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Benchmarking passive seismic estimates of cover-thickness

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Purpose of the study

- Evaluate capabilities of passive seismic methods used for engineering purposes (depth <30 m) to map deep structures up to ~500 m depth.
- Benchmark precision of basement depth determination against known drilling data.
- Establish survey methods and logistic strategies for efficient field campaigns.

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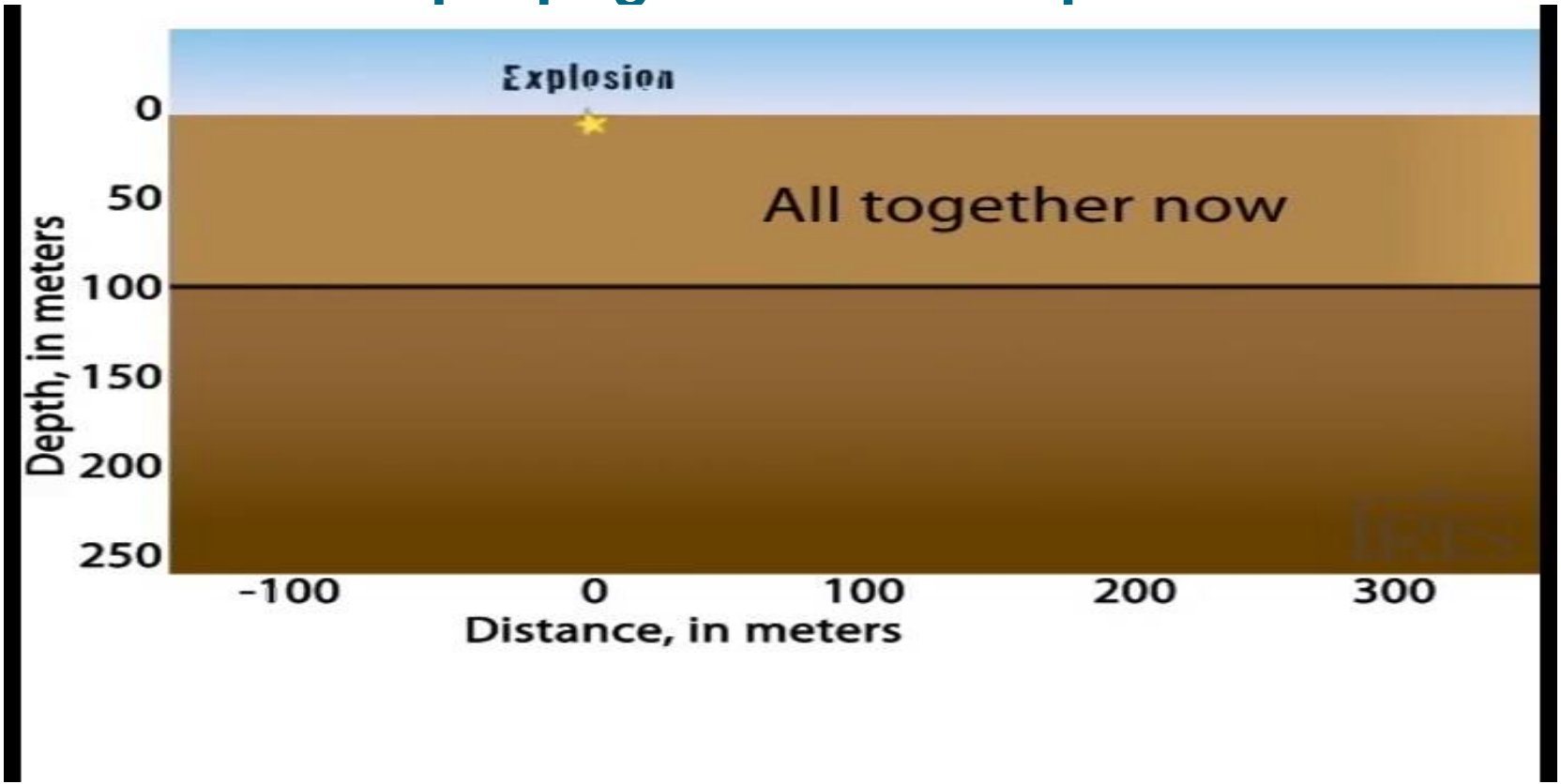
Seismic wave propagation from explosion



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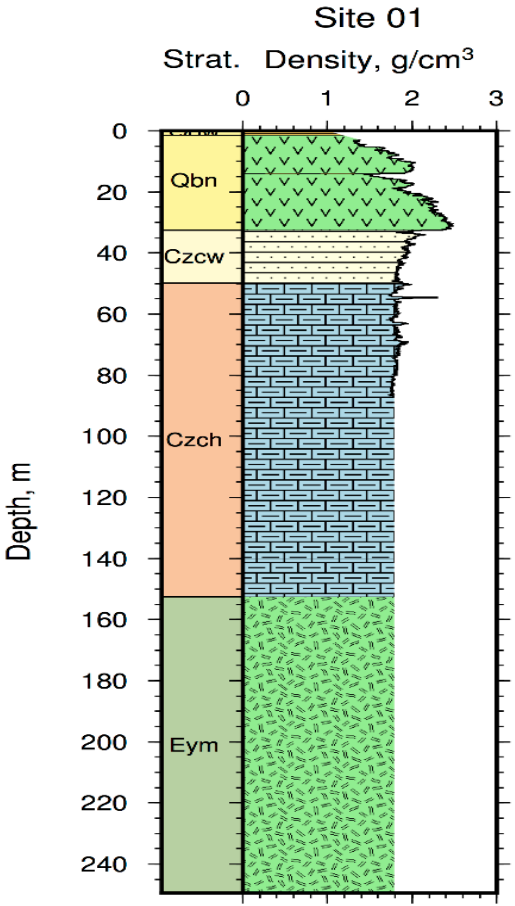
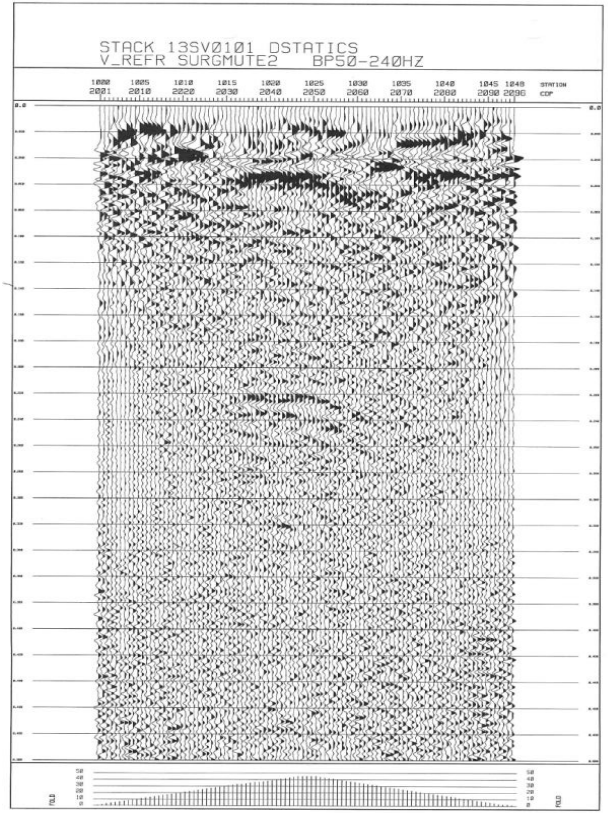
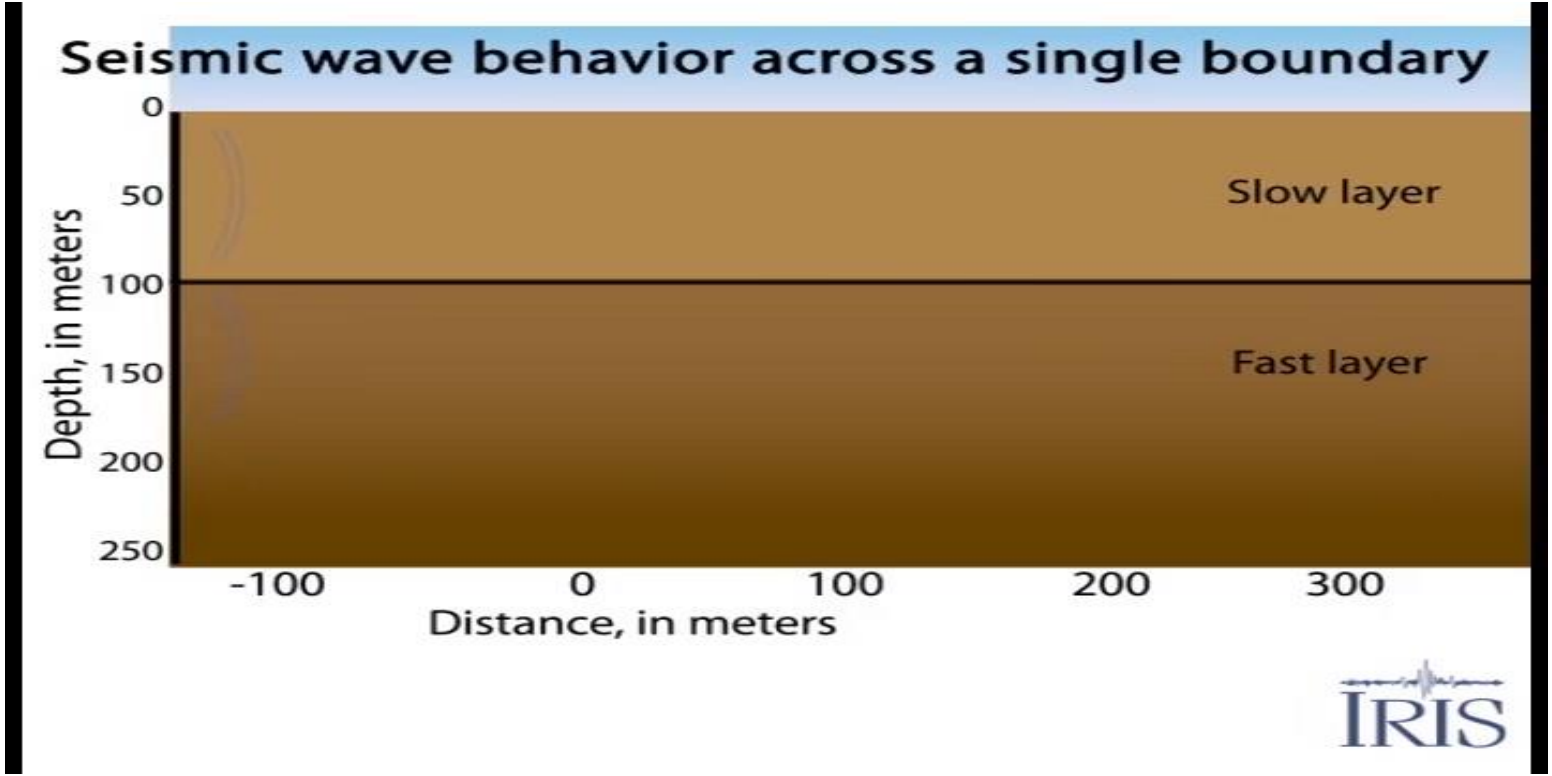
Shallow strong reflector shadows structures underneath





