Geophysical Research Abstracts, Vol. 7, 01289, 2005
SRef-ID: 1607-7962/gra/EGU05-A-01289

Bayesian inversion of ground deformations at Mt. Etna using FEM approach to model 3D volcano topography.

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In this work topographic effects on elastic ground deformation at Mt. Etna have been analyzed by a finite element approach and it has been demonstrated that topographic effects may significantly affect deformation patterns at central volcanoes with prominent variations in relief.

A large grid of isotropic sources of pressure, spaced at 0.5 Km in the three dimensions, has been simulated in a given volume, from the volcano's summit to 10 Km below sea level. Theoretical ground displacements computed by the finite element method (FEM), using a 3D model for the volcano incorporating the real topography, have been compared to analytical results computed for three different half-space models. The difference between the displacements obtained using FEM and half-space models describes the effect of volcano topography on ground deformation at Mt. Etna. It has been showed that using half-space models significant bias into the interpretation of volcano deformation is introduced. In particular for depths below sea level of the same order as the maximum topographic relief the effects of topography are very pronounced, with an incidence even larger than 300%, mainly on the vertical component; strong effects are also present on the ratio between radial and vertical displacement. It has been produced a dense set of tabulated values for topographic corrections to add the FEM topographic effect to half-space models results; this way, point source analytical solutions can be corrected for topographic effects without actually performing again FEM computations. This approach gives the first picture of fully 3D topographic effects at Mt. Etna, which can be used to carefully interpret observed ground deformations.

However it has also been found out a good approximation for topographic effects, with half-space analytical solutions, by considering a variable half-space height top for each point of measure, adding the height of each point to the source depth below sea level (Model C).

These results (topographic corrections) can be used to implement Bayesian and exhaustive search inverse procedures based on point source models, taking into account topographic effects. This would be virtually impossible if exact 3D calculations should be performed at each iteration.

In this work topographic corrections computed through simulations have been used in the 1994-1998 leveling data inverse procedure. The application of the Bayesian inverse method gives the most probable location for the point source at about 6 km of depth and 3 km North to the central craters.

This work, besides presenting an accurate description of topographic effects at Mt. Etna, also indicates the main qualitative effects expected on volcanoes of steep topography, and emphasizes the importance of taking full 3D topographic effects into account when interpreting ground displacement at volcanoes.