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Quasi-Newton algorithm using Fresnel wavepaths and frequency increase for P-wave tomography inversion: application to a landslide in the South French Alps

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This work presents a traveltime inversion method developed specially for imaging detailed subsurface features in the case of heterogeneous soils. The algorithm considers the initial SIRT algorithm proposed by Grandjean and Sage (2004) based on the use of Fresnel wavepaths and a probabilistic reconstruction approach. The method is improved by using a Quasi-Newton method, more robust than SIRT. It is demonstrated that the Jacobian matrix is approximated by the Fresnel weights, without introducing too large uncertainties.
In addition to its robustness, this inversion algorithm proposes a regularization strategy based on the physics of wave propagation in soil. This allows to overcome the use of numerical regularization operators, always difficult to parameterize, and to remove the subjectivity of the user in the inversion result.
Moreover, as the width of Fresnel volume is related to the frequency, an increase of frequency (and therefore a decrease of Fresnel wavepaths width) is introduced for each step in order to cover the entire finite bandwidth of the source signal. The inversion is thus controlled by large variations of velocities in the first steps and more and more detailed heterogeneities of the soil in the following steps.
This technique is applied to a real dataset acquired at the Super-Sauze landslide (French Alps) and allows to highlight the presence of a deep water supply interpreted as a preferential flow path within the landslide.