Characterization of eruption source parameters through infrasound

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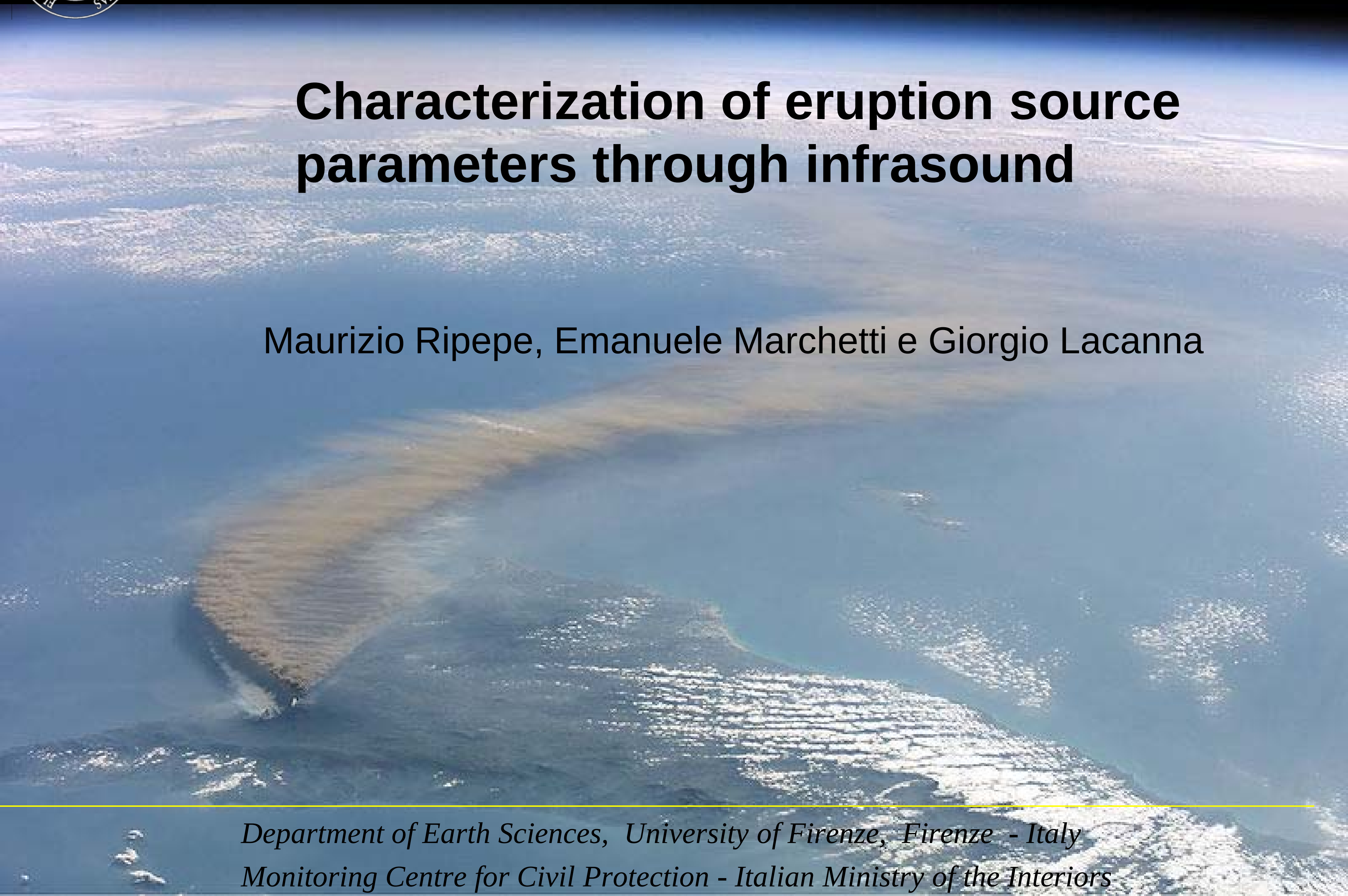
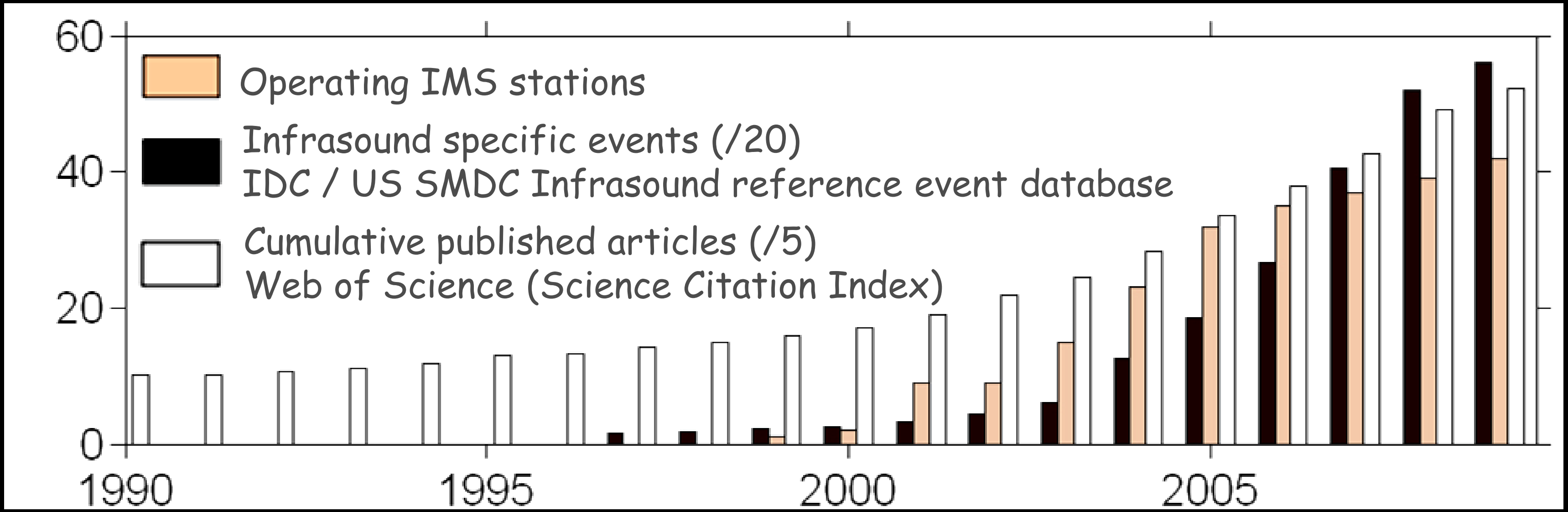
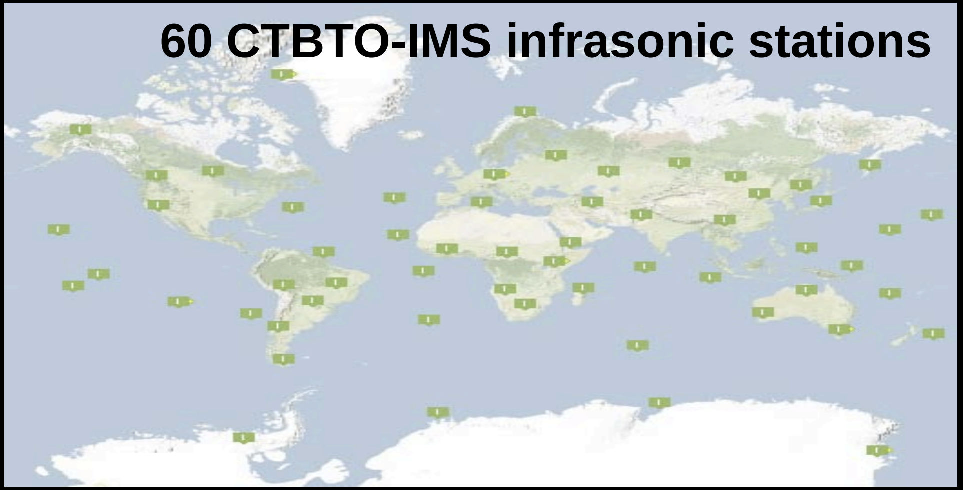


