EARTHQUAKE LOCATION AS AN INVERSE PROBLEM

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The location of earthquakes in space and time is an important practical inverse problem which may be used to illustrate features common to a wide range of situations.

The basic problem is:

Given the arrival times of seismic waves at a number of different receivers, deduce the origin time and spatial location of the hypocentre of the earthquake (i.e. the point at which radiation is initiated).

Incidental problems are:

i) The identification of the seismic phases whose arrival time is measured.

ii) The choice of earth model used to calculate the theoretical passage times for the seismic waves using ray theory.

We will assume that the earth model is known and that we have N observations

t_i - the arrival times of identified seismic phases at seismic receivers

Several different phases can often be recognised at the same receiver corresponding to different ray paths through the earth model or alternatively to different wave types. The specification of the location of the earthquake requires the determination of four parameters

t_h - the origin time of the seismic disturbance

x_h, y_h, z_h - the spatial coordinates of the hypocentre.

For the ith seismic phase we calculate the travel time $t_{ri}\,(x_s,y_s,z_s)$ for a source at (x_s,y_s,z_s) to the requisite receiver. This will be determined by ray tracing in a particular earth model. From the travel times we can construct estimates of the arrival times of the phases for an assumed origin time t_s as

$$t_{ci}\,(x_s,y_s,z_s,\,t_s) = t_s + t_{ri}\,(x_s,y_s,z_s)$$

and these values are to be compared with the measurements t_i. We note that there is a separation between the dependence of the estimated arrival time t_{ci} on the spatial and temporal components of the estimated location.

The conventional treatment due to Geiger (1910) is to adopt a least-squares measure C for the misfit between the observed and calculated travel times