TEMPORAL ANALYSIS OF THE MAGMA SUPPLY SYSTEM BENEATH THE OKMOK CALDERA BY INTERFEROMETRIC SYNTHETIC APERTURE RADAR AND STATISTICAL SEISMOLOGY

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1. ABSTRACT

Surface deformation in the area surrounding an active volcano is typically caused by the inflation or deflation of a shallow magma chamber. As the chamber's size and internal pressure (hydro-static) change, a stress field is created on the surface above it, which alters the local topography by producing measurable uplift or subsidence. The vertical surface deformation produced by a shallow magma chamber can be modeled using a spherical source in a semi-infinite elastic half space, which is defined as

$$\Delta h(x) = C\frac{d}{(x^2 + d^2)^{\frac{3}{2}}} \tag{1}$$

where $\Delta h(x)$ is the vertical displacement estimate, x is the point at which the displacement is estimated, and d is its depth [1]. The strength parameter, C, is defined as $\frac{3r^3P}{4\mu}$, where P is the change in internal hydro-static pressure, r is the chamber radius, and μ is Lame's constant. Substituting this constant for the unknown values of P and r, decreases the number of variables in Equation (1) and reduces the non-uniqueness of its solutions. If the chamber's depth is known *a priori*, then only the strength parameter needs to be determined. Once C is found, it can be used to estimate the volumetric change in magma, ΔV, which is calculated using

$$\Delta V = \frac{4\pi}{3}|C| \tag{2}$$

where we assume a Poisson solid and that ΔV is caused by magma influx only [2], [3].

Statistical seismology is often employed to map the location of magma chambers beneath active volcanoes. This is done by examining the frequency-magnitude distribution (FMD) of earthquakes in the area of interest. Earthquake FMDs are typically studied using a simple power law relationship of the form

$$log_{10}N(M) = a - bM \tag{3}$$

where M is the magnitude, N is the number of occurrence of a given magnitude, a is the productivity of the volume, and b is the slope of the linear portion of the distribution [4], [5]. On average, b-values of 1.0 are observed in tectonic regions, while values greater than 1.0 are reported in volcanic areas. It has been demonstrated that elevated b-values occur in the vicinity of magma, but remain close to 1.0 in its absence [6]. Numerous studies have since employed b-value mapping as a means of locating active magma chambers [e.g. [7],[8]]. Various studies have identified a variety of mechanisms that produce elevated b-values; such as thermal gradients, strong material heterogeneity, increased pore pressure, and reduced effective stress [9], [10], [11], [6]. Typically, one or more of these conditions are prevalent in the vicinity of magma chambers residing in the upper crust [12].

In this paper, the temporal characteristics of the magma supply system beneath the Okmok caldera is studied to gain insight into the geophysical processes occurring within the volcano. Interferometric Synthetic Aperture Radar (InSAR) is employed to map the surface deformation produced by the shallow magma chamber's fluctuating geometry. Statistical seismology provides the independent, *a priori*, depth estimate needed to reduce the number of unknown variables in the Mogi source model, Equation (1). In all cases, C is estimated empirically by visually matching the observed and simulated interferometric fringe patterns. Afterwards, C is substituted into Equation (2) to estimate the magma displacement or influx responsible for the observed deformation.

Preliminary results clearly show the presence of a magma chamber approximately 4.0 km beneath the center of the Okmok caldera. In addition, initial estimates show magma replenishment over a five year period is occurring at a nearly constant rate. Inteferograms and deformation estimates are consistent with those shown in previously published reports, over similar time intervals [2], [13]. All of the results presented in this paper are compiled using a multi-year ERS-1/2 dataset, provided by the Alaska Satellite Facility, and a seismic catalog provided by the United States Geological Survey Alaska Volcano Observatory.

2. REFERENCES

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