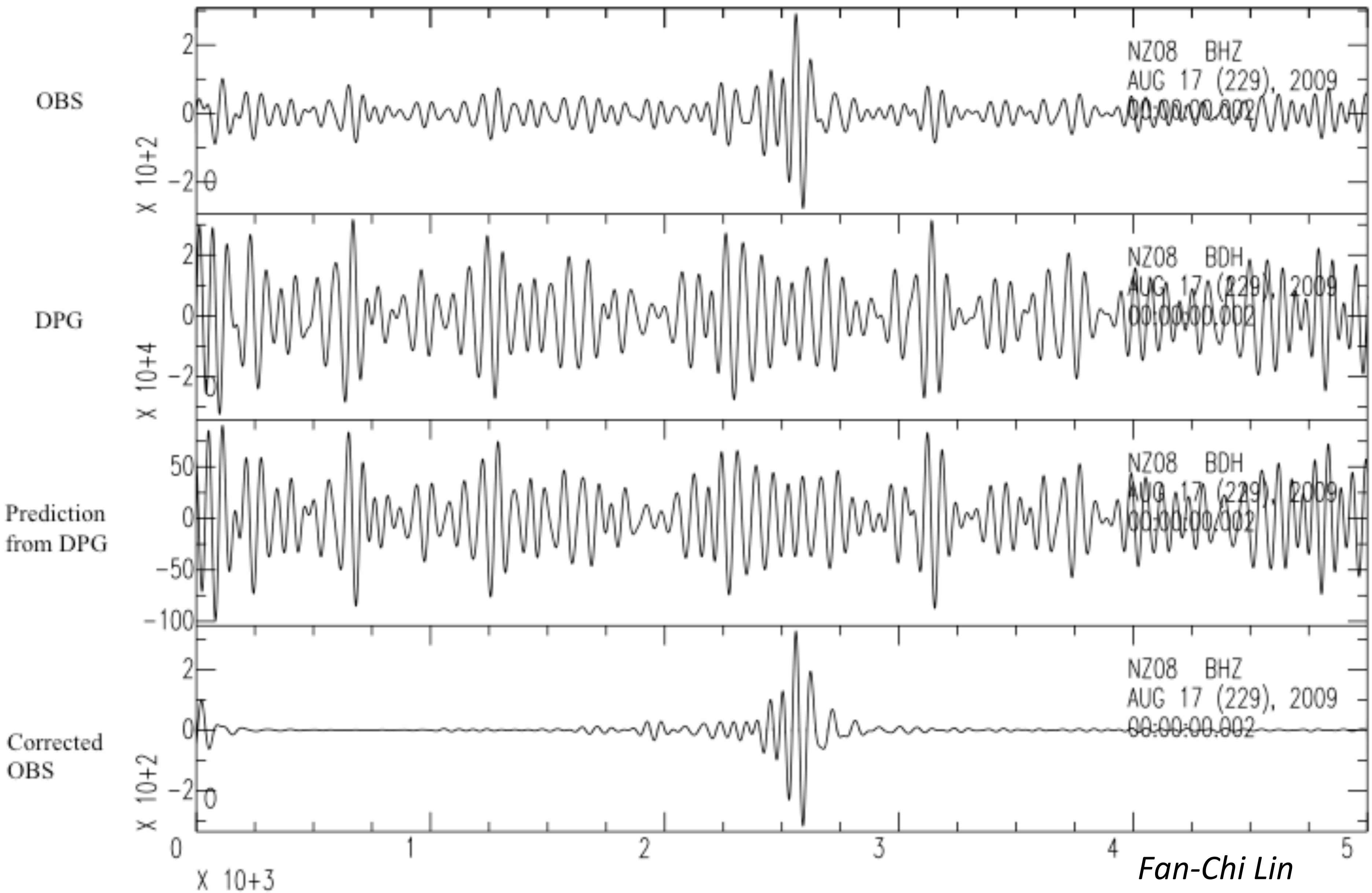


Figure 9. STS-2 vertical seismic record of a magnitude 6.2 earthquake (Δ = 44.2°). All traces are bandpass-filtered between 0.001 and 0.05 Hz. (a) Original vertical trace; (b) vertical trace after subtracting coherent pressure signal; (c) vertical trace after subtracting coherent pressure and horizontal signals.

