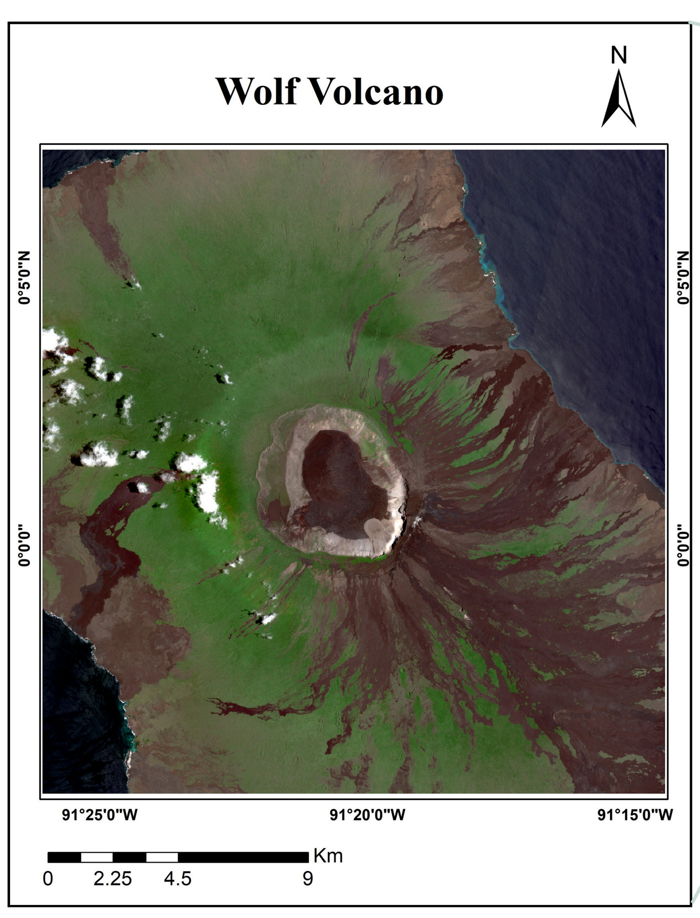
GIFTS SUMMIT 2025

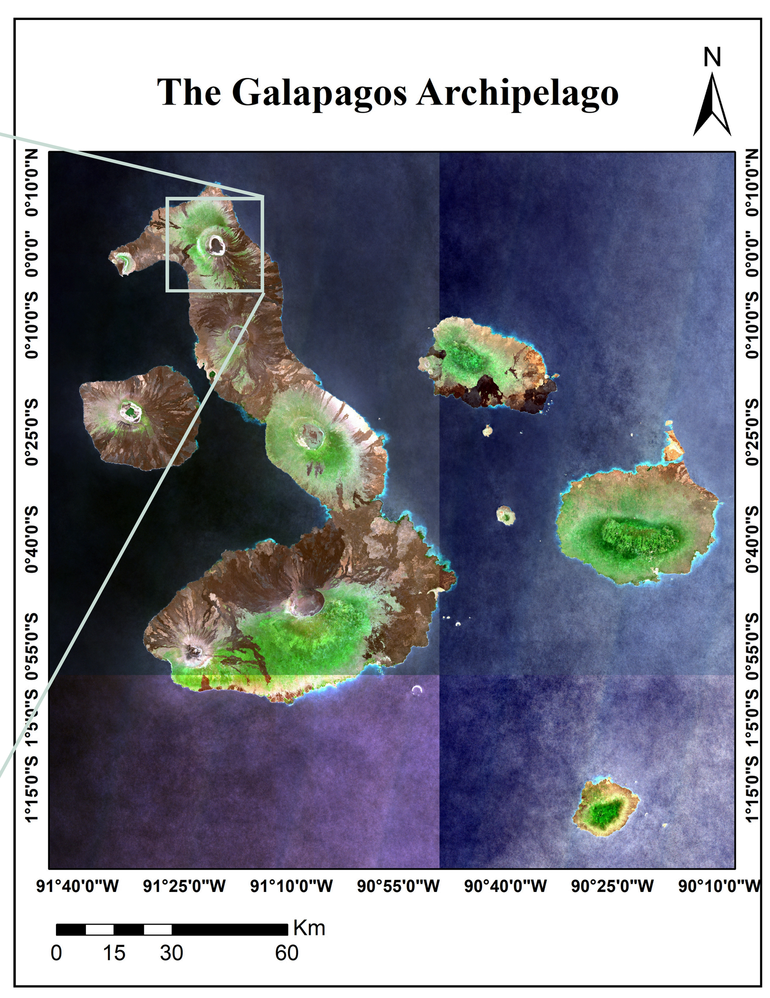
Spatio-Temporal analysis of the Volcanic Eruption Zone using SAR Interferometric Technique

