Velocity profiles extension for the seismic station of SEPFL

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This report summarizes an update of the site characterization performed by Michel et al. (2014). In particular, the velocity profile is extended at depth, by keeping the surface velocity profile from the site-characterization fixed within a limited range. The applied method is the Hybrid Heuristic Search algorithm (HHS), an inversion technique that estimates P- and S-wave velocity profiles using the H/V curve from earthquakes (Nagashima et al., 2014). It is based on the diffuse field theory proposed by Kawase et al. (2011) and can be applied at sites characterized by different levels of seismicity (Nagashima et al., 2014, Chieppa et al., 2023). The HHS inversion algorithm was applied at more than 50 sites of the Swiss Seismic network to improve the resolution of the subsurface down to 4 km. At these sites, the P- and S-wave velocity profiles were estimated by inverting the H/V curve from earthquakes that were computed by using the S-wave arrivals of local and regional earthquakes, recorded around each investigated area. The chosen sites were selected according to the availability of passive and/or active site characterization investigations (Michel et al. 2014, Poggi et al. 2017, Hobiger et al. 2021). This information was used to define the initial seismic velocities, thicknesses and densities of the shallowest layers of the initial velocity model. The deepest layers, instead, were defined according to the data contained in the high-resolution model from seismic tomography for the Alpine crust (Diehl et al., 2009). This model provides the information on seismic velocities and densities of the deepest (4) layers located between 2 and 4 km. The seismic velocities were retrieved by averaging 9 velocity profiles at 9 sites in Switzerland, located in different tectonic units (Fig. 1 – left plot). The averaged seismic velocities range between 5605 m/s at 2 km and 5744 m/s at 4 km for P-waves, and between 3245 m/s at 2 km and 3400 m/s at 4 km for S-waves (Fig. 1 – right plot). The initial thickness and density are set to 450 m and 2.8 g/cm^3, respectively.

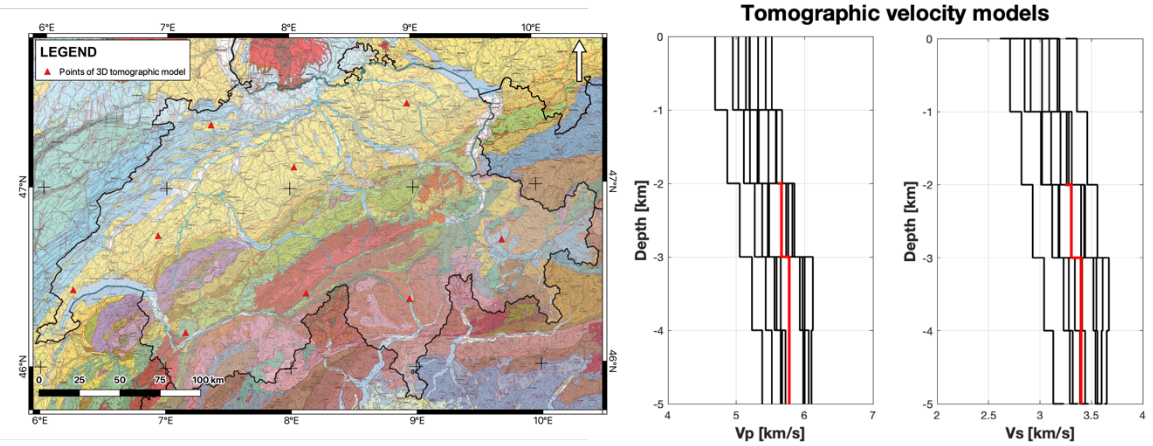

Figure 1: Tectonic map of Switzerland (left), P- and S-wave velocity profiles for the model of the Alpine crust (Diehl et al., 2009 – right). In black, the velocity profiles for the 9 sites represented by the red triangles in the left plot; in red, the average velocity profiles used to define the initial parameters of the deepest layers between 2 and 4 km.

Ten intermediate layers are added between the shallowest layers from the site characterization and the deepest layers from the tomographic model to improve the resolution of the subsurface spanning between few hundred of meters (different at each site according to the site characterization investigation) and 2 km. These intermediate layers adjust during the inversion and explore the parameter space with a variability of 50% from the initial value of seismic velocities and 10% for the thicknesses and the densities. The search for the best model is performed by the HHS algorithm according to the shape of the H/V curve from earthquake recordings and the initial parametrization.

