Source Characteristics of a Family of Long Period Events Recorded During an Intrusive Phase on Piton de la Fournaise, La Réunion

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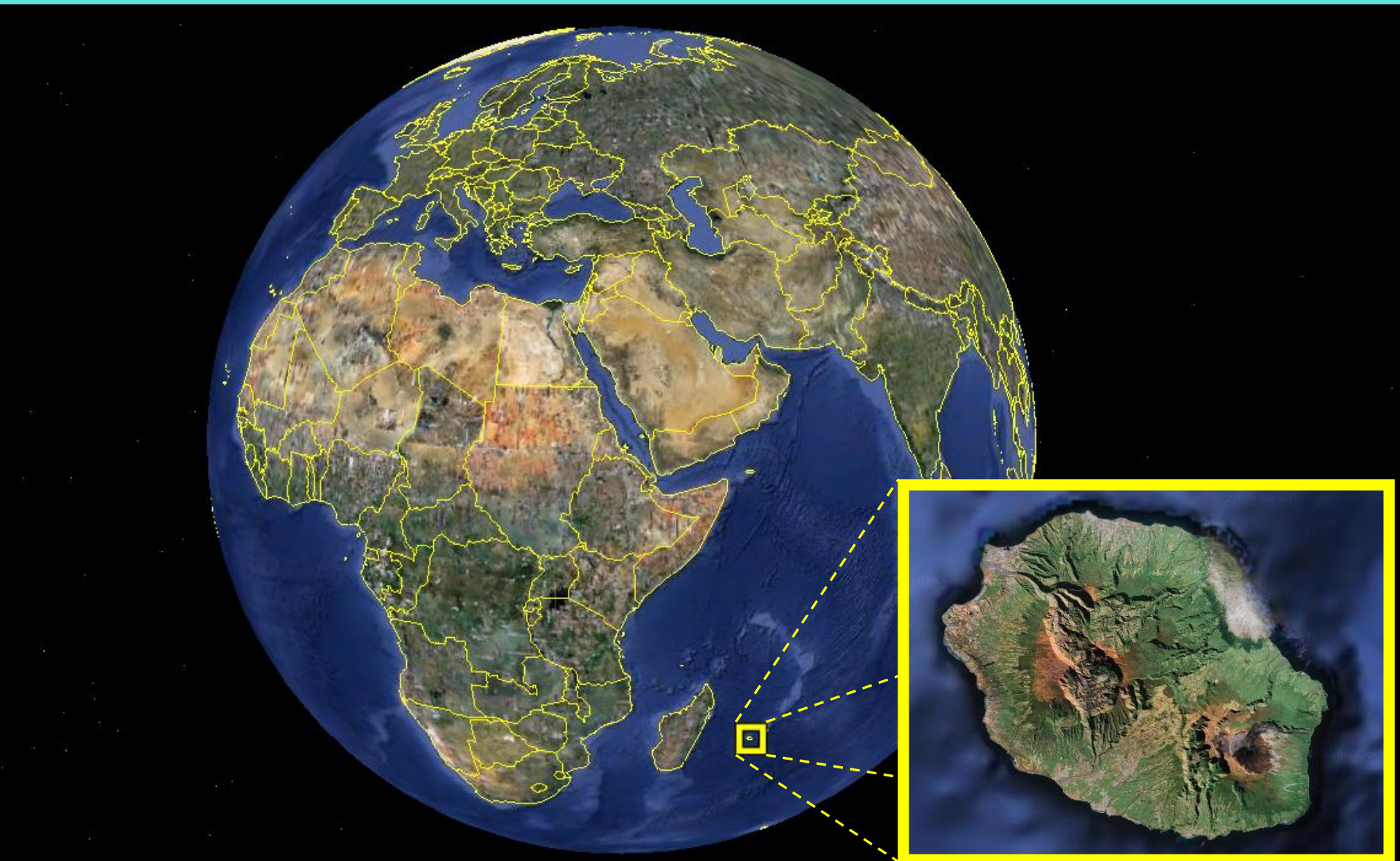
Long Period (LP) Events

- Typical Frequency 0.5-5.0 Hz
- Narrow, peaked spectra
- Emergent onset
- Cannot distinguish between P- and S- phases
- Often precede or accompany volcanic eruptions
- Related to fluids within volcano
- Theory: Resonance of a fluid-filled cavity
- Mechanism of excitation of cavity is unknown

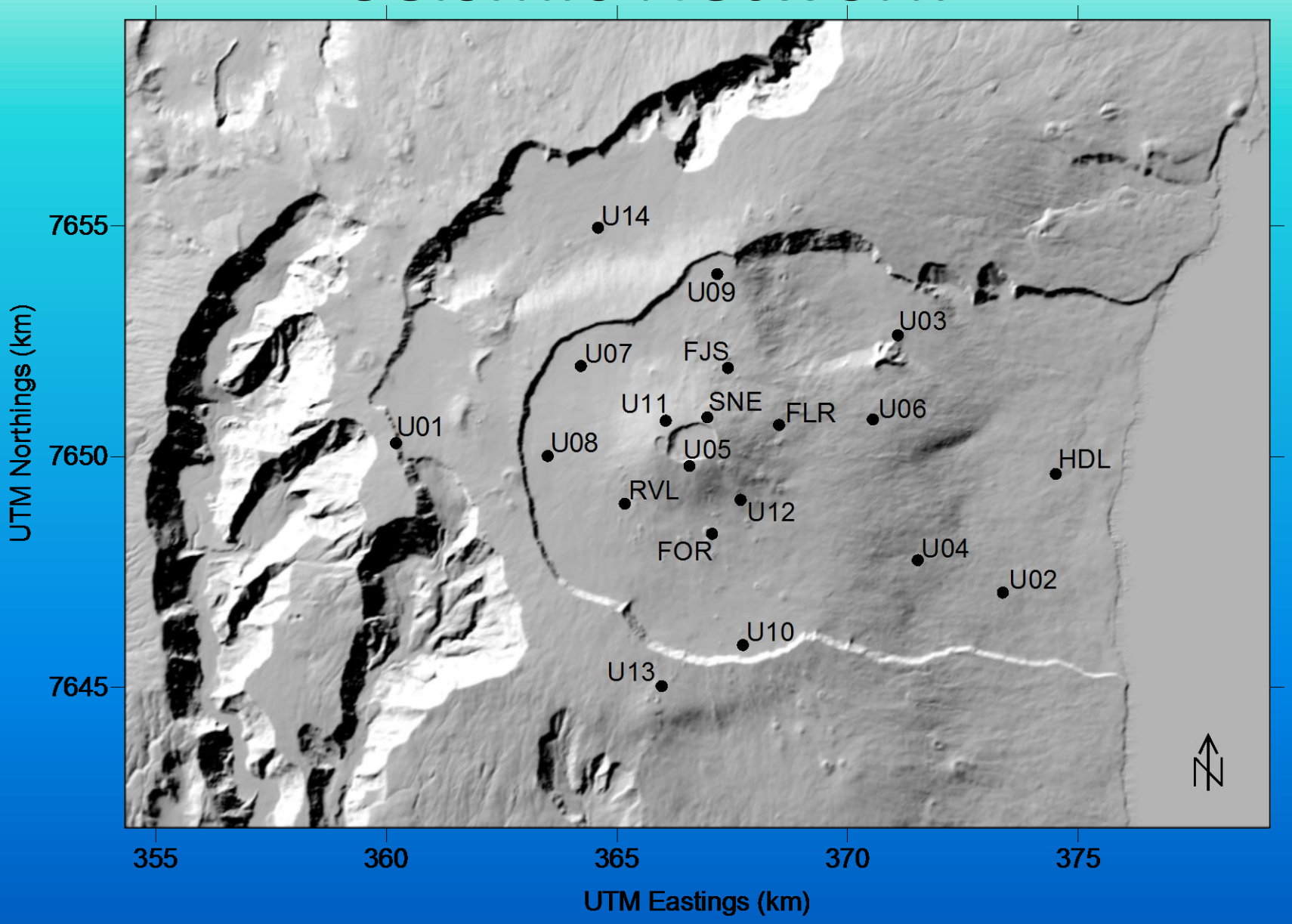
Where is La Réunion Island?



