Geophysical Research Abstracts, Vol. 7, 09282, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09282

Gravity gradiometry at the restless Campi Flegrei caldera (Italy) in the view of a layered and self-gravitating Earth model

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Ground deformation and gravity changes at restless volcanoes must be interpreted in terms of the structural response of the edifice to sub-surface volume and mass changes. The ratio of height change to gravity change (vertical gravity gradient) can provide valuable insights into the causative sub-surface processes as it enables the assessment whether deformation is induced by either mass or density changes or a combination of the two. Linear and non-linear gradients have been observed at active volcanoes but the underlying physics causing either is poorly constrained, because the information obtained from gravity gradiometry is very much biased on the modelling framework employed. Results from isotropic elastic models differ significantly from those accounting for anisotropy or inelasticity. Here we present results from the evaluation of gradients measured at the Campi Flegrei caldera between 1981 and 2001 in the context of mass/volume changes in a layered elastic-gravitational medium. Assuming a planar medium consisting of multiple layers overlying a half-space, we account for elasticity and self-gravitation. The model enables the discrimination of surface deformation induced by sub-surface mass changes from deformation dominated by sub-surface pressure variations. We identify periods of ground uplift caused by magma transport and those dominated by pressurisation of the hydrothermal system. We propose the contribution of multiple sources beneath Campi Flegrei to the observed unrest particularly during slow deflation since 1988, which appears to be dominated by short-term pressure fluctuations within distinct shallow hydrothermal reservoirs causing strongly non-linear gravity gradients. Evaluating gradients within this new concept provides quick and valuable insights into the causative processes behind volcano unrest and

thus complements results from data inversion for hazard assessment.