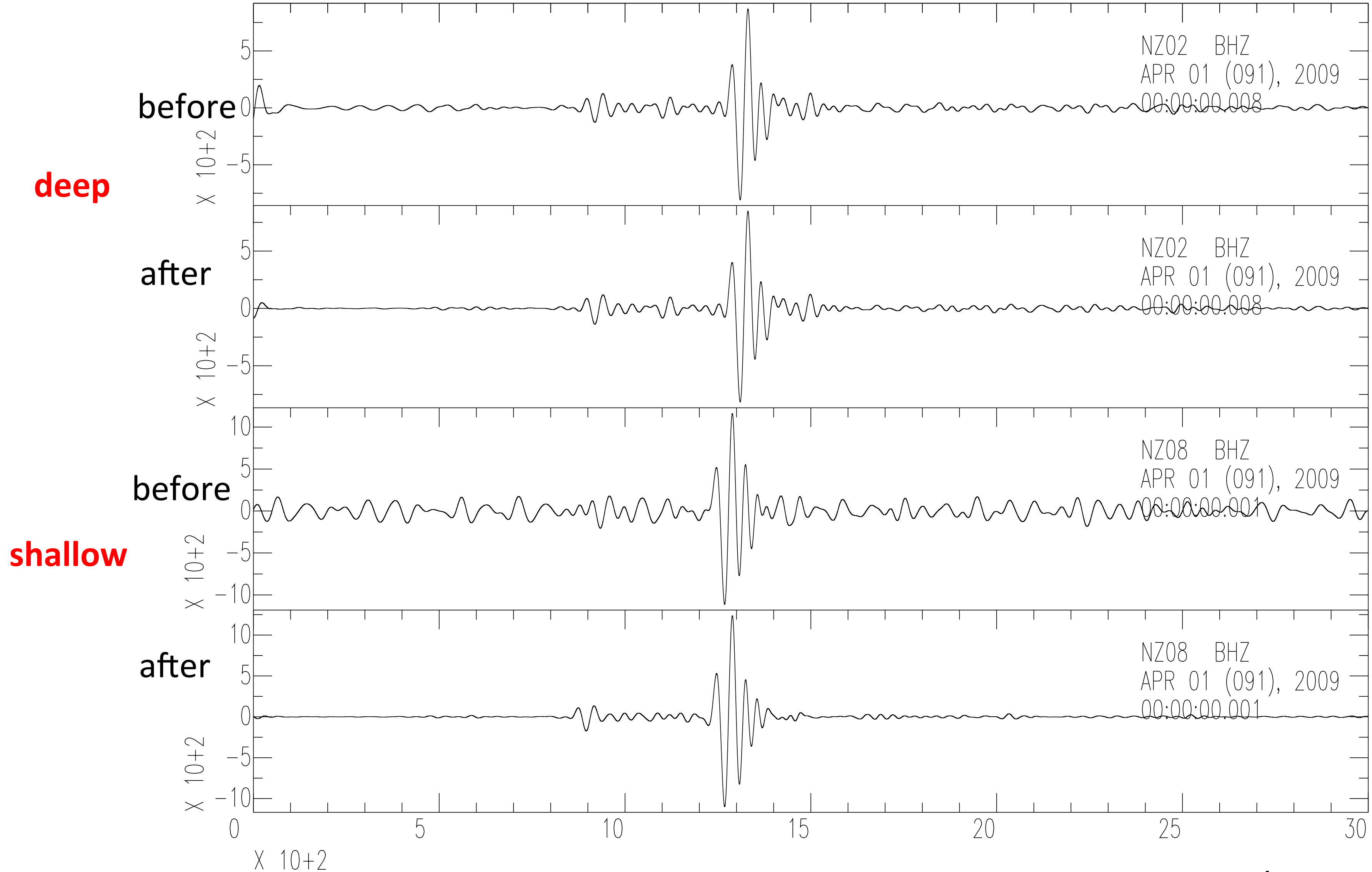
Can Improve SNR on vertical by removing compliance signal