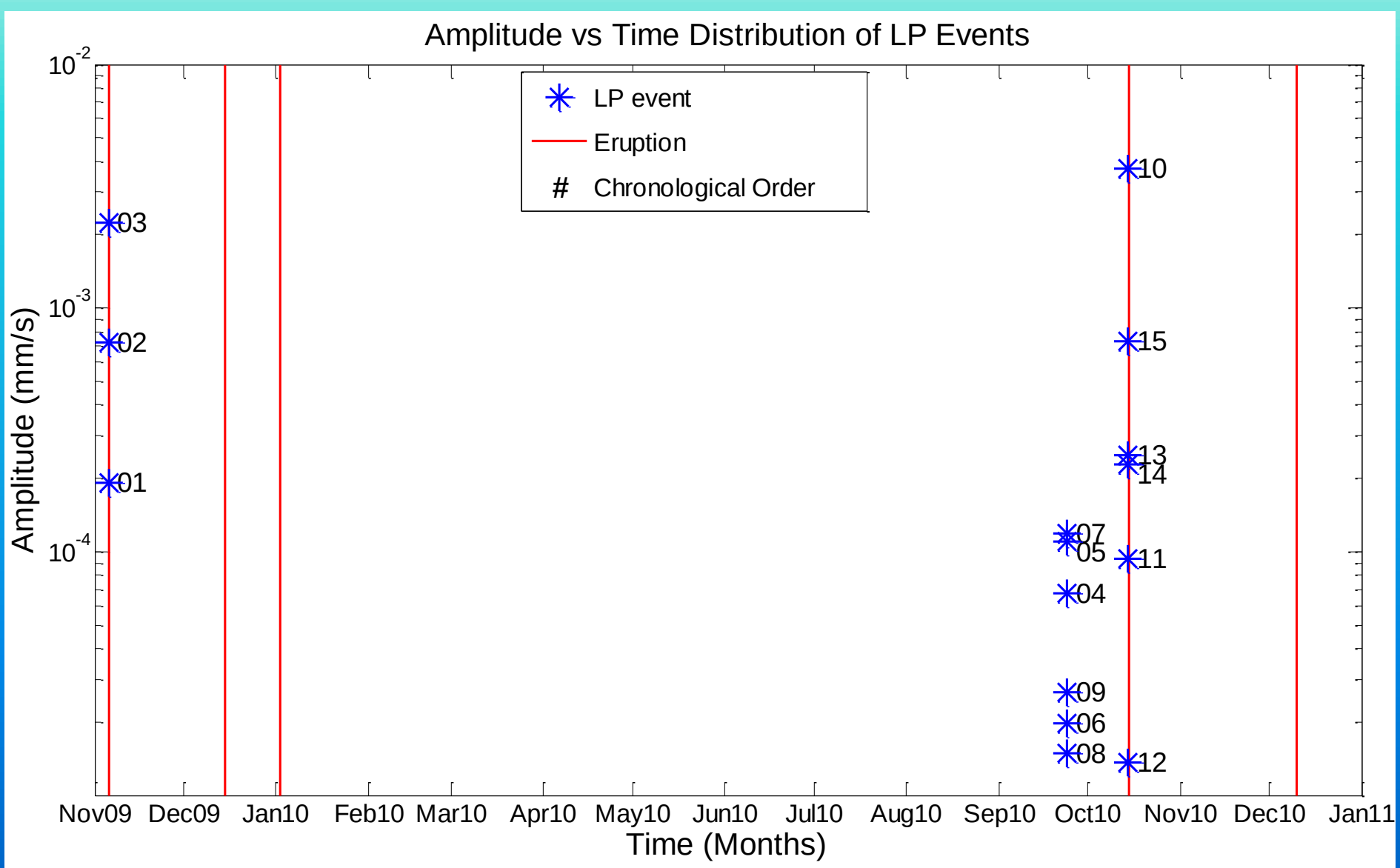
Piton de la Fournaise

- Basaltic shield volcano
- One of the most active volcanoes in the world
- At least 125 eruptions in the last century
- Modern observatory present since 1980
  - Seismic network
  - Deformation network
    - GPS
    - Tiltmeter
  - Acoustic station

