Multi-parameter investigations at Fuego and Santiaguito volcanoes

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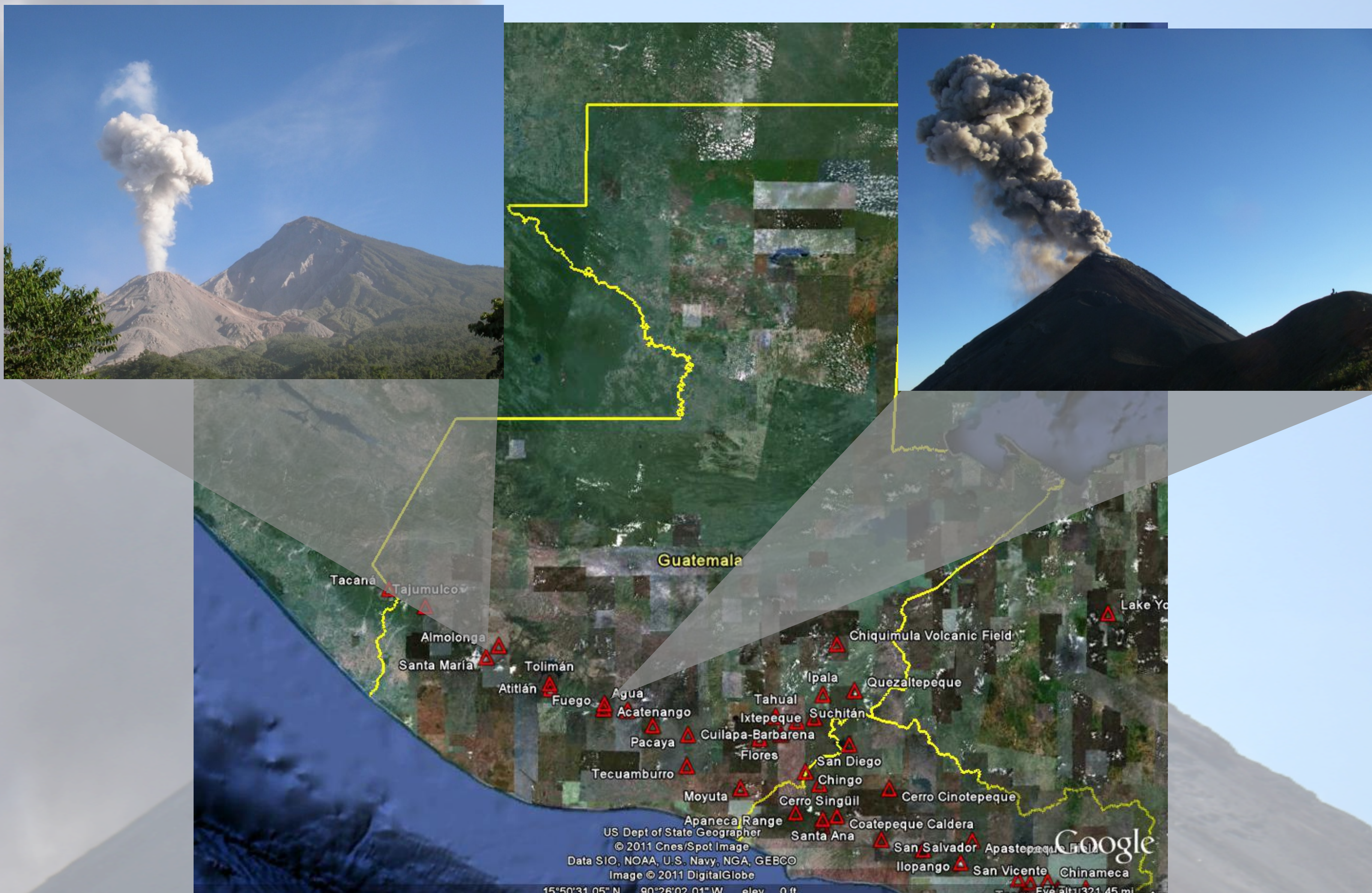
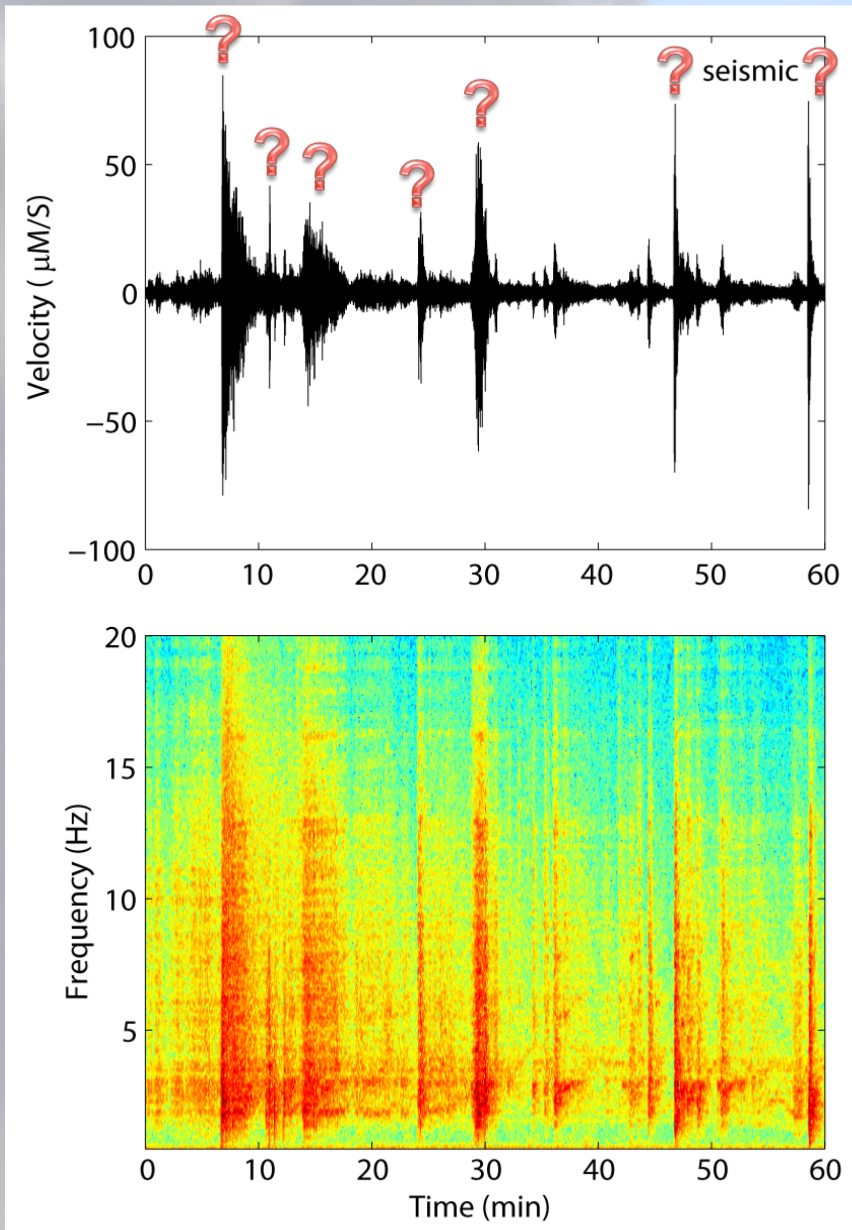
Multi-parameter approach to studying volcanic processes over variable timescales

- Seismic
  - Broadband 3-component
- Acoustic
  - Broadband microphones
- Gas
  - UV camera SO_2
- Video

Fuego and Santiaguito – laboratory volcanoes



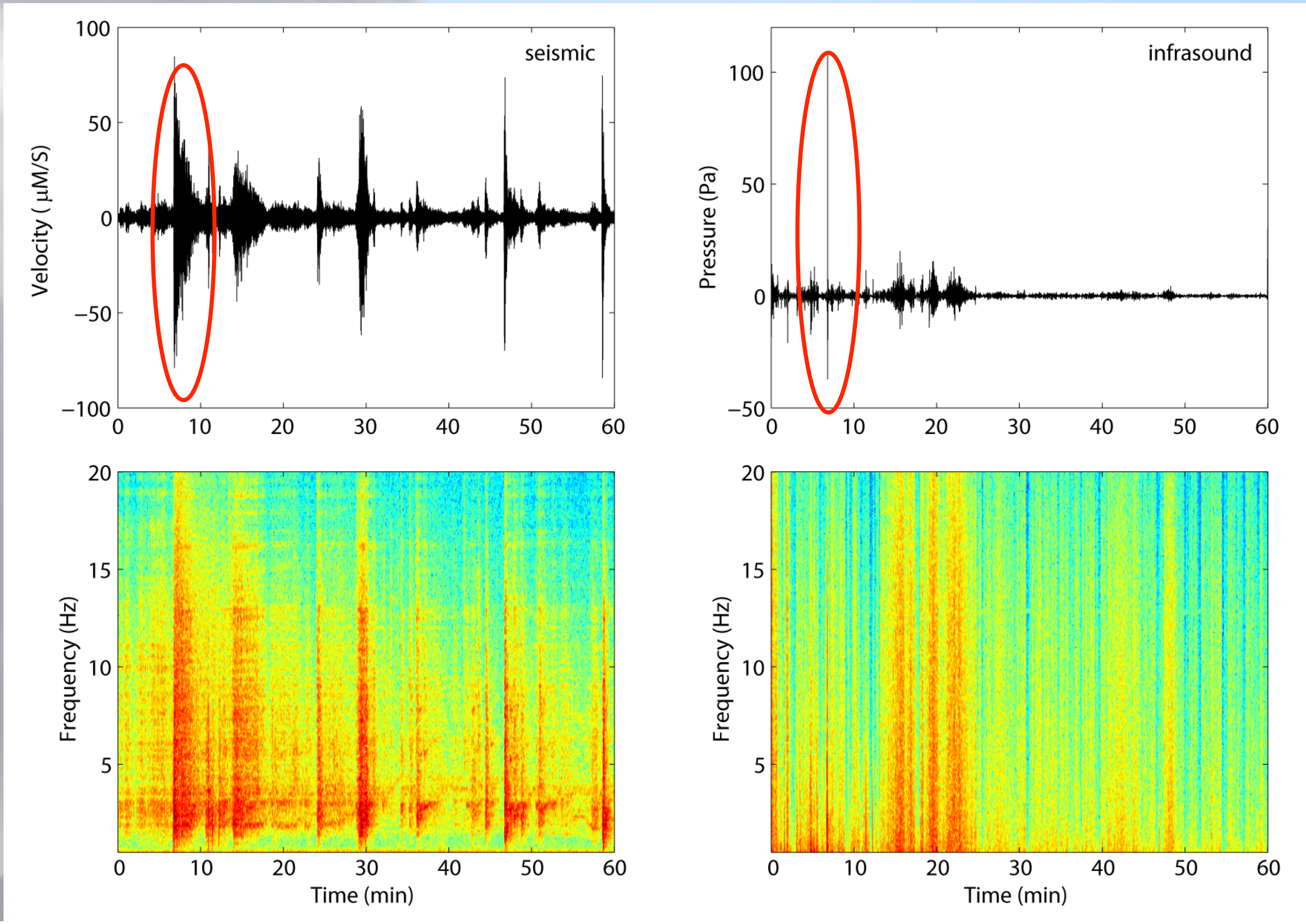
Seismic + acoustic for basic explosion identification