Fan-Chi Lin

Can Improve SNR on vertical by removing compliance signal

Has a larger effect at shallow depths



Fan-Chi Lin

Surface waves

8 s

20 s

40 s

70 s

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Josh Stachnik & Fan-Chi Lin

Surface waves

Unconstrained Moho

Constrained Moho

Unpublished figure removed

Stachnik, Ball, Lin

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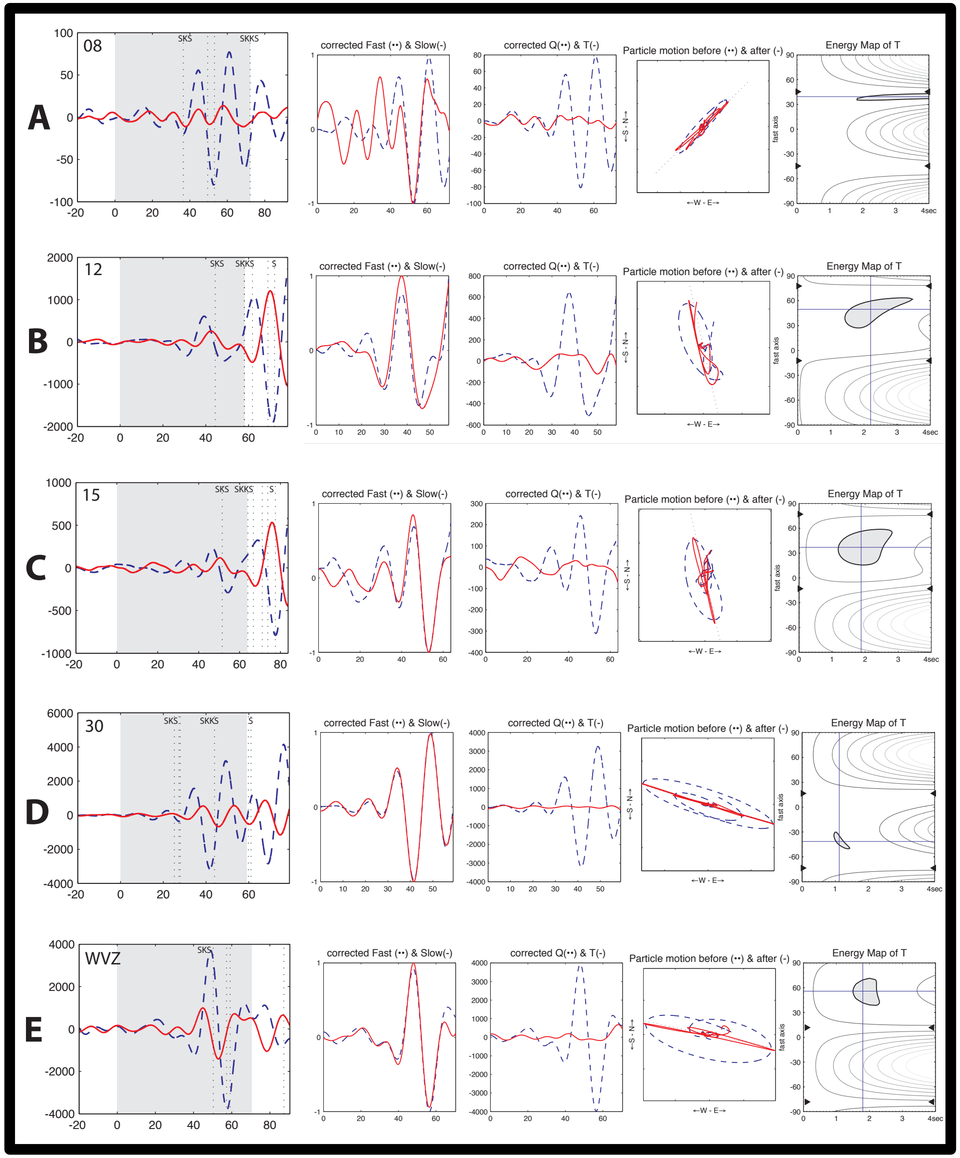
Shear Wave Splitting

