National Aeronautics and Space Administration

FY24 Strategic University Research Partnership (SURP)

Satellite observations of volcano topography change: A critical but immature measurement for eruption forecast models

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Year 3 Objective: Previous work compiled volcano topography data on a global scale [1]. Here, we focus on a case study to demonstrate the use of frequent topography data acquisitions.

Background: Topography and how topography changes over time are critical datasets for studying eruptive behavior [2]. **Nevados de Chillán** is one of the most active volcanoes in Chile and recently erupted from 2016-2022 (Fig. 1) [3]. We use **surface deformation and topographic change data** to determine deformation source geometry and erupted volume (Figs. 2-6) and better understand eruption dynamics.

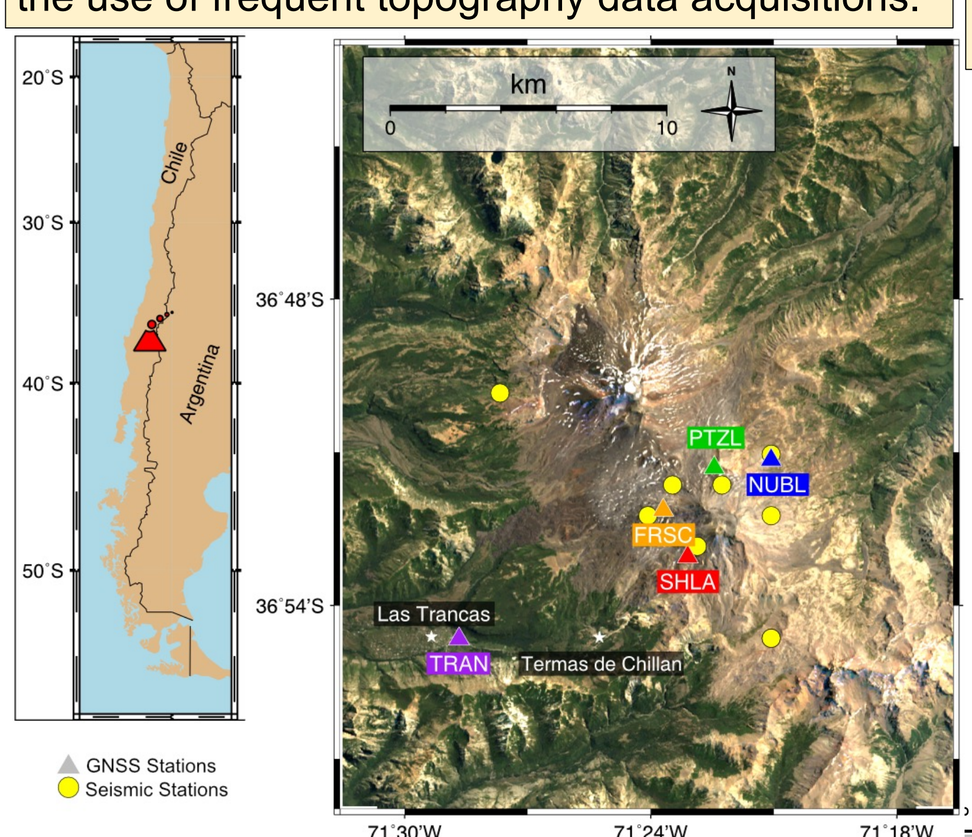


Figure 1. (above) Nevados de Chillán, Chile. White stars show nearby towns, colored triangles show GNSS stations, and yellow circles show seismic stations.

