SHEAR VELOCITY PROFILES OBTAINED FROM PASSIVE SEISMIC (MICROTREMOR) ARRAY DATA – NEWCASTLE, PROMINENT HILL, & TURKEY

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UNCOVER WORKSHOP ADELAIDE, 3 APR 2014

OUTLINE

Microtremor or ambient noise

H/V single station measurements

Array measurements

SOURCES OF MICROTREMORS (also MICROSEISMS)

Wave propagation principally as surface waves

- 0.05-0.5 Hz : Meteorological - (eg wave action)
- 1-30 Hz : Cultural - vehicles, trains, machinery

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TYPES OF SURFACE WAVES

- Rayleigh waves (P-SV particle motion) - solid or water free surface

- Love waves (SH particle motion)
  - solid layer(s) over half-space

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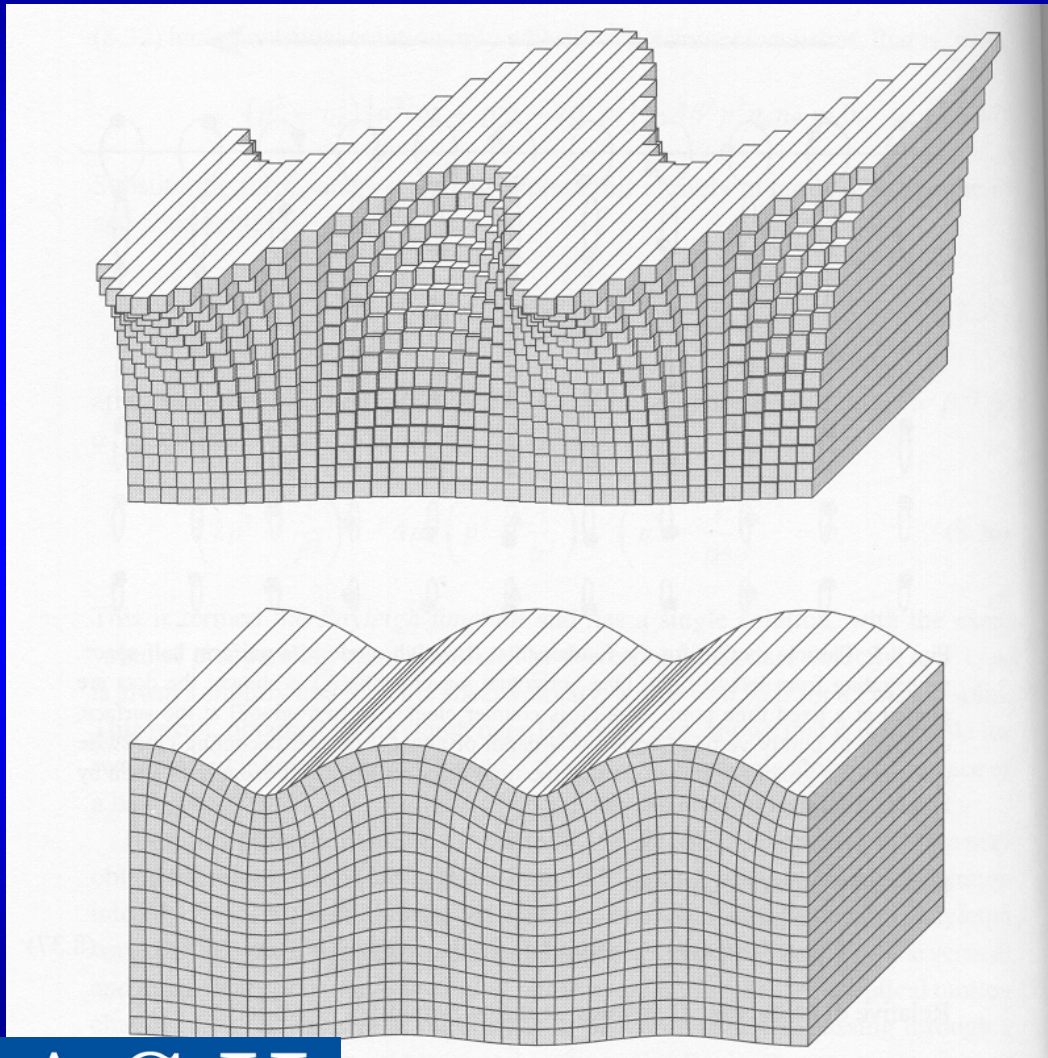
Surface wave particle motion



SH motion

Love wave

P-SV motion

Rayleigh wave

ove (top) and Rayleigh (bottom) surface wave displacements for hori-
the page. Love waves are purely transverse motion, whereas Rayleigh
al and radial motion. In both cases, the wave amplitude decays strongly

(Shearer 1999)

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INFORMATION CONTENT OF MICROTREMORS

- H/V spectral maxima indicate resonances which may be earthquake risks – can map relative thickness
- phase velocity gives thickness and shear-velocity profile of sediments

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THE DUCK TUTORIAL ON MICROTREMOR SURFACE WAVE PROPAGATION

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THE DUCK TUTORIAL ON MICROTREMOR SURFACE WAVE PROPAGATION

•Wave velocity is depth sensitive

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THE DUCK TUTORIAL ON MICROTREMOR SURFACE WAVE PROPAGATION

- Wave velocity is depth sensitive
- Can measure phase velocity with two detectors

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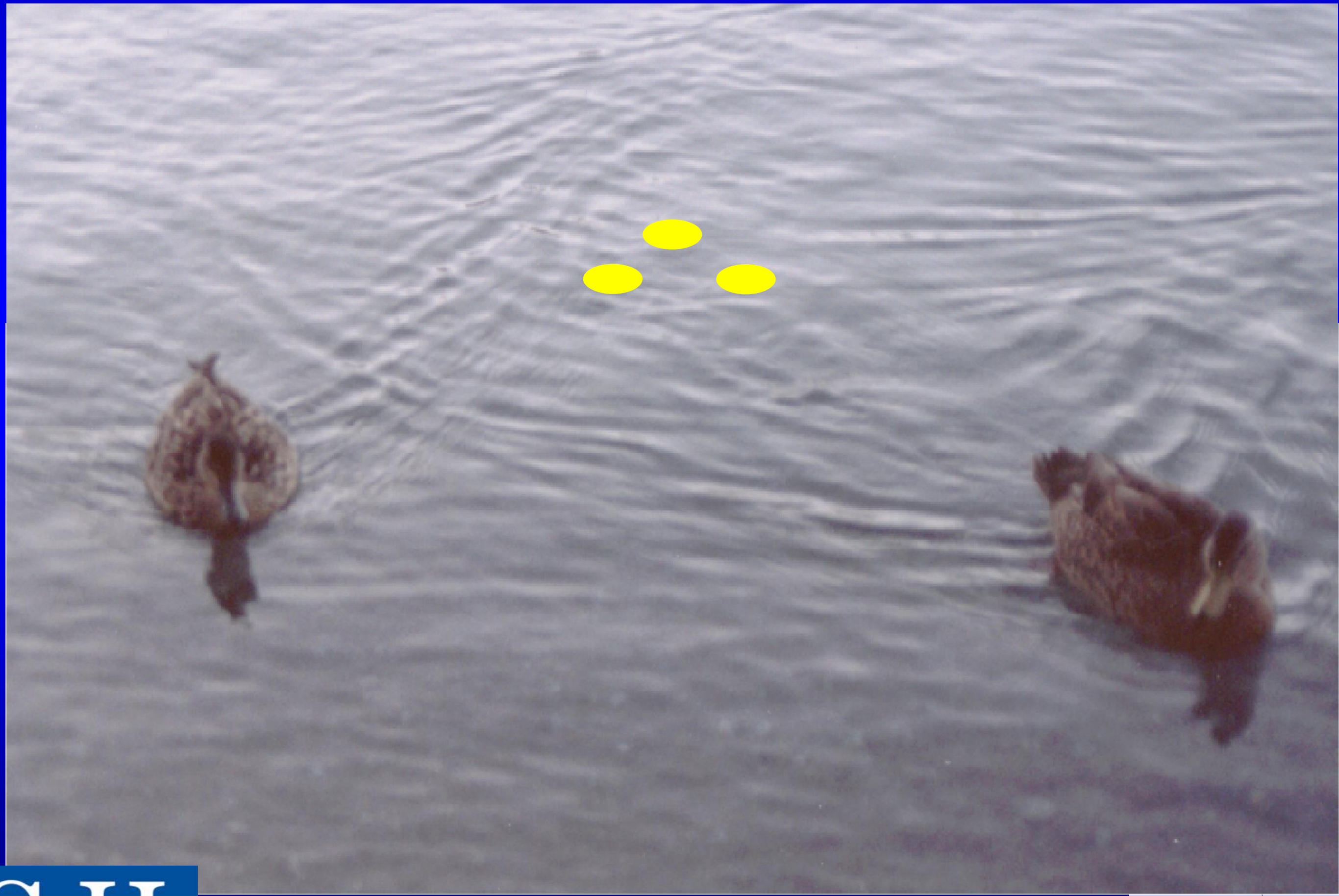
THE DUCK TUTORIAL ON MICROTREMOR SURFACE WAVE PROPAGATION

- **Two sources give summation of waves- need array of detectors**



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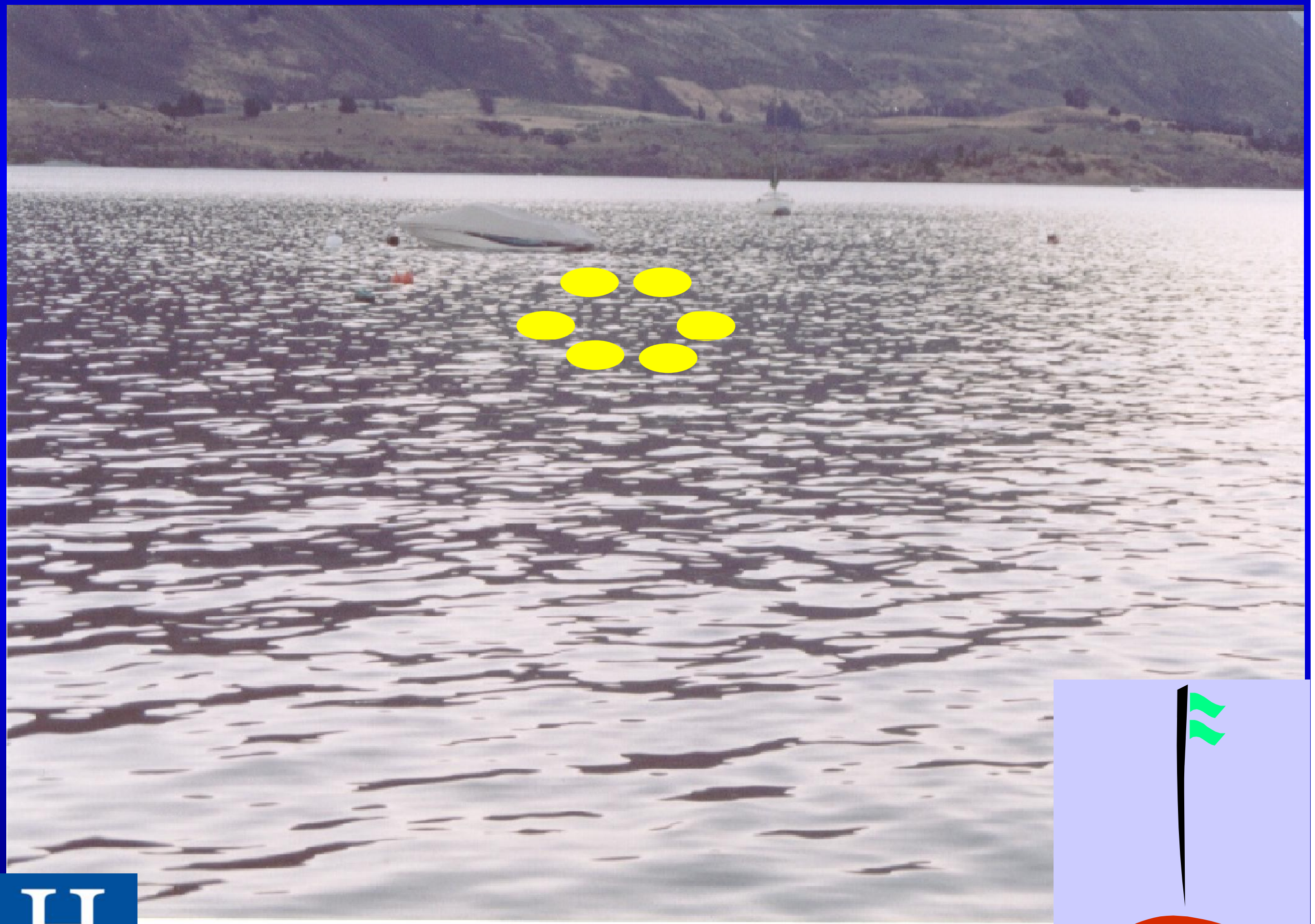
THE DUCK TUTORIAL ON MICROTREMOR SURFACE WAVE PROPAGATION

- multiple sources give apparent chaos BUT wave velocity still governed by physics



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SOURCES OF MICROTREMORS (also MICROSEISMS)

Wave propagation principally as surface waves

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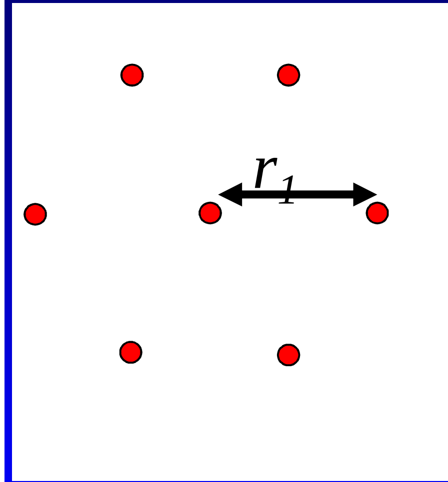

Spatial auto-correlation (SPAC)

- good for omni-directional sources

For a plane wave passing pairs of stations, *averaged in azimuth* ϕ, gives

$$\rho(f) = \quad e^{\,i\,k.r} \qquad (one\ pair)$$

where $k = 2\,\pi\,f\,/\,C(f)$

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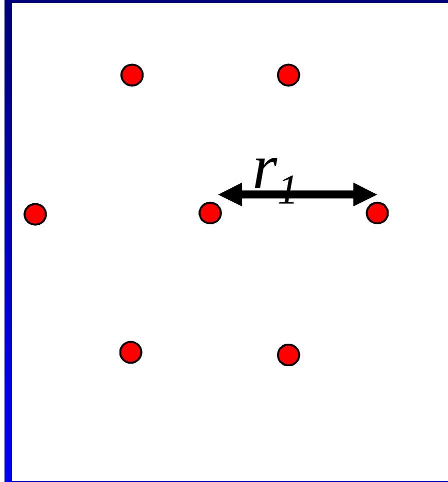

Spatial auto-correlation (SPAC)

- good for omni-directional sources

For a plane wave passing pairs of stations, *averaged in azimuth* ϕ, gives

$$\overline{\rho}(f) = \int e^{\,i\,k.r}\, d\,\phi = Jo\,(k.r),$$

where $k = 2\,\pi\,f\,/\,C(f)$

(Aki, 1957,1965)