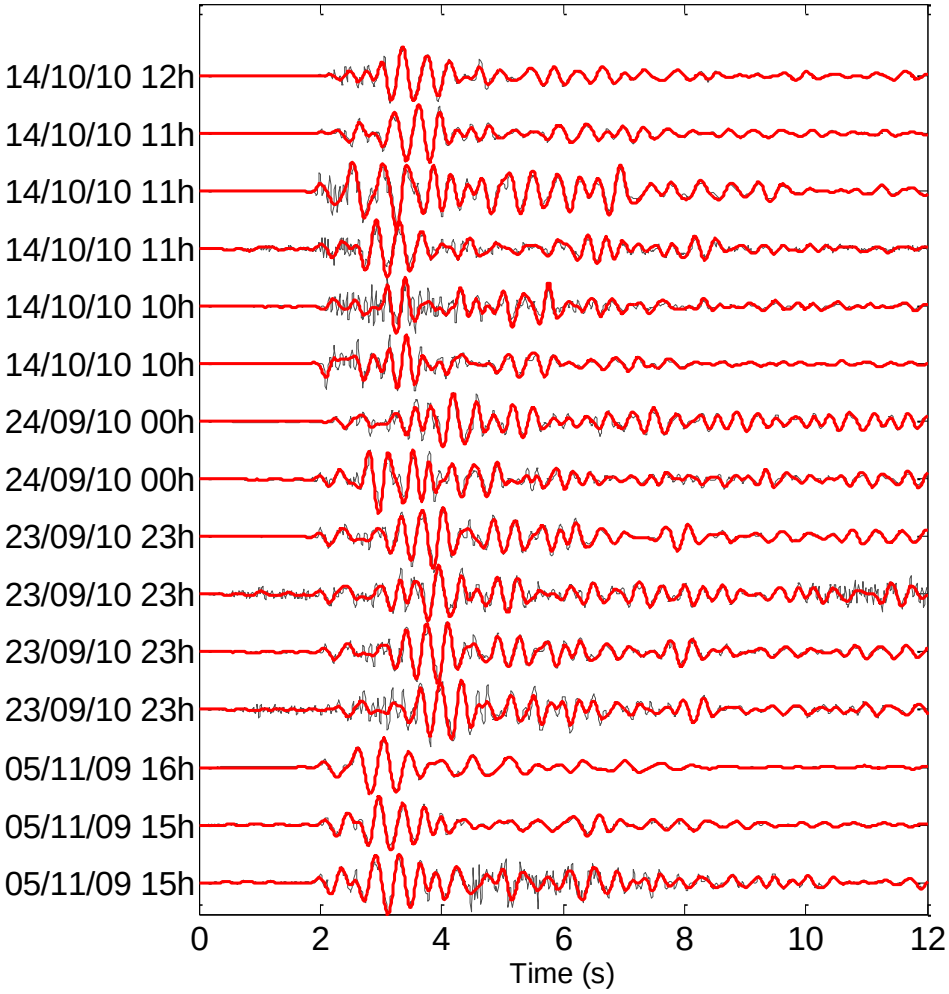
Seismic Network

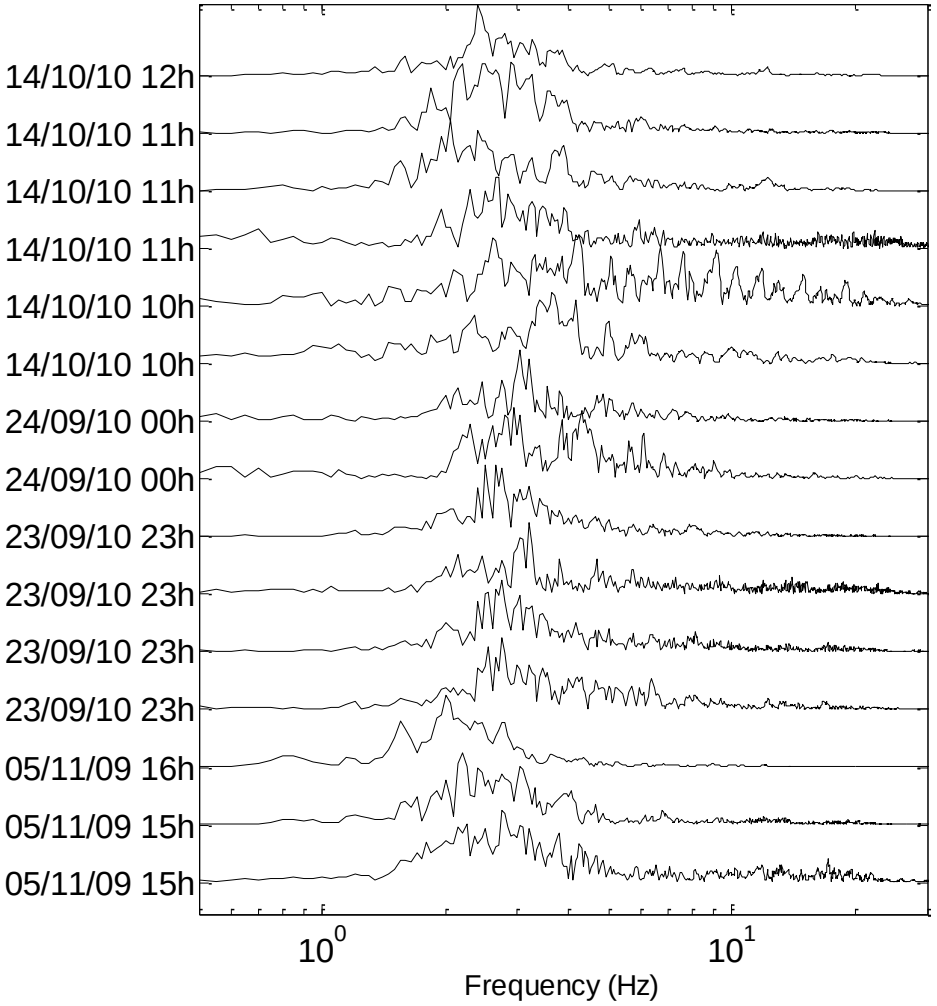


Temporal Distribution

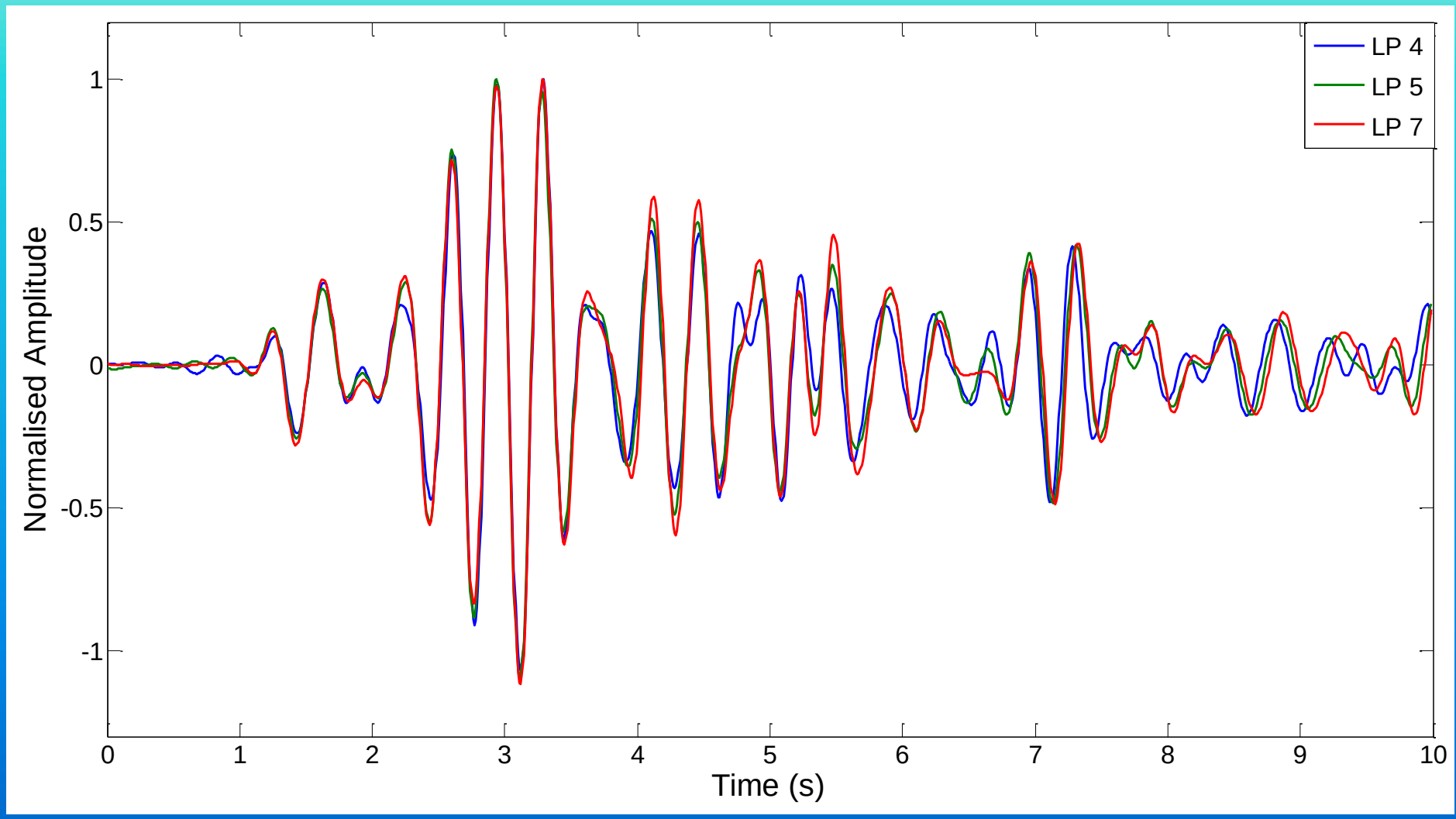


LP Events


14/10/10 12h
14/10/10 11h
14/10/10 11h
14/10/10 11h
14/10/10 10h
14/10/10 10h
24/09/10 00h
24/09/10 00h
23/09/10 23h
23/09/10 23h
23/09/10 23h
23/09/10 23h
05/11/09 16h
05/11/09 15h
05/11/09 15h
0
2
4
6
8
10
12
Time (s)