- Often difficult to quickly distinguish event types at open vent volcanoes
- Can you pick the explosions?

Seismic + acoustic for basic explosion identification

- Infrasound shows only one significant strombolian explosion



Explosive energy partitioning between seismic and acoustic

Volcanic Acoustic-Seismic Ratio (VASR): $\eta = E_A/E_S$

[Johnson and Aster, JVGR 2005]

<u>Total radiated explosive energy:</u>

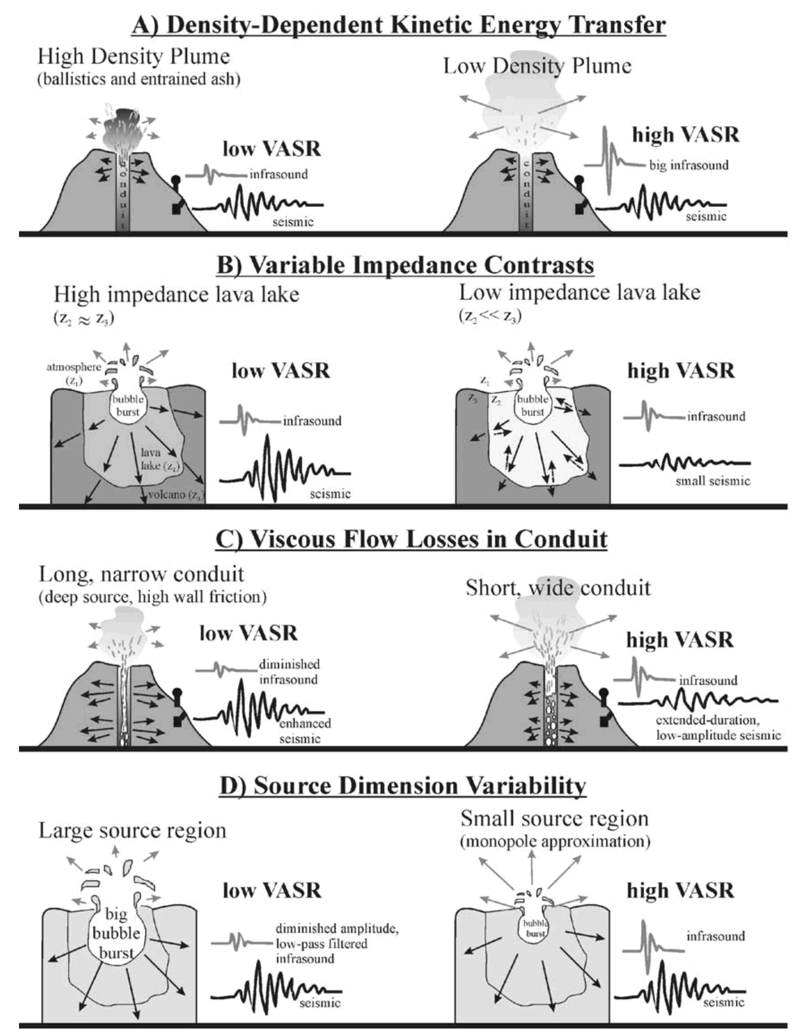
$$E_{acoustic} = (2\pi r^2)/(\rho_{atmos}c_{atmos})\int \Delta P(t)^2 dt$$

Assumptions: Point source monopole and isotropic radiation

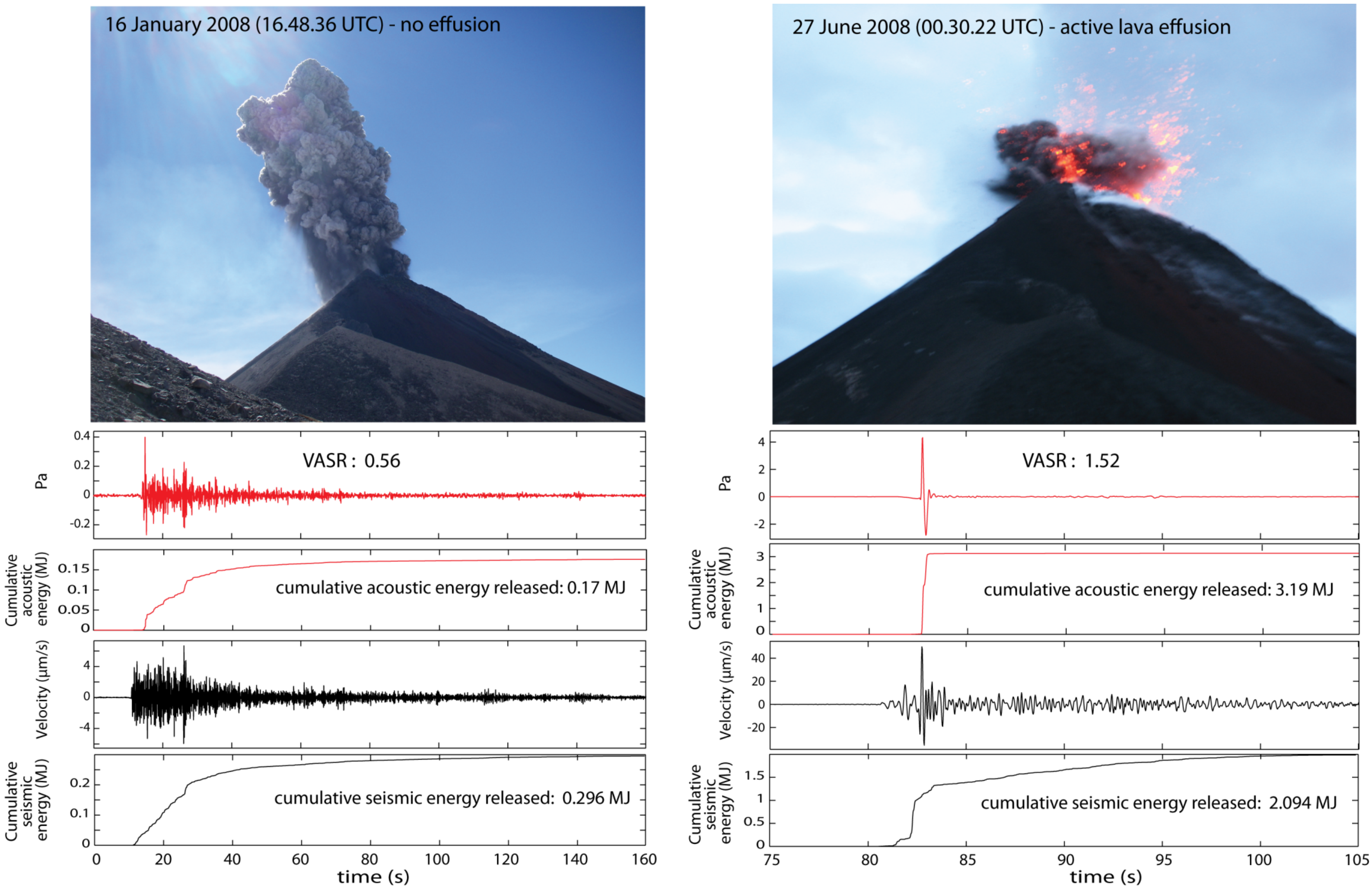
$$E_{seismic} = (2\pi r^2 \rho_{earth}c_{earth})\int \Delta U(t)^2 dt$$

Assumptions: All body waves, radial, isotropic radiation, no attenuation, known P wave velocity