Seismic wave propagation from distant source seismic noise case



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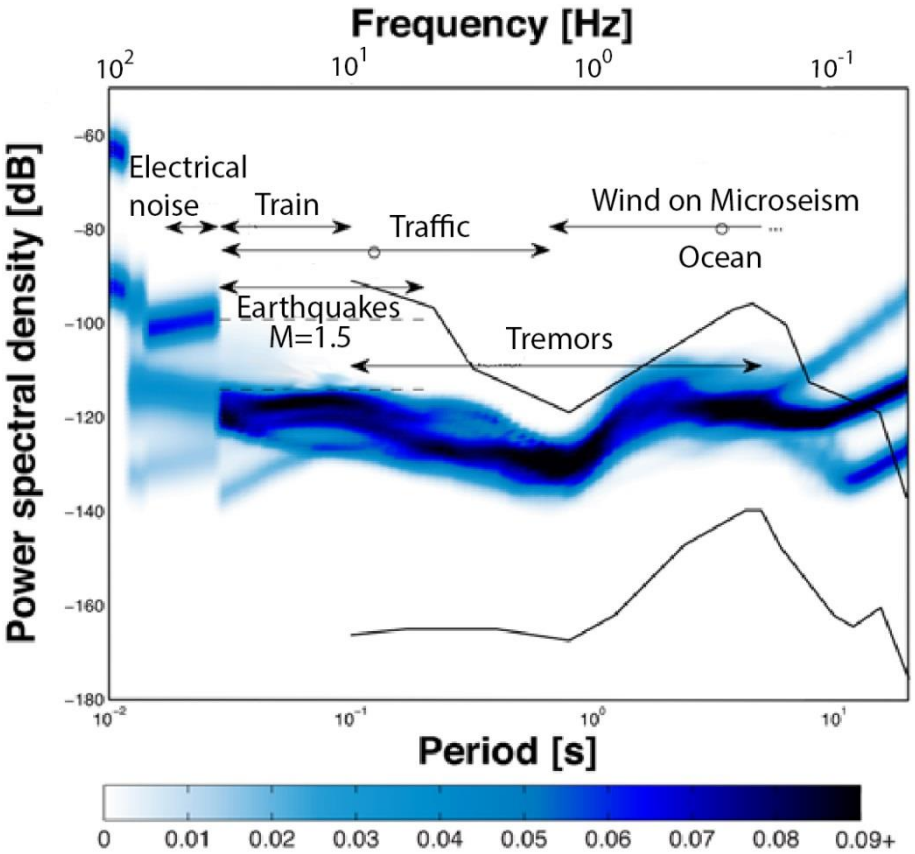
Source of the ambient noise



After Boese et al. [2015]

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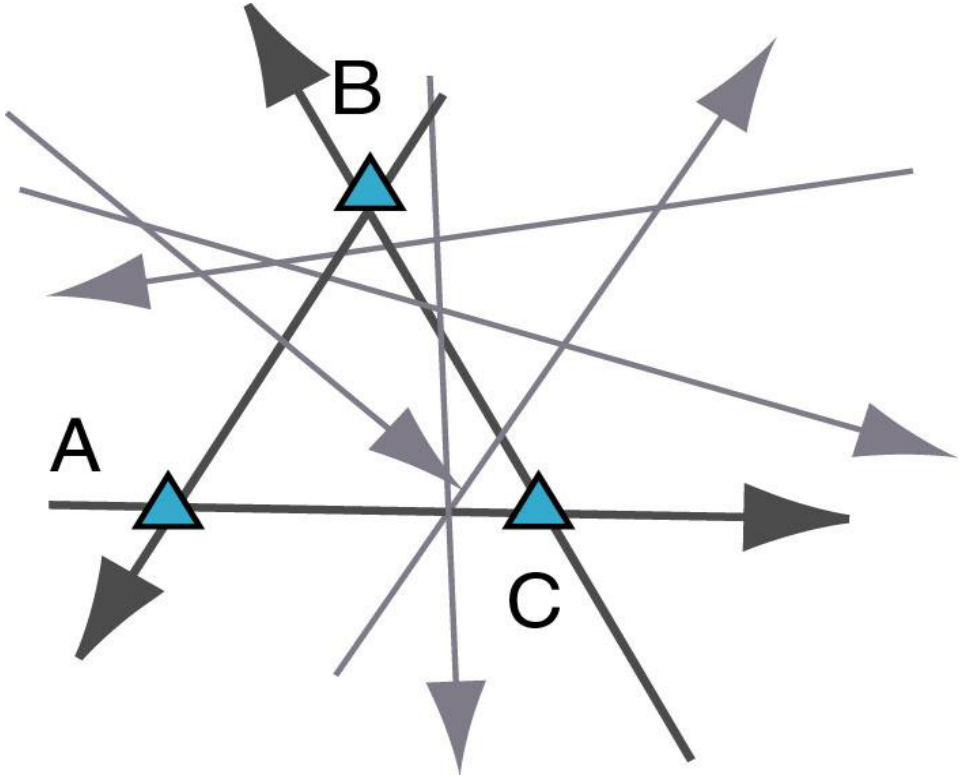
Ambient noise seismology based on assumption of diffuse seismic wavefield



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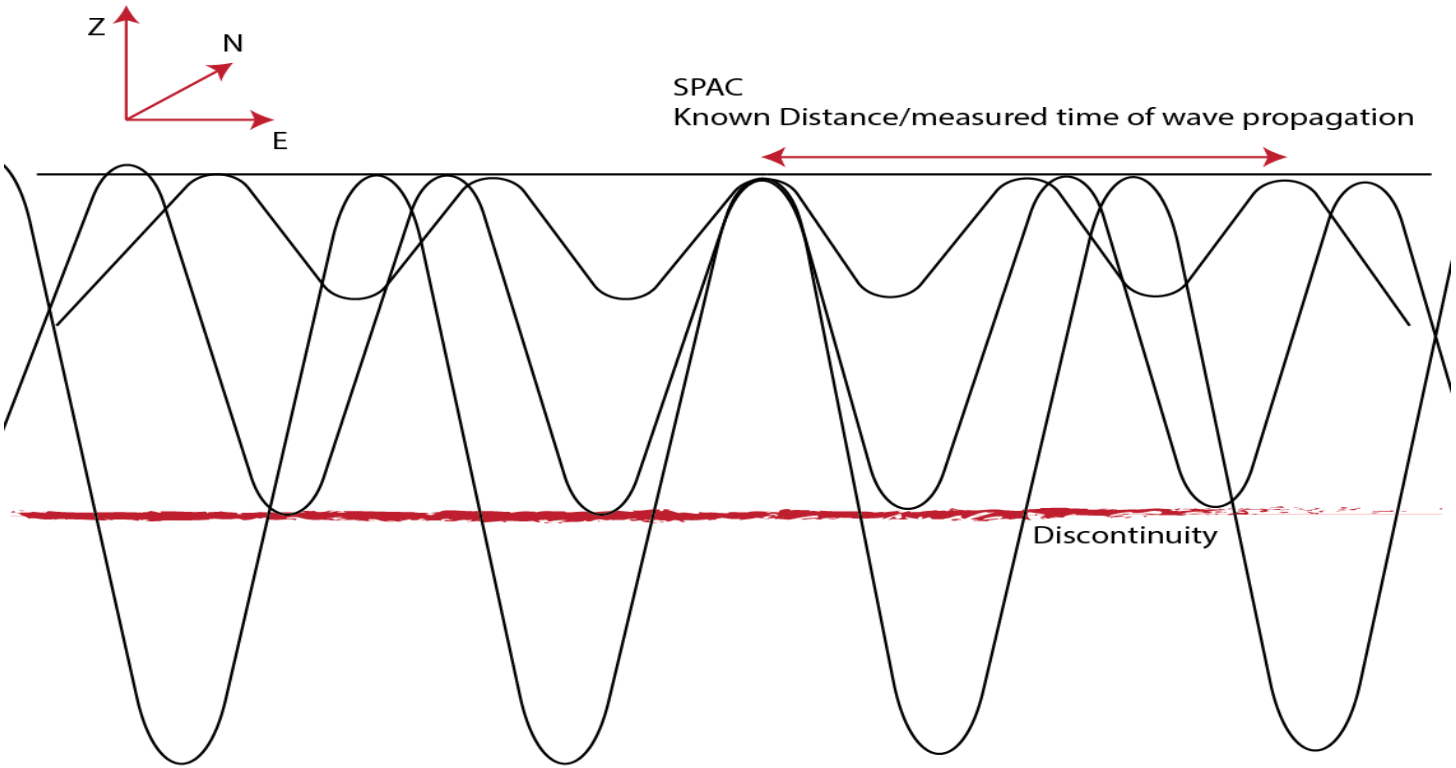
We use two methods: HVSR and SPAC

HVSR
Spectral ratio between
horizontal and vertical particle movement



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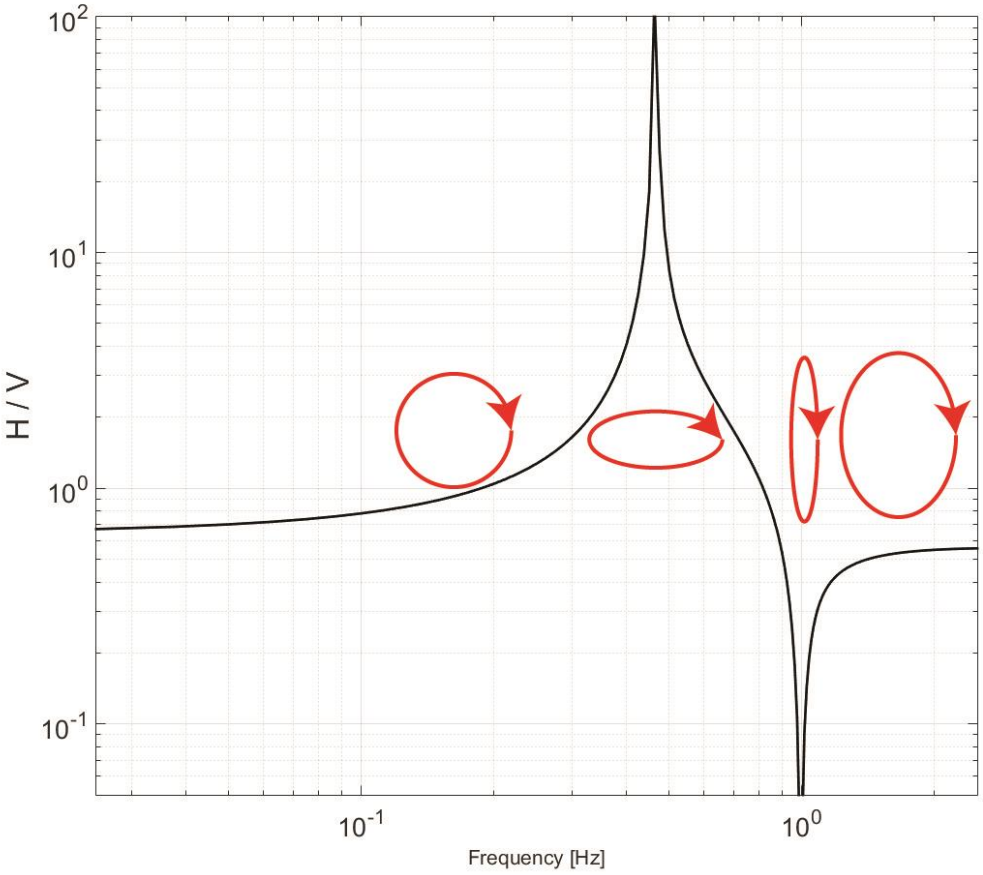
Horizontal to Vertical ratio of surface waves



