3-D ACOUSTIC MULTIPOLE INVERSION AT YASUR VOLCANO, VANUATU

Alexandra M. Iezzi¹, David Fee¹, Keehoon Kim², Arthur D. Jolly³, Robin S. Matoza⁴, Bruce Christenson³

¹Alaska Volcano Observatory, Wilson Alaska Technical Center, Geophysical Institute, University of Alaska
Fairbanks, 903 Koyukuk Drive, Fairbanks, AK 99775
²Geophysical Monitoring Program, Lawrence Livermore National Laboratory, Livermore, California, USA
³GNS Science, New Zealand
⁴Department of Earth Science and Earth Research Institute, University of California, 1006 Webb Hall, Santa
Barbara, Santa Barbara, CA 93106

Acoustic waveform inversion shows promise for improved eruption characterization that may inform
volcano monitoring. Well-constrained acoustic waveform inversion can provide robust estimates of erupted
volume and mass flux, increasing our ability to monitor volcanic emissions (potentially in real-time). Previous
studies have generally assumed a simple acoustic source (monopole) that radiates pressure waves equally in all
directions. More complex source reconstructions can be estimated using a combination of monopole sources.
However, to date, volcano infrasound source mechanisms have not been well constrained in three dimensions
due to infrasound sensors only being deployed on Earth’s surface, and the assumption of no vertical
directionality (dipole) has been made (e.g. Kim et al., 2012).

In this study we deployed a high-density seismo-acoustic network around Yasur Volcano, Vanuatu,
including multiple acoustic sensors along a tethered balloon that was moved every 15-60 minutes (Figure 1).
Yasur has frequent strombolian eruptions every 1-4 minutes from any one of three active vents within a 400 m
diameter crater. Our experiment captured numerous explosions from each vent at 38 tether locations covering
~200° in azimuth and a take-off range of ~50° (Jolly et al., 2017). Additionally, FLIR, FTIR, and a variety of
visual imagery were collected during the deployment to aid in the seismo-acoustic interpretations. The third
dimension (vertical) of pressure sensor coverage allows us to begin to determine the vertical directionality of the
acoustic source.

Our analysis employs Finite-Difference Time-Domain (FDTD) modeling to obtain the full 3-D Green’s
functions for each propagation path. This method, following Kim et al. (2015), takes into account realistic
topographic scattering based on a high-resolution digital elevation model created using structure-from-motion
techniques. We then invert for the source location and multipole source-time function using a grid-search
approach. We perform this inversion for 40 events from each vent (A and C) to examine the source
characteristics of the vents, including an infrasound-derived volume flow rate as a function of time. These
volume flow rates are then compared to those derived independently from geochemical techniques.

We find that the simple (monopole) source mechanism is a good approximation for the explosions at
Yasur Volcano, but a small directionality (dipole) component remains when topography is accounted for using
numerical Green’s functions. Furthermore, neglecting effects of topographic scattering leads to overestimation
of both the monopole and dipole strengths (i.e. overestimating erupted mass), therefore topography must be
constrained when performing acoustic source inversion. The addition of infrasound sensors on a tethered
aerostat allows for a broadened view of the infrasonic source radiation pattern in three dimensions with an
unprecedented view of the vertical dipole component.
Figure 1: Yasur Volcano location map and sensor deployment. Infrasound sensors used in this study are shown by inverted red triangles and the two active vents are indicated by pink diamonds. The green and blue circles denote the balloon location for each of the 80 events used for the acoustic source inversion for Vent A and Vent C, respectively.

References:
