INVESTIGATING ALTERNATIVE LOCATION METHODS AT THE ISC

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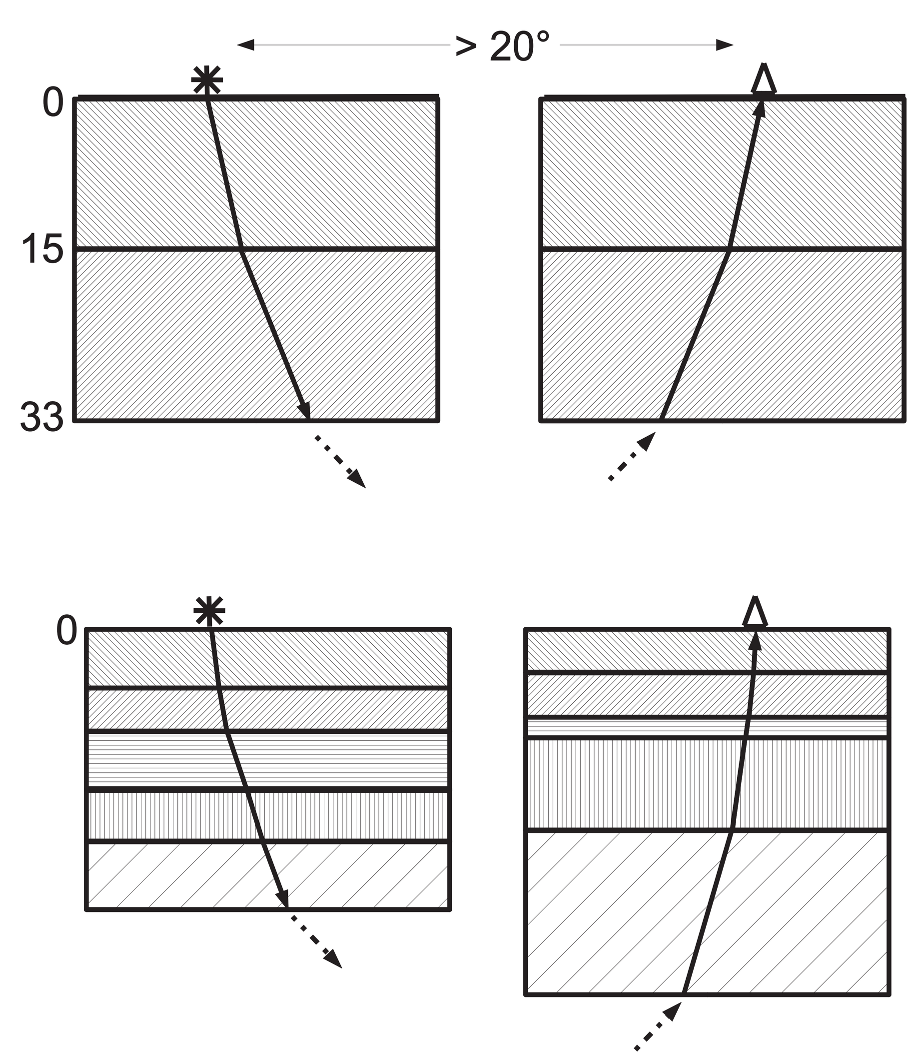
Abstract

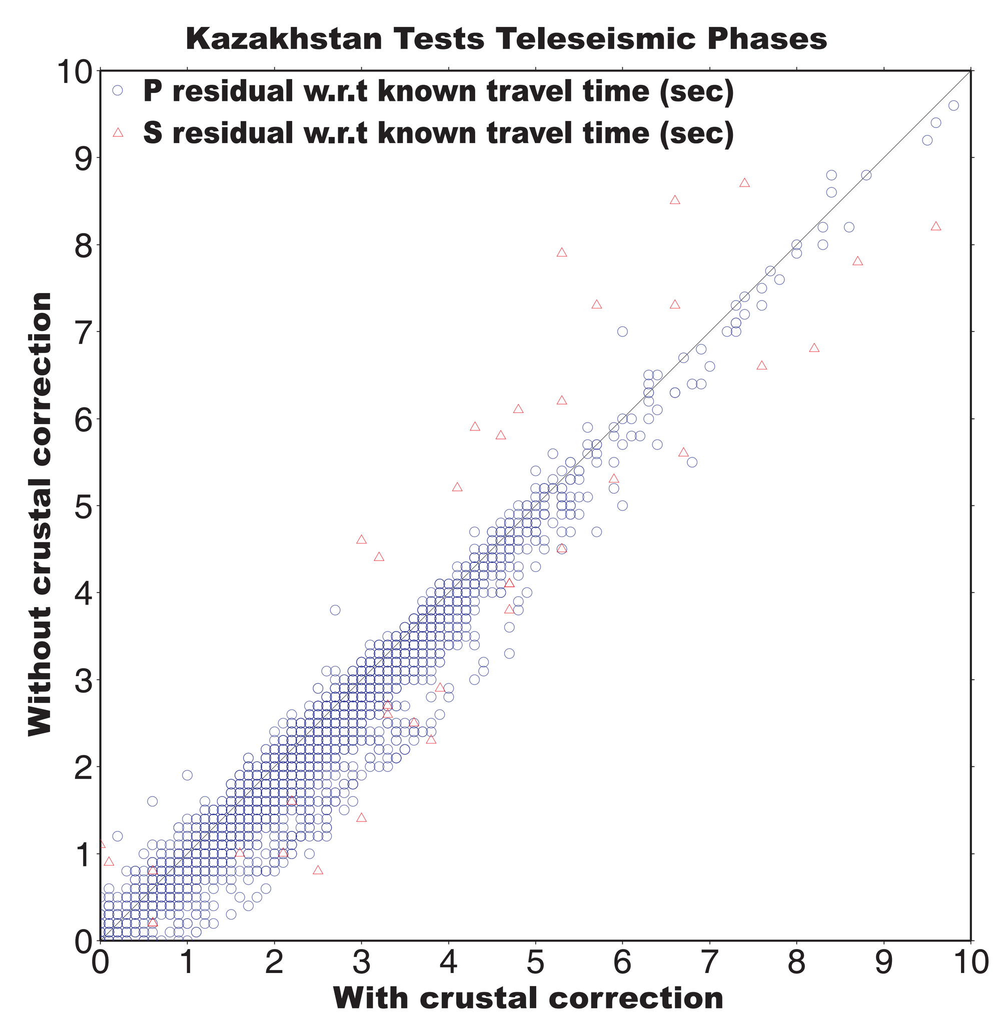
The International Seismological Centre is replacing the software it uses to calculate hypocentres, which it does using arrival times from all over the world. The new program will initially use the same algorithms as now but can also be used to test ways of improving solutions using modern methods. Here, we investigate using travel times from three dimensional earth models instead of from the Jeffreys-Bullen tables currently used. Travel times were calculated for every combination of station and source area using velocity models and ray tracing and the resulting source specific station times were stored and used in tables. Travel times for regional phases (delta less than 16 degrees) were calculated using a model for the upper mantle developed at the University of Colorado. Travel times for teleseismic phases (delta greater than 20 degrees) were calculated using a mantle model developed at Harvard University. As a test we calculated residuals for arrivals in the ISC bulletin for large nuclear explosions in Nevada and Kazakhstan. In general, the new travel time tables reduced residuals with respect to these known source times and locations and when we tried free solutions for these events the results were closer to the truth than when using existing ISC methods. Although initial indications are that solutions would improve using these methods the ISC would face many challenges if it were to adopt them for routine hypocentre computation. From a scientific perspective the models may lack sufficient resolution in regions without many earthquakes or local stations. From a technical perspective station specific tables become awkwardly large when calculated for many hundreds of stations at several depths and for various phases.