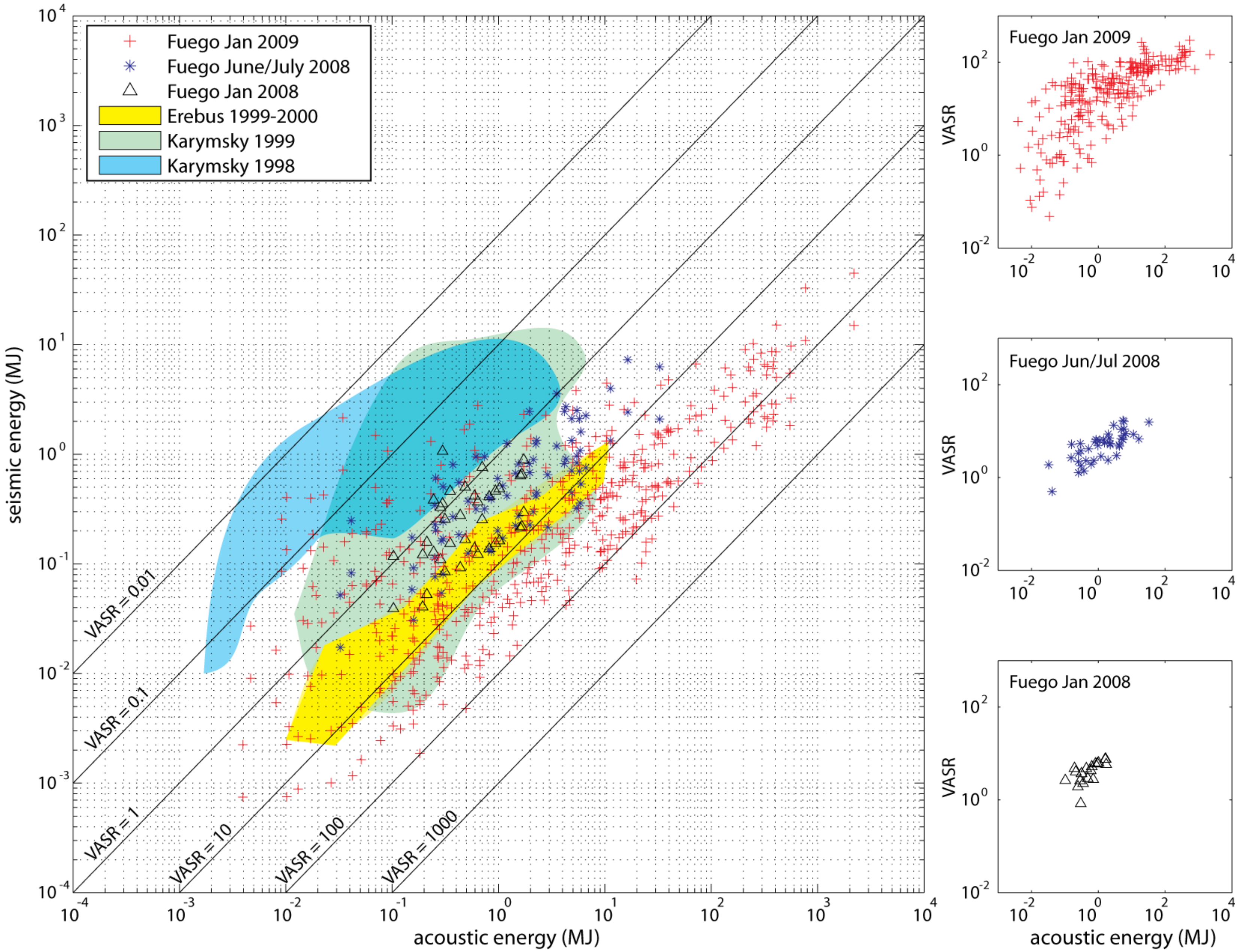
Possible methods of generating variable VASR



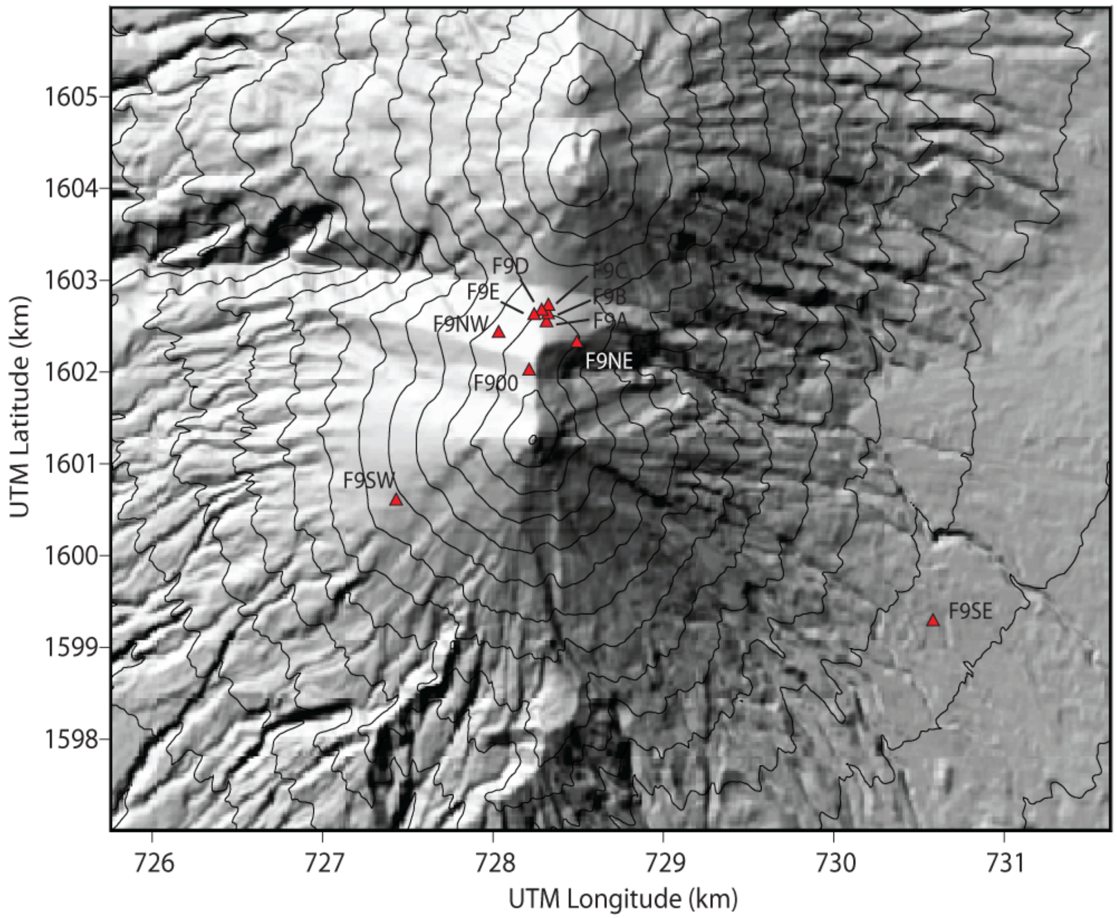
Fuego explosive energy partitioning and related activity



Fuego explosive energy partitioning 2008, 2009



Study site and experimental setup – Fuego 2009

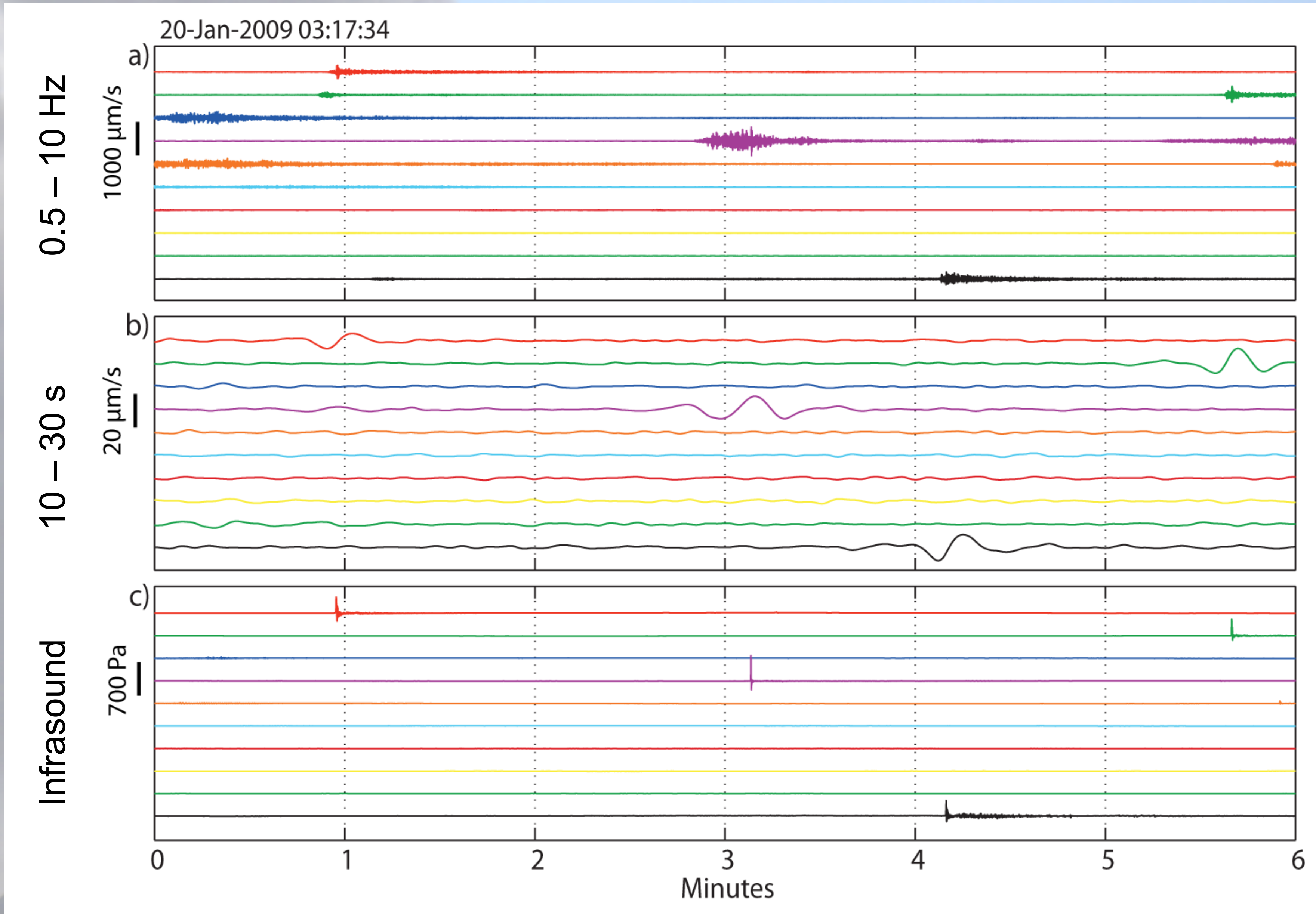


- 10 broadband seismometers (60 and 30 s corner)
- 8 infrasound sensors (50 s corner)
- UV camera (~1 Hz sample rate)
- 19 days of recording
- strombolian activity