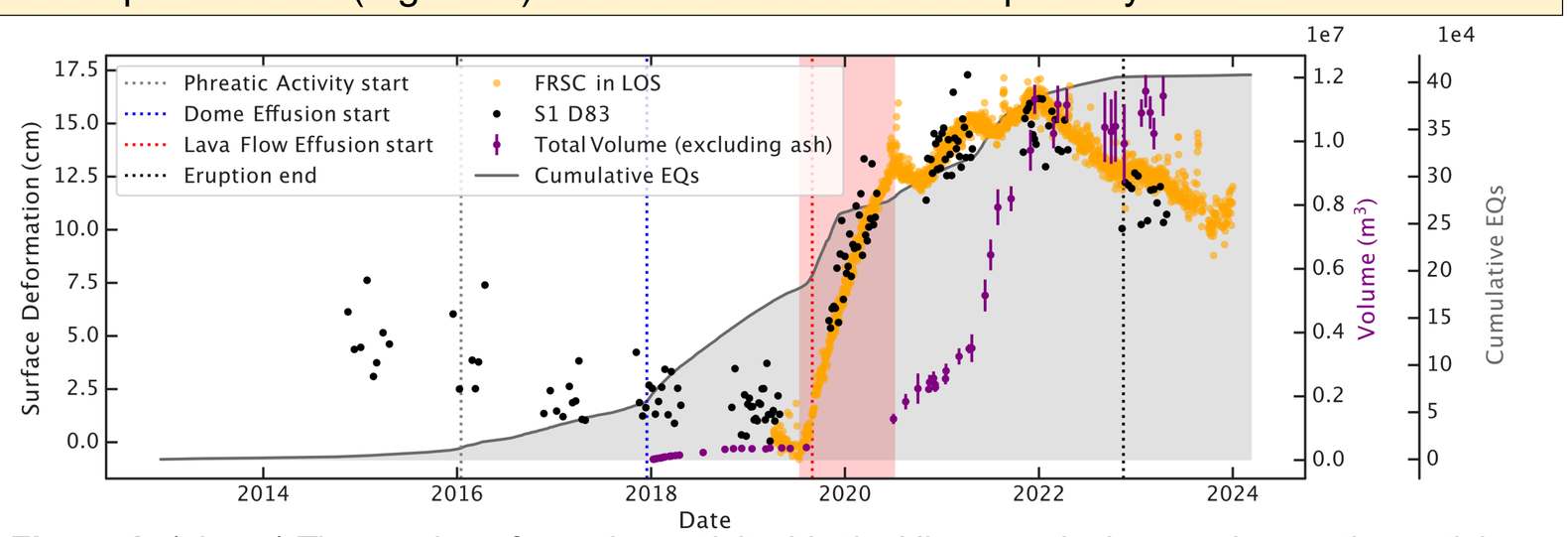


Figure 2. (above) Time series of eruptive activity. Vertical lines mark changes in eruptive activity. Orange (GNSS) and black (Sentinel-1) circles show surface deformation at station FRSC. Purple points show erupted volume. Gray shading shows cumulative earthquakes. Red shading shows period of inflation modeled in Fig. 3 and shown in Fig. 4.

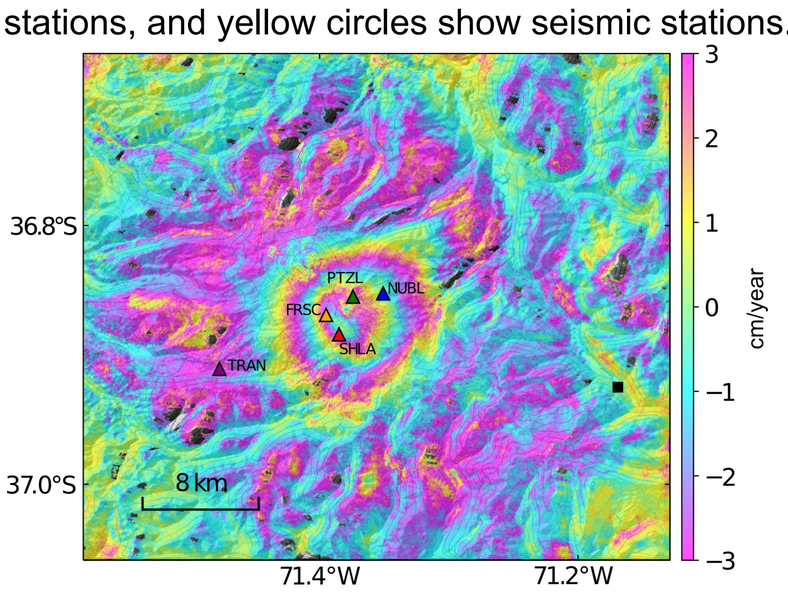


Figure 4. (above) Wrapped linear velocity map from 8/2019 to 7/2020.

