Seismological characterization of dynamics parameter of the Hunga Tonga explosion from teleseismic waves

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MONIFAULTS

SEISMAZE

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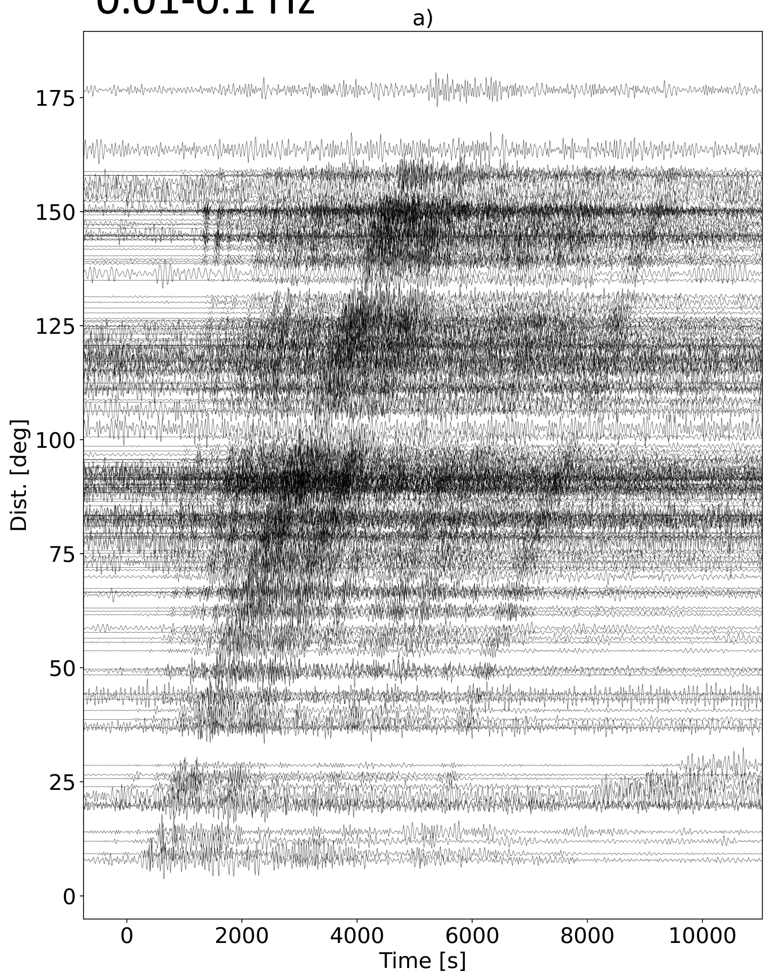
Outline

- seismological detection of volcanic explosions
- seismological characterization of explosion size
- results for the Hunga-Tonga explosion

