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Usages of a high-resolution weather forecasting model to observe volcano deformation via multi-pass InSAR observation: A case study on Mt Etna

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A chief concern of the interferometric synthetic aperture radar (InSAR) monitoring of active volcanoes is determining ways of regulating topographic, tropospheric and ionospheric error components. Among the circuitous ways of reducing topographic and ionospheric components, X band SAR imagery is less affected by total electron contents of the ionosphere and the stacking analyses of interferograms can be used to minimise the bias of inaccurate base topography. However, the tropospheric components have caused consistent difficulties for monitoring active volcanos with InSAR, especially considering the high-relief morphology of volcanic areas often influenced by local turbulence, water vapours induced by orographic effects and stratified signals. Although modelling the atmospheric phase screen (APS) has become crucial, current APS estimation based on a phase–topography power law or mid-resolution weather forecasting data (e.g. from the European Centre for Medium-Range Weather Forecasts) is only a tentative solution because they cannot fully accommodate complex phase delay patterns of major volcanoes.

In response, we introduced a high-resolution weather forecasting model to more precisely estimate APS near Mt Etna on Sicily, Italy. We calculated data of antisymmetric or irregularly populated water vapour around Mt Etna by using a 1-km resolution Weather Research and Forecasting (WRF) model established by supercomputing resources and improved land surface datasets. The proposed WRF APS model accommodated the complexity of distributions of spatial errors along high-relief target areas. Compared to InSAR deformations with high-resolution WRF-based correction, deformations after applying the phase–topography power law or mid-resolution weather model retained false signals. Therefore, multi-pass InSAR error regulation with high-resolution WRF for the swift, accurate estimation of volcanic risk proved effective in time-critical scenarios, including imminent volcanic eruptions or the landslides that they induce. We further conclude that integrating high-resolution WRF-based APS and InSAR time series analysis can considerably improve the accuracy of InSAR monitoring. Accordingly, we propose developing high-resolution InSAR error correction routines that can be applied to multi-pass and time series InSAR processors in combination. The outcomes and validations of the proposed approaches are presented with a few time series, multipass InSAR cases using TERRASAR-X images from 2012 to 2014 near Mt Etna.