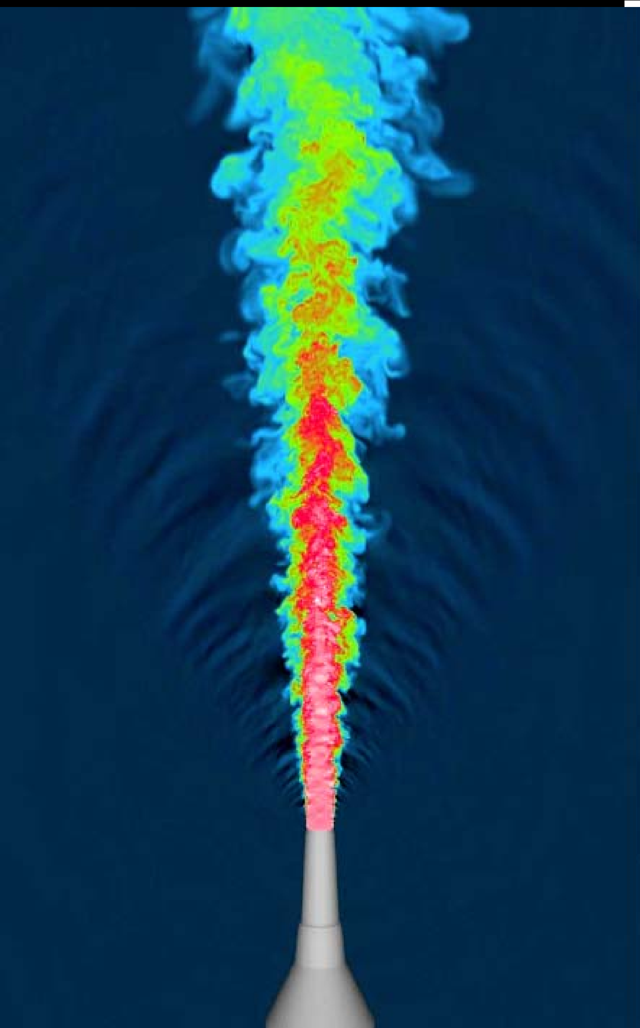
Infrasound : a growing research field in physics of atmosphere and volcanology

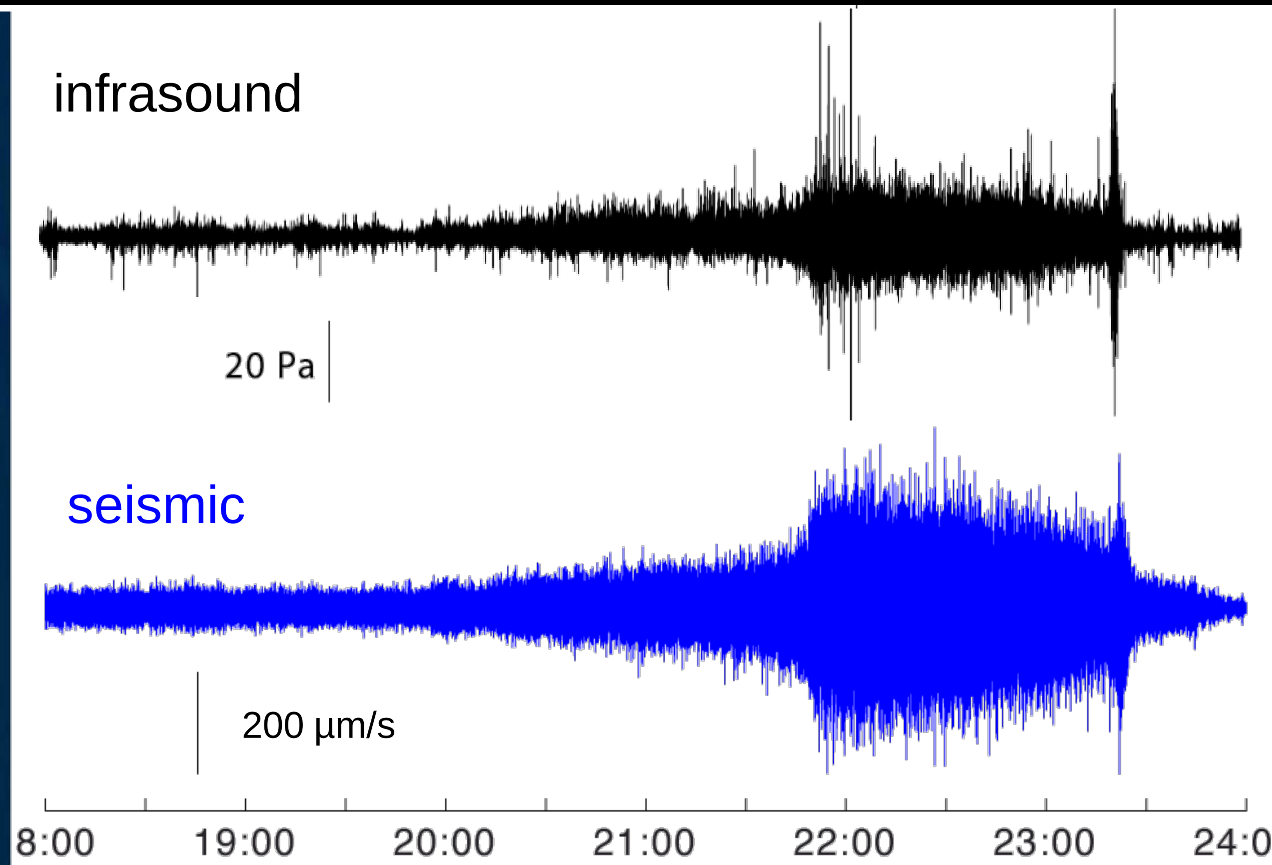


Number of published papers
- until 1998: 1 to 3 per year
- after 1998 : up to 30 per year)



Infrasound versus Seismic Records





Ulivieri et al. (2013)

Infrasound

$$dB_{acoustic} = 10^{-4}\left(\frac{dB}{km}\right)$$

Sutherland & Bass (2002)

Seismic

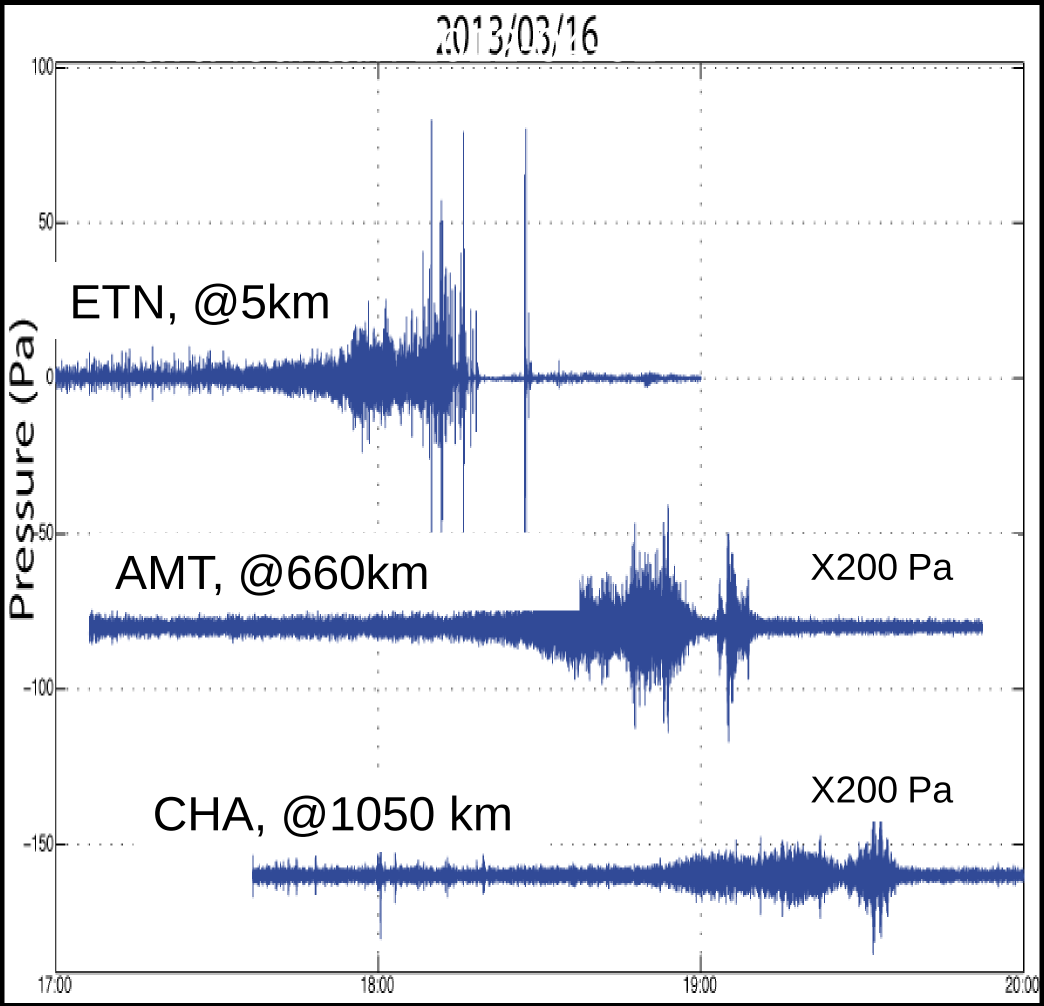
$$dB_{seismic}(4\,Hz) = 10^{0}\left(\frac{dB}{km}\right)$$