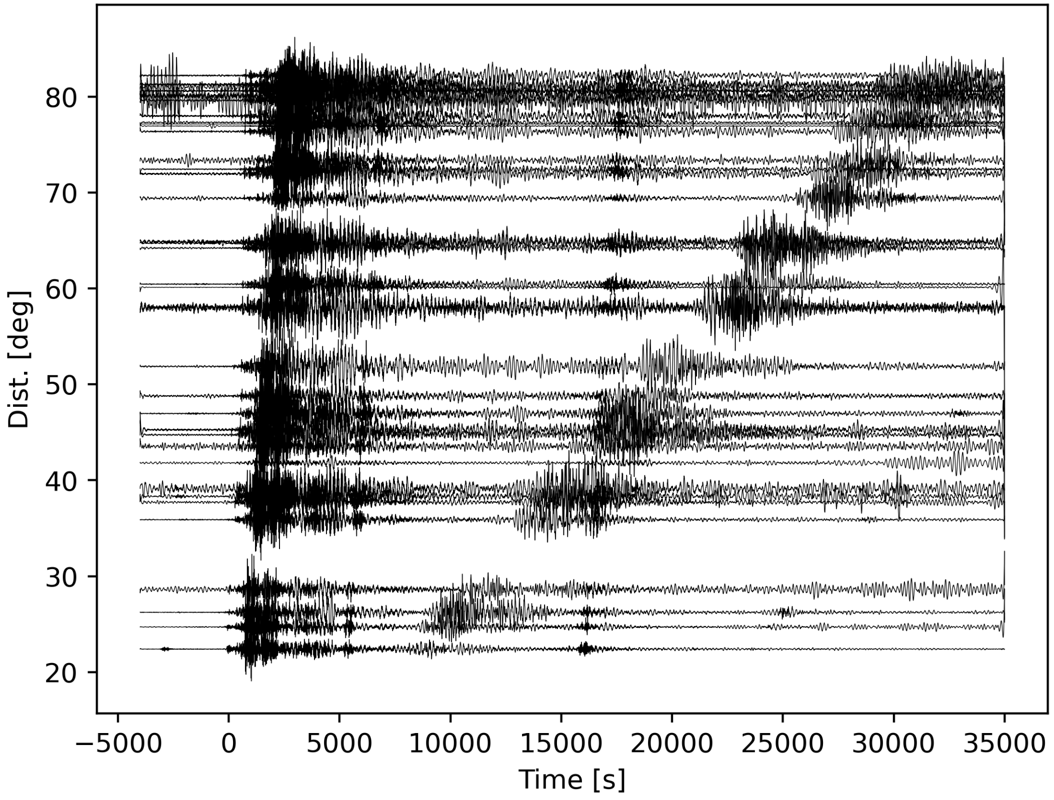
Hunga Tonga volcanic explosion

records of global seismological network

0.01-0.1 Hz



0.002-0.1 Hz



Data

- **NETWORKS:** _GSN, GE, G, _ARCTIC, _ANTARTICA
- **DATA CENTERS:** IRIS, GEOSCOPE, GFZ
- **CHANNELS:** LHZ, VHZ

  Data downloaded every day

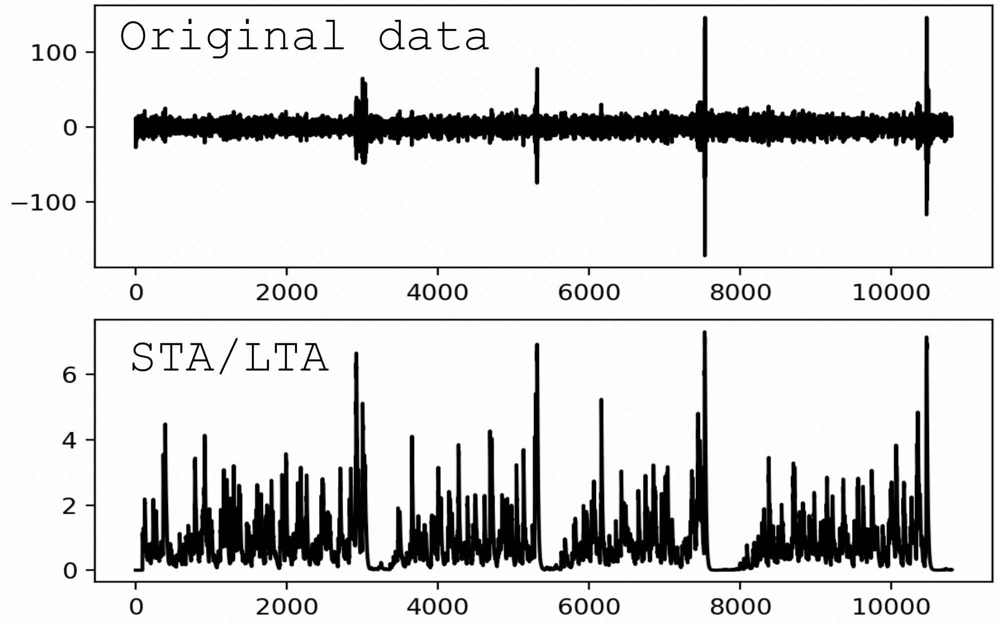
  T0 = 00h00m00s (for given day)

  Data span = T0-3h | T0+3h (To account for detections around midnight)

- **AVERAGE STATIONS NUMBER:** 130

Detection algorithm

- **FB:** 0.01-0.03Hz
- **Deconvolution Instrumental Response**
- **Characteristic function:** Recursive STA/LTA[1] (STA=120s LTA=900s)
- **Source grid:** One source every 2.5deg at 0Km depth (9940 sources)



1 -Withers, M., Aster, R., Young, C., Beiriger, J., Harris, M., Moore, S., and Trujillo, J. (1998),
A comparison of select trigger algorithms for automated global seismic phase and event detection,
Bulletin of the Seismological Society of America, 88 (1), 95-106.
http://www.bssaonline.org/content/88/1/95.abstract