Introduction

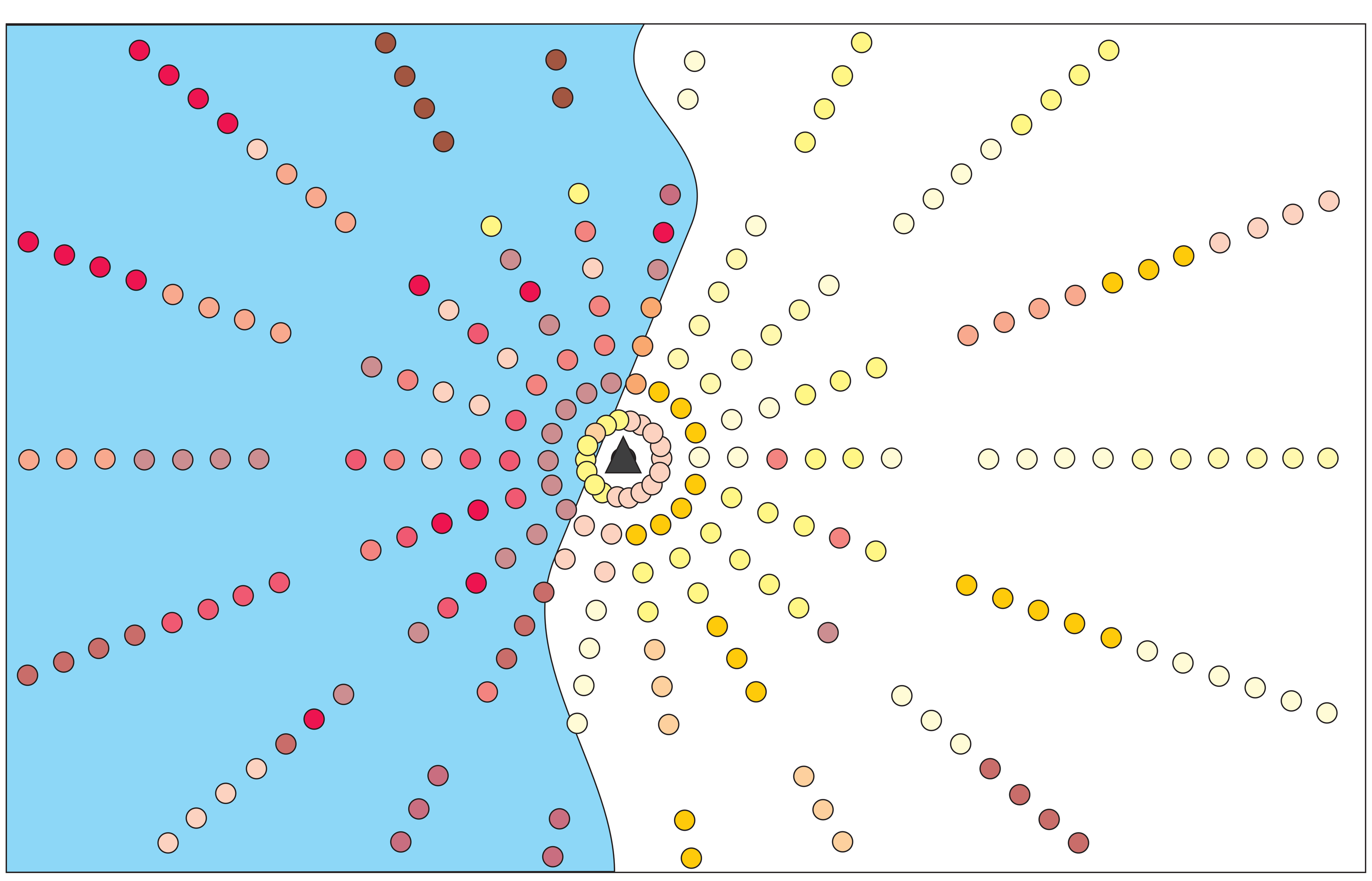
The ISC is currently reviewing the methods that are used to relocate earthquakes for the ISC bulletin. As a first step in this process we started to use S phases for the first time a year ago. This greatly improved convergence rates and the depth resolution of ISC hypocentres. Further improvements would have been extremely difficult with the existing software and a replacement location program named 'iscloc' has now been written. This program is available to download at www.isc.ac.uk/Documents/Location. Using iscloc we are experimenting into using travel times from modern earth models rather than from Jeffreys-Bullen tables as now. Separate models are being looked at for regional and teleseismic distances with a gap for source-station distances between 16 and 20 degrees where modelling ray paths is difficult. Regional travel times are found by ray tracing through a there dimensional cell model, CUB2, from the University of Colorado (Ritzwoller et al. 2002). Teleseismic travel times are found by ray tracing through a cubic spline model, J362D28, from Harvard University (Antolik et al. 2003). Both of the models incorporate the same crustal model and the first experiment that was done was to examine the effects of using this crustal model to refine Jeffreys-Bullen travel times.



