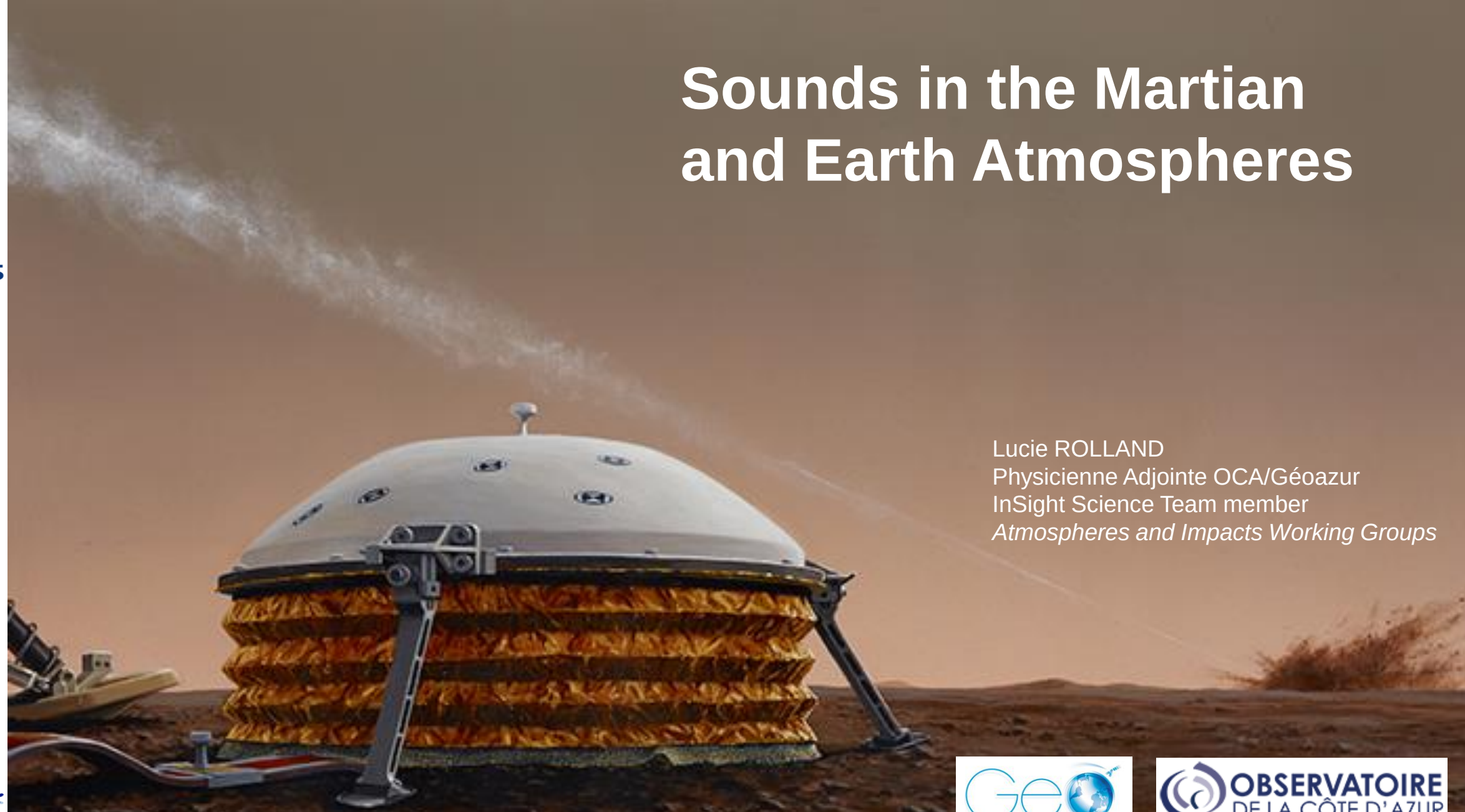
Sounds in the Martian and Earth Atmospheres

Lucie ROLLAND
Physicienne Adjointe OCA/Géoazur
InSight Science Team member
Atmospheres and Impacts Working Groups



InSight@School2022 *Observatoire de la Côte d'Azur*

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Outline of the presentation

- The sound propagation on Mars experiment by Perseverance
- Sounds from bolide entries by InSight (Mars2020)
- Sounds from meteor impacts by InSight
- Sounds from volcano eruptions, the Tonga case by Earth

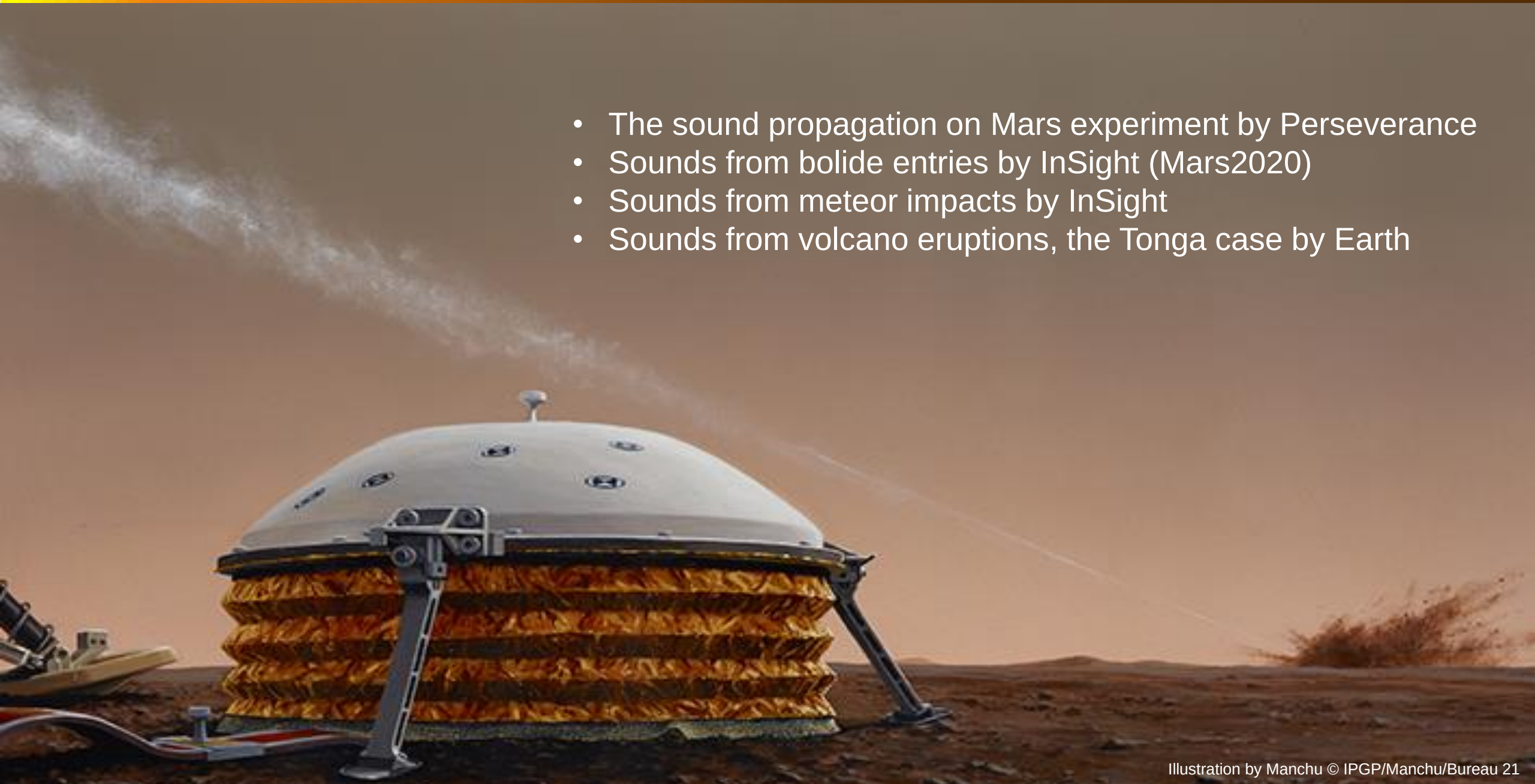
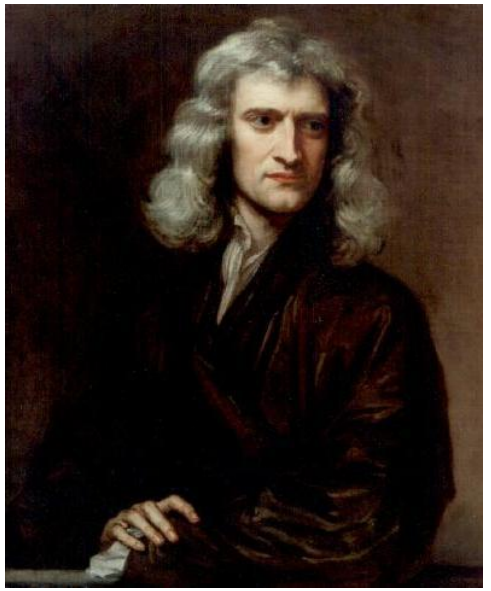


Illustration by Manchu © IPGP/Manchu/Bureau 21

The air sound speed on Earth

- Measured using the difference between **light** and **sound** by Mersenne in 1636
- First analytical determination by Newton in 1687 (Newton-Laplace law): $c = (K/\rho)^{1/2}$ where K denotes the gas elasticity and ρ the density
- Ideal gas: $\mathbf{c = (\gamma RT)^{1/2}}$ where T is the temperature
- c = 343 m/s at 20°C, 331 m/s at 0°C



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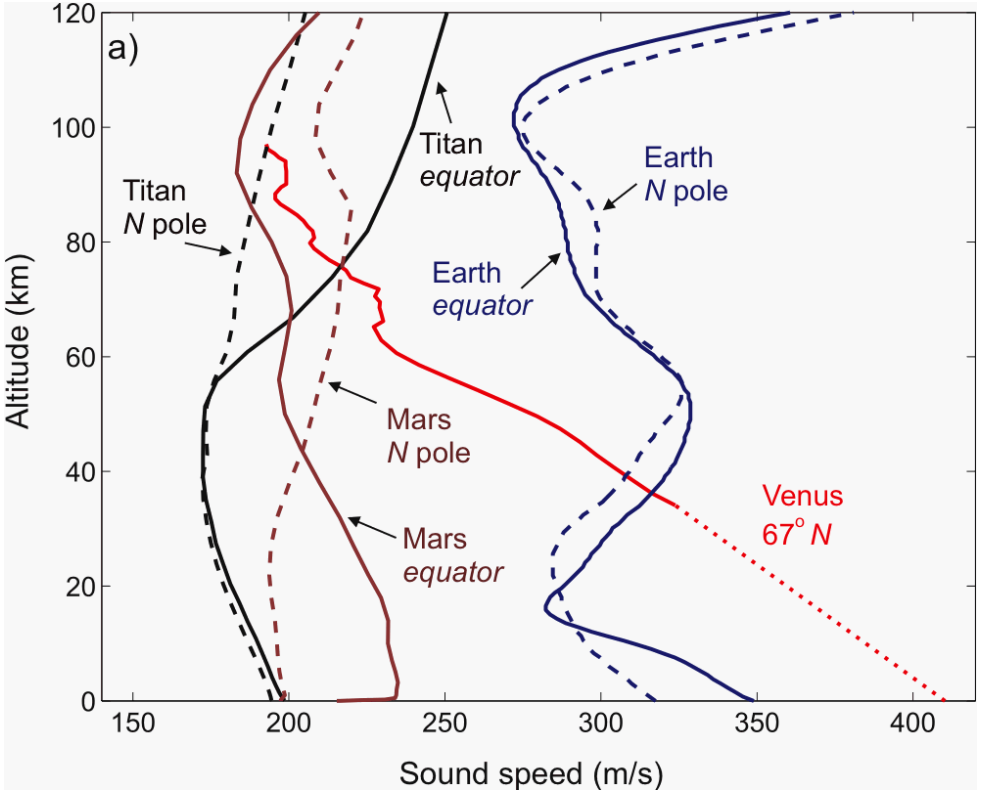
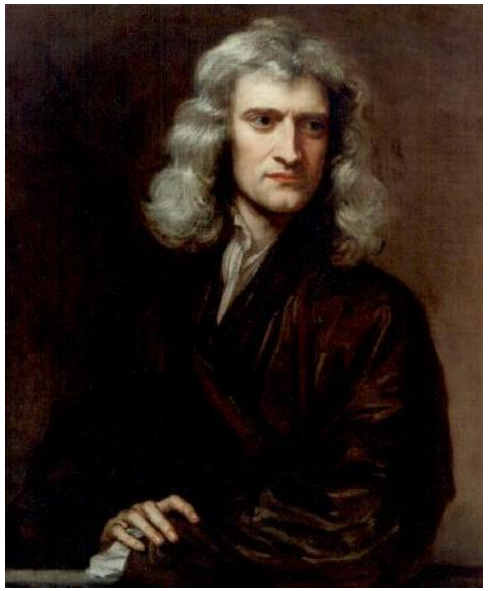
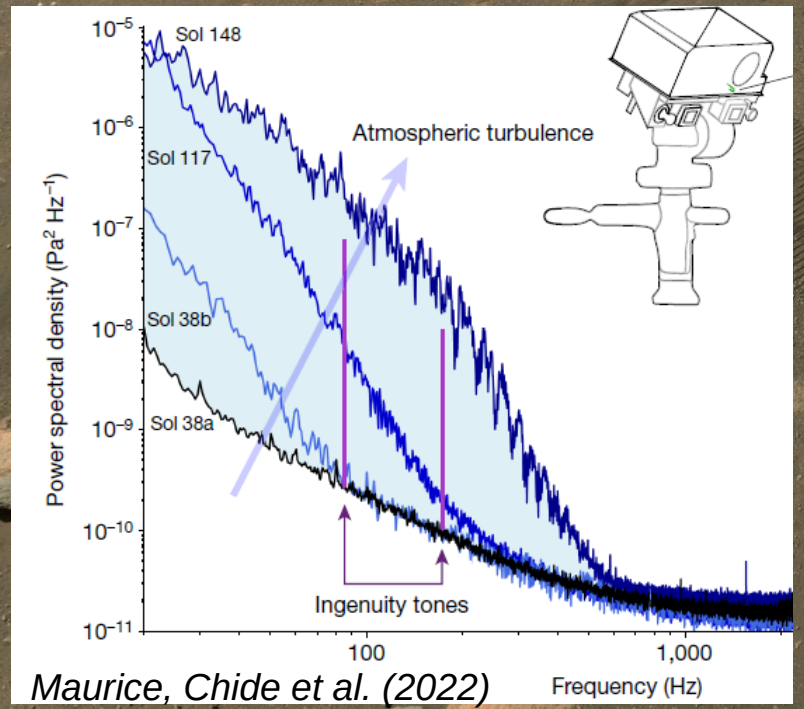


