GLOBAL NON-LINEAR EARTHQUAKE LOCATION: APPLICATION TO THE ISC ROUTINE LOCATION PROCEDURE

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NonLinLoc

In this work we relocate the 156 ISC reference events (GT0/GT5) with the program NonLinLoc (NLL; Lomax et al., 2000; www.alomax.net/nlloc). NLL constructs an estimate of the location PDF within the framework of the probabilistic earthquake location methods of Tarantola and Valette (1982). The NLL program uses efficient global sampling algorithms, such as the Oct-Tree search (Lomax & Curtis, 2001), to obtain an estimate of the posteriori probability density function (PDF) in 3D space for the hypocenter location using 1D or 3D velocity models. The location PDF provides a complete description of likely hypocenter locations and includes comprehensive uncertainty information.

Likelihood functions

NLL uses two likelihood functions to compute the PDF: the least-squares L2 norm (LSL2) and the equal differential-time (EDT) function (Lomax, 2005; Font et al., 2004). Whereas the LSL2 function tries to satisfy all observations in a least-squares sense, the EDT likelihood function satisfies the most pairs of observations. This is done by mapping all equal-time surfaces for all paris of observations in the 3-D space (Fig. 1). The EDT functions is much more robust in the presence of outliers (Fig. 1)

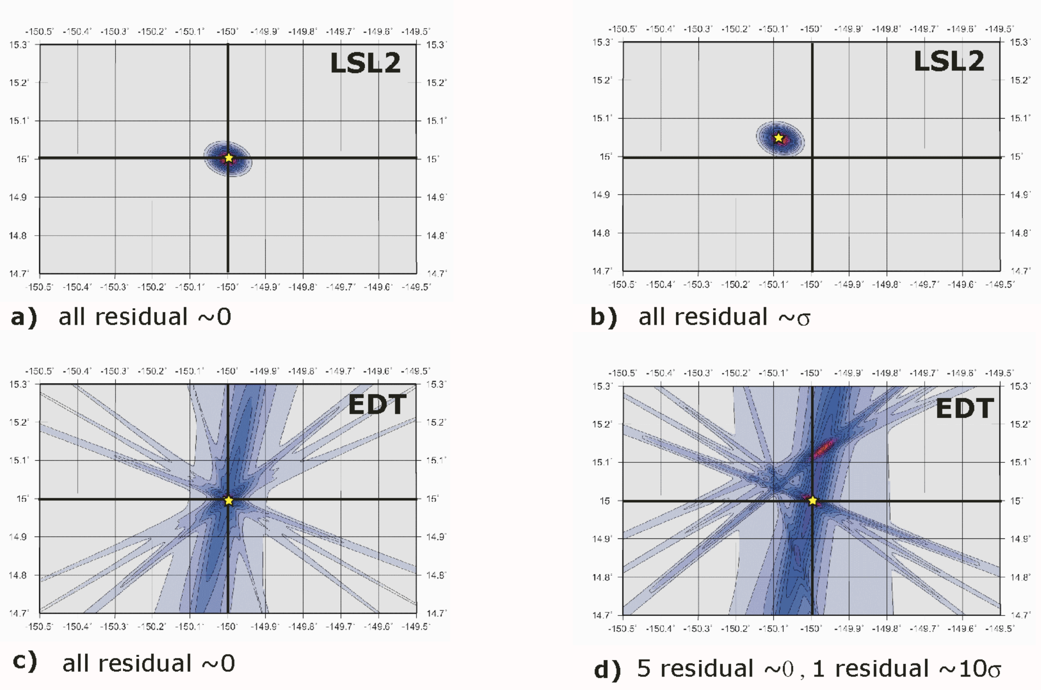

Figure 1. PDF of location problem for six observations using synthetic arrival times. a) and c): no outliers, b) and d) one outlier (= 10 σ). True location is at intersection of bold lines. Maximum likelihood hypocenter location is marked by yellow star. Note the complicated topography of the PDF of the EDT solution.

Application

To demonstrate the performance of NLL and the EDT function, we relocated the reference data set using only a simple 1-D model (ak135) with no station corrections or correction surfaces. Synthetic travel times were computed for all stations to all points in the model using the TauP software package (www.seis.sc.edu/software/TauP). For each station travel time fields were stored on hard disk for later access. We restricted the maximum number of phases to be used in the location to 200. The Oct-Tree search was always done over the whole earth from the surface to 700 km depth. Assigned phase errors were: iP 0.2s; eP 0.5s; other emergent phases 1.0s; remaining phases 2.0 s. Assigned travel time error was 0.5 s. On average, one location took 13.5 s and 77 s to compute for LSL2 and EDT solution, respectively.

We present the PDF by density scatter plots (Fig. 2). These density plots are obtained by drawing samples from the PDF with the number of samples proportional to the probability. Hence, areas of high probability are indicated by a high density of scatter points.