Some variability is also allowed to the shallowest and to the deepest layers of the initial velocity model in order to fit the inverted H/V curve. 10% and 50% variabilities are allowed to the thickness and seismic velocities of the deep layers, respectively. For the shallow layers, first a variability of 10% is allowed and then, if the fit between the estimated H/V curves and the H/V curve from earthquakes is not good, this value is raised up to 50% for the seismic velocities of the layers in the first 15 m. In case of SEPFL, only 10% variability was used due to the good results obtained (Figure 2).

A visual selection of the best models is then performed by comparing the inverted H/V curves with that obtained from earthquakes. In case all estimated H/V curves from inverted profiles fit the H/V curve from earthquakes over the entire frequency range, a second criteria is applied. This criteria considers the fit of Rayleigh- and Love-wave dispersion curves and/or the Rayleigh-wave ellipticity curves from the inverted profiles to those from site characterization analysis, which are not used as input by the HHS algorithm.

The final models, calculated according to the equations used for the computation of V_P (Nagashima et al., 2021), are shown in Fig. 2 using different colors (black and light/dark gray). In Fig. 2, we show (*a*) H/V curves from earthquakes, (*b*) inverted velocity profiles down to 4 km and (*c*) their zoomed-in view down to the depth available from site characterization. In the same figure, we also show (*d*) the synthetic and measured Rayleigh-wave dispersion curves, (*e*) the synthetic and measured Rayleigh-wave ellipticity curve, and (*f*) the SH-wave transfer functions from the inverted velocity profiles along with the amplification function obtained from empirical spectral modelling (ESM, Edwards et al., 2013).

The quarter-wavelength (QWL) representation is shown in Fig. 3 for the estimated velocity models of Fig. 2. According to the quarter-wavelength computed at depth (Fig. 3 – top row) and taking into account a frequency which is half the fundamental peak (f_0 = 2.0 Hz), a conservative estimate of the reliable investigation depth for the site of SEPFL is equal to 144 m. We might also extend a maximum depth of investigation to two times the QWL value (287 m), as the QWL approach can be considered conservative.

Network: CH
Station Name: SEPFL (Lausanne, EPFL, VD)
Installation date: 26.10.2011
Type of instrument: EpiSensor (HGZ, HGN, HGE)
Swiss Strong Motion Network (SSMNet): yes
Type of site characterization measurement: active
Depth of site characterization analysis: 38 m
Number of layers in the site characterization profile: 10
Number of recorded earthquakes: 64
Resulting Vs30 and uncertainty: 216 ± 5 m/s
Resulting depth of engineering bedrock (H800) and uncertainty: 38 +/- 1 m.
Soil class according to SIA261: D
Soil class according EC8: C