Petculetscu (2007)



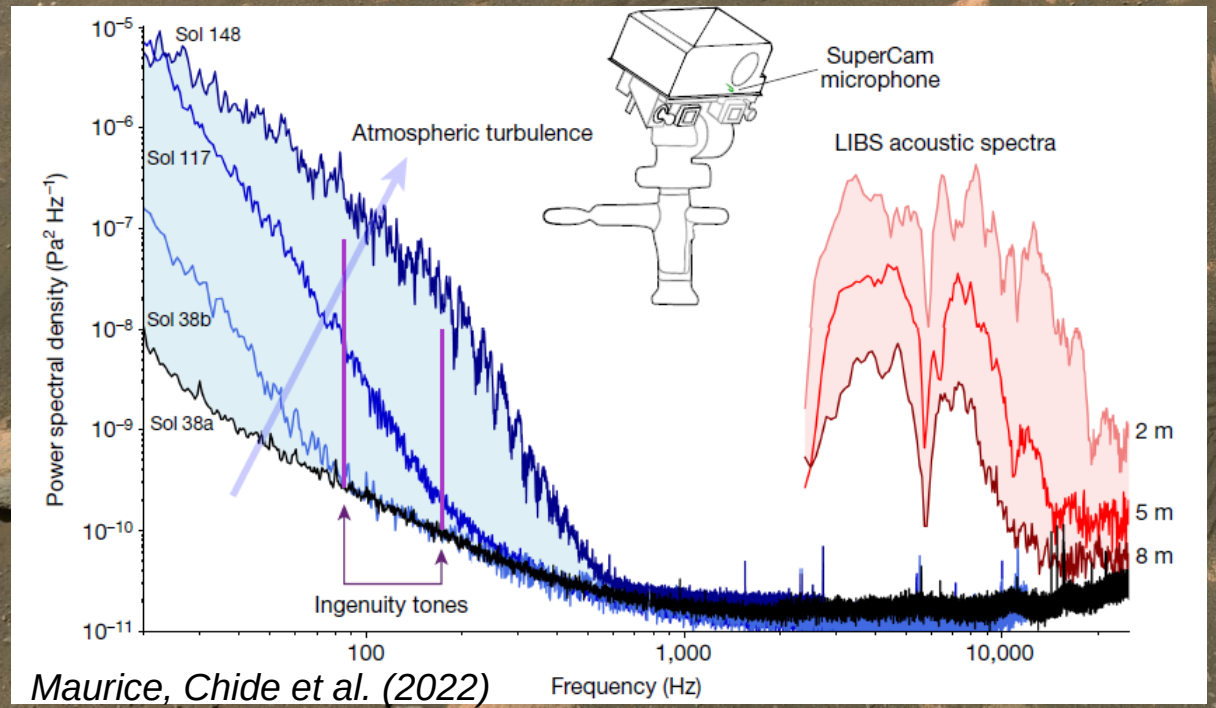
The Perseverance sound propagation experiment



Maurice, Chide et al. (2022)

Credit: NASA/JPL-Caltech/MSSS

The Perseverance sound propagation experiment

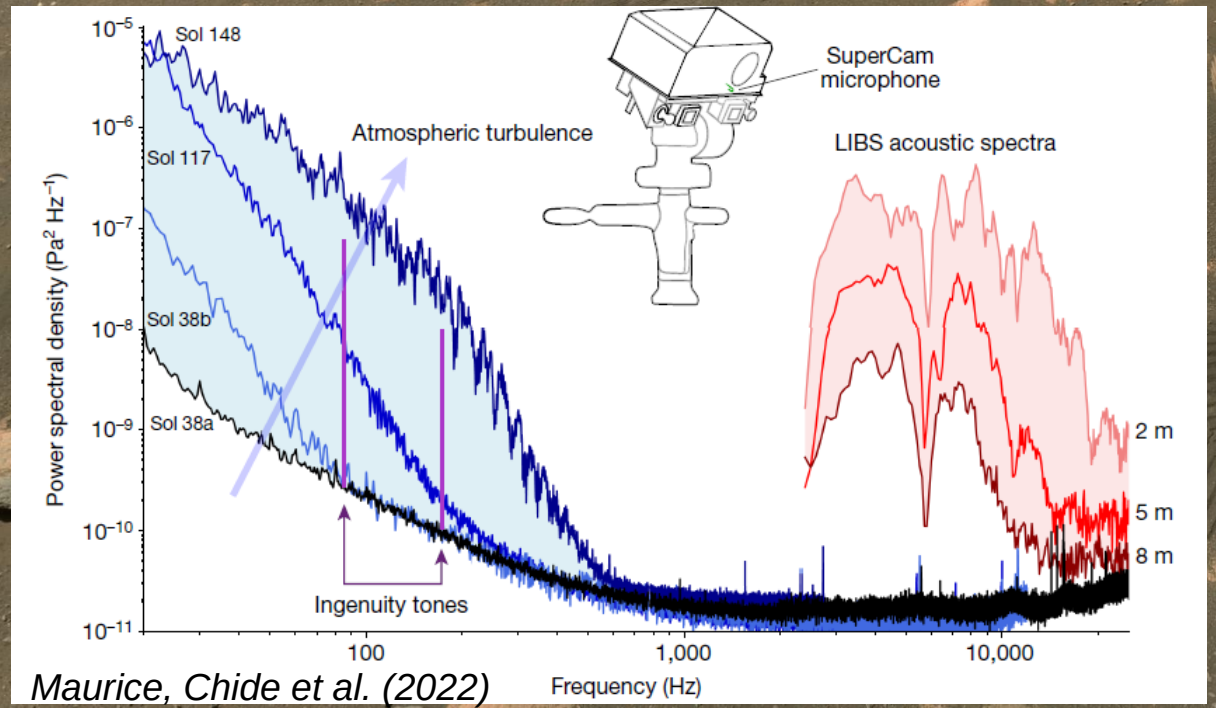


Maurice, Chide et al. (2022)

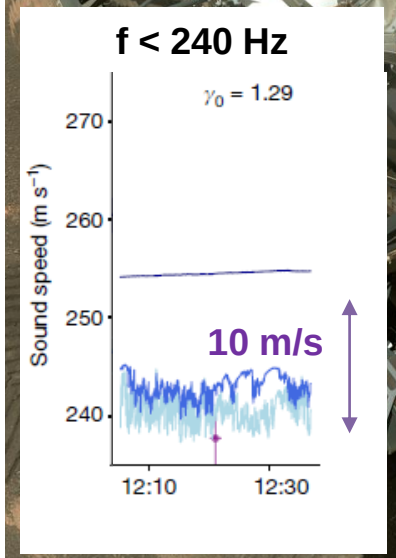
Credit: NASA/JPL-Caltech/MSSS

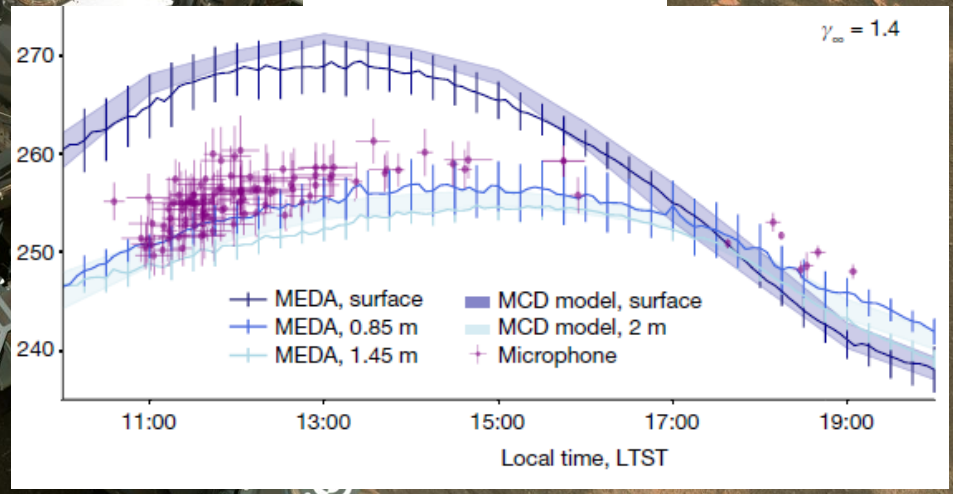
The Perseverance sound propagation experiment

Two key measurements:
1) Sound speed ~240m/s for f < 240Hz, ~250 m/s for f > 240Hz
2) Acoustic attenuation



Maurice, Chide et al. (2022)