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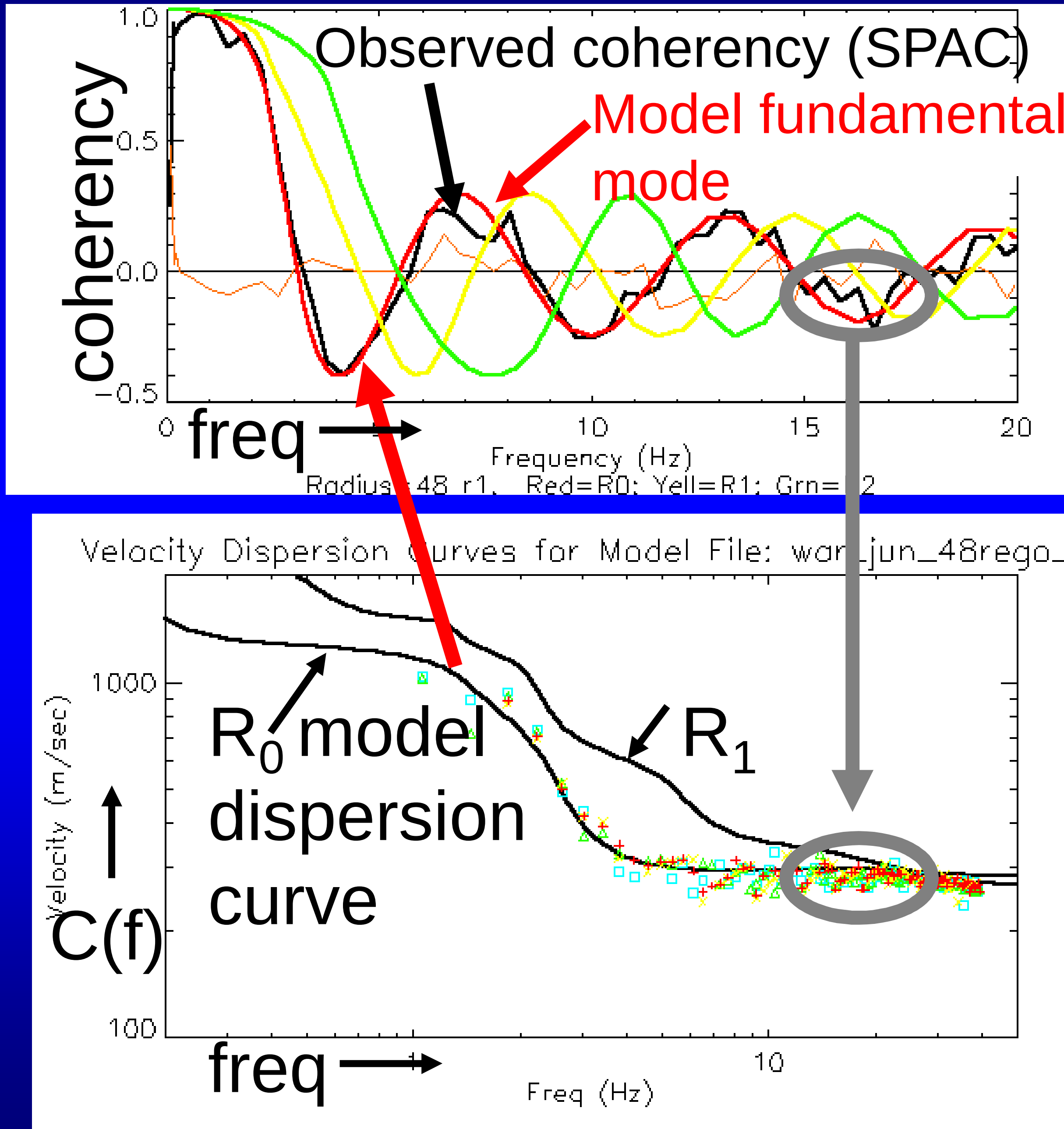
MultiMode
MMSPAC
ADVANTAGES

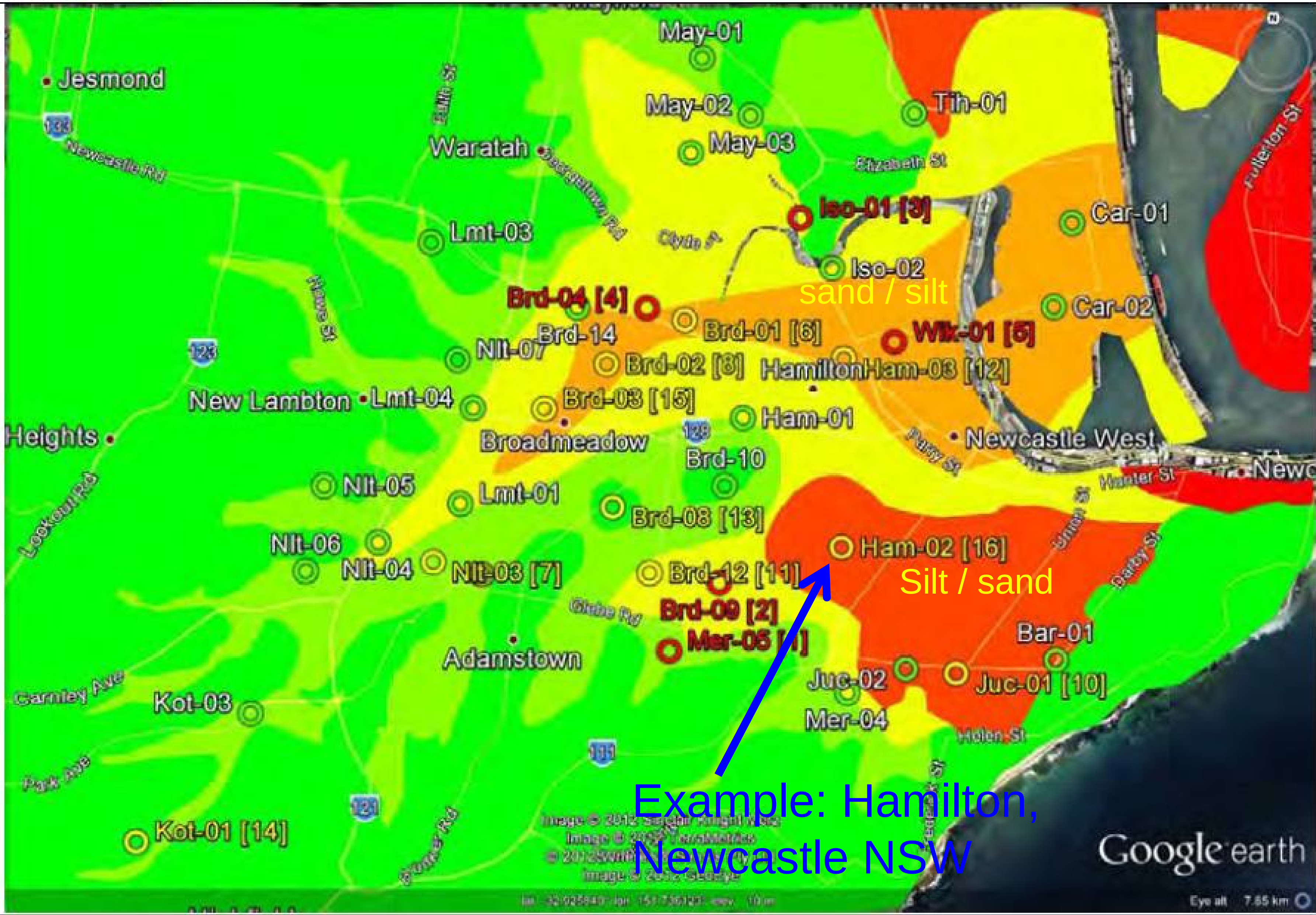
Fit data and model in coherency space

Extended wavenumber range

Data fit nearer to Gaussian



SITE CLASSES



Example: Hamilton, Newcastle NSW

5 km

NEWCASTLE WORKERS CLUB 28 DEC 1989

M=5.6

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HAMILTON (NEWCASTLE) SHOP FRONT
28 DEC 1989

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LESSONS – A PRODUCTION-ORIENTED SURVEY

Effective array geometries

Use of Horizontal/Vertical spectral ratio for depth sensitivity

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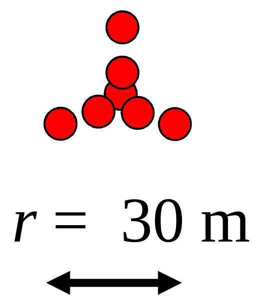
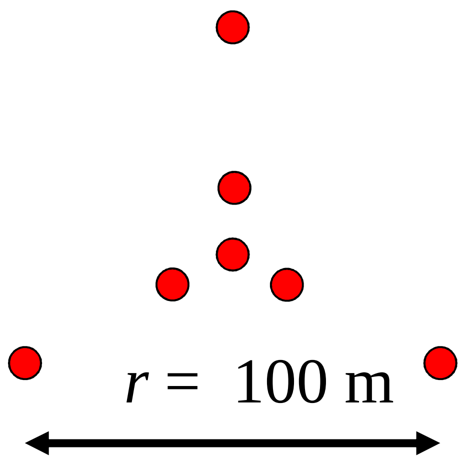


Nested triangle array of seven stations

Good for use in parkland



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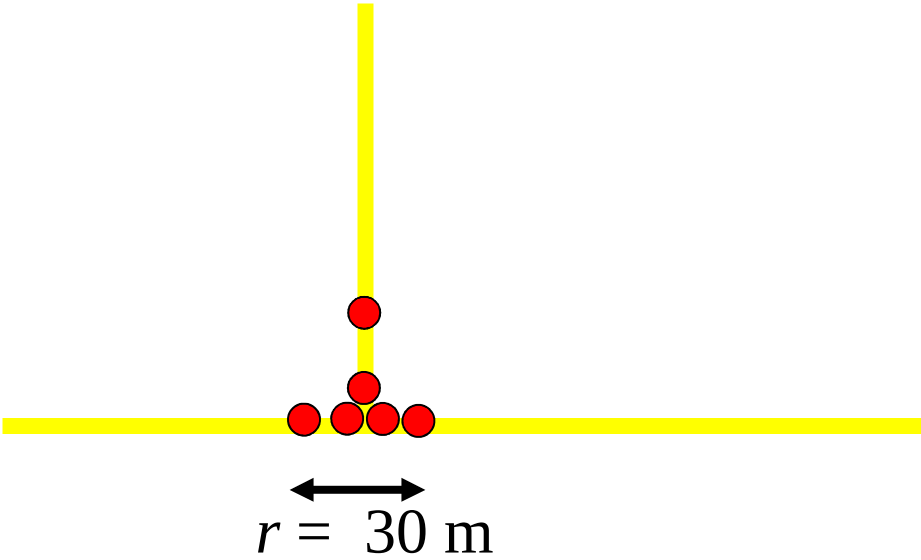

Nested common-base triangle array of seven stations

Good for use on a T-intersection

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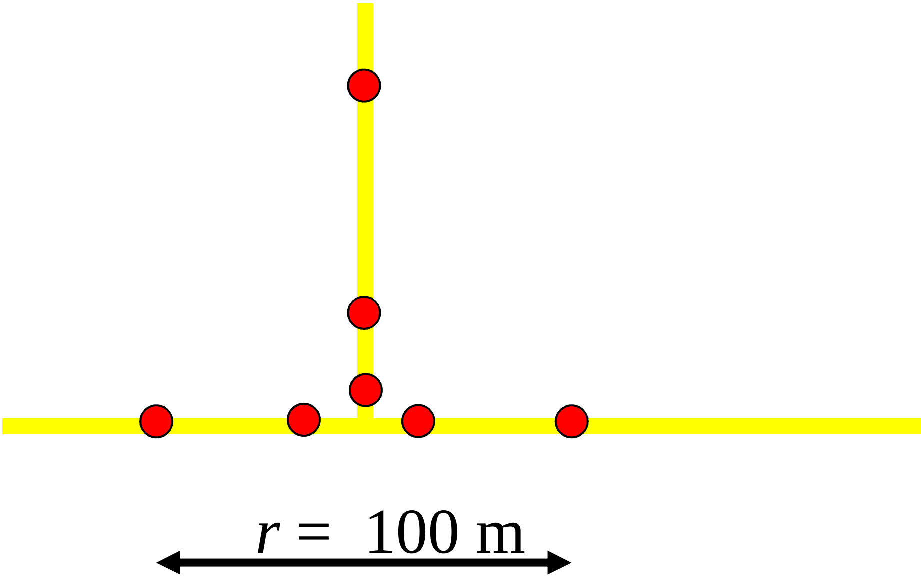

Nested common-base triangle array of seven stations

Good for use on a T-intersection

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National Soccer Ground, Newcastle

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LESSONS – A PRODUCTION-ORIENTED SURVEY

Effective array geometries

Use of Horizontal/Vertical spectral ratio for depth sensitivity

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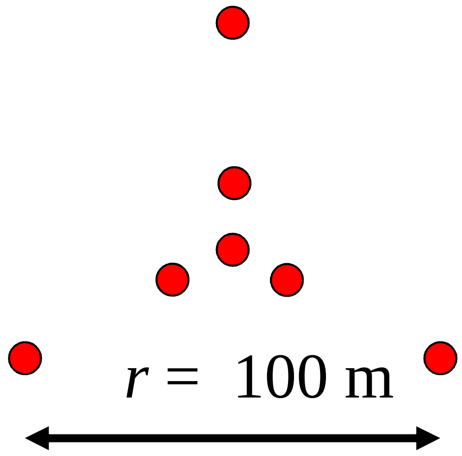
SITE HAM02



Nested triangle array of seven stations

Good for use in parkland

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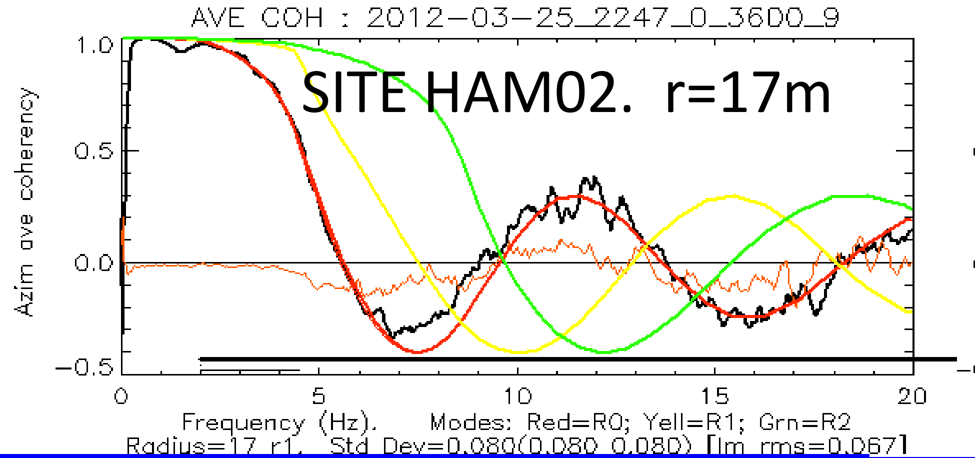

