

## **COMUNE DI PISA**

**RISULTATI DI UNA PROSPEZIONE GEOFISICA M.A.S.W. ESEGUITA**

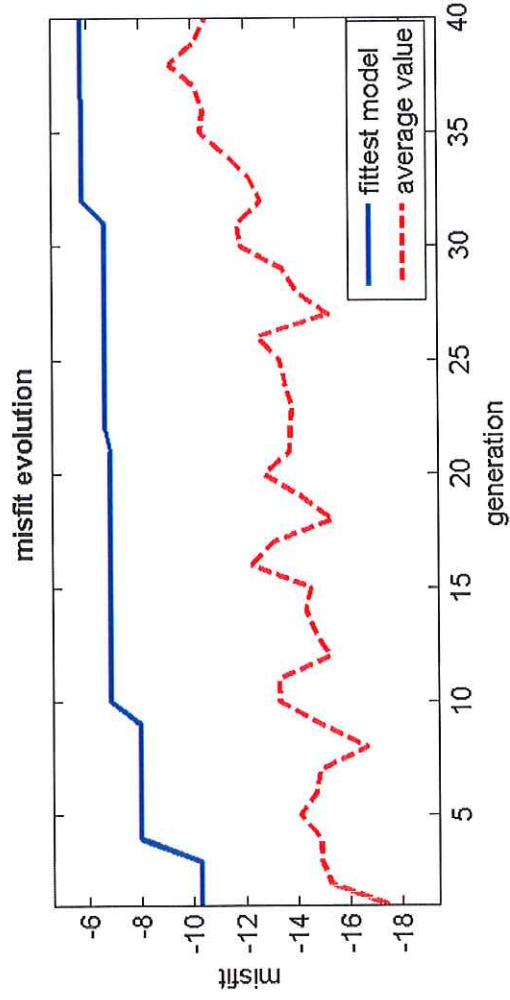