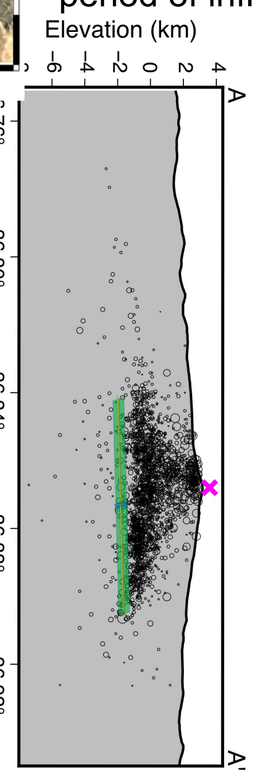
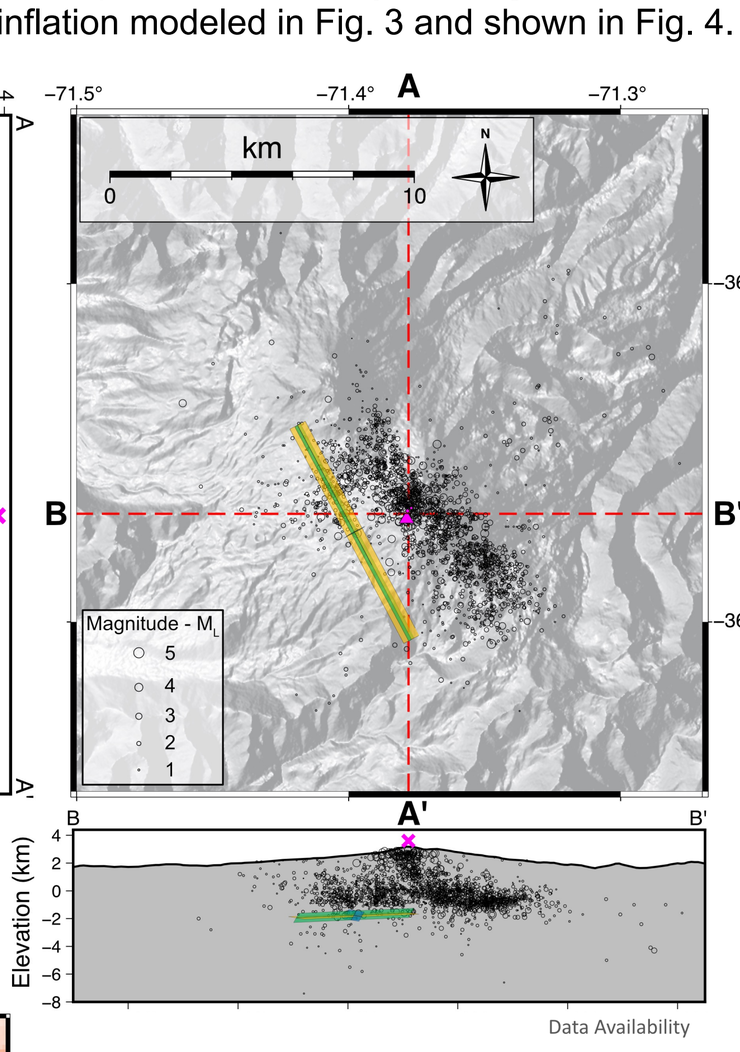


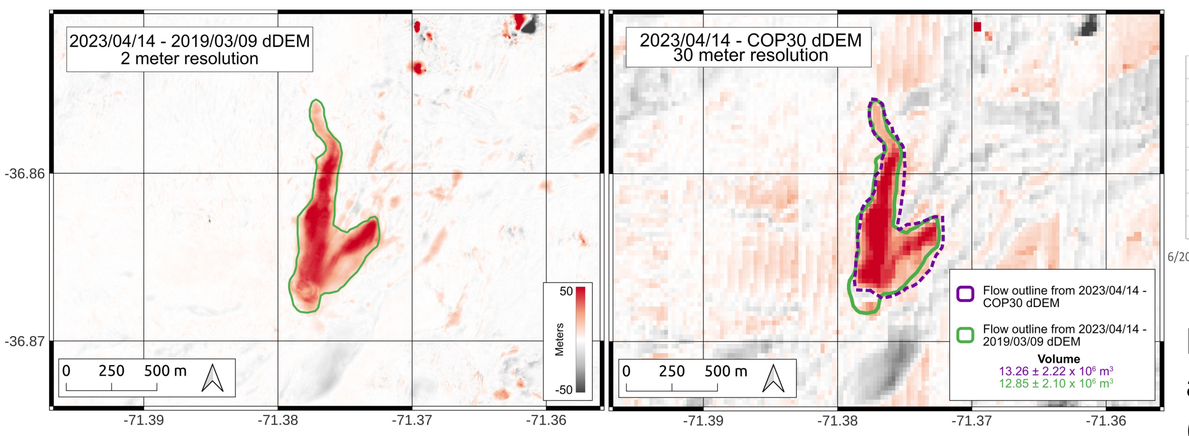
Figure 3. (right) Best fit CDM results plotted with earthquake locations during inflation 1.