Infrasound has lower absorption and propagates better than seismic waves

Remote Infrasonic Monitoring

ARISE
Atmospheric dynamics Research InfraStructure in Europe

WP4 – Monitoring of extreme events

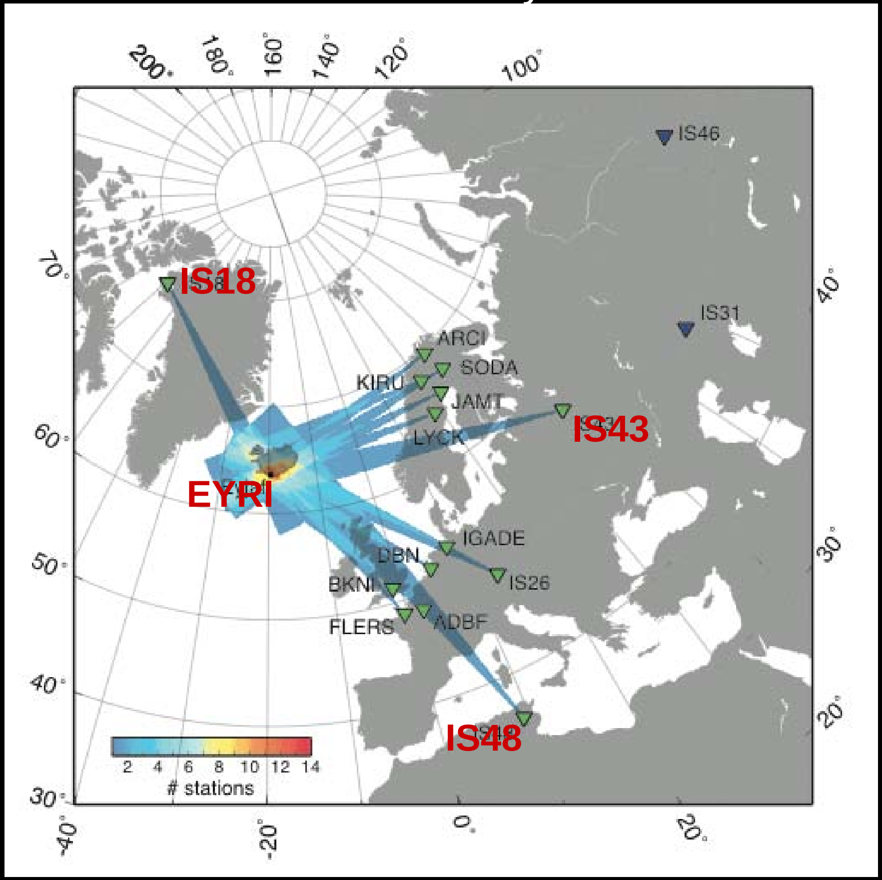


Marchetti et al., 2013

Infrasonic waveform can be preserved also with Arrival time of 66 minutes

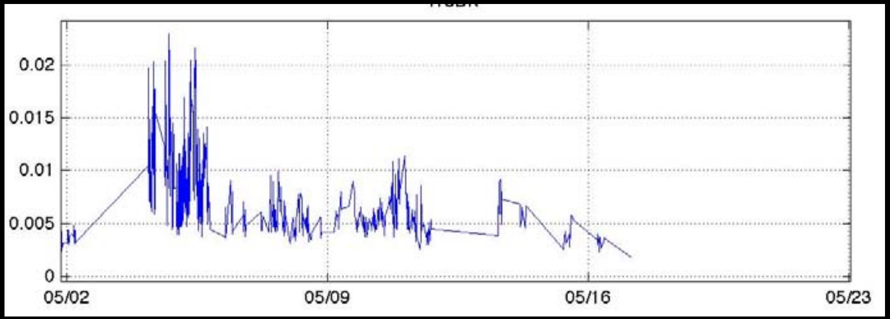
Infrasonic Monitoring at Regional Scale

Infrasonic IMS & Nat. Arrays

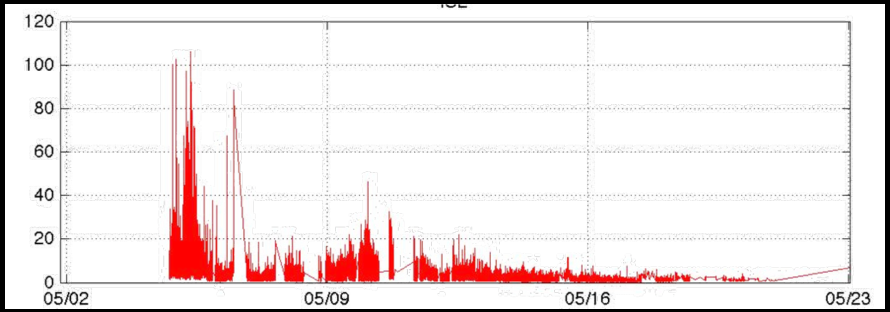


(Matoza et al., GRL, 2009)