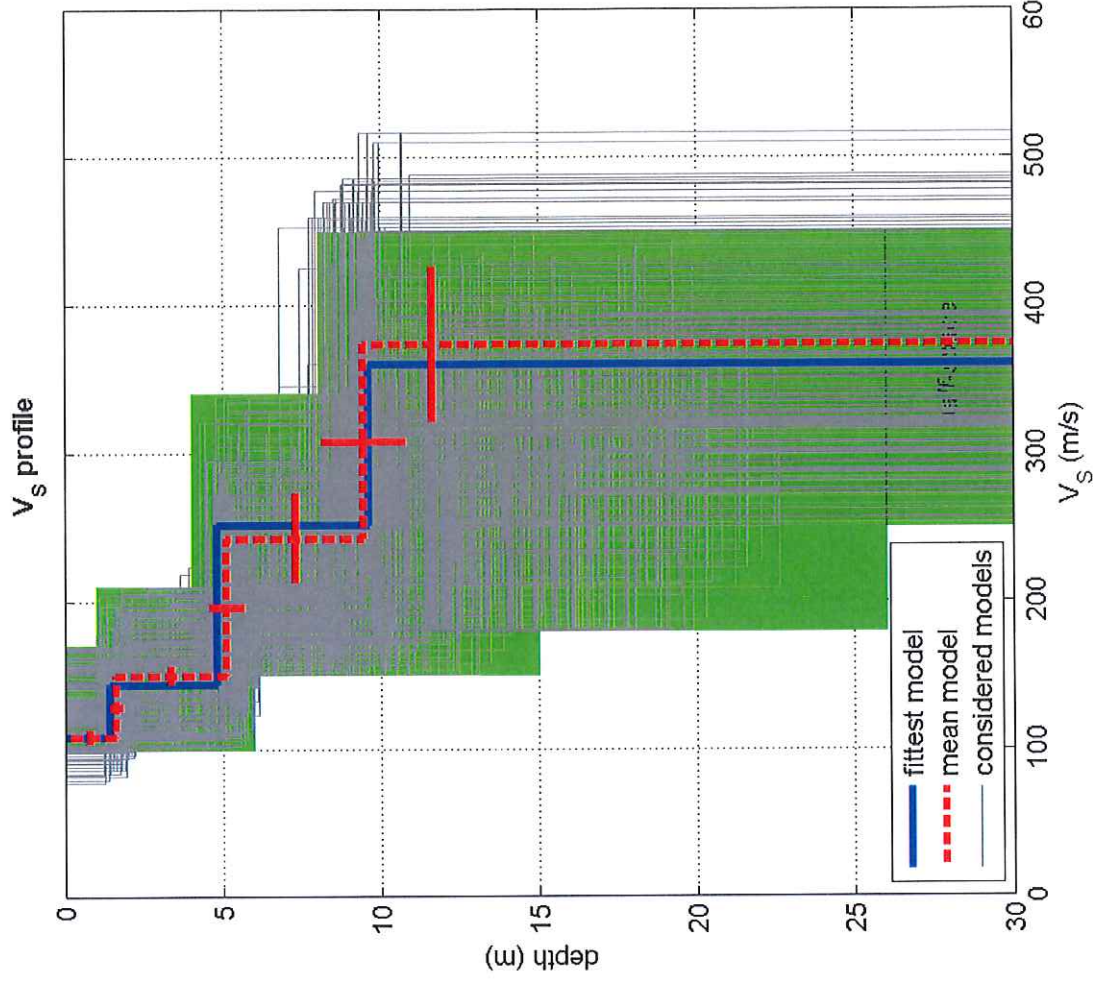
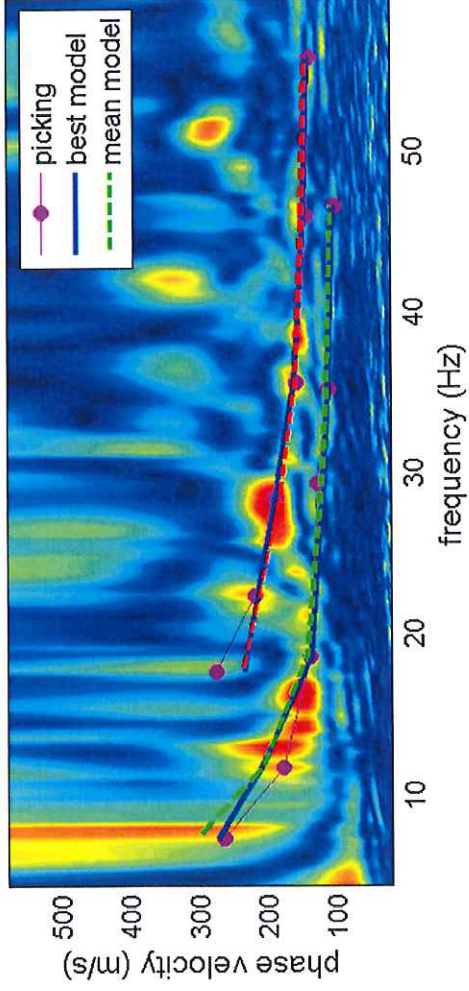
**IN VIA DEI GELSI N. 7, LOC. TIRRENIA**