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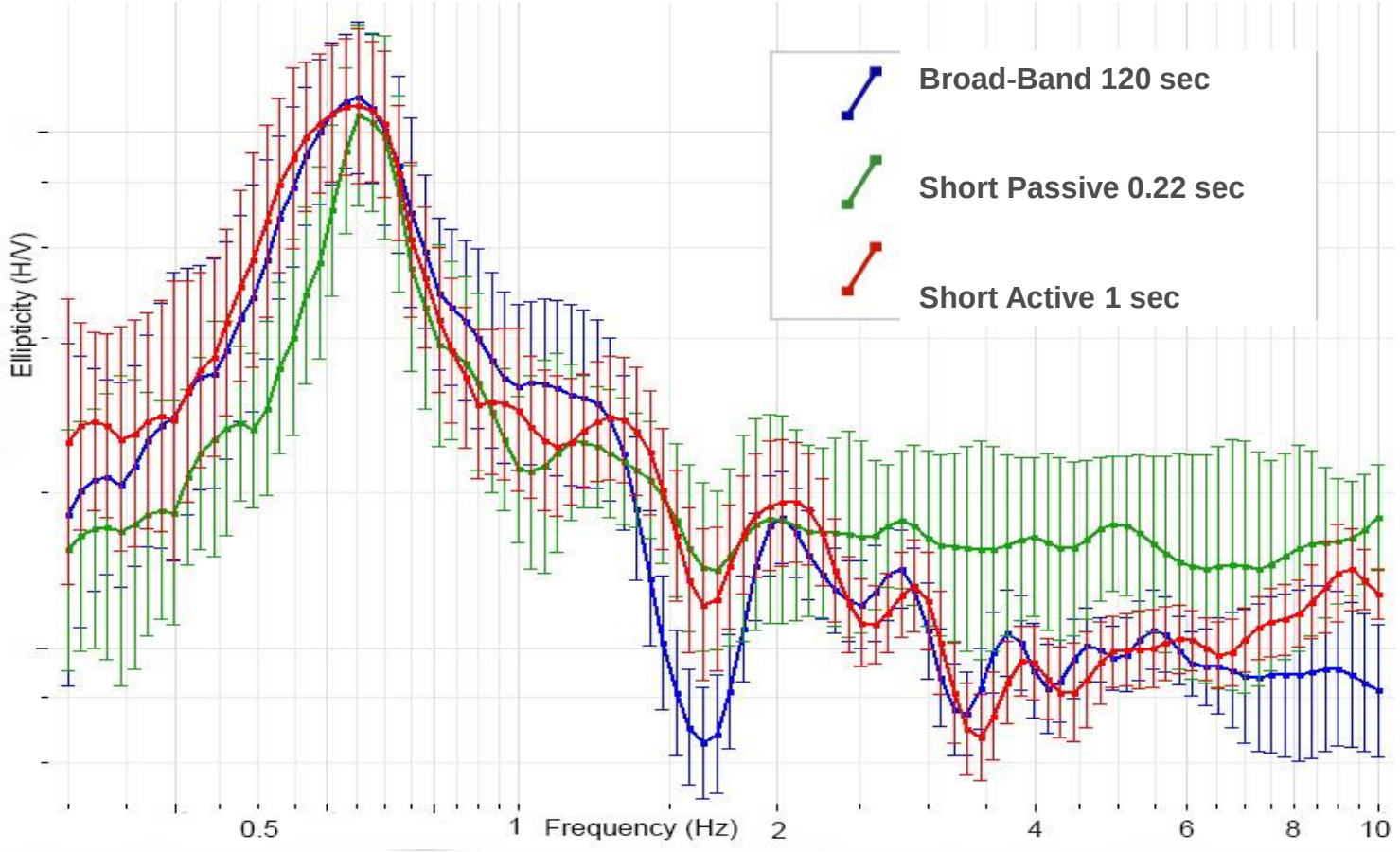
Seismic sensor selection – broad band?



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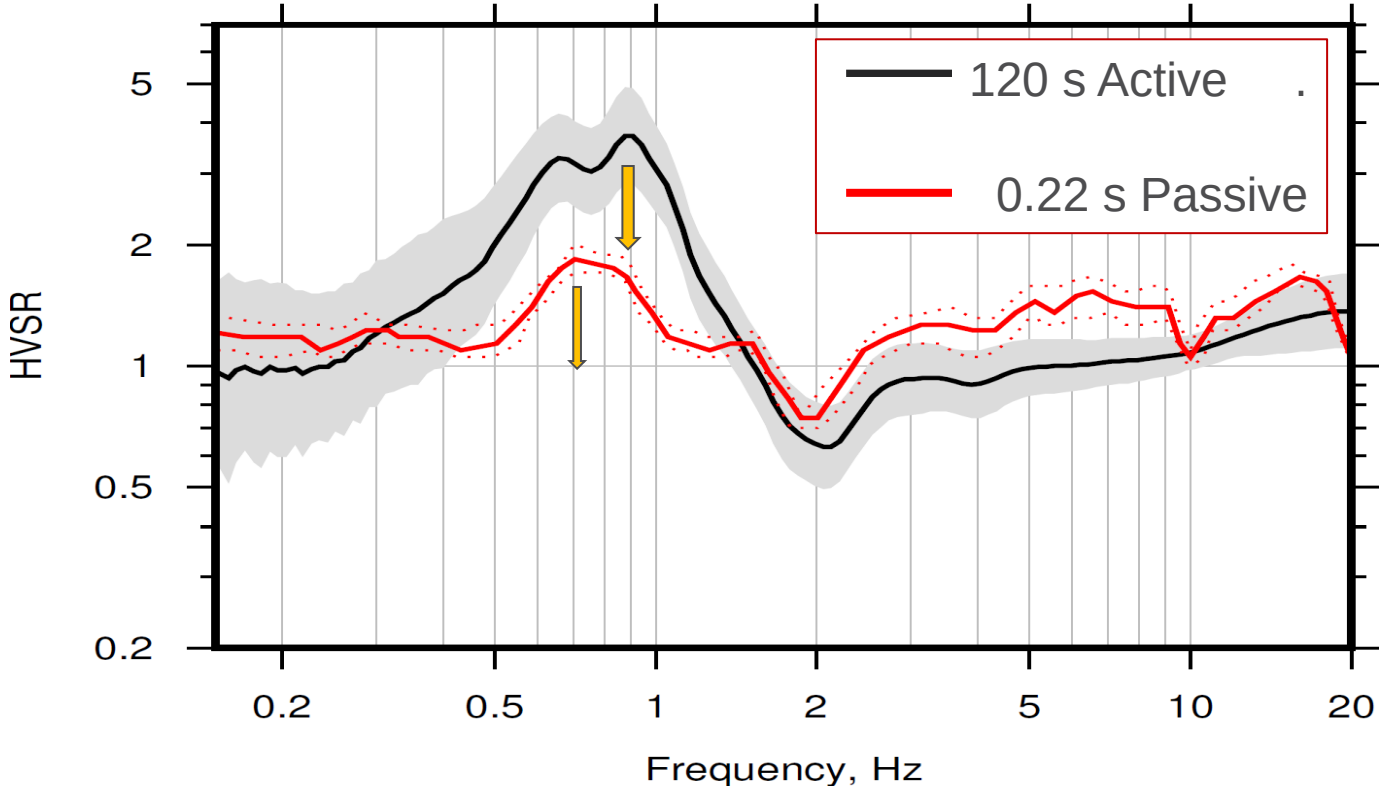
High distortion



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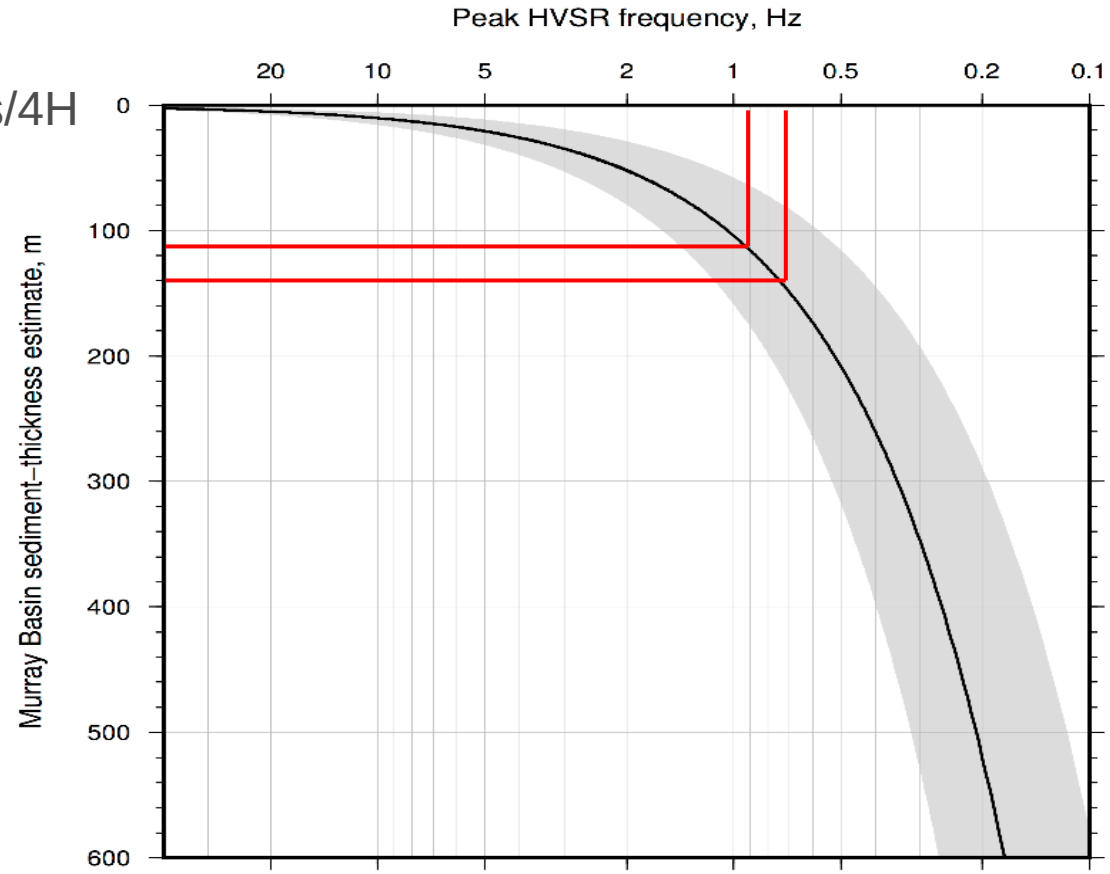
That could correspond to the error of ~30 m

