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Constraining S-wave velocity using Rayleigh wave ellipticity from polarization analysis of seismic noise - Supplementary material

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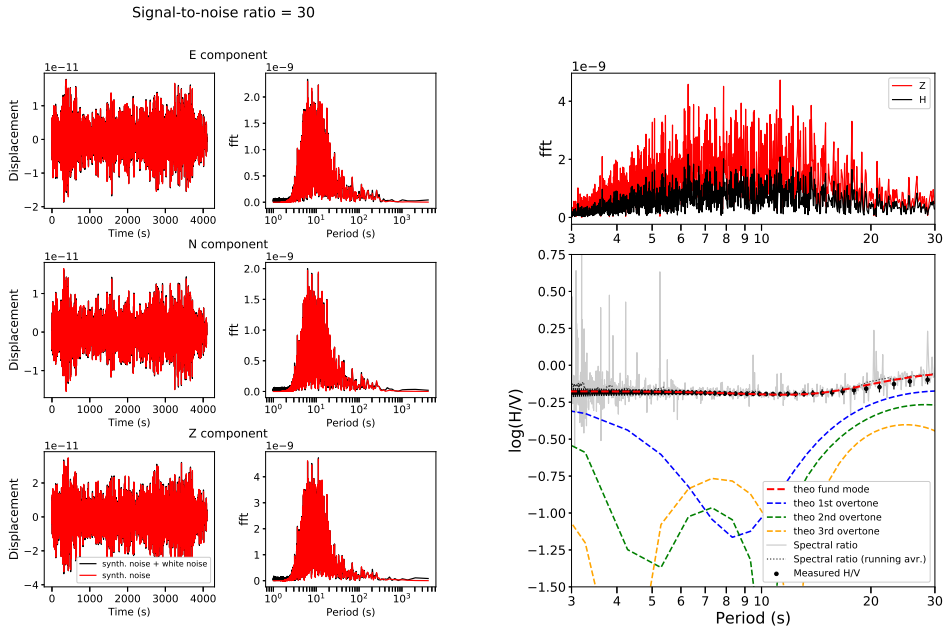
1 MEASUREMENT PARAMETERS

For reproducibility, in the following we briefly list and describe the parameters and values used with the computer code to generate the ellipticity data shown in the figures throughout this publication. Nevertheless, note that these values are flexible and that different sets can provide similar results. We also provide values which we typically use with other data and applications. The ideal values depend on the signal and noise characteristics of the data.

Name	Meaning	Value	Explaination
pow	DOP power	3	This is the DOP tuning power ν of eq. 1 in Schimmel et al., 2011. We use $\nu_1 = \nu_2$. (We usually employ pow=3, 4, or 5.)
wlenf	Frequency-dependent DOP analyzes window length	17	This is T(f) of eq. 1 in Schimmel et al., 2011. The window length is defined as number of samples at the highest frequency f_2. The window length *wlen* increases for decreasing frequency f as $wlen = wlenf \cdot \frac{f_2}{f}$. The longer this window the more longer-duration signals are favored in the analysis. The shorter this window is the more shorter-duration polarized signals are detected (together with any longer-duration signal). An optimum window should be sufficient long to avoid that instances of noise are detected as stable polarized features.
dopm	Minimum DOP	0.9	This is the threshold to limit the output to signals with elliptical DOP larger than *dopm*. (We usually employ values between 0.7 and 0.9)
cycle	Frequency-dependent Gauss window	1	This parameter controls the time-frequency resolution of the time-frequency representation of the real-valued 3-C seismograms. An S-transform (Stockwell et al, 1996) with Gaussian shaped window which linearly increases with signal period is used for the time-frequency representation. *cycle* is the variable k in eq. 3 of (Schimmel and Gallart, 2005) and equals the number of periods that would fit within a $\pm\sigma$ standard deviation window of a Gaussian distribution with same size. (We usually employ values 1, 2, or 3.)

