NonLinLoc Algorithm Documentation

EDT likelihood function

An alternative to the Lp-likelihood functions that is very robust in the presence of outliers is given by the equal differential-time (EDT) formulation . For the EDT case, the location likelihood is given by,

$$L(x)=\left[\sum_{a,b}\frac{1}{\sqrt{\sigma_a^2+\sigma_b^2}}\exp\left(-\frac{\{[T_a^o-T_b^o]-[TT_a^c(x)-TT_b^c(x)]\}^2}{\sigma_a^2+\sigma_b^2}\right)\right]^N , \tag{1}$$

where **x** is the spatial part of **m**, T_a^o and T_b^o are the observed arrival times and TT_a^c and TT_b^c are the calculated travel times for two observations a and b; the sum is taken over all pairs of observations, and N is the total number of observations. Standard deviations σ_a and σ_b summarize the assigned uncertainties on the observed arrival times and calculated travel times, where it is assumed that the observed and the calculated times are uncorrelated.

In Equation (1), the first and second terms in brackets in the exponent are, respectively, the differences between the observed arrival times and the differences between the calculated travel times. The exponent is the difference between these two terms, and thus the exponential has a maximum value of 1 which occurs at points **x** where the two differences are equal (hence, the name "equal differential time"). Such points **x** best satisfy the two observations *a* and *b* together, and, in general, the set of **x** where the exponential is nonzero forms a "fat," curved surface in 3D space. Because the summation over observations is outside the exponential, the EDT location *pdf* has its largest values for those points **x** where the *most* pairs of observations are satisfied and thus is far less sensitive to outlier data than L*p* norms which seek to best satisfy *all* of the observations simultaneously. Note that the EDT likelihood function $L(\mathbf{x})$ does not require calculation of an origin time t_0; this reduces the hypocenter search to a purely 3-parameter problem and contributes to the robustness of the EDT method. Nevertheless, a compatible estimate of t_0 is calculated for any hypocenter point **x**.

EDT posterior arrival weights

When EDT is used, the arrival weights output to the NLL-Hypocenter-Phase file are posterior weights indicating how each arrival contributed to the maximum likelihood hypocenter. The arrival weight is given by,

$$w_a=\frac{1}{k}L_a(x) , \tag{2}$$

where $L_a(x)$ is the sum over the subset of values inside the sum in (1) which include contributions from observation a. k is a normalisation constant so that the sum of weights w_i over all observations equals unity.