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Pressure and shear waves velocity models from near-surface seismic data and their interpretation in terms of water content

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Seismic methods are now part of the geophysical investigation toolbox commonly used to study the Critical Zone (CZ), not only its structure, but also its water content and flows. Acquisition setups usually consist in a collection of geophones implanted along linear profiles or arrays, at the surface of the ground excited by a portable mechanical source. Depending on the dimensions of the setups, the density of the arrays and the energy of the sources, the recorded wavefields can be analysed to image contrasts in mechanical properties of the near-surface (down to 1-100 m-depths and with 0.1-10 m-scale resolutions) using the standard equipments available for environmental applications. The most popular interpretation method is refraction tomography which consists in picking first arrivals times of the wavefield that are then inverted for pressure (P) or shear (S) waves velocity models (VP or VS, depending on the type of sources and sensors). As an alternative to S-wave refraction tomography, the recorded wavefield can also be processed to extract surface-wave dispersion data that are then inverted for VS models. VP and VS showing, by definition, partially decoupled behaviours in the presence of fluids, VP/VS or Poisson's ratio are usually estimated to image their presence in materials. We developed this approach in various contexts in the framework of the French program CRITEX. We present herein several experiments/surveys that helped describing both spatial and temporal variations of water content in the CZ, along the continuum between the saturated and unsaturated zones. Among these examples, only a few allowed the production of quantitative results (such as piezometric levels or actual saturation values). We illustrate how strong prior information about the probed CZ and/or alternative geophysical imaging techniques, geotechnical sounding or log data are mandatory to limit posterior uncertainties in VP and VS models. We also present means to estimate both traveltime and dispersion measurements errors and test their propagation in VP, VS models and derived criteria. We finally discuss the limits of discrete elastic forward problems currently used to interpret data recorded at the surface of poro-visco-elastic media with continuously varying properties.