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Numerical study of wave propagation around an underground cavity: acoustic case

Sofi Esterhazy (1,2), Ilaria Perugia (2), Joachim Schöberl (3), and Götz Bokelmann (1)

(1) University of Vienna, Faculty of Earth Sciences, Geography and Astronomy, Department of Meteorology and Geophysics, Vienna, Austria (sofi@esterhazy.net), (2) University of Vienna, Faculty of Mathematics, Vienna, Austria, (3) Vienna University of Technology, Institute for Analysis and Scientific Computing, Vienna, Austria

Motivated by the need to detect an underground cavity within the procedure of an On-Site-Inspection (OSI) of the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), which might be caused by a nuclear explosion/weapon testing, we aim to provide a basic numerical study of the wave propagation around and inside such an underground cavity.

The aim of the CTBTO is to ban all nuclear explosions of any size anywhere, by anyone. Therefore, it is essential to build a powerful strategy to efficiently investigate and detect critical signatures such as gas filled cavities, rubble zones and fracture networks below the surface. One method to investigate the geophysical properties of an underground cavity allowed by the Comprehensive Nuclear-test Ban Treaty is referred to as "resonance seismometry" - a resonance method that uses passive or active seismic techniques, relying on seismic cavity vibrations. This method is in fact not yet entirely determined by the Treaty and there are also only few experimental examples that have been suitably documented to build a proper scientific groundwork. This motivates to investigate this problem on a purely numerical level and to simulate these events based on recent advances in the mathematical understanding of the underlying physical phenomena.

Here, we focus our numerical study on the propagation of P-waves in two dimensions. An extension to three dimensions as well as an inclusion of the full elastic wave field is planned in the following. For the numerical simulations of wave propagation we use a high order finite element discretization which has the significant advantage that it can be extended easily from simple toy designs to complex and irregularly shaped geometries without excessive effort. Our computations are done with the parallel Finite Element Library NGSOLVE ontop of the automatic 2D/3D tetrahedral mesh generator NETGEN (http://sourceforge.net/projects/ngsolve/). Using the basic mathematical understanding of the physical equations and the numerical algorithms it is possible for us to investigate the wave field over a large bandwidth of wave numbers. This means we can apply our calculations for a wide range of parameters, while keeping the numerical error explicitly under control.

The accurate numerical modeling can facilitate the development of proper analysis techniques to detect the remnants of an underground nuclear test, help to set a rigorous scientific base of OSI and contribute to bringing the Treaty into force.