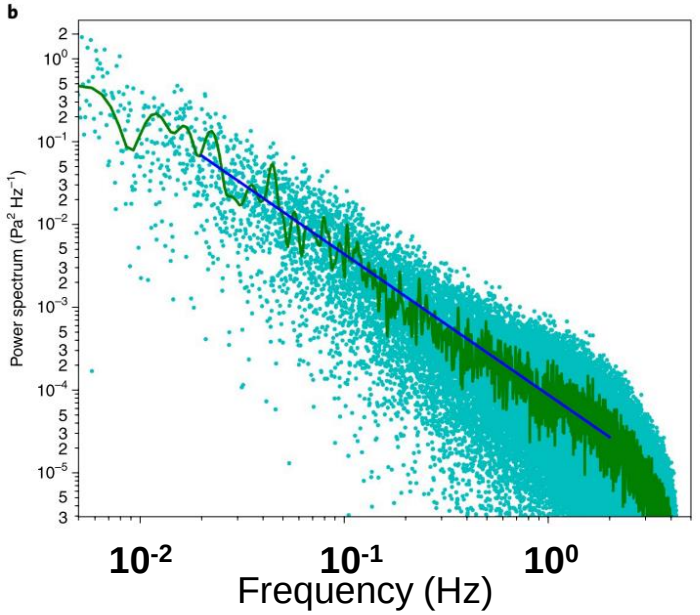




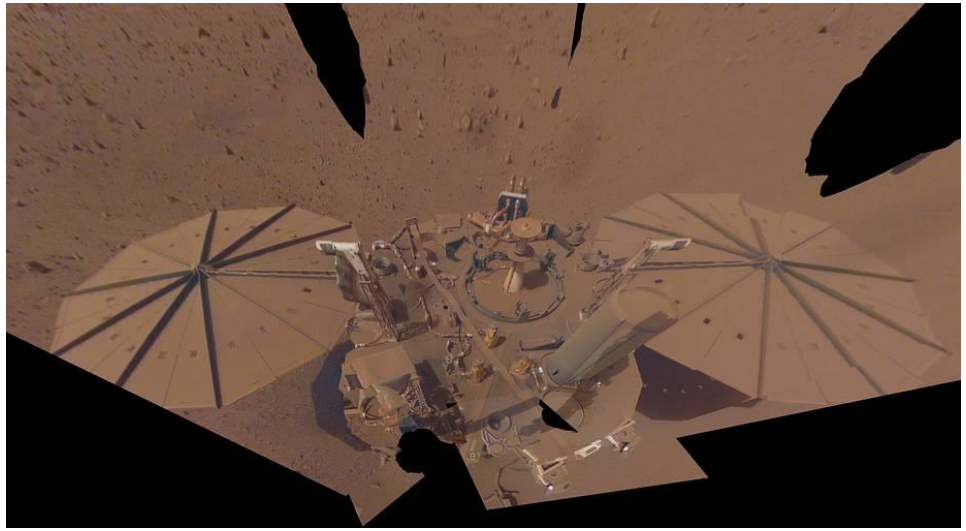
Credit: NASA/JPL-Caltech/MSSS

InSight pressure sensor explores a much lower range of frequencies

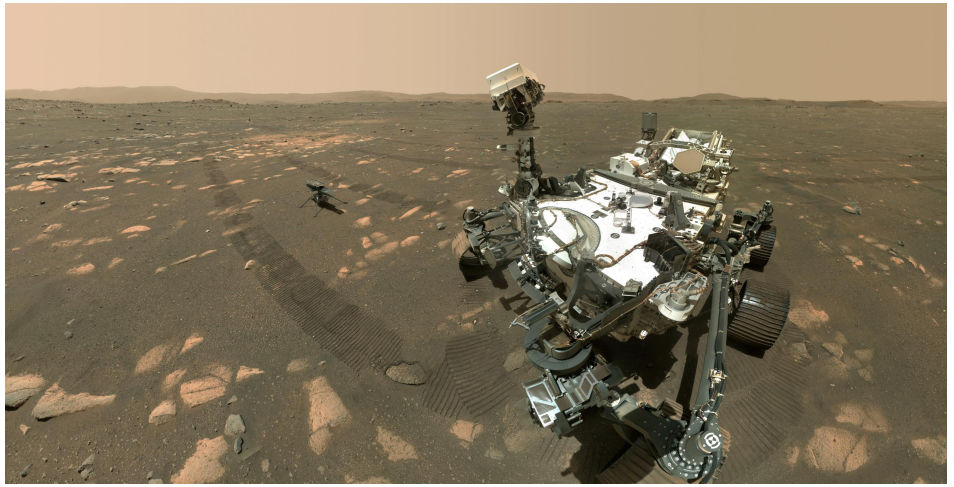
InSight

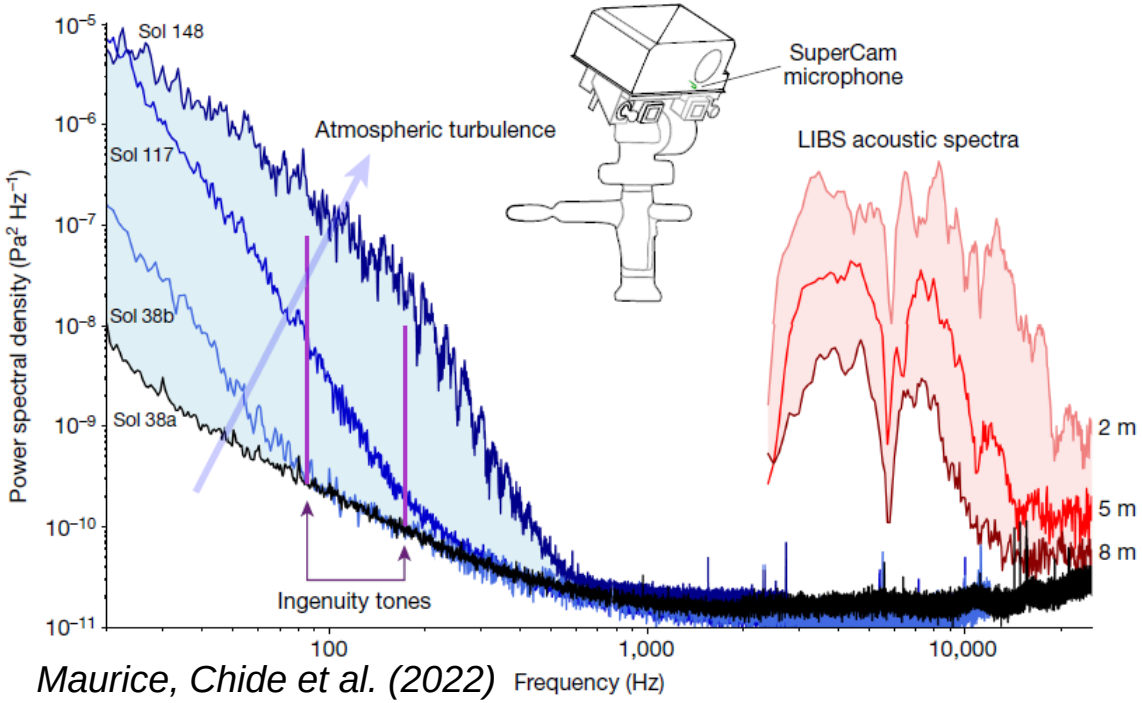


Banfield, Spiga et al. (2018)



Perseverance



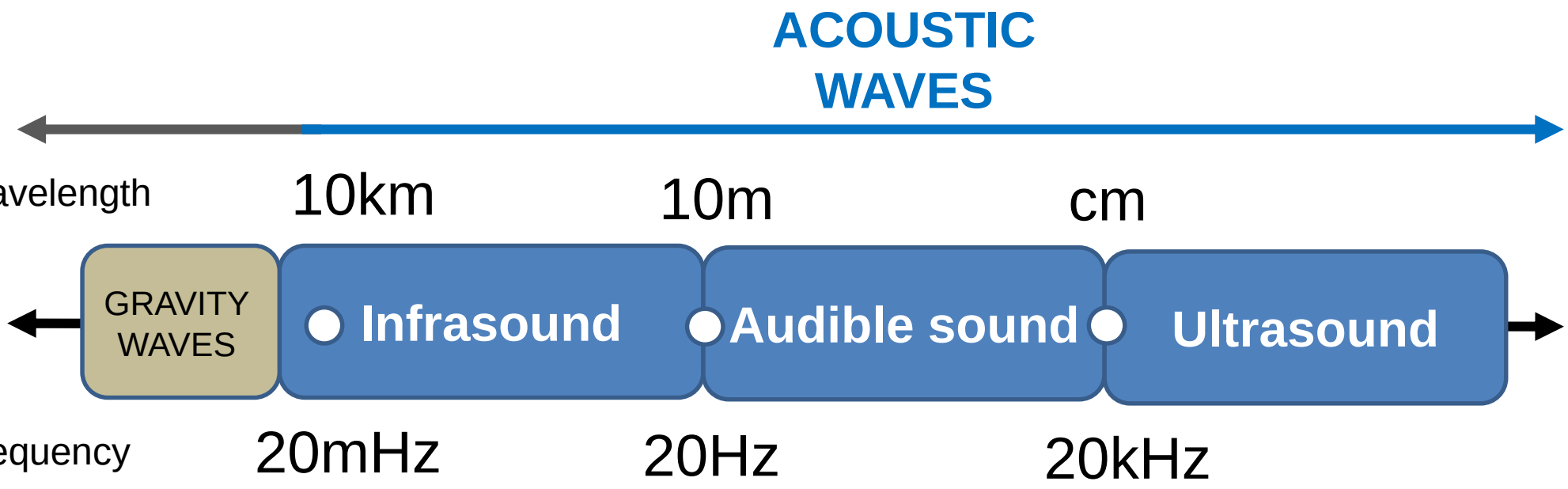


Maurice, Chide et al. (2022)

Infrasound and audible sound

InSight

Perseverance



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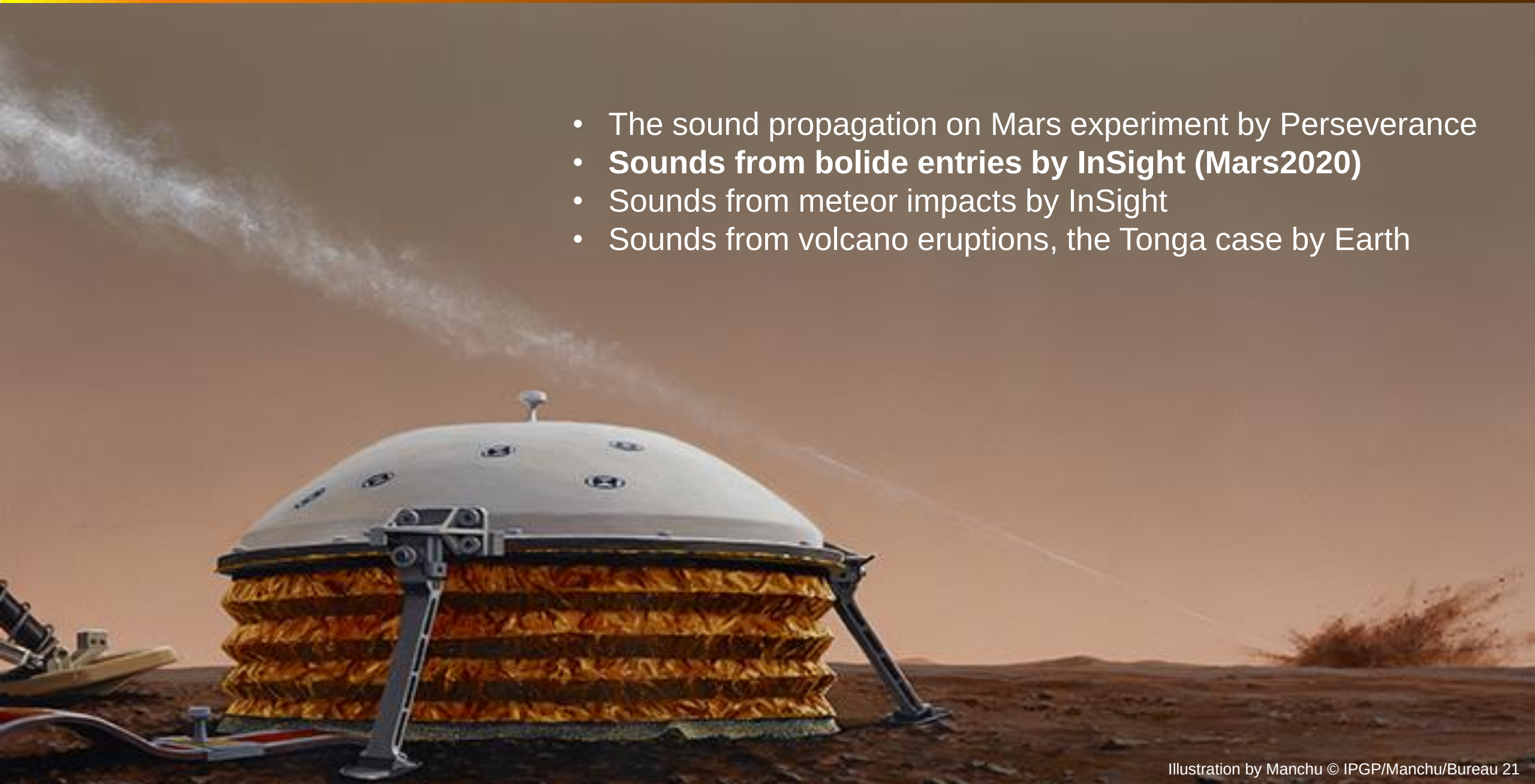
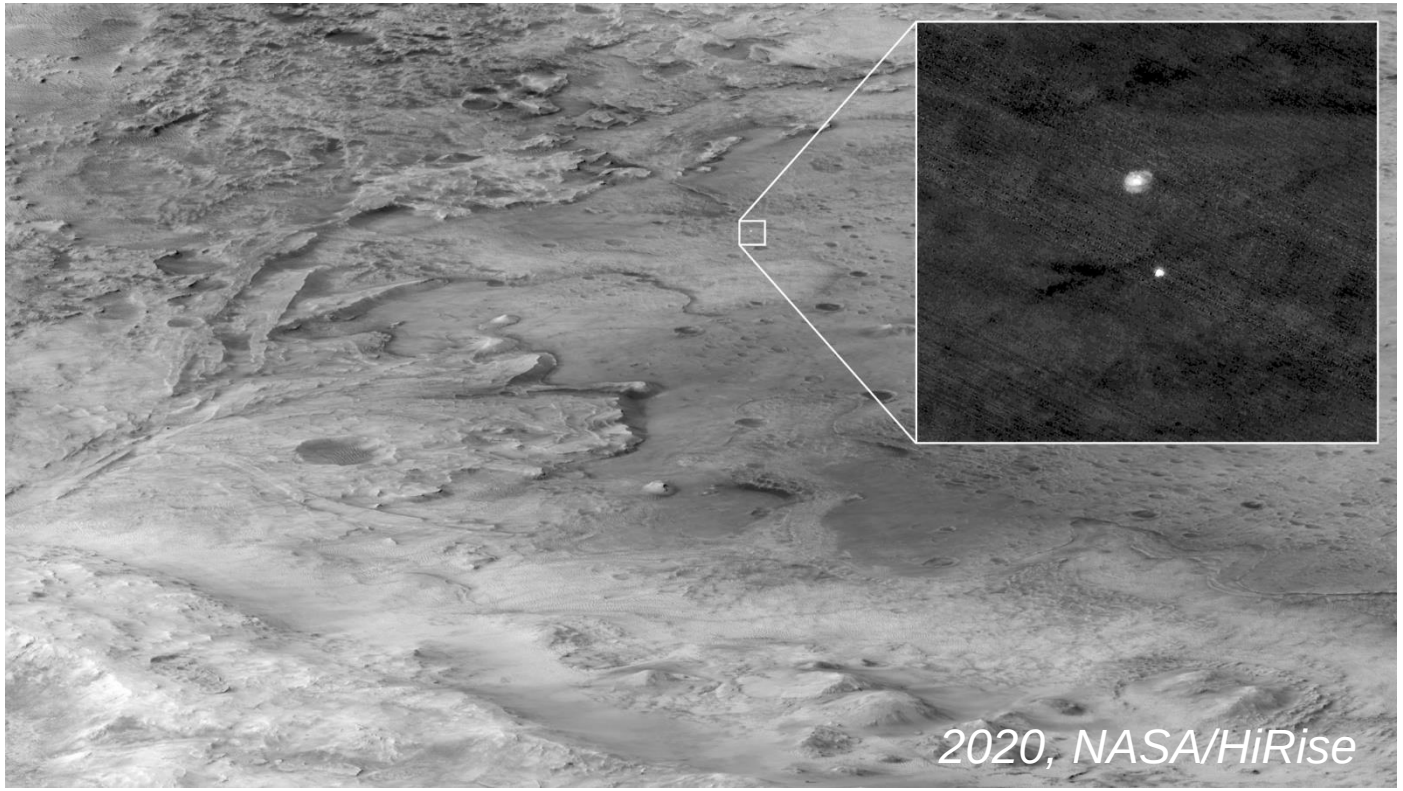