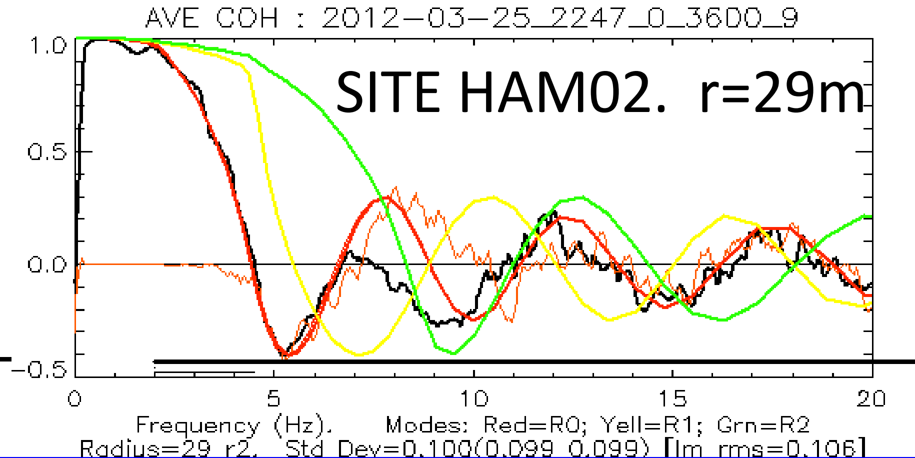

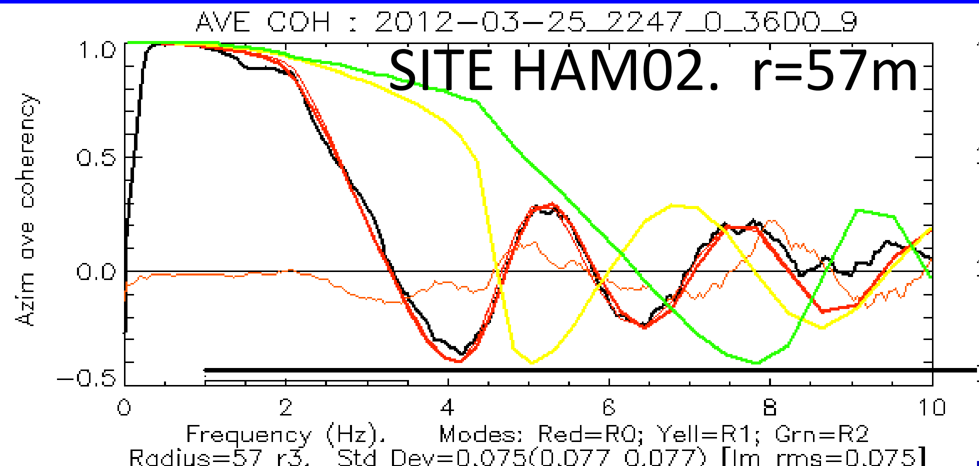

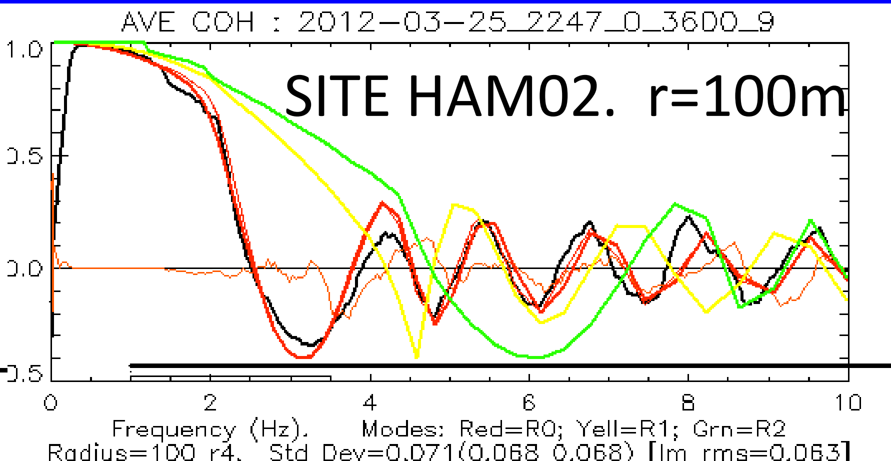

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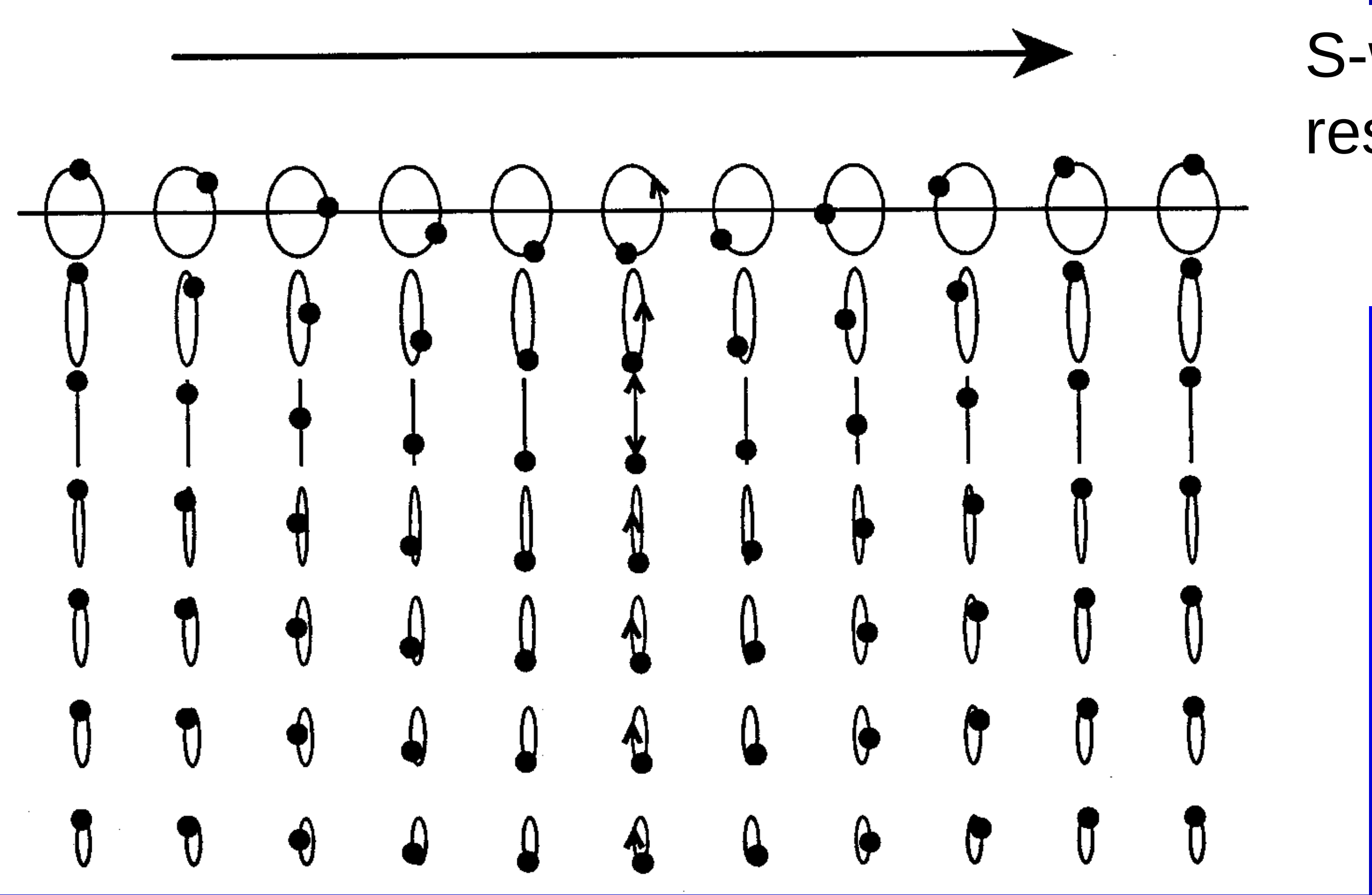
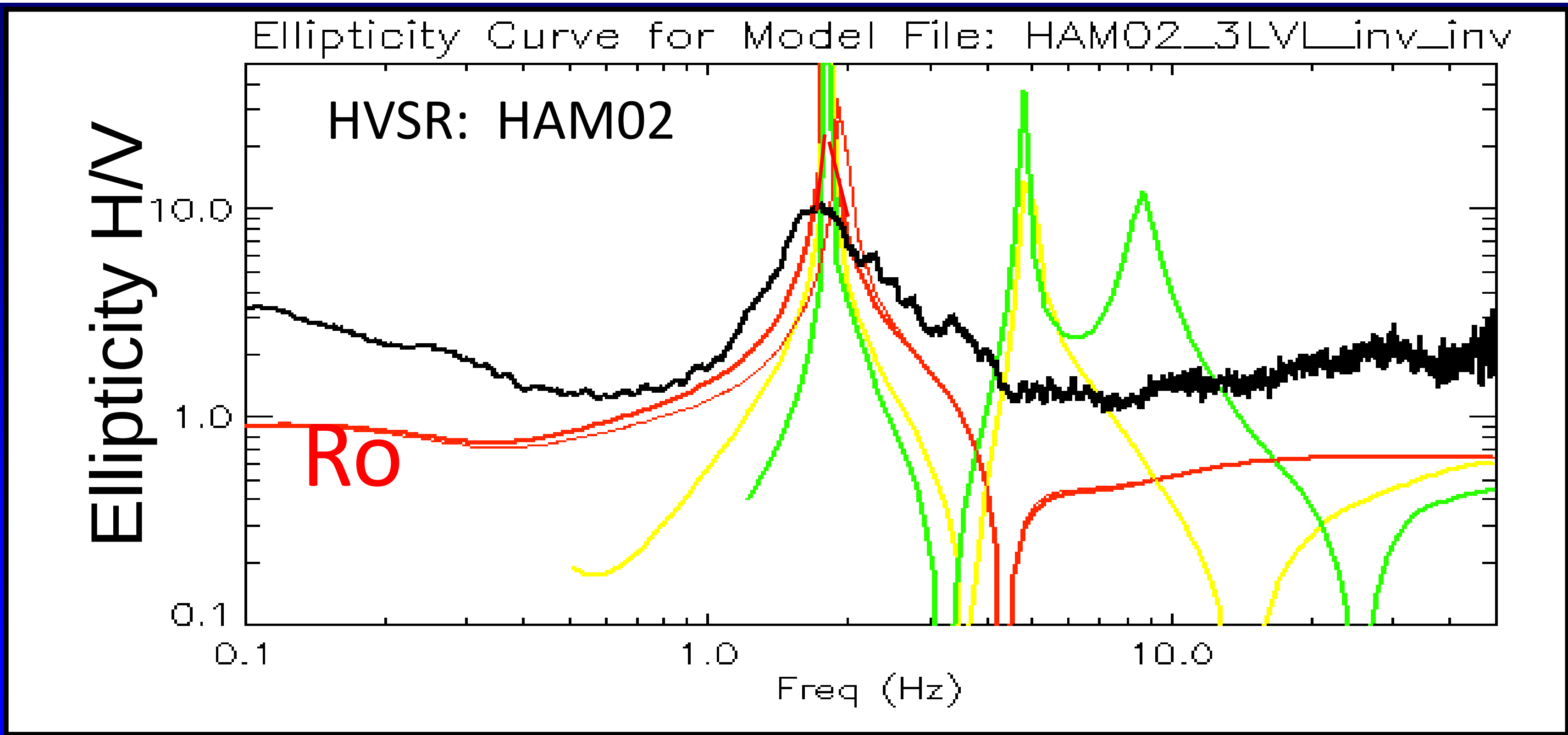
SITE HAM02: Black line – observed coherency spectrum

Red line: fitted model coherency spectrum, for best fit layered earth model.

Rayleigh wave particle motion



S-wave resonance



SITE HAM02: Black line – observed H/V spectrum
Red line: fitted model H/V spectrum, for best fit layered earth model.

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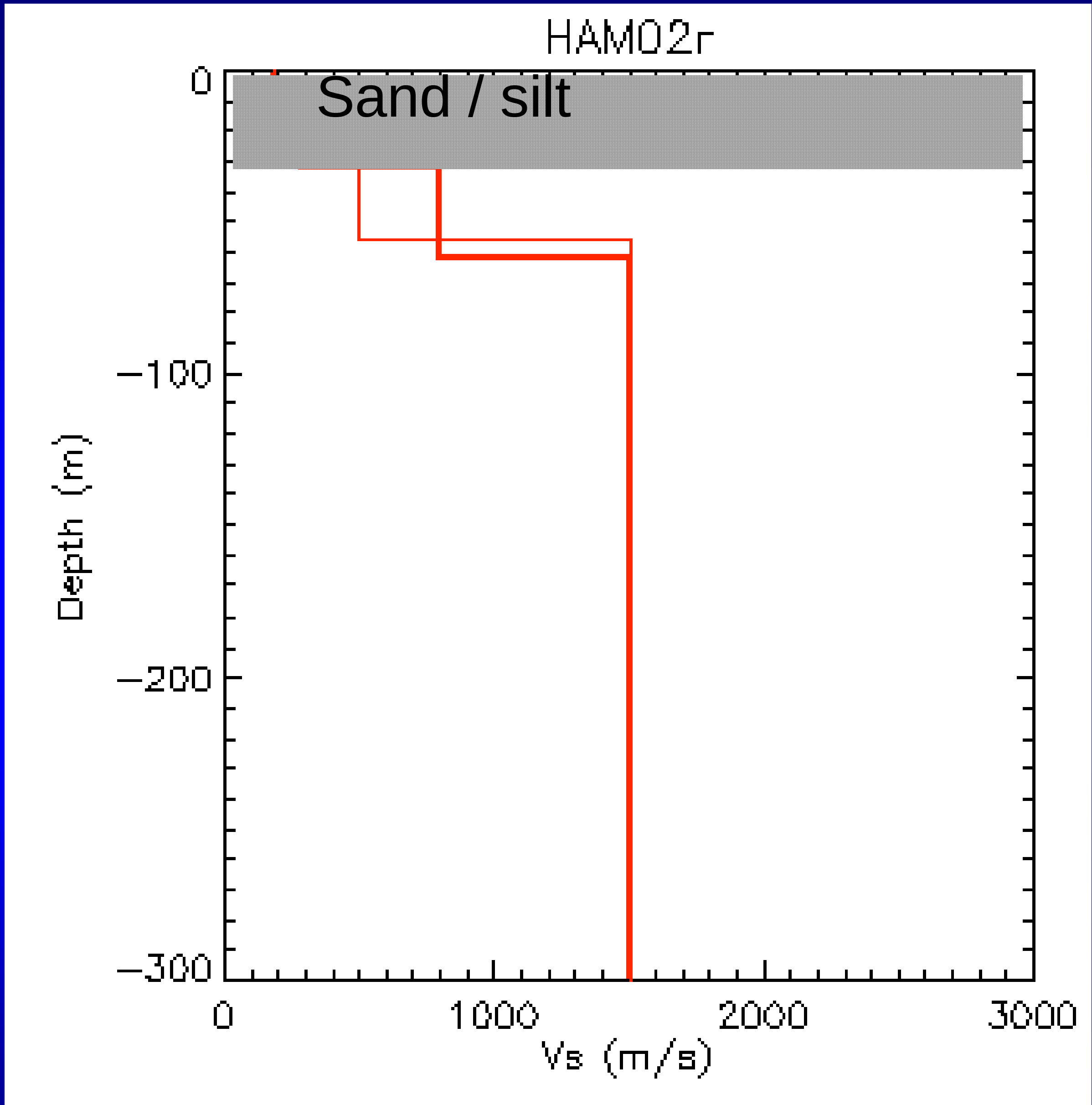

SITE HAM02: Thick red line – preferred best fit model.

