Using infrasound to infer volcanic jet parameters: revisiting acoustic power vs. jet velocity scaling laws

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A basic goal of volcano acoustics is to relate observed airborne acoustic signals (usually infrasound) to the eruptive processes generating them. A quantitative link between a volcanic jet flow and its radiated infrasound would allow volcanic jet parameters to be inferred from infrasound data. A promising approach is to use the results from man-made jet-noise studies as a starting model for understanding the infrasound produced by the larger and more complex volcanic jet flows, assuming that the source mechanisms are analogous. A classic paper by Woulff and McGetchin [1976] introduced the idea of using observed acoustic power P to infer volcanic gas exit velocity U. They proposed scaling laws of the form $P \sim U^n$, where the exponent n = 4, 6, or 8 for equivalent monopole, dipole, and quadrupole sources, respectively. This formulation was based on the prevailing acoustic analogy of jet noise. However, jet noise research has changed dramatically since then with the discovery of coherent structures in turbulence. Jet-noise studies in the last decade have largely abandoned the idea that jet noise is composed of equivalent monopoles, dipoles, and quadrupoles. New empirical scaling laws have been proposed for pure-air jet flows based upon detailed laboratory studies. The new scaling laws take into account the strong temperature and directional dependence of jet noise. We discuss the implications of these results for volcano acoustics. We explore the basic issues with trying to infer gas exit velocity from acoustic power using examples of volcano-acoustic data, as well as acoustic recordings of rocket and military aircraft jet noise. This work demonstrates that Woulff and McGetchin's formulation can lead to large errors when inferring eruption dynamics from infrasound. We propose a replacement framework based on modern aeroacoustics research, which is being developed through quantitative integration of field, numerical, and laboratory studies and could lead to a more accurate relationship between volcanic infrasound and eruption column parameters.

Woulff, G., and T. R. McGetchin (1976). Acoustic Noise from Volcanoes: Theory and Experiment. Geophys. J. R. astr. Soc. 45, 601-616.