Satwik Bhattacharya* , Shashi Kumar
* geosatwik@gmail.com/Photogrammetry and Remote Sensing Department/Indian Institute of Remote Sensing
shashi@iirs.gov.in/Photogrammetry and Remote Sensing Department/Indian Institute of Remote Sensing

Introduction

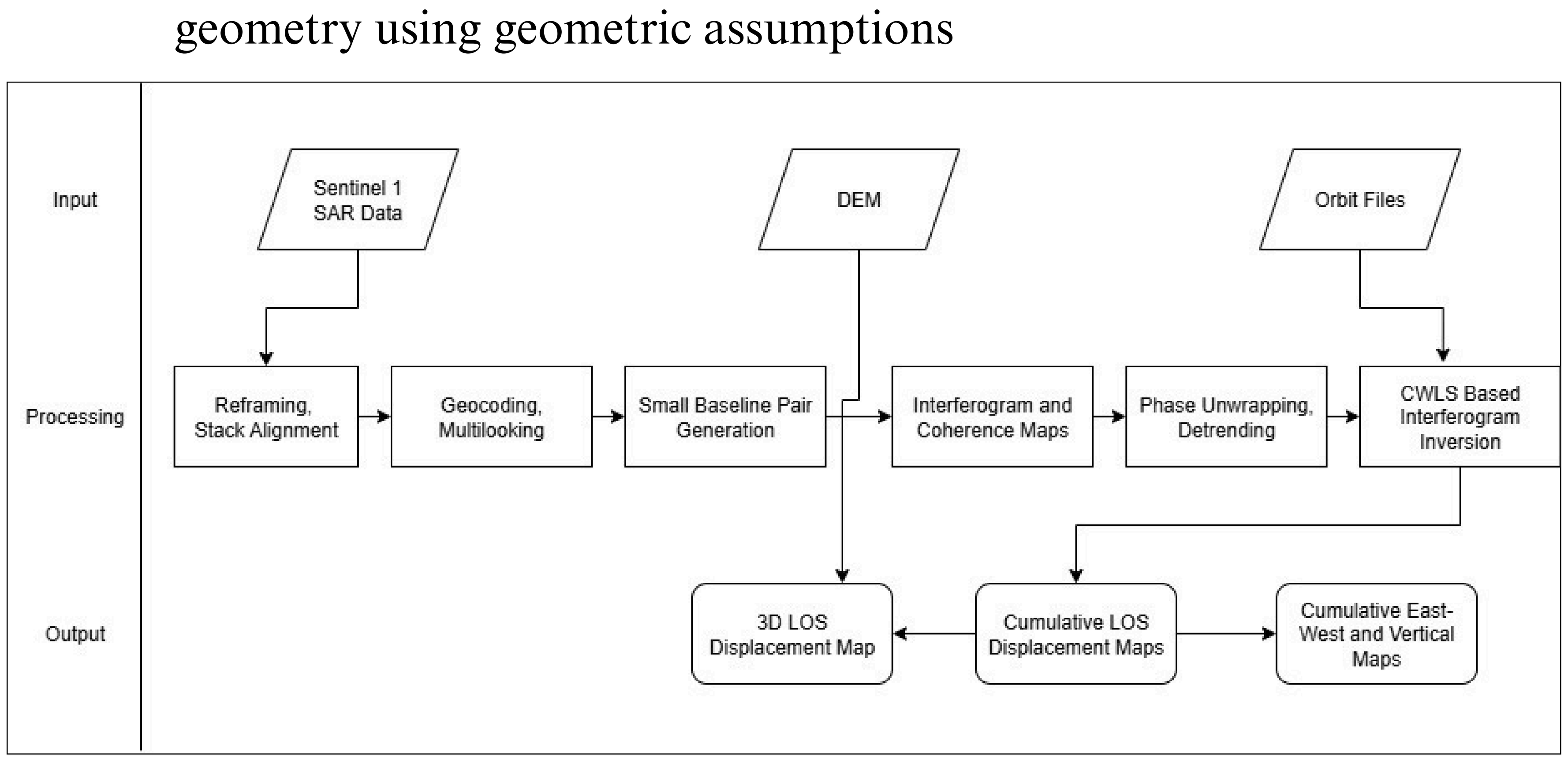
- Volcanic eruptions cause significant land deformation, providing insights into subsurface magmatic processes.
- Wolf Volcano (Galápagos), the highest in the archipelago, erupted in January 2022 after ~7 years of quiescence. The erruption continued for four months i.e till April 2022.
- Remote sensing, especially InSAR, is vital for monitoring such inaccessible, ecologically sensitive volcanoes.
- The aim of this study is to characterize eruption-induced ground deformation using the Small Baselime Subset, an Interferometric Synthetic Aperture Radar technique.