Thin red line – alternative model

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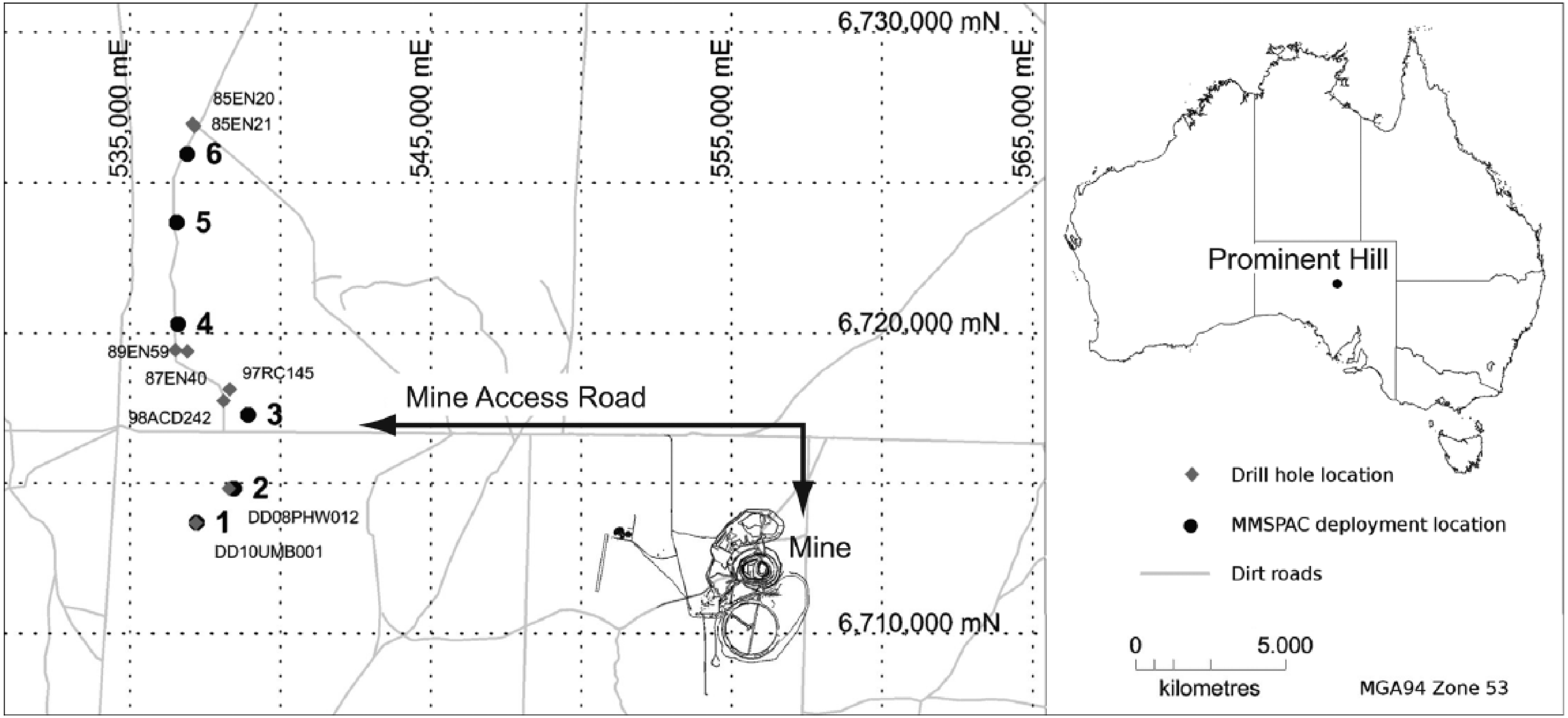
REGOLITH THICKNESS ESTIMATION AT PROMINENT HILL



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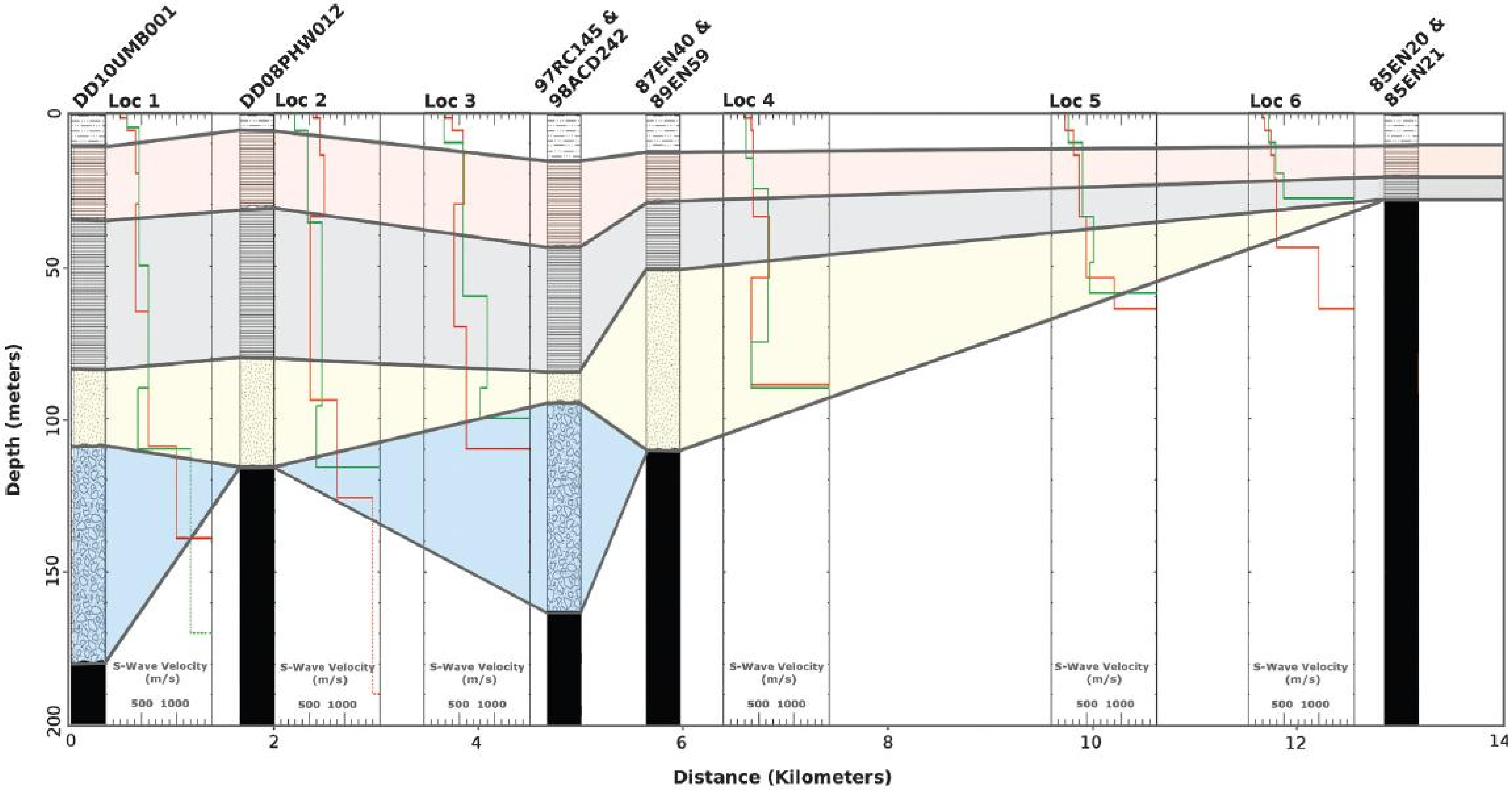
REGOLITH THICKNESS ESTIMATION AT PROMINENT HILL



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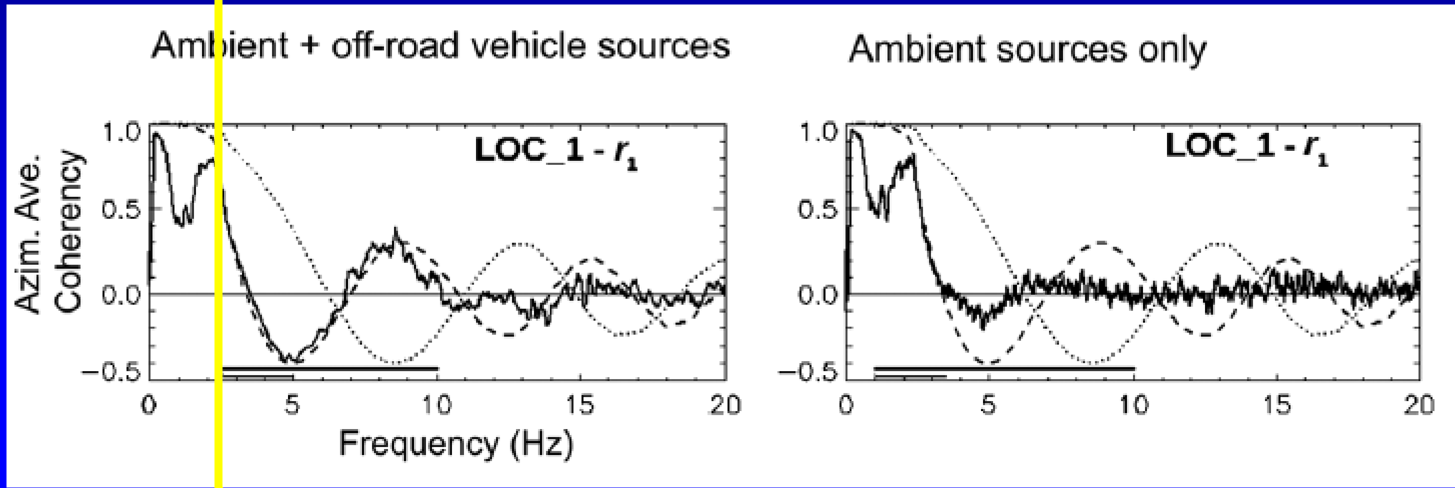
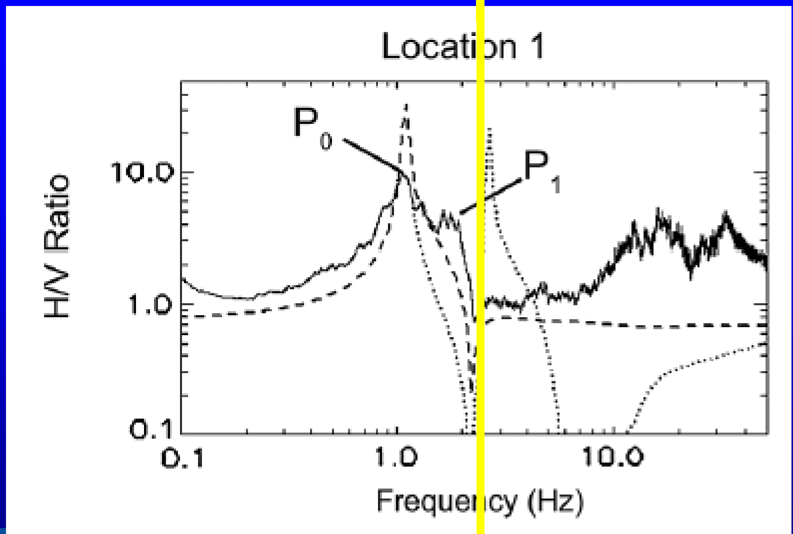
REGOLITH THICKNESS ESTIMATION AT PROMINENT HILL





(from Smith et al, GEOPHYSICS, VOL. 78, NO. 5 (SEPTEMBER-OCTOBER 2013); P. B227–B242)

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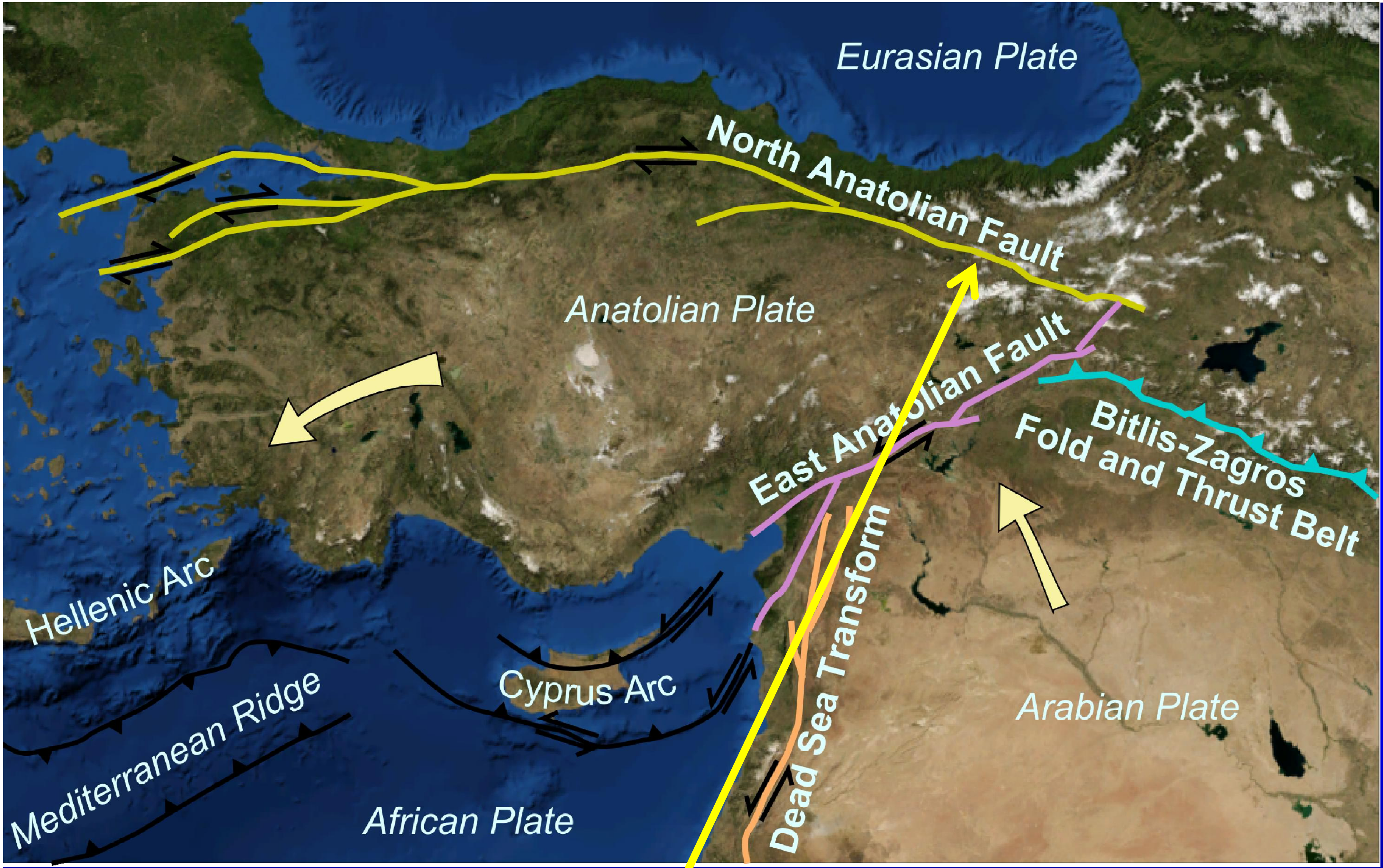

