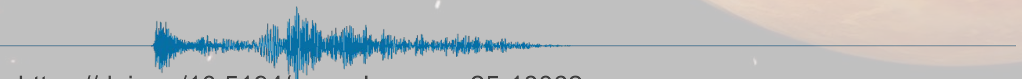
Sharing not permitted

Marouchka Froment, Quentin Brissaud, **Sven Peter Näsholm**, Johannes Schweitzer, Tina Kaschwich

Source and subsurface inversion using earthquake-generated infrasound recorded at a balloon platform: Application to the 2021 Mw 7.3 Flores earthquake

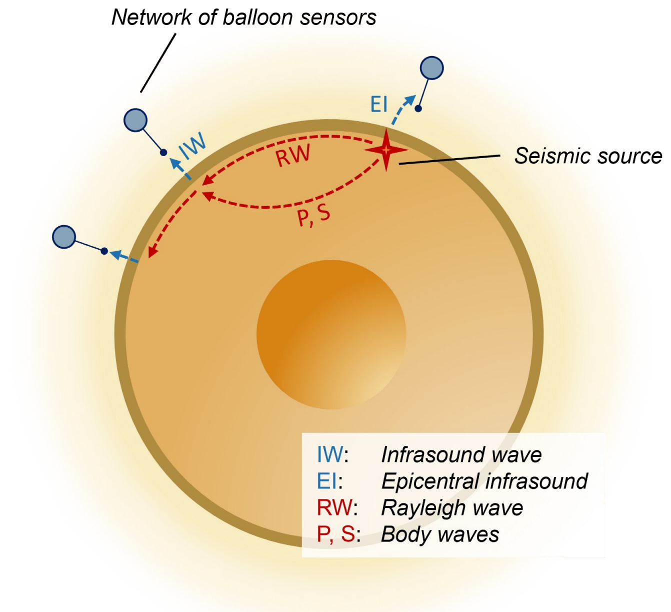
EGU PICO 5.14 – 2 May 2025

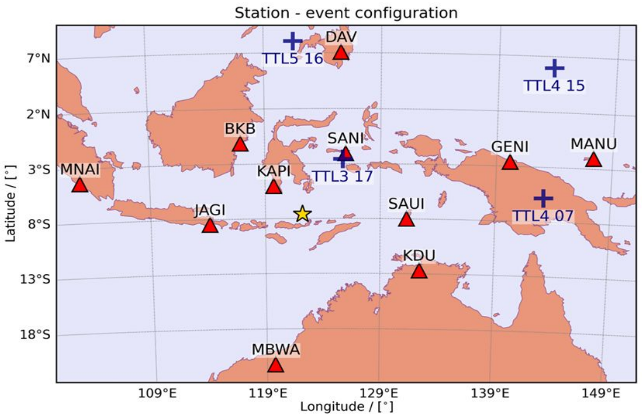


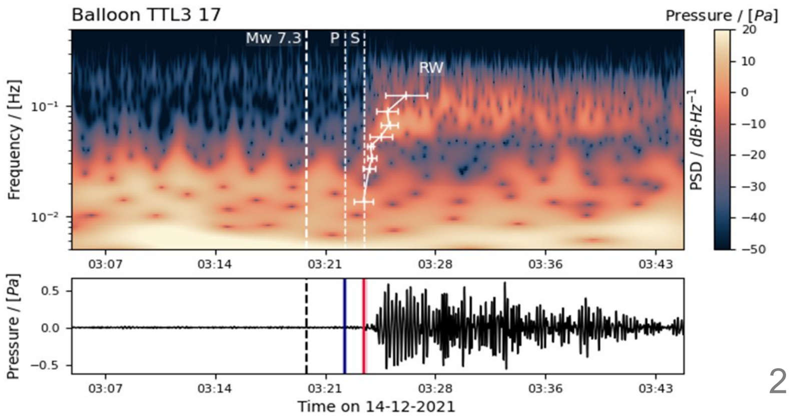
https://doi.org/10.5194/egusphere-egu25-18062

Funded by
The Research
Council of Norway

Flores sea earthquake – *A unique balloon dataset to prepare future planetary missions*



