Bayesian Inversion of Wrapped Satellite Interferometric Phase to Estimate Fault and Volcano Surface Ground Deformation Models

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Phase unwrapping is the process of recovering the absolute phase from unambiguous wrapped phase values that are measured modulo 2π rad. From a mathematical point of view, phase unwrapping is an inverse problem, however, it is ill-posed and notoriously difficult to solve in the presence of noise. Meanwhile, phase unwrapping errors severely impact the estimation of earthquake and volcano source parameters using interferometric observations, therefore avoiding phase unwrapping completely is desirable.

A potential solution to avoid the unwrapping error issue completely, is to carry out a geophysical inversion directly on the wrapped phase observations. To overcome the need for phase unwrapping, we propose a novel approach that we can invert directly the interferometric wrapped phase, circumventing the ill-posed phase unwrapping processing step. This approach includes (1) a downsampling algorithm, (2) a method to estimate the covariance function of the wrapped phase, (3) an appropriate misfit function between the observed and the simulated wrapped phase. We also assess the uncertainties of source parameters within a Bayesian approach, and finally we test the robustness of the inversion methodology in multiple simulations including variable decorrelation and atmospheric noise simulations.

We demonstrate the proposed methodology on synthetic cases with variable noise and one real earthquake case. We show that the method is robust in challenging noise scenarios. We also show an improvement with the Bayesian approach in performance with respect to similar previous methods, resulting in avoiding any influence of seed starting models, and escaping local minima. We study the impact of a small percentage of incorrectly unwrapped phase observations in current state-of-the-art methods, and show that the presence of a small fraction of unwrapping errors affect strongly the estimation process. We conclude that in the cases where phase unwrapping is difficult or even impossible, the proposed inversion methodology with wrapped phase will provide an alternative approach to assess earthquake and volcano source model parameters.