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Novembre 2016

velocity spectrum & dispersion curve



dataset: 2msp1m.SGY  
 dispersion curve: 2m.cdp  
 $V_{s30}$  (best model): 267 m/s  
 $V_{s30}$  (mean model): 270 m/s

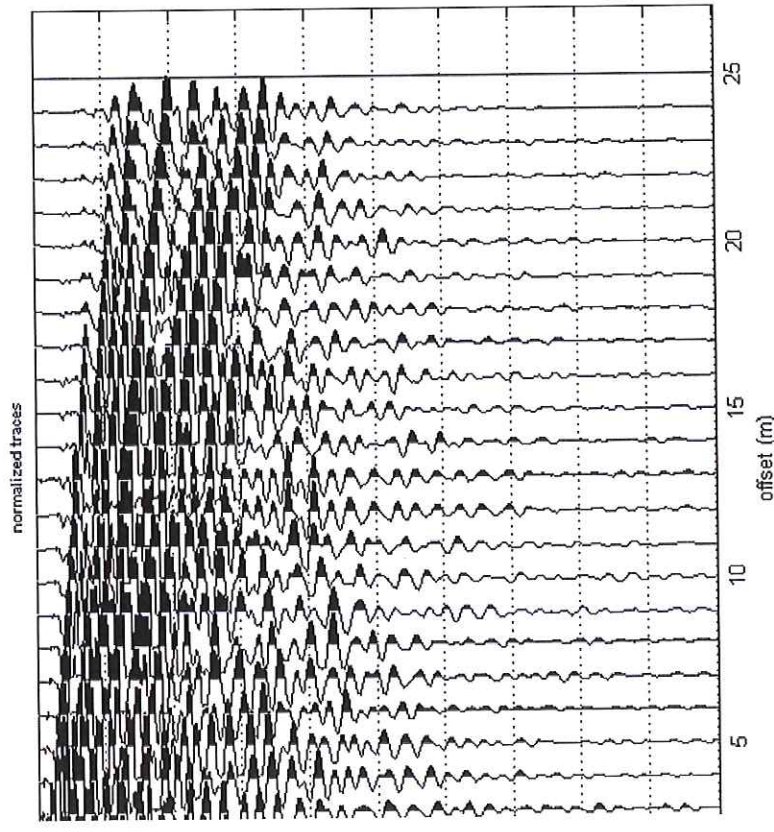


ng (MASW analyses)

GY

1

1 m



data selection

activate select cancel

60 save

filtering & spectra

filter cancel

spectrum spectrogram

refraction

refraction 100

upload save

clear refraction

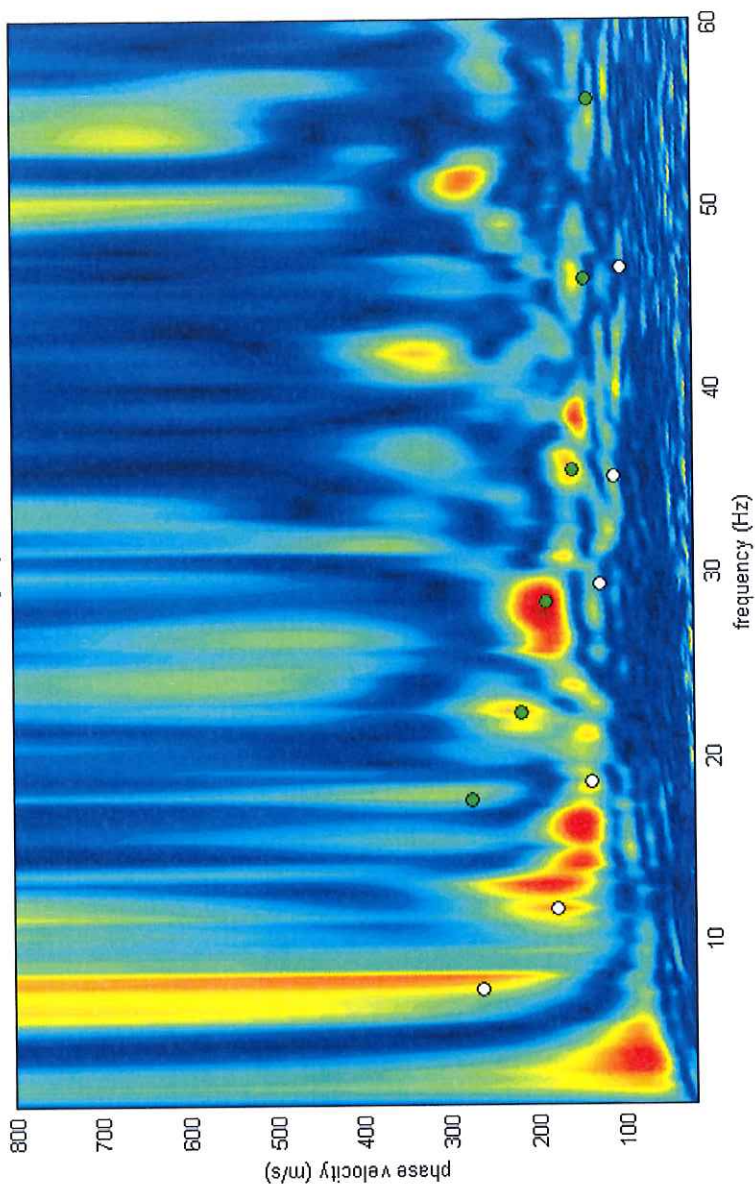
length to visualize (s)

flip traces

zero padding

done

velocity spectrum



general setting

? Rayleigh 3 phase vel

0 Reference depth Refraction

H/V body waves

0 H/V modes (SW ellipticity)

about Poisson

Vs (m/s)

