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Nuclear Test Depth Determination with Synthetic Modelling: Global Analysis from PNEs to DPRK-2016

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Seismic event depth determination is critical for the event screening process at the International Data Center, CTBTO. A thorough determination of the event depth can be conducted mostly through additional special analysis because the IDC's Event Definition Criteria is based, in particular, on depth estimation uncertainties. This causes a large number of events in the Reviewed Event Bulletin to have depth constrained to the surface making the depth screening criterion not applicable. Further it may result in a heavier workload to manually distinguish between subsurface and deeper crustal events. Since the shape of the first few seconds of signal of very shallow events is very sensitive to the depth phases, cross correlation between observed and theoretic seismograms can provide a basis for the event depth estimation, and so an expansion to the screening process. We applied this approach mostly to events at teleseismic and partially regional distances. The approach was found efficient for the seismic event screening process, with certain caveats related mostly to poorly defined source and receiver crustal models which can shift the depth estimate. An adjustable teleseismic attenuation model (t*) for synthetics was used since this characteristic is not known for most of the rays we studied. We studied a wide set of historical records of nuclear explosions, including so called Peaceful Nuclear Explosions (PNE) with presumably known depths, and recent DPRK nuclear tests. The teleseismic synthetic approach is based on the stationary phase approximation with hudson96 program, and the regional modelling was done with the generalized ray technique by Vlastislav Cerveny modified to account for the complex source topography. The software prototype is designed to be used for the Expert Technical Analysis at the IDC. With this, the design effectively reuses the NDC-in-a-Box code and can be comfortably utilized by the NDC users. The package uses Geotool as a front-end for data retrieval and pre-processing. After the event database is compiled, the control is passed to the driver software, running the external processing and plotting toolboxes, which controls the final stage and produces the final result. The modules are mostly Python coded, C-coded (Raysynth3D complex topography regional synthetics) and FORTRAN coded synthetics from the CPS330 software package by Robert Herrmann of Saint Louis University. The extension of this single station depth determination method is under development and uses joint information from all stations participating in processing. It is based on simultaneous depth and moment tensor determination for both short and long period seismic phases. A novel approach recently developed for microseismic event location utilizing only phase waveform information was migrated to a global scale. It should provide faster computation as it does not require intensive synthetic modelling, and might benefit processing noisy signals. A consistent depth estimate for all recent nuclear tests was produced for the vast number of IMS stations (primary and auxiliary) used in processing.