Peak HVSR = Vs/4H



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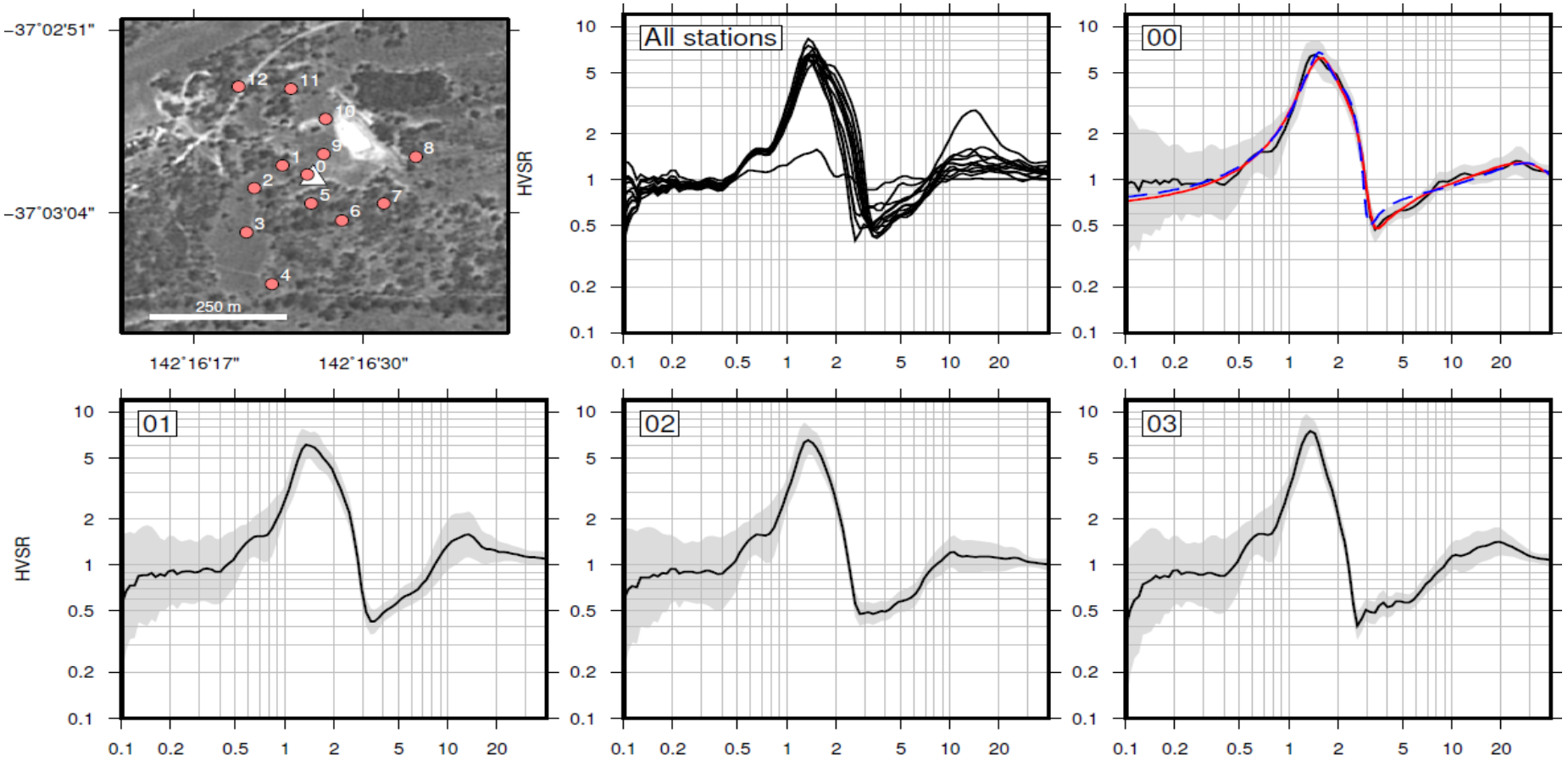
HVSR



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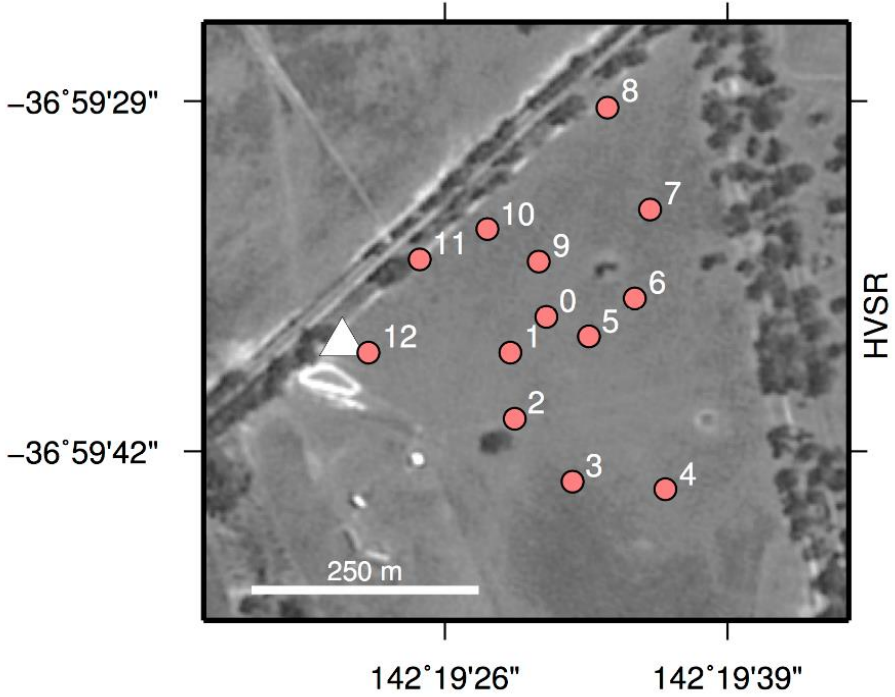
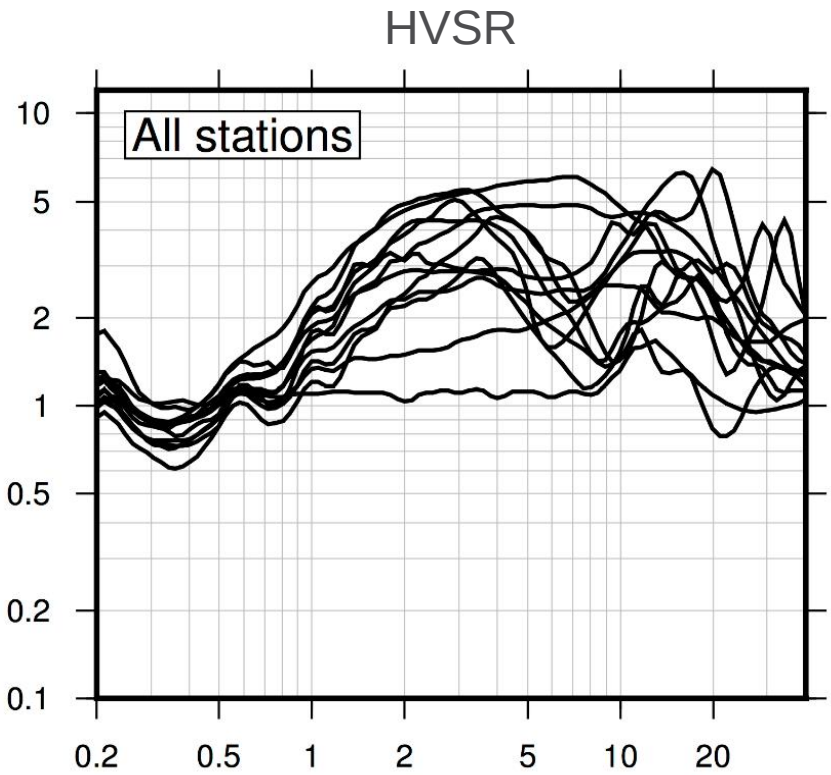
Why so many stations?





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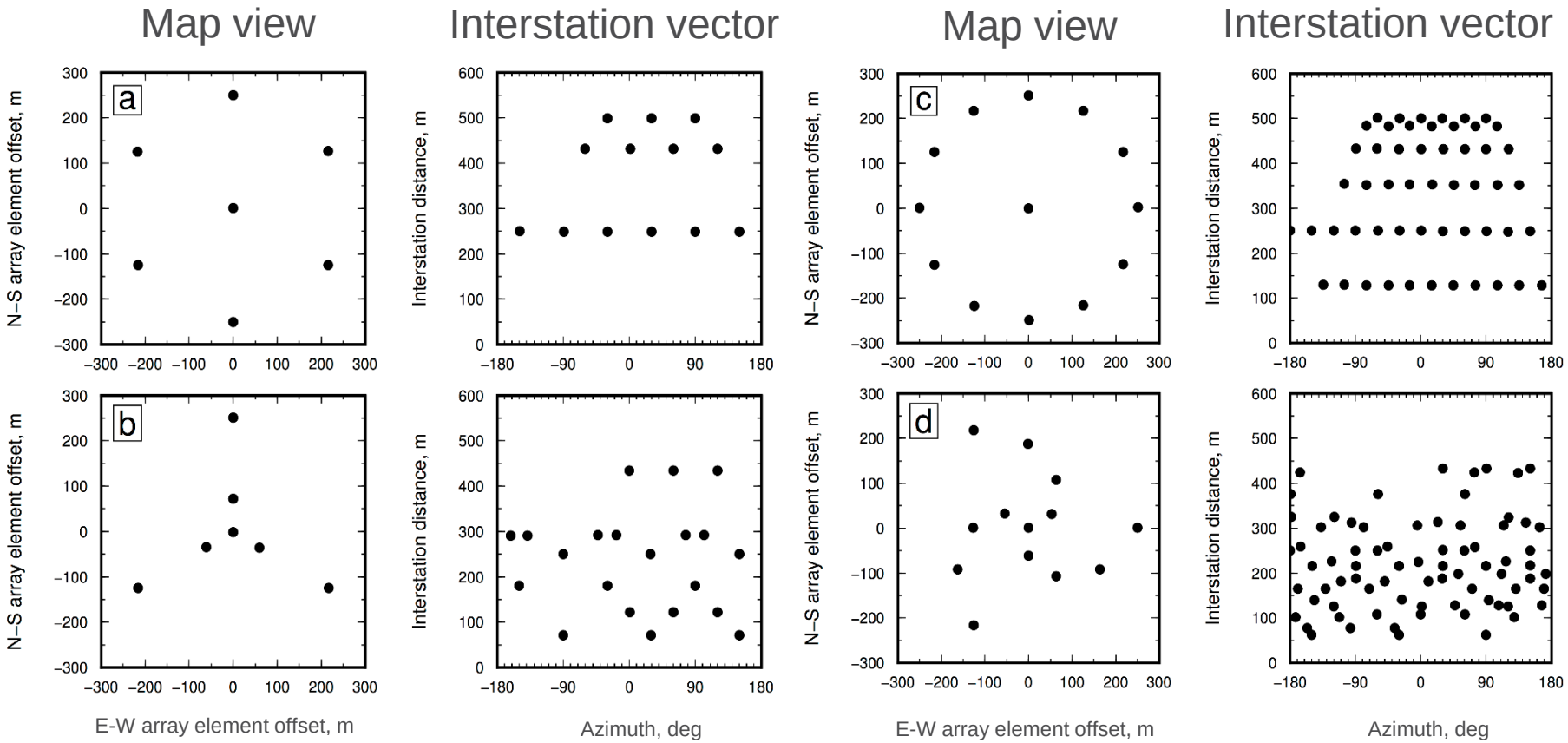
Seismic Array configurations