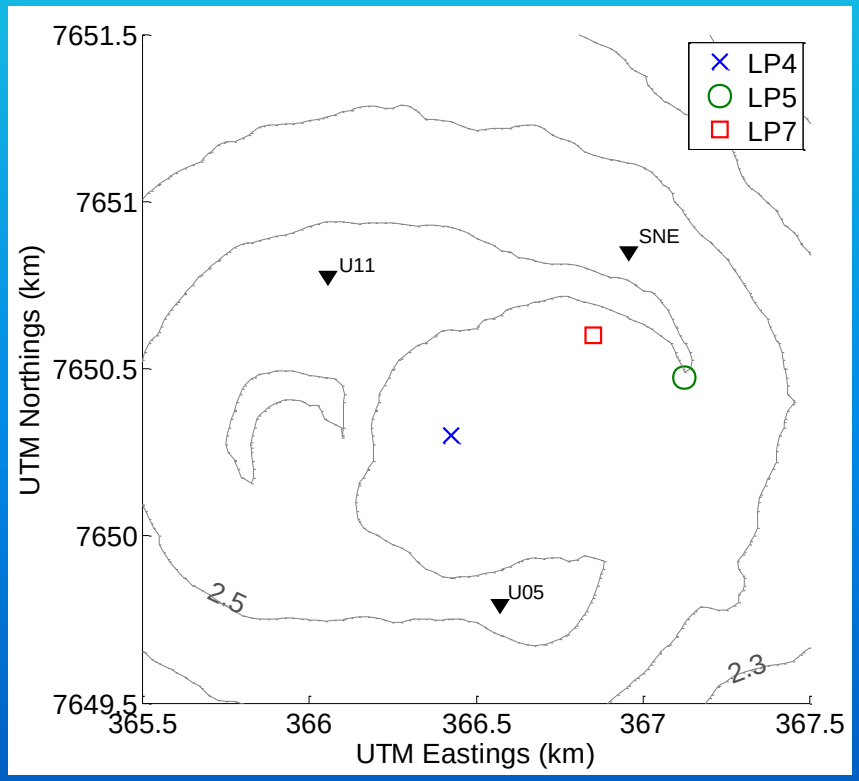

14/10/10 12h
14/10/10 11h
14/10/10 11h
14/10/10 11h
14/10/10 10h
14/10/10 10h
24/09/10 00h
24/09/10 00h
23/09/10 23h
23/09/10 23h
23/09/10 23h
23/09/10 23h
05/11/09 16h
05/11/09 15h
05/11/09 15h
10^0
10^1
Frequency (Hz)