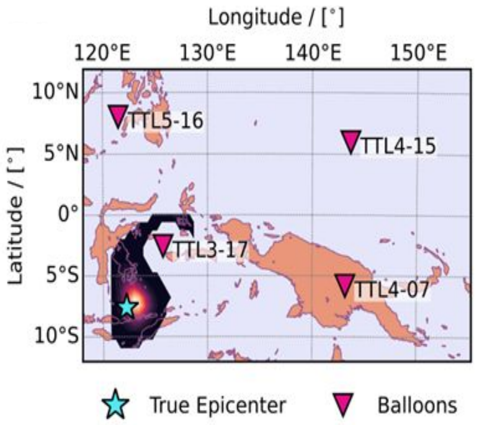


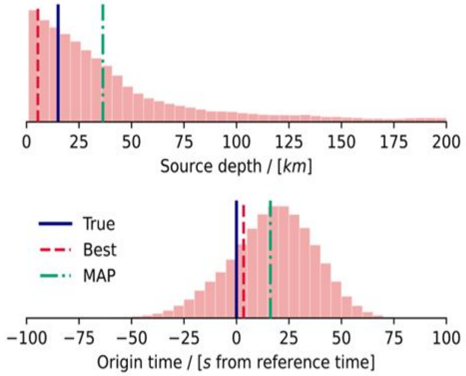


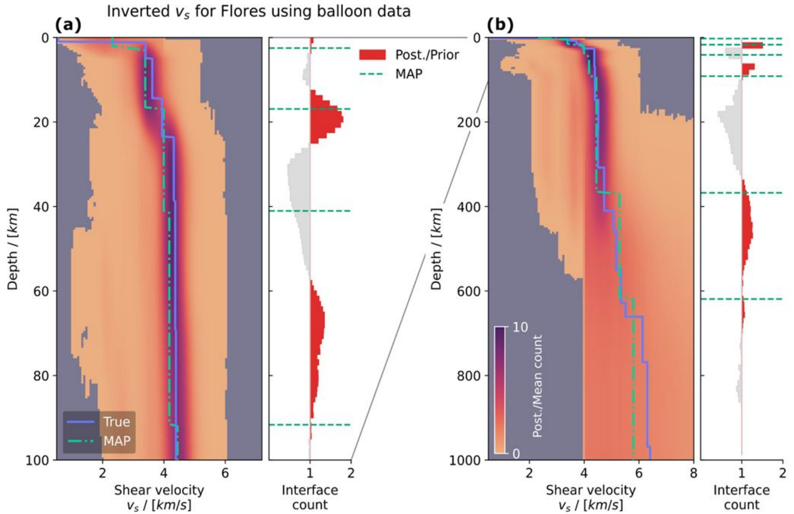
- Seismic waves can be detected from a balloon and used to **retrieve subsurface structures**
- The Mw7.3 Flores earthquake was detected across the Strateole2 balloon network in 2021
- Pressure waveforms show P, S, and Rayleigh waves