TECTONIC MAP OF TURKEY,
WITH ERZINJAN BASIN

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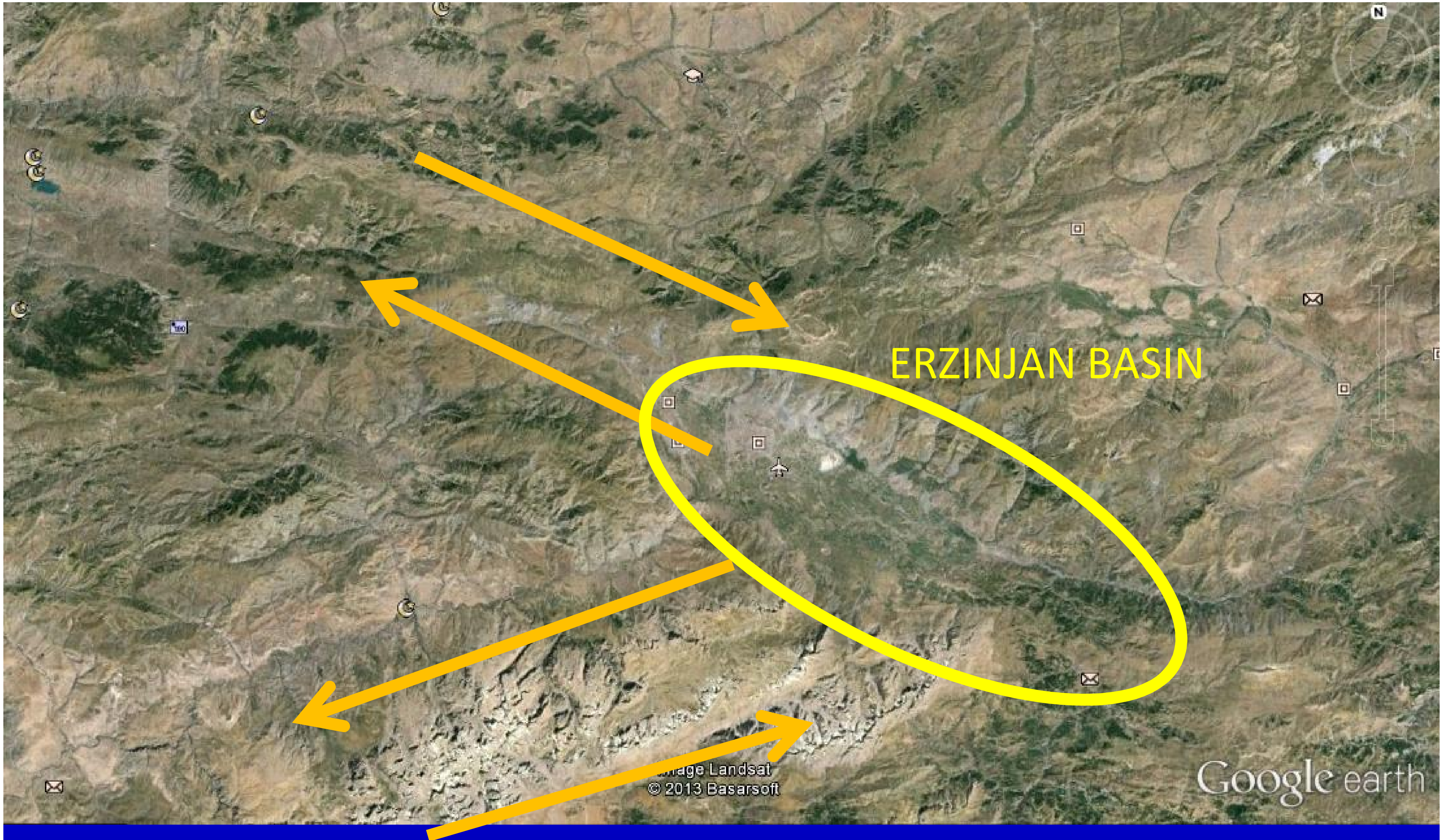

25km

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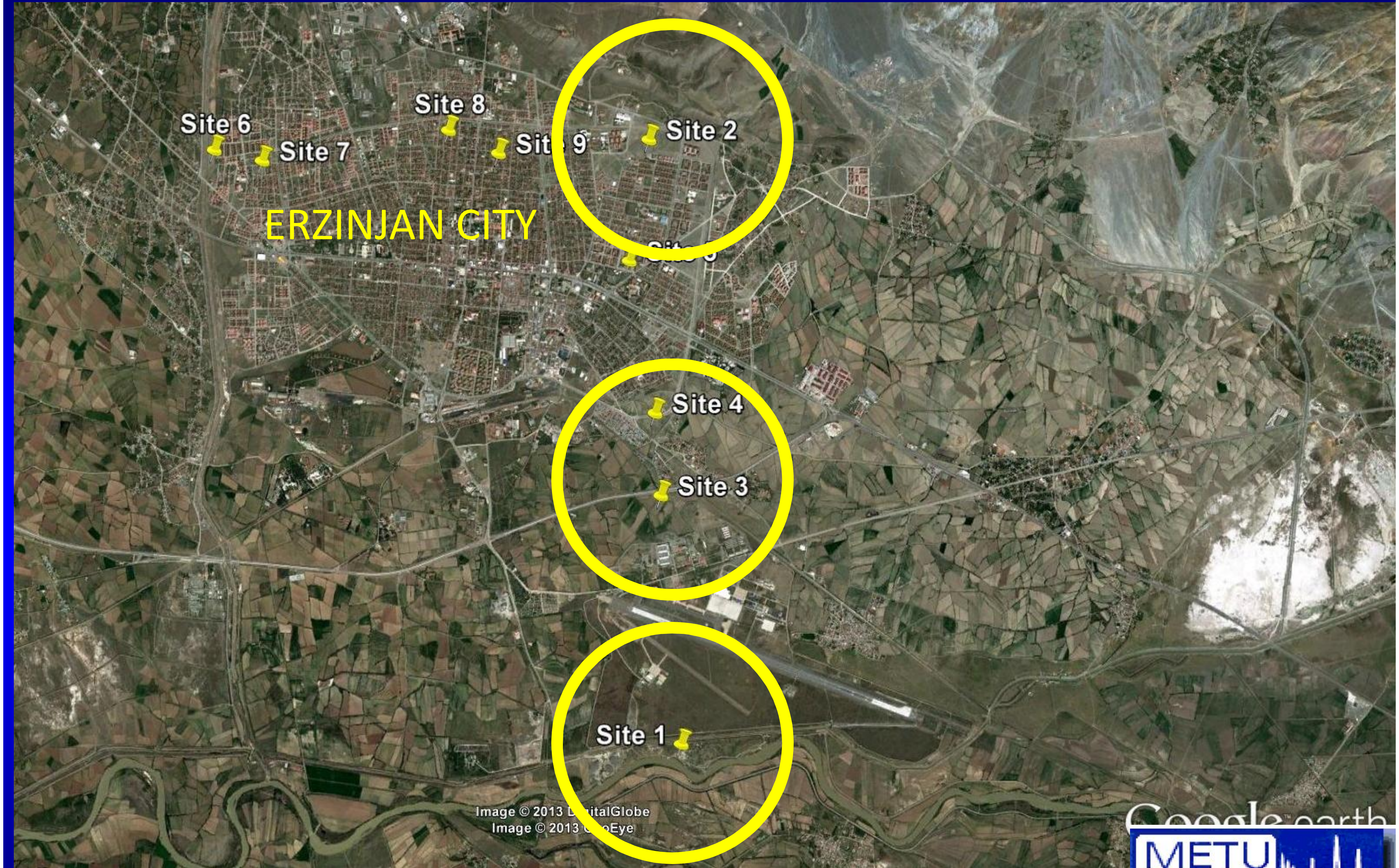

3km

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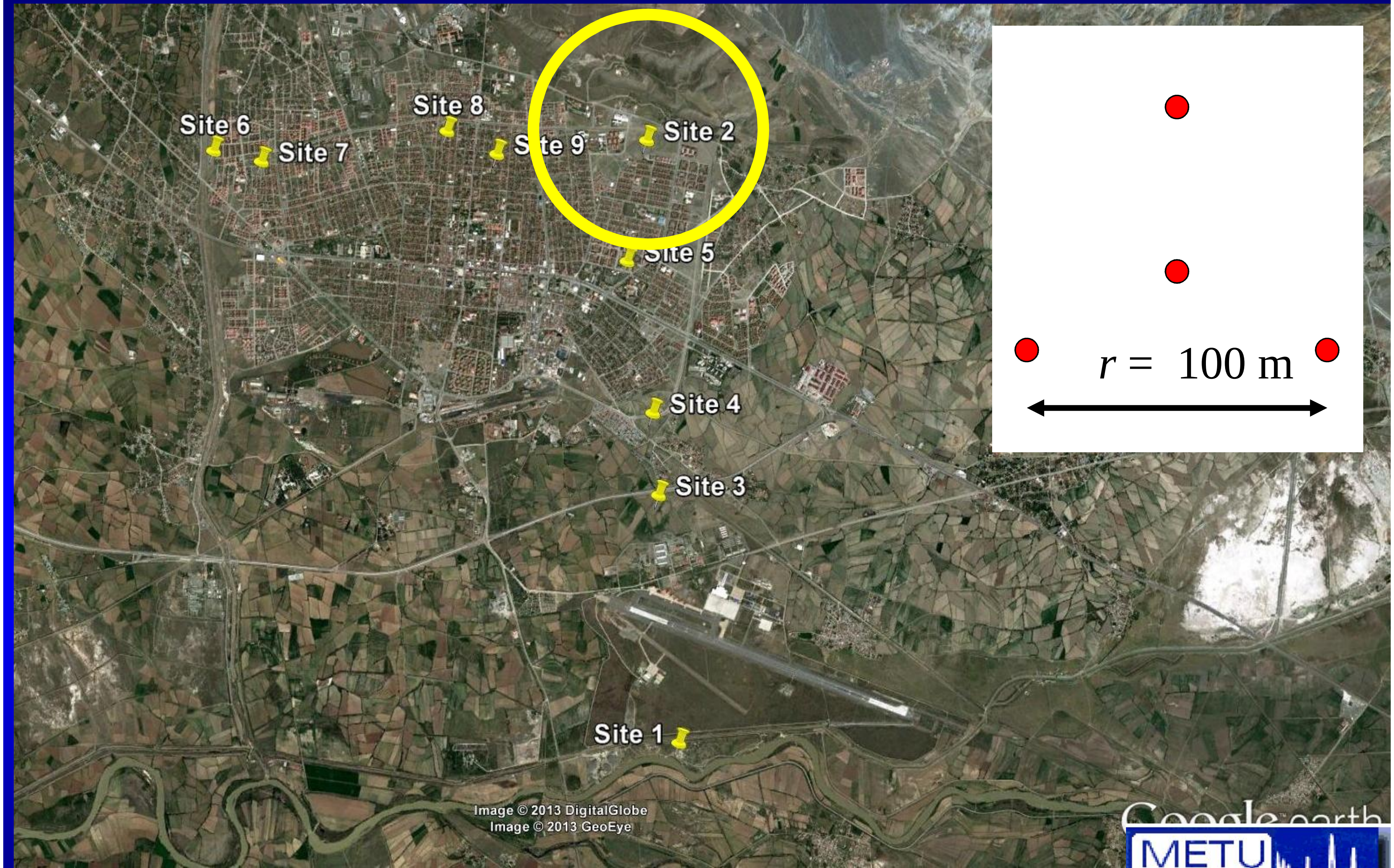

3km

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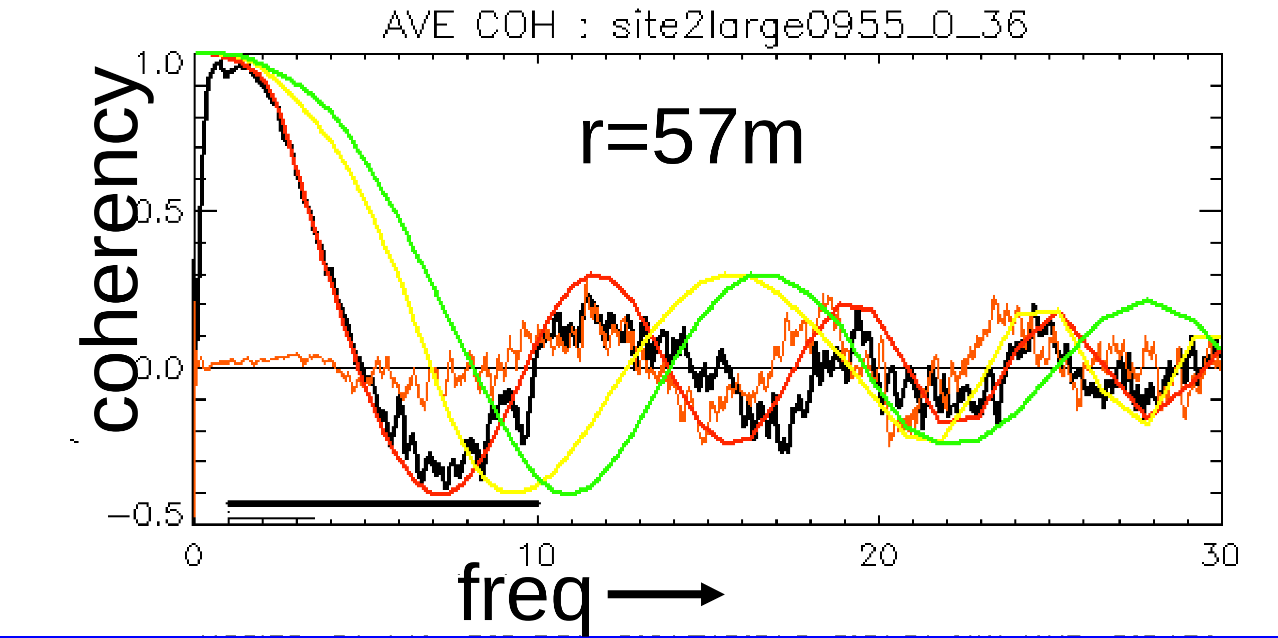
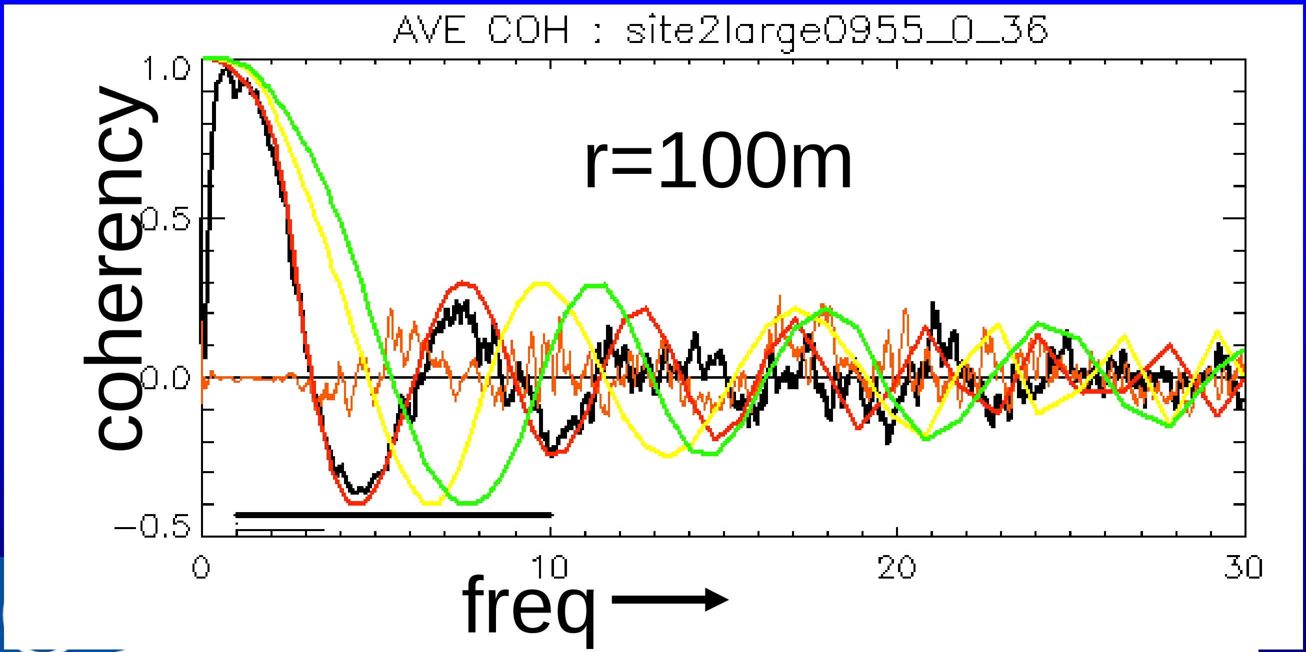