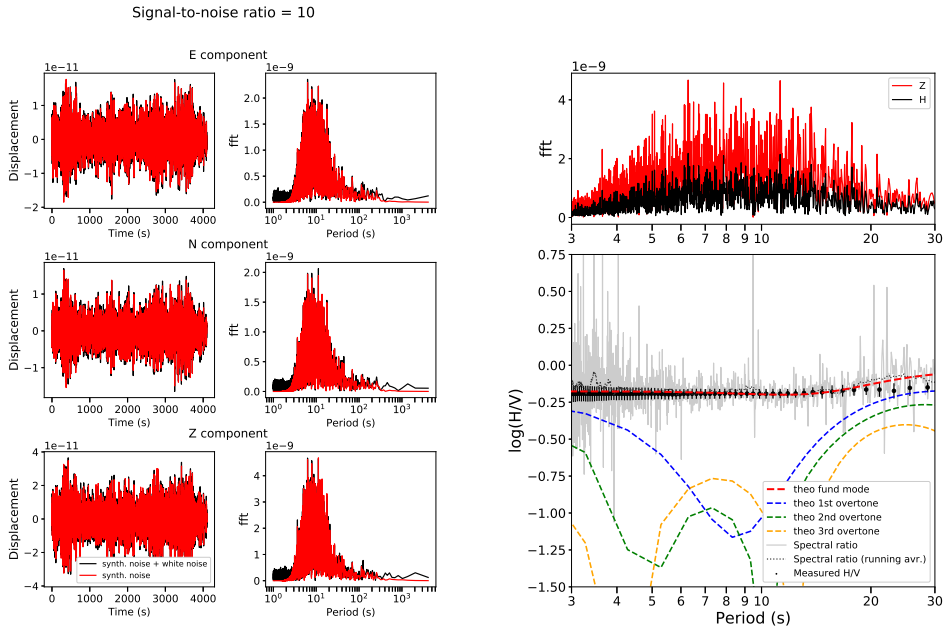
nflen	Neighbouring freq. to average	2	$2 \cdot$ *nflen* $+ 1$ frequency components can be used to average (stabilize) the spectrum before performing the eigen analysis. By default, we average the spectra rather than the spectral matrixes. Both options are possible with the code. (We usually employ *nflen* = 0, 1 or 2).
f1, f2	Min. and max. frequency in Hz	0.03, 0.5	Perform the computation in the frequency range *f1* - *f2* (Hz)
nfr	Number of frequencies in the frequency range	30	Perform the computations for *nfr* frequencies.
wdeg	w angle	10	Set DOP to zero whenever the semi-major vector deviates from the horizontal plane or vertical ax by more than *wdeg* deg. Otherwise, down-weight the DOP (using a cosine) for deviations from 0 deg. (We usually employ values smaller than 15 deg.)
zdeg	z angle	10	Set DOP to zero whenever the plane of particle motion deviates from the vertical by more than *zdeg* deg. The deviation is measured by the deviation of the planarity (eq. 6 in Schimmel and Gallart, 2003) from the horizontal plane. Otherwise, down-weight the DOP (using a cosine) for deviations from 0 deg. (We usually employ values smaller than 15 deg.)

Table 1: Parameter values used in the DOP-E measurement scheme.