Detection algorithm: delay and stack

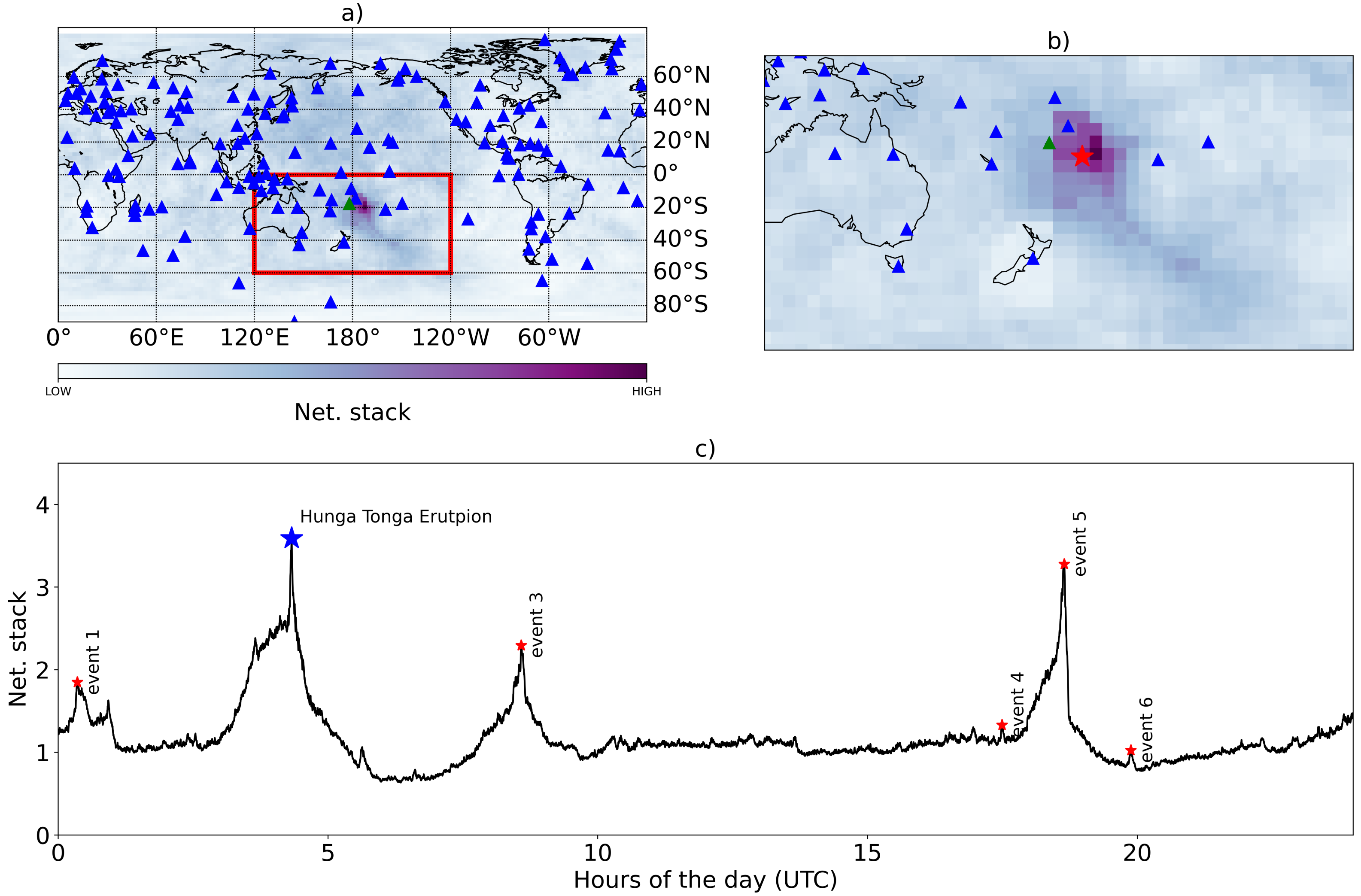
- **i = sources**
- **j = stations**

- $E(i,t) = \sum_{j=1}^{N} u_j(t - dt)$ **Matrix = [Sources;Time]**

- ***[max E] (t)***

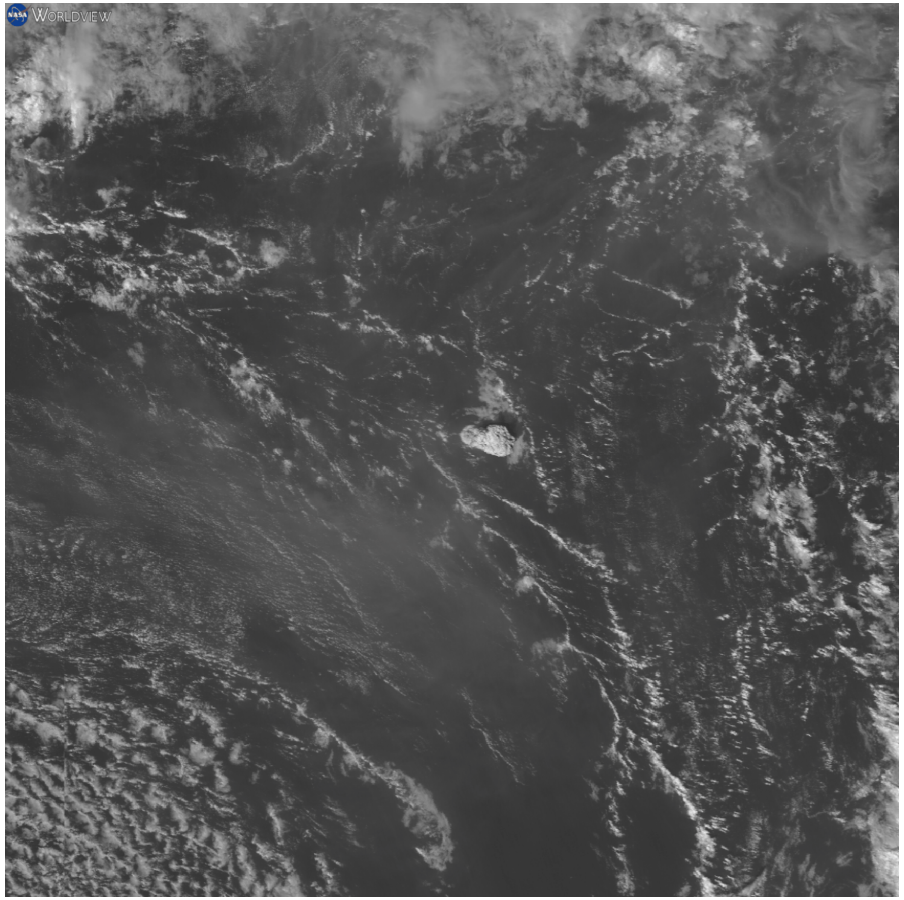
dt is the propagation estimated from distance from the sources assuming **Rayleigh waves** speed from **PREM** model

