# 3D analytical and numerical modeling of the regional topography influence on the surface displacement, strain and gravity change due to underground heat source

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Abstract: Thermo-elastic strains and stresses play a considerable role in the stress state of the lithosphere and its dynamics, especially at pronounced positive geothermal anomalies. Topography has a significant effect on ground deformation. The contribution presents the results of the modeling of the influence of the topographic features on the thermo-(visco)-elastic deformations due to the underground heat source. The first method gives the approximative estimation of the topography influence obtained by the analytical approach. The second one is numerical, the computations of deformation field due to heat source are performed by the finite element method.

The simple analytical method for evaluating the topographic effect in three-dimensional deformation model is based on the assumption, that the main effect of the topography is due to the distance from the heat source to the free surface. The solution on the surface is achieved by the consecutive computation of the

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source influence with corresponding depth of the heat source for the each point. The varying depth methodology was introduced by *Williams and Wadge (1998)* and elaborated e.g. in *Charco et al. (2002)*.

The numerical approach is based on the finite element computations. The two identical models (with and without cone-shaped topographical feature) were processed, the thermoelastic deformations due to the underground heat source were computed. The models were homogeneous, isotropic, axi-symmetric with respect to vertical axis, the heat source was modelled by the spherical body in the 5 km depth. The dimensions of the computational domain were 120 km × 40 km in order to minimize the influence of the boundaries. In the computation only the forces of thermal origin were considered. The computations were obtained by the COMSOL Multiphysics® software. The influence of the topography was obtained from the comparison of the solutions of both models.

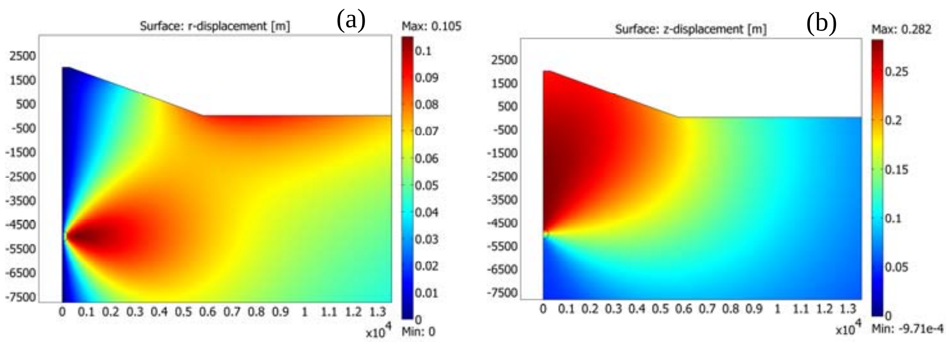


Fig. 1. The computed horizontal (a) and vertical (b) component of the displacement field.

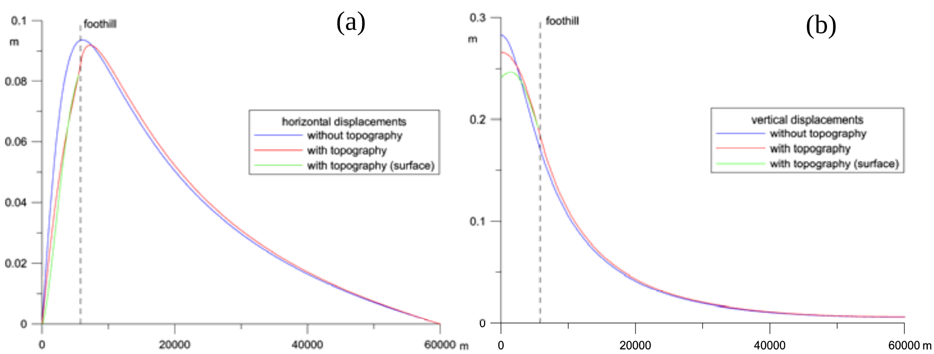


Fig. 2. The comparison of the horizontal (a) and vertical (b) displacements for the both variants of the model.

The results (Figs 1-2) show that for the volcanic areas with an pronounced topography the perturbation of the thermo-elastic solution due to the topography can be quite significant. In consequence, neglecting topography could give erroneous results in the estimated source parameters.

The methods described in this work can be very suitable to more complex models that consider sources of different geometries and allows elastic properties of the medium to vary with depth. While the analytical approximate methodology can be very attractive for solving the inverse problem, the numerical method described above may be used to include the topography when accurate solution is desired since it permits the consideration of non-uniform elastic and thermal properties of the medium and the local shape of the Earth's surface.

**Key words:** ground deformation, analytical model, numerical model, finite element method, thermoelasticity

## References

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