Comparing Q factor methods for the analysis of volcano seismic events

Sophie Butcher[1], Andrew Bell[1], Stephen Hernandez[2], Eliza Calder[1], Mario Ruiz[2]

[1] School of GeoSciences, The University of Edinburgh, [2]Instituto Geofísico Escuela Politécnica Nacional, Quito, Ecuador

Motivation

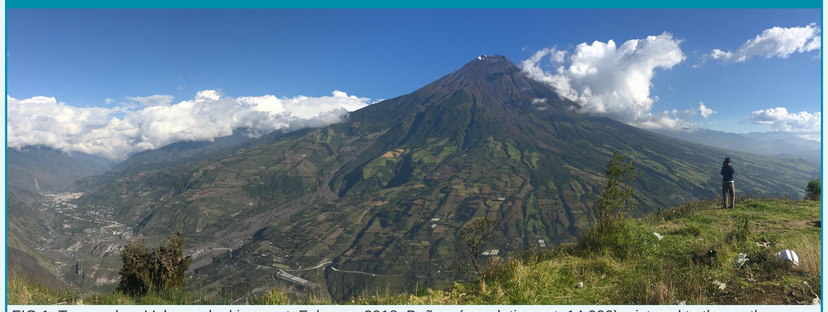


FIG 1. Tungurahua Volcano, looking east, February 2018. Baños, (population est. 14,000), pictured to the north.

- Volcanic earthquakes are an important tool in understanding internal processes and eruption forecasts.[1] Vital for communities living near active volcanoes.
- Earthquake classification broadly determined by metrics like frequency and duration.[2]
- The quality factor (Q) is presented in a variety of ways across previous studies. It is a measure of waveform energy and can provide insights into driving and damping mechanisms.[3]

Data

Drumbeat sequences – periodic repeating events that appear very similar to one another. A pre and post explosion sequence from Tungurahua, November 2015.

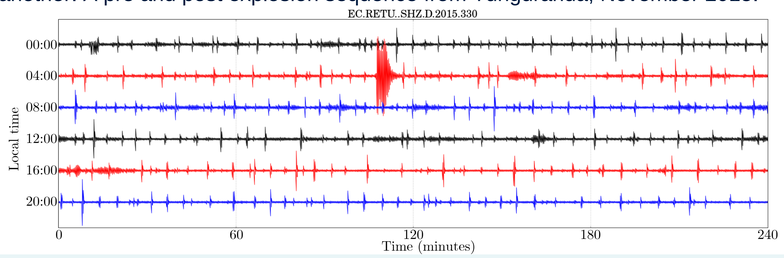


FIG 2. Summary of activity at Tungurahua Volcano, November/December 2015.

Synthetic events – different styles of observed volcanic event types can be generated synthetically for testing. Individual events with added random noise can make analogous series.

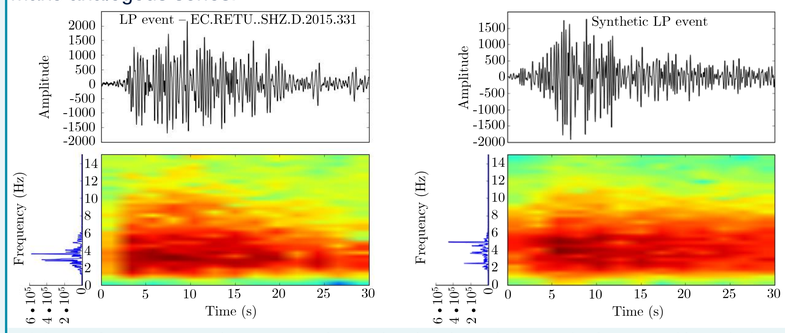


FIG 3. Waveforms, spectra and spectrograms for a real earthquake, and an example of a comparable synthetic event.

Assorted data sets – as well as the periodic events at Tungurahua. Mixed sequences of VTs and LPs from Cayambe Volcano are used to validate methods.