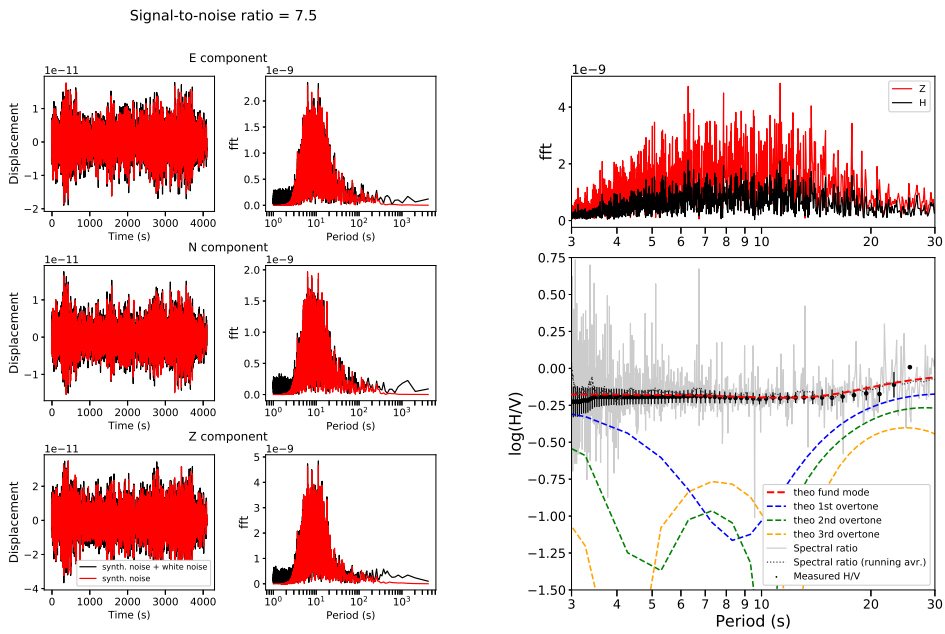
(a) (b)

Figure S1. (a): Comparison between time series and Fourier amplitude spectra of synthetic ambient noise containing Rayleigh wave only (red) and simulated ambient noise containing also white noise with a signal-to-noise ratio equal to 30. (b): top panel: vertical (red) and horizontal (black) components of the simulated ambient noise; bottom panel: ellipticity curve measured from the simulated ambient noise using the DOP-E method (black dots), theoretical ellipticity computed from model Prem (Dziewonski, & Anderson, 1981) (red dashed line), spectral ratio (gray line) and its running average (dotted black line) and ellipticity of the first 3 overtones (colored dashed lines).



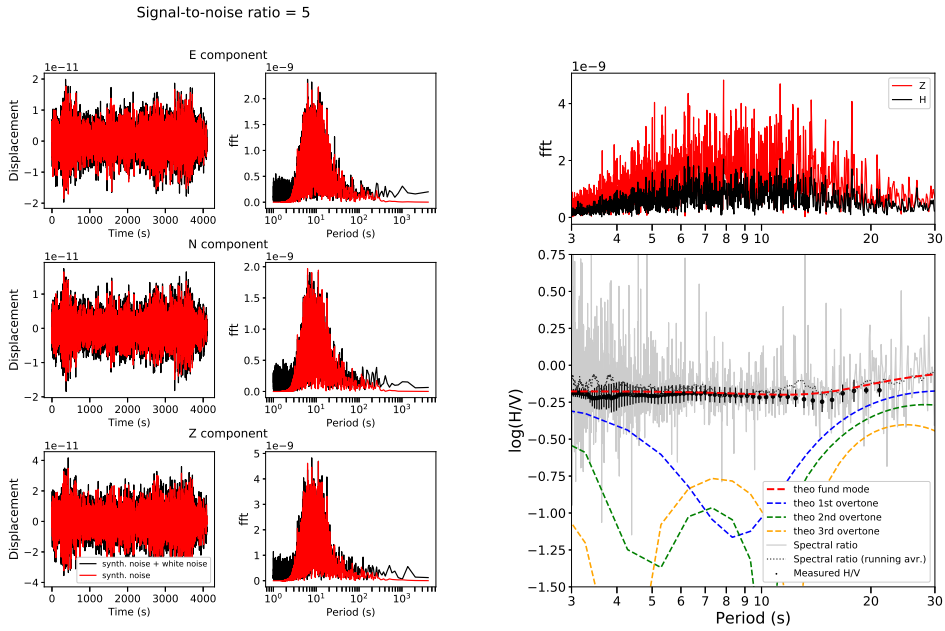
(a) (b)

Figure S2. Same as figure S1 but using a signal-to-noise ratio equal to 10.