100 180 260 400 600 800 1200 0

Poisson

0.4 0.35 0.35 0.35 0.35 0.35 0.3

thickness (m)

1 2 5 5 7 80 0

calculate upload mod. save model refresh

report

modelling

synthetics

ZVF

elastic

shows DC

synthetics

explore spectrum

mode separation

handling the spectra

save upload merge

phase velocity f<sub>0,k</sub> group velocity

MASW: compute velocity spectrum

Analyzing phase velocities

==o== SECTION#1  
dataset: 2msplm.SGY  
minimum offset (m): 2  
geophone spacing (m): 1  
sampling (ms): 0.131  
Dispersion curve: 2m.cdp  
Number of individuals: 30  
Number of generations: 31

Rayleigh-wave dispersion analysis

Analyzing phase Velocities

Adopted search space (minimum Vs & thickness): 100 1 150 3 180 4 250  
Adopted search space (maximum Vs & thickness): 170 6 210 9 340 11 450  
Adopted Poisson values: 0.4 0.35 0.35 0.35

Output folder: C:\studio giuseppe\lavori\sismiche\output\_disp

==o== SECTION#2

Rayleigh wave analysis

Optimizing Vs & Thickness - generation: 1; average & best misfits: -17.611 -10.2981  
Optimizing Vs & Thickness - generation: 2; average & best misfits: -15.2887 -10.2912  
Optimizing Vs & Thickness - generation: 3; average & best misfits: -14.9301 -10.2912  
Optimizing Vs & Thickness - generation: 4; average & best misfits: -14.9133 -7.98923  
Optimizing Vs & Thickness - generation: 5; average & best misfits: -14.1046 -7.98923  
Optimizing Vs & Thickness - generation: 6; average & best misfits: -14.7506 -7.98923  
Optimizing Vs & Thickness - generation: 7; average & best misfits: -14.8776 -7.98923  
Optimizing Vs & Thickness - generation: 8; average & best misfits: -16.6867 -7.98923  
Optimizing Vs & Thickness - generation: 9; average & best misfits: -14.9397 -7.98923  
Optimizing Vs & Thickness - generation: 10; average & best misfits: -13.3486 -6.86679  
Optimizing Vs & Thickness - generation: 11; average & best misfits: -13.3191 -6.86679  
Optimizing Vs & Thickness - generation: 12; average & best misfits: -15.2515 -6.86679  
Optimizing Vs & Thickness - generation: 13; average & best misfits: -14.7376 -6.86679  
Optimizing Vs & Thickness - generation: 14; average & best misfits: -14.3451 -6.86679  
Optimizing Vs & Thickness - generation: 15; average & best misfits: -14.5509 -6.86679  
Optimizing Vs & Thickness - generation: 16; average & best misfits: -12.2982 -6.86679  
Optimizing Vs & Thickness - generation: 17; average & best misfits: -13.1168 -6.86679  
Optimizing Vs & Thickness - generation: 18; average & best misfits: -15.393 -6.86679  
Optimizing Vs & Thickness - generation: 19; average & best misfits: -14.1814 -6.86679  
Optimizing Vs & Thickness - generation: 20; average & best misfits: -12.7705 -6.86679  
Optimizing Vs & Thickness - generation: 21; average & best misfits: -13.7439 -6.86679  
Optimizing Vs & Thickness - generation: 22; average & best misfits: -13.7795 -6.68906  
Optimizing Vs & Thickness - generation: 23; average & best misfits: -13.8613 -6.68906  
Optimizing Vs & Thickness - generation: 24; average & best misfits: -13.5975 -6.68906  
Optimizing Vs & Thickness - generation: 25; average & best misfits: -13.3858 -6.68906  
Optimizing Vs & Thickness - generation: 26; average & best misfits: -12.523 -6.68906  
Optimizing Vs & Thickness - generation: 27; average & best misfits: -15.2595 -6.68906  
Optimizing Vs & Thickness - generation: 28; average & best misfits: -14.032 -6.68906  
Optimizing Vs & Thickness - generation: 29; average & best misfits: -13.5009 -6.68906  
Optimizing Vs & Thickness - generation: 30; average & best misfits: -11.9193 -6.68906  
Optimizing Vs & Thickness - generation: 31; average & best misfits: -11.7592 -6.68906  
Forcing search space

