ANALYSIS OF STATION TRAVEL TIME RESIDUALS BASED ON THE AK135 VELOCITY MODEL AND PHASE WEIGHTING SCHEME IN LOCATION PROCEDURES

B.E. Vera, A. Shapira, D.A. Storchak and J. Harris
International Seismological Centre – ISC
www.isc.ac.uk

ABSTRACT

The International Seismological Centre (ISC) currently uses the Jeffreys-Bullen (JB) velocity model in its routine operation. Based on IASPEI recommendation, ISC is now considering substitute it with the modern 1D velocity model AK135 (Kennett et al, 1995).

To evaluate possible outcome, we have examined travel time residuals to seismic stations that recorded 156 well-located globally distributed events (GT0/GT5) and studied their statistical characteristics. The set of events were selected from the IASPEI collection of Ground-Truth events.

Travel time residuals were computed with respect to GT and with respect to solutions obtained using AK135 velocity model. The main motivation of analyzing travel time residuals is to re-examine the applicability of different weighting scheme in earthquake location. Alternative weighting schemes were compared by integrating them into the Geiger based location algorithm (ISCloc) and a grid-search algorithm for location (GSL).

T LOCATION SCALE DISTRIBUTION

The classical issue in the location problem is to identify outliers and exclude or downweight them in some way. However, the differences between theoretical and observed is a combination of random errors measurements and biases from the inexact knowledge. The *t location scale* distribution looks as a natural choice of model for residuals data, providing a parametric approach to robust statistics.

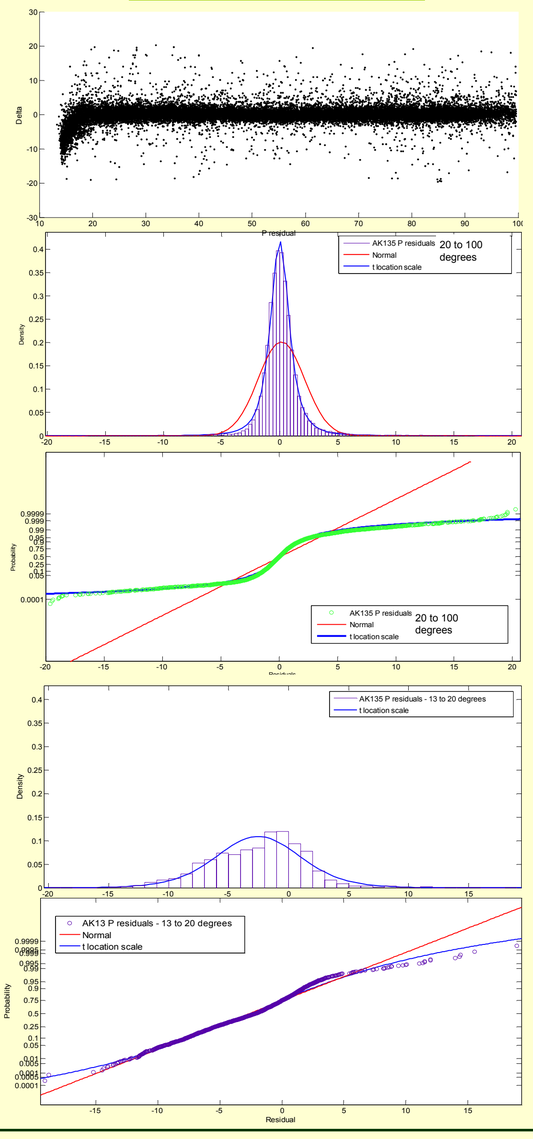
the *t location-scale* distribution has the density function $\frac{\Gamma\left(\frac{v+1}{2}\right)}{\sigma\sqrt{v\pi}}\left[\frac{v+\left(\frac{r-\mu}{\sigma}\right)}{v}\right]^{-\left(\frac{v+1}{2}\right)}$

with location parameter μ, scale parameter $\sigma > 0$,
and shape parameter $v > 0$, $\Gamma(\cdot)$ is the Gamma function.

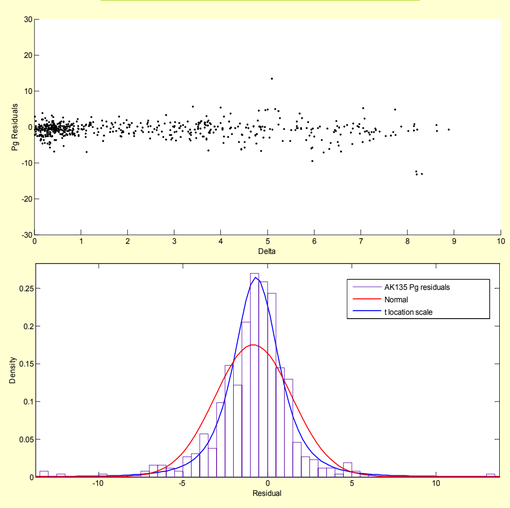
This distribution is useful for modeling data distributions with heavier tails (more prone to outliers) than the normal distribution allows for. It approaches the normal distribution as v approaches infinity, and smaller values of v yield heavier tails.