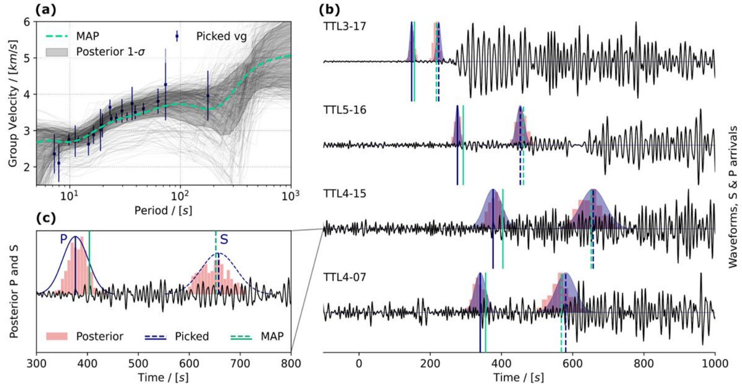
Sharing not permitted

First balloon-borne inversion results

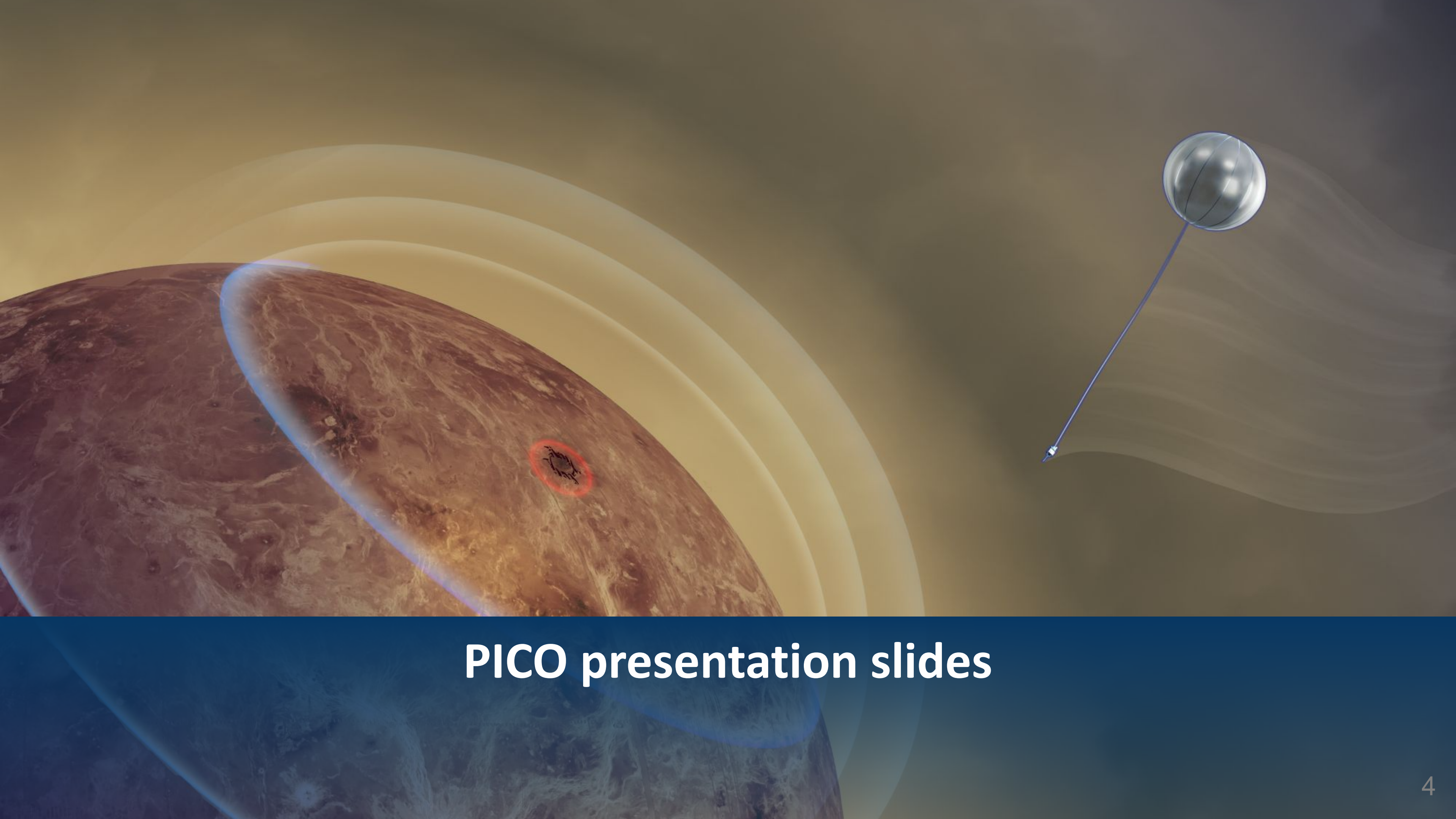








- **Location** is well captured with ~15 km uncertainty
- **Source depth** and **origin time** not as well captured
- **20-km crustal interface**, matching regional CRUST2.0 velocity profiles
- Surface- and body-wave travel time measurements provide **constraints on velocity down to ~500 km**, although at limited resolution



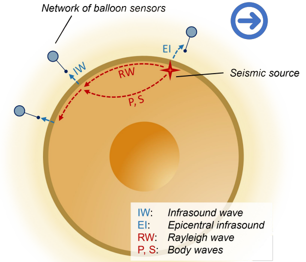
PICO presentation slides

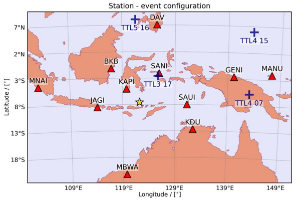
Sharing not permitted

Source and subsurface inversion using earthquake-generated infrasound recorded at a balloon platform: application to the 2021 Mw 7.3 Flores earthquake - PICO 5.14 - 2 May 2025