Approach: We used Markov chain Monte Carlo methods to constrain a **Compound Dislocation Model** for the first inflation period (Figs. 3-4) [4] and ellipsoids for other deformation periods (not shown). We used **Ames Stereo Pipeline** to generate 2m resolution Digital Elevation Models from stereo-optical imagery and differenced them to calculate volume change (Figs. 5-6) [5].

Results: From the dDEMS, a total of 11.4 ± 0.6 x 10^6 m^3 lava flows and domes erupted. Based on kinematic model inversions, the uplift periods totaled 31.3 x 10^6 m^3 of positive volume change and the subsidence periods totaled 1.3 x 10^6 m^3 of negative volume change.

Figure 5. (below) Comparison of 2m difference DEM (left) and 30m dDEM (right). 2m DEM was created using commercial data, 30m DEM was created using open-access data. Volume estimates are within error.



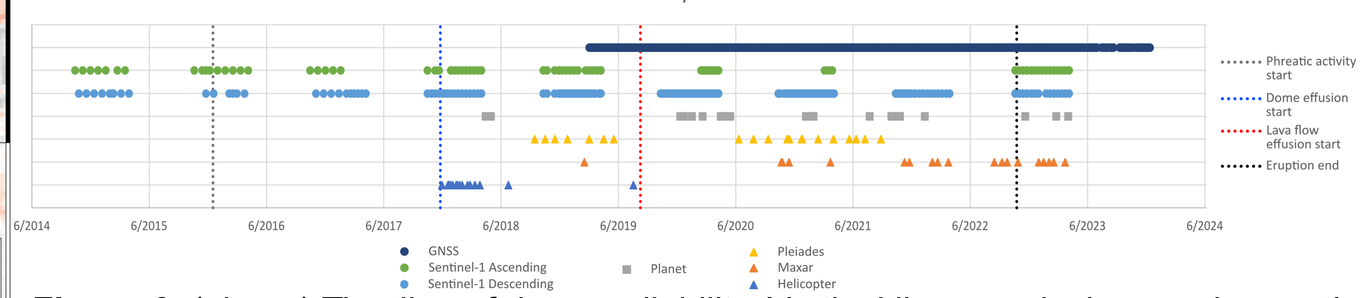


Figure 6. (above) Timeline of data availability. Vertical lines mark changes in eruptive activity. We have surface deformation (circles), optical (squares), and stereo-optical (triangles) data. Importantly, there is no stereo-optical data at the start of flow effusion.

Benefits to JPL and NASA and Takeaways: The deliverables from this project will be directly relevant for Surface Topography and Vegetation (STV) future mission proposals. We show that eruptions can be complex and change rapidly. Multiple eruptive phases make eruption forecasting difficult and dependent on a volcano's behavior. Daily acquisitions of topographic change data are needed during transitions in eruptive behavior. Space-based datasets are critical for monitoring changing behavior. Future work will be using these data in an operational sense which emphasizes our need for low-latency products.

References: **[1]** Eiden, E., Pritchard, M. E., & Lundgren, P. R. (2023). Spatial and Temporal Resolution Needs for Volcano Topographic Change Data Sets Based on Past Eruptions (1980–2019). Earth and Space Science; **[2]** Delgado, F., Kubanek, J., Anderson, K., et al. (2019). Physicochemical models of effusive rhyolitic eruptions constrained with InSAR and DEM data: A case study of the 2011-2012 Cordón Caulle eruption; **[3]** Moussallam, Y., Bani, P., Schipper, C. I., et al. (2018). Unrest at the Nevados de Chillán volcanic complex: a failed or yet to unfold magmatic eruption? *Volcanica*; **[4]** Nikkhoo, M., Walter, T. R., Lundgren, P. R., & Prats-Iraola, P. (2016). Compound dislocation models (CDMs) for volcano deformation analyses. Geophysical Journal International; **[5]** Beyer, R. A., Alexandrov, O., & McMichael, S. (2018). The Ames Stereo Pipeline NASA s Open Source Software for Deriving and Processing Terrain Data. Earth and Space Science.

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