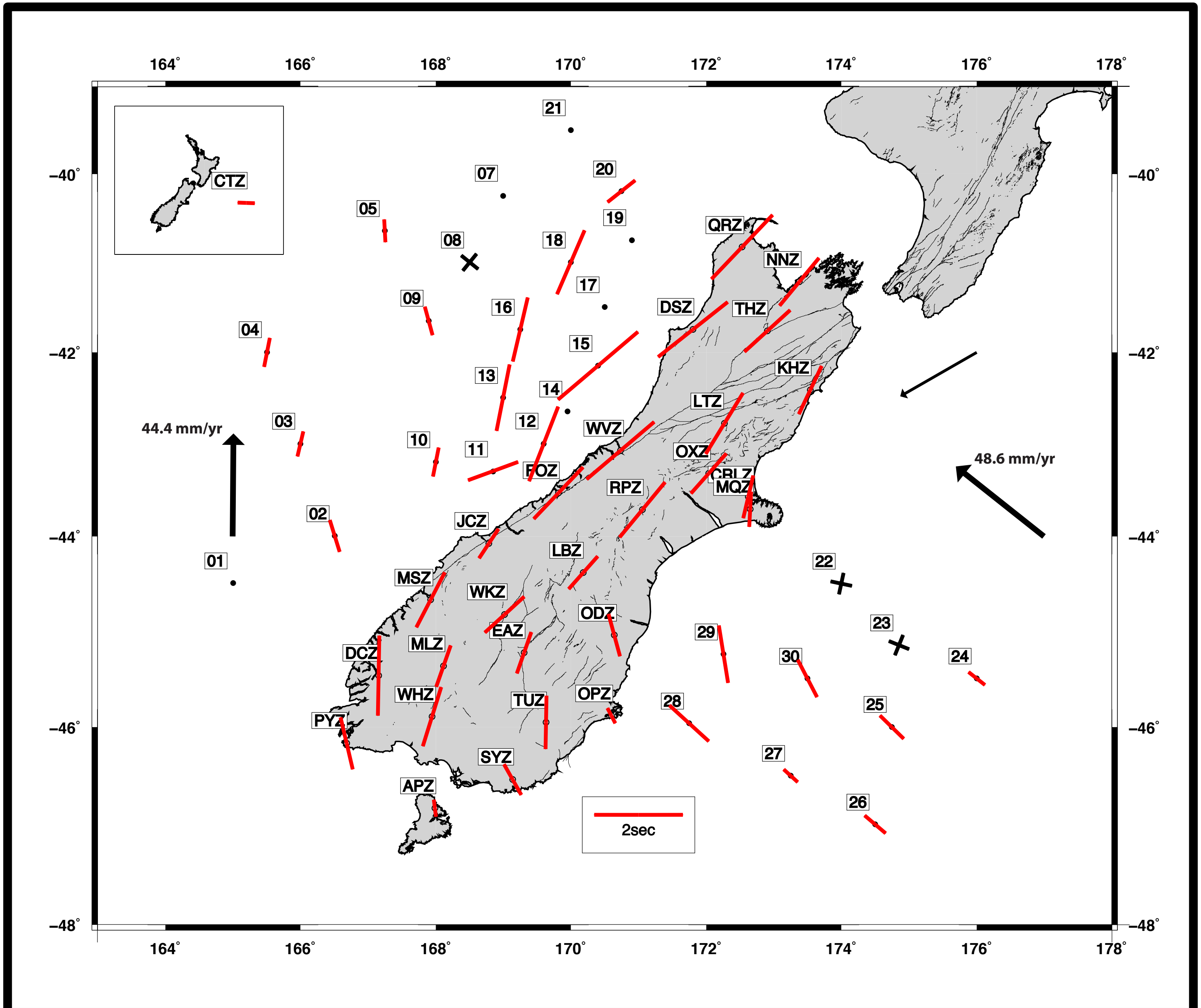
Challenging to find good events



See workshop poster by Dan Zietlow

Dan Zietlow

Shear Wave Splitting



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OBS Receiver Functions

- Sediment reverberations (Ultra-low Vs)
- Water layer reverberations
- Noise often totally obscures arrivals like Moho