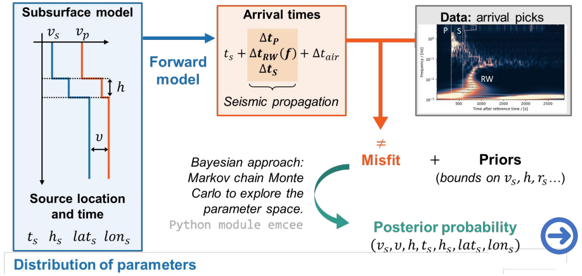
1 - Event & experiment

- Balloon borne inversions might be the only way to investigate **Venus interior structure**
- Seismic waves can couple to the atmosphere as sound
- 2021 Flores sea **earth**quake recorded by a balloon network and seismic stations



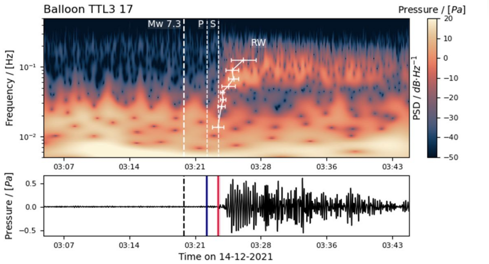


- We invert for source location/depth & subsurface velocities using **MCMC sampling**

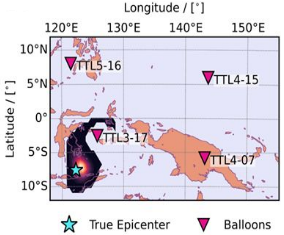


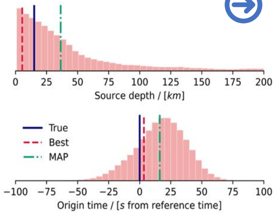
2 - Inverted source parameters & Data

- Pressure waveforms show P, S & Rayleigh waves



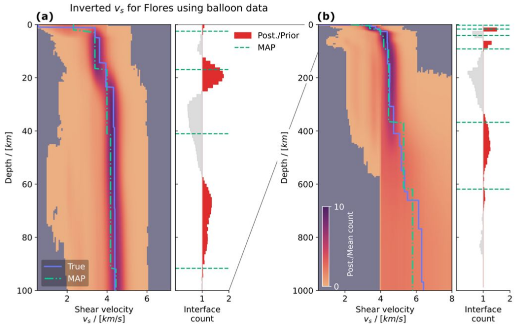
- **Location** is well-captured with ~15 km uncertainty
- **Source depths** and **origin time** not as well captured due to strong trade-offs between inverted distributions





3 - Inverted crust & mantle

- Resolve a 20±5 km crust similar to CRUST2.0 estimates below islands
- Changes in velocity down to around ~500 km are suggested, although at limited resolution



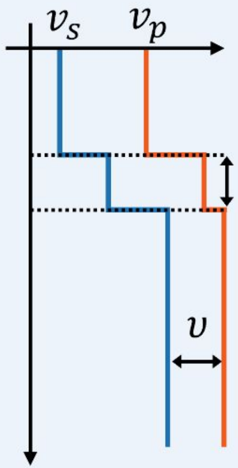
4 - Discussion

- *First seismic inversion using balloon infrasound*
- *A joint inversion framework (source location + seismic velocities) yields satisfying results*

- Difficulty in picking seismic phases in single-component traces.
- Improving the LF balloon oscillation removal for better RW picking?
- Other balloon noise sources - balloon wake turbulence?
- Infrasound propagation effects - topographic scattering?

Inversion method - Markov Chain Monte Carlo

Subsurface model



Source location and time

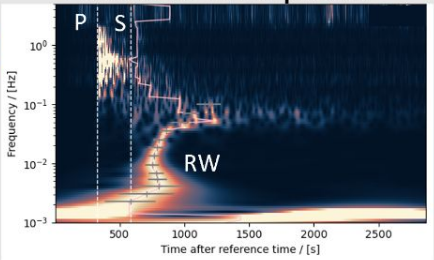
$t_s \quad h_s \quad lat_s \quad lon_s$

Forward model

Arrival times

$$t_s + \underbrace{\begin{matrix}\Delta t_P \\ \Delta t_{RW}(f) \\ \Delta t_S\end{matrix}}_{\text{Seismic propagation}} + \Delta t_{air}$$

Data: arrival picks



$\neq$

Misfit + **Priors**

(bounds on $v_s, h, r_s \ldots$)

Bayesian approach: Markov chain Monte Carlo to explore the parameter space.