Hunga Tonga volcanic explosion

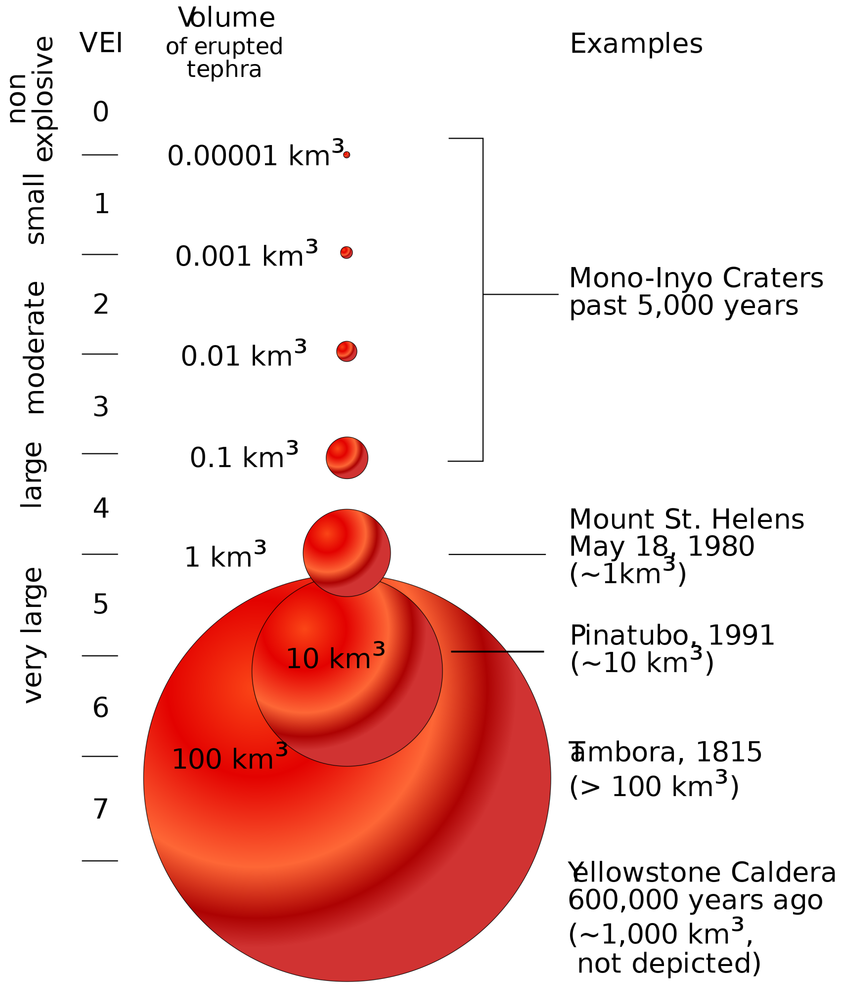


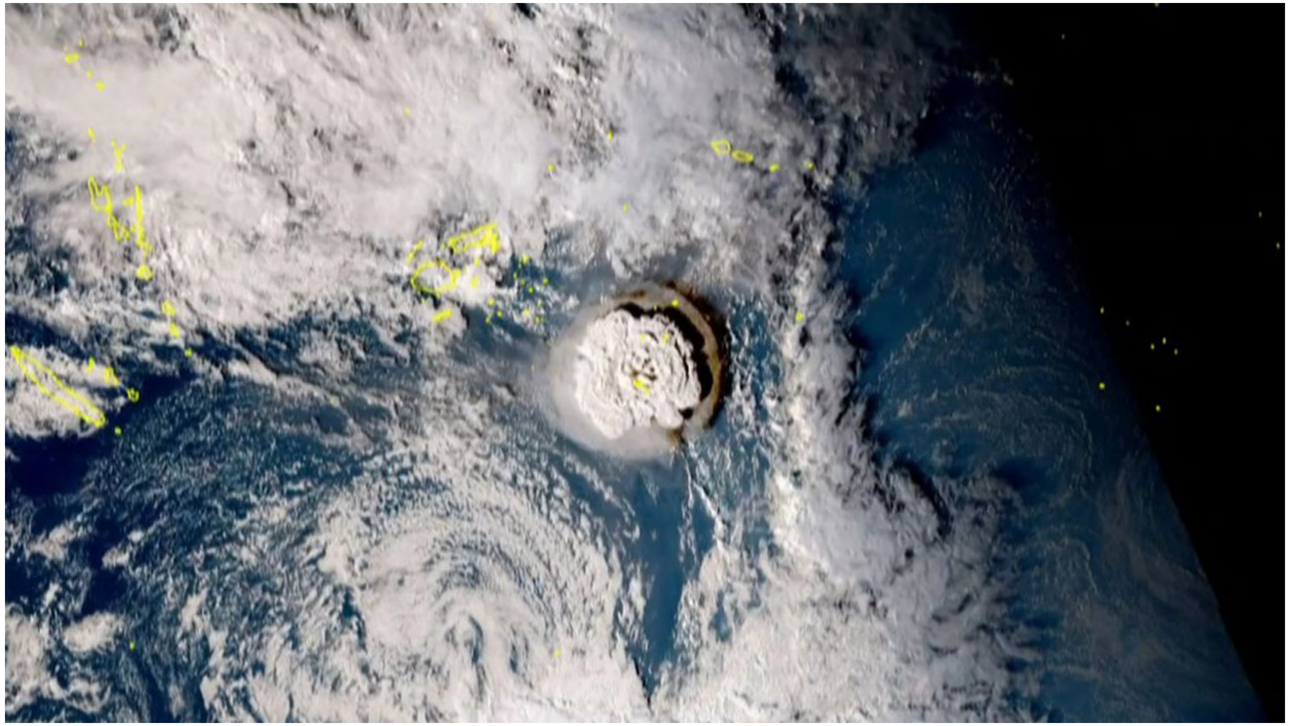
Poli & Shapiro, 2022

Hunga Tonga volcanic explosion



Seismological assessment of the Hunga Tonga volcanic explosion