I18DK @2300 km

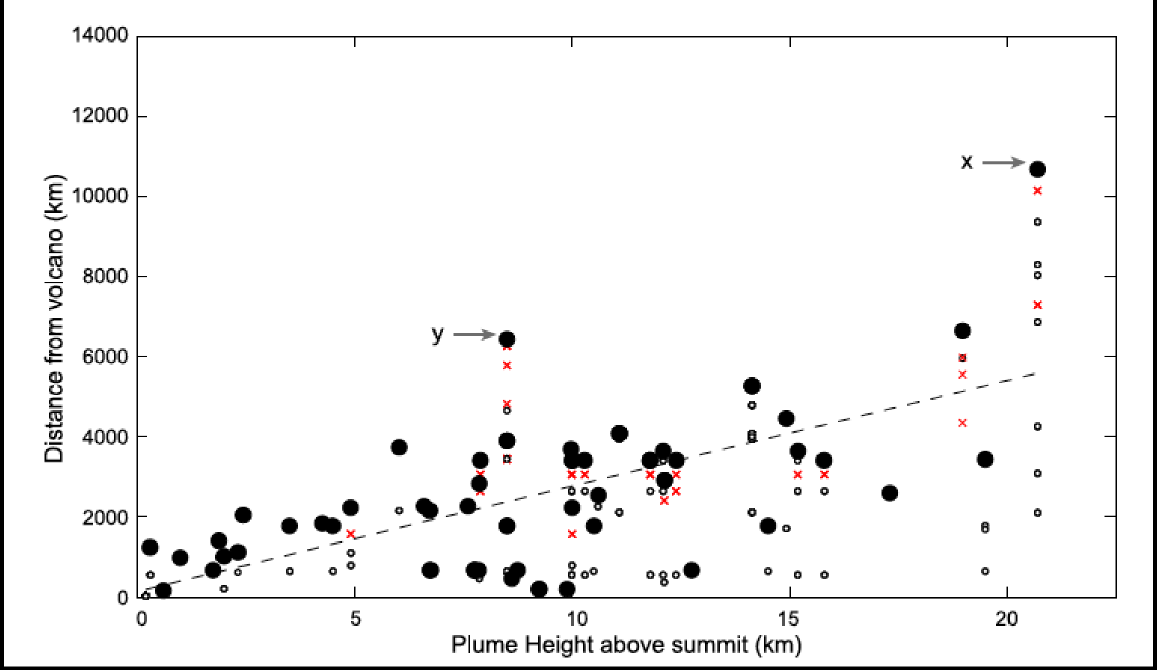


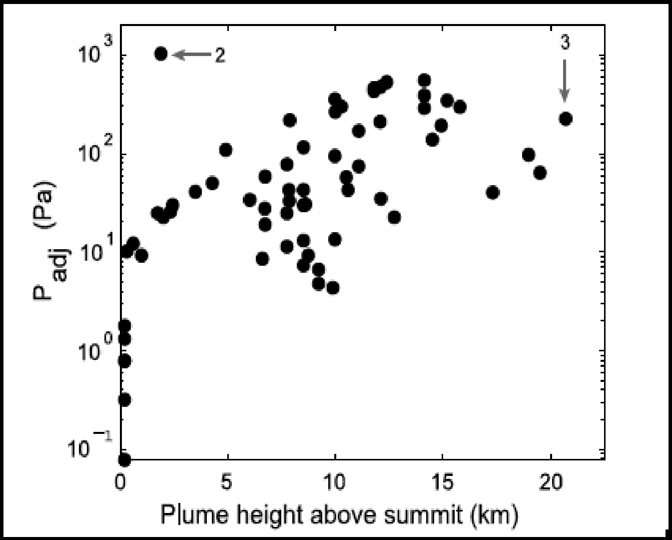
EYRI @8 km



Acoustic Pressure in Greenland shows same variation as at the Source

Infrasonic Monitoring at Regional Scale

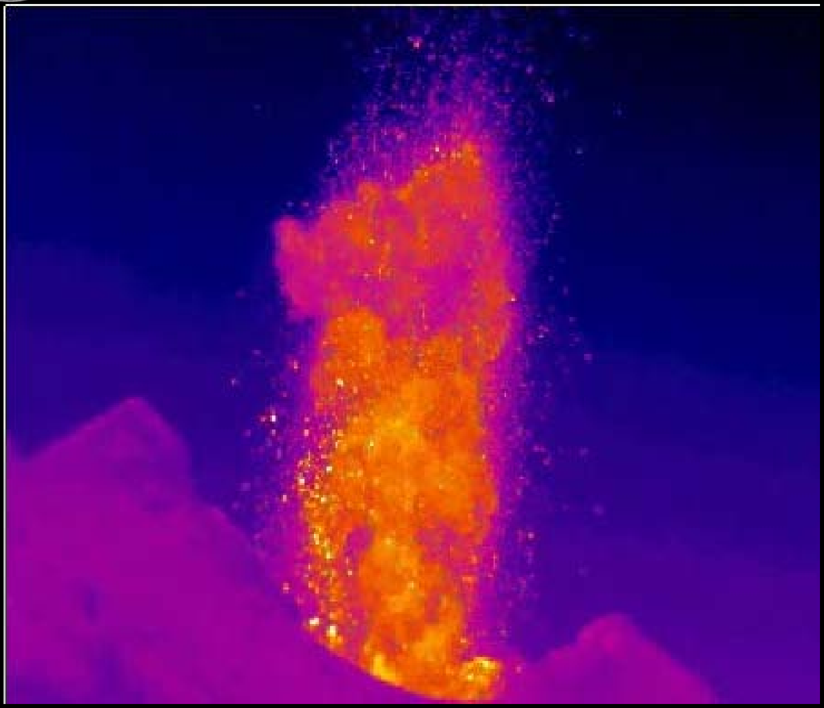


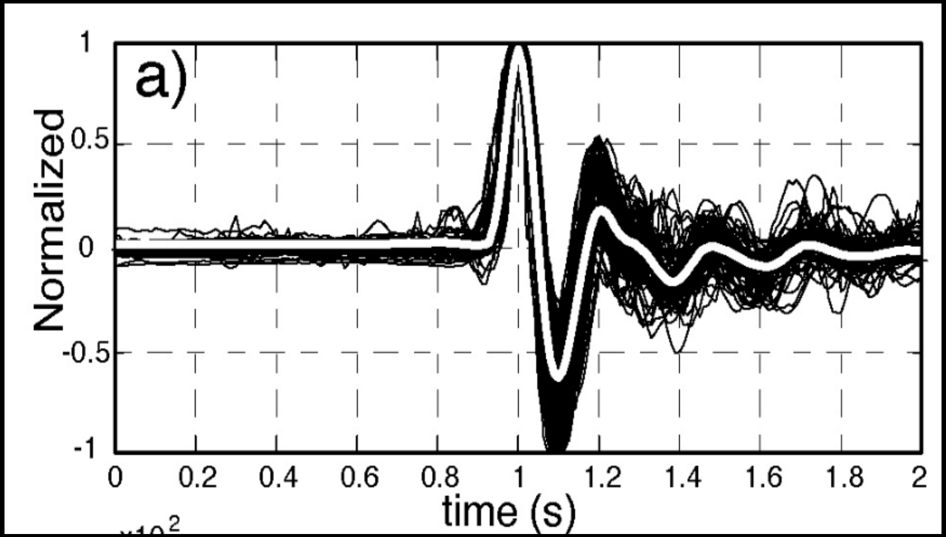


Dabrowa et al., EPSL, 2011

maximum distance of detection generally increases with the plume height,

Modelling Volcano Acoustic Source





Acoustic Pressure and Source Expansion Velocity

$$p(t) \approx U^n$$

$n = 2, 3, 4$ *According to source dynamics (monopole, dipole, quadrupole)*

Acoustic pressure (*p*) can be linked to Volumetric Flux Q

Volumetric Flux (m³/s)

$$Q = \pi a^2 \cdot U$$

→

Plume Height (m)

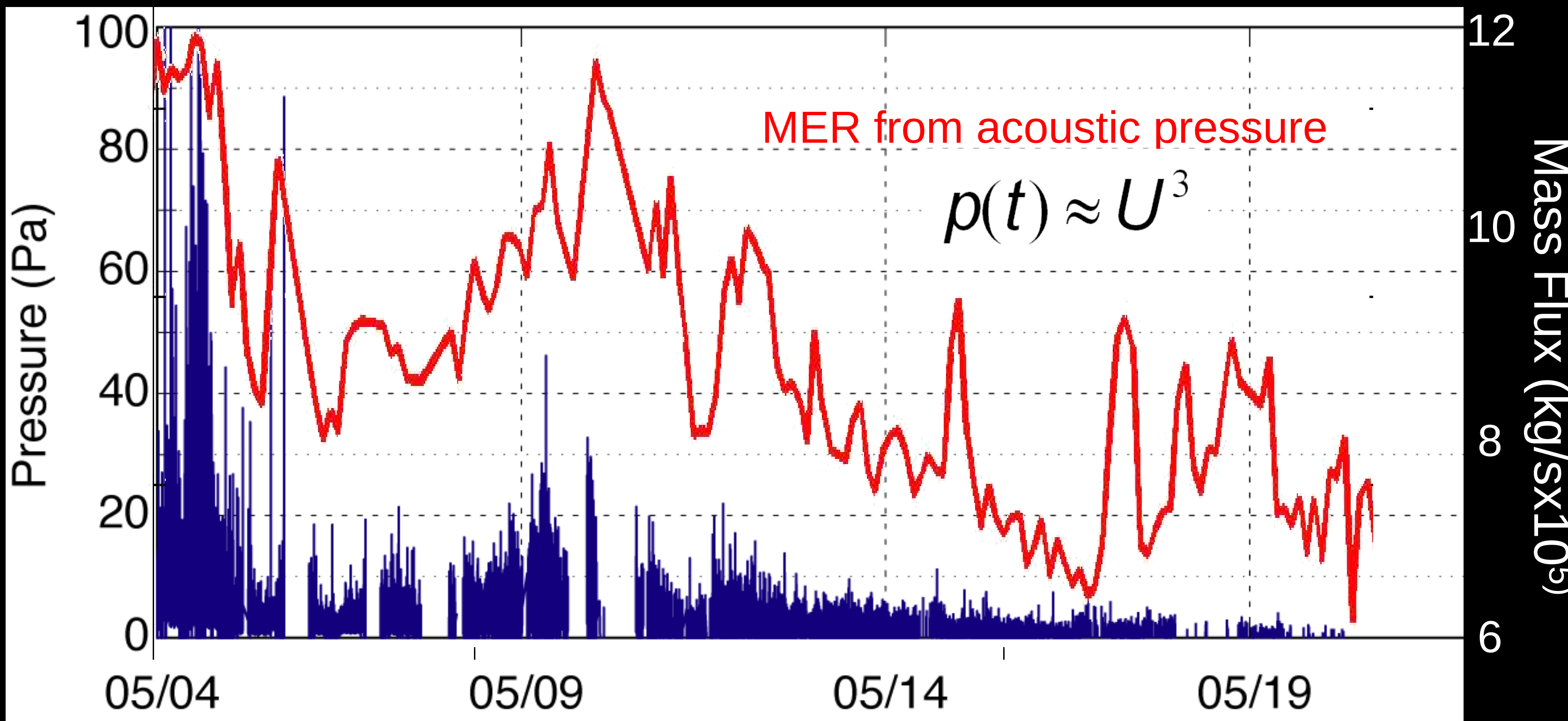
$$H = 2 \times Q^{0.241}$$

Mastin et al., 2009

Infrasound and Mass Eruption Rate

Eyjafjallajökull

Acoustic Pressure recorded by array



Acoustic-derived Mass Eruption Rate

$$Q = 6.76 \cdot \rho_{plume} a^{1.66} \cdot \left(\frac{rc\langle p \rangle}{\rho_o} \right)^{1/3}$$

