A model-data fusion approach for assessing volcanic unrest

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A primary motivation for investigating volcanic systems is developing the ability to predict eruptions and mitigate disaster for vulnerable populations. Robust model-data fusion techniques must be developed to tackle the problem of combining multiple, disparate volcano monitoring datasets with increasingly sophisticated numerical models. In this investigation, we present a sequential data assimilation framework to combine multiple datasets with dynamic models using the Ensemble Kalman Filter (EnKF). The goal of this investigation is to test the EnKF as a potential sequential data assimilation technique for forecasting volcanic unrest. We adapt the EnKF to assimilate GPS and InSAR data into viscoelastic, time-forward, finite element models of an evolving magma system. The numerical tests of the EnKF provide a proof of concept for using the EnKF to assimilate multiple datasets for investigating volcanic activity and the comparison of spatially limited, but temporally dense, GPS data to temporally limited InSAR observations for evaluating magma chamber dynamics during periods of volcanic unrest. Results indicate that the temporally dense information provided by three-component GPS observations results in faster convergence and more accurate model predictions than single-component line of sight (LOS) deformation from InSAR. However, most importantly, the EnKF is able to swiftly respond to data updates by changing the model forecast trajectory to match incoming observations. This initial study demonstrates a great potential for utilizing the EnKF for multiple dataset assimilation to assess volcanic unrest and provide model forecasts of active systems. The development of these new techniques provides: (1) a framework for future applications of rapid data assimilation and model development during volcanic crises; (2) a mechanism for hind-casting to investigate previous volcanic eruptions, including potential eruption triggering mechanisms and precursors; and (3) a method for optimizing survey designs for future data collection campaigns at active volcanic systems.

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