Volcanic tremor, a continuous seismic signal, accompanies virtually all eruptions. Several published studies have examined relations between tremor reduced displacement (DR, a normalized amplitude measure; Aki and Koyanagi, 1981; Fehler, 1983) and the Volcanic Explosivity Index (VEI; Newhall and Self, 1982) or ash plume height. The goals of these studies are to determine the physical relationships between tremor and eruptions and to use DR values to provide real-time estimates of eruption parameters.

This study examines tremor for 50 eruptions from 31 volcanoes. This is a significant expansion of the data set from an earlier study of 21 eruptions from 14 volcanoes (McNutt, 1994). Several new trends are observed when DR is plotted versus VEI (Figure 1); 1) large eruptions produce stronger tremor than small ones; 2) fissure eruptions produce stronger tremor than circular vents for the same fountain height (F in Figure 1); 3) eruptions with higher gas content (H in Figure 1) produce stronger tremor than those with low gas content (L in Figure 1); and 4) phreatic eruptions produce stronger tremor than magmatic eruptions for the same VEI (P in Figure 1).

The three volcanoes with varying gas content are Redoubt 1989-1990, based on eruption type (vertically oriented pumice eruption versus dome collapse; Miller, 1994); Mount Spurr in 1992 based on SO2 measurements (Bluth et al., 1995); and Shishaldin volcano in 1999 based on presence or absence of large explosions on a pressure sensor (Caplan-Auerbach and McNutt, 2003).

Using tremor DR to estimate eruption parameters is a statistical problem with several factors contributing to uncertainties. First, tremor occurs when volcanoes do not erupt as well as when they do. Based on a worldwide sample, 60-80 percent of tremor episodes accompany eruptions, while 20-40 percent of episodes do not. Thus, there is a significant chance that no eruption is occurring. Second, for each VEI, there is a range of DR, so it is possible to overestimate or underestimate the VEI. Hence there will always be a false alarm rate (~10 percent). Improvements can be made in the estimates if the types of eruptions, shapes of vents, and gas contents are known in advance. These can be estimated from previous eruptions or measured near-real-time from independent data. However, adding additional information takes time, delaying forecasts. A primary benefit of seismic data is that they are real-time, are not affected by darkness, and are usable during poor weather, although the signal-to-noise ratio can be worsened. Monitoring tremor DR is therefore an effective way to characterize eruptions in progress.

References:


Figure 1. Reduced displacement, a normalized measure of amplitude, versus the Volcanic Explosivity Index for 50 eruptions at 31 volcanoes. The regression line is from McNutt (1994) based on a smaller data set and is shown for comparison. Fissure eruptions are labeled F; a phreatic eruption is labeled P; deep (40 km) tremor from Kilauea is labeled D (no eruption for this one); and three pairs of values from VEI=3 eruptions with high and low gas content are labeled H and L, respectively.