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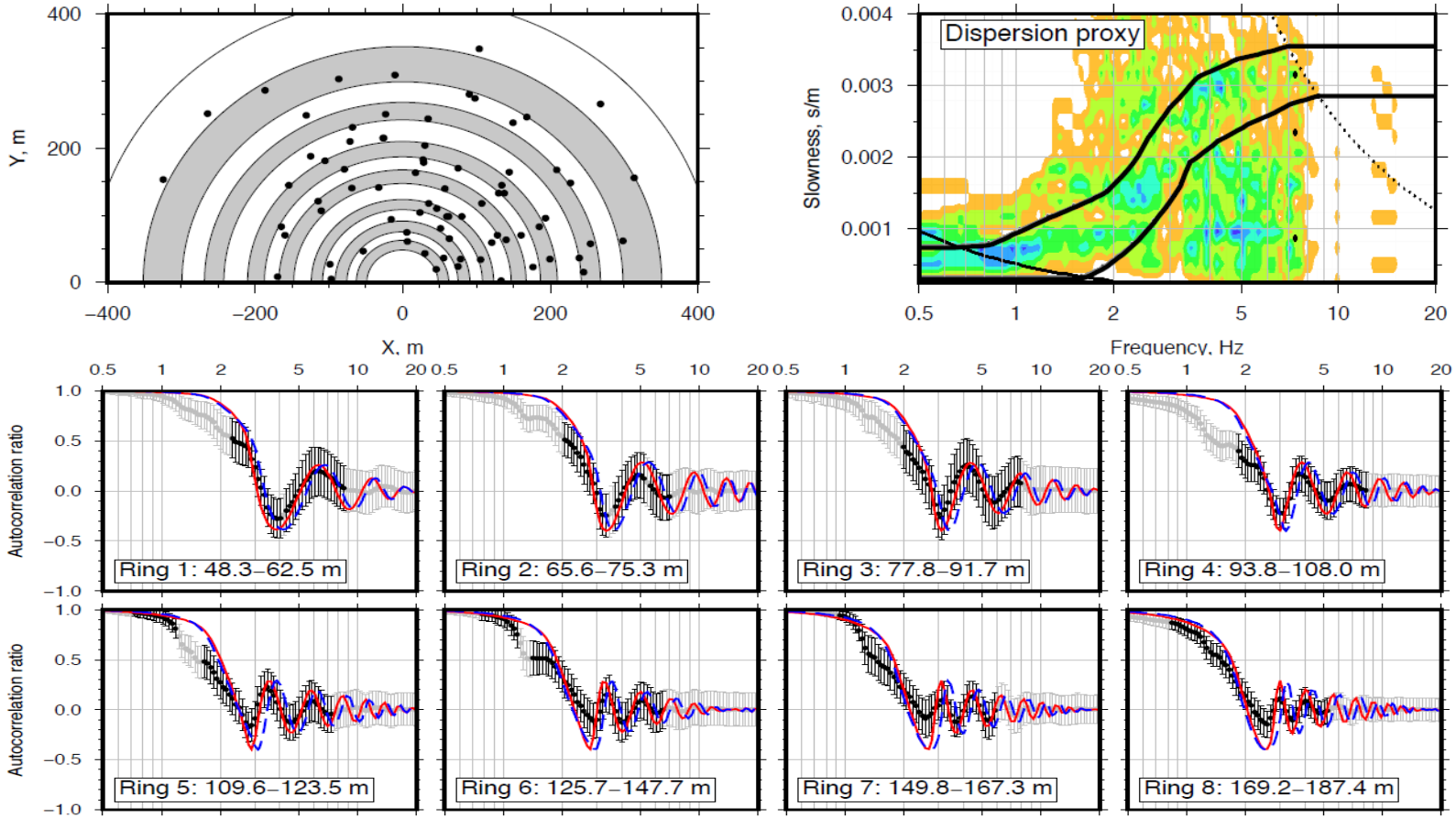
Example of SPAC processing



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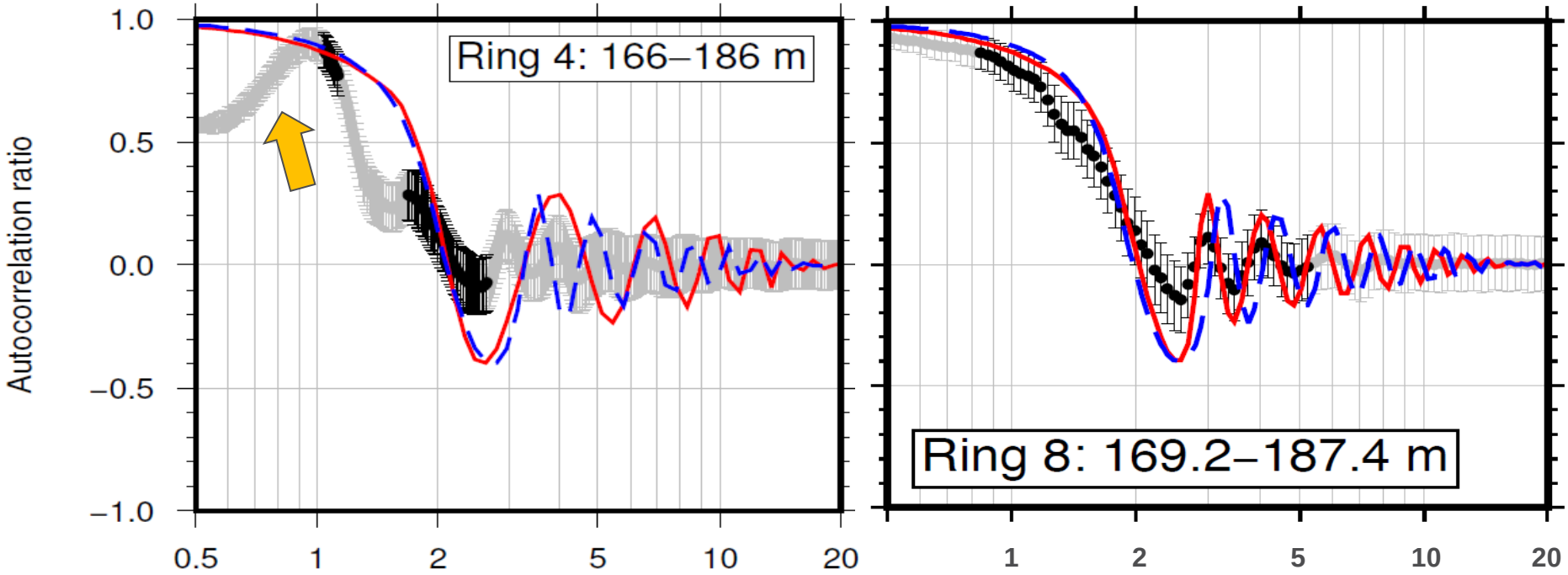
Example of recorder timing error



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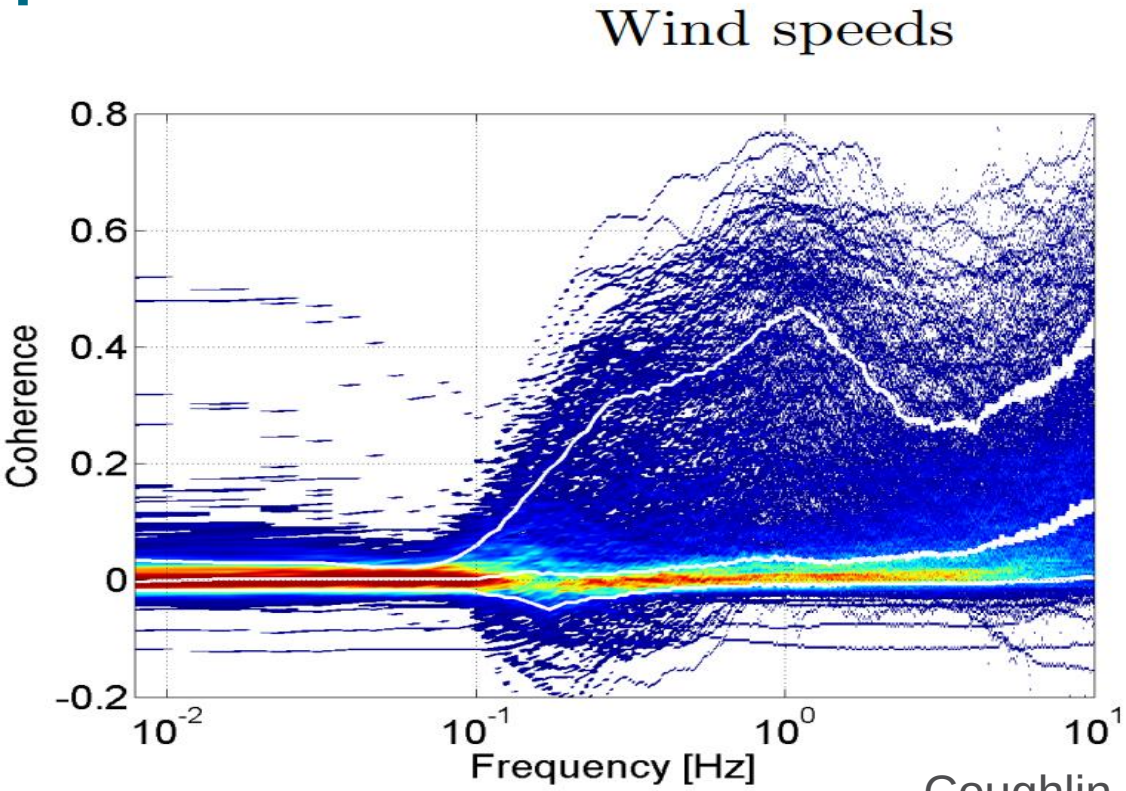
However some ambient noise sources can pose problems such as wind at the site



Coughlin and Harms [2012]

