Sources of long-period swarms and very-long-period signals during the explosive and dome-building phases of the 2009 eruption of Redoubt Volcano

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The 2009 eruption of Redoubt Volcano, Alaska, produced as many as 4 lava domes and over 19 explosions between March 23 and April 4. Following the explosive phase, the volcano began a dome-building phase that continued until mid-summer. We present the analysis of swarms of small, repetitive, long-period (LP, 0.5-2 s period) events that occurred during both the explosive and dome-building phases of the eruption. The results complement previous research conducted on the source of very-long-period (VLP, 2-30 s period) signals observed to accompany several of the explosions. We also observe ultra-long-period (ULP, >100 s period) signals following the onset of certain explosions in the local seismic and infrasound that vary from 120 s to more than 400 s, which may indicate ultra-long-period oscillations of both the explosion ash plumes and the surrounding atmosphere, the latter producing acoustic-gravity waves.

We apply waveform inversion to locate the LPs and find their source mechanism. We focus on two prolific LP swarms from the eruption: a swarm of 5500+ similar events that occurred from April 2-4 (the April swarm) and a swarm of 30,000+ similar events that took place in early May (the May swarm). The April swarm ended with the final explosion of the eruption, a dome-collapse on April 4. The May swarm, in contrast, was not associated with an explosion, although a small dome-failure and steam and ash emission occurred approximately midway through the swarm.

A challenge in the analysis of the swarms is that the individual LPs are relatively small in amplitude. We exploit the similarity in waveforms among the individual LPs and improve the signal-to-noise ratio substantially by stacking over all events on each station. An additional challenge is that the LPs, being higher in frequency than the VLPs, suffer more from path effects. This limits the maximum range for stations to be included in the inversion. From waveform inversion using the 5 broadband seismometers on the Redoubt edifice within 4.5 km of the summit crater, we find a source depth of 1.5 km ASL, slightly shallower than obtained from a standard earthquake location. This places the LPs between the VLP source at Redoubt (0.8 km ASL) and the summit crater (2.3 km ASL). Based on our previous study of VLPs at Redoubt, we consider a moment-only inversion since the local network is not dense enough to uniquely resolve both moments and forces. The obtained moment tensor indicates the LPs are dominantly volumetric with consistently shaped source-time functions. Typical moments are on the order of 10^{10} Nm. We plan to further refine the LP source model by conducting reconstructions of the moment tensor with combinations of cracks and pipes. In addition, waveform inversion of the May swarm should provide clues to the variation in the dynamics of LP generation during different phases of the eruption.