Video: http://www.youtube.com/watch?v=QaQ--2jdOgU

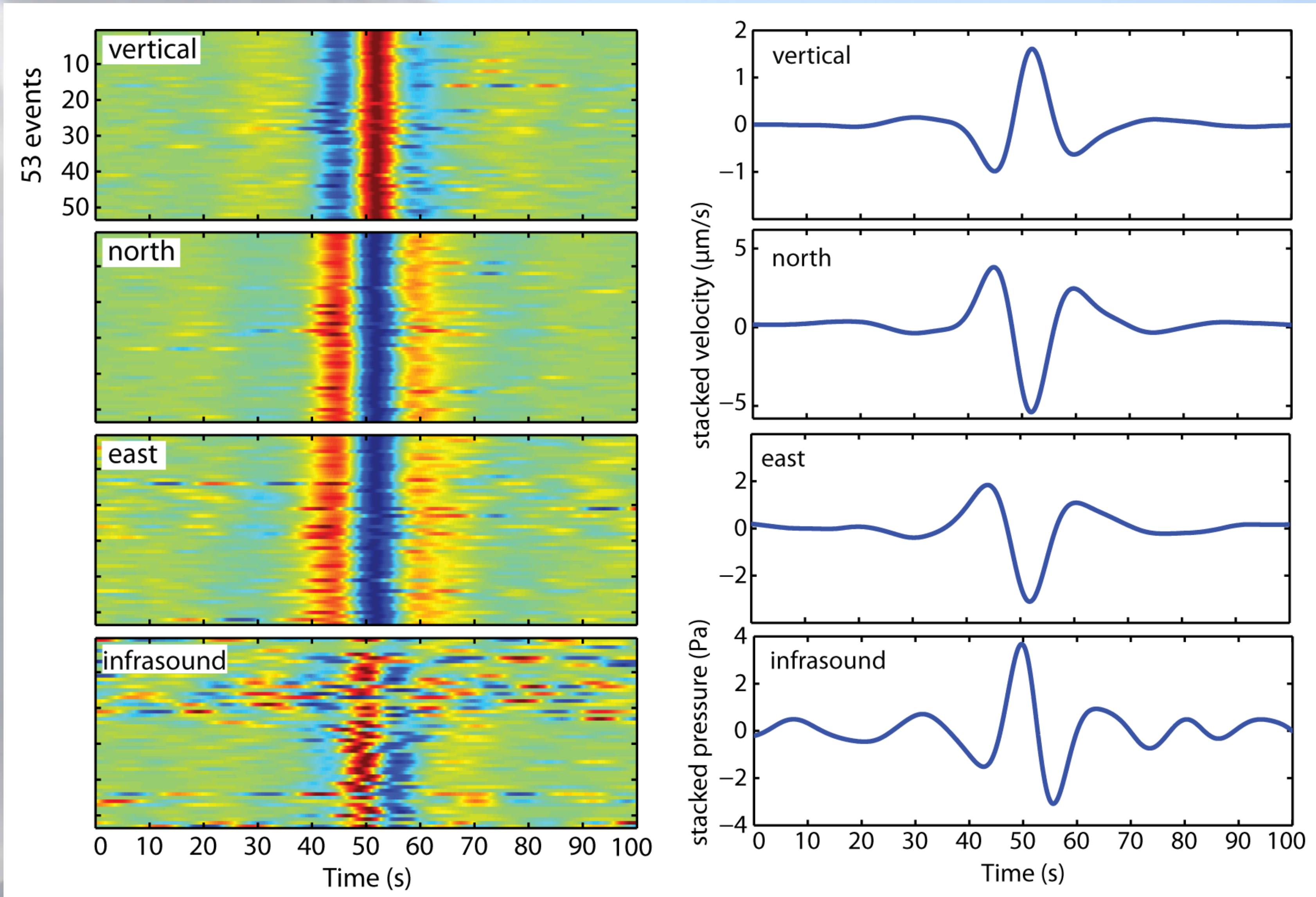
Fuego strombolian explosion VLPs 2009

- All significant (>100 Pa @ 800m) strombolian explosions accompanied by VLP signal