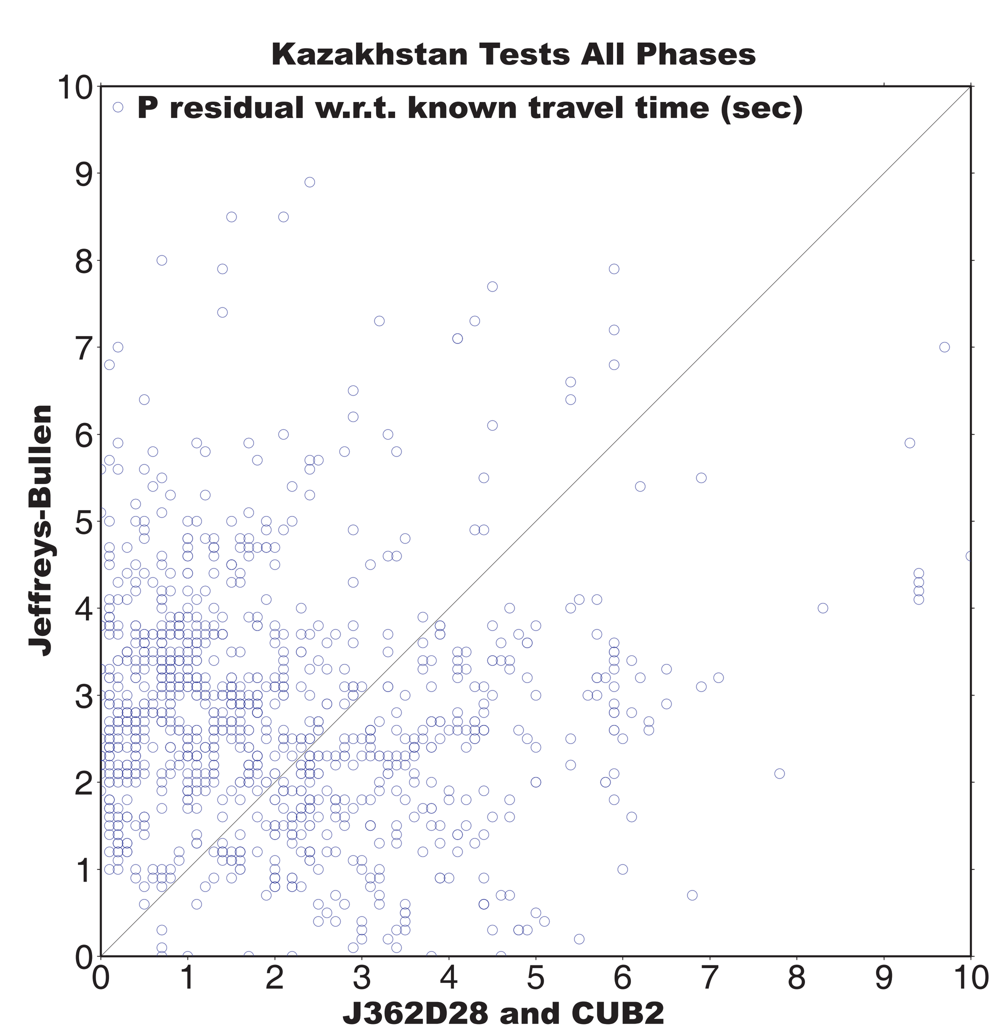
In the Jeffreys-Bullen travel time tables the crust is considered to have two layers of constant thickness and velocity all over the world. Recently a global model was made available on the Real Earth Model web site (Bassin, Laske, and Masters, 2000) that splits the crust into 2x2 degree 'tiles'. Each of these tiles has its own velocity structure based on crust type and tomography studies and 5 layers of varying thickness are used to model these structures. It is relatively simple to correct travel times for teleseismic phases (delta greater than 20 degrees) by subtracting the time that the phase would have spent in the J-B crust and replacing it with the time the phase would take to traverse the more detailed crust for the tile at the station, and for shallow sources, the tile at the source. In carrying out this correction an isostatic calculation must be made to compensate for differing thicknesses of upper mantle beneath the two crusts and for this the mantle is assumed to have the velocity of the uppermost mantle layer in the J-B earth model.