Hunga Tonga volcanic explosion

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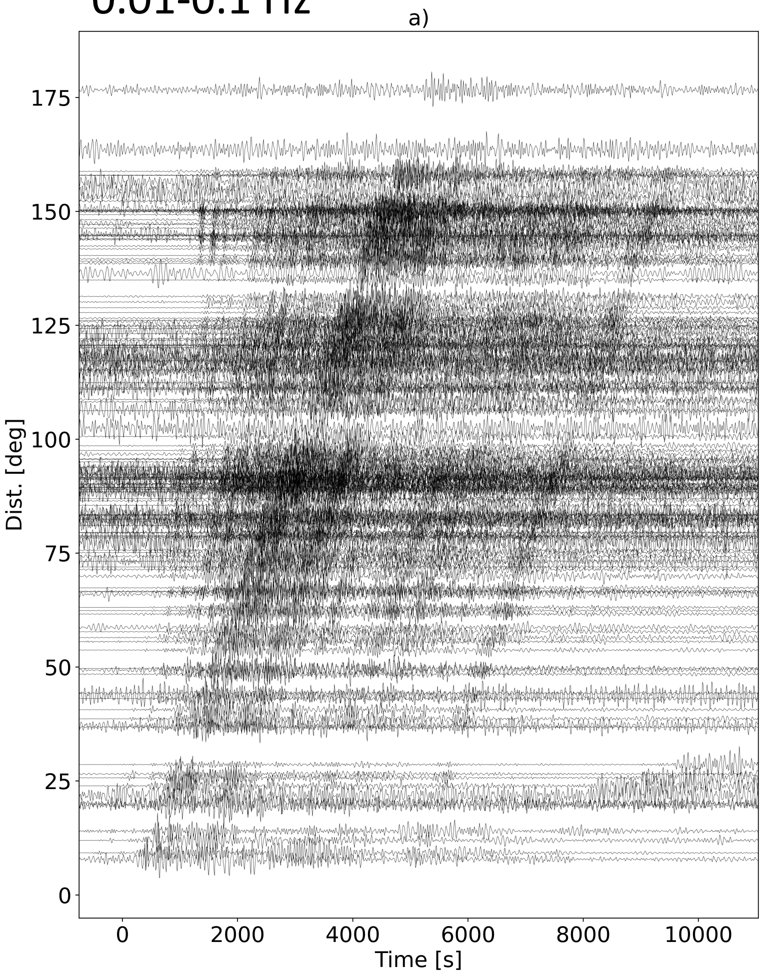

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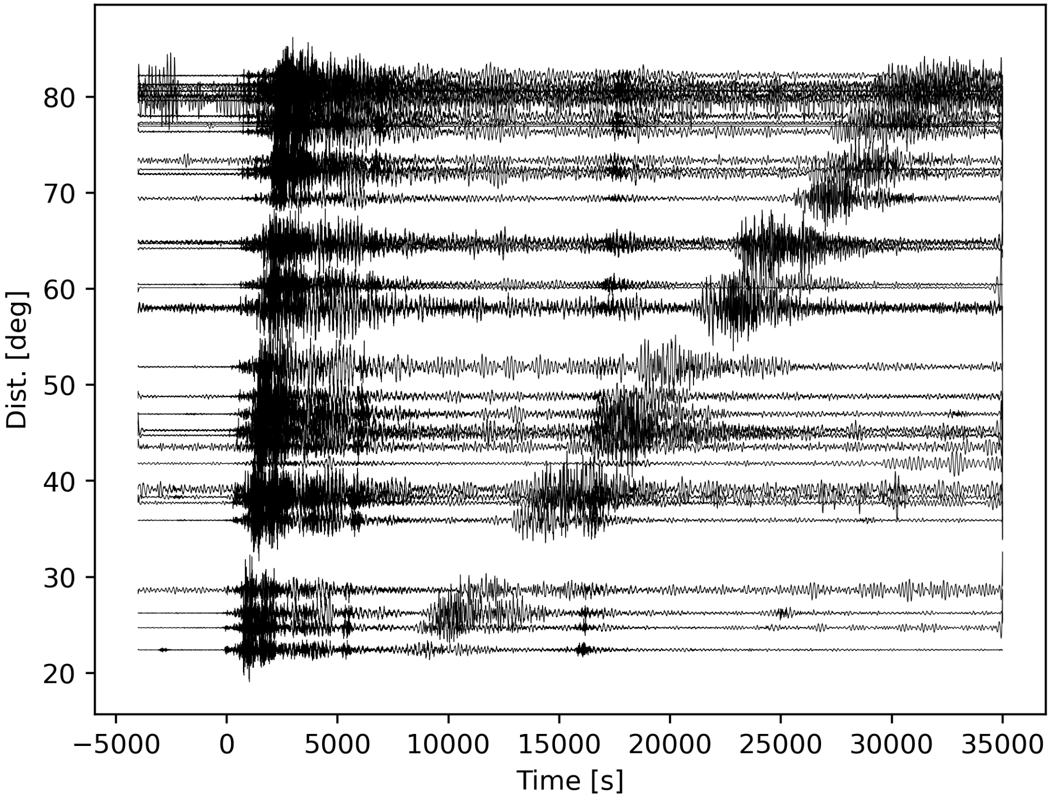


