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The 1982-1984 unrest of the Campi Flegrei caldera (Italy): clues on the resolving power of the available geodetic data and the robust features of the deformation source

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The explosive Campi Flegrei caldera suffers a secular subsidence, on which are superposed very fast uplifts giving rise to only one eruption since Roman times in 1538. The caldera has been generally subsiding (at about 1.5 cm/yr) from 1538 till 1969, but a ground uplift of more than 1.5 m occurred in the period 1969-1972 and, after a small subsidence of about 30 cm after 1972, a very large uplift occurred in the period 1982-1984 (about 1.8 m), with subsequent partial recovery.
A wealth of studies is available for the 1982-1984 unrest, and a long-standing controversy characterizes its interpretation, both in the source geometry and unrest cause (intrusion of magma and/or magmatic fluids or instability of the hydrothermal system). This unresolved controversy is partly due to the consistency of available geodetic data with many different physical models, while no general mathematical model of a deformation source is available but in the far field (point moment tensor). The point moment tensor representation is equivalent to the monopole term in the multipole expansion of any extended deformation source.
We have tested different physical source models, embedded in a 1-D layered half-space proper for the Campi Flegrei area, aiming at (i) getting clues on the actual resolving power of the available geodetic data and (ii) determining the robust features of the deformation source, if any. In particular, we deal with:
1) one uniformly pressurized spheroidal cavity, having a vertical axis of symmetry;
2) one uniformly pressurized tri-axial ellipsoidal cavity, mathematically modelled under the quadrupole approximation; this source does not provide any release of shear stress;
3) one uniform-opening tensile fault, e. g. due to the intrusion of magma or fluids into the fault gouge; it does not provide any release of shear stress and does not fulfill the uniform-pressure boundary condition;
4) one mixed mode (shear and tensile) fault, with uniform opening and slipping;
5) one finite distribution of isotropic sources (quadrupole approximation), e. g. due to an increase of pore pressure and/or temperature caused by fluid injection and/or movements.
Given the available deformation data, models 2, 3, and 4 are statistically indistinguishable, while models 1 and 5 are statistically unfavoured. This result puts strong constraints on the possible cause of the unrest. We also find that centre position, orientation and volume change of the source are quite invariable, although related to different physical source models. Similar considerations hold even adding a deeper deflating source (vertically flattened crack at 7500-m depth).
We also invert synthetics from the best-fit models 2 and 3 for a single moment tensor, obtaining eigenvalues which are out of the permitted region for a tri-axial ellipsoidal cavity, including the moment tensor of a tensile fault. The fact that a similar result is obtained when inverting real deformation data might thus be a mere consequence of the monopole approximation (point source) inadequacy.