Illustration by Manchu © IPGP/Manchu/Bureau 21

Sounds for InSight: hypersonic sonic boom entries

Sonic boom:
A sound associated with shock waves created when an object travels through the air faster than the speed of sound.

Spacecrafts entries

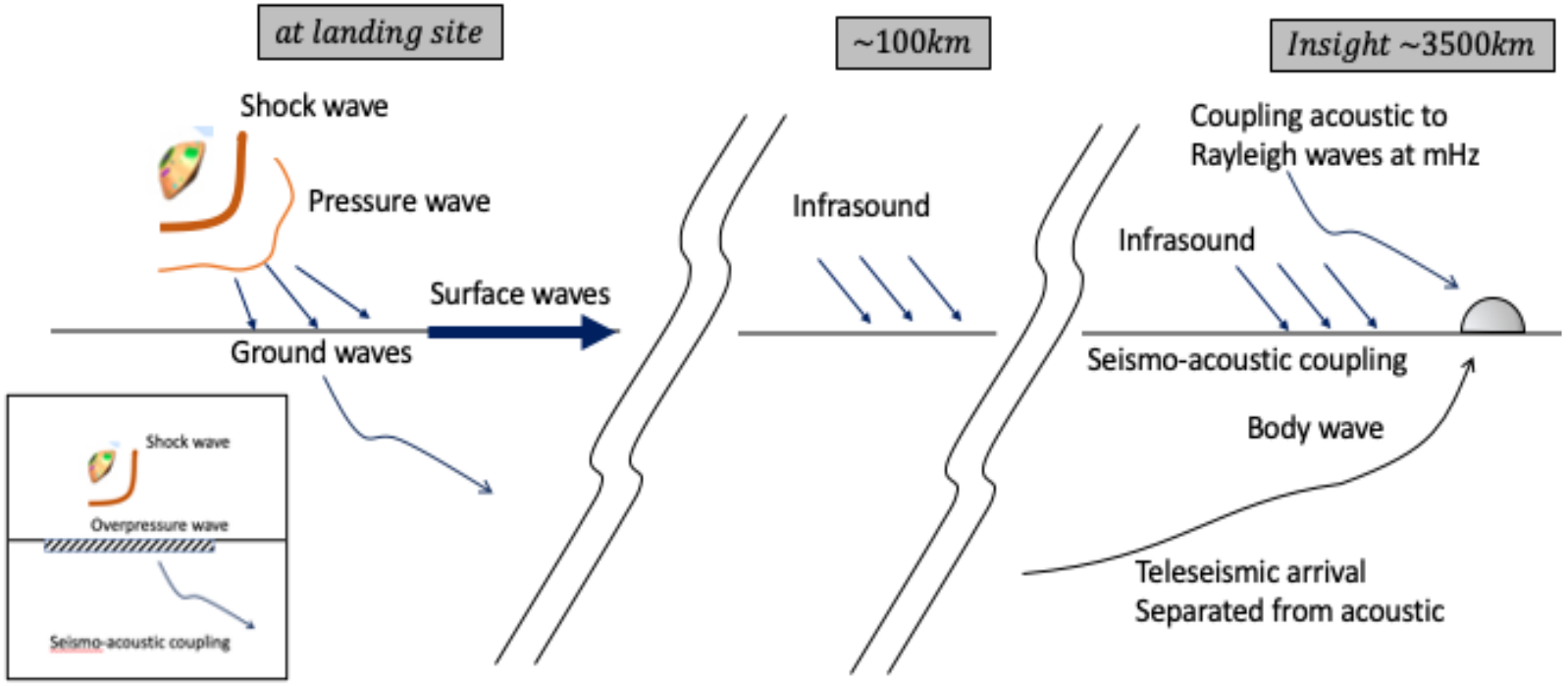


Meteor entries

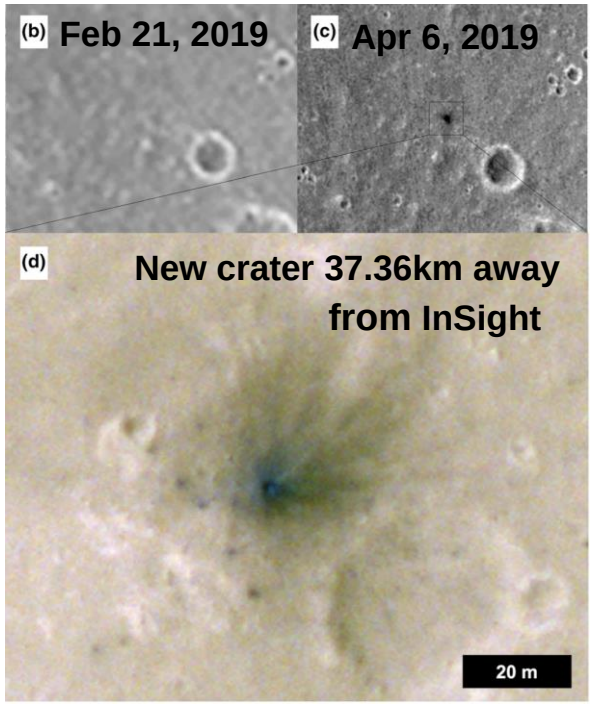
At ground: Speed of sound ~240 m/s and pressure 7-10 mbar
CO_2 rich atmosphere

Detect sonic booms on Mars ?

Spacecrafts entries



Meteor entries



Daubar et al. (2020)

Issue: no meteor or impact signature confirmed with InSight till Fall 2021.

Solution: Exploit InSight data return from InSight and Tianwen spacecrafts **EDL** as ”ground-truth” to determine the efficiency of the **seismo-acoustic coupling** and the **acoustic properties** of Mars atmosphere.

3 planned entries in 2021 (as of last InSight@School2020 conference)

Phoenix

Feb 18, 2021 Mars 2020 (NASA)

Viking 2

Viking 1

Pathfinder

ExoMars

Mars 2020

Beagle 2

InSight

Schiaparelli

Opportunity

Curiosity

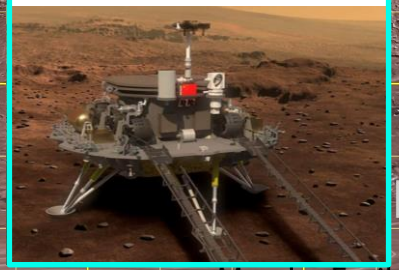
Spirit

Mar 19, 2021 ExoMars(ESA)

Mars 3

Mars 2

Apr 23, 2021
HX-1 (CNSA)



Mars Polar Lander

Map by Emily S. Lakdawalla atop Viking color MD

Today: 2 more landers on Mars

Phoenix

Feb 18, 2021 Mars 2020 (NASA)

Tianwen-1

Viking 2

Viking 1

Pathfinder

ExoMars

Mars 2020

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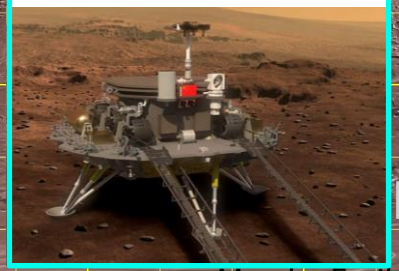


Mars Polar Lander

Map by Emily S. Lakdawalla atop Viking color MD

Sonic booms signatures of spacecrafts on Earth

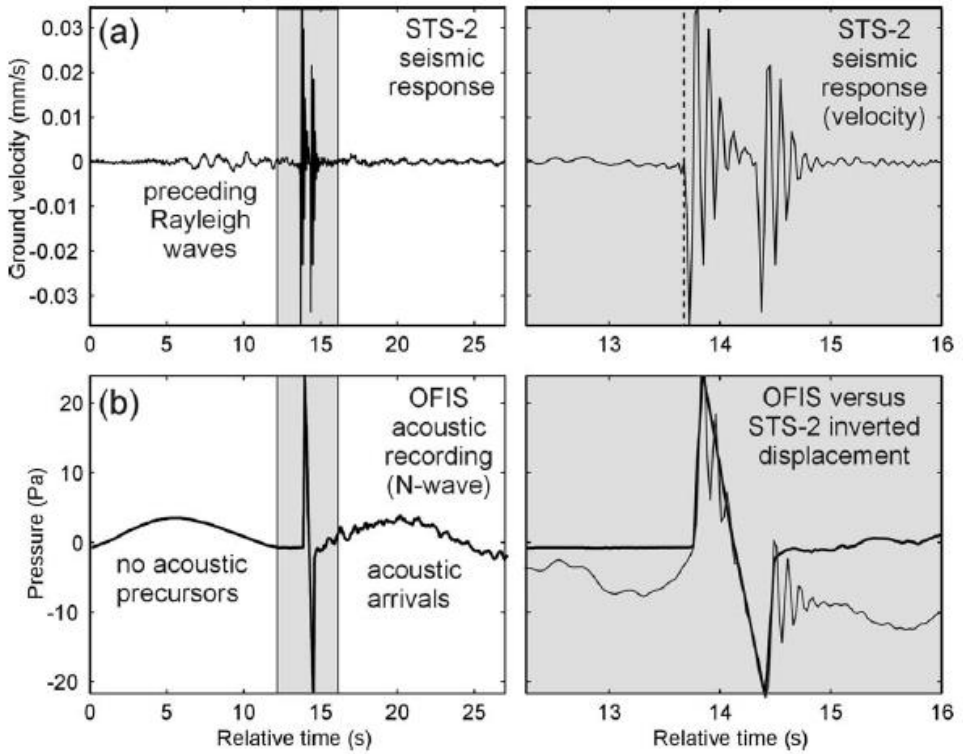
- N-wave in pressure
- Inverted N-wave in displacement