Methods

- Data: 15 Sentinel-1 descending-pass SAR images (Dec 2021 – May 2022) + Copernicus 1" DEM.
- The Processing is implemented Small Baseline Subset (SBAS) in PyGMTSAR (Python) on Google Colab.
- Displacement Estimation:
  - LOS displacements mapped.
  - The general LOS displacement is modeled as a projection of the ground displacement vector onto the LOS direction using $LOS = -(E \cdot \sin\theta \cdot \sin\phi + N \cdot \sin\theta \cdot \cos\phi + U \cdot \cos\theta)$, where LOS is the Line of Sight displacement. E, N, & U are East-West and Upward displacement vectors. θ = incidence angle ϕ = azimuth angle
  - Vertical & E–W components approximated from descending geometry using geometric assumptions



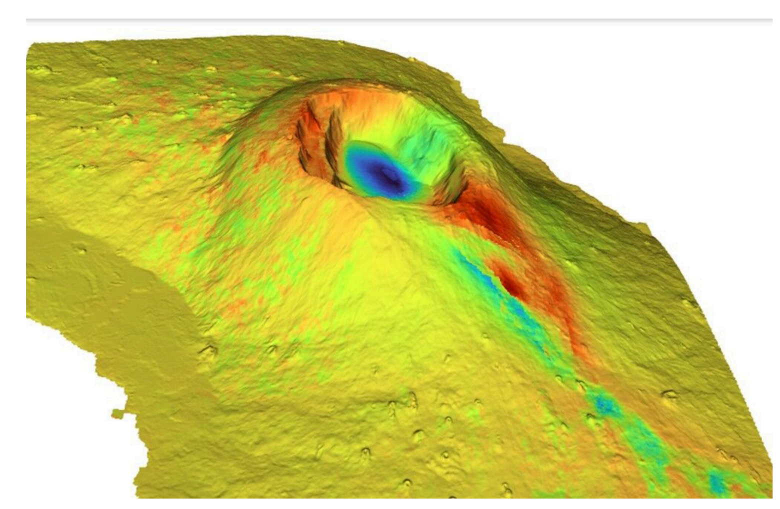
