17.0 Hypocenter Determination Methods

The objective is this section is to understand how to determine earthquake hypocenter locations, \( x, y, z \) in Cartesian coordinates, or \( \lambda, \phi, h \) (focal depth) in earth spherical coordinates, origin time \( t_0 \) (in GMT), and if possible magnitude. \( \Delta \) is the commonly used symbol used to define the epicentral distance.

The Cartesian coordinate system is used to specify the hypocenter coordinates for a flat earth approximation, i.e., for distances of \( 0 < \Delta < 500 \) km. Spherical coordinates are used for distances requiring corrections to a \( \Delta > 500 \) km. Note that we specify distances in either kilometers, for the flat-earth case, or angular degrees measured from the earth's center for spherical coordinates.

Distance measurements from spheroidal map projections for a spherical earth, i.e., for \( \Delta > 500 \) km, can be made using a spherically-corrected flat-earth distance by applying a corrected Pythagorean theorem. The latter method is commonly used in local earthquake locating routines (Richter, 1958). The definition of local earthquakes imply that the arrivals are from the crust and upper-mantle and hence a flat earth model with Cartesian coordinates is the appropriate choice.

\[
\begin{align*}
\Delta^2 &= (A\Delta X)^2 + (B\Delta Y)^2, \text{ where } A \text{ and } B \text{ are corrections for sphericity} \\
\text{This method, known as Richter's method, is accurate to } \pm 0.01 \text{ km.}
\end{align*}
\]

For teleseismic distances, i.e., beyond 500 to 1700 km, we must use an ellipsoid corrected form of the cosine law: where \( \theta = \) co-latitude and given by:

\[
\cos \Delta = (\sin \theta_c \cos \lambda_c) (\sin \theta_s \cos \lambda_s) + (\sin \theta_c \sin \lambda_c) (\sin \theta_s \sin \lambda_s) + (\cos \theta_c) (\cos \theta_s)
\]