- Pulse duration depends on the size of the spacecraft

- Max. detection distance on Earth: 500 km

- Strong effects of winds

Atlantis shuttle reentry recordings

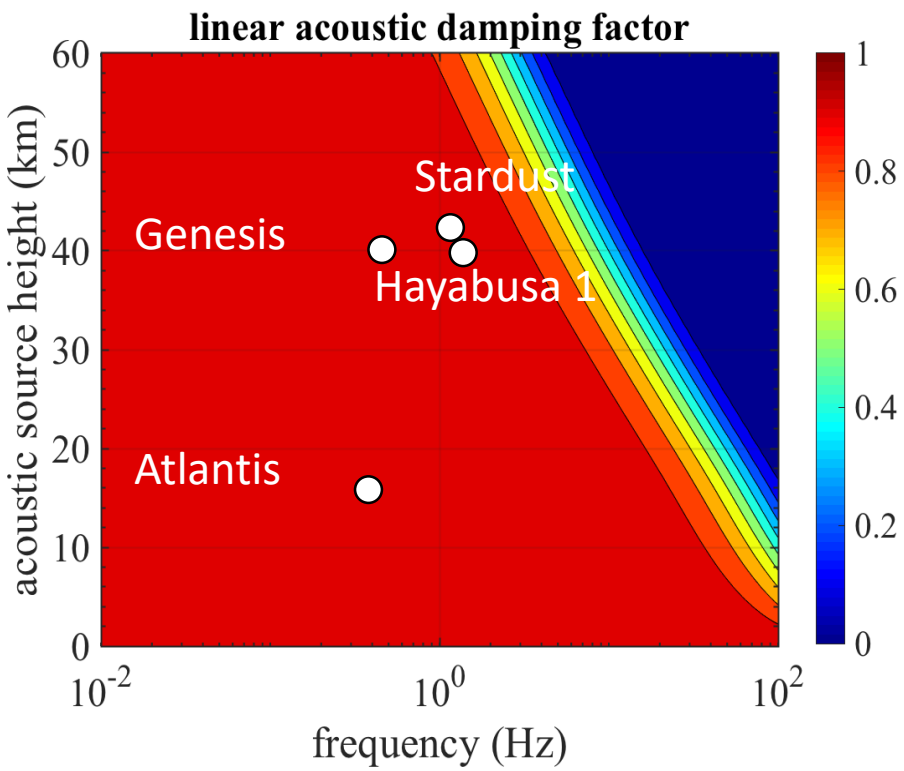


De Groot-Hedlin et al. (2008)

Acoustic damping factor (cumulative attenuation)

Assumption of vertical propagation, right under the trajectory

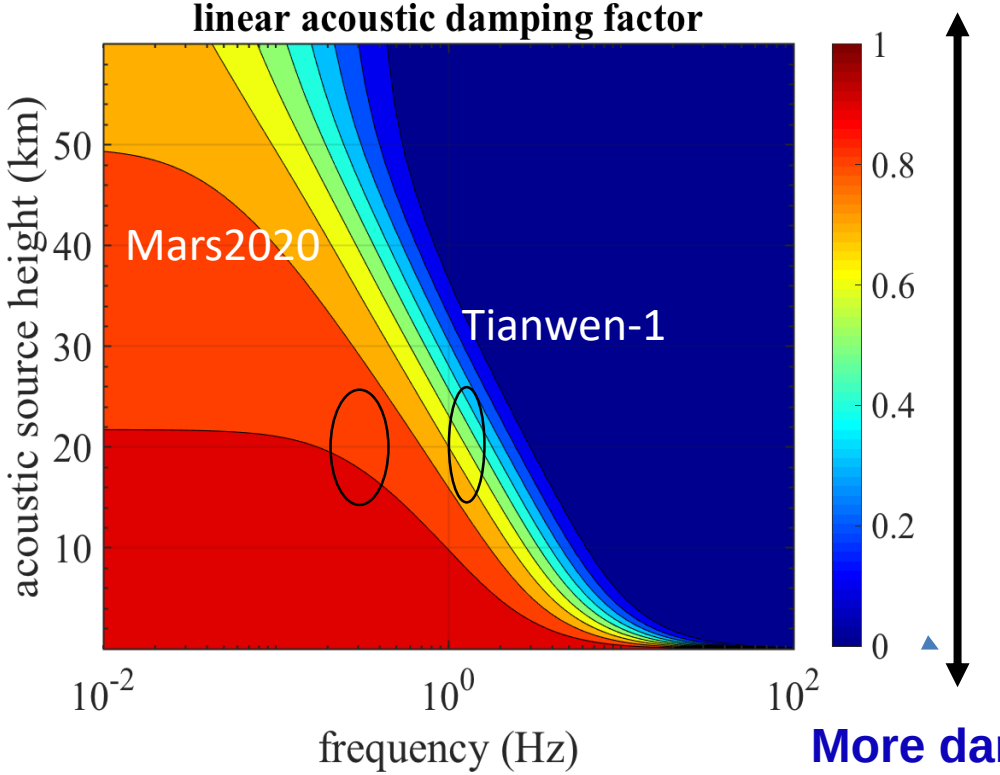
EARTH



Fundamental frequency measured at ground

MARS

Less damped



More damped

Fundamental frequency modelled at ground

Detection of a spacecraft hypersonic entry **at close distance** is possible on Mars

Sonic boom search in InSight data related to Mars2020 entry

3600km away

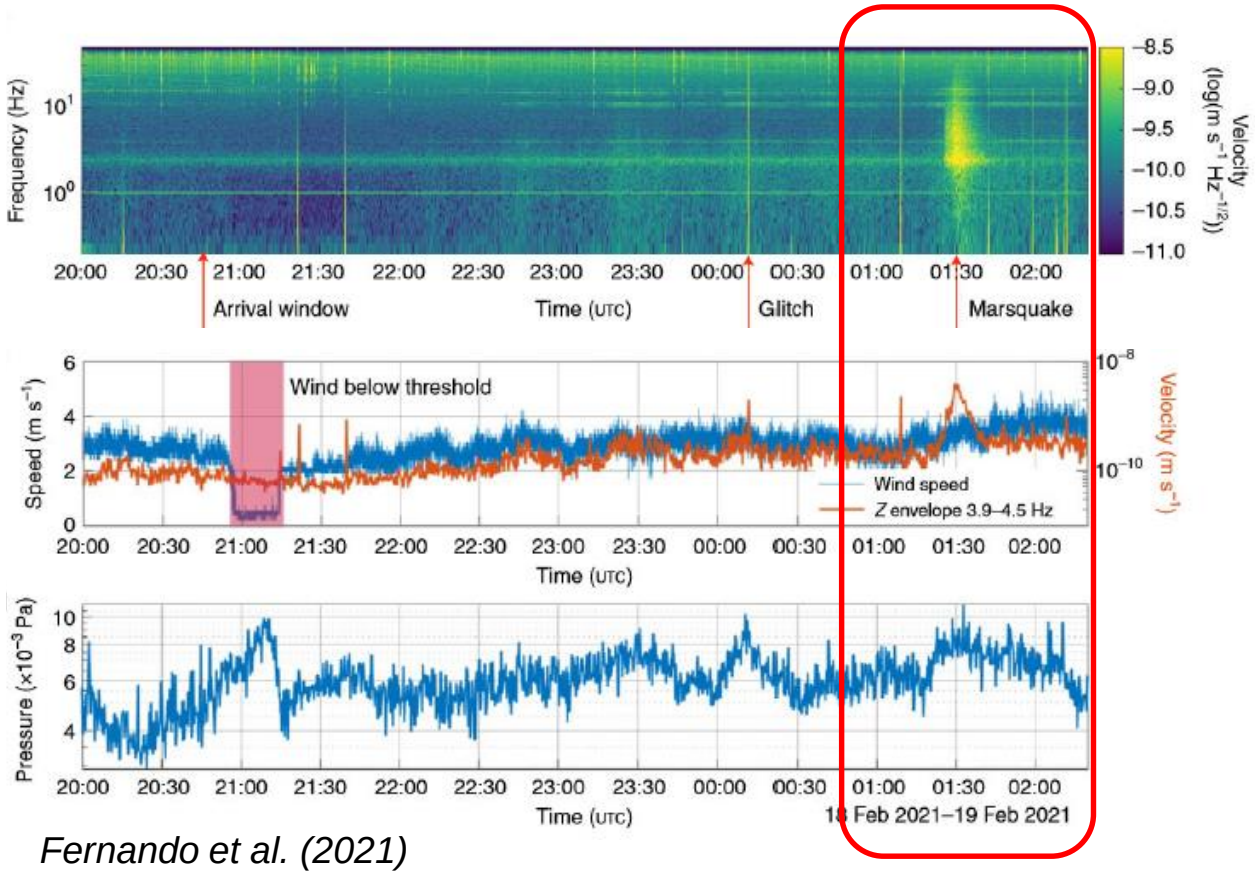
Seismic, pressure and wind data

- Atmosphere to solid coupling:

better detectability of infrasound signatures in seismic data (high sensitivity of the VBB seismometer SEIS)

- Presence of spurious signals (glitches)
- Presence of a typical marsquake event with high frequency signature
- **No sonic-boom like signature found, same for Tianwen-1**

Sonic boom search window



Fernando et al. (2021)

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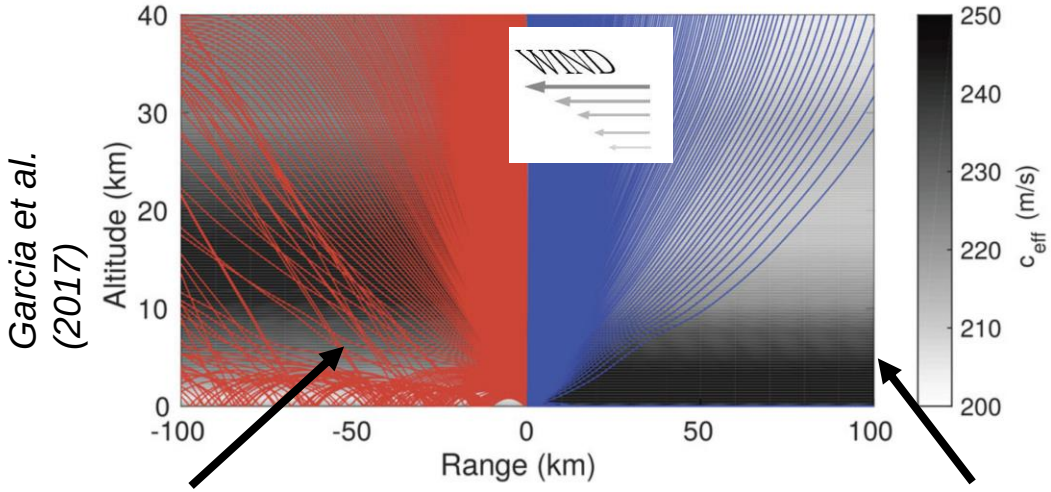
Illustration by Manchu © IPGP/Manchu/Bureau 21

How to detect a Meteor entry signal ?



Slower zone
(« downwind »)

Faster zone (« upwind »)

h

(T0, r0) **v** ~ 5-10 km/s
(Mach~20-50)

S0) Conic shock
or airburst ?

S1) Trapped ac. wave

S2) Trapped ac.
wave from impact

Wind

InSight

Seismic waves
(=> impact + shock wave ?)

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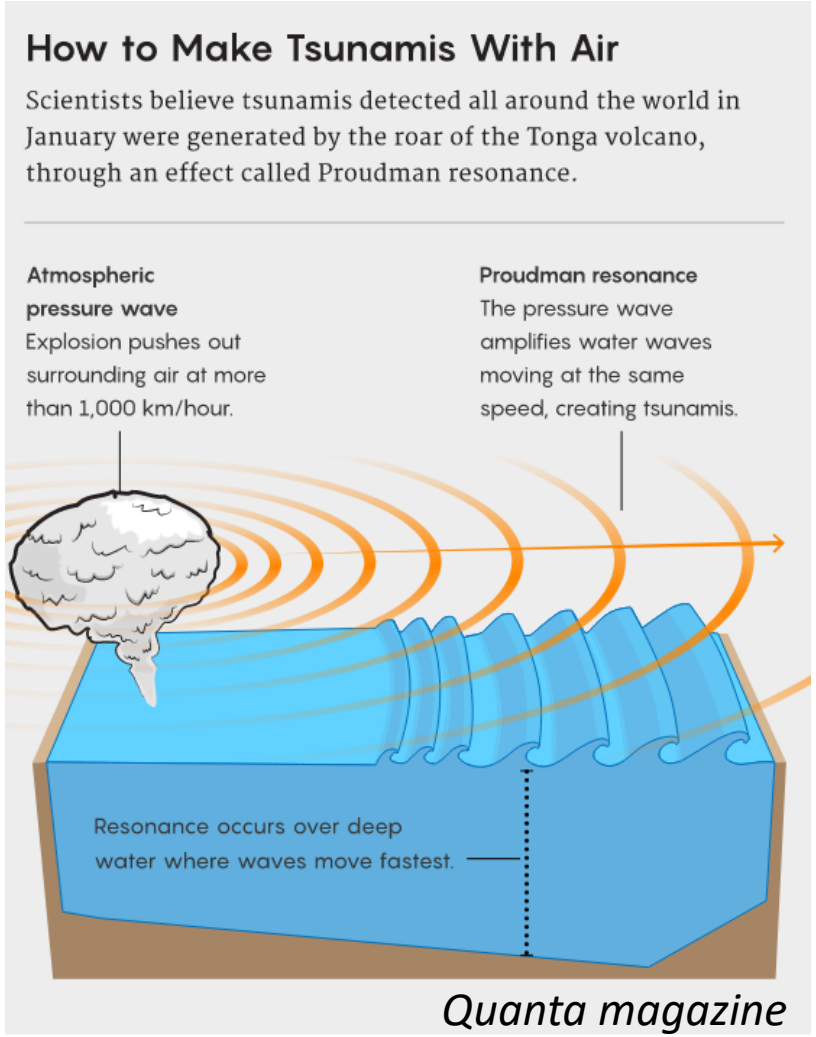
The 2022 Hunga Tonga-Hunga Ha'apai volcano eruption

