Lessons Learned from Three Decades of Continuous GNSS Monitoring at Cascade Range Volcanoes

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The U.S. Geological Survey Cascades Volcano Observatory (CVO) has monitored volcanic hazards in the Pacific Northwest since its inception in 1982 following the eruption of Mount St. Helens. CVO installed its first permanent GNSS monitoring station at Johnston Ridge Observatory, 8 km north of Mount St. Helens, in 1997. Between 2001 and 2004 three new permanent stations were installed in the Three Sisters Wilderness, in central Oregon, in response to inflation centered just west of South Sister volcano detected using Interferometric Synthetic Aperture Radar (InSAR). In 2004, following renewed eruptive activity at Mount St. Helens, CVO and UNAVCO (now EarthScope) collaborated to dramatically expand the continuous GNSS network there, including installation of 17 new permanent stations as part of the Plate Boundary Observatory (now Network of the Americas).

As of 2024, CVO operates 30 continuous, telemetered GNSS stations at six major volcanic centers in Oregon and Washington and provides support for monitoring stations at California volcanoes operated by EarthScope and the USGS California Volcano Observatory. At many sites, dual-frequency GNSS is co-located with a broadband seismic instrument. Measurements from some of the permanent networks are complemented by episodic GNSS campaign deployments. CVO works collaboratively with EarthScope to maintain and expand overlapping networks.

Permanent GNSS stations in the Cascade Range are subject to harsh conditions that make consistent, year-round operations challenging. Dense tree coverage hinders signals in some areas and is problematic for solar power and line-of-sight telemetry. Heavy snow and ice loads in the winter at high elevations can reduce station reliability and have led to permanent monument damage. In addition, most Cascade Range volcanoes are within the boundaries of sensitive areas, including designated wilderness, National Monuments, and National Parks. The potential impacts of installing and maintaining GNSS stations in such locations require careful justification and permitting for the tools and impacts required to install quality monumentation.

Cascade Range volcanoes have been monitored using ground-based GNSS for nearly three decades. CVO has experienced many successes and failures in maintaining these networks. When robust networks are available, GNSS time series provide the ability to detect subtle changes in ground deformation that could be related to volcanic processes.