Methods

Decay: $Q = 2\pi f_0 \tau$ where f_0 is the peak frequency, and τ is the point at which the amplitude of the waveform reaches $1/e$ of the maximum.[4,5]

Bandwidth: $Q = f_0/\delta f$ where f_0 is the peak frequency, and δf is bandwidth, where the spectra is ½ the power at f_0 (the corner frequencies).[3,6]

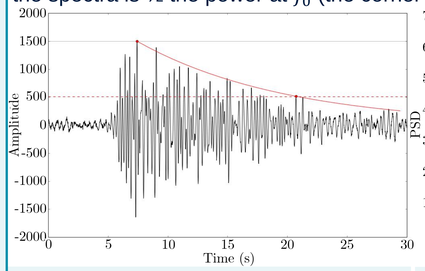


FIG 4. Decay method to calculate Q, illustrated on an event from Tungurahua, November 2015.

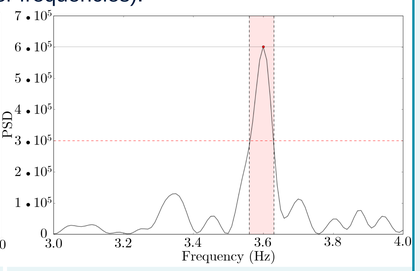


FIG 5. Bandwidth method. Dashed lines show corner frequencies. Spectra from Tungurahua event.

Auto-regressive moving average (ARMA): decomposes complicated signals with peaked spectra into components of harmonic decaying oscillations.[7,8] Each component is represented in the complex frequency space as frequency, f, and growth rate, g, and $Q = -f/2g$.[9]

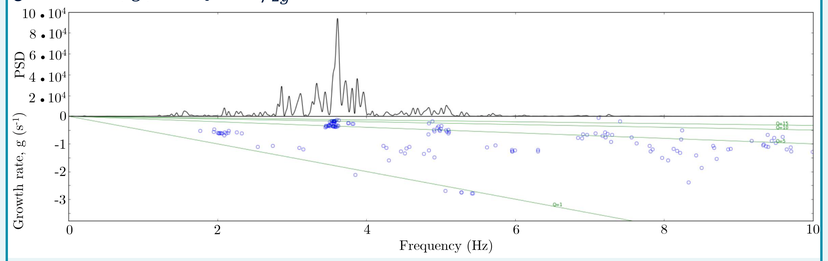


FIG 6. ARMA method GUI. Poles from the decomposition of the waveform are plotted in complex frequency space. The user selects the pole associated with the peak frequency and an average Q can be calculated.

Validating with Cayambe Data

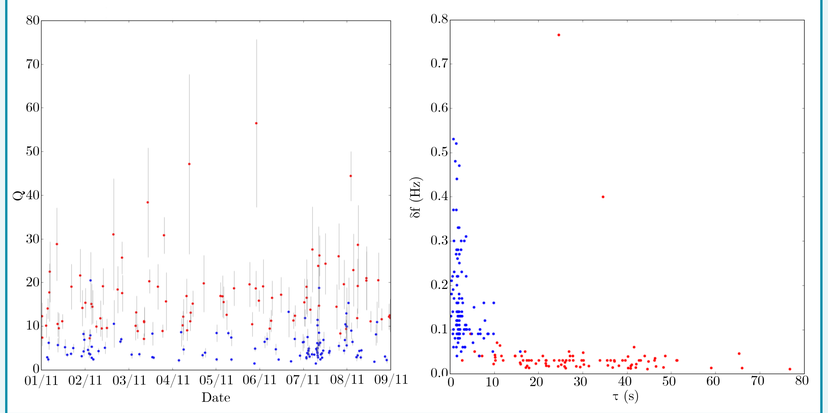


FIG 7, 8. 200 manually picked events at station EC.CAYA, 2016 days 306-313. ARMA analysis on the left clearly separates distinguished event types. When considering the decay and bandwidth methods, the event types separate and are constrained by bandwidth and event duration

