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An infrasound array study of Mount St. Helens

Robin S. Matoza [a,*], Michael A.H. Hedlin [a,1], Milton A. Garcés [b,2]

[a] *Laboratory for Atmospheric Acoustics (L2A), Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego, USA*
[b] *Infrasound Laboratory (ISLA), University of Hawaii, Manoa, USA*

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Abstract

The ongoing activity of Mount St. Helens provides an opportunity to study the infrasonic wavefield produced by an active, silica-rich volcano. In late October 2004, as a pilot experiment for the Acoustic Surveillance for Hazardous Eruptions (ASHE) project, we deployed two infrasound arrays, each co-located with a broadband seismometer and weather station, to continuously record seismo-acoustic signals from Mount St. Helens. The nearest array, Coldwater, was deployed on the northern flank of the volcano, ~ 13 km from the summit. The second array, Sacajawea, was deployed ~ 250 km east of the volcano, at a distance where stratospherically ducted acoustic waves may be expected during the winter. This paper presents an overview of the experimental setup, and preliminary results from this unique data set. Eruptions on January 16th 2005 and March 9th 2005 produced strong infrasonic signals. The aseismic January 16th eruption signal lasted ~ 9.4 min beginning at ~ 11:20:44 01/16/05 UTC, while the March 9th eruption signal lasted ~ 52.8 min beginning at ~ 01:26:17 03/09/05 UTC, with the main steam and ash venting stage probably lasting ~ 7.2 min. The March 9th signal was an order of magnitude larger than the January 16th signal, and was clearly recorded 250 km east at the Sacajawea array. Infrasonic expressions of long period (LP) seismic events ('drumbeats') have also been intermittently observed, and are recorded as acoustic waves mimicking the waveform and temporal sequence of their seismic counterparts. These acoustic observations provide important constraints for source models of long period events and eruptions.

Keywords: volcano acoustics; infrasound; infrasound array; Mount St. Helens; long period event; eruption

1. Introduction

In this document, *infrasound* refers to acoustic energy traveling through the atmosphere at frequencies below the 20 Hz hearing threshold of the human ear. A large variety of natural and man-made phenomena produce infrasound, including avalanches, meteors, ocean waves, tornadoes, auroras, earthquakes, atmospheric nuclear tests, rockets, and supersonic aircraft (Bedard and Georges, 2000; Hedlin et al., 2002). The study of infrasound produced by volcanoes has a long history tracing back to 1883, when low frequency pressure signals from the eruption of Krakatoa were recorded on barometers distributed around the globe (Strachey, 1888). Almost a century later, infrasound radiated from the 1980 Mount St. Helens eruption was used to estimate the explosive yield of the main blast (e.g. Reed,

* Corresponding author. Mailing address: IGPP, SIO, Mail Drop 0225, U.C. San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0225, USA. Tel.: +1 858 534 8119; fax: +1 858 534 6354.
E-mail address: rmatoza@ucsd.edu (R.S. Matoza).
[1] Mailing address: IGPP, SIO, Mail Drop 0225, U.C. San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0225, USA.
[2] Mailing address: ISLA, 73-4460 Queen Kaahumanu Hwy., #119, Kailua-Kona, HI 96740-2638, USA.

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1987). The utility of dedicated infrasonic observations close to volcanoes has now been well established (e.g. Yamasato, 1997; Garcés and Hansen, 1998; Garcés et al., 1998, 1999; Hagerty et al., 2000; Ripepe and Marchetti, 2002; Johnson et al., 2003; Garcés et al., 2003; Johnson et al., 2004; Green and Neuberg, 2005; Johnson and Aster, 2005). However, to date, most volcano-infrasound studies have focused on small Strombolian-type explosions, simply because this type of activity is most abundant and reliable. Consequently, very little is known about the infrasound produced by large eruptions from silica-rich volcanoes. In addition, a large number of volcano-infrasound studies have acquired data using networks of low-cost microphones deployed near active vents (Johnson et al., 2003). Data acquired in this way are prone to wind noise and have a limited ability to discriminate volcanic sources of infrasound from other sources, although some progress has been made in this area (Johnson et al., 2006). Furthermore, microphones deployed close to vents are at risk of being destroyed during eruptions (Moran et al., in press), causing data loss at critical moments. The use of infrasound arrays as remote monitoring systems yields significant advantages in wind noise reduction and signal discrimination, as well as the ability to observe explosive eruptions at a safe distance.