where:

a = 25 m source radius

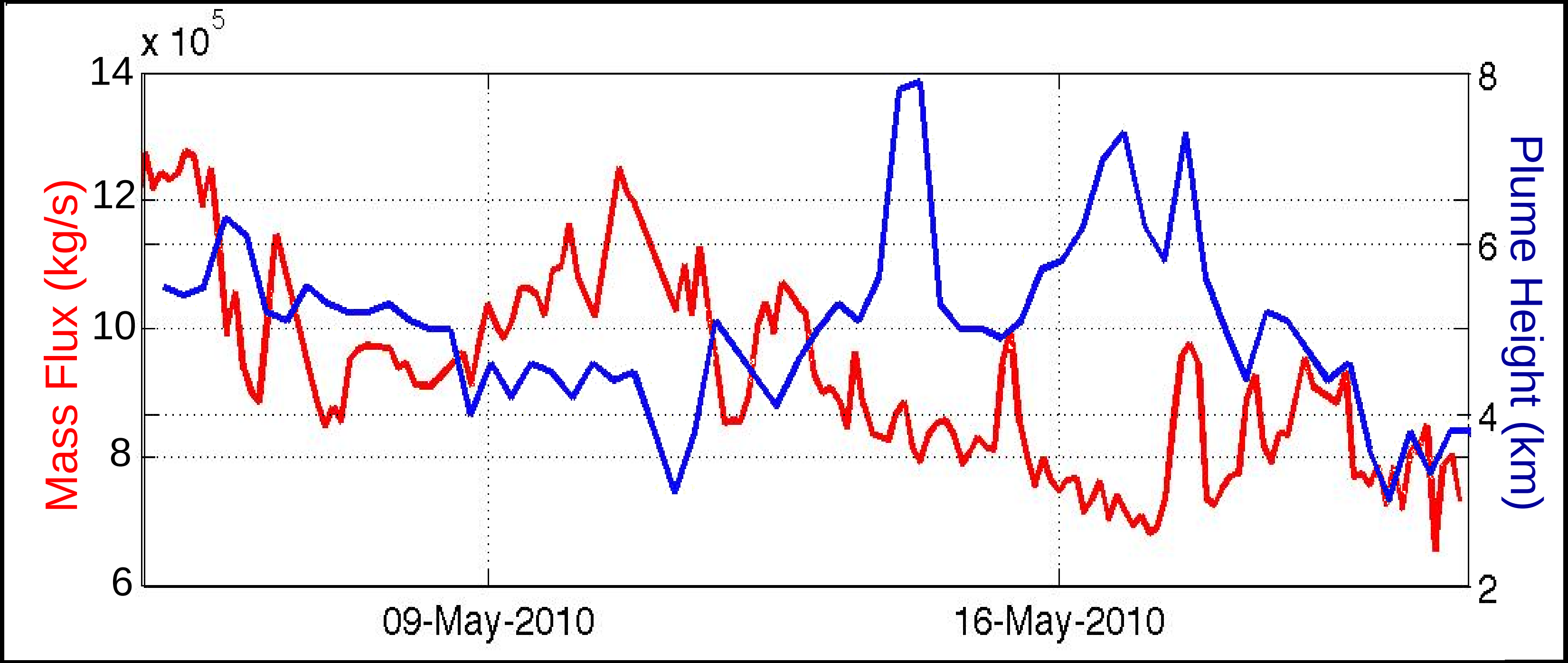
r = 8300 m distance from source

c – 330 m/s Speed of sound

ρ_o – air density

$\rho_{plume} = 5.4$ Kg/m3 plume density

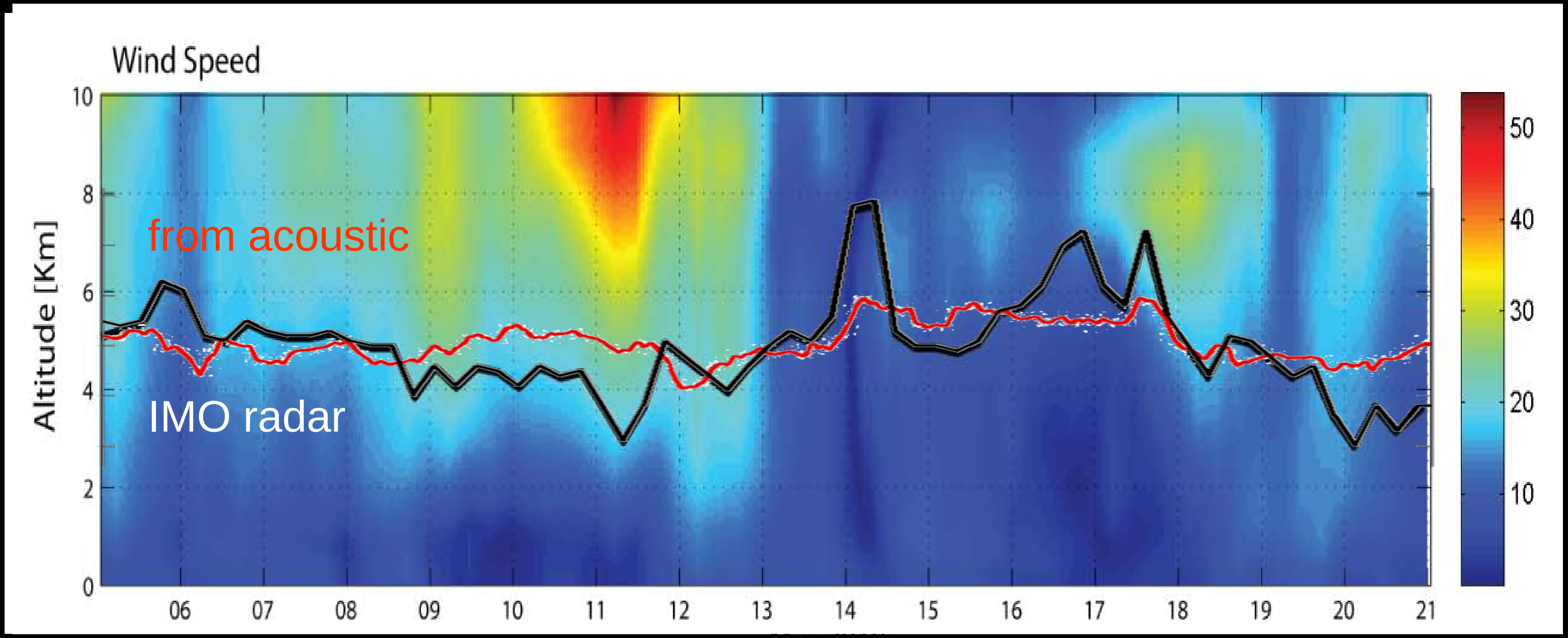
Acoustic-Derived Mass Flux & Plume Height