Acknowledgements

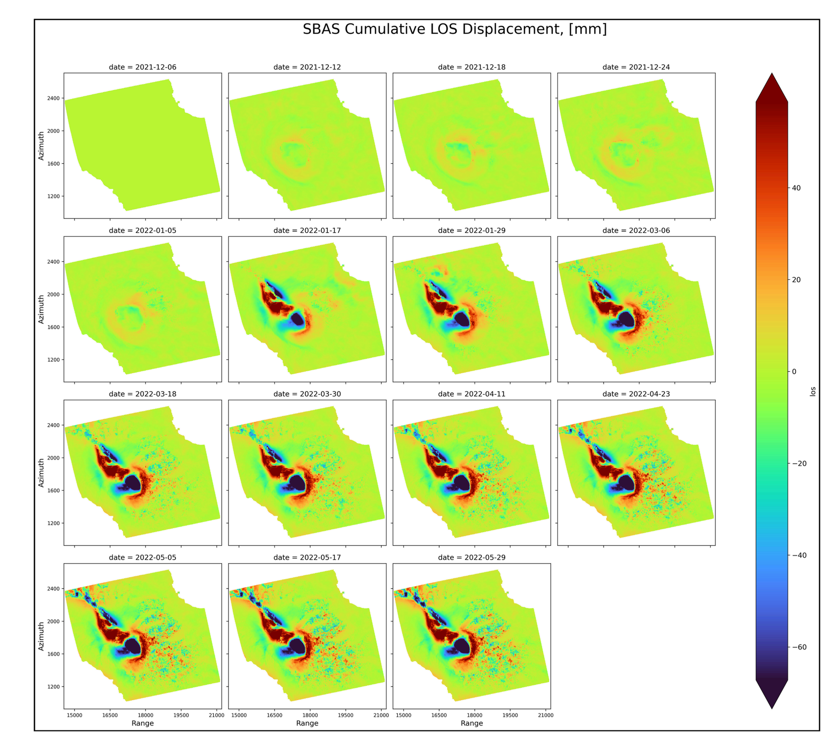
We thank the European Space Agency for providing Sentinel-1 SAR data, the Alaska Satellite Facility for enabling data access, Alexey Pechnikov for the development of PyGMTSAR, the Smithsonian Institution – Global Volcanism Program for eruption data, and the Indian Institute of Remote Sensing, ISRO for facilities and support.

Results & Discussion

Line-of-Sight (LOS) Displacement

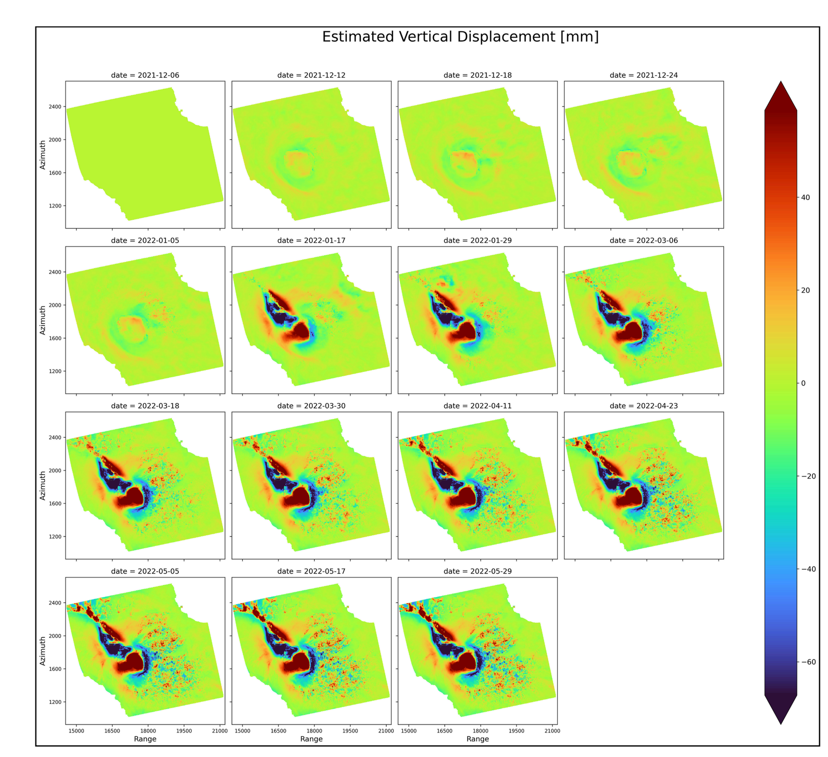
- Clear deformation pattern across Wolf Volcano.
- Summit & SE flank: uplift of ~+50 to +60 mm, spatially coinciding with lava effusion paths.
- Central caldera: subsidence of ~–55 to –60 mm, linked to magma withdrawal from a shallow reservoir.