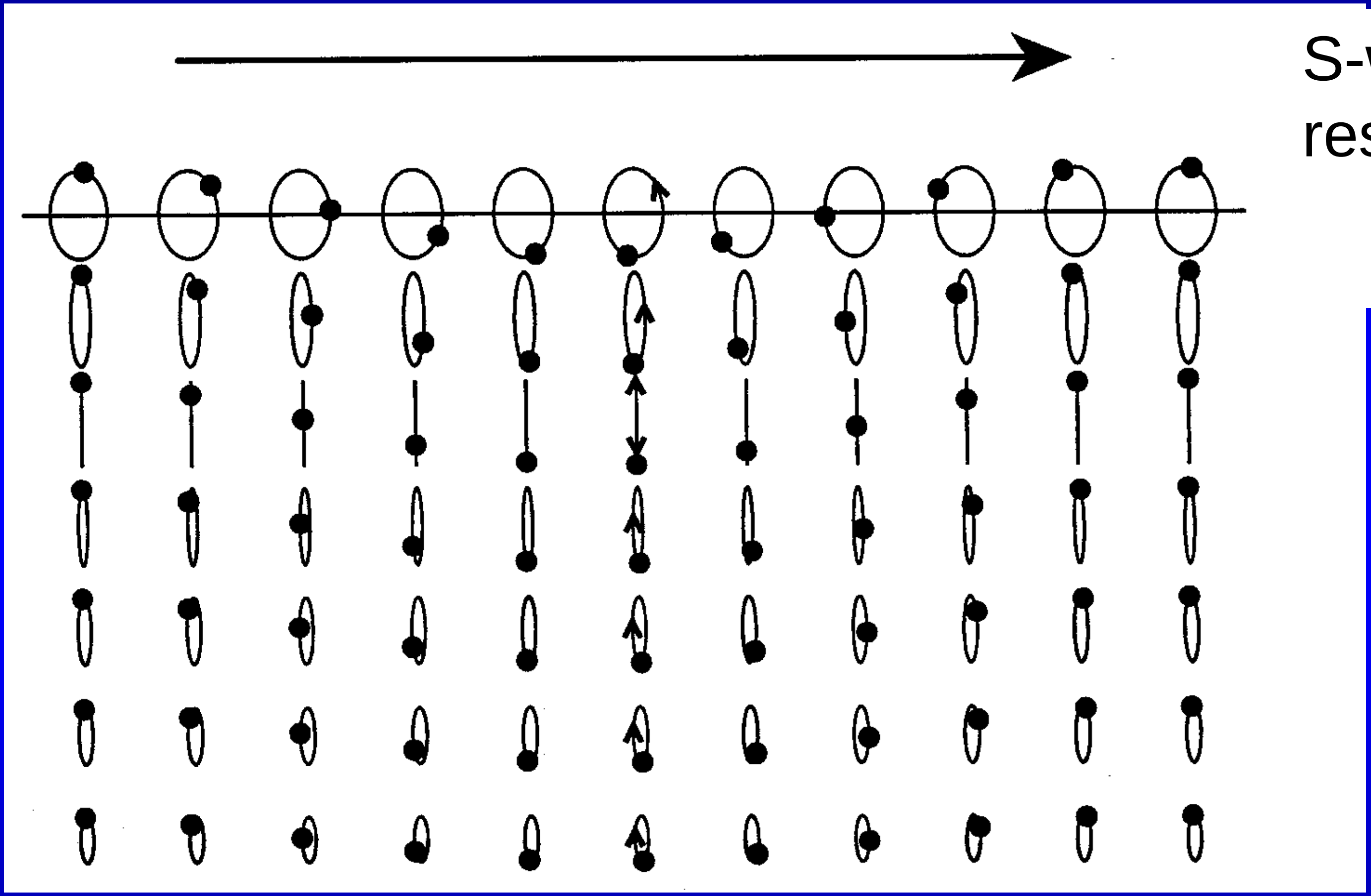
SPATIALLY AVERAGED COHERENCY

SITE 2
100 m triangle array

Black line – observed coherency spectrum

Red line: fitted model coherency spectrum, for best fit layered earth model.

Rayleigh wave particle motion



S-wave
resonance

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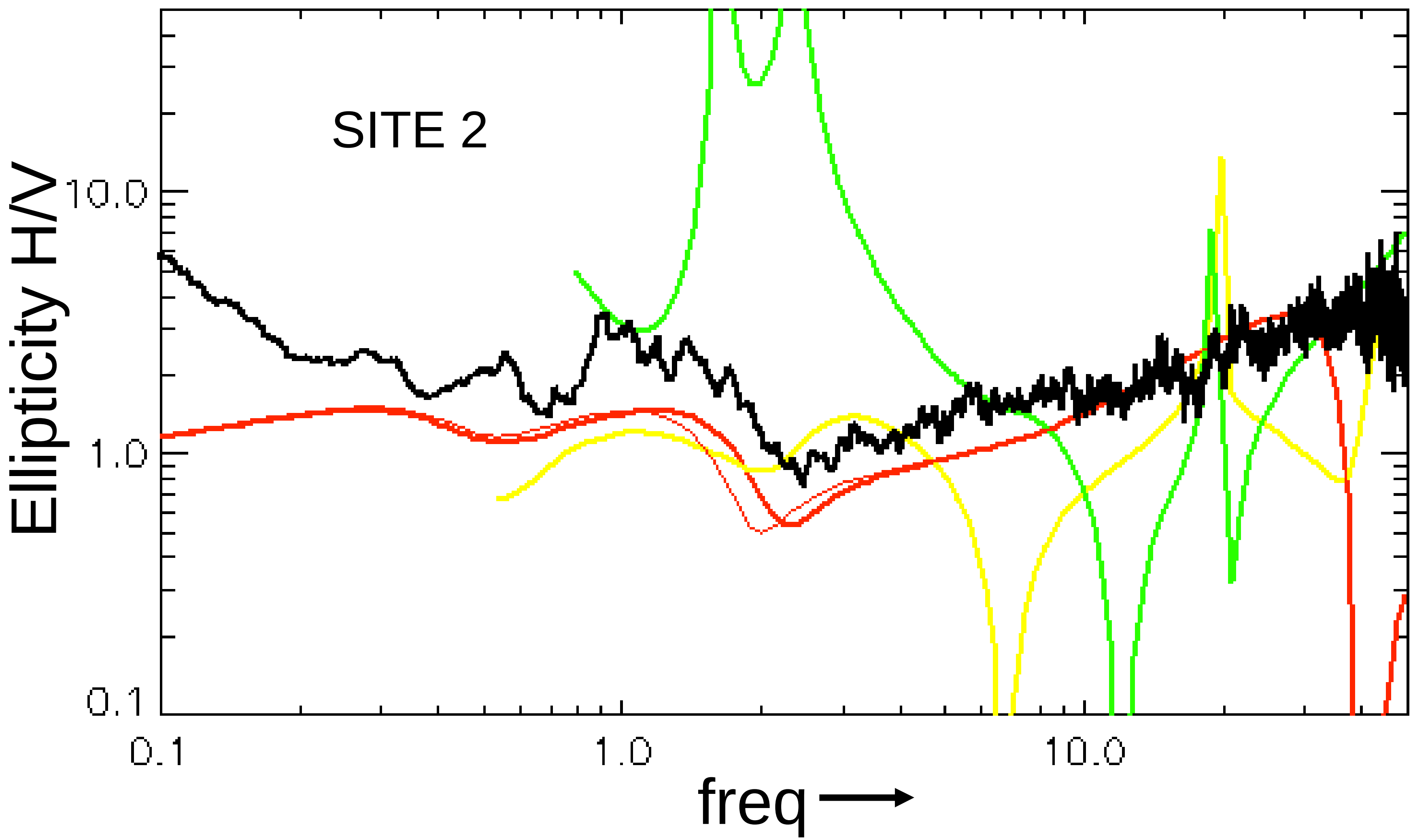

SITE 2: Black line – observed H/V spectrum
Red line: fitted model H/V spectrum, for best fit layered earth model.

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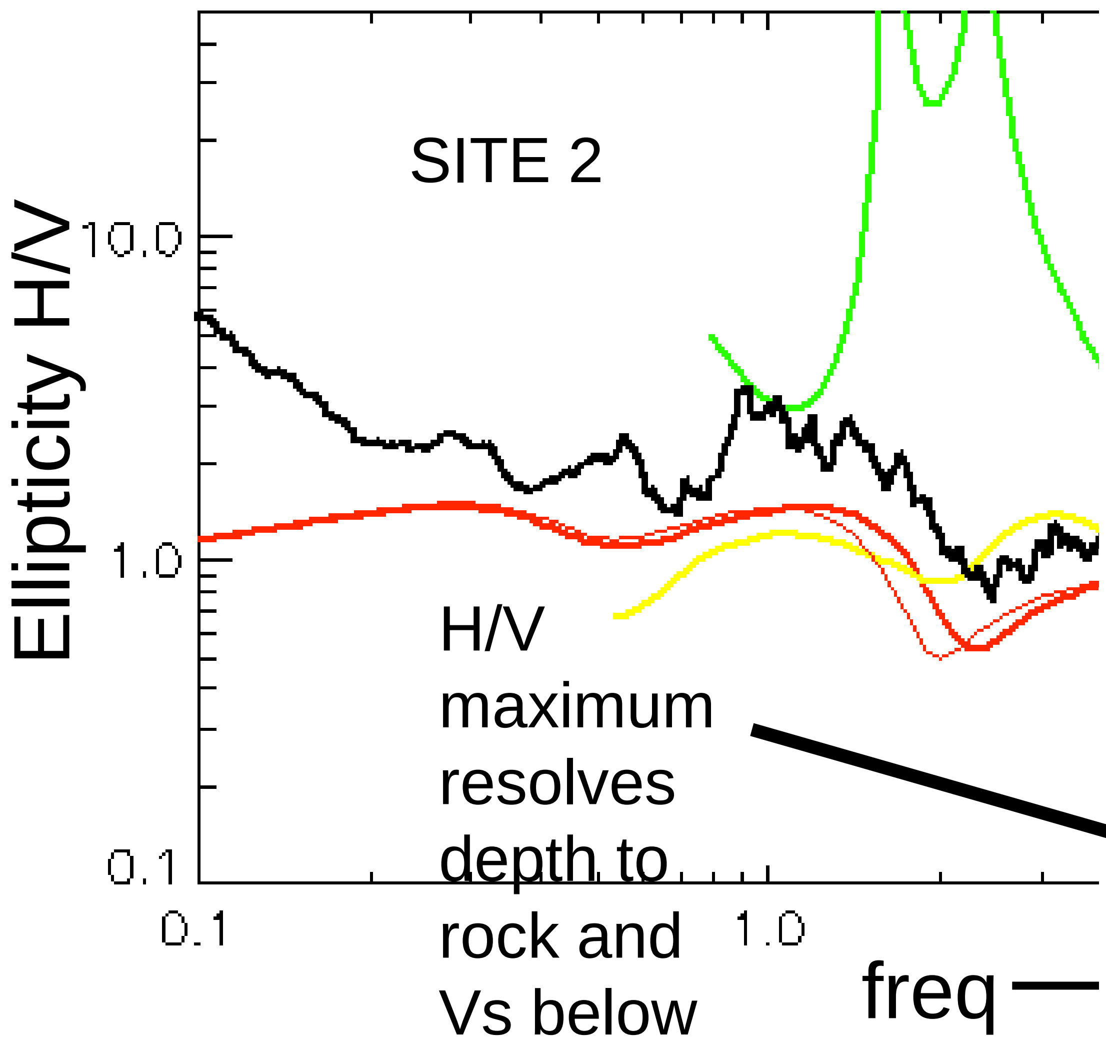
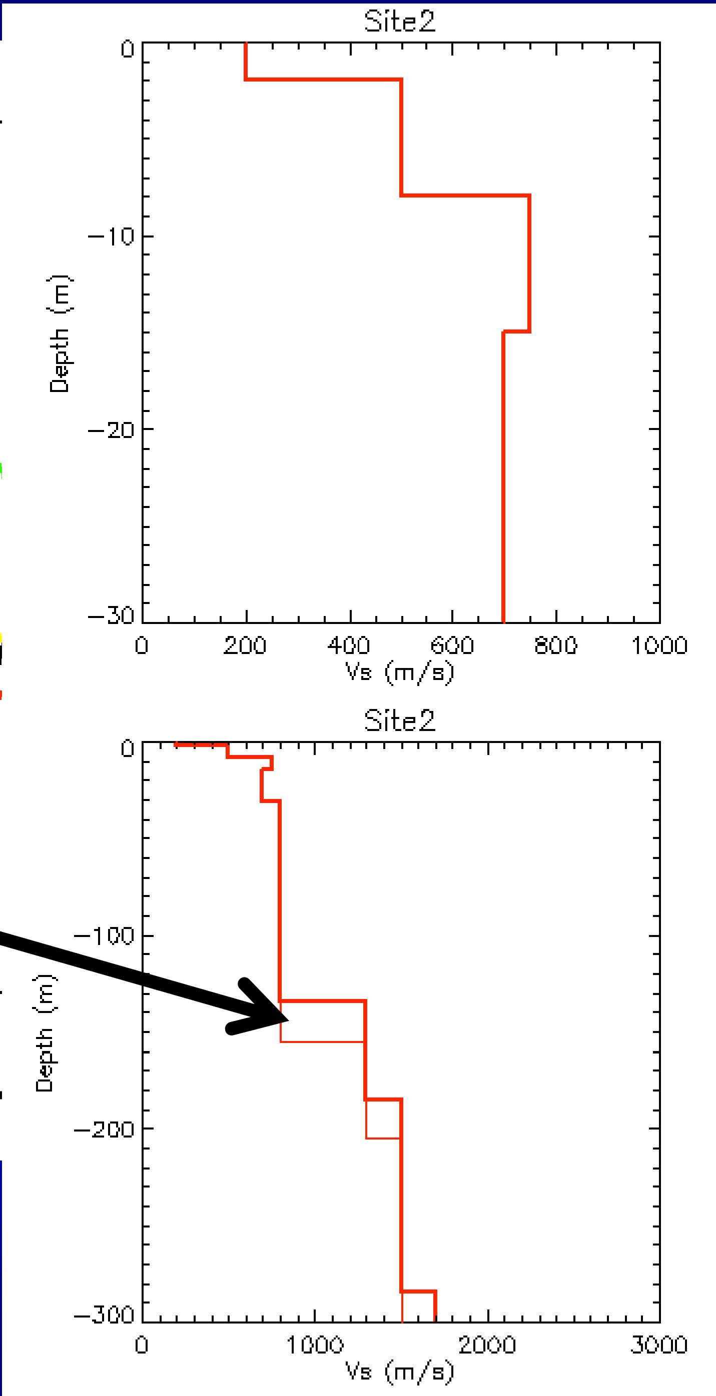