Mass Eruption Rate derived by acoustic is decoupled from Plume height

Acoustic-Derived Plume Height

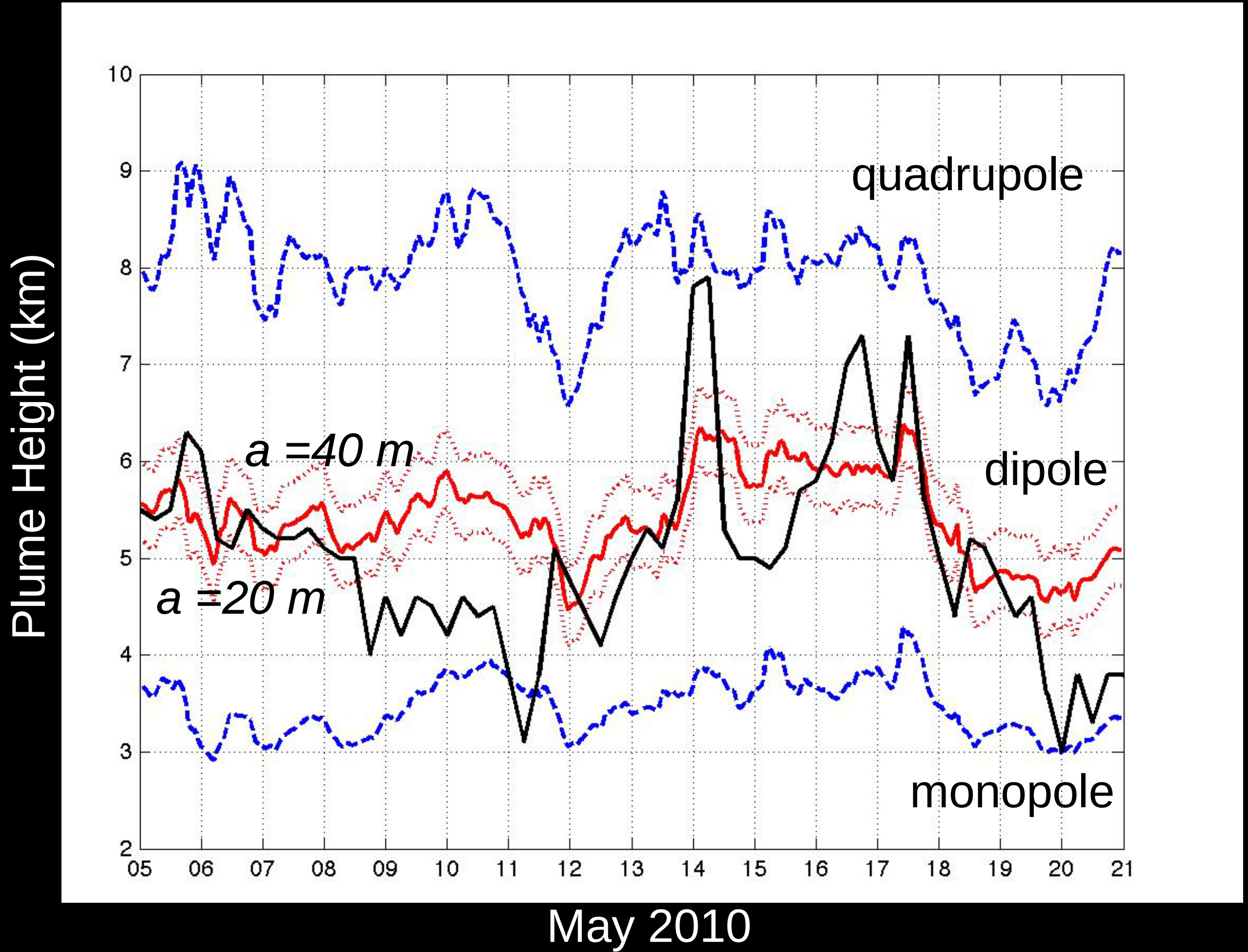
Plume height calculated from acoustics and Wind Profile



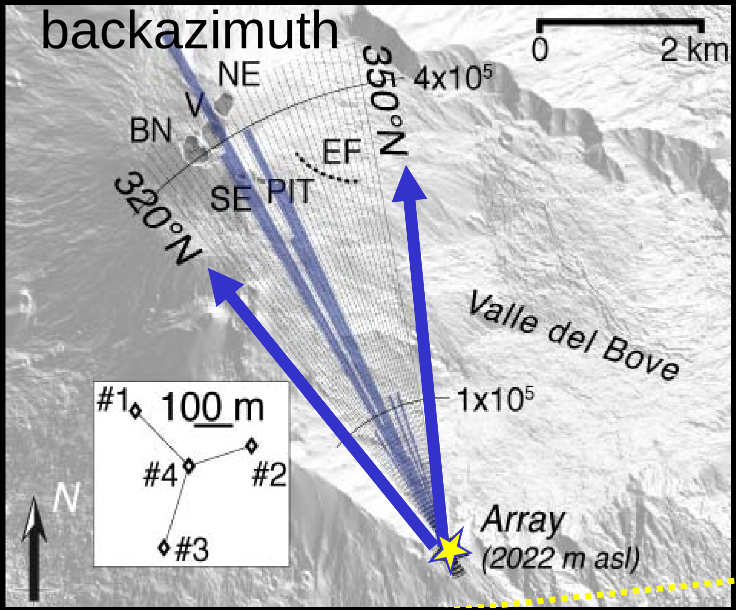
(Ripepe, Bonadonna, Folch, et al., EPSL, 2013)

Buoyancy Plume Theory (BPT) 1D modelling using acoustic-derived MER including wind field and temperature profiles from the ECMWF

