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Understanding why first-arrival travel times do not obey banana-doughnut sensitivity.

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Associated with the rising popularity of cross-correlation methods (e.g. Vandecar and Crosson, 1990) arrival times of seismological phases are often determined as maxima of cross correlations for which the Born approximation sensitivity kernel has the banana-doughnut character with the surprising zero sensitivity along the ray, see Sigloch and Nolet (2006) for a multi-bandpass development.

Despite its counter-intuitiveness these sensitivity kernels have become widely accepted as "near-best practice" for general use in tomography, also when arrivals have been determined by more classical picking of first-breaks and other characteristic points on the time-domain waveform.

We show how Born-approximation sensitivity is computed by a simple and very intuitive time-domain method. It has the classical banana-doughnut kernels as a special case, but allows also easy computation of sensitivity for arrival times of characteristic points on time-domain waveforms.

We explain why arrival times of characteristic points like zero crossings and flank thresholds have sensitivities which typically deviate very substantially from banana-doughnut shapes. In particular, early fore-flank picks have a comforting maximum sensitivity along the mathematical ray ☺.

References

Sigloch, K, Nolet, G, 2006: Measuring finite-frequency body-wave amplitudes and traveltimes. Geophysical Journal International, 167, 271-287.

Vandecar, J.C., and Crosson, R.S., 1990: Determination of teleseismic relative phase arrival times using multi-channel cross-correlation and least-squares. Bulletin of the Seismological Society of America, 80,150-169.