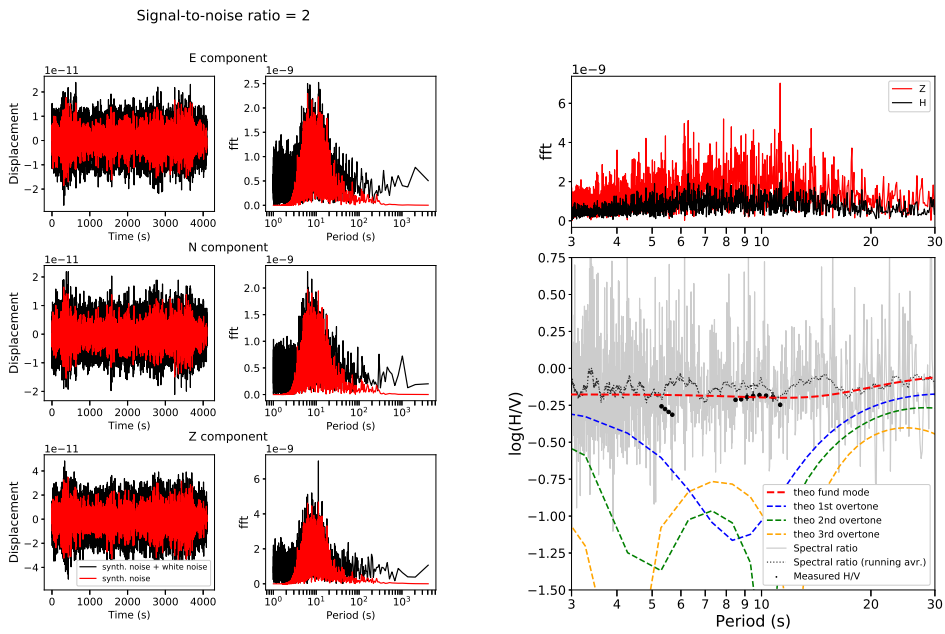
(a) (b)

Figure S3. Same as figure S1 but using a signal-to-noise ratio equal to 7.5.



(a) (b)

Figure S4. Same as figure S1 but using a signal-to-noise ratio equal to 5.



(a) (b)

Figure S5. Same as figure S1 but using a signal-to-noise ratio equal to 2.

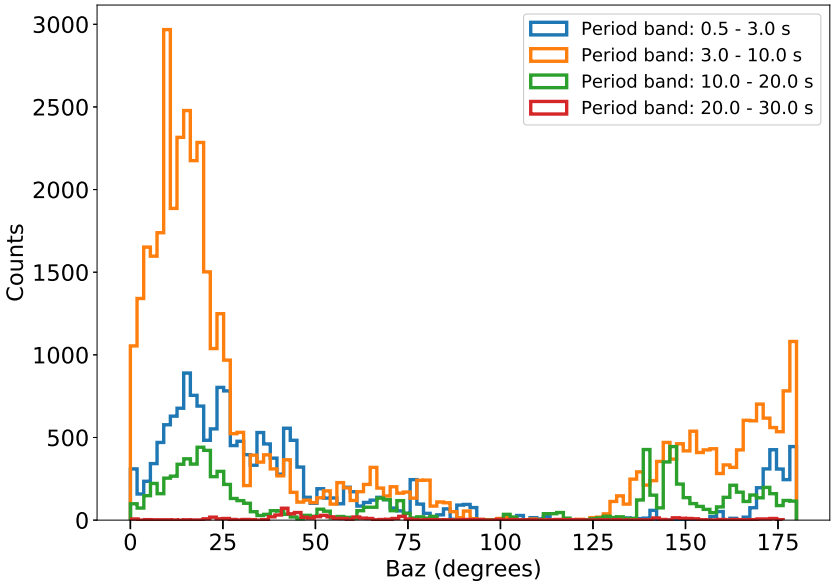


Figure S6. Histogram of the measured back azimuths for station Concordia (CCD) separated by period bands.

