

Title : Advancing Volcanic Mechanism Classification with Neural Networks and Synthetic Aperture Radar (SAR) Displacement Data

Labs : LISTIC, Université Savoie Mont Blanc, ISTerre, Université Grenoble Alpes, LMV, Université Clermont Auvergne

Candidate profile : The Ph.D candidate should have good skills in machine learning or volcanology.

Ph.D subject description :

Satellite based remote sensing offers a unique source of information to monitor the environnement, with fine spatial resolution, wide coverage and frequent revisit. This enables addressing the challenge of natural hazard monitoring and forecasting, which has a significant societal impact.

The inverse modeling of surface displacement is one of the major techniques of exploring the subsurface feature of volcanoes. In this Ph.D thesis, we consider the classification of volcanic mechanisms from Interferometry Synthetic Aperture Radar (InSAR) surface displacement estimations. This work is challenging, because surface displacement fields lack distinct features that can reliably distinguish different volcanic mechanisms at depth. We will begin with a blind supervised learning experiment based on synthetic simulations and frugal machine learning models (e.g. random forest) in order to validate the proof-of-concept (Indeed, Cayol et al. 2014 proposed a tedious approach based on a manual decision tree). Afterwards, we can take two approaches: on one hand, increasing the model expressivity, such as transitioning to frugal deep learning models, with the aim of improving classification accuracy; on the other hand, incorporating multimodal input to the model. This includes using directional displacement gradient's value and sign, as well as horizontal/vertical displacement ratio to complement displacement values, based on expert's knowledge. Furthermore, inspired by the approach adopted by volcanologists for a similar task - recognizing key physical parameters of fracture displacement (such as faults, magma intrusions, or sheared intrusions), as well as the dip and depth of the fracture and the ratio of host rock stress exerted on the fracture - we aim to train deep learning models to extract physical features. By incorporating physics-informed loss functions, we seek to enhance the universality of solutions proposed by previous deep learning models. Real InSAR displacement measured at the Piton de la Fournaise volcano since 1998 and previously analyzed through Monte Carlo inversions (Dumont et al. 2022) will be used for further validation in real applications.

Selected references :

Cayol V., Carry T., Michon L., Chaput M., Famin V., Bodart O., Froger J.L., Romagnoli C. (2014), Sheared sheet intrusions as mechanism for lateral flank displacement on basaltic volcanoes: Applications to Réunion Island volcanoes, *Journal of Geophysical Research*, 119, 7607-7635.

Dumont, Q., Cayol, V., Froger, J. L., & Peltier, A. (2022). 22 years of satellite imagery reveal a major destabilization structure at Piton de la Fournaise. *Nature communications*, 13(1), 2649.

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