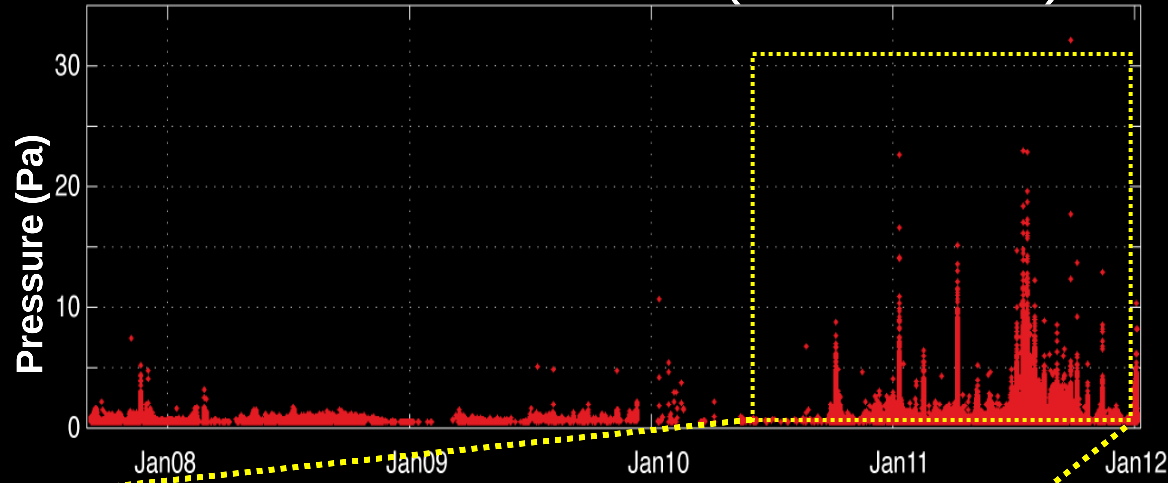
Infrasonic Modelling Uncertainty

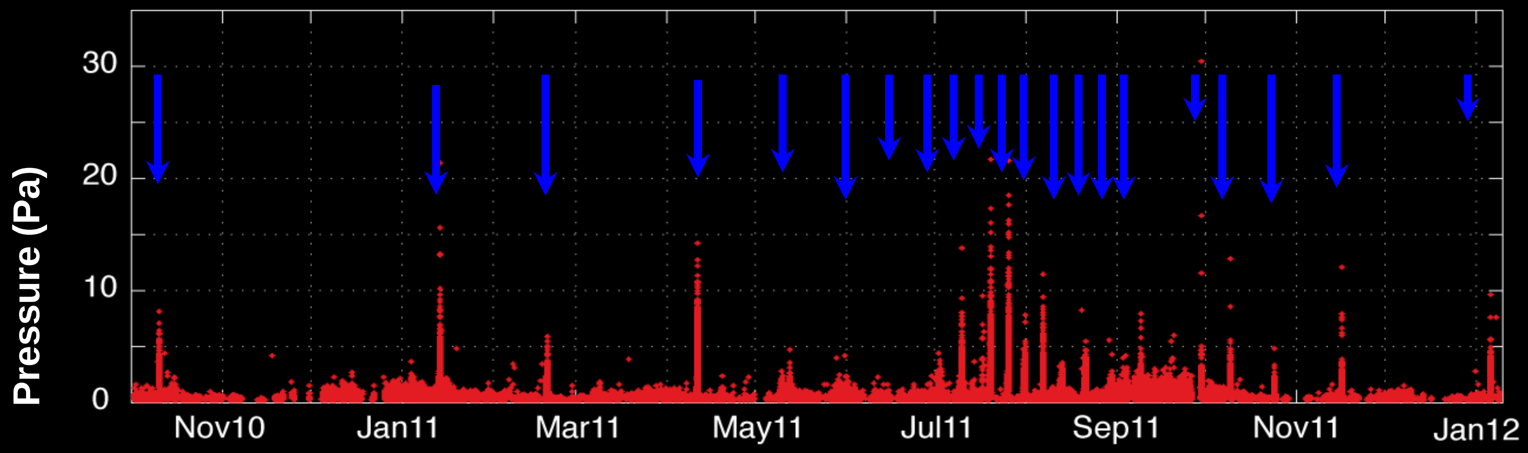


Infrasound Real-Time Monitoring at Etna



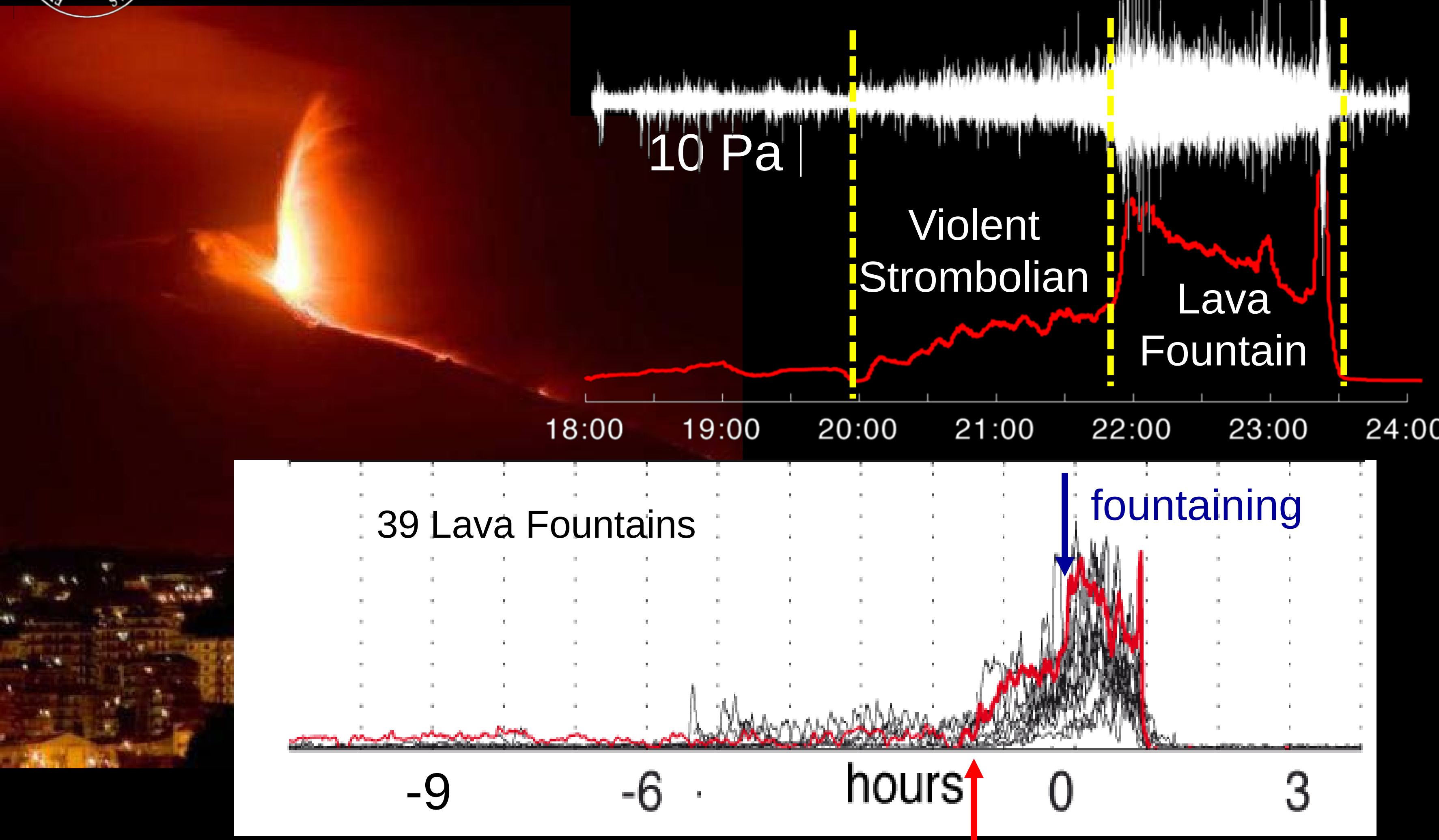
Infrasound Detections (~4 millions)





43 Lava-fountains in the last two years

Infrasound Real-Time Monitoring at Etna

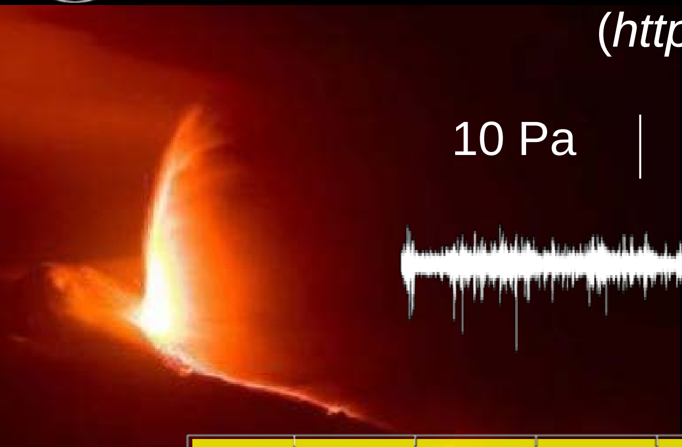


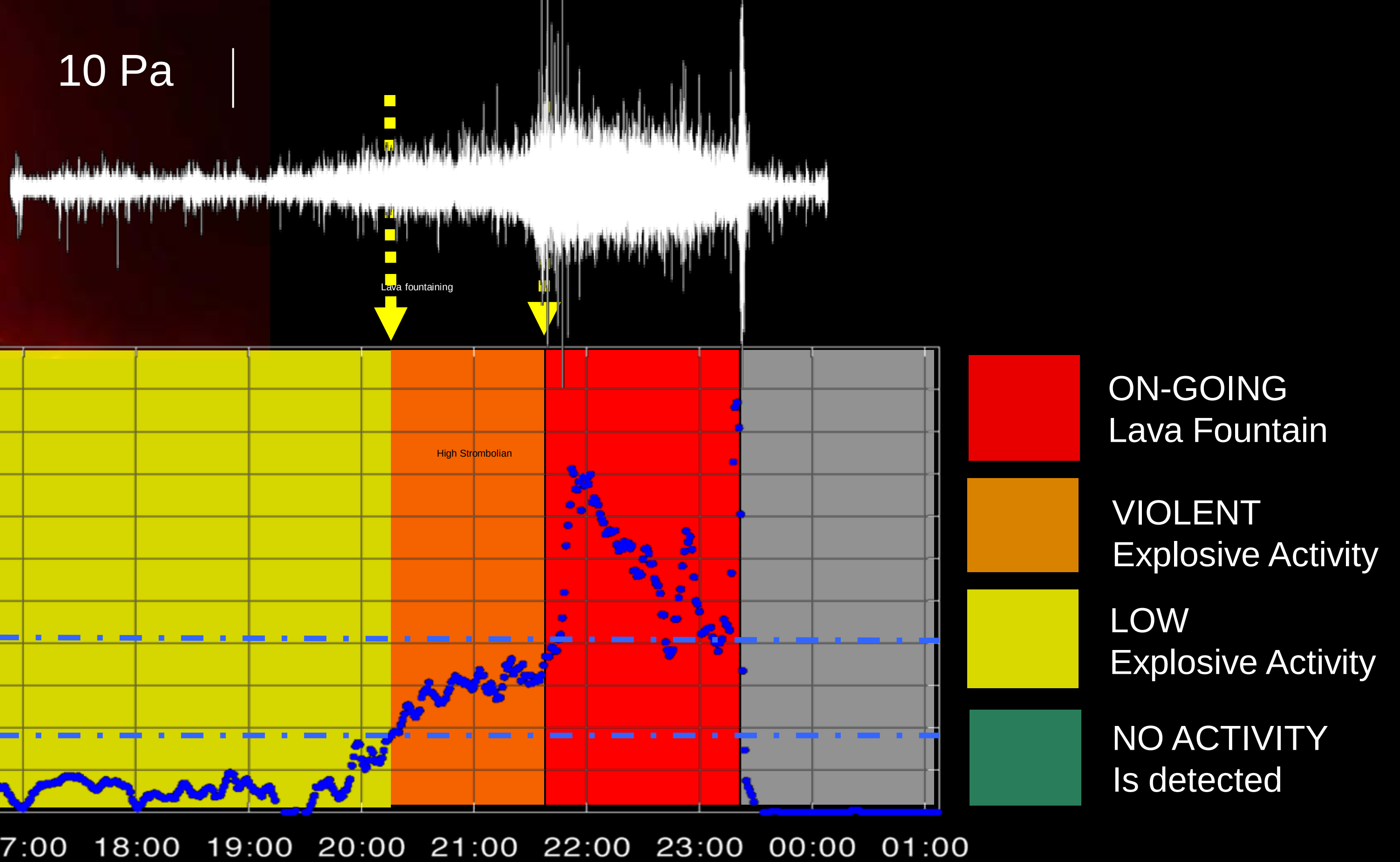
(Uliveri et al., 2013)

Infrasound has similar trend, increasing up to 3 hours before the fountaining

Infrasonic Early-Warning System

(*http://lgs.geo.unifi.it/etna*)