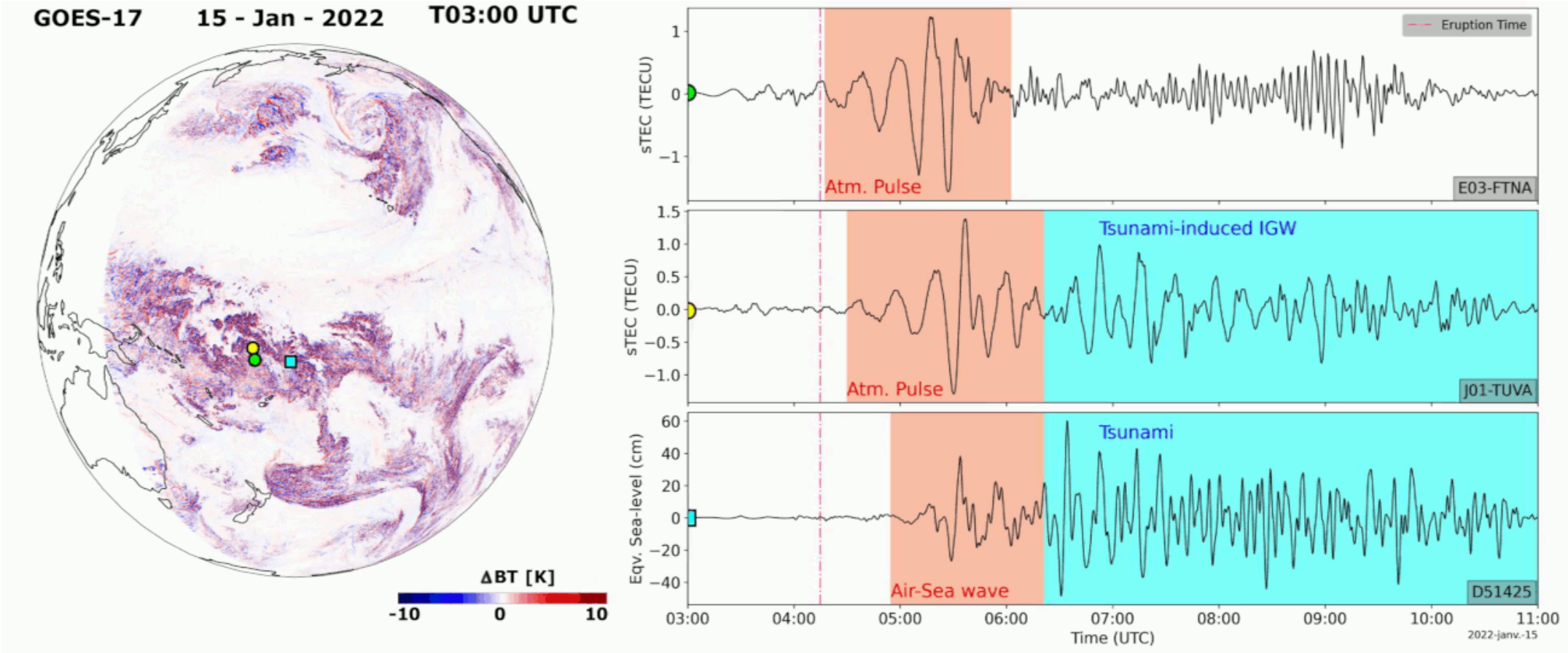
© AFP / EYEPRESS NEWS

https://fealse.com/2022/01/15/tonga-volcano-eruption-one-of-the-biggest-ever-captured-from-space/



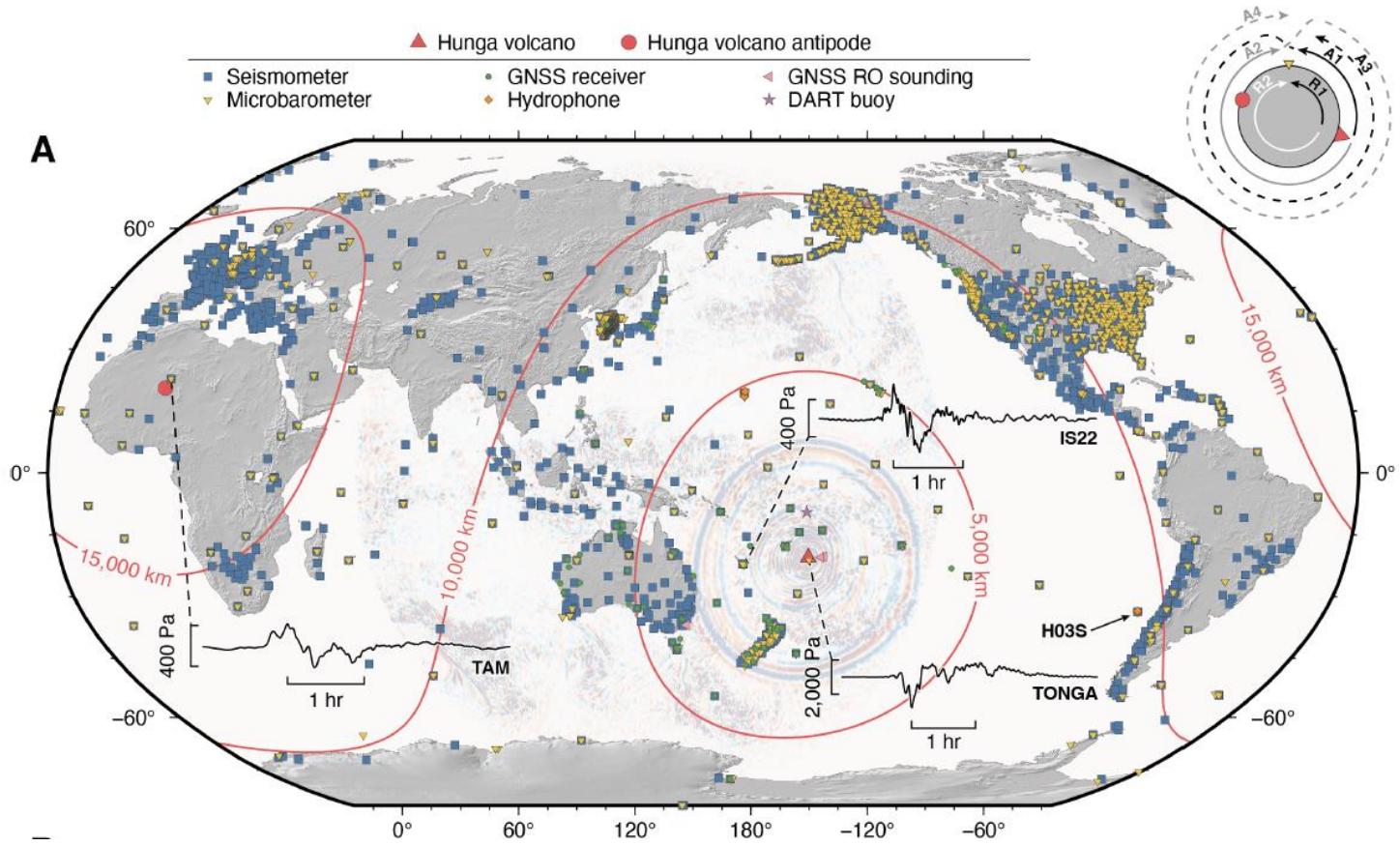
Quanta magazine

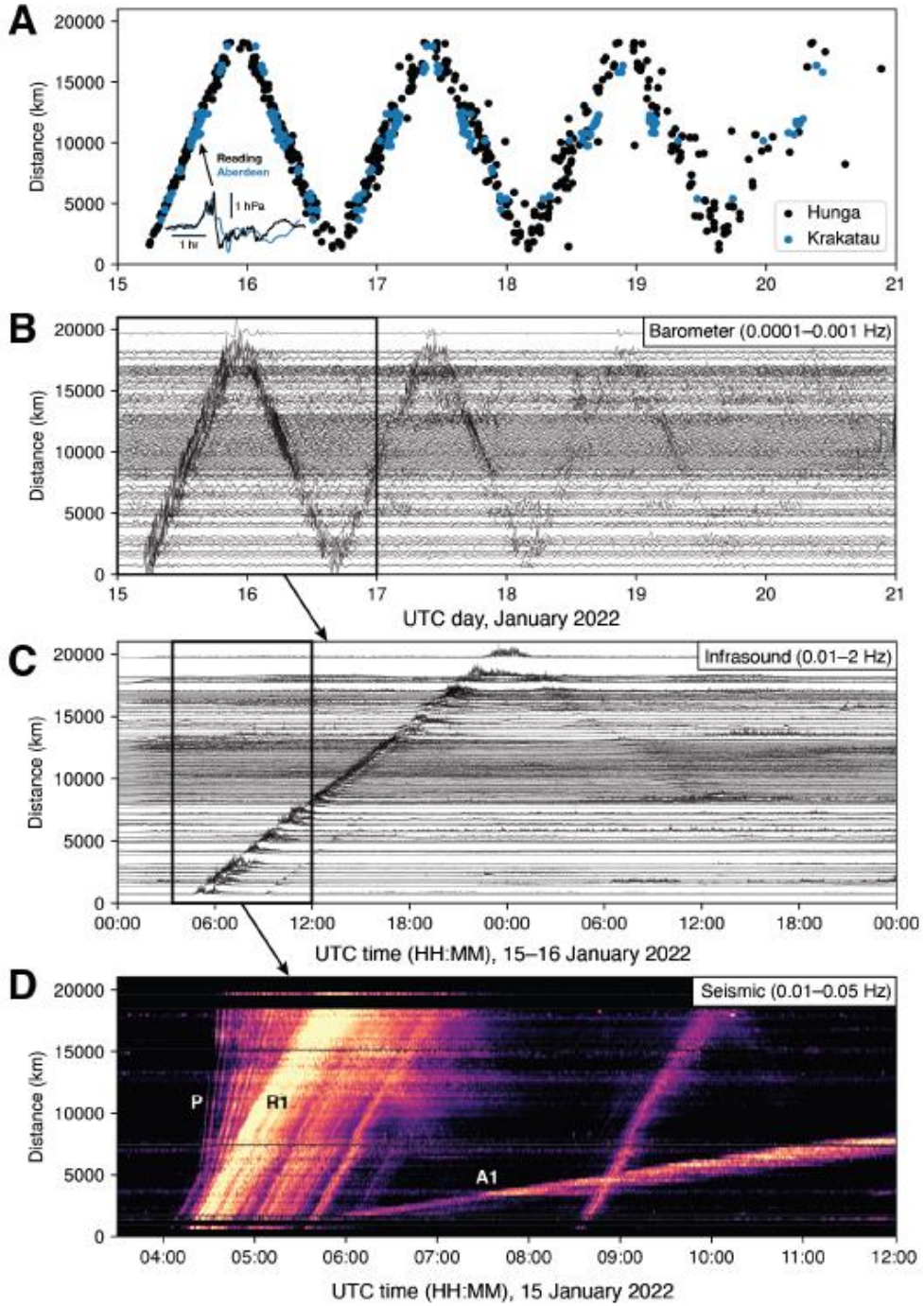
An air wave, an air-sea wave and a tsunami



Matoza et al. (2022). Video: F. Manta & E. Munaibari

An air « surface » wave





The 2022 Hunga Tonga-Hunga Ha'apai volcano eruption

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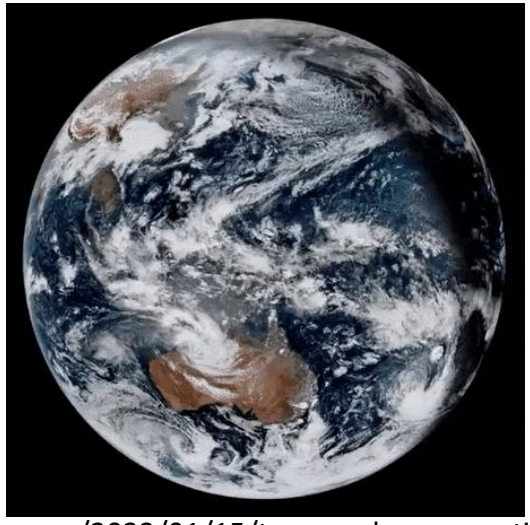