`Python module emcee`

Posterior probability

$(v_s, v, h, t_s, h_s, lat_s, lon_s)$

Distribution of parameters

Observations of earthquake infrasound

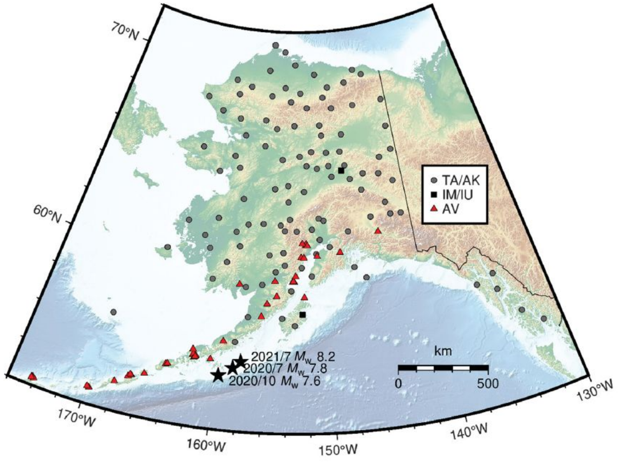
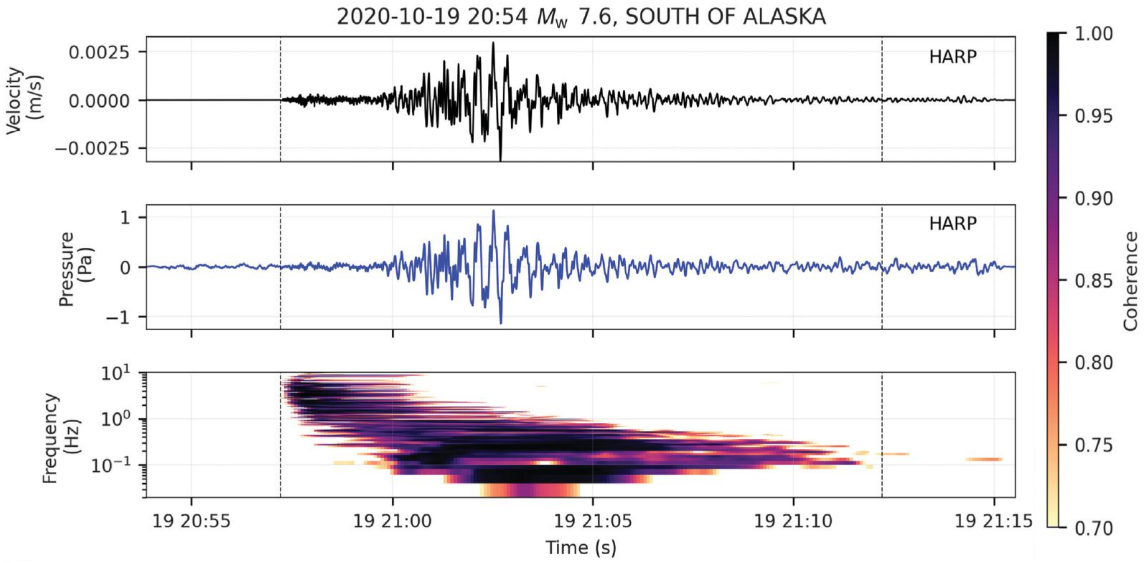


Figure 1. Map of infrasound stations in Alaska in 2020–2021. Each station's marker indicates the network: circles indicate TA/AK, squares indicate IM/IU, and triangles indicate AV. All but one station has a colocated seismometer. The locations of the three large earthquakes used in this study are plotted as stars.