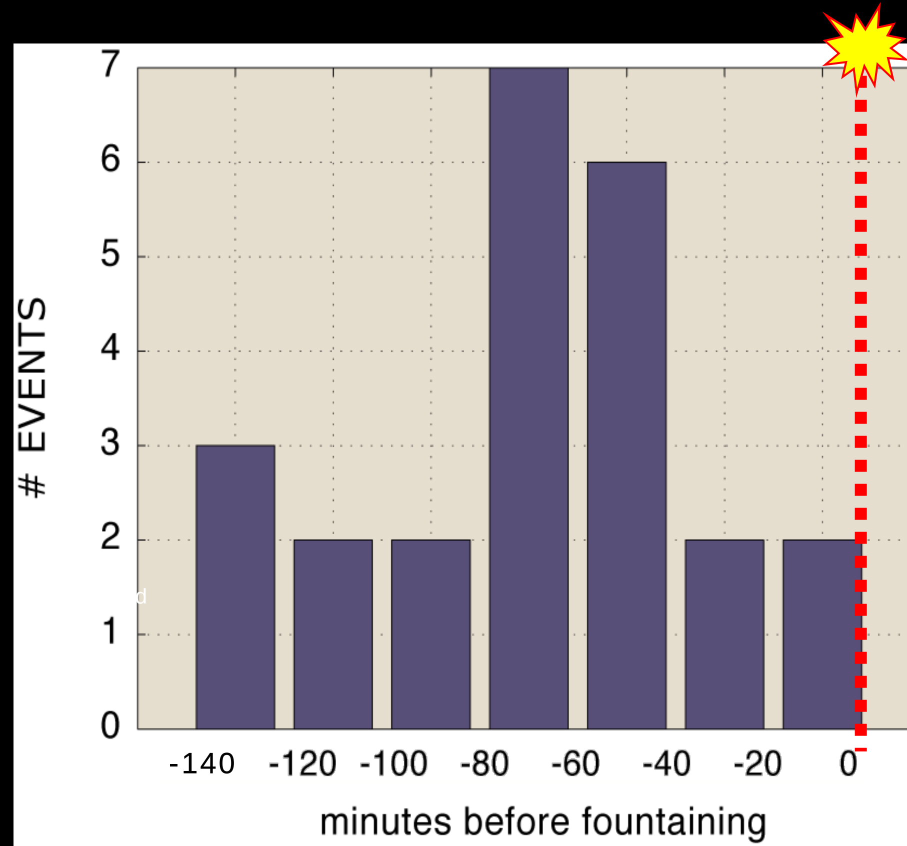


42/43 Lava fountains detected (97%) No FALSE Alerts in the last 4 years

Infrasonic Early-Warning System

-------- Messaggio originale --------
Oggetto: ETNA EARLY-WARNING
Data: Tue, 5 Mar 2013 23:41:42 +0100 (CET)
Mittente: labgeofisica@geo.unifi.it
A: labgeofisica@unifi.it

```
time: 05-Mar-2013 22:41:00 GMT
ALERT LEVEL: HIGH (RED)
Ongoing lava fountain
```



Alerts automatically delivered to Italian Civil Defence by e-mails and SMS messages in average ~60 minutes before the lava fountaining

Summary

Infrasound Monitoring is ready to deliver in Real-Time

- Onset of the Eruption
- Location of the Source
- Duration of eruption

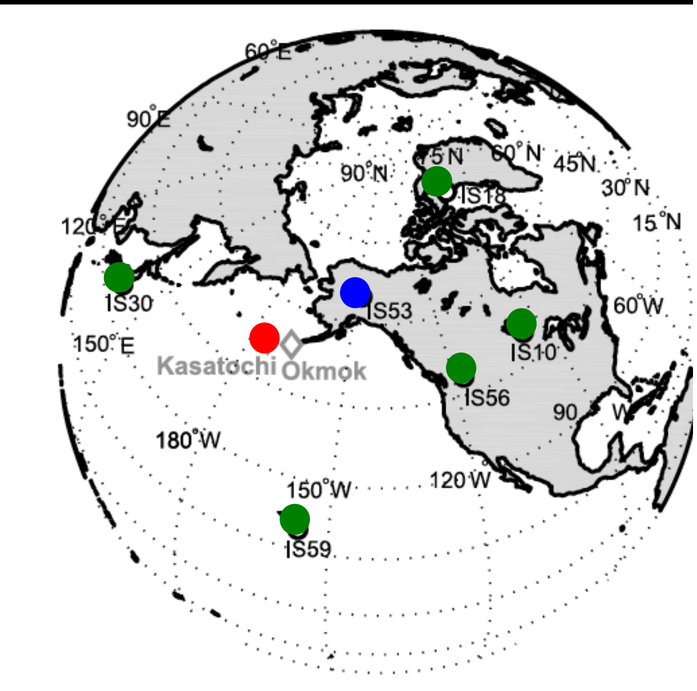
Given the appropriate Source Model can provide

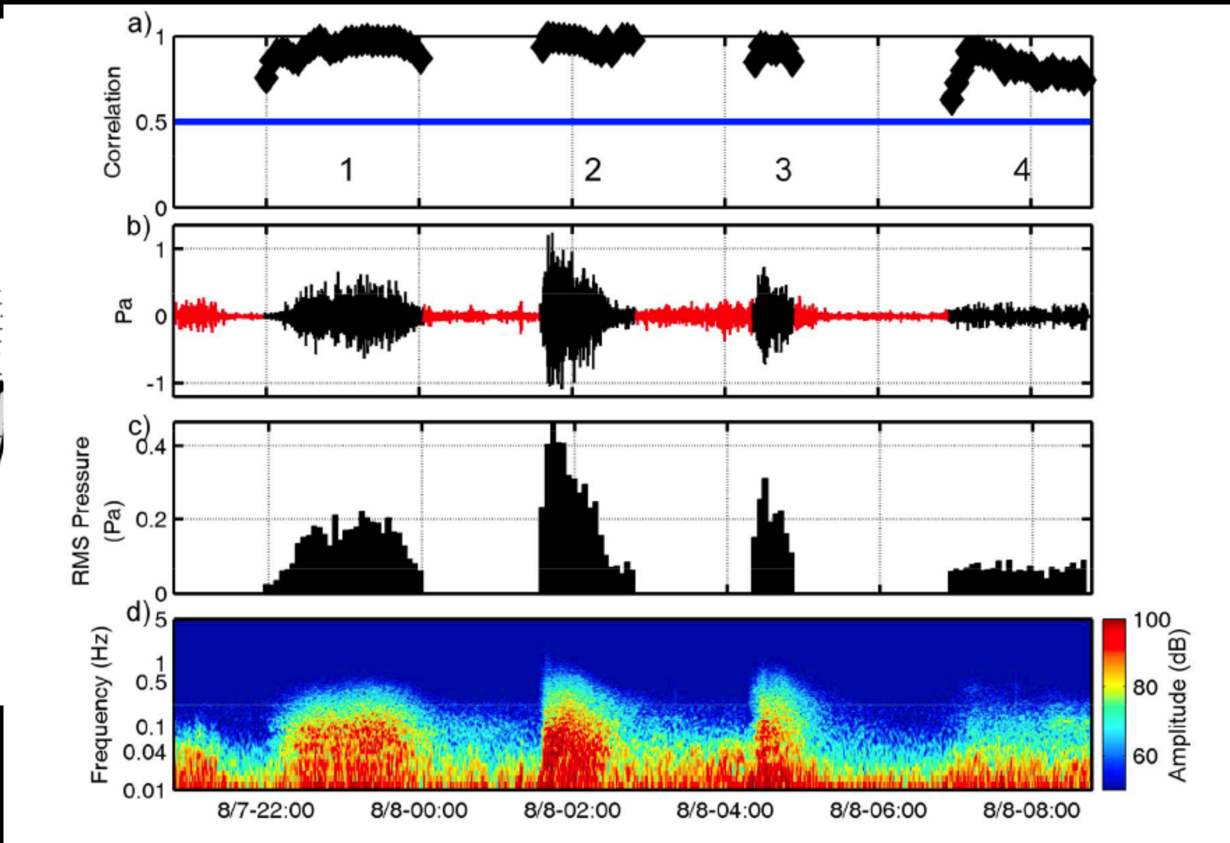
- Plume exit velocity
- Volume Eruption Rate
- Plume Height

Next Challange:

- Monitoring at Regional scale and in REAL-TIME

Infrasonic Monitoring at Regional Scale





(Fee et al., 2010)

Infrasound recorded at IS53 @2100 km for Kasatochi eruption
6 stations ranging from 2100 to 5400 km recorded the eruption