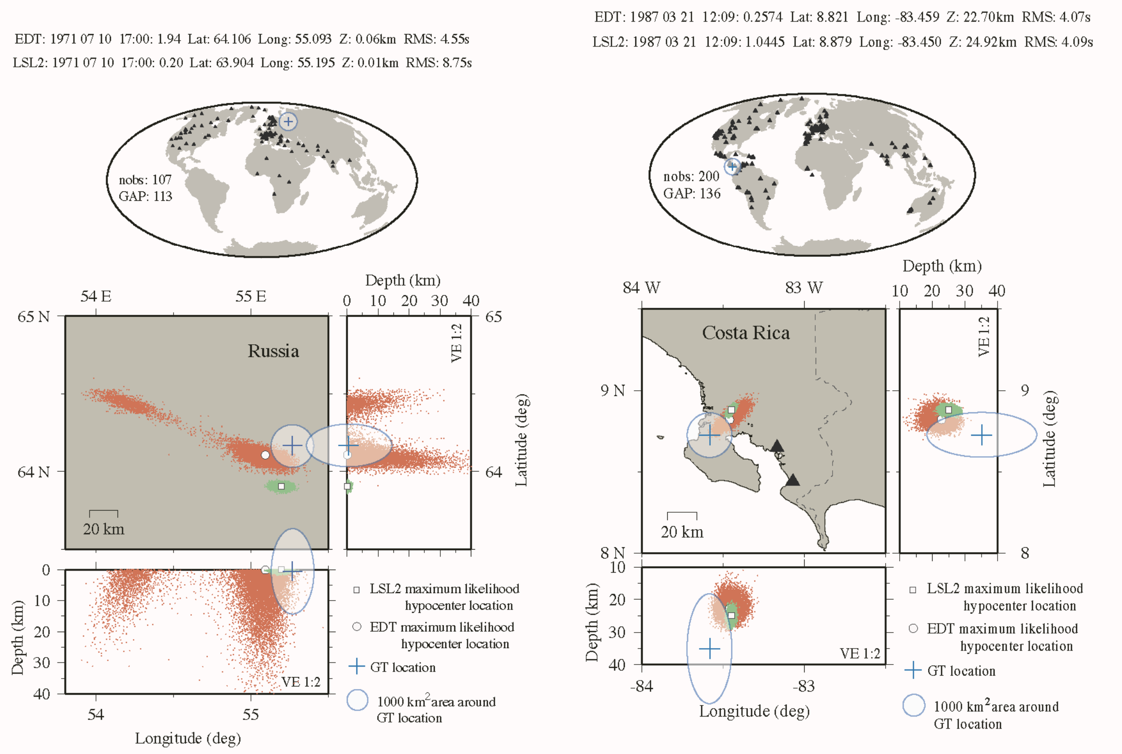

Figure 2. PDF density scatter plots of two examples events. Red: EDT; green: LSL2. Shown are map view and two vertical cross sections. Vertical exaggeration is 2. Top plot shows distribution of recording stations. Note the smaller size of the PDF for LSL2.

Results

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The EDT solution outperforms the LSL2 solution for most events: The EDT hypocenter is closer to the true location (Table 1; Fig. 3) and the EDT PDF intersects the GT location sphere much more often (Fig. 2). At the same time, LSL2 often underestimates the true location error (Fig. 2). We attribute the better performance of EDT to the presence of many outlier readings (readings with residuals larger than the assigned errors), which more strongly affect the LSL2 solution. These outliers are likely caused by a) bad phase readings or phase identifications, and b) 3D velocity structure, especially at regional and local distance, that is not accounted for in the 1D velocity model.

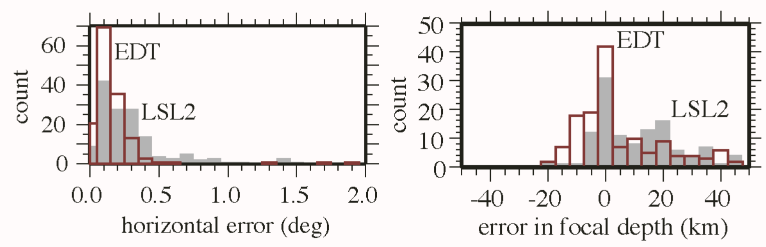

Figure 3. Distribution of errors of all relocated hypocenter location relative to GT hypocentre location of reference data set

	distance	horizontal	depth
LSL2	46 km	25 km	29 km
EDT	25 km	13 km	18 km

Table 1. Mean error of all relocated hypocenter location relative to GT hypocentre location of reference data set

Conclusions

- Global, non-linear earthquake locations is efficient; the PDF provides valuable information on location uncertainties.

- The large number of residual outliers require the use of robust likelihood functions, such as the EDT function. In the presence of outliers, traditional likelihood functions, such as LSL2, yield mislocations and location uncertainties are under-estimated.

- Application of NLL using 3D velocity models is straight forward once travel times have been calculated.

References

Font, Y., H. Kao, S. Lallemand, C.-S. Liu, and L.-Y. Chiao, Hypocentral determination offshore Eastern Taiwan using the maximum intersection method, Geophys. J. Int., 158, 655-675, 2004.

Lomax, A., J. Virieux, P. Volant, and C. Thierry-Berge, Probabilistic earthquake location in 3D and layered models, in Advances in Seismic Event Location, edited by C.H. Thurber and N. Rabinowitz., 101-134, 2000.

Lomax, A., and A. Curtis, Fast, probabilistic earthquake location in 3D models using Oct-Tree importance sampling, Geophys. Res. Abstr., 3, 955, 2001.

Lomax, A., A Reanalysis of the hypocentral location and related observations for the great 1906 California earthquake, Bull. Seism. Soc. Am., 91, 861-877, 2005.

Tarantola, A. and B. Valette, Inverse Problems = Quest for Information, J. Geophys. Res., 50, 159-170, 1982