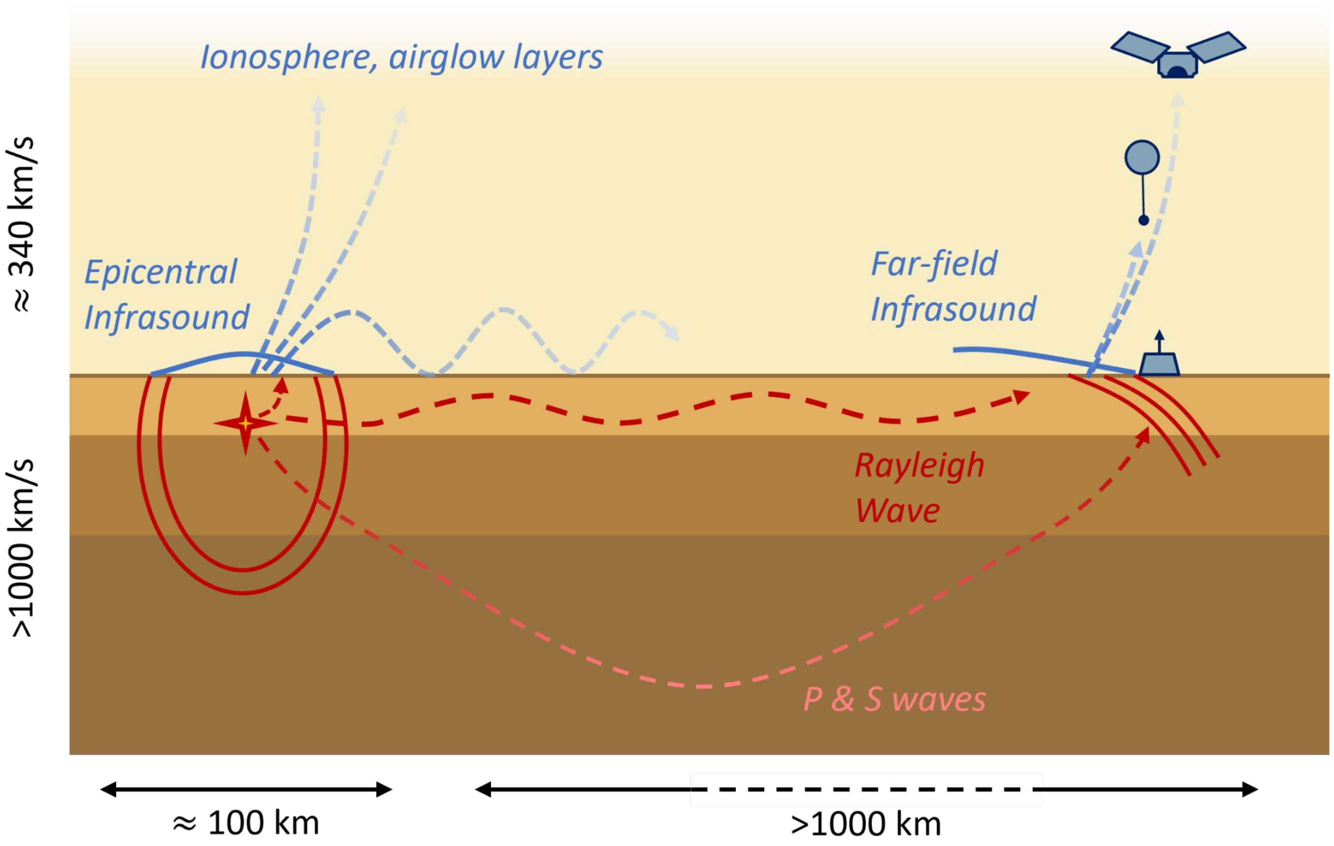
Alaska network: many pressure sensors collocated with infrasound sensors. Excellent coherence between Pressure and seismic velocity following large earthquake.