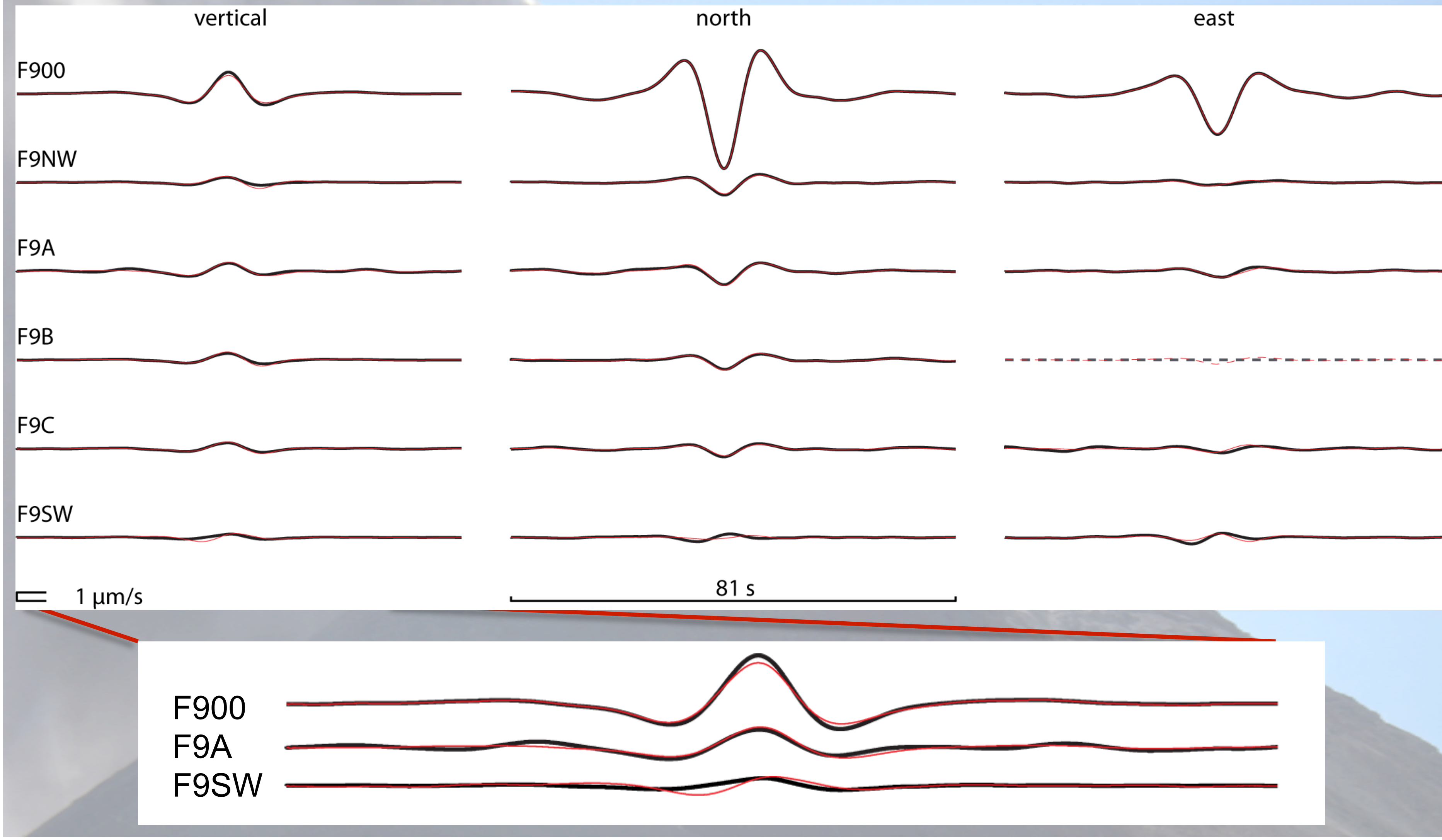
Repeating VLP events in 2009

- 53 strombolian explosions (>100 Pa) over 19 days

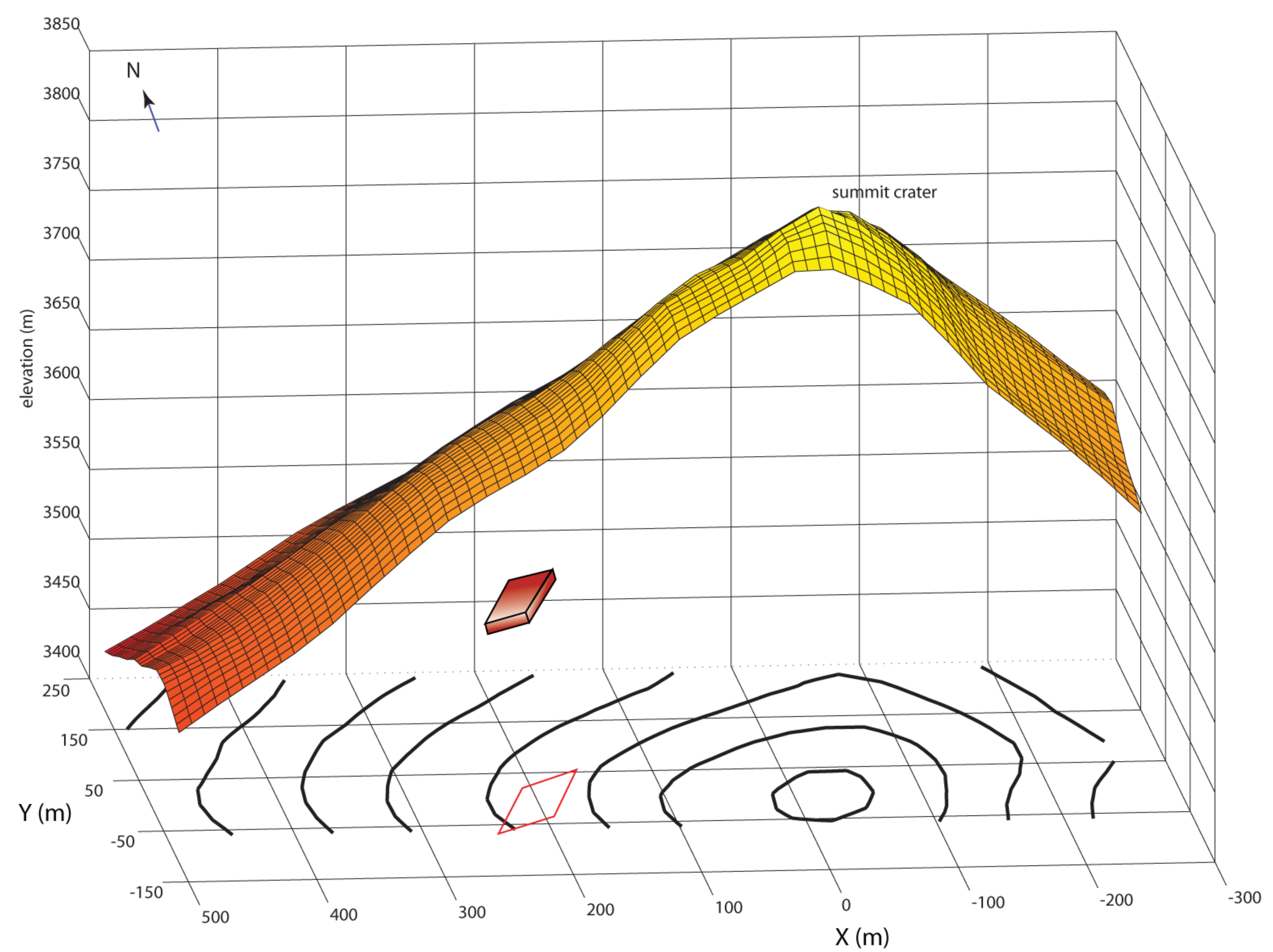


Fuego 2009 VLP waveform inversion results

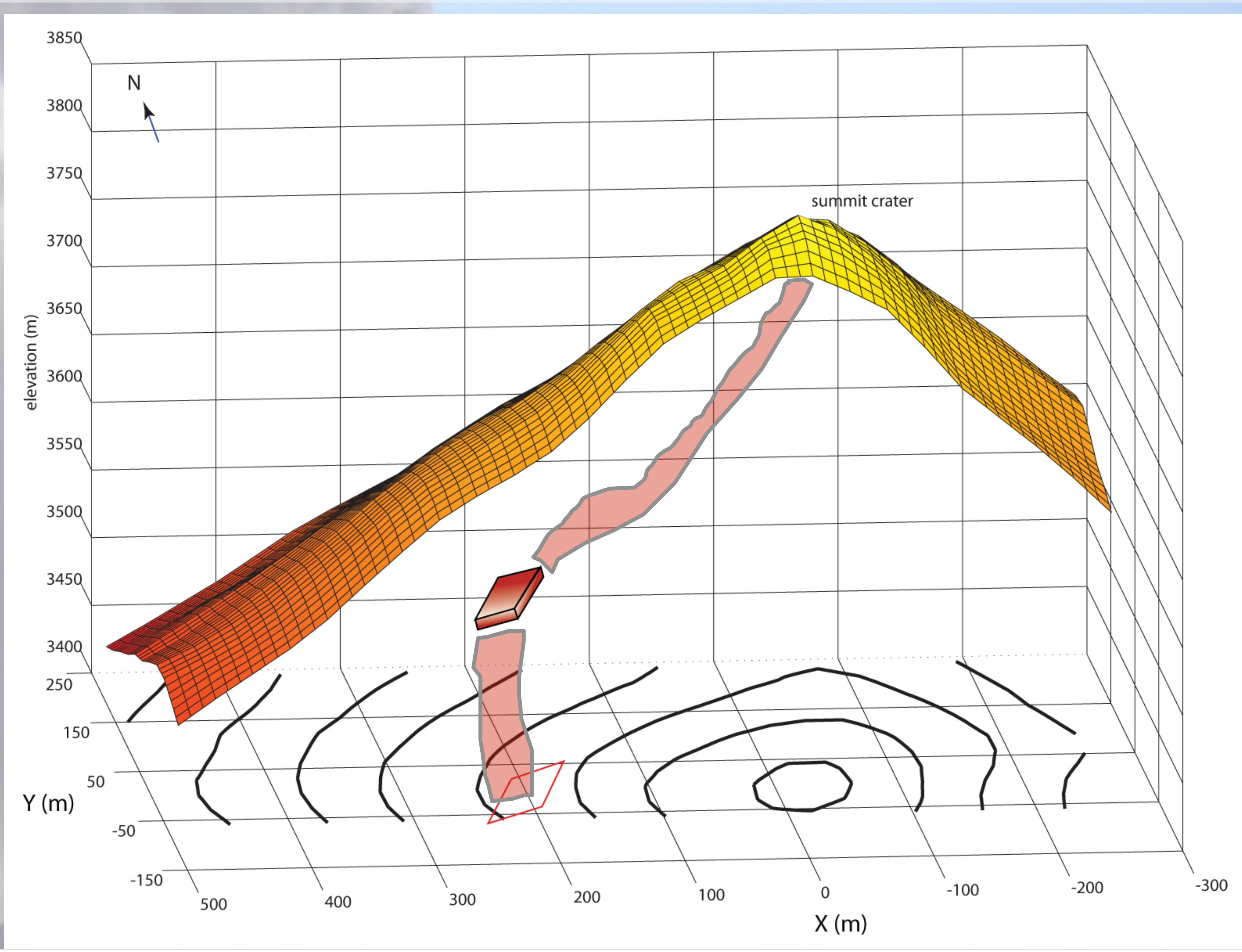
- 6 moment component best fit source (240 m west, 380 m below summit crater)



Fuego seismic VLP location 2009



Fuego seismic VLP location 2009



Extracting apparent tilt from broadband seismic data

- Horizontal components of broadband seismometers are highly susceptible to tilt due to gravitational acceleration

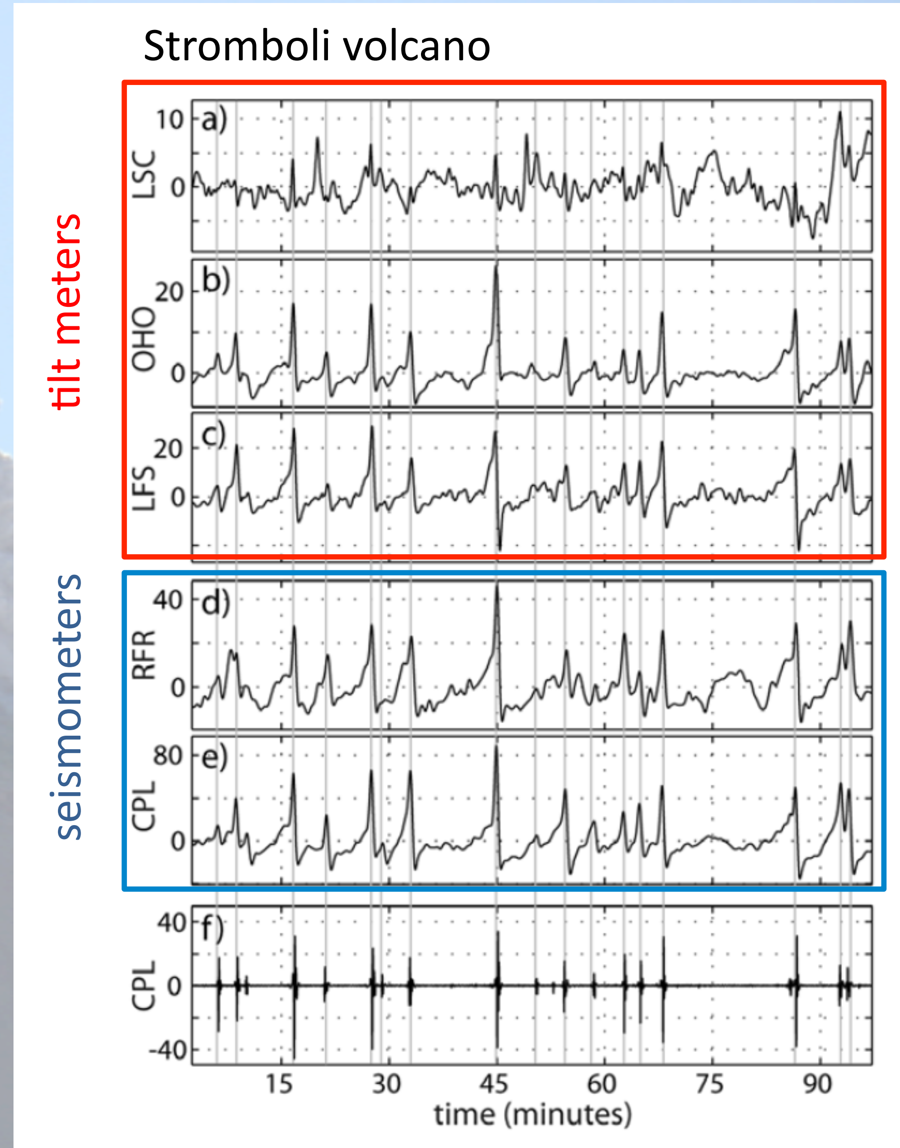
- Possible to record ultra long period tilt at stations located proximal to volcanoes