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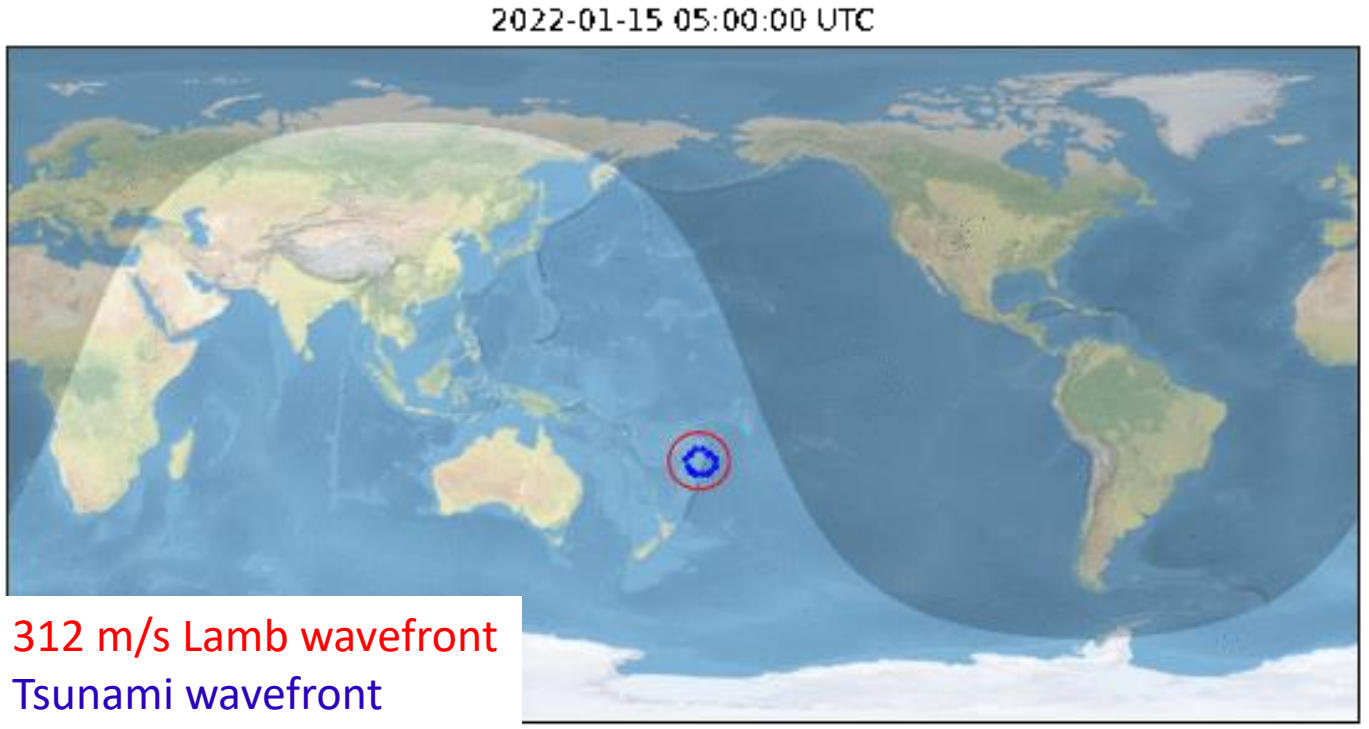


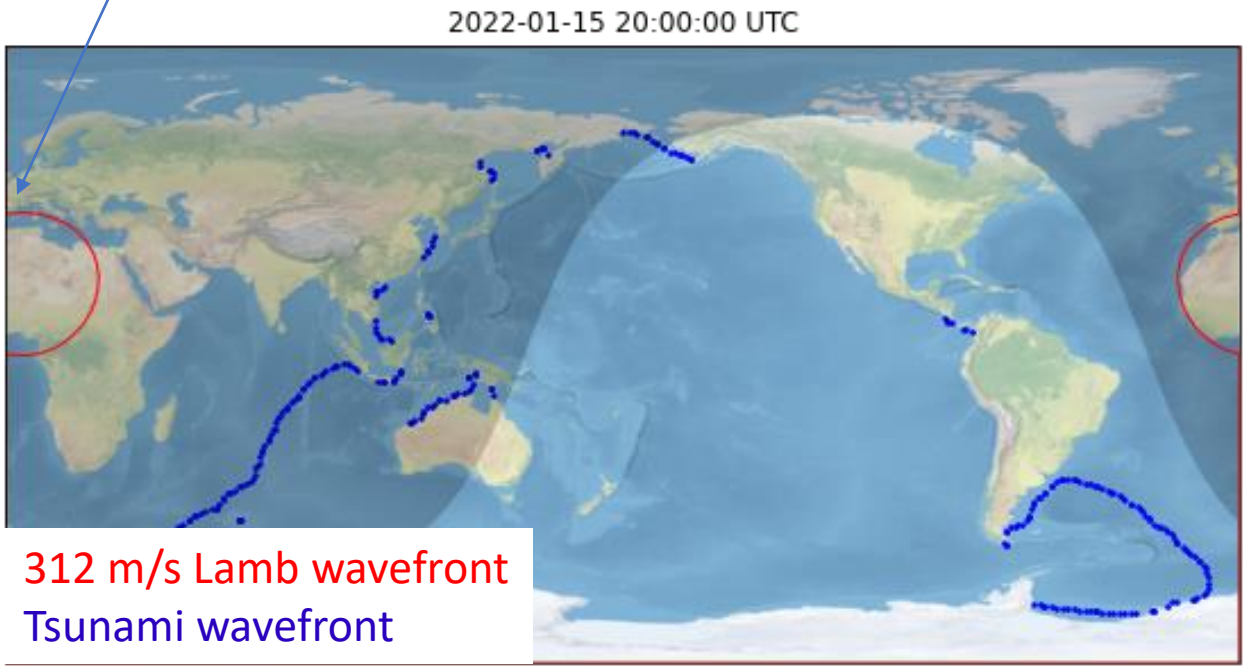
312 m/s Lamb wavefront
Tsunami wavefront

The 2022 Hunga Tonga-Hunga Ha'apai volcano eruption

© AFP / EYEPRESS NEWS

https://fealse.com/2022/01/15/tonga-volcano-eruption-one-of-the-biggest-ever-captured-from-space/

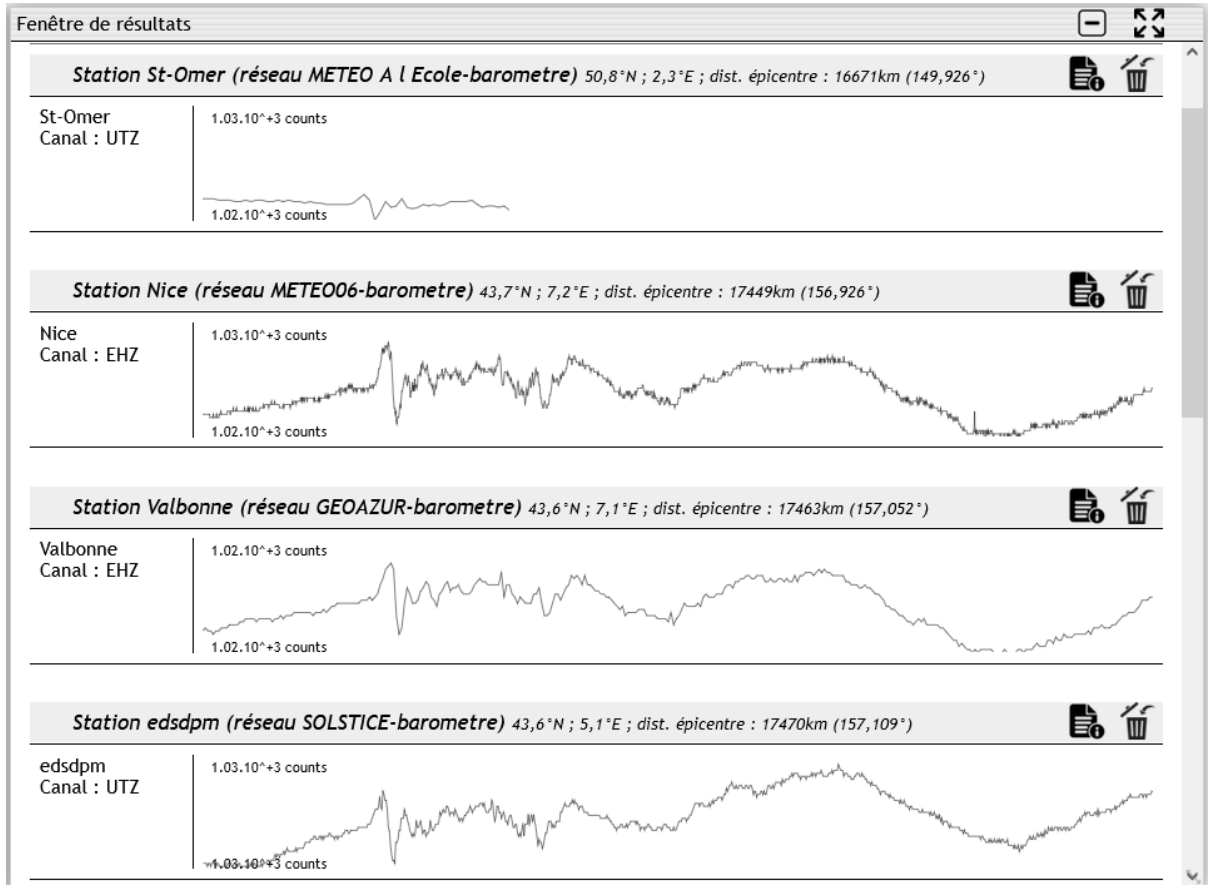
Arrives in France at ~20 UTC



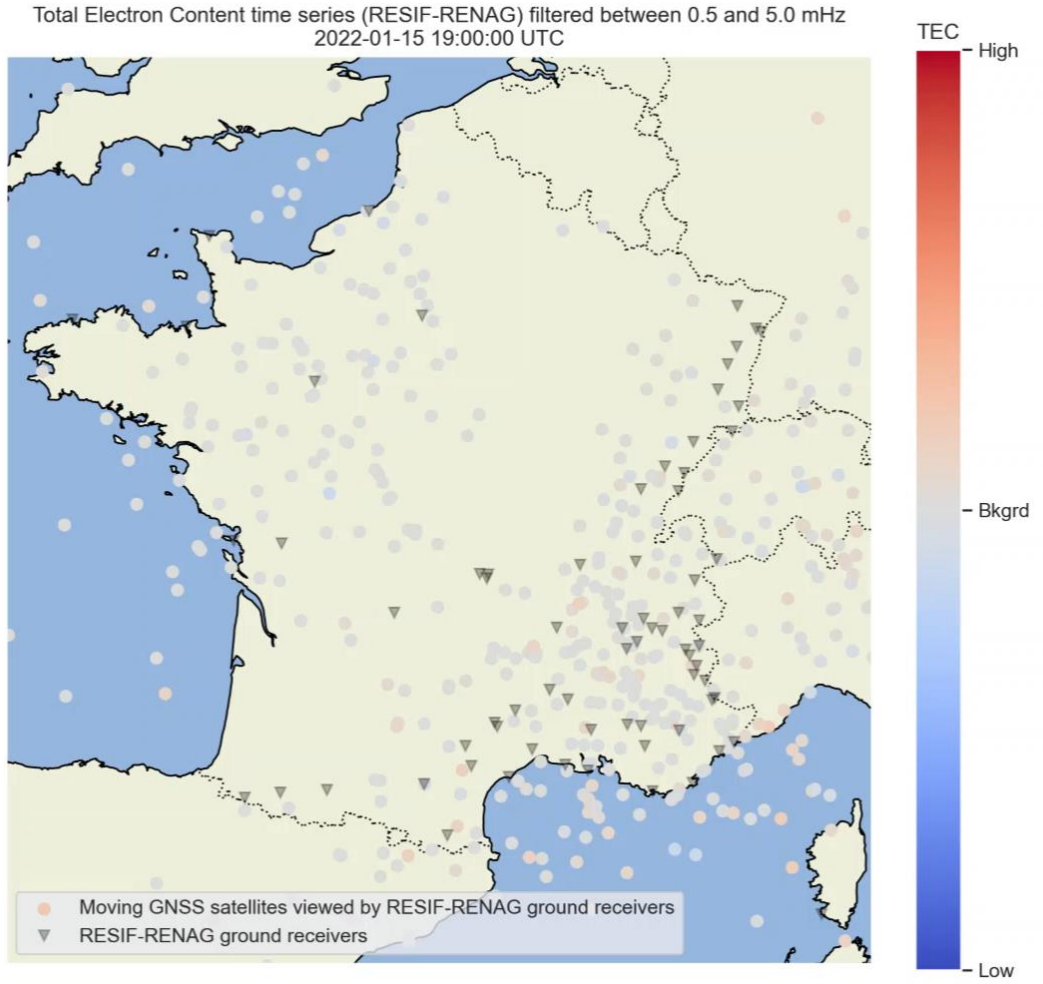
Observations of the Hunga-Tonga eruption from France