Hunga Tonga volcanic explosion

Simplified seismic source model: vertical force

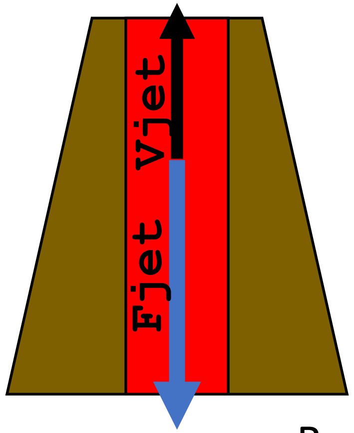
Data Source Propagation

$$u_z(t,r) = F_z(t) * G_{zz}(t - t_s, r, r_s)$$

$$|u_z(\omega)| = |F_z(\omega)||G_{zz}(\omega)|$$

Gzz = 1N vertical force

$$\frac{|u_z(\omega)|}{|G_{zz}(\omega)|} = |F_z(\omega)|$$

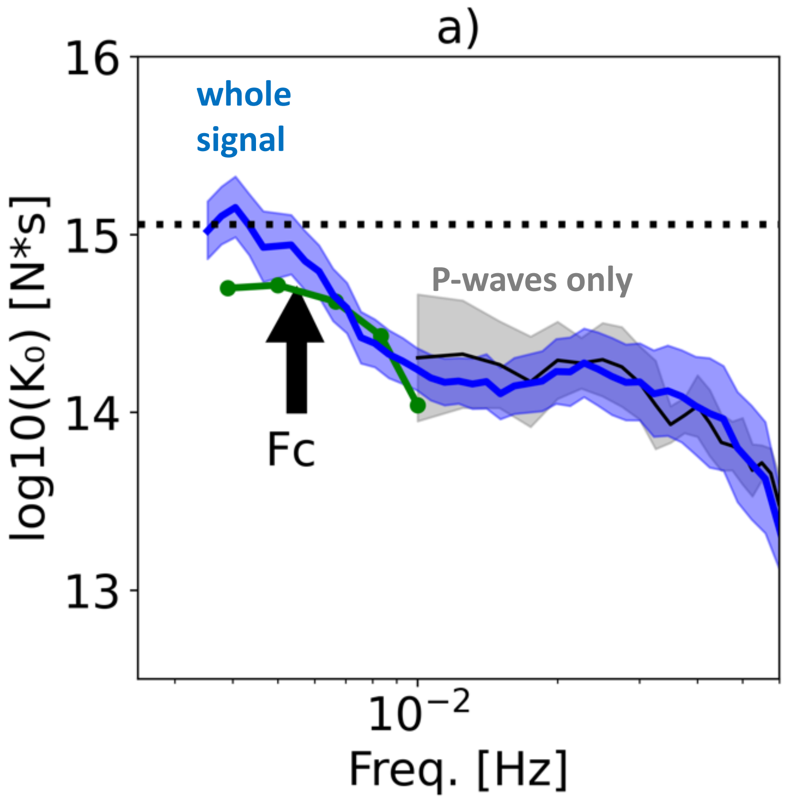


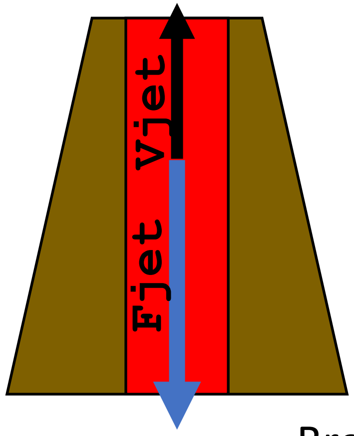
Brodsky et al., 1999

Hunga Tonga volcanic explosion

Main seismological source parameter: **Explosion impulse K_o**

$$\frac{|u_z(\omega)|}{|G_{zz}(\omega)|} = |F_z(\omega)|$$





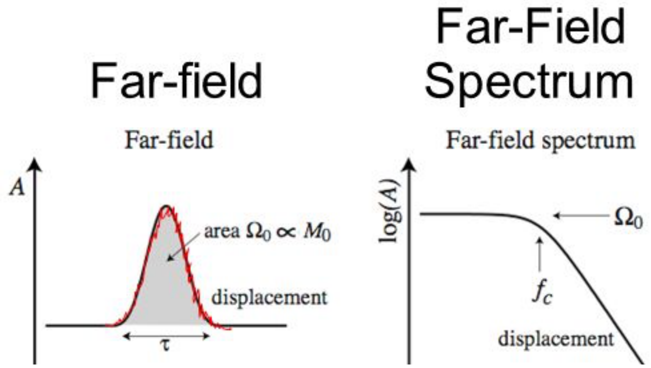
Brodsky et al., 1999

analogy with seismic moment for tensorial sources

$$F_z(\omega) = \int F_z(t) e^{i\omega t} dt$$

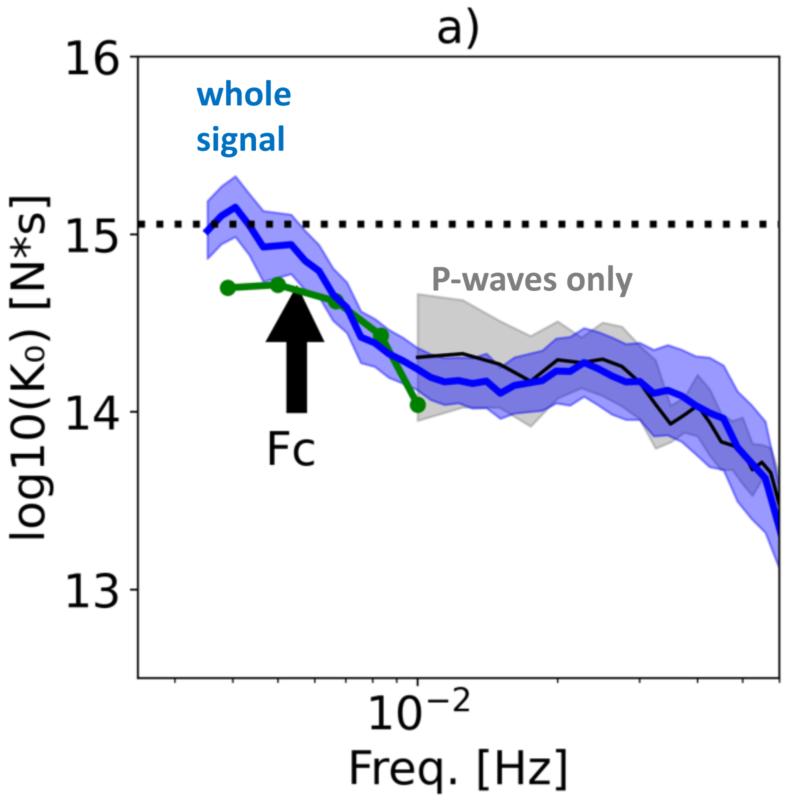
$$\lim_{\omega \to 0} F_z(\omega) = \int F_z(t) dt = K_0$$