Now a finer search around the most promising search space area

Rayleigh wave analysis

|                                                                             |          |
|-----------------------------------------------------------------------------|----------|
| Optimizing Vs & Thickness - generation: 1; average & best misfits: -12.6841 | -5.81853 |
| Optimizing Vs & Thickness - generation: 2; average & best misfits: -12.2091 | -5.81853 |
| Optimizing Vs & Thickness - generation: 3; average & best misfits: -11.3624 | -5.81853 |
| Optimizing Vs & Thickness - generation: 4; average & best misfits: -10.3831 | -5.81853 |
| Optimizing Vs & Thickness - generation: 5; average & best misfits: -10.4688 | -5.81853 |
| Optimizing Vs & Thickness - generation: 6; average & best misfits: -10.174  | -5.76722 |
| Optimizing Vs & Thickness - generation: 7; average & best misfits: -9.1882  | -5.7672  |
| Optimizing Vs & Thickness - generation: 8; average & best misfits: -10.1653 | -5.76722 |
| Optimizing Vs & Thickness - generation: 9; average & best misfits: -10.5942 | -5.76722 |

Model after the Vs & Thickness optimization (fixed Poisson values):

Vs (m/s): 109 144 252 361

Thickness (m): 1.4 3.4 4.8

Poisson: 0.4 0.35 0.35 0.35

Vp & Density Optimization

p14 =

1

p15 =

12

p16 =

|        |        |        |        |        |        |
|--------|--------|--------|--------|--------|--------|
| 0.1562 | 0.2502 | 0.3987 | 0.6298 | 0.7557 | 1.0000 |
| 0.3157 | 0.4005 | 0.5087 | 0.6374 | 0.8242 | 1.0000 |
| 0      | 0      | 0      | 0      | 0      | 0      |
| 0      | 0      | 0      | 0      | 0      | 0      |

Rayleigh wave analysis

|                                                                          |         |
|--------------------------------------------------------------------------|---------|
| Optimizing Vp & Density - generation: 1; average & best misfits: -6.1803 | -5.2149 |
| Optimizing Vp & Density - generation: 2; average & best misfits: -5.9496 | -5.2149 |
| Optimizing Vp & Density - generation: 3; average & best misfits: -5.6655 | -5.1523 |
| Optimizing Vp & Density - generation: 4; average & best misfits: -5.4669 | -5.1523 |
| Optimizing Vp & Density - generation: 5; average & best misfits: -5.4102 | -5.1373 |
| Optimizing Vp & Density - generation: 6; average & best misfits: -5.3966 | -5.1373 |
| Optimizing Vp & Density - generation: 7; average & best misfits: -5.379  | -5.1373 |
| Optimizing Vp & Density - generation: 8; average & best misfits: -5.4186 | -5.108  |
| Optimizing Vp & Density - generation: 9; average & best misfits: -5.5211 | -5.108  |

Number of models considered to calculate the average model: 104

#####  
RESULTS  
#####

Dataset: 2msp1m.SGY

Analyzed curve/spectrum: 2m.cdp

===== SECTION#3

Analyzing Phase Velocities

Analyzing Rayleigh-Wave Dispersion

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## MEAN MODEL

Vs (m/s): 109 150 243 374  
Standard deviations (m/s): 4 6 30 52

Thickness (m): 1.6 3.5 4.3  
Standard deviations (m): 0.2 0.6 1.3

Approximate values for Vp, density, Poisson & Shear modulus

Vp (m/s): 389 789 543 890  
Density (gr/cm3): 1.83 2.00 1.91 2.03  
Vp/Vs ratio: 3.57 5.26 2.23 2.38  
Poisson: 0.46 0.48 0.37 0.39  
Shear modulus (MPa): 22 45 113 283  
Estimated static shear modulus (MPa): 0 0 0 0

### Fundamental mode

#### Mean model

| f(Hz)   | VR(m/s)  |
|---------|----------|
| 7.27878 | 305.5846 |
| 11.6559 | 208.5716 |
| 18.5718 | 142.9376 |
| 29.3395 | 121.4089 |
| 35.2048 | 114.1596 |
| 46.5853 | 107.4531 |

### First higher mode

#### Mean model

|         |          |
|---------|----------|
| 17.6088 | 238.3633 |
| 22.3361 | 212.6974 |
| 28.3765 | 182.1926 |
| 35.555  | 160.0633 |
| 45.9726 | 149.6793 |
| 55.7773 | 145.6379 |

