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Use of frequency-dependent multi-offset phase analysis of surface waves for a riparian zone characterization

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Multi-offset phase analysis (MOPA) of seismic surface waves has been developed as an alternative technique for the lateral variation sensitive extraction of dispersion curves. One of the goals of MOPA is to increase the lateral resolution with respect of the more traditional surface wave methods, and, consequently, to allow a more detailed investigation of the subsurface in terms of 2D shear wave velocity distribution. However, in the published literature, there are still few examples of field applications of this promising technique.
The standard MOPA makes possible to calculate, frequency-by-frequency, the derivative of the phase (retrieved by the seismogram) with respect to offset and, by doing that, to extract the information concerning the Rayleigh wave velocity as a function of frequency (i.e. the dispersion curve) with a lateral resolution that depends on the length of the window used to calculate the derivative. Here, we describe a novel MOPA implementation characterized by a moving window with a frequency-dependent width. The window's length is in fact chosen to be smaller for higher frequencies (investigating the shallower layers) and increasingly larger at lower frequencies (where the longer wavelengths supply information about the deeper formations). This approach is clearly in accordance with the physics of the method (the smaller footprint of the shorter wavelengths provides spatially detailed information, while larger wavelengths inevitably average, to some degree, the soil spatial variations). Hence, this frequency-dependent MOPA maximizes the lateral resolution at high frequencies, while assuring stability at the lower frequencies. In this way, we can retrieve the shallow lateral variability with high accuracy and, and the same time, obtain a robust surface wave velocity measurement at depth. The extracted dispersion curves (one for each receiver location) can be then inverted providing an S-wave velocity section.
Here we discuss the application of this novel MOPA implementation to a dataset collected for hydrogeophysical purposes, and compare the inversion result against those obtained by using refraction seismic and electrical resistivity tomography. In this specific test, the dispersion curves along the profile have been inverted individually and a standard Occam's regularisation approach has been applied (along the vertical direction). Still, the 2D section generated by putting side-by-side the independent 1D inversion results provides a consistent picture indirectly confirming the robustness of the method. With this field example we demonstrate the capabilities of the method for the upper subsoil where differences in S-wave velocities can be particularly subtle. In the hydrological context these little variations can play a relevant role on water flow and solute migration, due to the differences in porous media permeability. In this case, the classical P-wave refraction and electrical resistivity tomography result is highly influenced by the presence of the water. Moreover seismic refraction, being blind to velocity inversion, cannot recover the spatial complexity of the site's geology. On the contrary, the surface wave method (sensitive only to the soil matrix velocity and capable to retrieve velocity inversion) match the borehole information and helps to develop a robust interpretation of the seismic refraction and electrical resistivity tomography results, otherwise difficult to justify per se.