Method

1. Deconvolve the signal in the passband of interest *below* the low corner of the instrument
2. Convert to acceleration
3. Remove gravitational acceleration

Tilt (radians): $\theta(t) = a_x(t)/g$

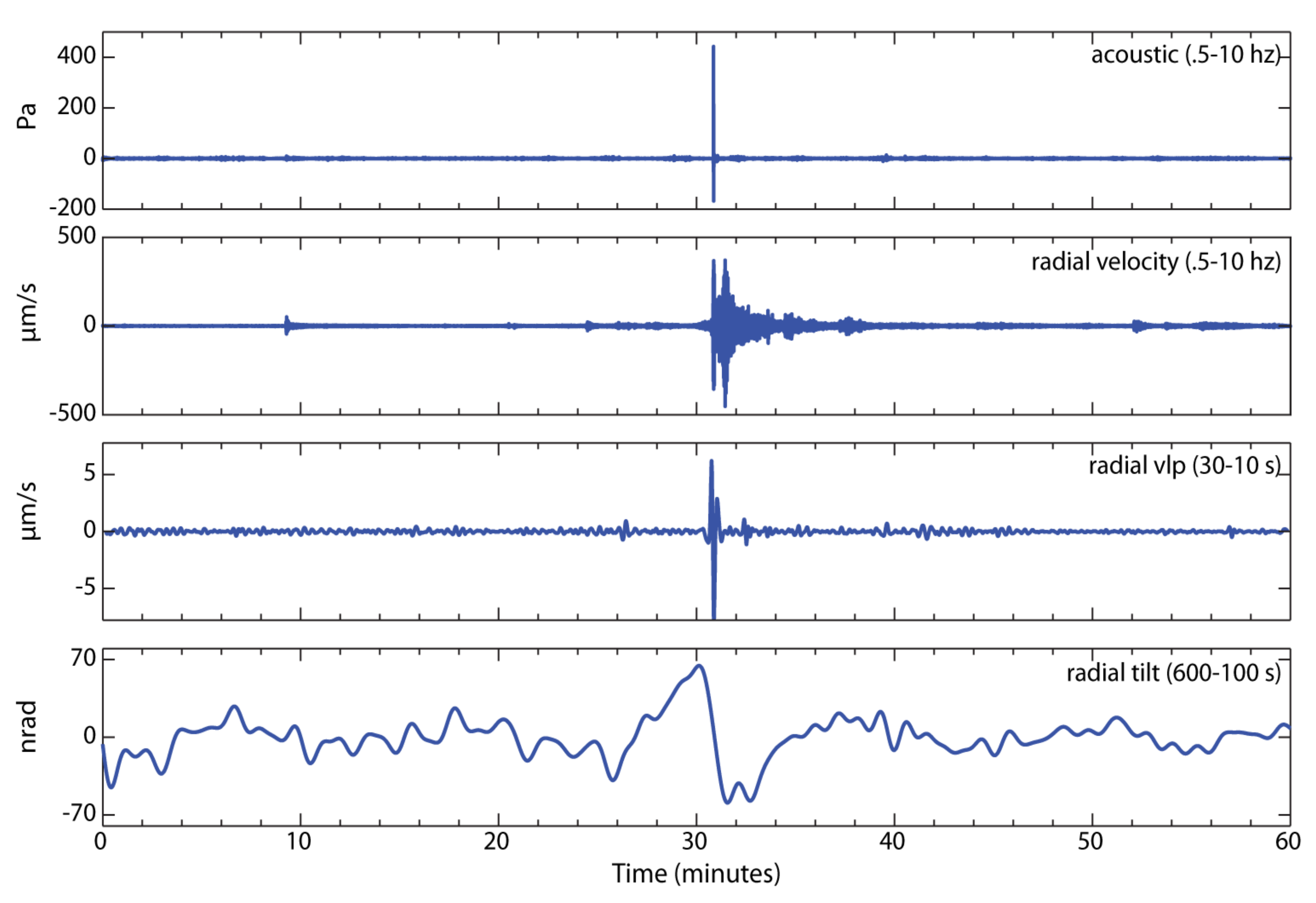
[Wielandt and Forbriger, Ann. Geofis., 1999]



[Genco and Ripepe, GRL, 2010]

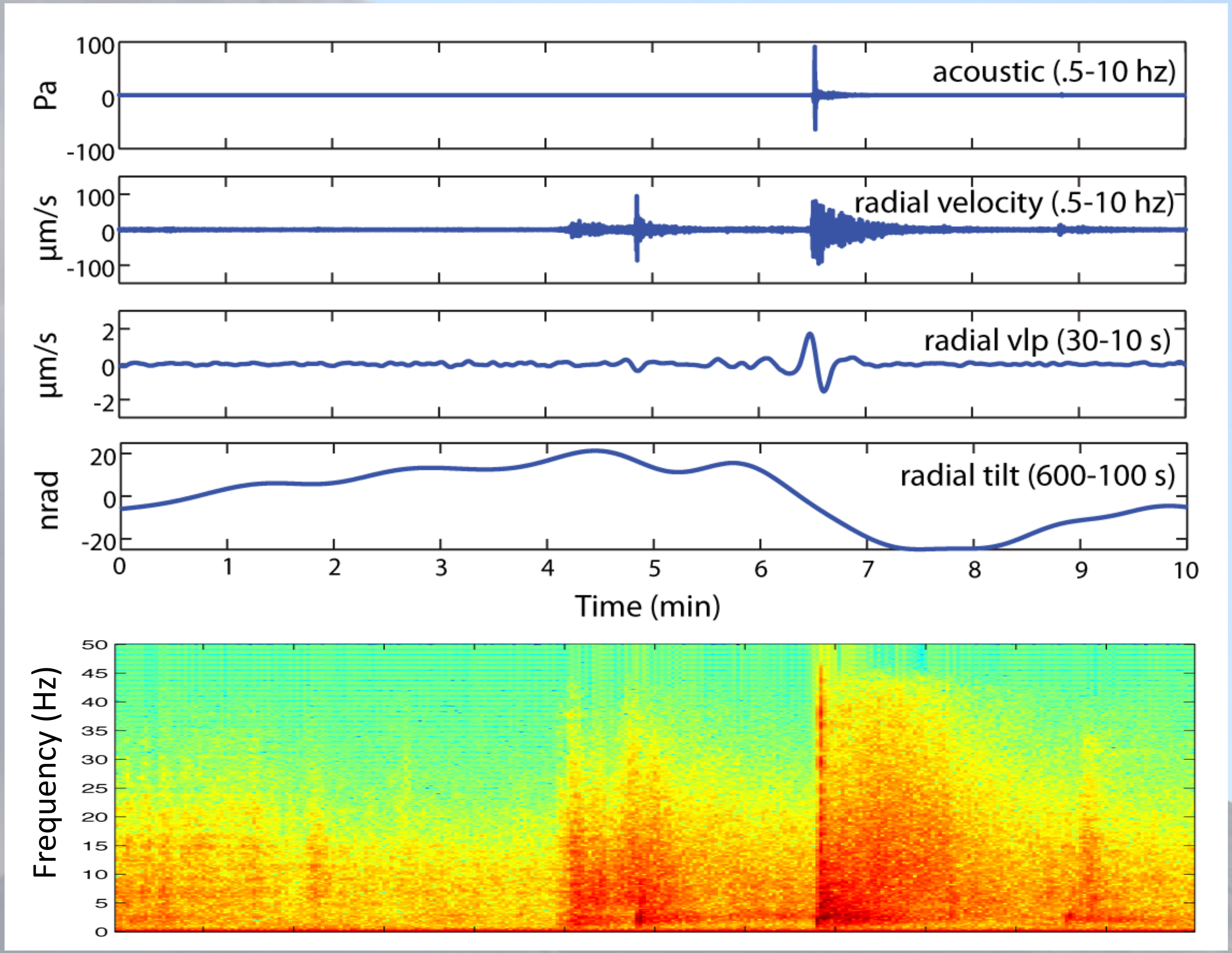
Tilt signal accompanies 2009 Fuego strombolian explosions

- Apparent tilt derived from Guralp-40T (30s) seismometer located 800m from crater
- Positive tilt away from summit crater 4-6 minutes prior to explosions