H/V maximum resolves depth to rock and Vs below



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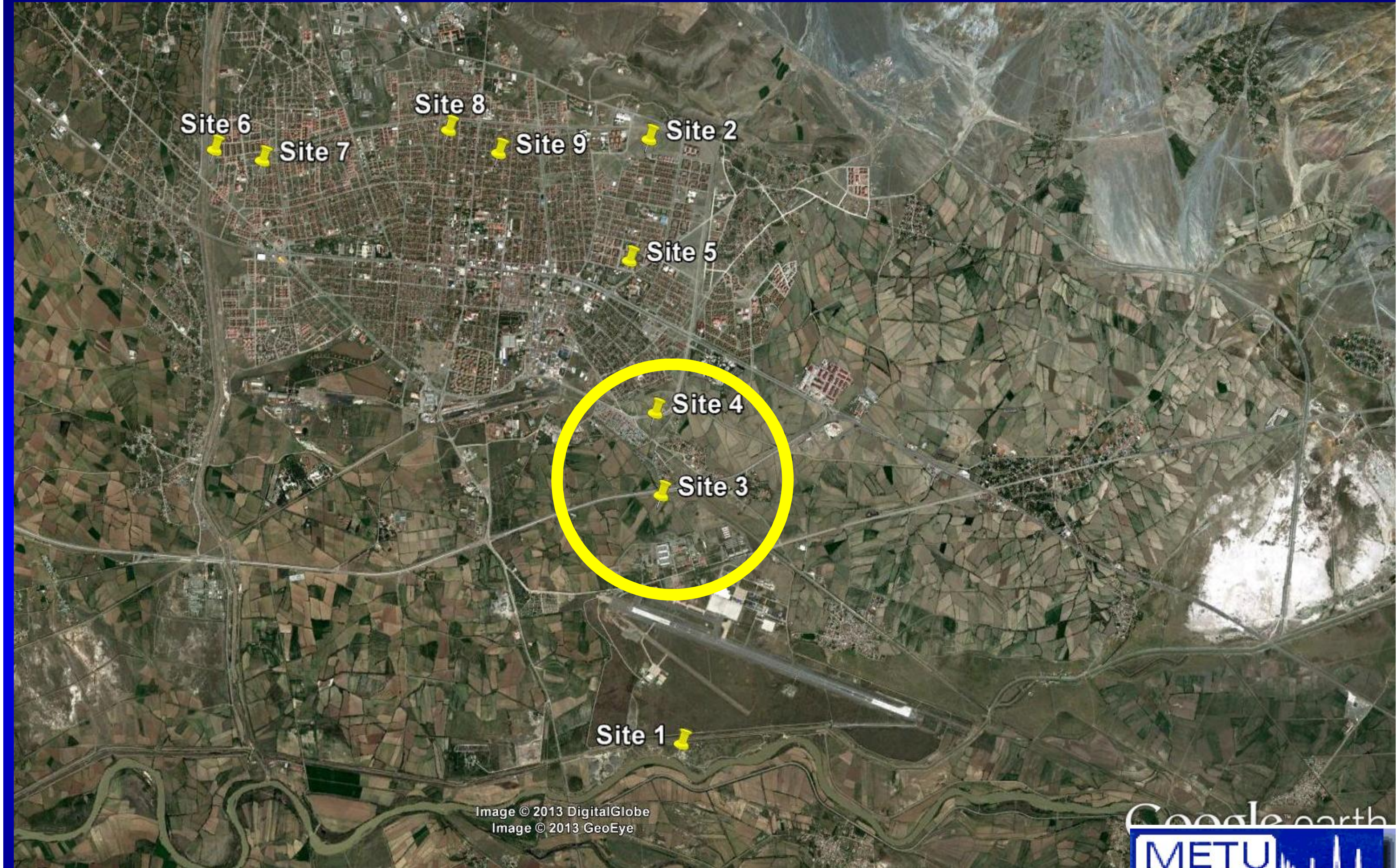

3km

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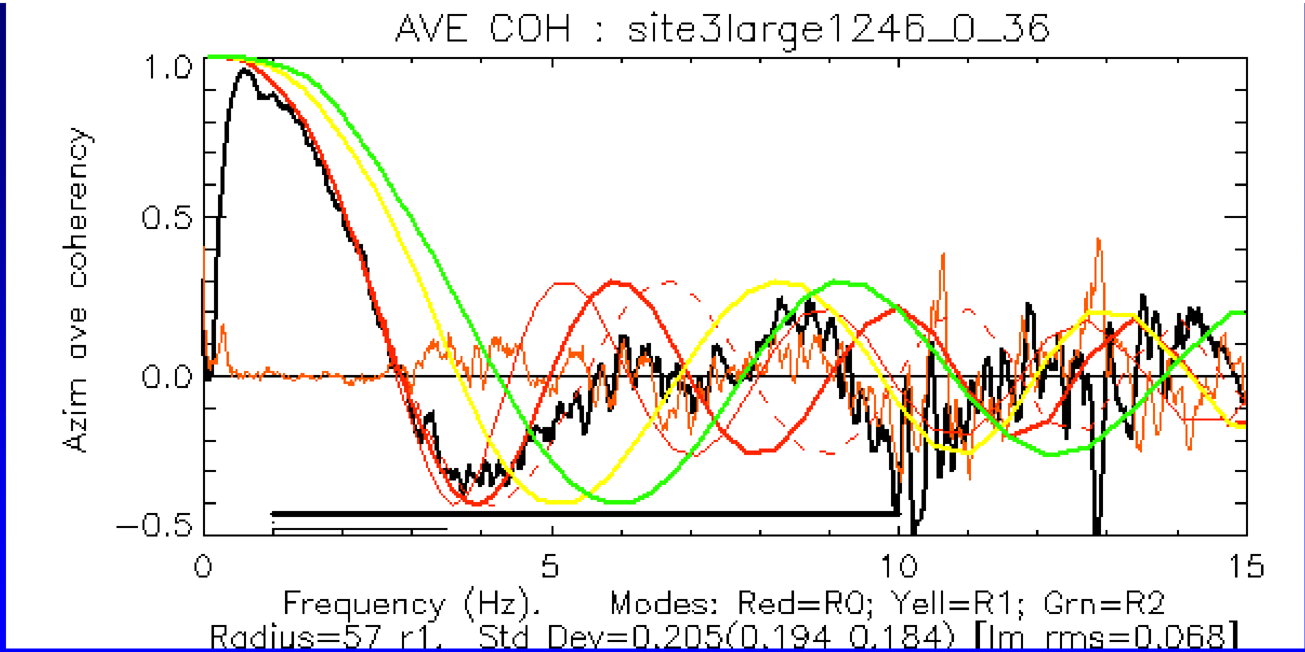
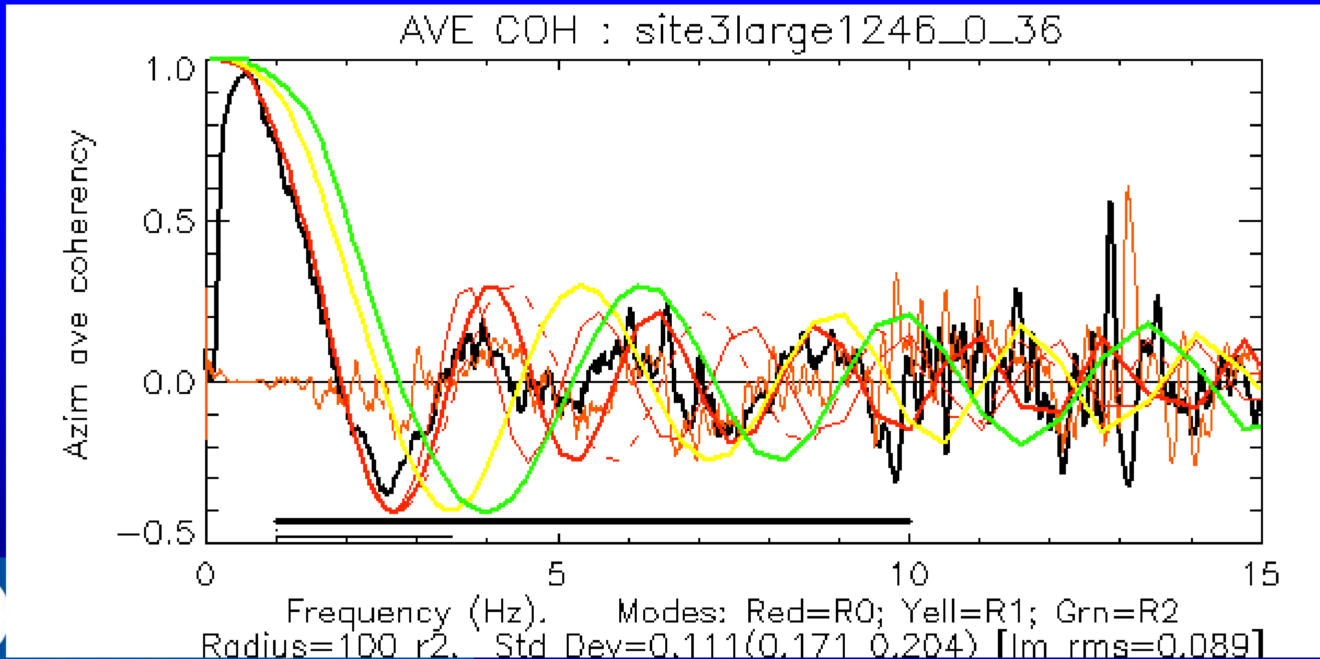
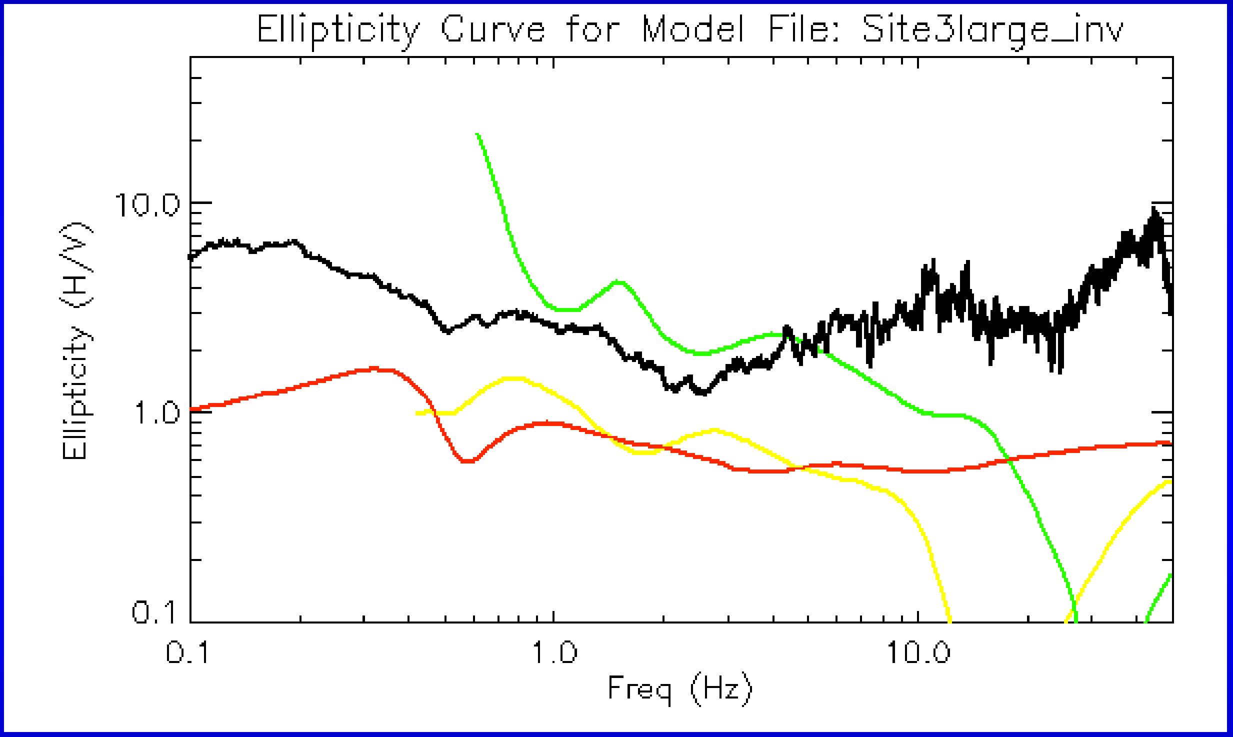


SITE 3
100m triangle array



SITE 3



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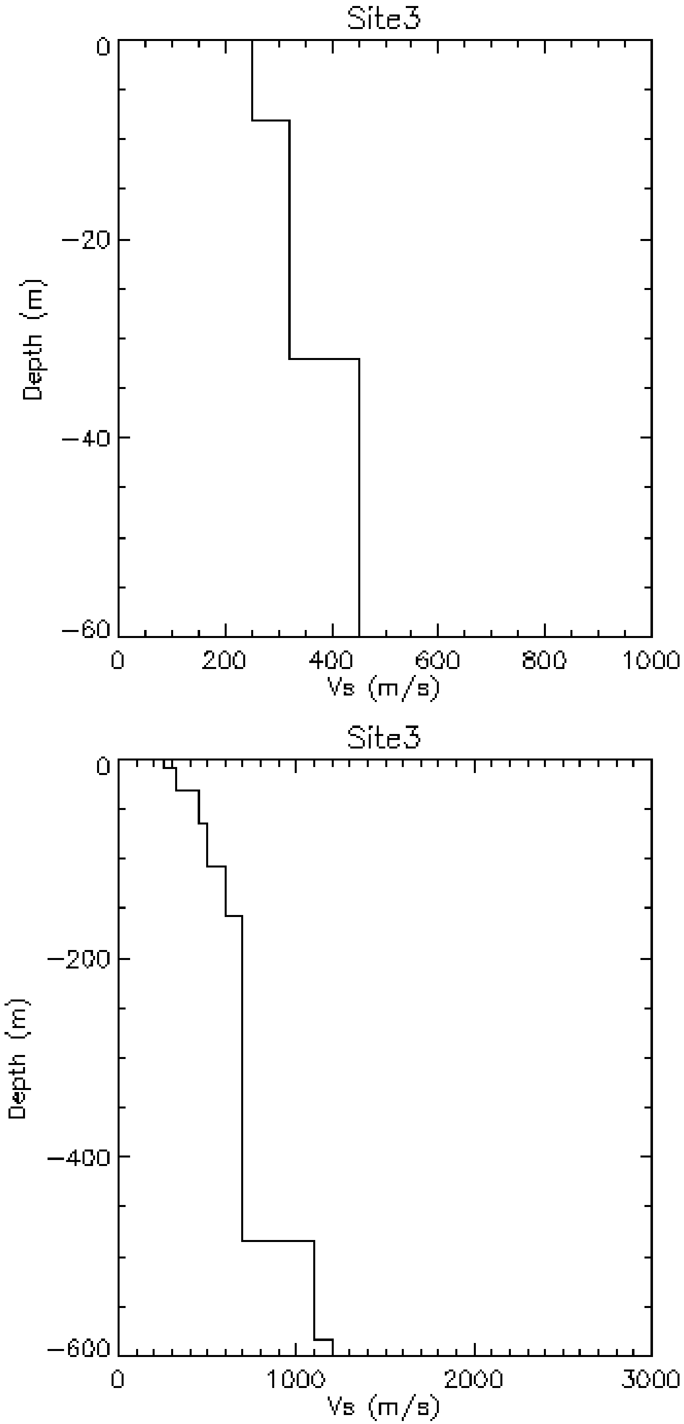
SITE 3