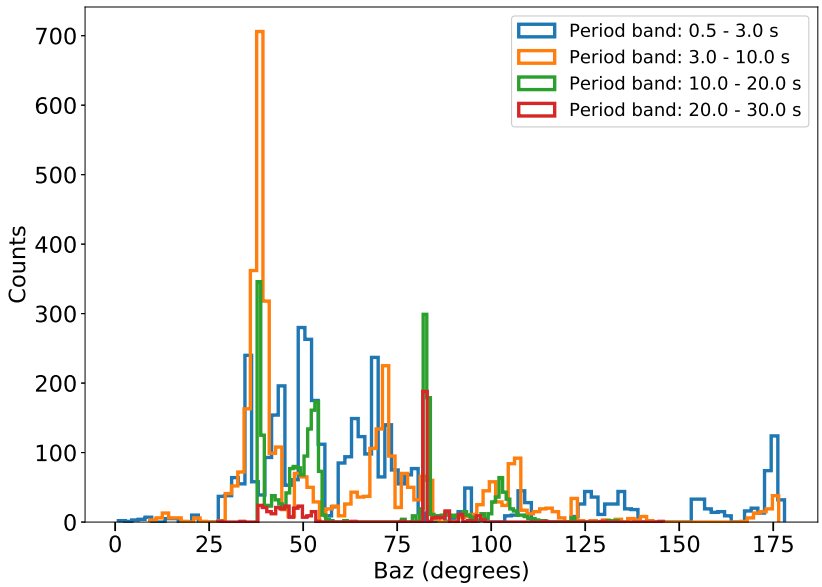


Figure S7. Histogram of the measured back azimuths for station Parma (PRMA) separated by period bands.

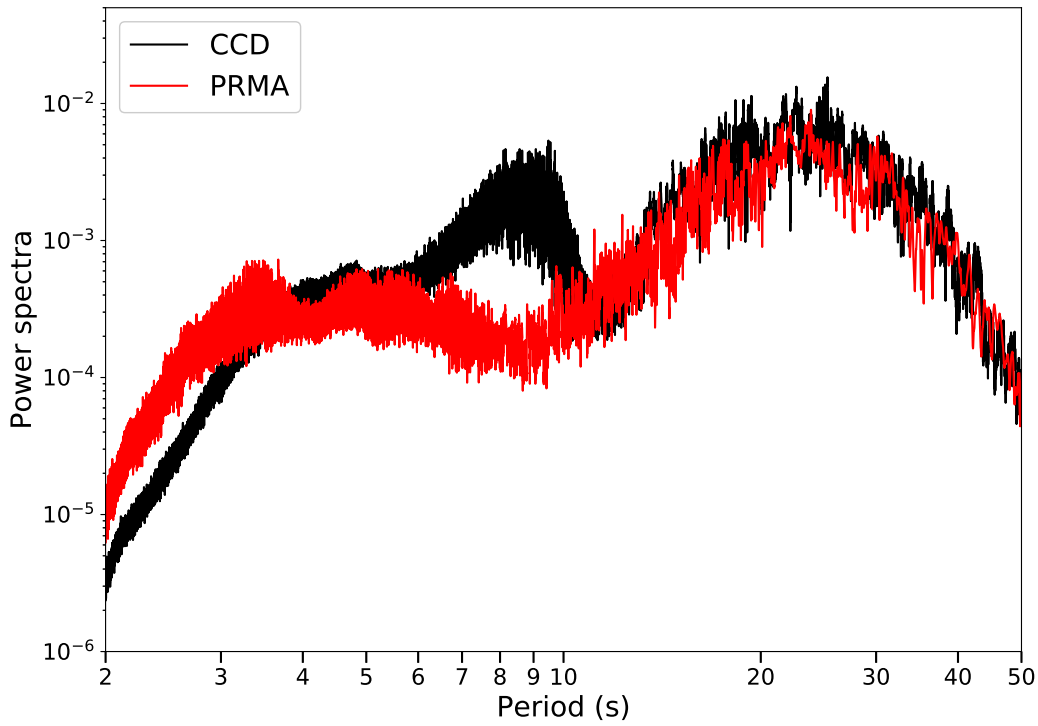


Figure S8. Power spectra from data from station CCD (black) and PRMA (red).

