



Relative Locations of the DPRK Nuclear Tests Using Regional and Teleseismic Data

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Accurate relative location estimates for the announced nuclear tests carried out at the Punggye-ri test site in North Korea make it far easier to constrain the absolute coordinates of the events. With four tests now recorded well both at regional and teleseismic distances with excellent azimuthal coverage, we have a vast number of differential traveltimes measurements which reduce substantially the variability in the relative location estimates. A large redundancy of data allows for independent relative location estimates for each event pair using different sets of stations and phases. Superposition of multiple grids of differential traveltimes residuals results in relative event location estimates which are less sensitive to uncertainties in the time measurements or in the modelled traveltimes gradients. Of particular interest is the location of the October 9, 2006, test. This event was approximately 2 km to the East of the 2009, 2013, and 2016 nuclear tests and its precise location will help to fix the template of relative locations in the terrain at the test site. This smaller event was recorded by fewer stations and with poorer signal-to-noise ratio. Due to the somewhat different source location the waveform semblance with the other events is diminished and this complicates the measurement of differential time-delays, in particular for the higher frequency regional observations. The uncertainty in the location of the 2006 event is reduced considerably by being able to be estimated relative to 3 different events with exceptionally accurate relative location estimates.