TRAVEL TIME RESIDUAL DISTRIBUTION

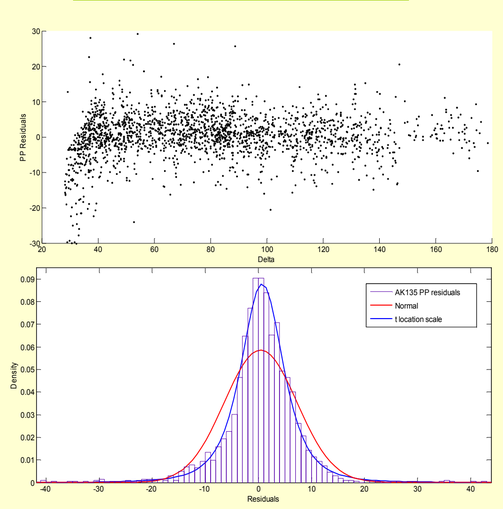
P phase



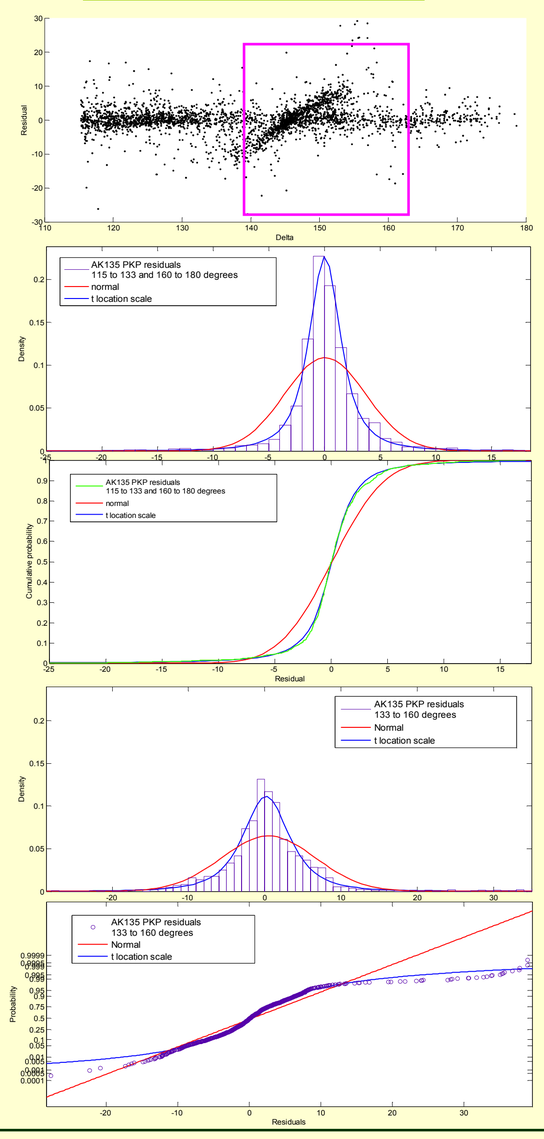
Pg phase



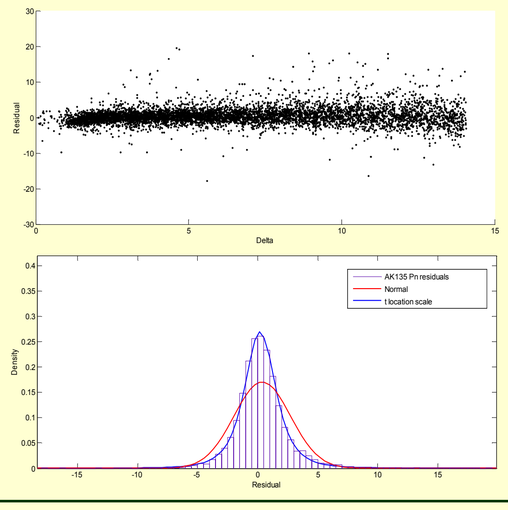
PcP phase



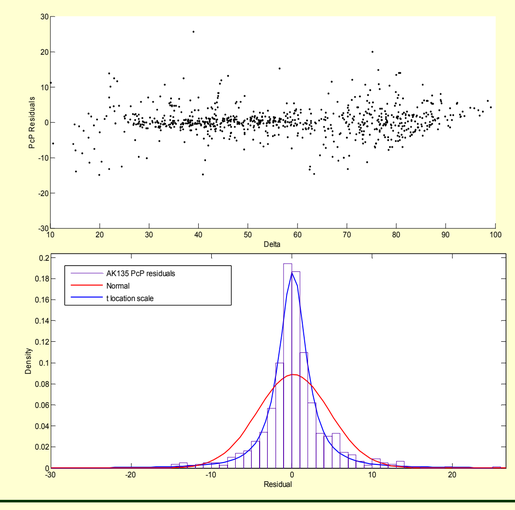
PKP phase



Pn phase



PP phase



CURRENTLY ISC WEIGHTING SCHEME

ISC is currently using for earthquake relocation Geiger's least square location technique. The weights are computed using Jeffreys' method of Uniform Reduction.

Uniform Reduction does not assume a priori information about data quality, but assigns smaller weights to arrival times with larger residuals. The weights (w) are computed iteratively, based from the residuals in the previous iteration using

$$w = \frac{1}{1 + \mu e^{\frac{1}{2}\left(\frac{r}{\sigma}\right)^2}}$$

With μ=0.05 and σ =1.145. After each iteration, σ is recalculated down-weighting observations with large residuals.

The W function has infinite variance and it is a redescending weighting function, which may yield infinite solutions. Although W converges to a unique solution when the starting point is close to the real solution.

SUGGESTED WEIGHTING SCHEME

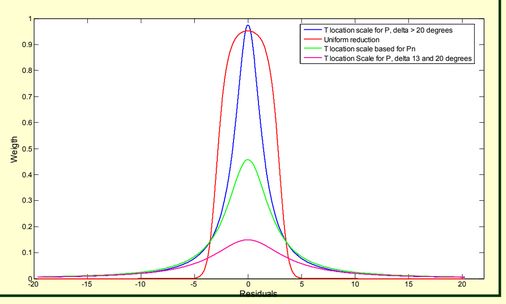
Although ak135 velocity model is designed to represent the empirical traveltimes for a wide variety of seismic phases, it is not a full representation of seismic velocities in the Earth. Resolution of structure in some zones remains weak, especially at the base of the mantle and in the uppermost core (Kennett et al, 1995).