NZ16 R

NZ16 T

See workshop poster by Justin Ball

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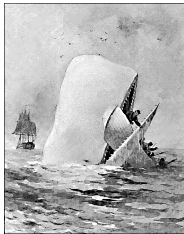
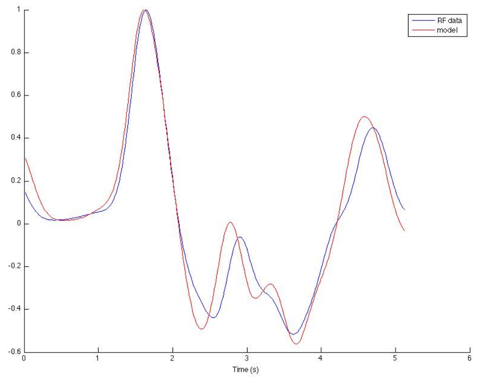
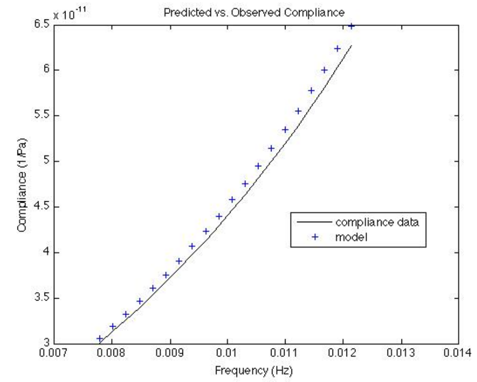
Epicentral Stacks



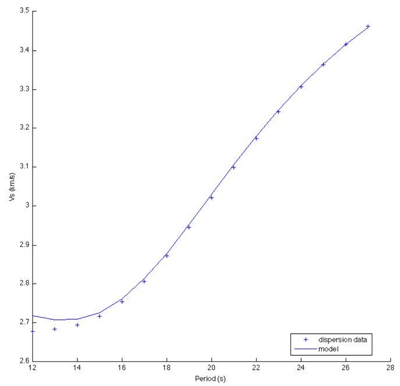
Joint inversion of compliance, receiver functions, and surface wave dispersion: synthetic test



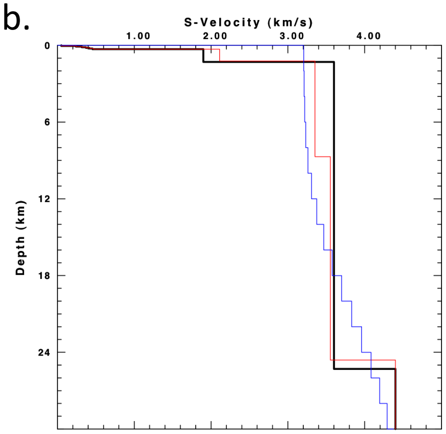
a.



b.



c.



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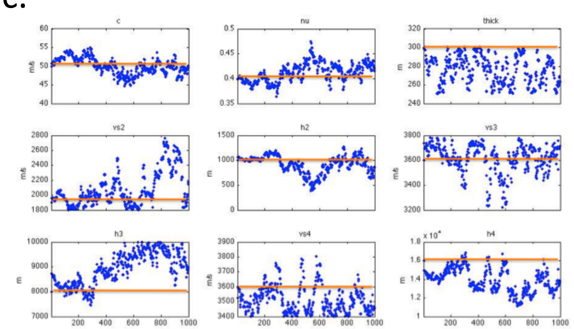
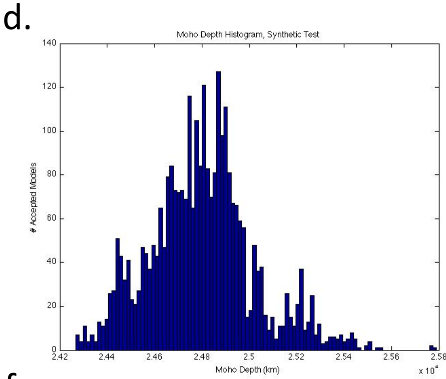


e.



f.

See workshop poster by Justin Ball

SUMMARY

1. Noise spectra useful for QA/QC
   Infragravity wave interferometry possible with DPG data
2. Uses of noise –
   ambient noise to check clock drift
   ambient noise to orient sensors (Zha et al., 2013)
   ambient noise tomography
      short periods can be tricky
3. Significant noise reduction on vertical component possible
      following method of Crawford and Webb, 2000
4. Measurements requiring horizontal components in teleseismic body wave band can be challenging – such as shear wave splitting, receiver functions
   Need larger events than equivalent on-land studies
   Improvement via Stacking
   Supplement with other constraints