METEO (EDUCATIVE network)

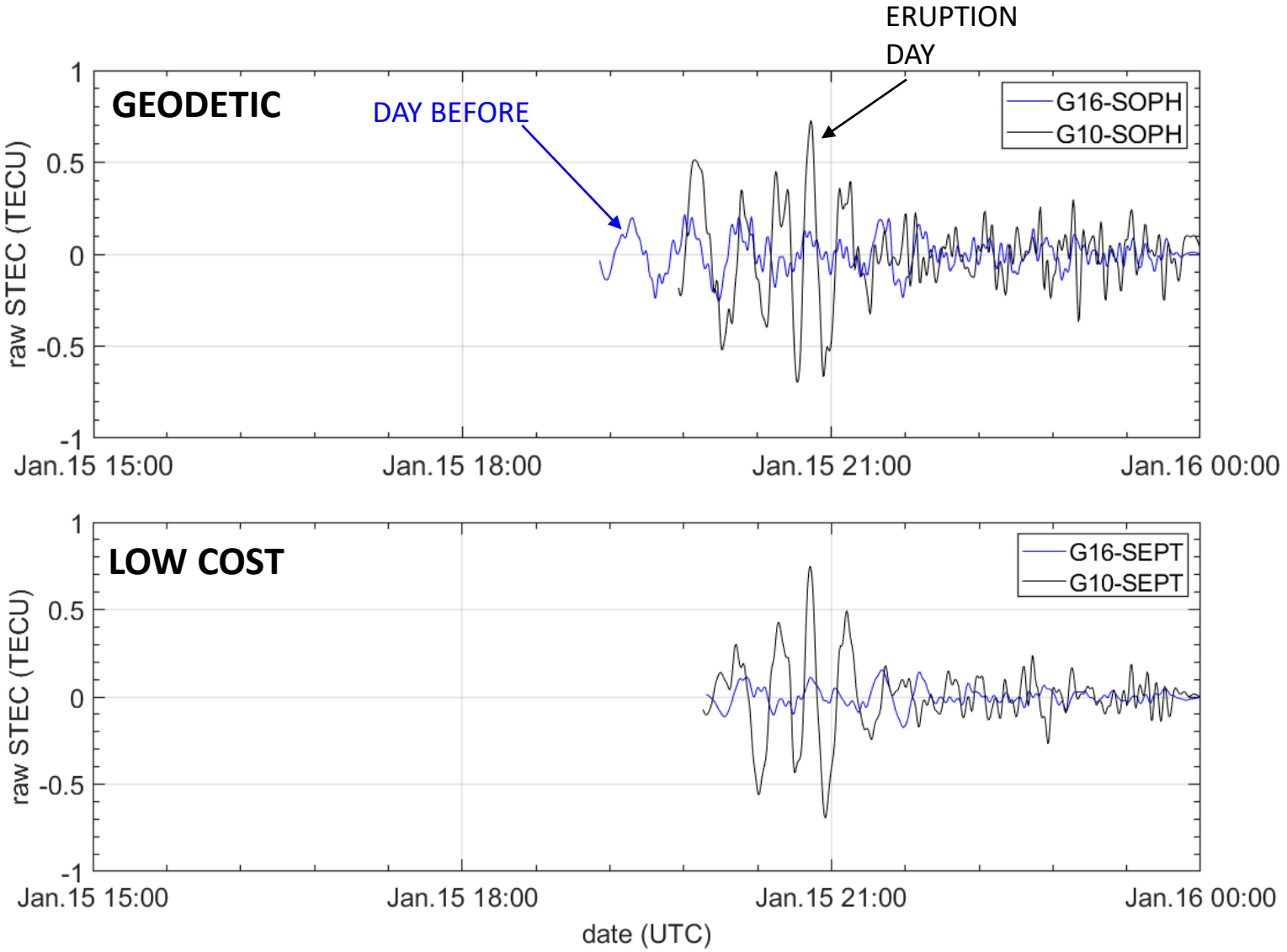
http://edumed.unice.fr/data-center/volcano/

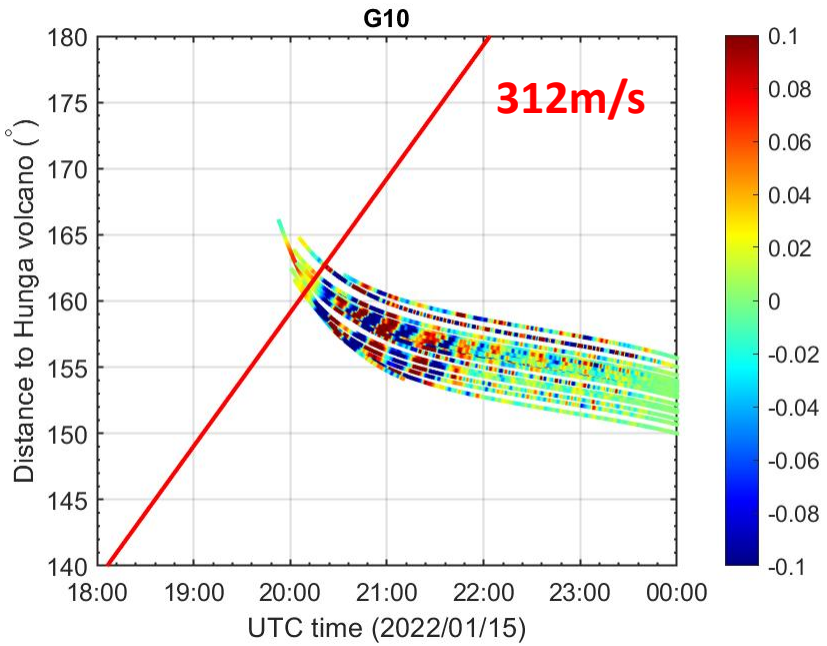


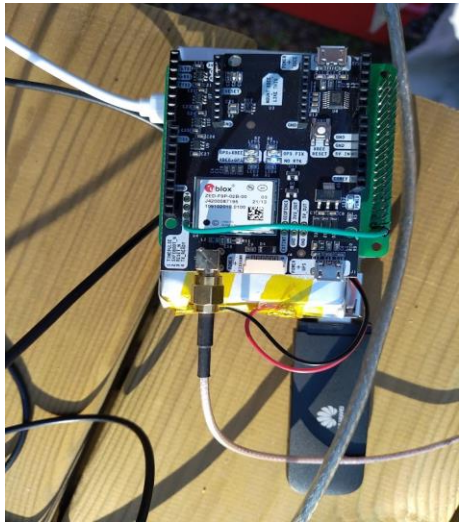
IONOSPHERIC (RENAG GNSS network)



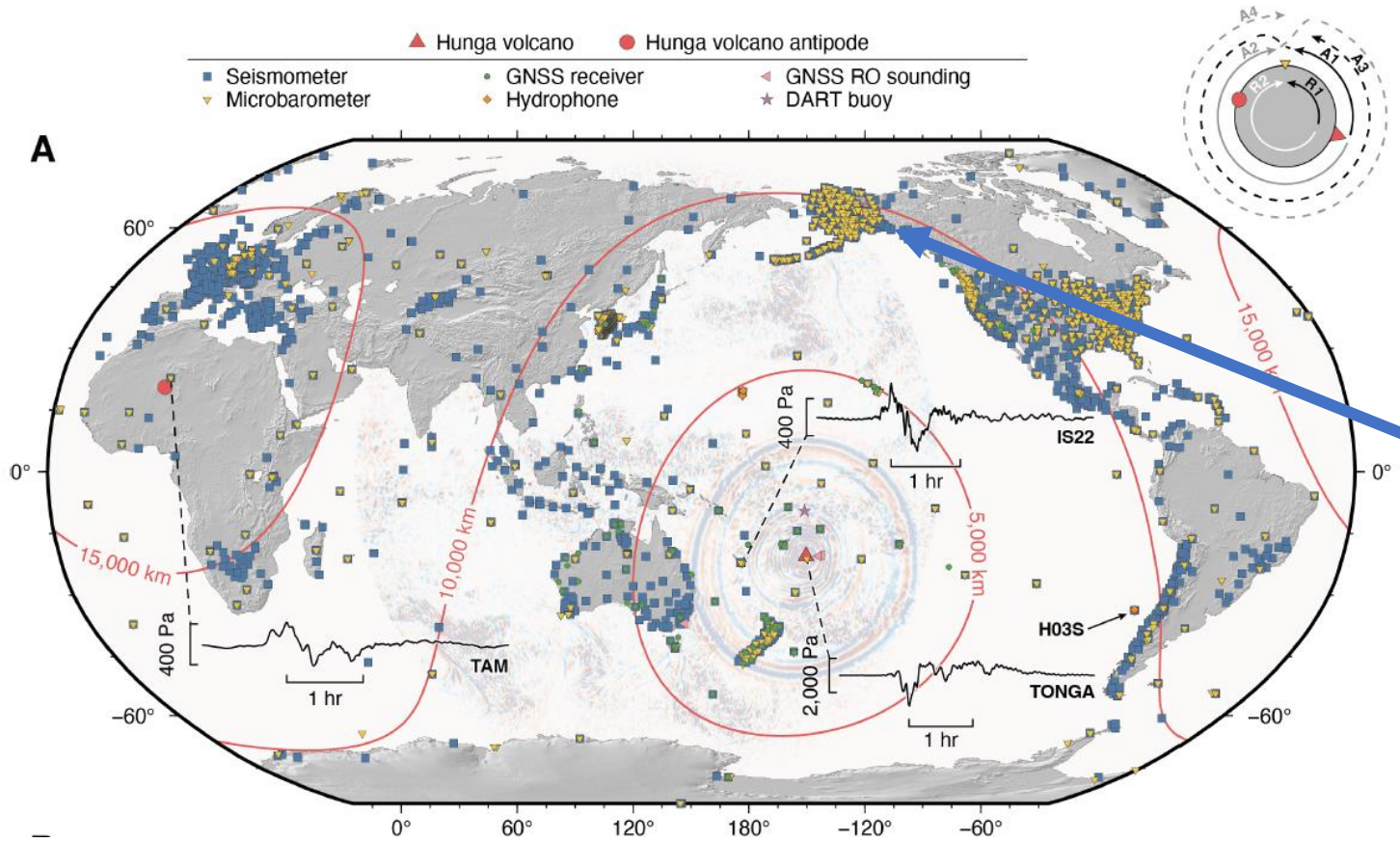
A low cost GNSS receiver also measured the ionospheric wave

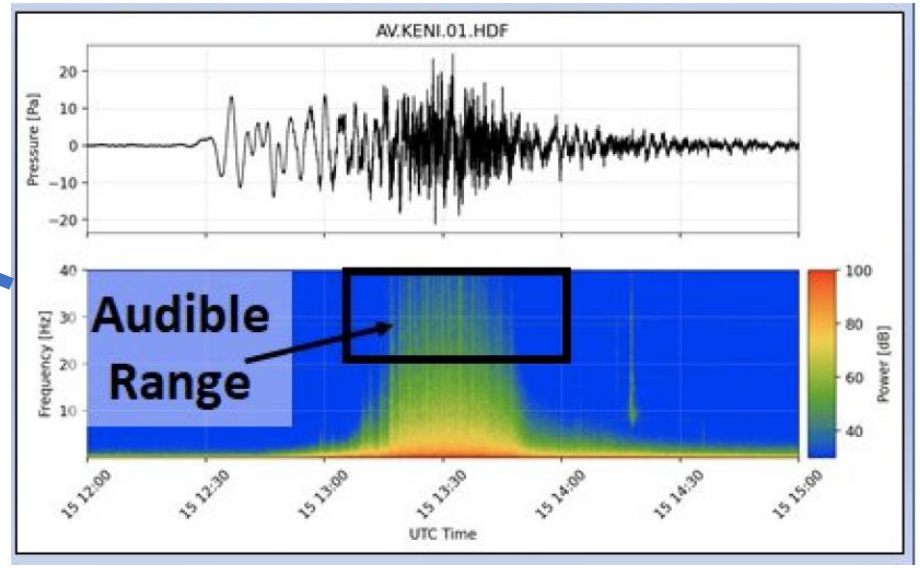






A volcano eruption also heard in the audible range ~10 000 km away





Courtesy: D. Fee

Matoza et al. (2022)

Merci !
Thank you !

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