Residuals for a total of 674 stations were calculated with respect to the known location and time of 25 controlled nuclear explosions in Kazakhstan. This was done once using uncorrected Jeffreys-Bullen travel times and once correcting these travel times using the crust model as explained in the previous figure. The plot shows that many more residuals are smaller without the correction than with it. This indicates that the correction makes travel times less rather than more accurate and this was confirmed by doing similar tests for 241 controlled nuclear explosions in Nevada. There are two possible reasons that the correction does not work; either the crustal model does not accurately represent the crust beneath the stations or invalid assumptions have been made in splitting travel times from Jeffreys-Bullen tables into time spent traversing the crust and time spent elsewhere. The first explanation must sometimes be true as a 2x2 degree tile can, for example, contain high mountains as well as low coastal plains and stations in the two places would receive the same correction. Worsening residuals are, however, observed for stations in the centre of reasonably uniform tiles. The second explanation also seems likely, for example, when the Moho is shallow the uppermost mantle velocity might be slower than when the Moho is deep, rather than constant as assumed in the correction calculation. The effect of using the Laske crust as the upper part of the other two models investigated will depend on which of the two reasons put forward above is true. If the crustal model is inaccurate then it will decrease the accuracy of the new total travel times. If it is the assumption of an incorrect upper mantle velocity that is causing the residuals to increase then using the crustal model in combination with a model for the mantle could solve the problem.



The earth models and accompanying ray tracing programs given to the ISC by Harvard University and the University of Colorado have been developed so that they output Source Specific Station Corrections (SSSCs) in the format required by the International Data Centre in Vienna for use in verifying the comprehensive test ban treaty. This takes the form of a table of corrections for each station with values given at intervals of latitude and longitude. These corrections are added to the IASPEI travel time for a phase originating at a near surface source with such a latitude and longitude and recorded by the station in question. The ISC proposes to use the same models and ray tracers to produce tables that are more immediately useful to our new location program. These will take the form of a set of tables of travel times for each station with values given at intervals of distance and source depth. One table will be required for each interval in back azimuth between the station and source. Figure 3 explains this by plotting surface source travel times for an imaginary coastal station _ faster travel times are red and slower ones in yellow. Note the gap in travel times between 16 and 20 degrees away from the station where there is no coverage from either model.



Travel times from the two earth models together are tested in a similar manner to that shown previously for the crustal correction. Times are calculated for ground truth events in Kazakhstan by interpolating between table values that were obtained by ray tracing. These are then subtracted from the actual travel times and the residuals are compared to those for Jeffreys-Bullen travel times. As can be seen, the times from the tables produced from the models are closer to reality more often than those from J-B. This only tests one source area but does test many different stations and both models (the models individually also generally reduce residuals for those stations within the corresponding range of distances from the source).