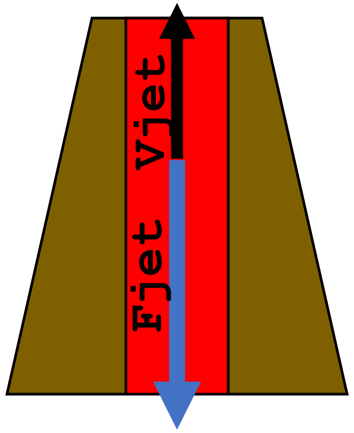
$$f_c \approx 1/\tau_{exp}$$



Hunga Tonga volcanic explosion

Simplified model to relate explosion impulse with ejected mass

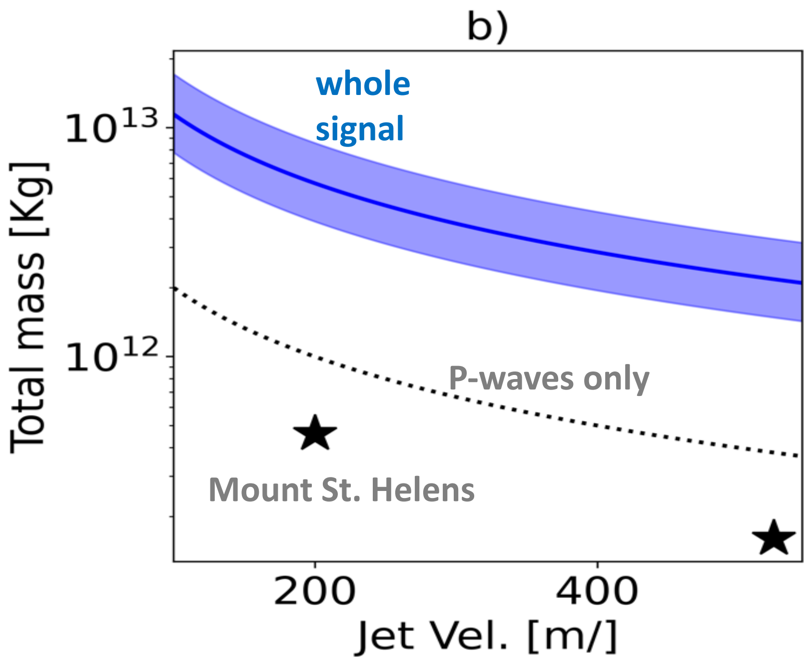




$$F_{jet}(t) = V_{jet}\dot{m}(t)$$

$$m_{total} = \int \dot{m}\, dt$$

$$m_{total} = K_0/V_{jet}$$



Brodsky et al., 1999

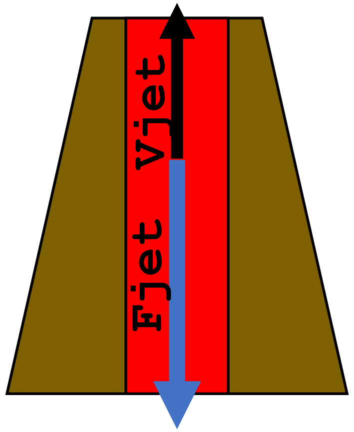
Hunga Tonga volcanic explosion

Source parameters

$$VEI = \log(V_{total}/10^9) + 5$$

$$VEI = \log(K_0/V_{jet}/\rho_{tephra}) - 4$$

ρ_{tephra}=1000 kg/m^3



$$F_{jet}(t) = V_{jet}\dot{m}(t)$$

$$m_{total} = \int \dot{m}\, dt$$

$$m_{total} = K_0/V_{jet}$$