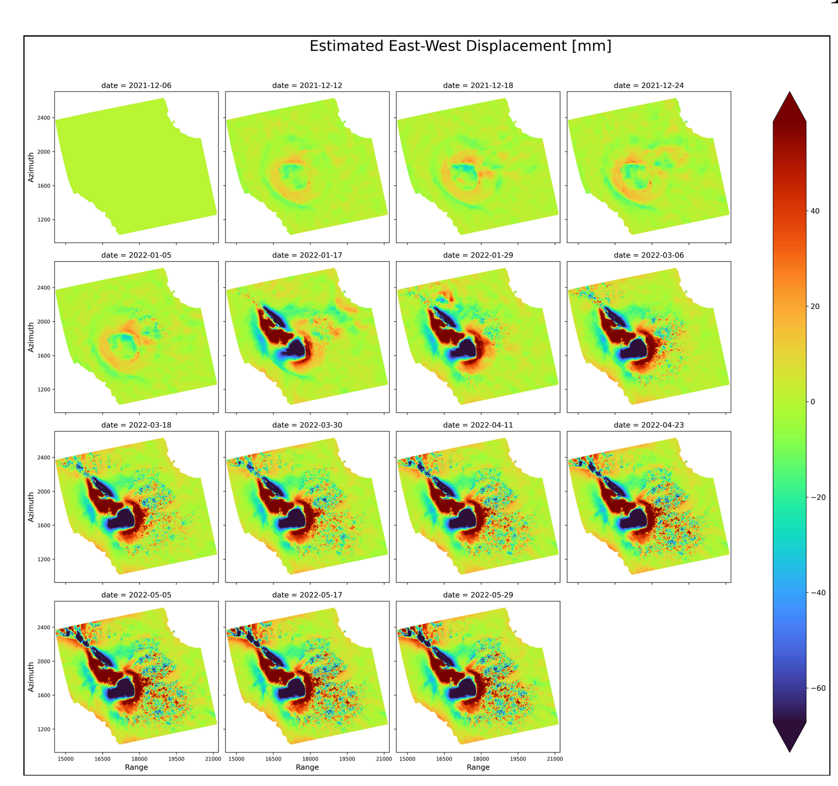


Vertical Displacement

- Minimal motion before the eruption (Dec 2021 – early Jan 2022).
- Strong uplift developed after eruption onset (Jan–Apr 2022), reaching ~+60 mm.
- SE flank showed subsidence up to –55 mm, likely due to magma evacuation or flank instability.
- Deformation stabilized after mid-April, indicating post-eruptive equilibrium.



East–West Displacement



- No significant lateral movement before eruption.
- From mid-Jan onwards:
  - SE flank shifted westward (–70 mm).
  - NW flank moved eastward (+50 mm).
- Pattern consistent with dyke intrusion and flank spreading during magma transport.

Conclusion

- SBAS-InSAR effectively captured pre-, co-, and post-eruptive deformation at Wolf Volcano.
- Deformation patterns reveal summit inflation, caldera deflation, and flank spreading.
- Demonstrates the utility of satellite-based InSAR for hazard monitoring in remote volcanic islands.

References

Xu et al., 2023, GRL: The 2022 eruption of Wolf Volcano.
Global Volcanism Program, 2022, WVRA: Report on Wolf (Ecuador).
Bernard et al., 2019, JVGR: Chronology of 1982 & 2015 Wolf eruptions.
Mora et al., 2002, IEEE: SBAS InSAR methodology.
Pechnikov, 2024: PyGMTSAR open-source library.