Geophysical Research Abstracts
Vol. 20, EGU2018-19132, 2018
EGU General Assembly 2018

Towards full waveform seismic imaging of volcanic systems

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Recent advances in geophysical inversion promise to revolutionize the amount of information and level of detail that we can gain from geophysical data. Full-waveform inversion (FWI) exploits the information contained in the full record of natural or man-made seismic sources, resulting in 3-5 times better resolution than traditional traveltime-based seismic inversion techniques. FWI also allows the recovery of a wider range of elastic parameters including attenuation, anisotropy and S-wave velocities. 3D FWI is being applied to image Santorini Volcano, Greece, using data from the joint NSF-Imperial funded PROTEUS experiment (Plumbing Reservoirs Of The Earth Under Santorini). The experiment was designed to densely sample the plumbing system down to the lower crust and allow us to apply state-of-the-art inversion methods. The dataset includes 89 ocean bottom seismometers, 65 land stations and 13,300 airgun shots. The seismic data were first processed with traditional methods, extracting and inverting 140,000 first-arrival traveltimes to obtain a 3D P-wave velocity (Vp) model of the upper crust. The traveltime-based model is used as starting model for FWI. Comparison of synthetic waveforms shows that the starting model is accurate enough to avoid cycle skipping at the frequencies considered (3.0-6.0 Hz) for offsets of up to 20 km. We use acoustic time-domain FWI to recover the finer scale Vp structure inside and around Santorini caldera, to a depth ∼5 km. We show that a shallow low-Vp volume at 0-2 km depth likely corresponds to high porosity, associated with the fractured collapsed chamber roof. A deeper low-Vp anomaly at 4-5 km depth is interpreted to include partial melt and to correspond to the inflation source responsible for the 2011-12 ground deformation episode.