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3D time dependent thermo-fluid dynamic model of ground deformation at Campi Flegrei caldera

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In active volcanic areas deformation signals are generally characterized by non-linear spatial and temporal variations [Tizzani P. et al., 2007]. This behaviour has been revealed in the last two decades by the so-called advanced DInSAR processing algorithms, developed to analyze surface deformation phenomena [Berardino P. et al., 2002; Ferretti C. et al., 2001].

Notwithstanding, most of the inverse modelling attempts to characterize the evolution of the volcanic sources are based on the assumption that the Earth's crust behaves as a homogeneous linear elastic material. However, the behaviour of the upper lithosphere in thermally anomalous regions (as active volcanoes are) might be well described as a non-Newtonian fluid, where some of the material proprieties of the rocks (i.e. apparent viscosities) can change over time [Pinkerton H. et al., 1995].

In this context, we considered the thermal proprieties and mechanical heterogeneities of the upper crust in order to develop a new 3D time dependent thermo-fluid dynamic model of Campi Flegrei (CF) caldera, Southern Italy. More specifically, according to Tizzani P. et al. (2010), we integrated in a FEM environment geophysical information (gravimetric, seismic, and borehole data) available for the considered area and performed two FEM optimization procedures to constrain the 3D distribution of unknown physical parameters (temperature and viscosity distributions) that might help explaining the data observed at surface (geothermal wells and DInSAR measurements). First, we searched for the heat production, the volume source distribution and surface emissivity parameters providing the best-fit of the geothermal profiles data measured at six boreholes [Agip ESGE, 1986], by solving the Fourier heat equation over time (about 40 kys). The 3D thermal field resulting from this optimization was used to calculate the 3D brittle-ductile transition. This analysis revealed the presence of a ductile region, located beneath the centre of the CF caldera between 5 and 11 km depth, that represents the sub-domain setting for the subsequent fluid dynamic optimization.

We considered the 3D non-isothermal field resulting from the thermal optimization as the input to solve the Navier-Stokes equations in a non-Newtonian conditions. Thus, we determined the upper lithosphere viscosity distribution that best-fits the CF caldera long term displacement time series, measured via the SBAS-DInSAR approach during the 1992-2010 time interval.

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