===== SECTION#4

## BEST MODEL

Vs (m/s): 109 144 252 361  
thickness (m): 1.4366 3.3991 4.7907

Approximate values for Vp, density, Poisson & Shear modulus

Vp (m/s): 200 1022 427 598  
Density (gr/cm3): 1.67 2.06 1.85 1.93  
Vp/Vs ratio: 1.83 7.10 1.69 1.66  
Poisson: 0.29 0.49 0.23 0.21  
Shear modulus (MPa): 20 43 117 251  
Estimated static shear modulus (MPa): 0 0 0 0

dispersion curve (frequency - velocity)

### Fundamental mode)

#### best model

| F(Hz)   | VR(m/s)  |
|---------|----------|
| 7.27878 | 272.7538 |
| 11.6559 | 209.8951 |
| 18.5718 | 137.4858 |
| 29.3395 | 118.3269 |



35.2048 112.0002  
46.5853 105.2115

First higher mode)

best model

17.6088 233.9606  
22.3361 215.9676  
28.3765 189.9751  
35.555 161.2607  
45.9726 146.966  
55.7773 142.5605

Vs5 (mean model): 134 m/s

Vs5 (best model): 134 m/s

Vs20 (mean model): 237 m/s

Vs20 (best model): 237 m/s

Vs30 (mean model): 270 m/s

Vs30 (best model): 267 m/s

==o== SECTION#6

For Italian Users:

Dalla normativa (modifiche del D.M. 14/09/2005 Norme Tecniche per le Costruzioni, emanate con D.M. Infrastrutture del 14/01/2008, pubblicato su Gazzetta Ufficiale Supplemento ordinario n° 29 del 04/02/2008):

A - Ammassi rocciosi affioranti o terreni molto rigidi, caratterizzati da valori di VS30 superiori a 800 m/s, eventualmente comprendenti in superficie uno strato di alterazione, con spessore massimo di 3 m.

B - Rocce tenere e depositi di terreni a grana grossa molto addensati o terreni a grana fine molto consistenti, con spessori superiori a 30 m, caratterizzati da graduale miglioramento delle proprietà meccaniche con la profondità e valori del VS30 compresi tra 360 m/s e 800 m/s (ovvero NSPT30 > 50 nei terreni a grana grossa e  $cu_{30} > 250$  kPa nei terreni a grana fina).

C - Depositati di terreni a grana grossa mediamente addensati o terreni a grana fine mediamente consistenti, con spessori superiori a 30 m caratterizzati da graduale miglioramento delle proprietà meccaniche con la profondità e valori del VS30 compresi tra 180 m/s e 360 m/s (ovvero  $15 < NSPT30 < 50$  nei terreni a grana grossa e  $70 < cu_{30} < 250$  kPa nei terreni a grana fina).

D - Depositati di terreni a grana grossa scarsamente addensati o terreni a grana fine scarsamente consistenti, con spessori superiori a 30 m caratterizzati da graduale miglioramento delle proprietà meccaniche con la profondità e valori del VS30 inferiori a 180 m/s (ovvero  $NSPT30 < 15$  nei terreni a grana grossa e  $cu_{30} < 70$  kPa nei terreni a grana fina).

E - Terreni dei sottosuoli dei tipi C o D per spessori non superiori a 20 m, posti sul substrato di riferimento (con VS > 800 m/s).

S1 - Depositati di terreni caratterizzati da valori di VS30 inferiori 100 m/s (ovvero  $10 < cu_{S30} < 20$  kPa) che includono uno strato di almeno 8 m di terreni a grana fina di bassa consistenza, oppure che includano almeno 3 m di torba o argille altamente organiche.

S2 - Depositati di terreni suscettibili di liquefazione, di argille sensitive, o qualsiasi altra categoria di sottosuolo non classificabile nei tipi precedenti.

Results saved in the folder "C:\studio giuseppe\lavori\sismiche\output\_disp".

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winMASW  
Surface Waves & Beyond  
www.winmasw.com

Number of models used to define the mean model: 104

Vs5 for the best model: 134

Vs30 for the best model: 267

Analyzing phase velocities

Elapsed time is 48.436895 seconds.