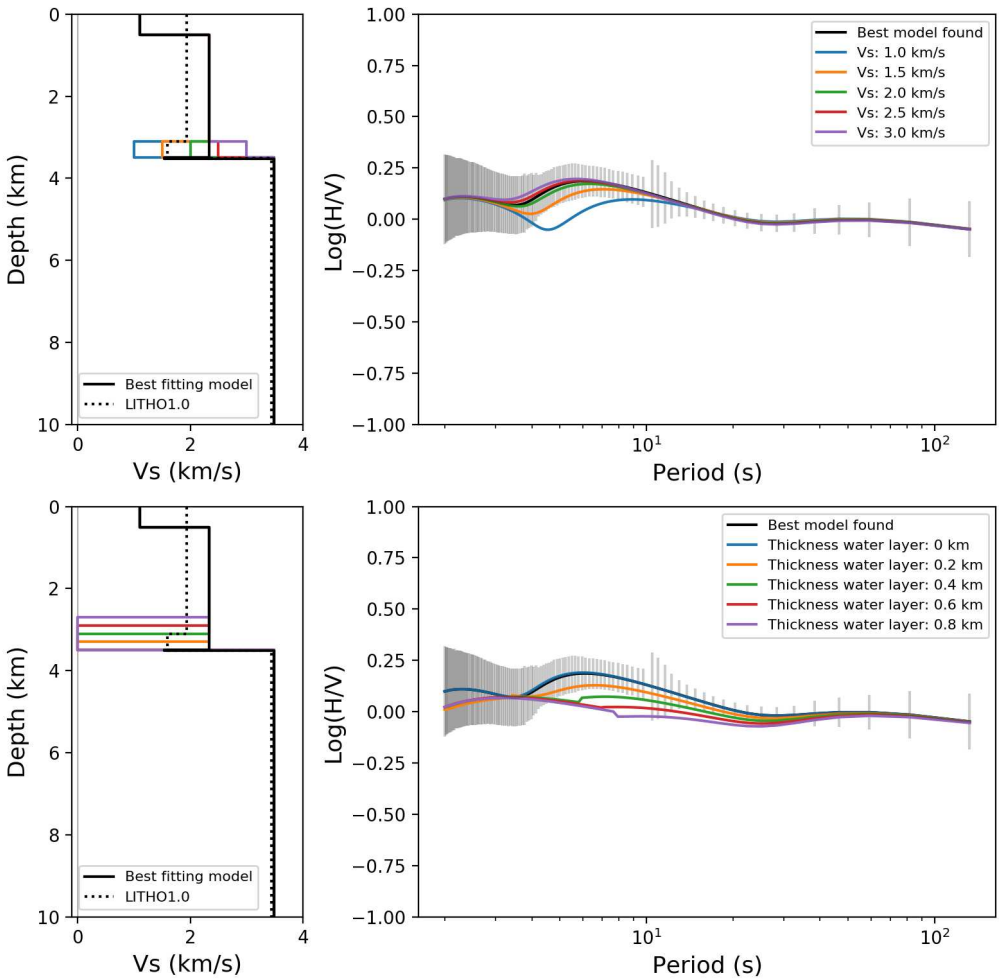


Figure S9. Sensitivity test for a thin layer at $\approx 3km$ depth. *Top panels:* test of the sensitivity to v_S variations. *Left:* Black line: best model found in the inversion (figure 10 in the main text); black dotted line: LITHO1.0 model (Pasyanos et al., 2014); colored lines: test models; *Right:* Black line with errorbars: ellipticity curves computed by modal summation from input model with standard deviations from real data measurements at station Concordia; colored lines: ellipticity computed from corresponding models on the left panel. *Bottom panels:* test of the sensitivity to the thickness of a layer of liquid water at $\approx 3km$ depth. *Left:* Black line: best model found; colored lines: test models. *Right:* Black line with error bars: ellipticity computed from model LITHO1.0 and standard deviations from real data measurements from station Concordia; Colored lines: ellipticity computed from corresponding models plotted in the left panel.

