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Probabilistic inversion of geophysical datasets for subsurface interface detection

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Near-surface geophysics provides remotely sensed data that are sensitive to subsurface properties and discontinuities. Discontinuities are of growing interest for different fields of Earth science, for example the saltwater/freshwater interface in coastal areas needed to understand mixing processes, the discontinuity between frozen and unfrozen ground for monitoring of permafrost or between bedrock and soil for landslide or critical-zone investigations. Even though standard geophysical approaches provide useful information, accurate detection of sub-surface boundaries and their geometry is hampered by common inversion routines with smoothness constraints that smear out any naturally-occuring interfaces. Moreover, uncertainty quantification of interface locations is still an open problem. Here, we present a probabilistic formulation and solution to the inverse problem of using geophysical datasets to infer interfaces in the presence of heterogeneous sub-domains. We implement an empirical-Bayes formulation that separates geometric (interfaces) and physical (physical property values) parameter updates within a Markov chain Monte Carlo scheme. Both the geometric and the physical properties of the problem are constrained to favor smooth spatial transitions and to honour pre-defined property bounds. We demonstrate our methodology using synthetic and actual surface-based electrical resistivity tomography datasets with the aim of inferring soil-bedrock interfaces.