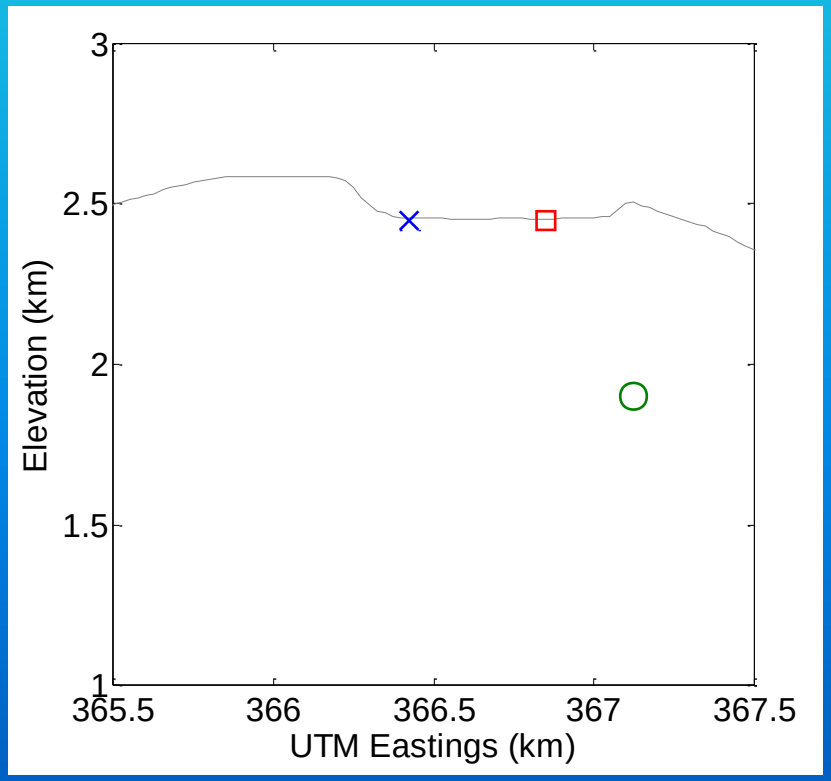
Family of LP Events



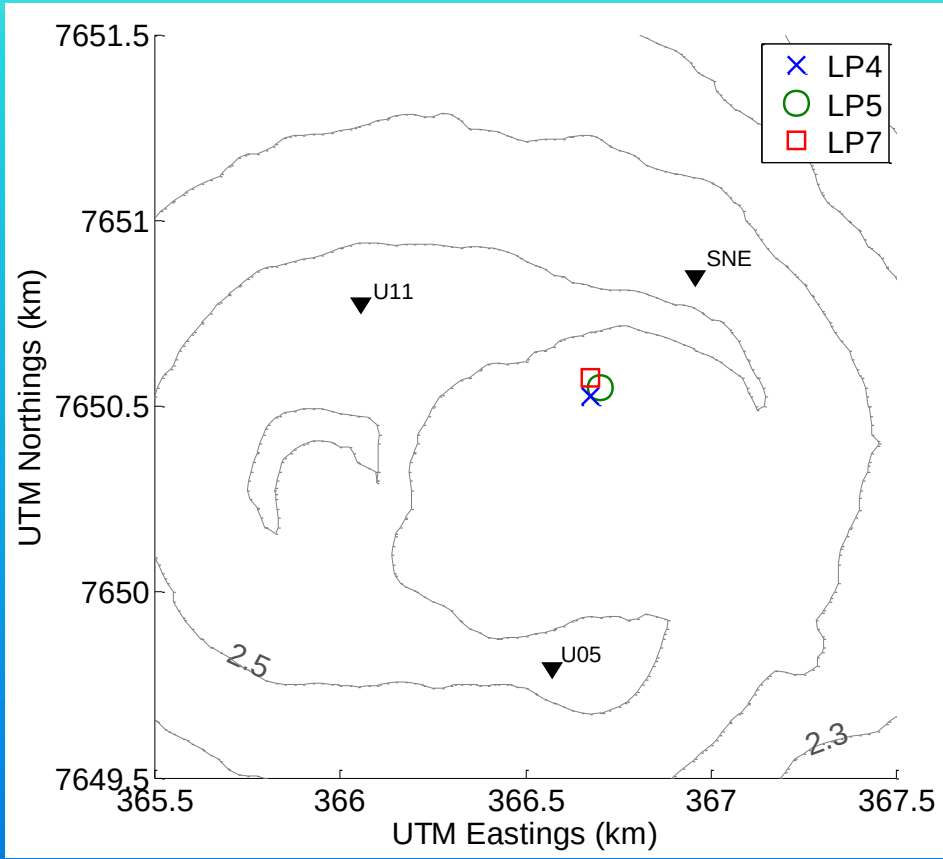
Locating LP Events

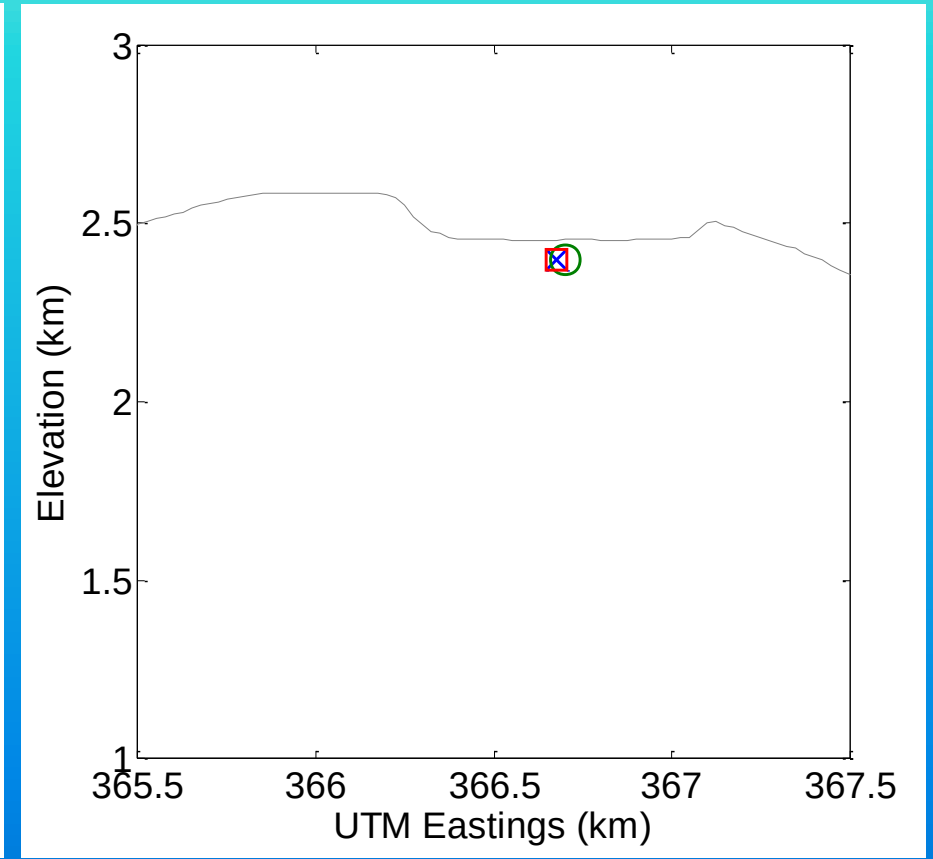
- Cannot locate using conventional earthquake location methods
- Pick first arrivals on some stations
- Assume spherical wavefront propagation
- Grid Search
- Homogeneous velocity => 3500 ms^{-1}





Relocating using Double Difference

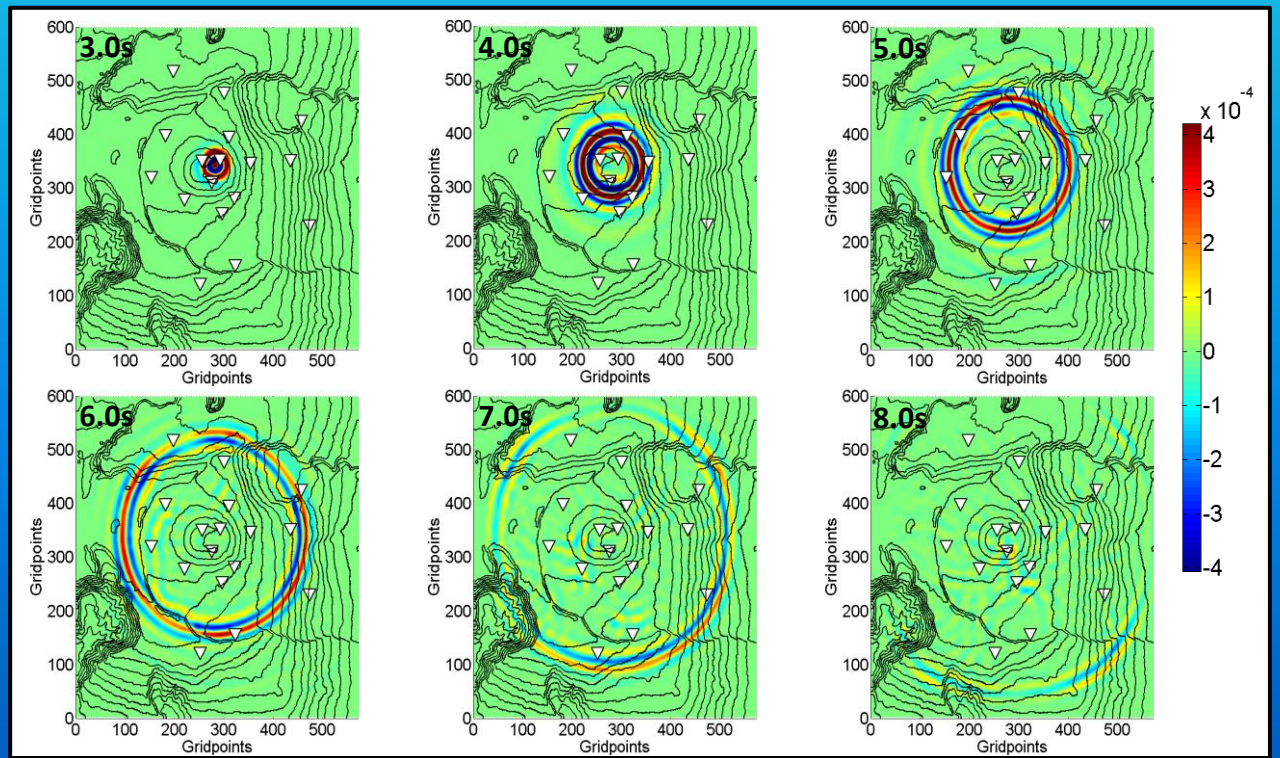




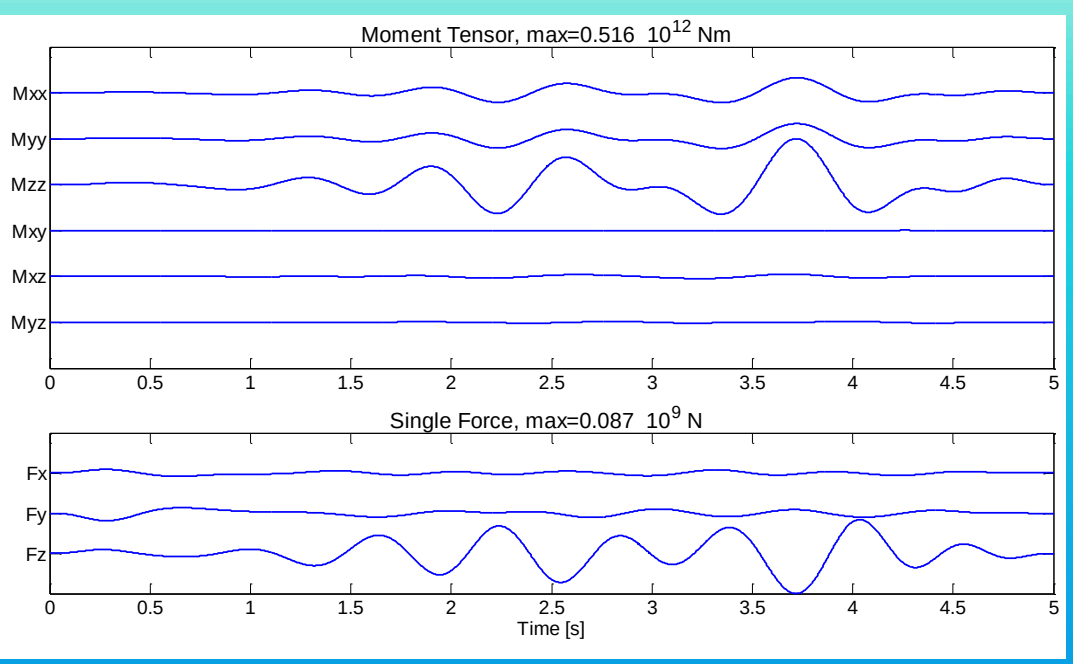
Moment Tensor Inversion (MTI)

$$u_n(x, f) = M_{pq}(f).G_{np,q}(x, f) + F_p(f).G_{np}(x, f) \qquad n, p = 1,2,3$$

