Fast, probabilistic earthquake location in 3D models using oct-tree importance sampling

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Abstract

Accurate earthquake location and a complete understanding of location uncertainties are critical to seismotectonic and seismic hazard studies, to "real-time" seismic notification, and to nuclear test ban treaty (CTBT) verification. With the increasing availability of 3D structural models it is important to have location methods valid for 3D velocity models. Probabilistic earthquake location with non-linear, global-search methods allows the use of 3D models and produces comprehensive uncertainty and resolution information in the form of a probability density function (PDF) **exp(-misfit))**.

In this paper we present a new "oct-tree importance sampling" method for accurate determination of location PDF's in 3D space (x,y,z). This method involves an initial global sampling of the misfit function on a coarse grid, followed by repeated application of: (1) division of the grid cell with the highest location probability P (P = PDF * cell volume) into 8 sub cells (2x,2y,2z), and (2) the evaluation of the misfit function in each of these 8 sub-cells. This recursive procedure rapidly converges to a cascade of oct-tree structures specifying location PDF values in 3D space, with a larger number of smaller cells in the regions of higher PDF (lower misfit).

Using synthetic locations and microseismic locations from Southern France, we show that this new method is simpler, faster, more stable and more complete than a rapid, Metropolis-simulated annealing approach (Lomax et al. 2000; http://www.alomax.net /nlloc). Both of these methods are about 100 times faster than a pure grid search, and only about 10 times slower than standard linearised location algorithms. We also discuss the application of the oct-tree approach to teleseismic location in a spherical earth.

Lomax, A., J. Virieux, P. Volant and C. Berge, (2000), Probabilistic earthquake location in 3D and layered models: Introduction of a Metropolis-Gibbs method and comparison with linear locations, in Advances in Seismic Event Location, C.H. Thurber,, and N. Rabinowitz (eds.), Kluwer, Amsterdam, 101-134.