Tilt signal accompanies 2009 Fuego strombolian explosions

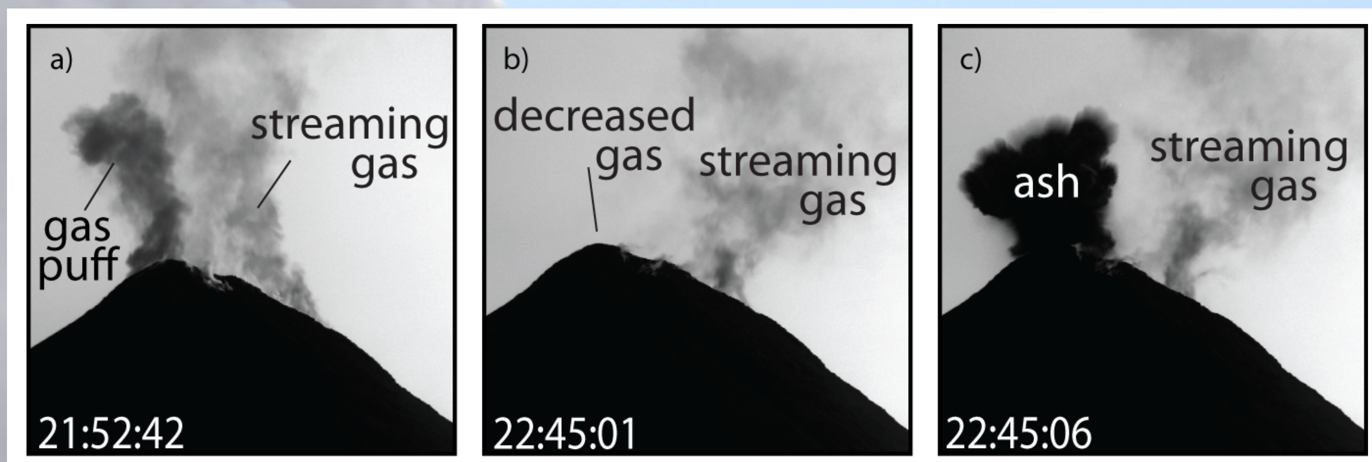
- Seismicity prior to explosion initiates decrease in tilt

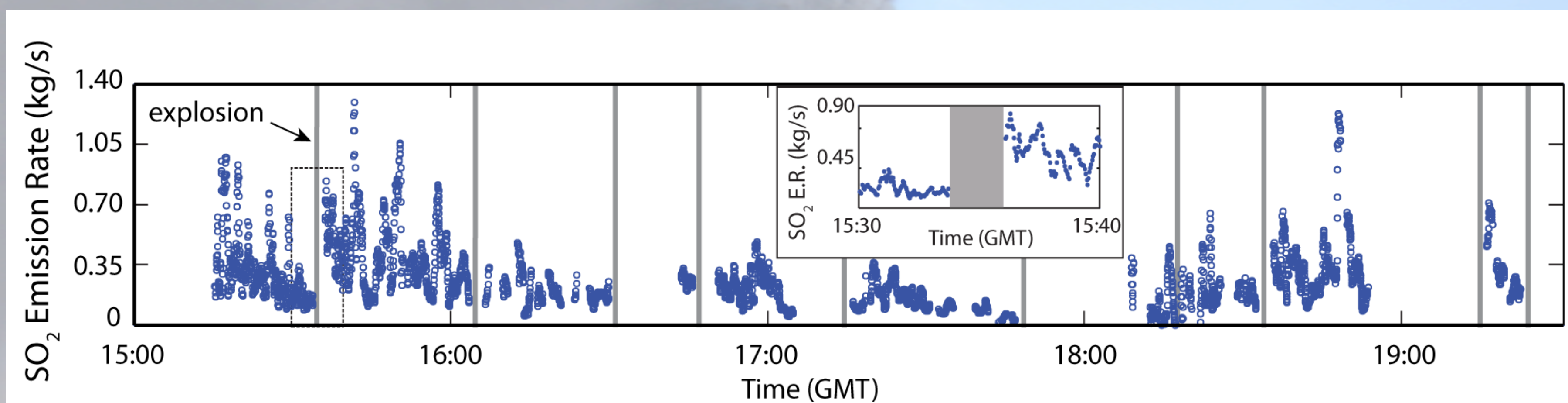


UV camera SO_2 emissions

- UV images reveal 2 active vents
- Decrease in SO_2 prior to explosions

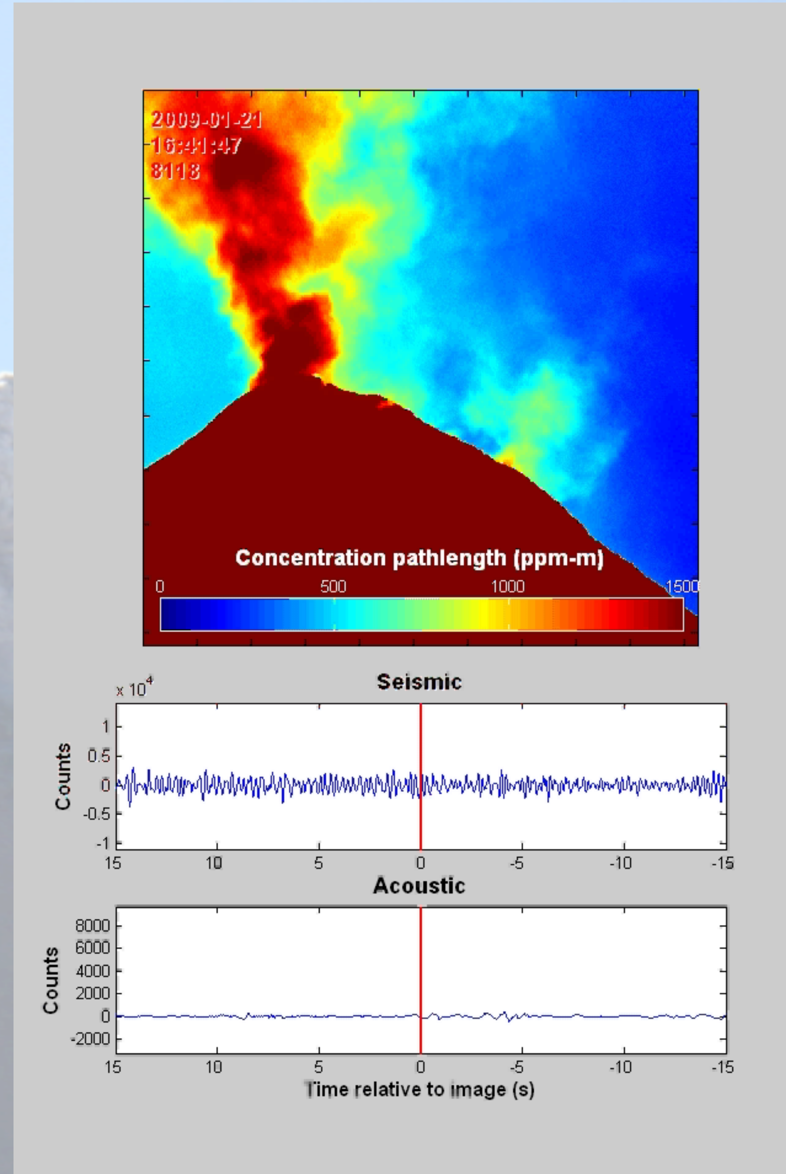
[Nadeau, Palma, Waite, JGR, 2010]





UV camera SO_2 emissions and tilt

- 10s of minutes of gradual SO_2 decrease prior to explosions
- Positive tilt away from summit 4 - 6 minutes prior to explosions
- Restriction of gas escape by cooling and/or crystallization pressurizes the upper portion of the conduit and drives explosions



Video: Tricia Nadeau

Fuego volcano multi-parameter data summary

- Combined seismic and acoustic records greatly aid in distinguishing explosive events

- Tracking explosive energy partitioning relatively easy way to track activity and has potential as a continuous monitoring tool

- VLP studies made possible through use of broadband instruments and allow for source location and constraint of geometry and volume

- Broadband seismometers can be used as tilt meters near volcanic sources

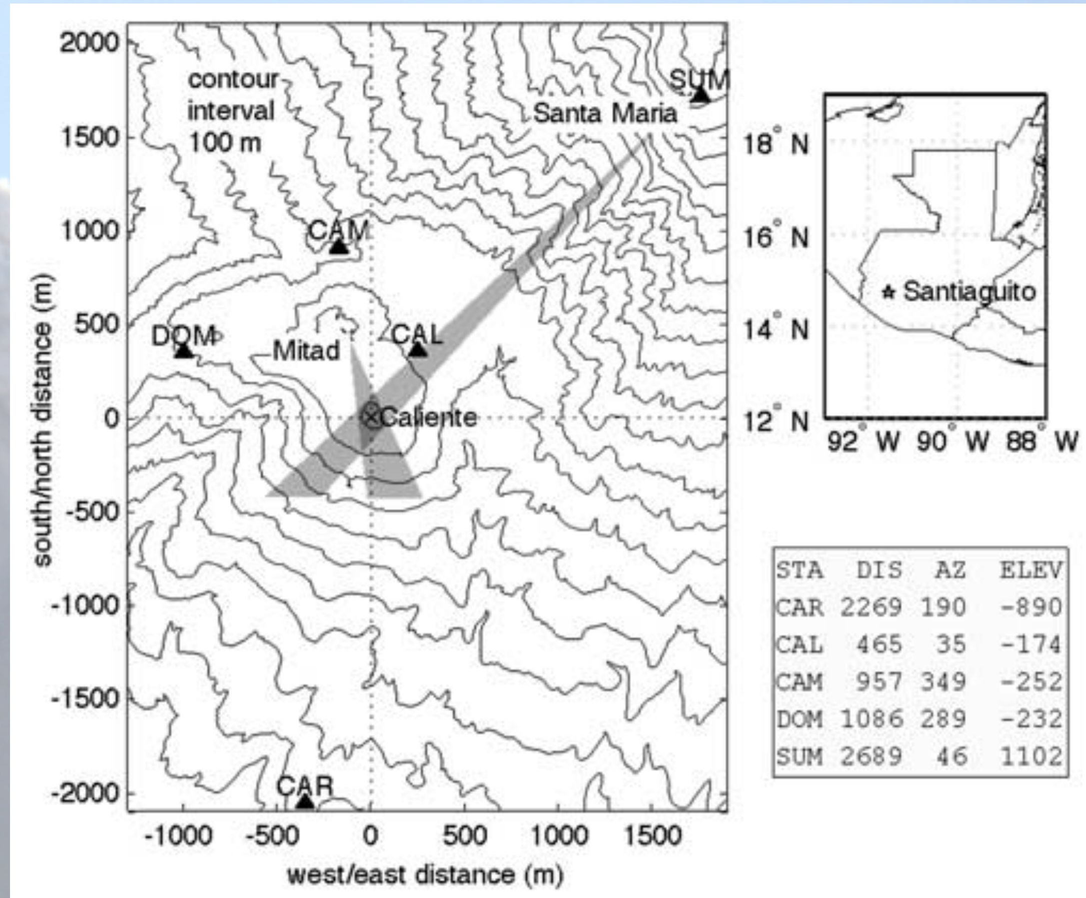
- Combining seismic, acoustic and gas data allow recording and interpretation of volcanic processes at variable timescales