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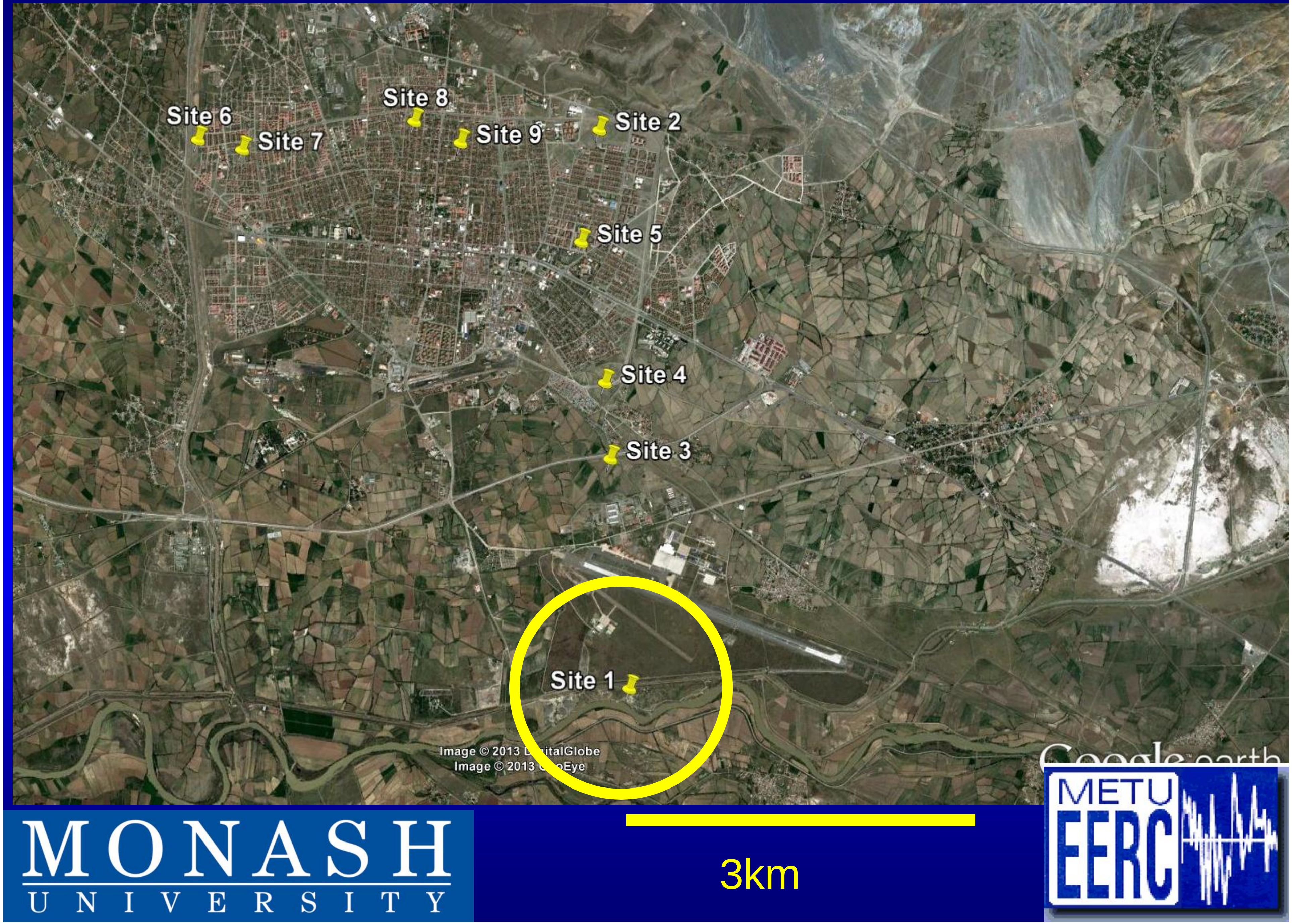

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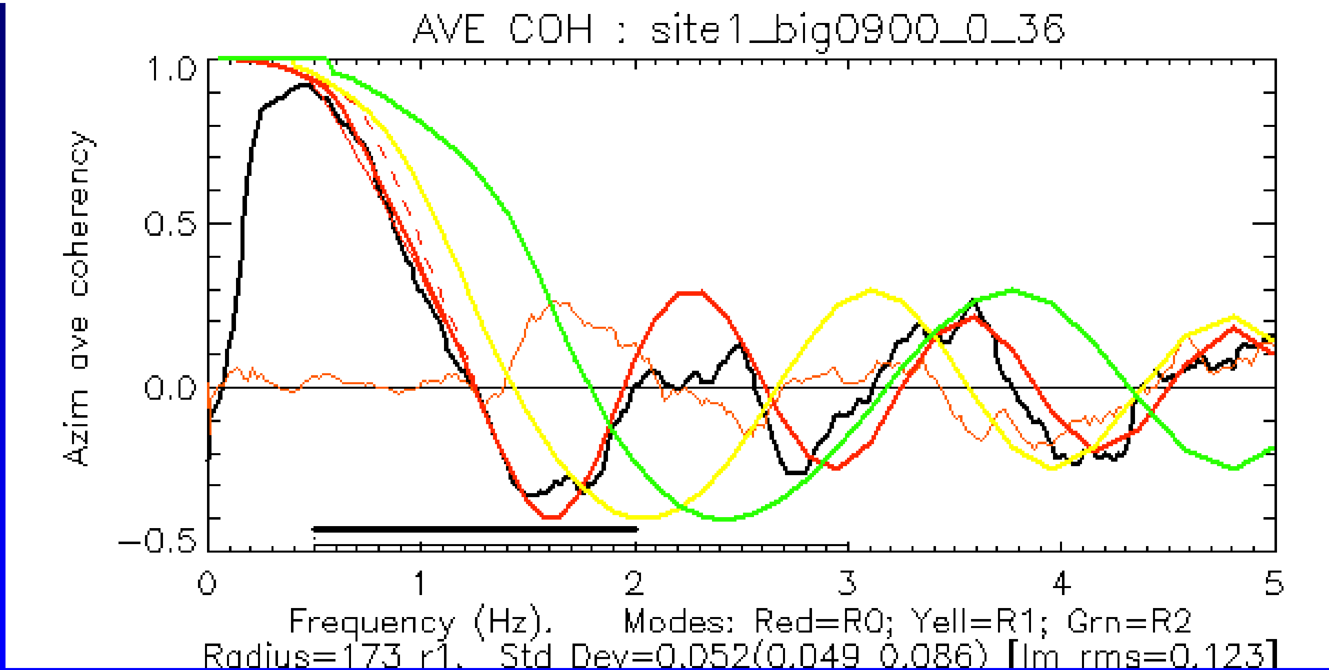
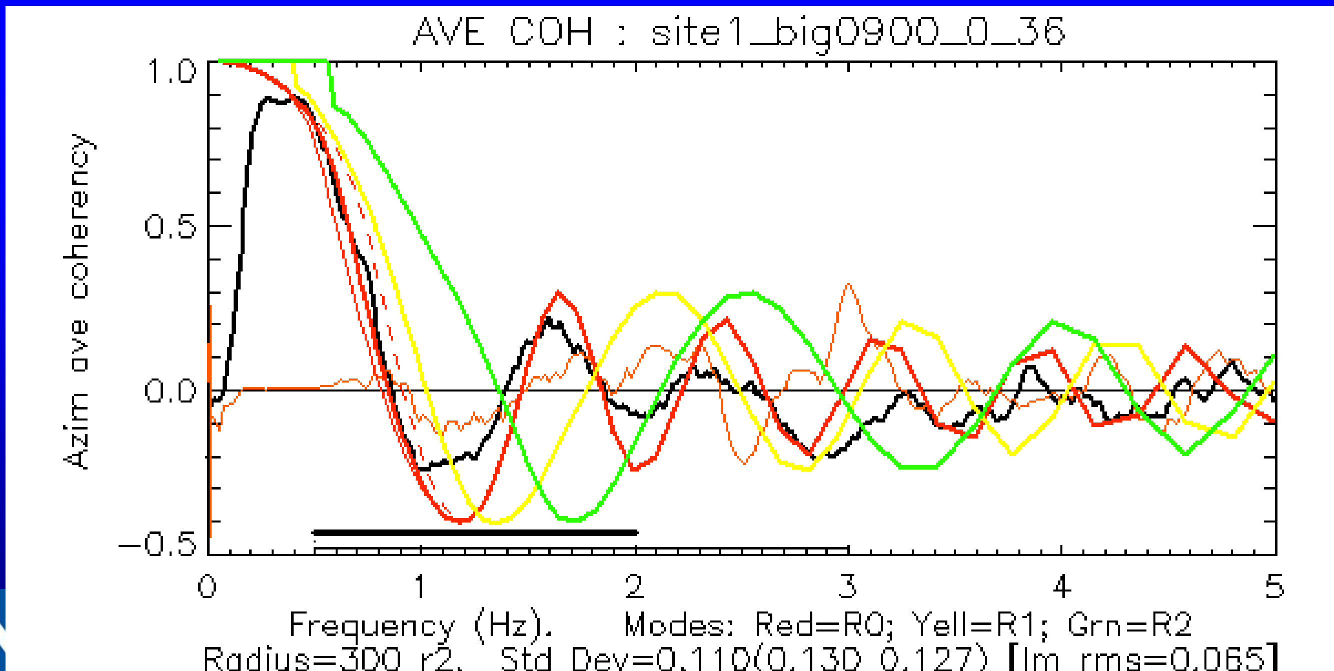
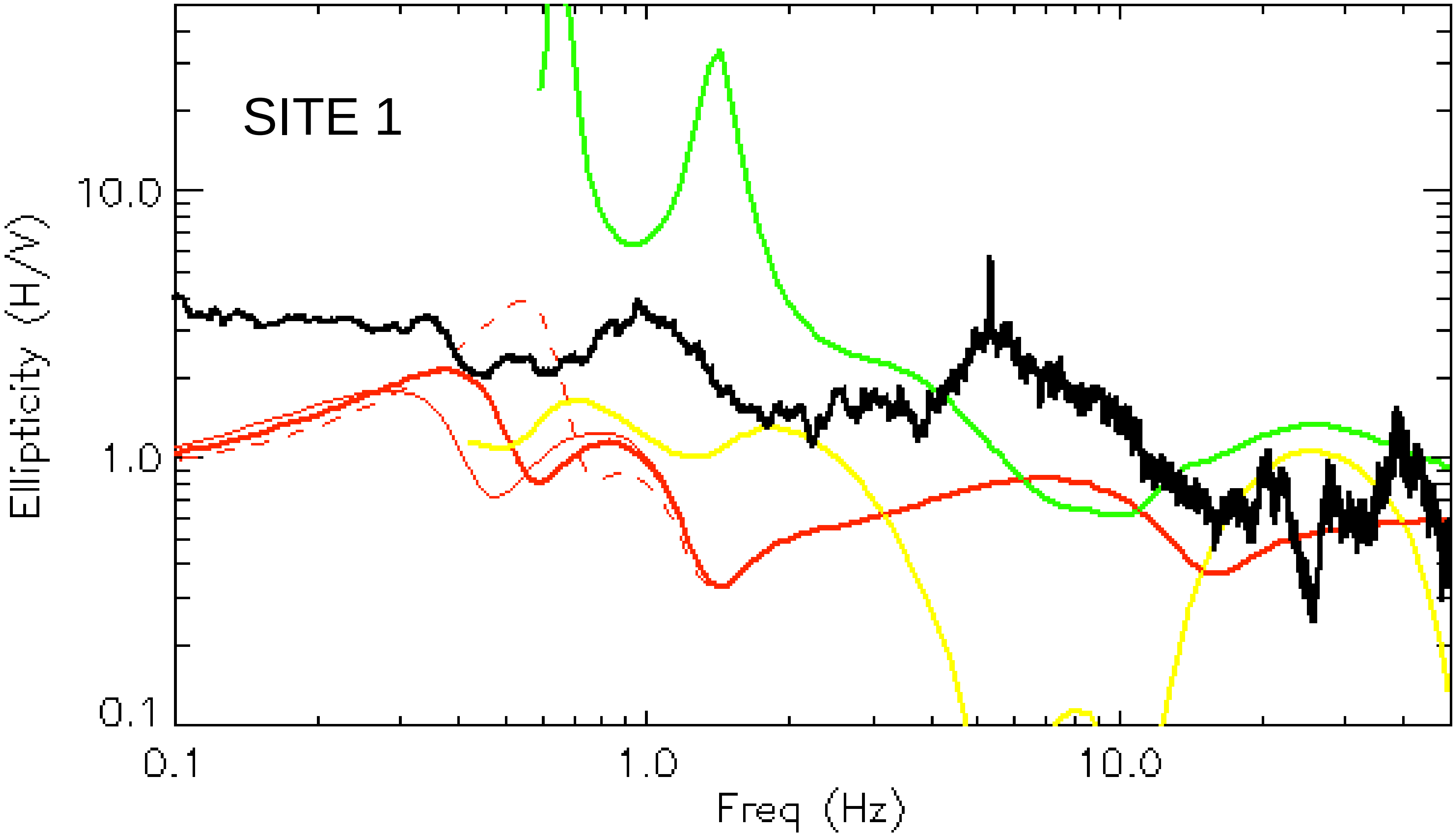




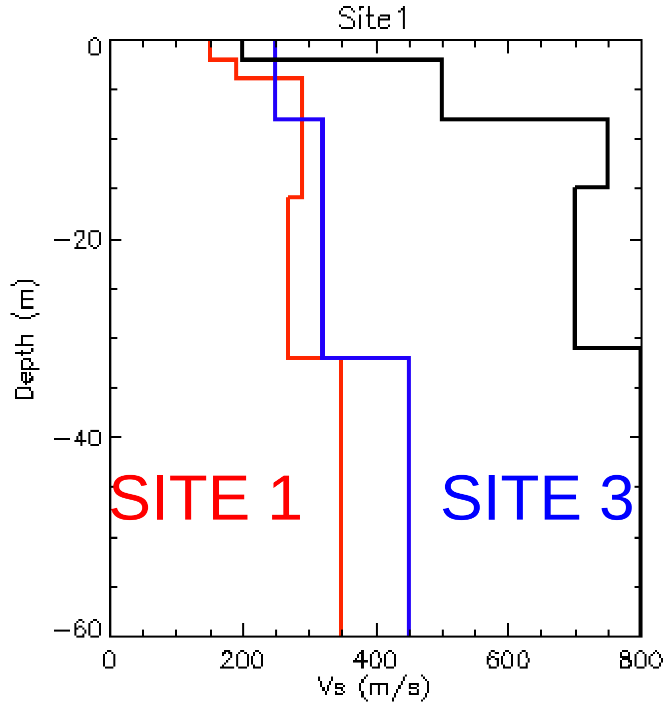
SITE 1

300m triangle array

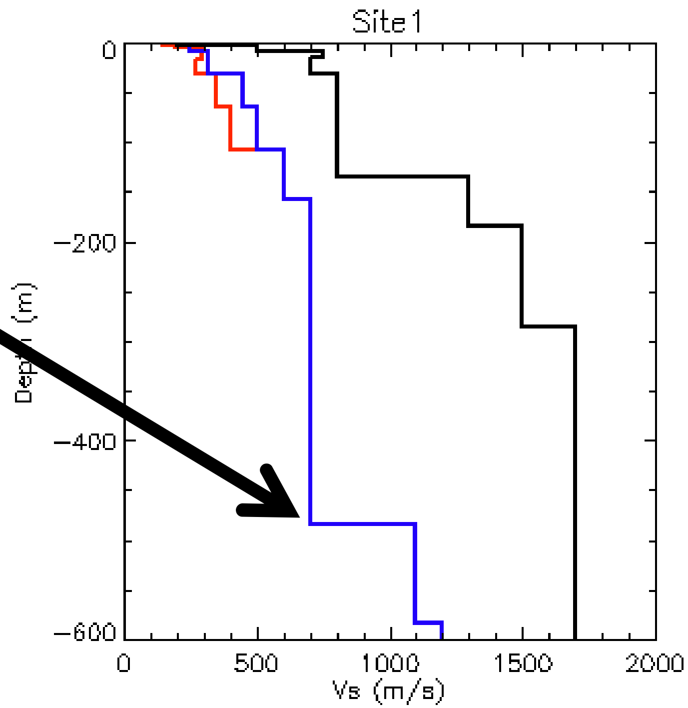
Ellipticity Curve for Model File: Site1bigto600m_3topMud_inv



SPAC 0.5 Hz resolves depth to rock at 470m, and Vs below 470m



SITE 2



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SUMMARY OF MICROTREMOR APPLICATIONS

NEWCASTLE: basement 20-100m depth

PROMINENT HILL: basement 100-200m depth

Erzincan (Turkey): basement 470m depth