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How do volcanic rift zones relate to flank instability? Evidence from collapsing rifts at Etna

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Volcanic rift zones, characterized by repeated dike emplacements, are expected to delimit the upper portion of unstable flanks at basaltic edifices. However, the relationship between flank instability and rift zone behavior, activity, and location on longer, inter-diking timescales is poorly understood. To characterize the relationship between rift kinematics, dike emplacement and flank instability at Etna, we used long-term (1992-2010) InSAR ground deformation time series, giving unprecedented coverage of the volcano's summit. As snow coverage prevents coherence of the backscattered radar signal, long-term InSAR time series on the summit of seasonally snow-capped volcanoes, such as Mount Etna, are affected by decorrelation, which hinders detection of any summit deformation. To increase the summit coverage, we removed from our Etna dataset all the SAR images possibly affected by snow-related decorrelation phenomena. We then jointly processed ERS data between 1992 and 2010 and ENVISAT data between 2003 and 2010, acquired from both ascending and descending orbits, and computed 204 ascending and 194 descending interferograms. These were inverted by applying the Small BAseline Subset (SBAS) technique (e.g., Pepe et al., 2005) to produce combined ERS-ENVISAT velocity maps and deformation time series. Ascending and descending maps and time series were used to separate vertical and East-West components of on-going displacements. This approach greatly improved the spatial coverage of elevated areas. A spatial comparison with a similar dataset used by Solaro et al. (2010), but limited to 1994-2008, shows an increase of the summit coverage of about 14 km2 in our dataset. The results highlight a general eastward shift of the volcano summit, including the northeast and south rifts. This steady-state eastward movement (1-2 cm/yr) is interrupted or even reversed during transient dike injections. Detailed analysis of the northeast rift shows that only during phases of dike injection, as in 2002, the rift transiently becomes the upper border of the unstable flank. The flank's steady-state eastward movement is inferred to result from the interplay between magmatic activity, asymmetric topographic unbuttressing, the gravitational load of the intrusive complex, and eastward dipping detachments. This study documents the first evidence of steady-state volcano rift instability interrupted by transient dike injection at basaltic edifices. More broadly, this study shows that volcanic rift zones may not be the upper boundaries of unstable volcano flanks, as other non-magmatic processes may control the evolution of volcanic rift zones.