Photo: Nick Varley

Santiaguito: A composite volcanic earthquake

- 4 broadband seismometers
- 6 acoustic pressure transducers
- HD video cameras on Sta. Maria and La Mitad
- > 10 explosive eruptions per day
- Relatively long duration events (>8 min) and broadband instruments allow for investigation of events with different timescales

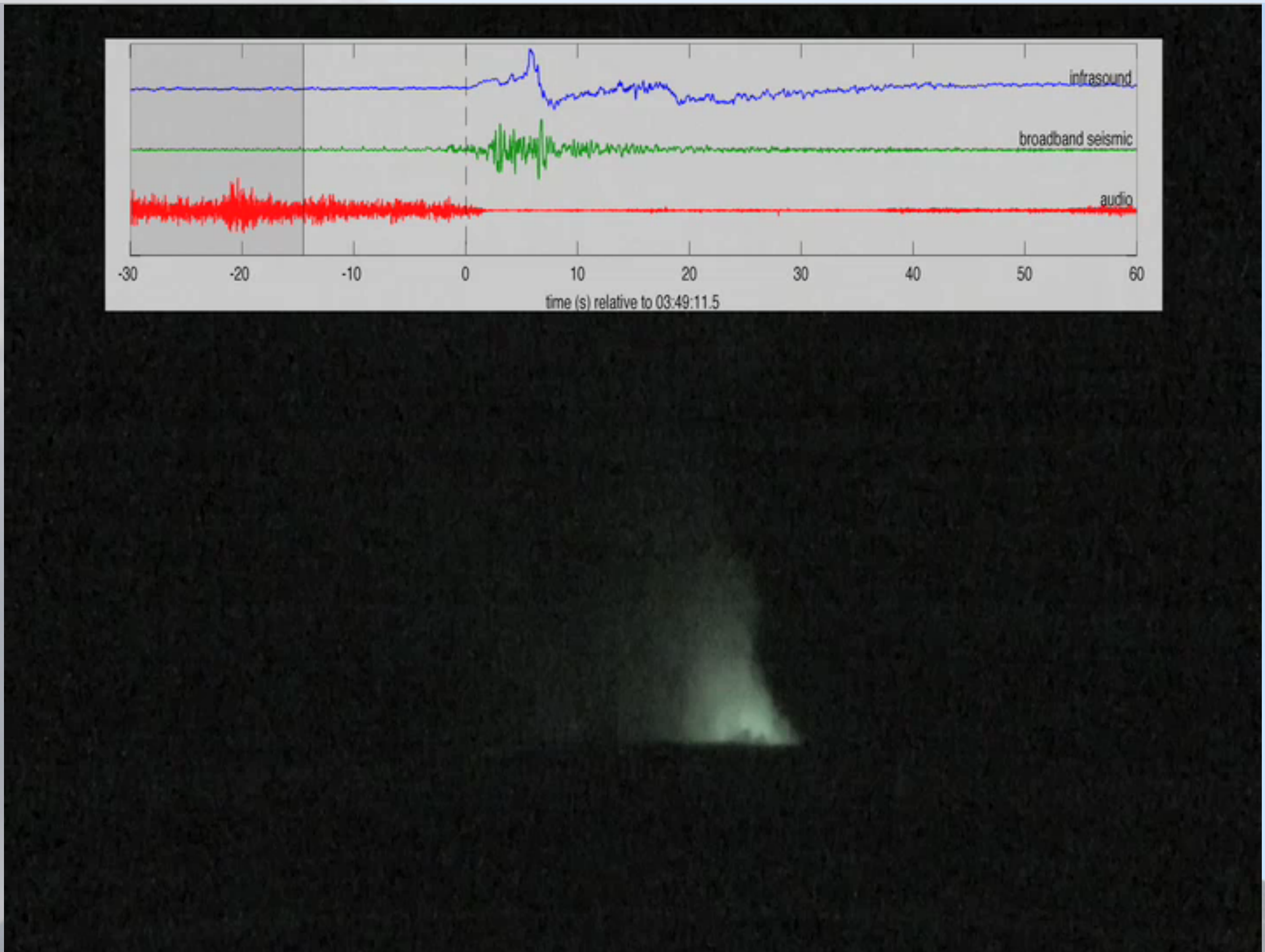
- Multiple filters allow for distinction of many volcanic processes
- ULP 600 – 30 s
- VLP 30 – 5 s
- LP 5 – 1 s
- SP 1 – 10 Hz
- HF 10 -50 Hz



STA	DIS	AZ	ELEV
CAR	2269	190	-890
CAL	465	35	-174
CAM	957	349	-252
DOM	1086	289	-232
SUM	2689	46	1102

[Johnson, Sanderson, Lyons, Escobar-Wolf, Waite, and Lees, GRL, 2009]

Santiaguito: A composite volcanic earthquake



HD video: [*http://www.youtube.com/watch?v=M5Kfv8_ZC2c*](http://www.youtube.com/watch?v=M5Kfv8_ZC2c)

Santiaguito: A composite volcanic earthquake

i. Start of jetting noise and incandescence (video and audio)

ii. Infrasound (SP and LP) and seismic transient (SP, LP and HF)

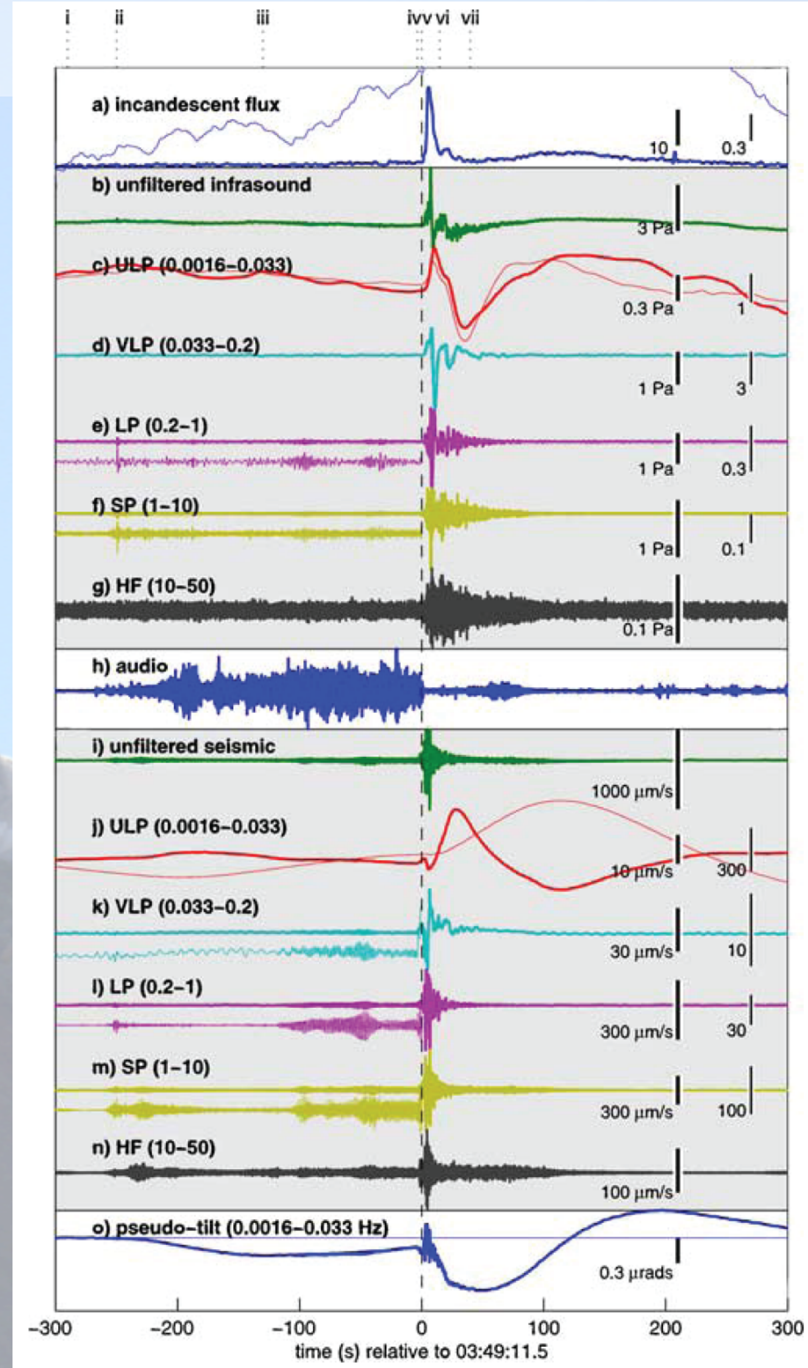
iii. Emergence of harmonic infrasonic and seismic tremor (0.43 Hz)

iv. Rapid increase in seismic amplitude (HF and VLP)

v. Explosion visible at the vent and jetting noise stops

vi. Secondary explosion visible accompanied by seismic pulse (SP and LP)

vii. Return of audible jetting




Questions?