Some estimates:

$K_0 \approx 1.3\ 10^{15}$ Ns

$m_{total} \approx 1.3\ 10^{13}$ kg

$$VEI_{V_{jet=200m/s}} = 5.8$$

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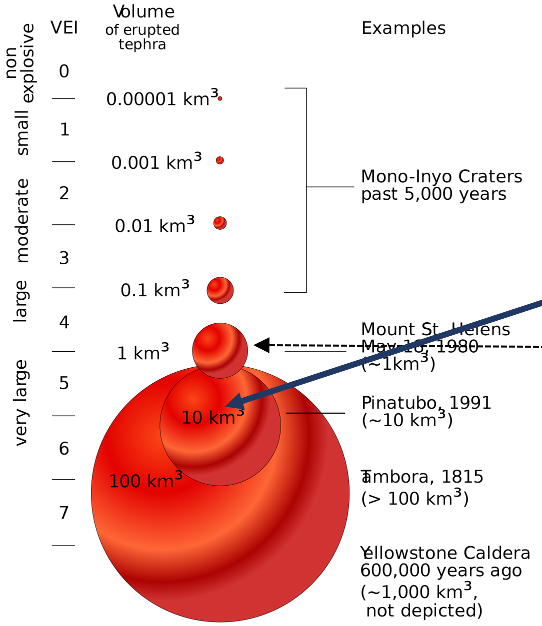

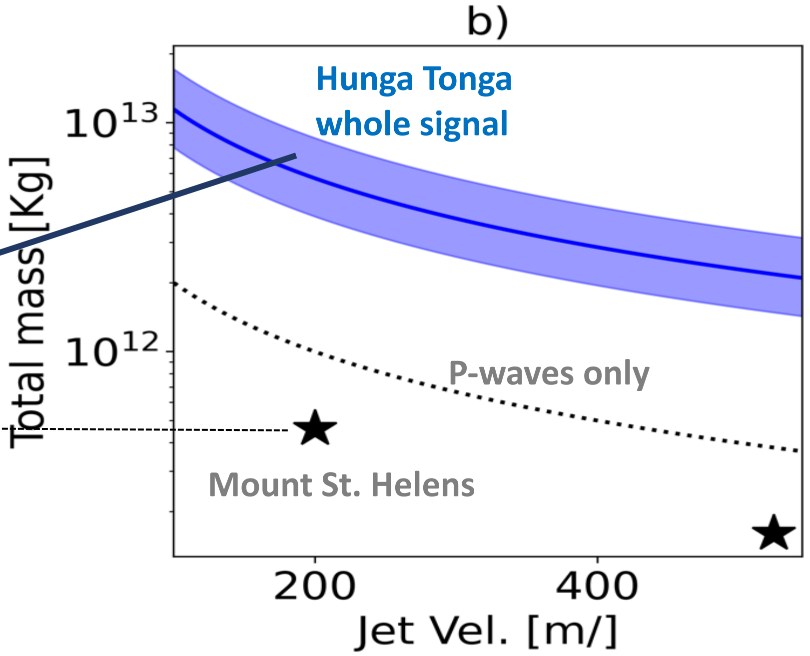

Some conclusions

- **Continuous analysis of seismic data can help to monitor (in near real time)volcanic explosions especially in remote places**
- **Rapid characterization of newly detected signals is easy to implement and provide rapid estimates of explosion dynamics parameters**
- **For the Hunga-Tonga eruption several parameters are derived and helped to constraint a first estimate of a VEI~6**