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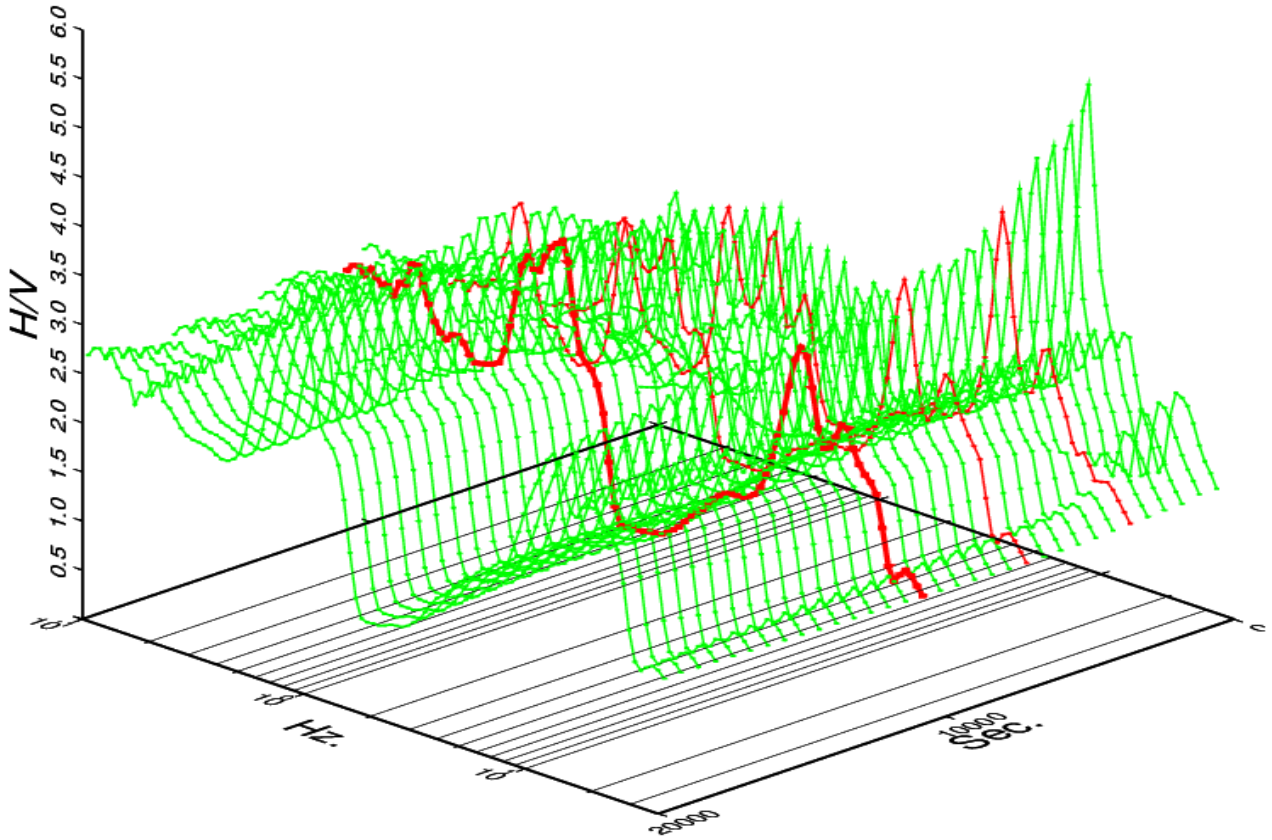
H/V stabilization occurs after ~3 hours



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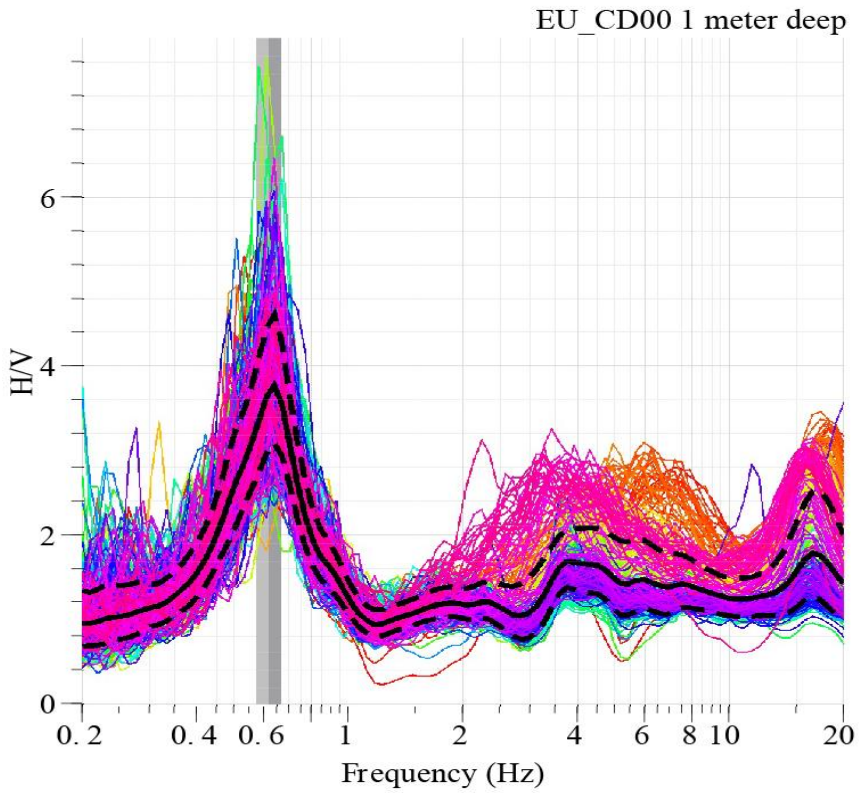
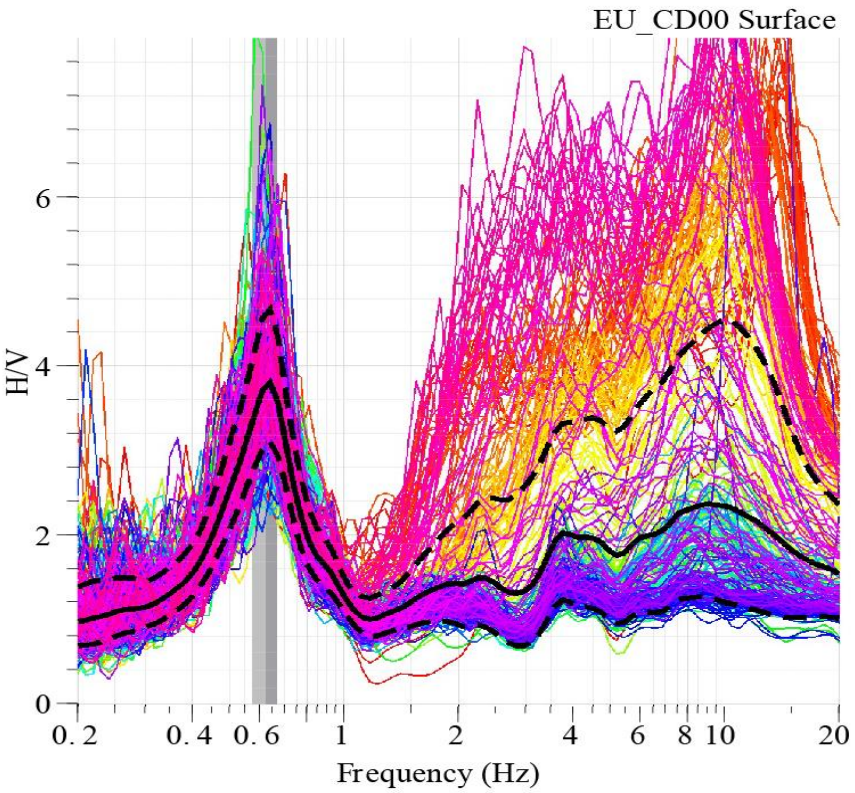
Effect of wind on H/V survey (15 hours)