The 2004–2006 eruption of Mount St. Helens (Dzurisin et al., 2005) has come at a time when the science of infrasound is modernizing rapidly. The 1996 Comprehensive Nuclear Test Ban Treaty (CTBT) has resulted in the ongoing deployment of a 60-station global network of infrasound arrays comprising part of the International Monitoring System (IMS) (Hedlin et al., 2002). After the third international workshop on volcanic ash and aviation safety in Toulouse (2003), the International Civil Aviation Organization (ICAO) requested that State Signatories of the Comprehensive Nuclear Test-Ban-Treaty (CTBT) investigate the use of the IMS for eruption warnings. In response, the Geological Survey of Canada (GSC), in collaboration with US infrasound experts in academia, developed the ASHE project as a proof of concept experiment to determine if timely eruption information could be provided to the Washington DC Volcanic Ash Advisory Center (VAAC). Mount St. Helens is currently an ideal active volcano with which to test the ASHE concept. Therefore, in late October 2004, the University of California, San Diego (UCSD), in collaboration with the GSC, began a pilot experiment consisting of two infrasound arrays recording seismo-acoustic signals from Mount St. Helens. This deployment has resulted in an excellent and unique volcano-acoustic data set.

Mount St. Helens is also one of the most closely monitored volcanoes in the world, observed by almost every geophysical and geological method. Consequently, the ongoing eruption of Mount St. Helens provides a unique opportunity to use state-of-the-art infrasound arrays to study pre-eruption and eruption signals produced by a silicic volcano, with the aim of integrating and cross-correlating these observations with existing seismic, geodetic, visual, and gas measurements. In this paper, we outline the experimental setup and present preliminary results from this infrasound data set. The research described in this paper was conducted with the support of the ASHE program, and adds to the growing body of literature on this subject, including work by researchers in Indonesia, Madagascar, France, Australia and the US who have studied the acoustics of volcanoes in the Indian Ocean and the Pacific for ash monitoring and basic research (Brown et al., 2005; Fee et al., 2005; Rambolamanana et al., 2005; Guilbert et al., 2005).

2. Data acquisition

In late October 2004, UCSD, in collaboration with the GSC, deployed two infrasound arrays to record signals from Mount St. Helens. The nearest array, Coldwater, was deployed on the northern flank of Mount St. Helens (Fig. 1), ~ 13 km from the summit. This array is located in a young forest owned by the Weyerhaeuser forest products company and provides a direct line-of-sight into the crater, as well as excellent low-noise recordings of acoustic signals from the volcano. The second array, Sacajawea, was deployed in Sacajawea State Park near Kennewick, WA, ~ 250 km east of the volcano (Fig. 1 inset). At this location, ray tracing for a typical winter atmosphere predicts that stratospherically ducted acoustic waves from Mount St. Helens would be recorded at the array. Each array consists of four MB2000 (DASE/Tekelec) broadband aneroid microbarometers arranged in a centered triangle with an aperture of ~ 100 m (Fig. 2). The array element locations are known to within 50 cm accuracy by differential GPS. Connected to each microbarometer are four ~ 15 m microporous hoses, which act as a spatial filter to preferentially sum coherent acoustic energy, and filter out spatially uncorrelated noise from wind turbulence (Hedlin et al., 2003). The central element is co-located with a Guralp CMG-40T broadband seismometer and Vaisala temperature, ultrasonic wind velocity, and wind direction sensors. The infrasound data sampled at 40 Hz have a flat response between 100 s and 17 Hz. The data are digitized using a 24-bit Nanometrics Polaris Trident digitizer and transmitted in real-time to a hub in Ottawa,