A hierarchical Bayesian approach for earthquake location and data uncertainty estimation in 3D heterogeneous media

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Solving inverse problems requires an estimate of data uncertainties. This usually takes the form of a data covariance matrix, which determines the shape of the model posterior distribution. Those uncertainties are yet not always known precisely and it is common practice to simply set them to a fixed, reasonable value. In the case of earthquake location, the hypocentral parameters (longitude, latitude, depth and origin time) are typically inverted for using seismic phase arrival times. But quantitative data variance estimates are rarely provided. Instead, arrival time catalogs usually associate phase picks with a quality factor, which is subsequently interpreted more or less arbitrarily in terms of data uncertainty in the location procedure.

Here, we present a hierarchical Bayesian algorithm for earthquake location in 3D heterogeneous media, in which not only the earthquake hypocentral parameters, but also the P- and S-wave arrival time uncertainties, are inverted for, hence allowing more realistic posterior model covariance estimates. Forward modeling is achieved by means of the Fast Marching Method (FMM), an eikonal solver which has the ability to take interfaces into account, so direct, reflected and refracted phases can be used in the inversion.

We illustrate the ability of our algorithm to retrieve earthquake hypocentral parameters as well as data uncertainties through synthetic examples and using a subset of arrival time catalogs for mainland Portugal and its Atlantic margin.