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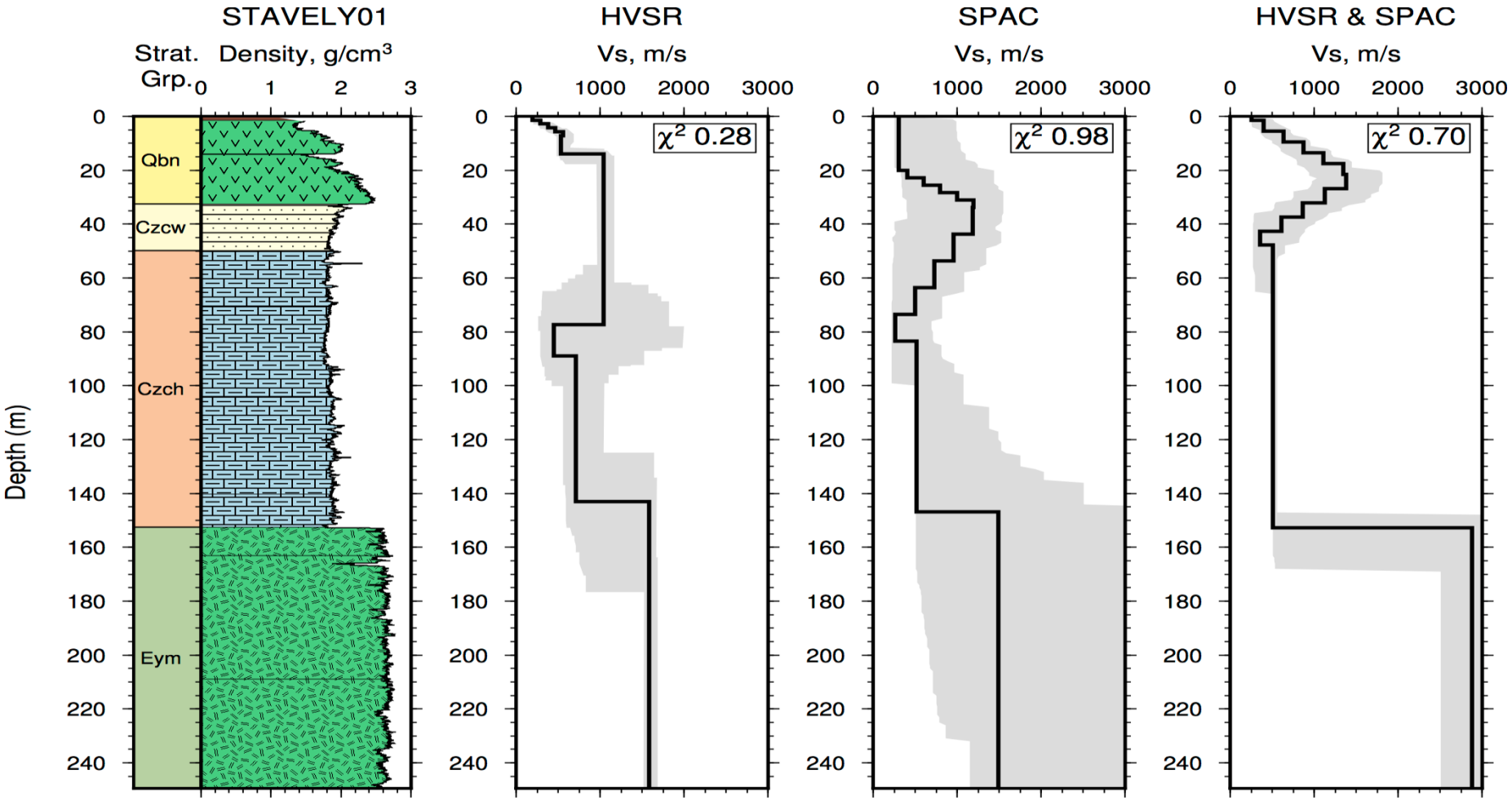
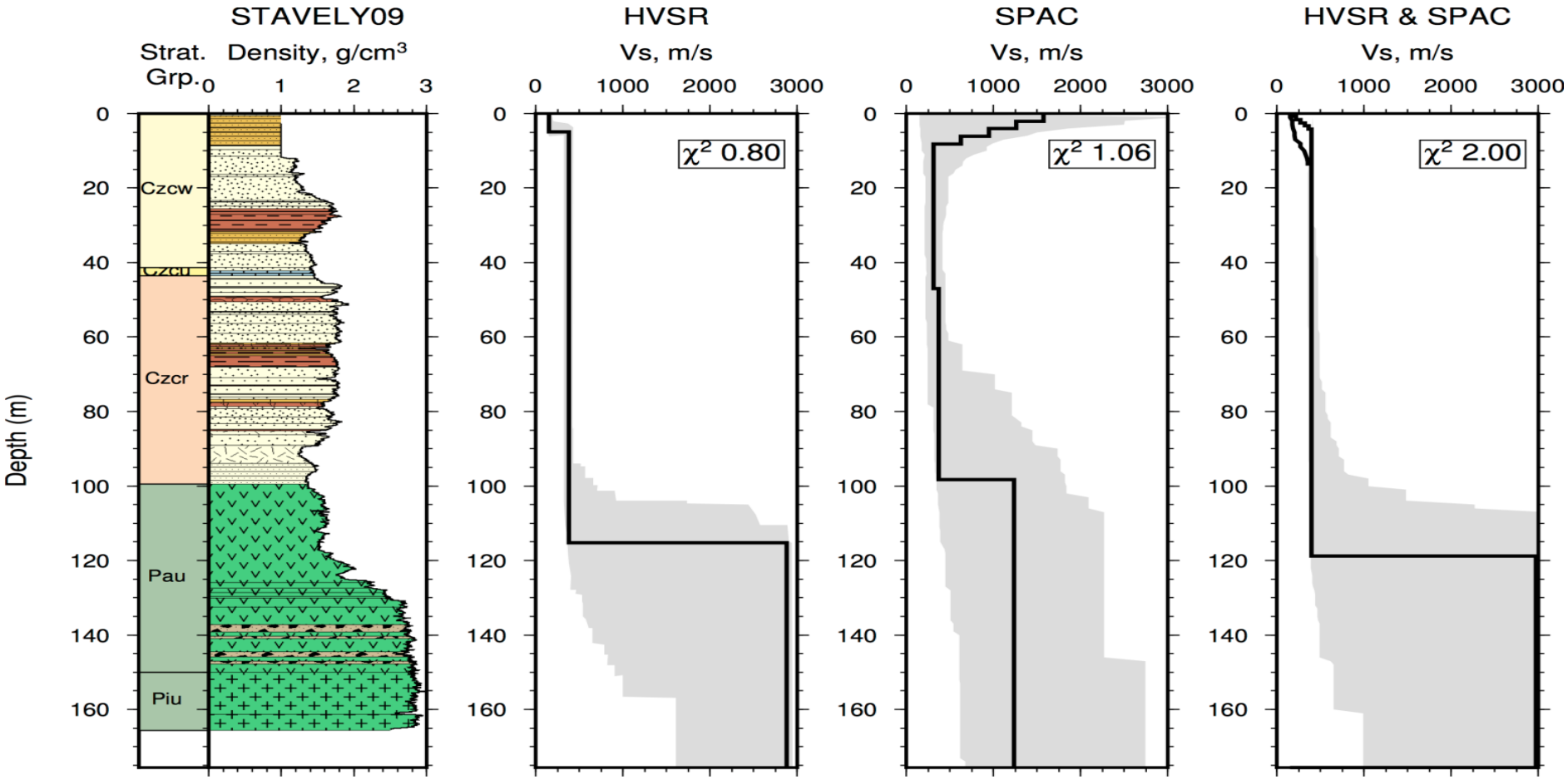
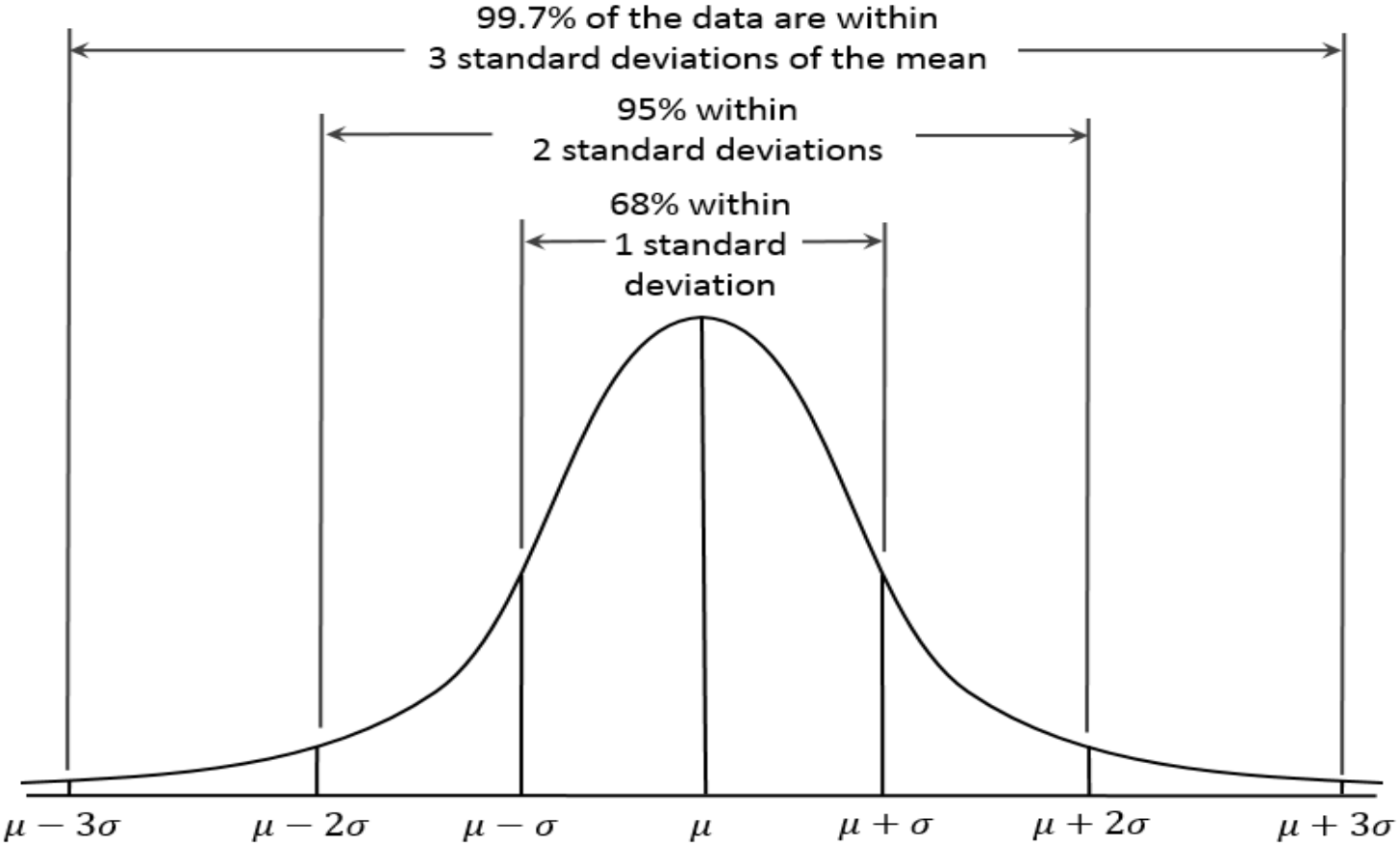
Ability to probe below the surface reflectors



Density measurements are important



Testing confidence limits



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Sources of uncertainty

- Our results are not direct measurements but process of non-linear multi-dimensional fitting
- Measurement errors are multisource : “unwanted” noise and instrumental
- Theory approximation error
- Measurement error propagation into parameter space can not be reliably estimated
- Benchmarking against known drilling logs give us an estimate that interface depth can be recovered with an error of 10–20%

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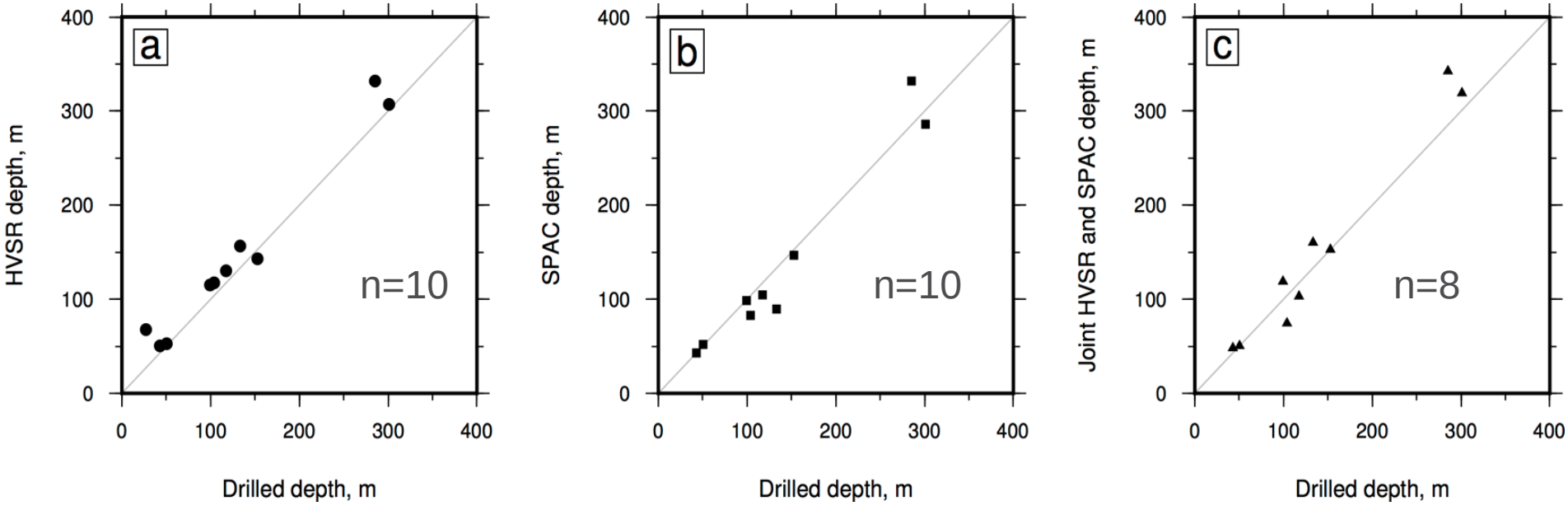
Comparison to the drill log depth to the basement



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How can we improve our results?

