Under the radar: New activity beneath the “Roof of Patagonia”, Domuyo volcano, Argentina

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Motivation: 1
Forecasting system evolution during unrest

Research Questions:

1. Does caldera inflation unrest imply future eruption?

2. How is caldera breathing related to magma ascent and volcanic outgassing?
Motivation: 2

Understanding and forecasting require **physics-based** models

**Deflation/inflation with dome effusion**

- **Source geometry** and pressure/volume change are important constraints on physics-based volcano models.
- **Single reservoir with viscoelastic shell**

**Two-tiered reservoir system**

Physics-based models use **deformation time series** (among other information) to constrain a few types of mass conservation continuum and fluid mechanical models.

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Anderson and Segall (2011, 2013), Segall (2013)

Reverso et al. (2012), Bato et al. (2017)
Motivation: 2

Understanding and forecasting require **physics-based** models

Deflation/inflation with dome effusion

But models based on fitting geodetic observations are often for single events and may lack assessment of longer term system behavior

Reverso et al. (2012), Bato et al. (2017)
Outline

✓ Motivation
  • Domuyo background
  • Domuyo volcano InSAR deformation
  • Domuyo TIR time series
  • Conceptual physics-based model
Looking for Nev. de Chillán...

Laguna del Maule

Domuyo

Nev. de Chillán

ALOS-2 2018-2017 1-year interferogram
Domuyo volcano

Located in the Southern Andes of Argentina
Domuyo volcano
Domuyo volcano


Geothermal output from SW slopes of Domuyo (Chiodini et al., 2014)

Fig. 1. (Left panel) The Domuyo volcanic complex, north of the Cordillera del Viento chain, and (right panel) geological map showing the distribution of Permian-Triassic to Pleistocene rocks; the arrow points to a K-Ar dating location (modified from Miranda et al., 2006).
Domuyo volcano

Chiodini et al. (2014):
• Second largest energy hydrothermal energy release measured in the world after Yellowstone (1.1 GW)
• High heat flux hard to explain from 0.1 Ma most recent activity, and may suggest more recent magma intrusion.

Tassi et al. (2016):
• Silicic (rhyolitic to dacitic) domes
• Geothermal chemistry suggests water from two different reservoirs (600m and 2-3 km depth)
• Actively degassing magmatic gasses evident above 3000m

Tassi et al., 2016
ALOS-2 2015-2018 interferograms

Feb. 2015 – Apr. 2018

Apr. 2015 – Jan. 2018

10 km
12 cm/cycle

33°
41°

37°
ARIA project performed a rapid response to request for data. Within a few days interferograms spanning 3 years confirmed the ALOS-2 results (special thanks to Hook Hua and Lan Dang at JPL)
Sentinel-1 D83
When did inflation start?
Domuyo preliminary model results

- Bayesian inference MCMC CDM source model solution
- Based on ALOS-2 and Sentinel-1 asc and desc TS linear rates

We model ellipsoidal cavity volume change of arbitrary geometry using the compound dislocation model (CDM) of Nikkhoo et al. (2017)

Source parameters are estimated using a Bayesian Markov chain Monte Carlo approach (e.g. Lundgren et al., 2017).
- CDM solution represents a near horizontal pancake-like ellipsoidal magma body
- Depth ~5.5 - 6 km, too deep for a hydrothermal system
Thermal time series

From Girona et al., 2018
Domuyo source inversion results

- Negative dilation immediately above the source might be expected to reduce fluid flux from magma body (e.g. Zhang et al., 2008)
What can explain the phase-shift between deformation-thermal time series?

**HYPOTHESIS:**
- deformation ↔ pressure
- thermal evolution ↔ outgassing

**AIM:**
Understand the pressure – outgassing coupling

**PHYSICAL APPROACH/ASSUMPTIONS:**
- Linearized momentum and mass conservation equations
- Ideal gas law
- Infinite permeable medium approximation

**FIRST-ORDER ANALYTICAL SOLUTION (IN FREQUENCY DOMAIN):**

\[
\mathcal{F}\{\Delta Q_{ex}(t)\} = \frac{\mathcal{F}\{\Delta P(t)\}}{\left[\frac{\beta_B + j\beta_c \omega \lambda_\omega}{\beta_a} - jk_\omega \frac{\lambda_\omega}{k_\omega^2 + \lambda_\omega^2} - \frac{\beta_d}{\beta_a}\right] (e^{\lambda_\omega L} e^{jk_\omega L} - 1)}
\]

Model under development by Társilo Girona, JPL
The phase-shift between pressure-outgassing (deformation-thermal) is governed by the crustal permeability.

\[ \kappa = 2 \cdot 10^{-16} \text{ m}^2 \]

\[ \kappa = 2 \cdot 10^{-17} \text{ m}^2 \]

Arbitrary pressure perturbation

Calculated outgassing
Summary

- **Domuyo Volcano** is another example of **abrupt shallow crustal inflation** from a volcano with **no historical eruption record**. Rapid, **12 cm/year inflation started by mid-2014** and is on-going.

- Source is sub-horizontal **tabular body at ~6 km** below the surface using an elastic half-space.

- The **combination of geodetic data and long-wavelength thermal infrared data** can help to constrain the processes governing the evolution of volcanic calderas.

- Caldera breathing may be controlled by **the transfer of gases through the shallow crust**, which **produces spontaneous pressure oscillations in magma reservoirs**.

- The **phase shift** observed in the **geodetic-thermal time series** of Domuyo may be consistent with **gas-controlled breathing and low crust permeability**.

- **Long-term Inflation** does not necessarily mean continuous magma ascent.

- **Future work** includes to: solve numerically the full momentum equation (without linearizing and using the infinite permeable medium approximation); account for the crust viscoelasticity; incorporate thermal evolution of the magma reservoir; and link pressure and outgassing with deformation and thermal infrared emissions.

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