Scaling factor: ΔP(t)= ρ_atm cv_z (t)

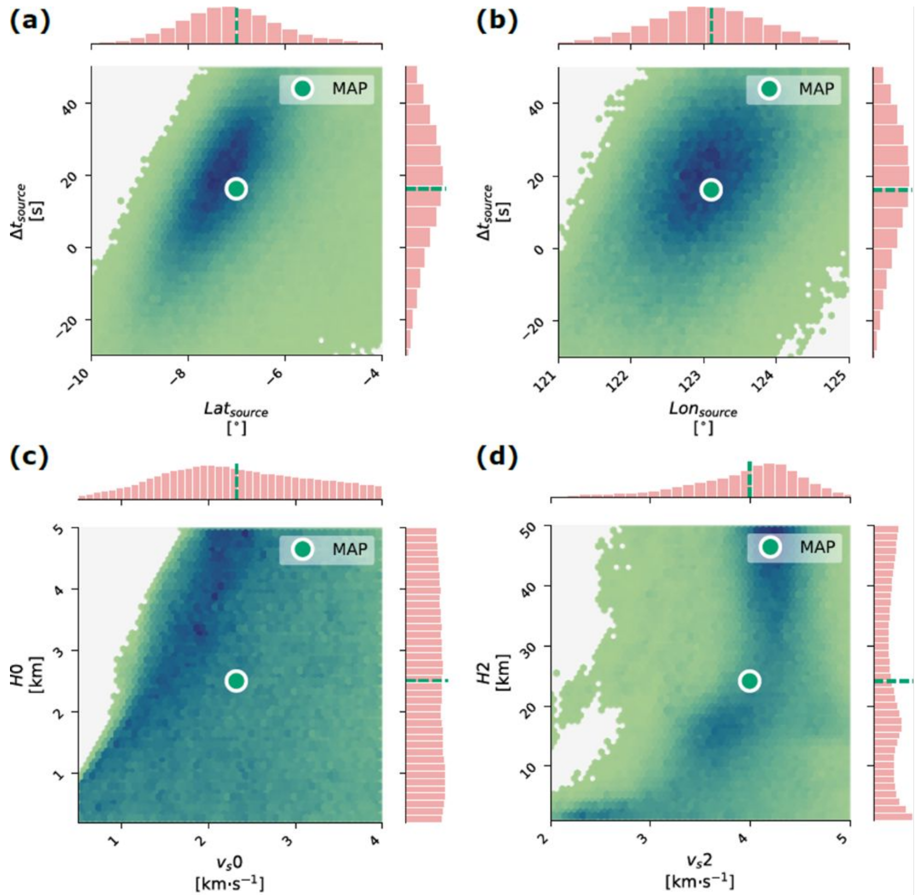
Figures from:
Fee, D., Macpherson, K., Gabrielson, T., (2023). *BSSA*, **113**, 1581–1595. 10.1785/0120220226, Macpherson, K., Fee, D., Coffey, J., Witsil, A. (2023) *BSSA*, **113**, 10.1785/0120220237

Coupling of earthquake infrasound

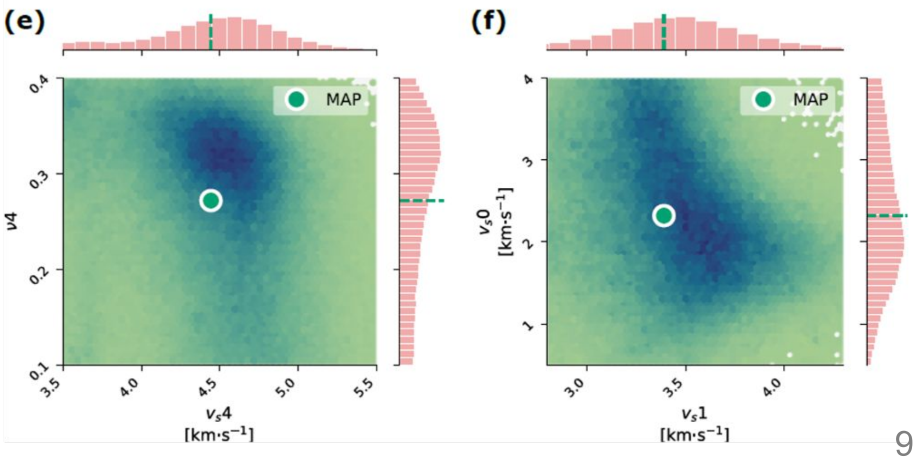
Two types of earthquake infrasound: *epicentral* and *far-field*.



Trade-offs in the joint inversion



There exist trade-offs between source location and origin time, and seismic velocities.



Crust and mantle near the Flores Sea

A lot of variety in crustal thickness and sediment deposits around the event. We construct a "**Median model**" from the available data in the literature at each station location. It is our baseline for assessing our inversion results.