Results at Tungurahua

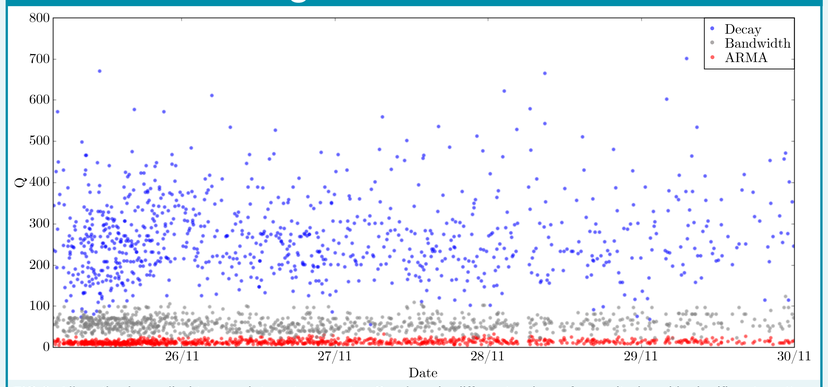
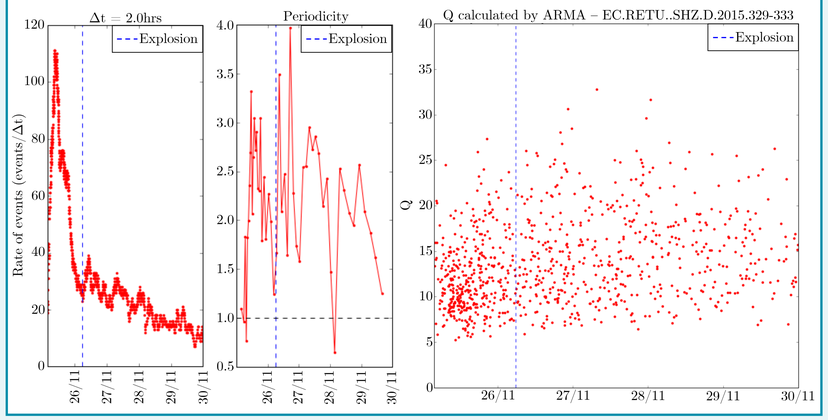


FIG 9. All methods applied to one data set generates Q values in different orders of magnitude, with significant scatter.

- Three methods generate **Q values in different orders of magnitude**.
- Increase and decrease in event rate is not coincident with explosion and Q remains unaffected. Overall **slight increase in Q** through the whole episode, in all three methods.
- **ARMA results correspond best** with previous findings.[10] Still to investigate similar periods of drumbeat activity for comparison.[11]

FIG 10. Event rate and periodicity for LPs surrounding 26/11/2015 explosion at Tungurahua.

FIG 11. Q by the ARMA method at Tungurahua. Picked LP events surrounding 26/11/2015 explosion.



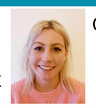
References

[1]Chouet & Matoza, *J. Volcanol. Geotherm. Res.*, **2013**, 252, 108-175
[2]Lees et al, *J. Volcanol. Geotherm. Res.*, **2007**, 176(1), 179-190
[3]Rossing & Fletcher, *Springer Pub*, **2004**
[4]Elmore & Heald, *Courier Corp*, **1985**
[5]Del Pezzo et al, *Seismol. Res. Lett.*, **2013**, *84*(2), 190-198
[6]Johnson et al, *Geophys. Res. Lett.*, **2018**, 45(11), 5436-5444
[7]Kumagai & Chouet, *Geophys. J. Int.*, **1999**, 138(2), F7-F12.
[8]Lesage et al, *J. Volcanol. Geotherm. Res.*, **2002**, 114(3-4), 391-417
[9]Kumazawa et al, *Geophys. J. Int.*, **1990**, *101*(3), 613-630
[10]Molina et al, *Geophys. Res. Lett.*, **2004**, 31(3)
[11]Bell et al, *Earth Planet Sc Lett.*, **2017**,*475*, 58-70.

Get in touch

@sophie_butcher_

sophie.butcher@ed.ac.uk



Check out my blog where I'll be posting updates from travel, conferences and training across my PhD
https://blogs.ed.ac.uk/sophiebutcher/