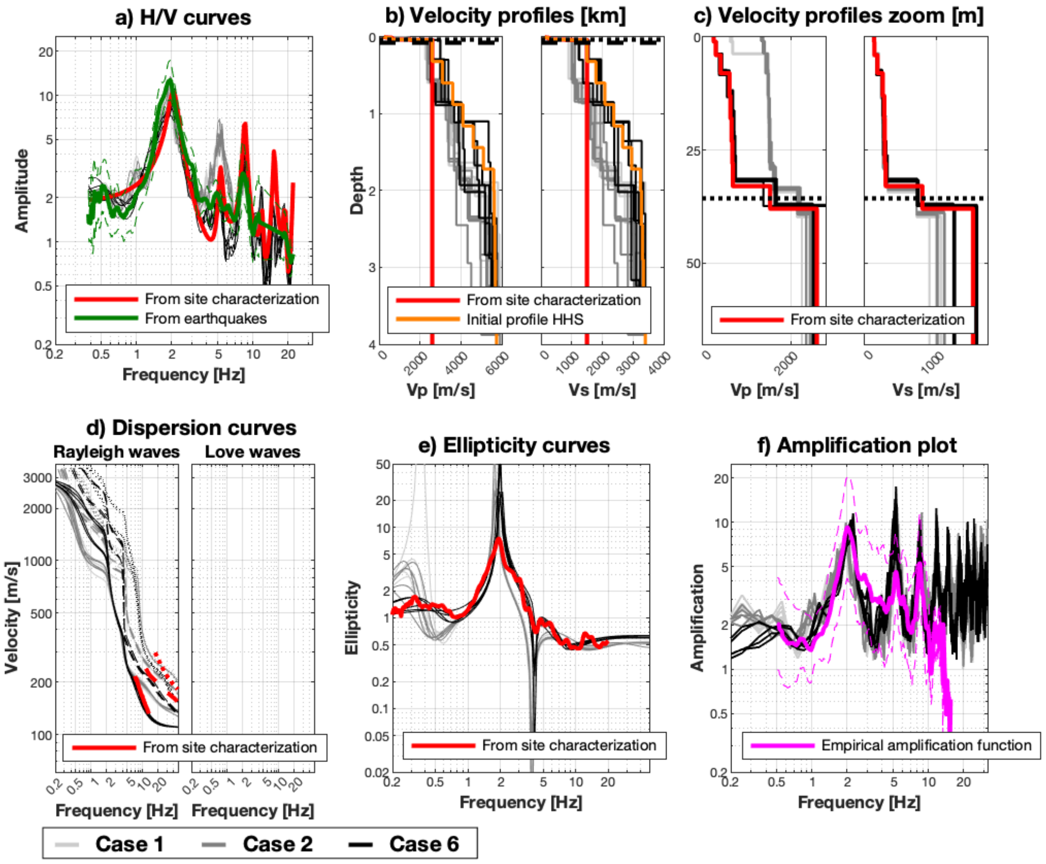

*Figure 2: Estimated models from the HHS inversion for seismic station SEPFL. The models estimated by the HHS algorithm are shown in light/dark gray and black. In the velocity profiles plots (b), the dotted and dashed horizontal lines correspond to the QWL depth at a frequency of 0.5*f_0 (= 1.0 Hz) and to 2 times the QWL depth, respectively.*

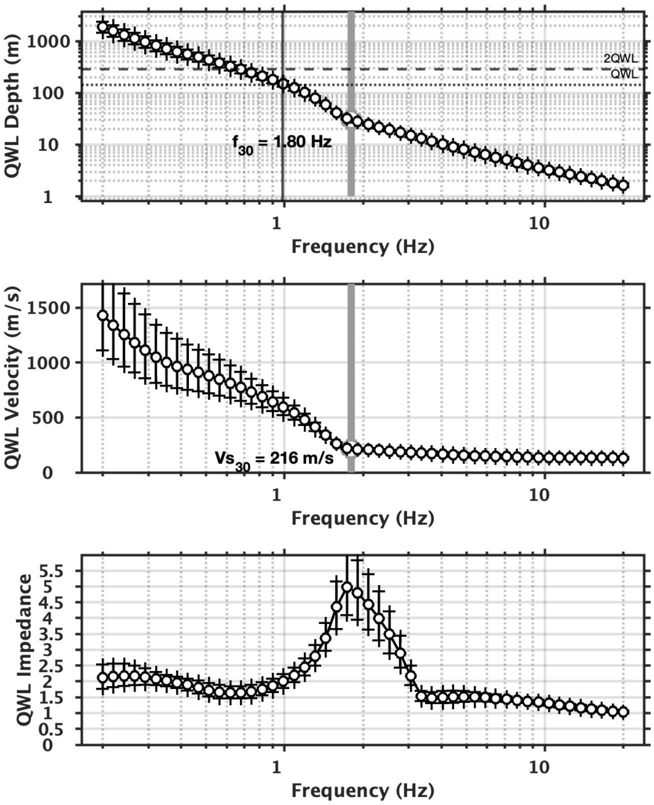

Figure 3: Quarter wavelength representation for the best models generated by the HHS inversion (top: depth, center: velocity, bottom: inverse of the impedance contrast). The grey band and the grey circle mark the frequency (top row) and the V_S (central row) at 30 m depth. The dotted and dashed horizontal lines in the top row correspond to the QWL depth and to 2 times the QWL depth at a frequency of 1.0 Hz (vertical solid line in black), respectively, as defined in Figure 2.

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