- Green's functions
  - 3D full-waveform simulations using an elastic lattice method (O'Brien and Bean, 2004)
  - Include topography and homogeneous velocity model

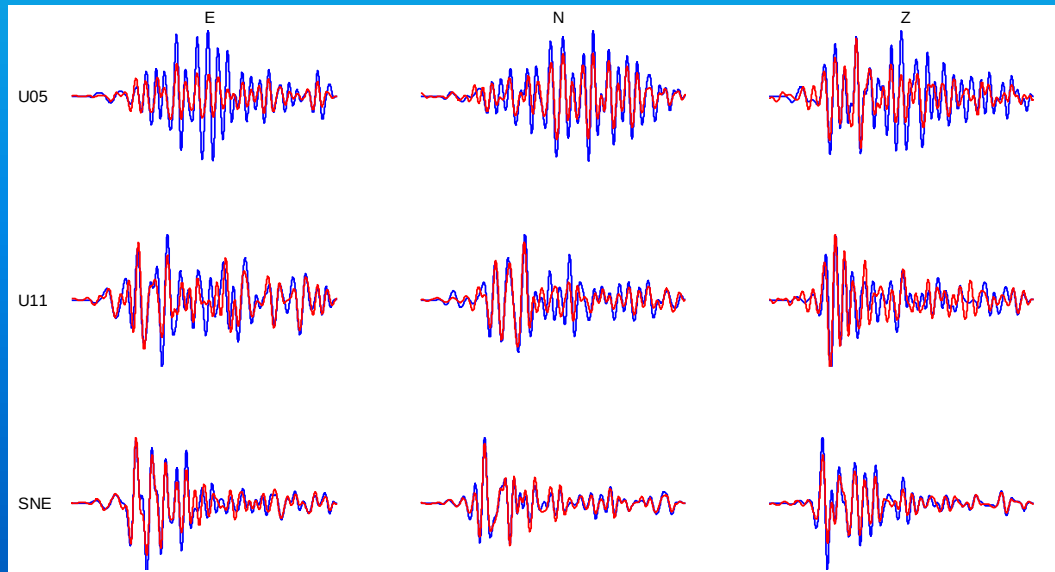


MTI Solutions

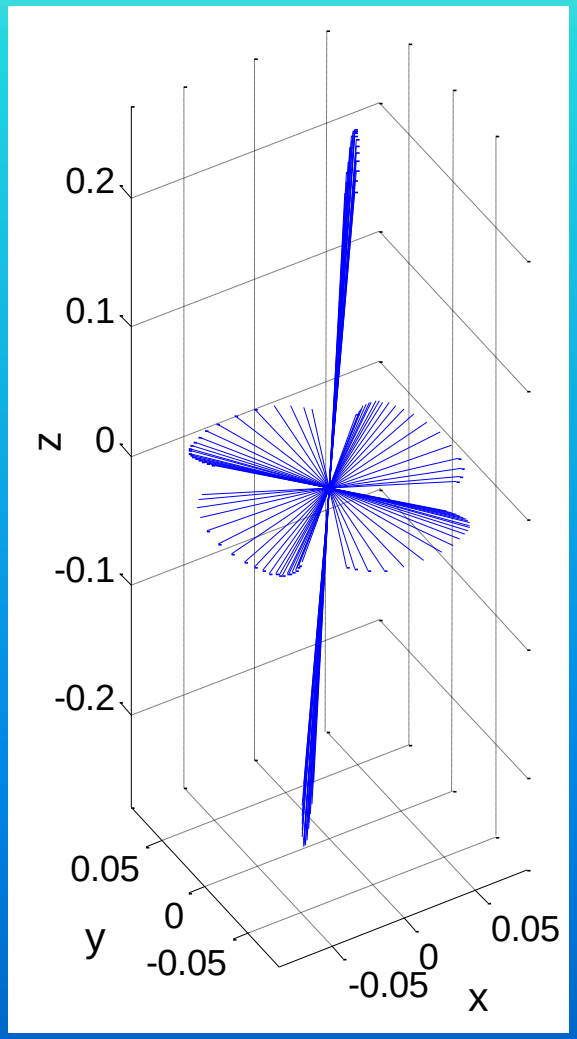


- Amplitude ratios of 1:1:3
- Source Mechanism best described as a horizontal crack

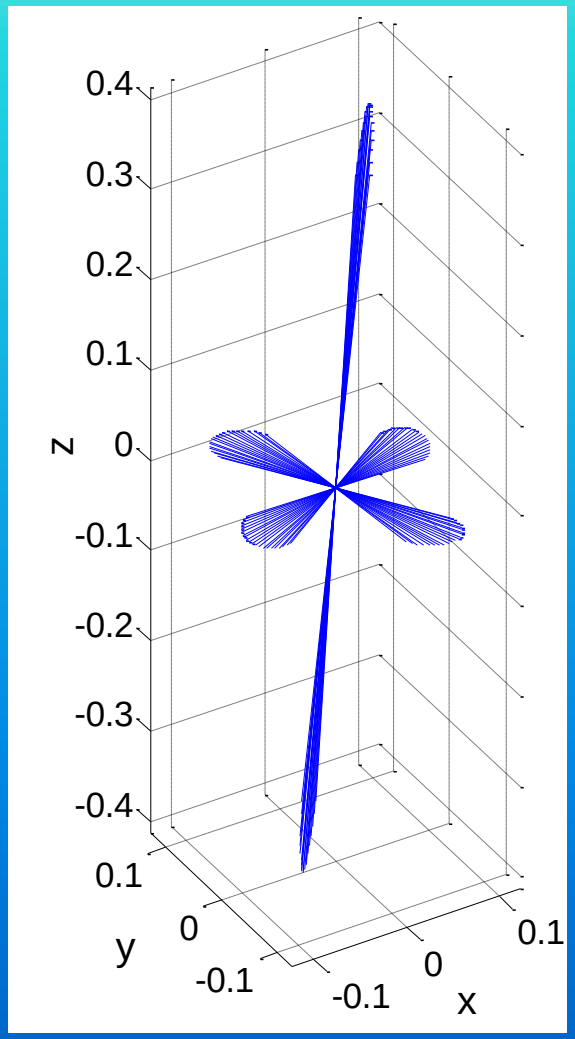
- Reconstructed waveforms have a good fit with real data



