Project Proposal: Tremor Location Program

My research involves trying to locate volcanic tremor at Okmok Volcano. Data from eight short-period seismometers showed seismic tremor signals occurring from mid 2003, when data first started arriving, until mid 2005. The signals appeared at multiple stations as pulses of increased amplitudes lasting between 3 – 60 minutes, with dominant frequencies between 2 and 6 Hz. These signals are interesting because tremor is often associated with fluid movement within the volcano, as well as being the dominant signal during volcanic eruptions. These fluids may be hydrothermal, gaseous, or magmatic, though I am unable to distinguish between them. Candidates for the location of the tremor signals include the center of the 10 km caldera (where notable inflation has occurred), and Cone A, a cinder cone in the southwest portion of the caldera. Cone A is the most recently active volcanic feature, having partially filled the caldera floor with lava effused during a 1997 eruption. During the time of my investigation, the caldera was experiencing episodes of both active inflation and deflation, while Cone A has been observed to steam vigorously. Incandescence had even been noted within Cone A's vent.

Tremor episodes are notoriously hard to locate. The signals emerge slowly from the background noise, making location via traditional arrival-time methods impossible. The signals, while coherent in general amplitude behavior across stations are too ragged to correlate on the scale required to determine lag-times (which could then be used to determine arrival-times and thus facilitate traditional location).

I have opted to use a location technique that takes advantage of amplitude distributions across the network to wrangle out the likely source location. As a signal is transmitted through the ground, its amplitude is controlled by geometric spreading and energy loss due to the earth not being perfectly elastic. The basic equation governing amplitude *A* at distance *r* for body-wave decay (waves travelling within the earth) is $A(r) = A_0 \frac{e^{-Br}}{r}, B = \frac{\pi f}{Q\beta}$, while that for surface-wave decay is $A(r) = A_0 \frac{e^{-Br}}{\sqrt{r}}$. A_0 is the source amplitude, *f* is the signal frequency, *Q* is quality factor (describing attenuation within rocks), and *β* is the propagation velocity. The source is assumed to have no directionality.

Because the amplitude fluctuates strongly on short timescales, because the signal decay is frequency dependent, and because the signal is within a limited band of frequencies, I opt to use RMS amplitude ratios for time windows for frequencies between 1-5 Hz, windowed for 20.48 seconds, examined at 20 second intervals.

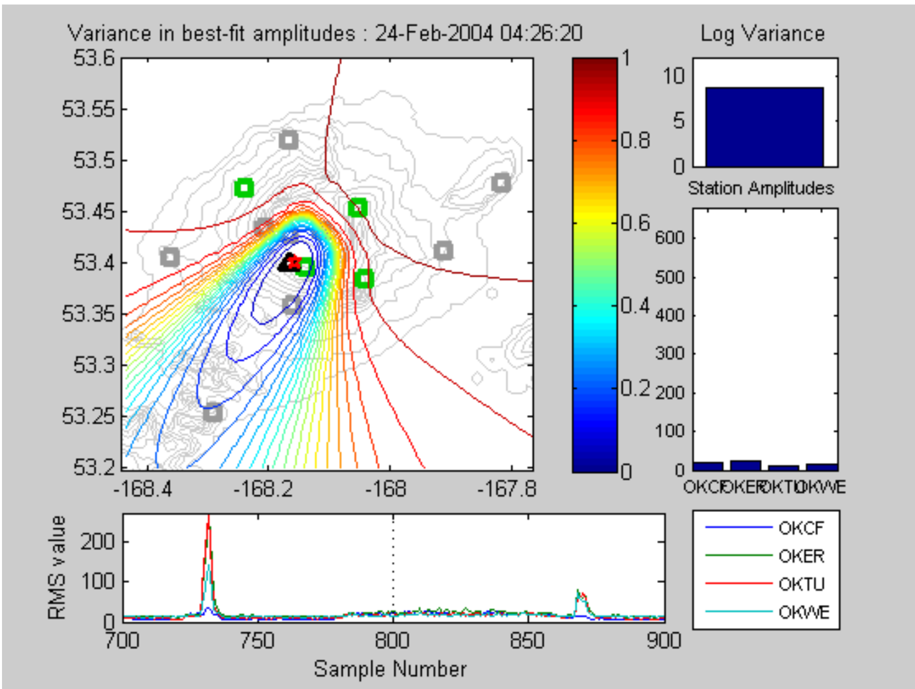
I have existing code, written in MATLAB, which comes up with best-fits for the observed signal. It takes advantage of station to search grid distances being constant to then calculate expected decay to each search grid point. I invert that to get expected signal strength A_{calc} at each station. These values are then compared against the observed amplitudes A_{obs} to come up with a best-fit location (and amplitude)

Two obvious aspects of this code lend themselves to parallelization.

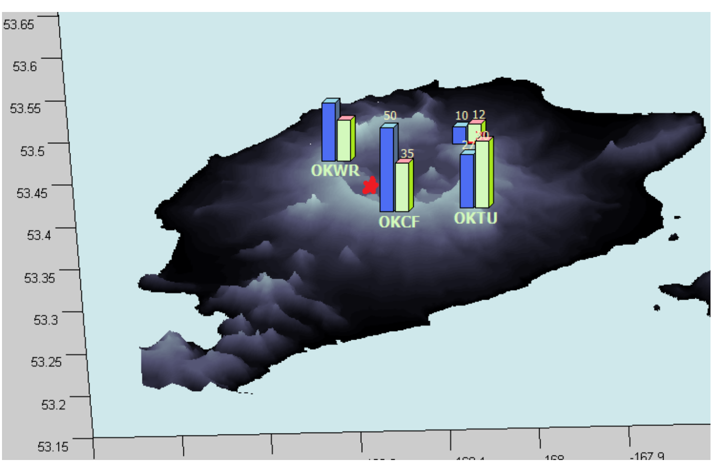
1. Tremor location uses a grid search, with results from one grid section (depth, for example) completely independent of results from other grid sections.

2. I've got REAMS of data to process. That is, I have over two years of data for ~8 stations at this volcano, sampling at 100Hz. Should this technique be fruitful, it may be enlightening to examine tremor episodes at other volcanoes.

For visualization, my original output looks like so:



However, I'm interested in changing the Station Amplitudes bars (which show calculated vs. observed station amplitudes) to a separate map so I can see spatially how it is working. Here is a mockup:



The red star is located tremor, the bars are the observed and calculated amplitudes at the station.

Inspiration for this technique from :

Battaglia, J., and Aki, K., 2003. Location of seismic events and eruptive fissures on the Piton de la Fournaise volcano using seismic amplitudes. *Journal of Geophysical Research,* 108(B8), 2364, doi:10.1029/2002JB002193.