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Quantifying location uncertainties in seismicity catalogues: Application to the Pyrenees

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There are plenty of methods available for locating earthquakes. Linearized optimization methods are commonly used to construct seismic catalogues, as they are fast, simple to implement, and can be easily automatized. These methods minimize the root-mean-square (RMS) of travel time residuals to find the best fitting location coordinates and origin time. However, a well-known issue is that error estimates are biased and strongly depend of the level of regularization used to stabilize the inversion. For example, one can artificially decrease the size of estimated location errors by increasing the damping parameter.
In this work, we propose a method to quantify unbiased uncertainties with a series of synthetic tests. We first generate travel times for events from all possible coordinates on a 3D grid and then locate each synthetic event by using a conventional location software (here we use HYPOCENTER but this can be applied to any location method). Finally, we produce a 3D error map, where at each grid point, we plot the location error, i.e. the distance between the event at the given grid point and its inverted location. We apply our procedure to the Pyrenees, where mimic the procedure carried out by the “Observatoire Midi-Pyrénées” to located small events, and construct error maps for this region. We show how location errors vary with the quantity and quality of data, and with user-defined parameters.