Thus, ak135 can be used to predict the arrival times in event location or phase association, but different weighting scheme is necessary for those seismic phases no “well modeled” because of the lack of resolution.

The suggested weighting scheme is based on the t location scale distribution of the residuals.

This distribution fit very well the natural behaviour of the residual, assuming less dispersion than in the normal distribution, so the variance of the residual is smaller..

$$W(r) = \frac{2}{3}\frac{(v+1)}{v\sigma + r^2}$$

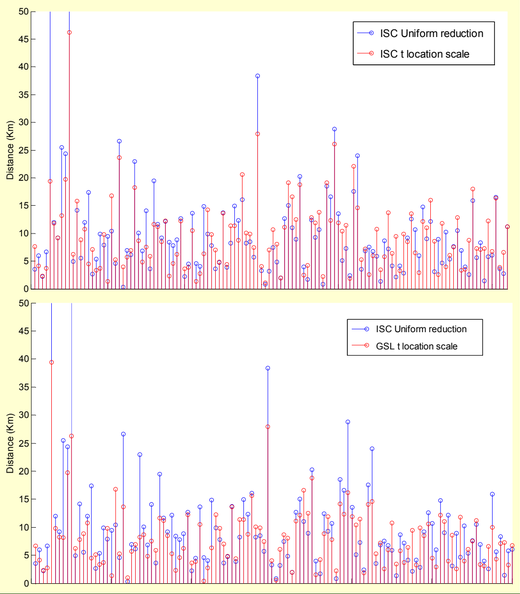


RESULTS

Relocation using the suggested weighting scheme and Uniform Reduction where computed using ISCLoc and compared with GT events. Also, we compared using GSL method with L1-norm and both weighting schemes.

Top graphic shows the distance between each GT and ISC with Uniform Reduction (blue) and t location scale based weight (red). At least 60% of the location with the suggested weighting scheme were closer to the GT location.

Bottom graphic shows the distance between each GT and ISC whit Uniform Reduction (blue) and GSL using the t location scale based weight (red). At least 75% of the location with GSL and the suggested weighting scheme were closer to the GT location.



❑ B.L.N.Kennett, E.R.Engdahl and R. Buland, 1995. Constraints on seismic velocities in the Earth from traveltimes. *Journal Geoph Int*, 122, 108-124.
❑ Ray Buland, 1986. Uniform reduction error analysis. *BSSA*, 76, 217-230.
❑ Willemann R. J., 2003. Evaluating the Fit of Alternative Hypocenters to Arrival Times, *BSSA*, 93, 519-525