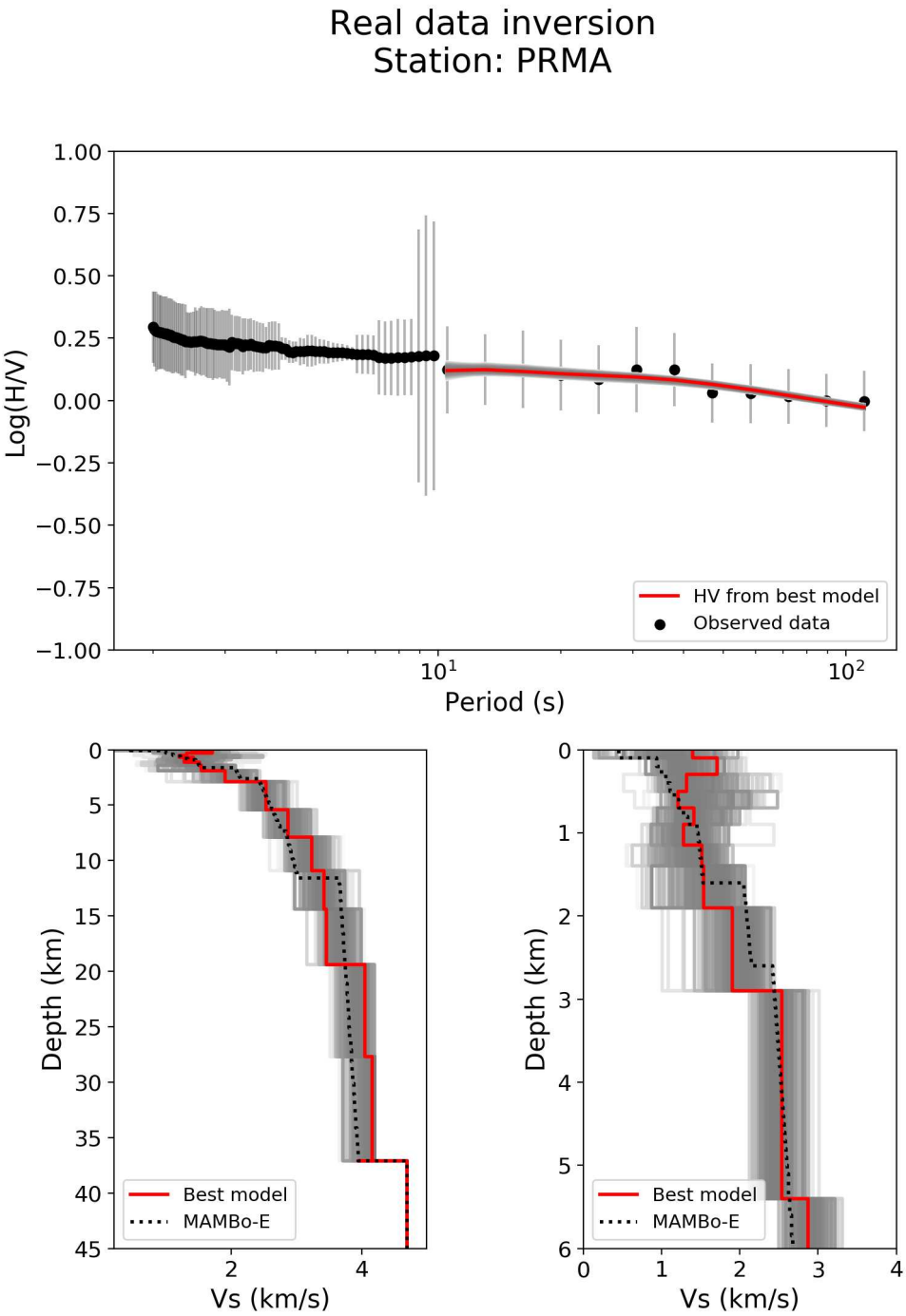


Figure S10. Inversion results from real data measurements at station PRMA (Parma, Italy) using earthquakes data only. *Top panel:* Observed data (black dots with error bars); ellipticity computed from the best value found (red line); ellipticity computed from models with cost function within 20% from the best model. *Bottom panels:* Best model found (red solid line); models with cost function within 20% from the best model (shadows of gray); model MAMBo-E by Berbellini et al. (2017) (black dashed line). *Bottom right panel:* Zoom of the shallowest 6 km.