- Accurate measurements and account for unwanted noise such as weather effects over seismic station
- Realistic physical models
- More sophisticated inversion strategies

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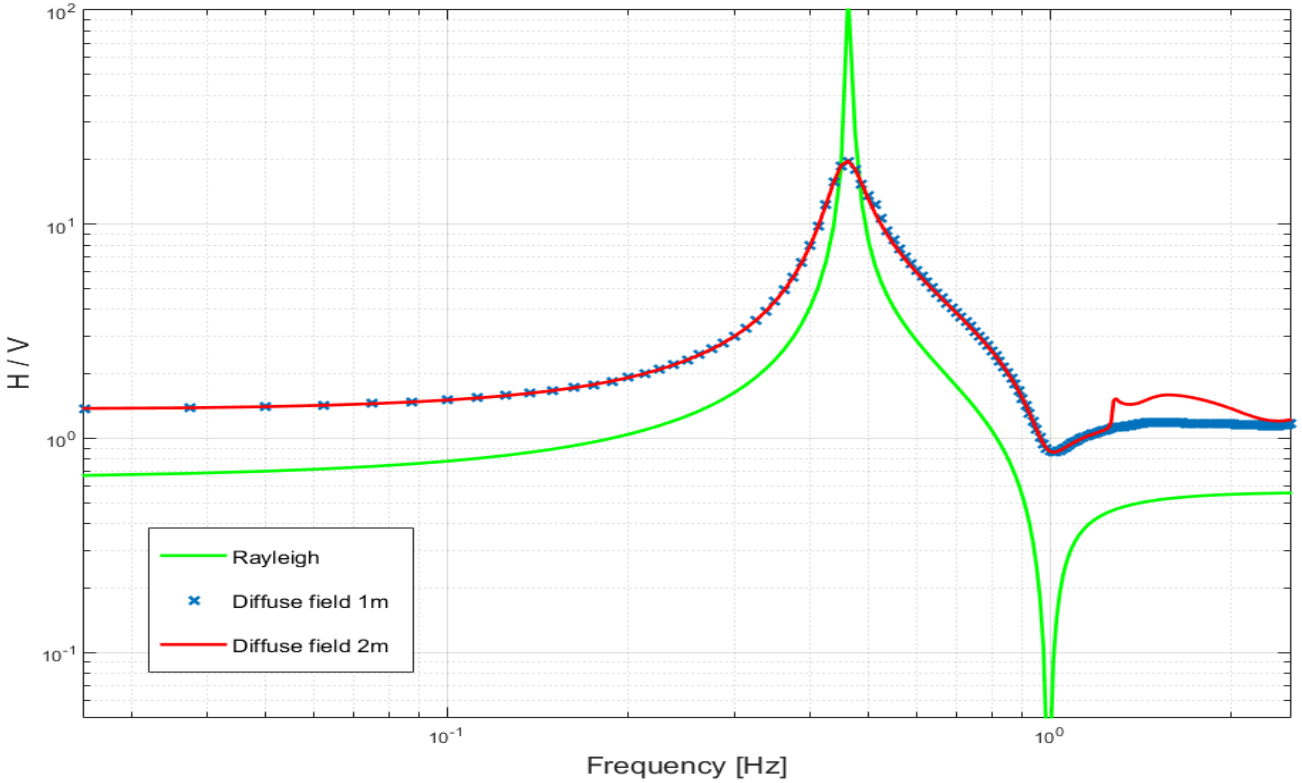
Realistic physical model

Diffuse field theory vs pure Rayleigh wave approximation



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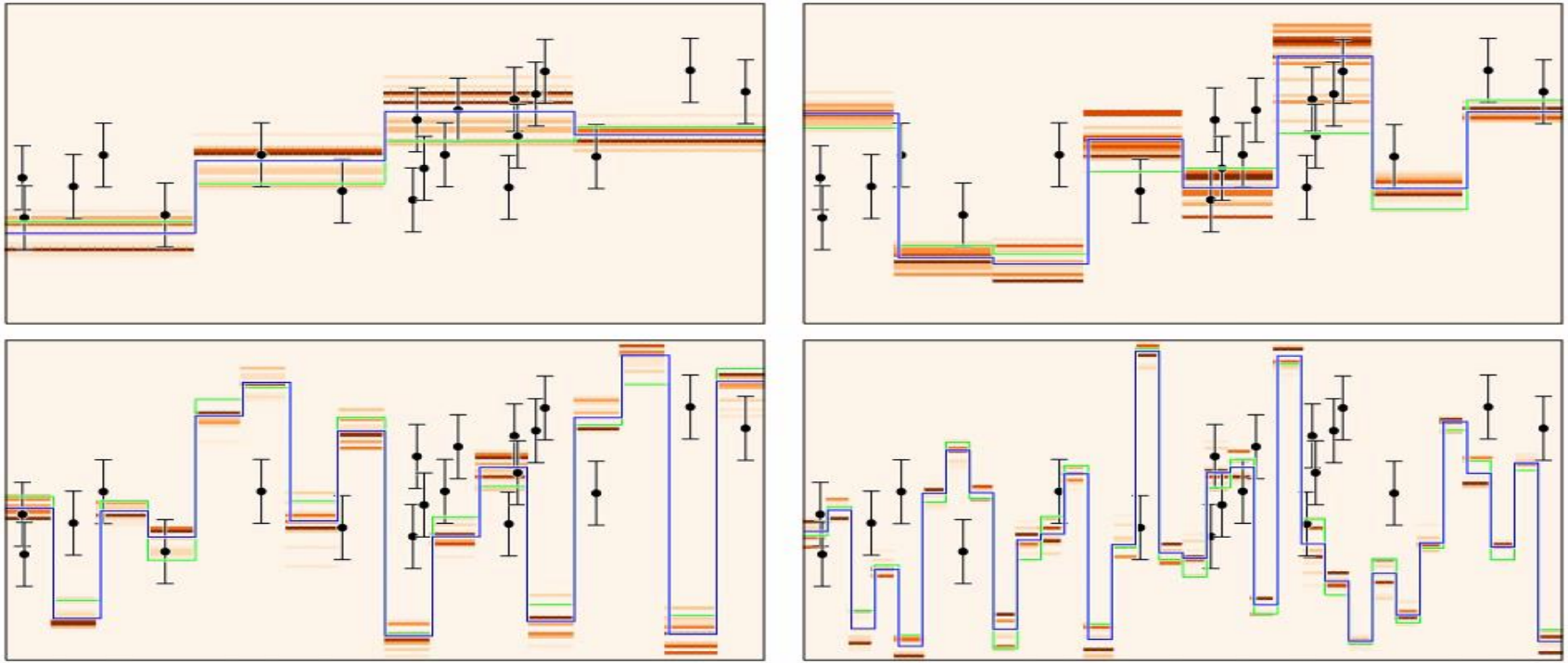
Trans-dimensional inversion algorithm

Pre-defined parameterization of conventional nonlinear inversion



Courtesy of Rhys Hawkins, RSES, ANU

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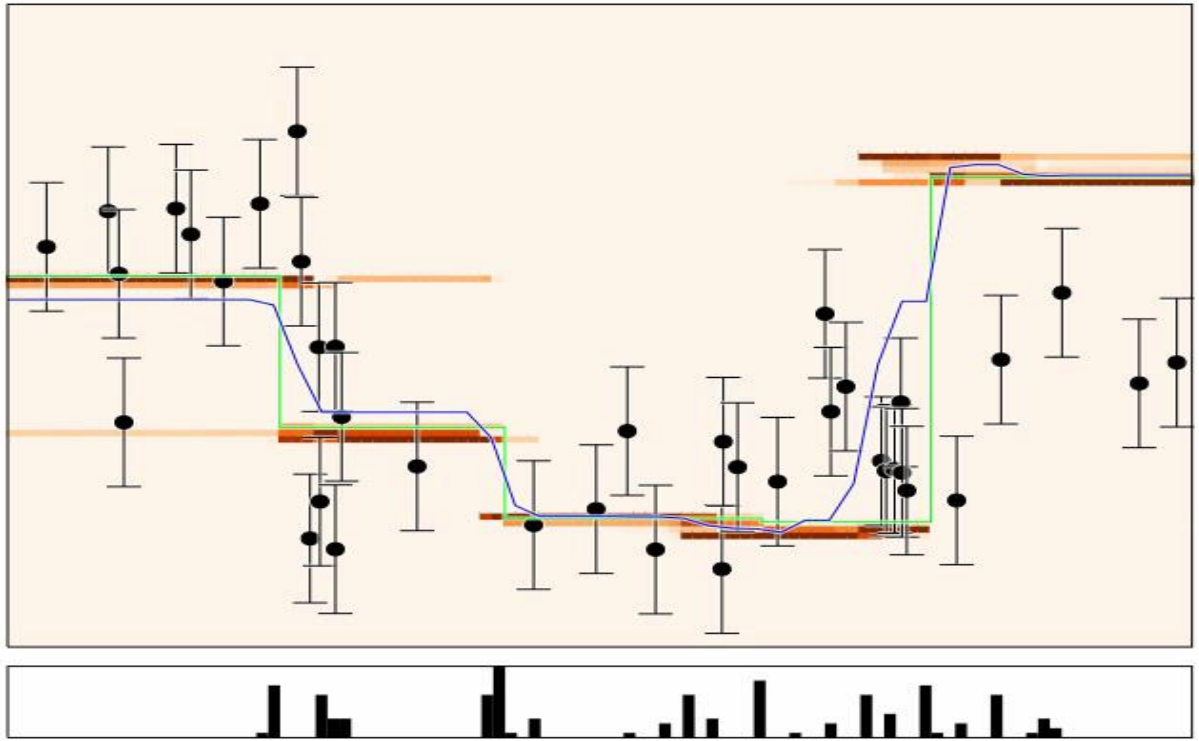
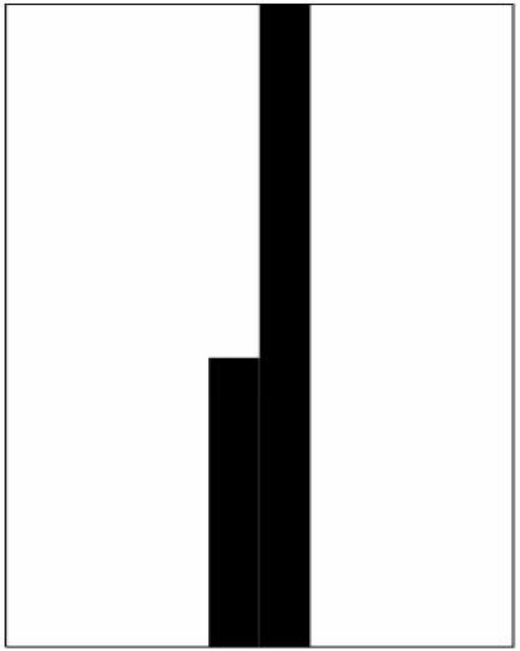
Inversion-driven parameterization





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Field work suggestions

- For benchmarking spiral arrays are ideal
- If acquiring HVSR data at a single site deploy more than one instrument.
- Instrument response is important, suggest ≥20s instruments.
- Deploy for at least 3 hours

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Conclusions

Key findings:

- Application of inversion algorithms provides robust results
- Surprisingly HVSR data seems to provide more information on earth structure than SPAC data at the sites we have tested

Current efforts:

- Implementation of trans-dimensional HVSR & SPAC inversions
- Adoption of realistic multi-mode physical models of wave field into inverse algorithms
- Continuation of benchmarking across the range of Australia's cover materials

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Thank you!

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