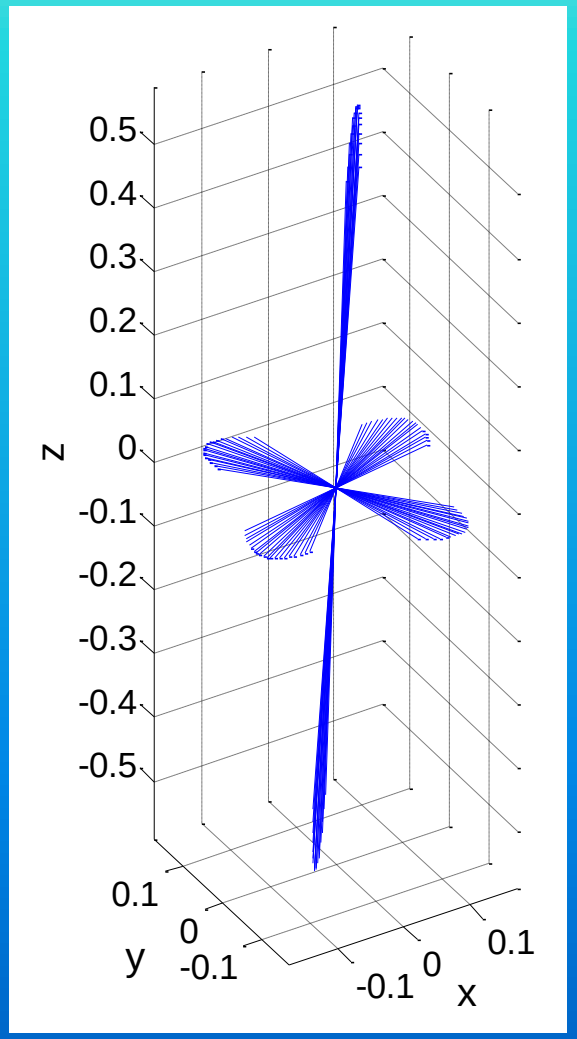
Horizontal Crack



LP4



LP5

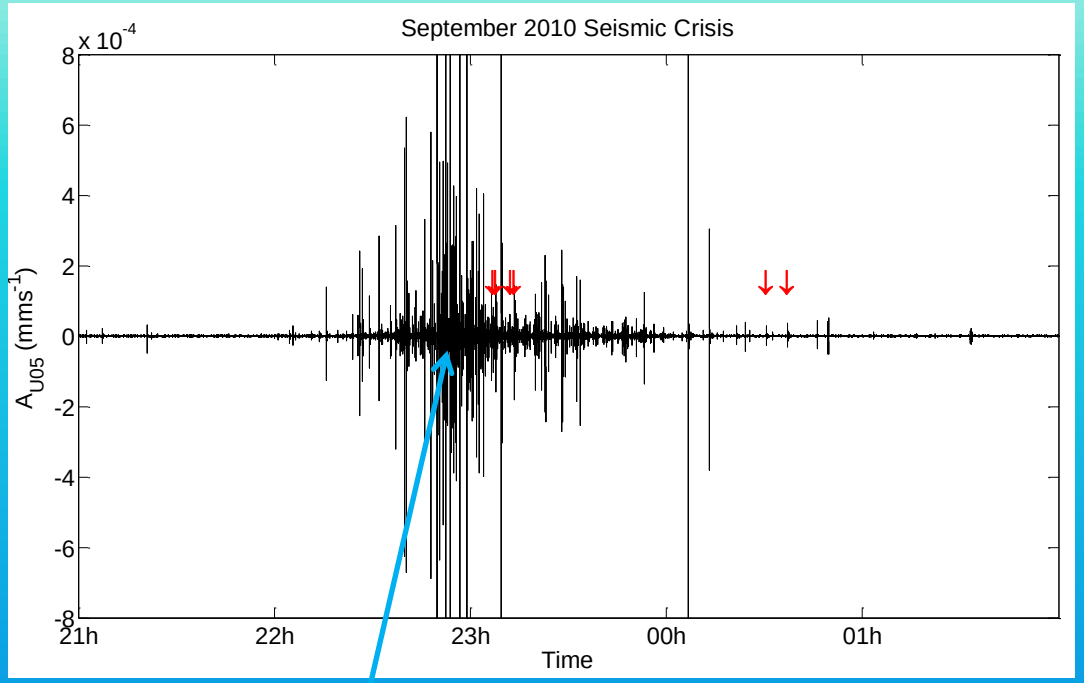


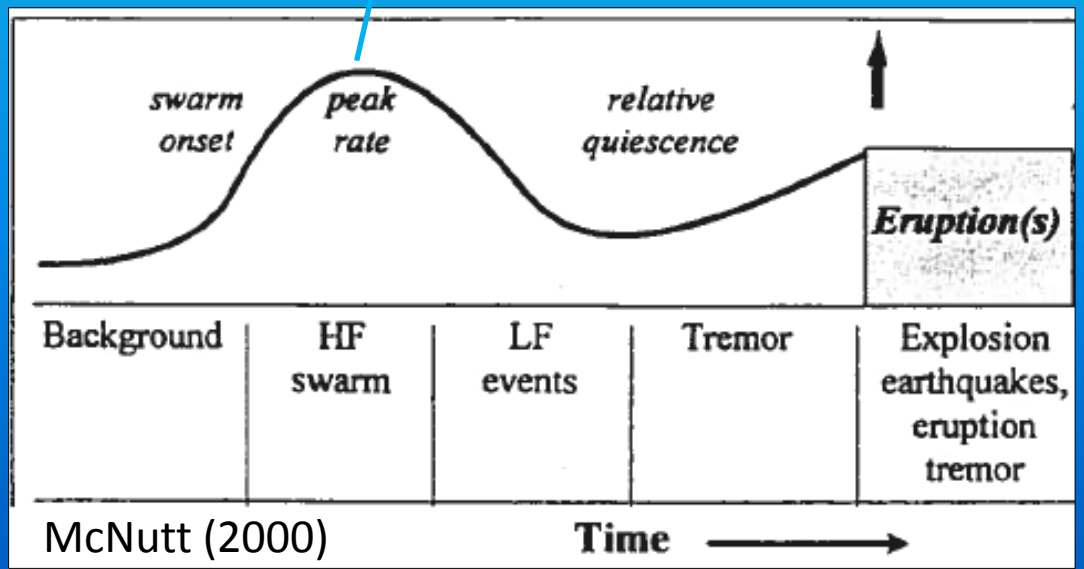
LP7

Tests

- Include/Exclude single forces in MTI
- Different source depths
- Tested for a layered, homogeneous and constant-gradient velocity model
- Jackknife stations
- Constrain inversion for most probable source mechanisms
  - Pipe, crack, and isotropic source

Eruptive Context





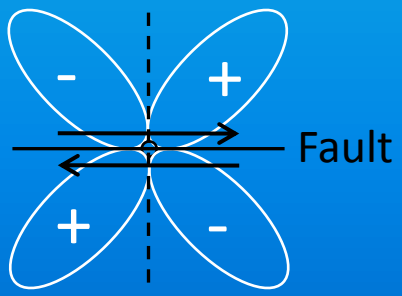
McNutt (2000)

- Seismic crisis before each eruption.
- LP events tend to occur towards end of seismic crisis.
- Can't distinguish between eruption and intrusion.
- Accompany flank eruptions (Aki & Ferrazzini (2000)).

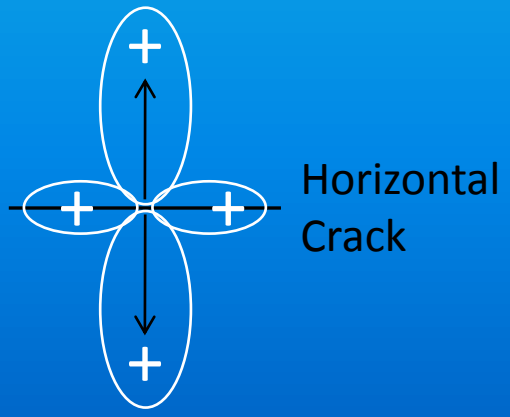
VT Events vs. LP Events

- Depths
  - VTs are deep – between sea level and 800m a.s.l.
  - LPs are very shallow – 2000m a.s.l.

