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Identification of cavity due to an underground nuclear explosion using seismic wave fields

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Nuclear explosions are banned by the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Obviously, the CTBT needs robust and comprehensive verification tools to make sure that no nuclear explosion goes undetected. In addition to the global monitoring systems it is necessary to have reliable tools for on-site inspections (OSI) and investigations. Among other candidate methods, possibility of detecting and interpreting of the so-called resonance seismic phenomena has to be comprehensively investigated and potentially elaborated for practical use.

Numerical modelling of seismic wave fields makes it possible to investigate resonance phenomena and their signatures in free-surface records. The necessary condition for reasonable results is an optionally accurate and computationally efficient numerical-modelling tool together with a sufficient set of realistic structural models. In collaboration with the CTBT Organisation and based on extensive review of the available literature we have developed 3D realistic models of the underground structure after an UNE. The most general model consists of cavity, chimney with apical void, crushed zone, fractured zone, environment and free surface. The models include a) 2 yields of the UNE (1 kt and 10 kt), b) 4 different types of the pre-shot geological environment (tuff, alluvium, granite, rock salt) characterized by P- and S-wave speeds and quality factors, and density, c) vacuum or fluid in cavity, d) 2 depths of burial (minimal and 2-times minimal).

We performed extensive parametric numerical modelling of seismic wave fields due to plane-wave excitation (representing regional and distant events), near point double-couple sources (representing aftershocks) and seismic ambient noise. We then comprehensively analysed the simulated wave fields in the time, frequency and time-frequency domains.

In a seismic wave field due to a distant source it is possible to identify resonant motion and locate cavity. A seismic wave field generated by an aftershock is much more difficult to interpret in terms of the cavity presence due to strong effects of a radiation pattern. Analysis of seismic noise makes it possible to identify cavity at least for relatively shallow cavities. Simulation of a sufficiently long record of seismic noise for deep cavities is hard to achieve.