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Gradient-based inversion independent of layers from surface wave dispersion curves

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Estimating the elastic properties of near-surface materials(such as soil and rocks) is important in groundwater, engineering, and environmental studies, and the inversion of Rayleigh waves has been extensively applied to the estimation of the 1D S-wave velocity profile. The optimization algorithm is one of the most important parts of the inversion. Generally, the algorithms can be divided into two categories: the gradient method and the heuristic method. The former, e.g. Conjugate Gradient method, BFGS method, evaluates the misfit function values and gradients (or Hessians) to improve the rate of convergence. The latter, e.g. Simulated Annealing method, Differential Evolution method, is to approximate global optimization by iteratively trying to improve a candidate solution with regard to a given measure of quality, using only the misfit function values. Usually, the heuristic method is much slower than the gradient method. For our surface wave inversion problem, the gradient of depth is too difficult to calculate. Therefore, for gradient methods, the depth of layers needs to be fixed during the inversion. Studies show that layers configuration plays an important role in the inversion. Different layers distribution will lead to divergent inverted model.

This paper presents a new gradient-based algorithm for finding an optimal model in a large space of candidate layers configuration. The objective here is to find a model with nearly continuously variable S-wave velocities along the depth, rather than seeking a model with a given layers configuration. The new algorithm runs with different layers configurations and obtains an optimal statistical model using weighting functions based on misfit function values. It is fairly efficient due to the gradient method and naturally easy for parallel computation. Meanwhile, it's easy to analyze the confidence of inversion results. The new algorithm is illustrated with an application to the inversion of synthetic dispersion curves for a low-velocity-layer model. Moreover, the algorithm is also applied onto the case of synthetic ambient noise data, where dispersion curves can be extracted by vector wavenumber transform method (VWTM). In the end, we perform it onto ambient noise data of a real field survey with drilling data. Whether in the synthetic case or in the real case, it is shown that the new algorithm produces a fairly optimal inverted model basically independent of layers configuration.