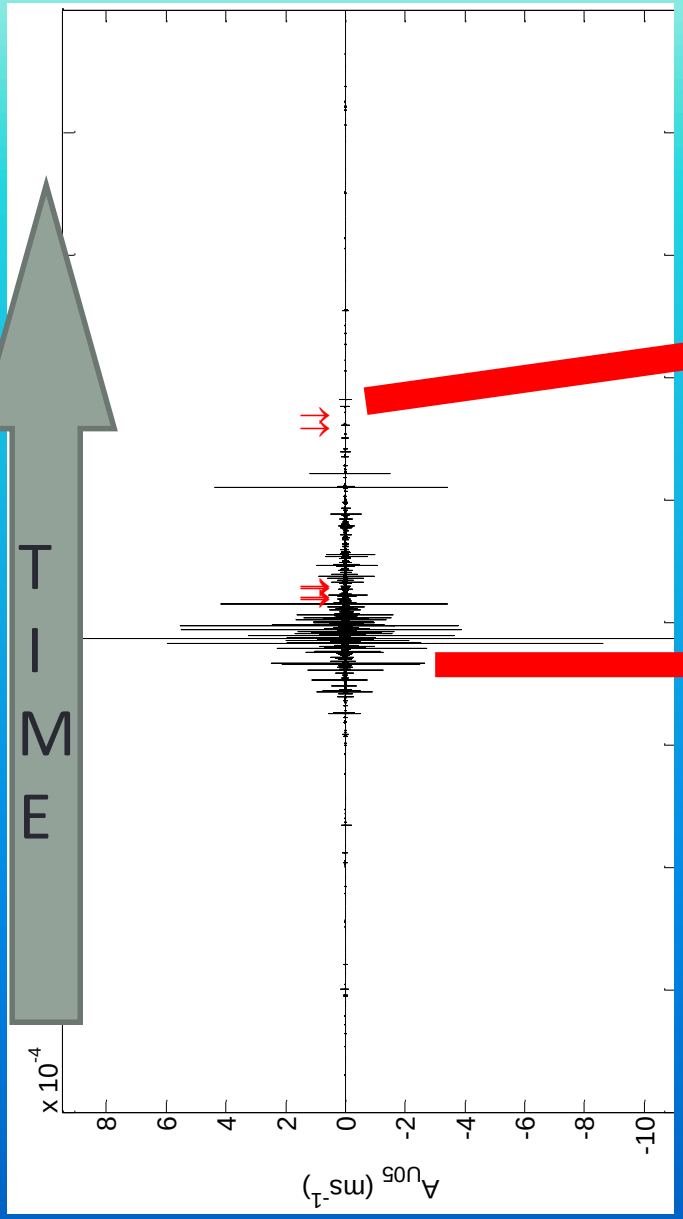
- Mechanisms
  - VT => Double-couple

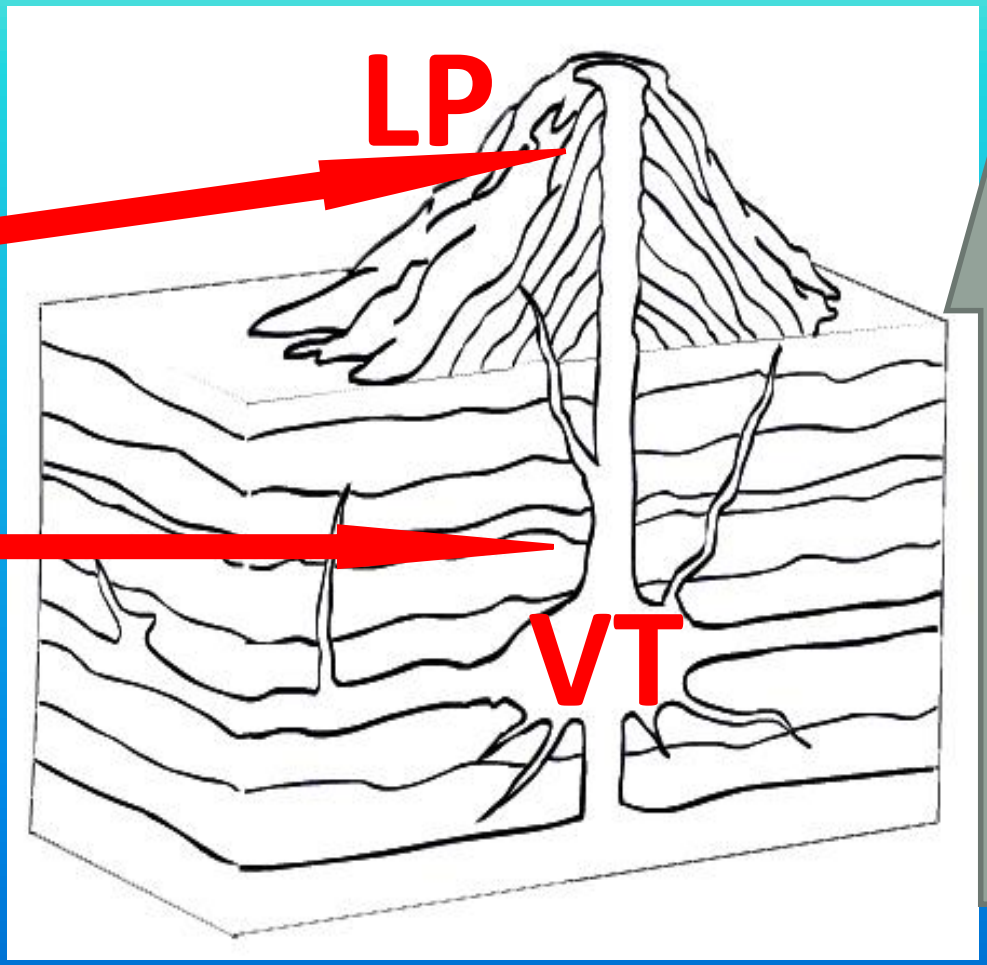


  - LP => horizontal crack



Fluid or Stress field?

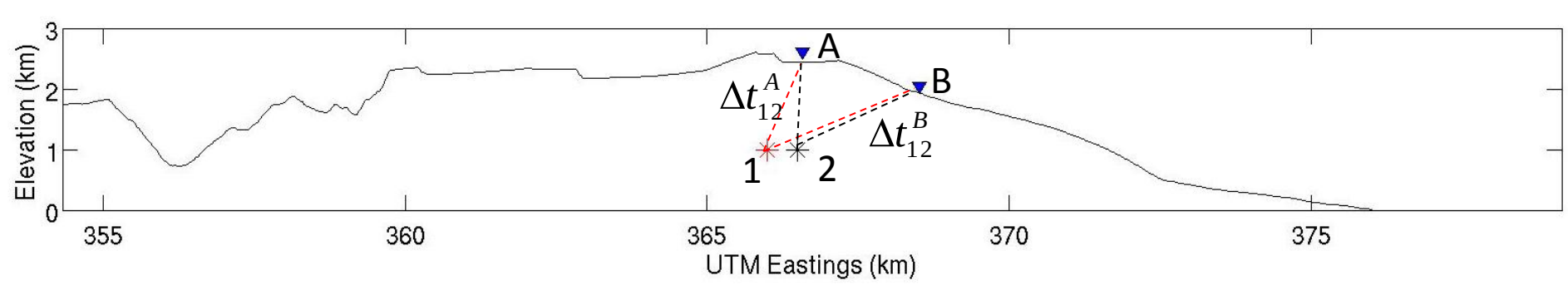




Conclusion

- Very few LP events
  - 15 LP events recorded in a 16 month period
- Not all eruptions associated with LP events
  - Accompany flank eruptions?
- Occur after a series of VT events
- Are LP events associated with fluids or stress field?
  - Properties of magma different to other volcanoes?
  - Medium is stiffer than other volcanoes?

Relocating Using Double Difference



$$\Delta t_{12}^{A} - \Delta t_{12}^{B} \equiv \Delta t_{1}^{AB} - \Delta t_{2}^{AB}$$

- Family of LP events have similar waveforms at each station
- Initial location not required
- Grid search
- Homogeneous velocity => 3500 ms^{-1}

MTI Tests

- How can you test the robustness of your results?
- Rerun MTI
  - without single forces
  - with summit stations removed
  - for source depths of 200m and 500m

Source Depth	With single forces	w/o single forces	Constrained inversion	Stations removed
50m	Horizontal crack 1:1:3	Horizontal crack 1:1:3	Horizontal crack 1:1:3	Horizontal crack 1:1:3
200m	Horizontal crack 1:1:5	✘	Horizontal crack 1:1:5 or 1:1:3	Horizontal crack 1:1:3
500m	✘	✘	✘	✘