3D GEODETIC IMAGE OF LONG-TERM DEFORMATION SOURCE AT RABAUL CALDERA (PNG) FROM FEM-BASED LINEAR INVERSION OF INSAR DATA.

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Introduction & Objectives

After the 2006 sub-plinian eruption of about 0.2 km³ or 900×10⁶ m³ ⁴ due to anandesite from Tavurvur, Rabaul caldera experienced a long-term steady subsidence marked by almost continuous volcanic eruptions at Tavurvur between February 2007 and December 2010.

Main goals of geodetic imaging:
- Determine the subsidence mass movement of magma through inversion of InSAR data without imposing an a priori source
- Provide a 3D free-boundary of the reservoir dictated by the data

How do we achieve this?
- Integration of a family of finite element models (FEM) into the regularized linear inversion of InSAR data

Why?
- Understand the spatial and temporal dynamics of magmatic systems activity helps to effectively predict the behavior of future eruptions

Methods

The inversion is based on an array of FEM sources:

Source validation:
- Source: Hydro-fluid elements cost the cavity walls and provide the coupling between structure deformation and pressure (P, exerted by the injected fluid).
- Fluid properties: density (ρ), bulk modulus (K), and mass flux (q).

F – ρg ̅ p = dp/dt ̅ p = dp/dt ̅ K = dp/dt ̅ q = dp/dt ̅
- Validation of different FEM sources with McPhee analytical solution. Sources are removed by 8 hexahedral elements are validated (Fig. 2).

Family of heterogeneous FEMs with topography:
- FEMs (Fig. 3) are made of two parts: a prism that hosts the cavity sources (included in the blocks) (Fig. 2) and the surrounding domain. The FEMs share the same mesh, in which only one source is activated at a time by removing the corresponding element and applying the unitary fluid flux (10⁹ Pa/s) to the cavity.

Resolution & uncertainties (Fig. 7):
- Higher resolution at shallower levels at the sides of the array (closer to the data) (Fig. 7)
- Lower resolution in the S-Z corner (Fig. 7a)
- Lower uncertainties in the S-Z corner (Fig. 7d)

Conclusions

More realistic models (free-source geometry, topography, and heterogeneities) allow to predict the observed deflation and, more importantly, to image in space and time interactions with complex free geometry. This widens the understanding of magmatic systems and their dynamics with implications for the kind of eruption that we can expect. At Rabaul, the inversion allows us to identify two lobes only sheared and connected > 3.5 km (Fig. 6 e and 5).

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Reference