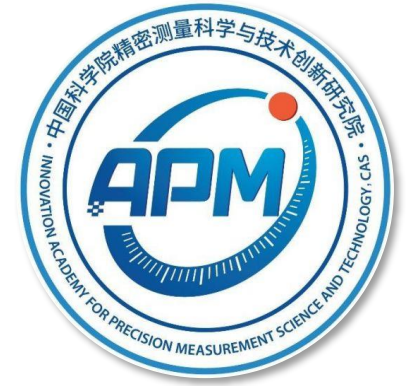# SnT 2023

CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Generation mechanism of the 26s and 28s tremors in the Gulf of Guinea from statistical analysis of magnitudes and event intervals

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2023.06.22

OUTLINE

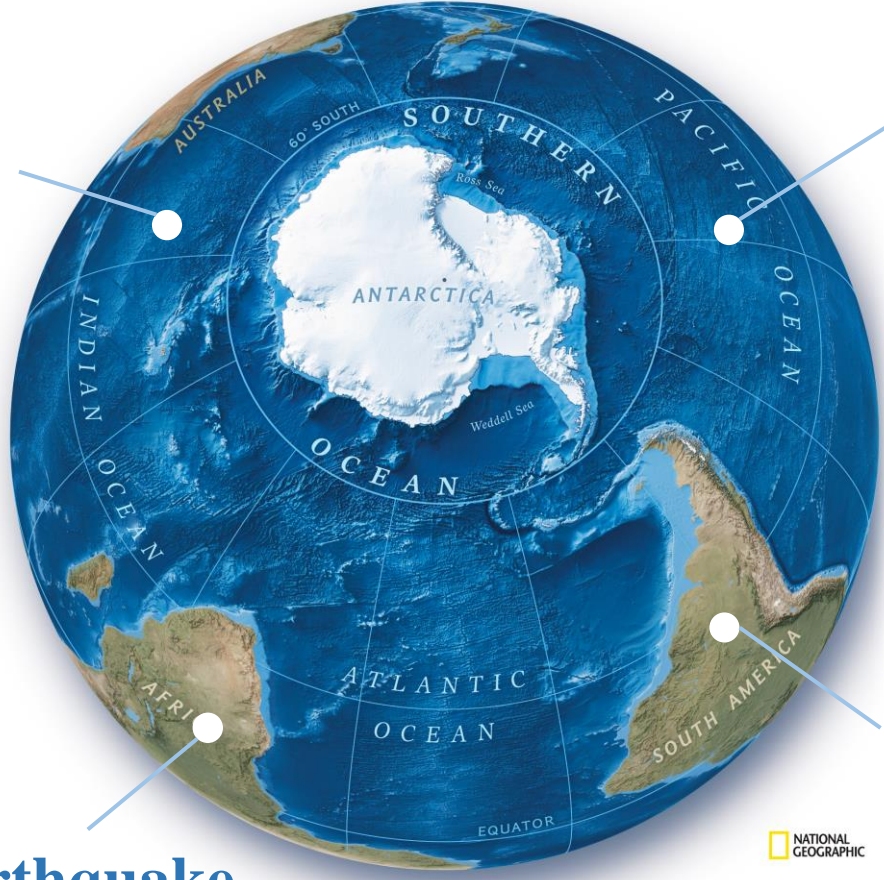The earth is a dynamic planet with abundant **vibrating processes.**

Tsunami

Volcano Eruption

Earthquake

Landslide

......

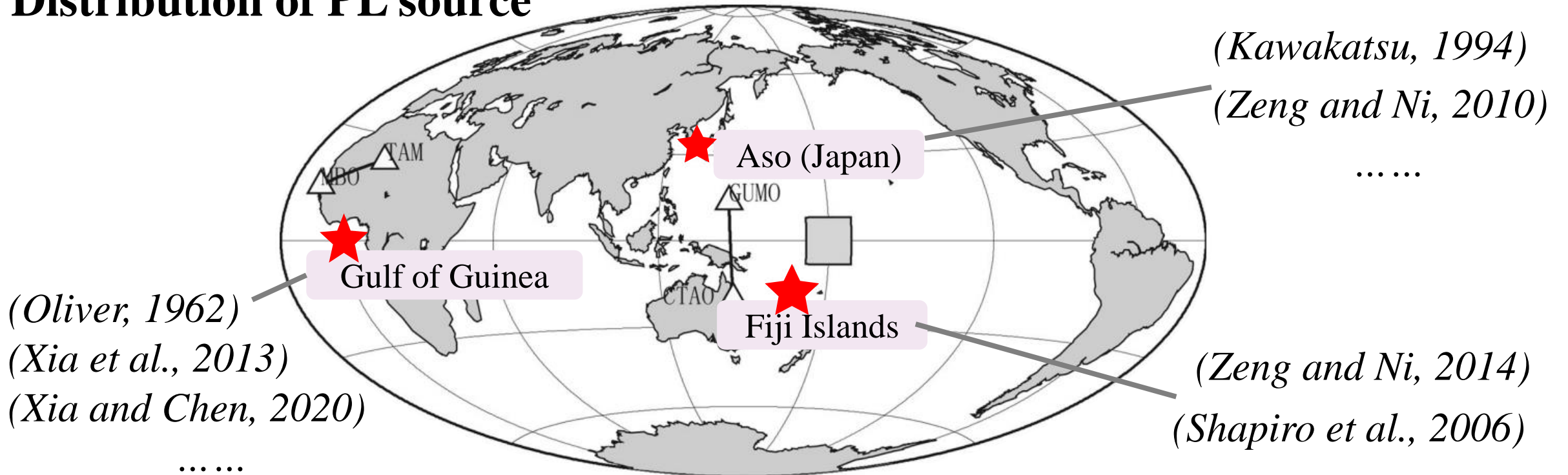# Four possible types of dynamic activities on the earth

Localized

SPACE

Persistent Localized Source

(PL source)

- Long duration
- Fixed location
- Specific period

① Earthquake Events

② Volcano Eruption

③ Landslides

…

Occasional ──────────── **TIME** **Persistent**

. . .

① The primary microseism

② The secondary microseism

…

Ubiquitous
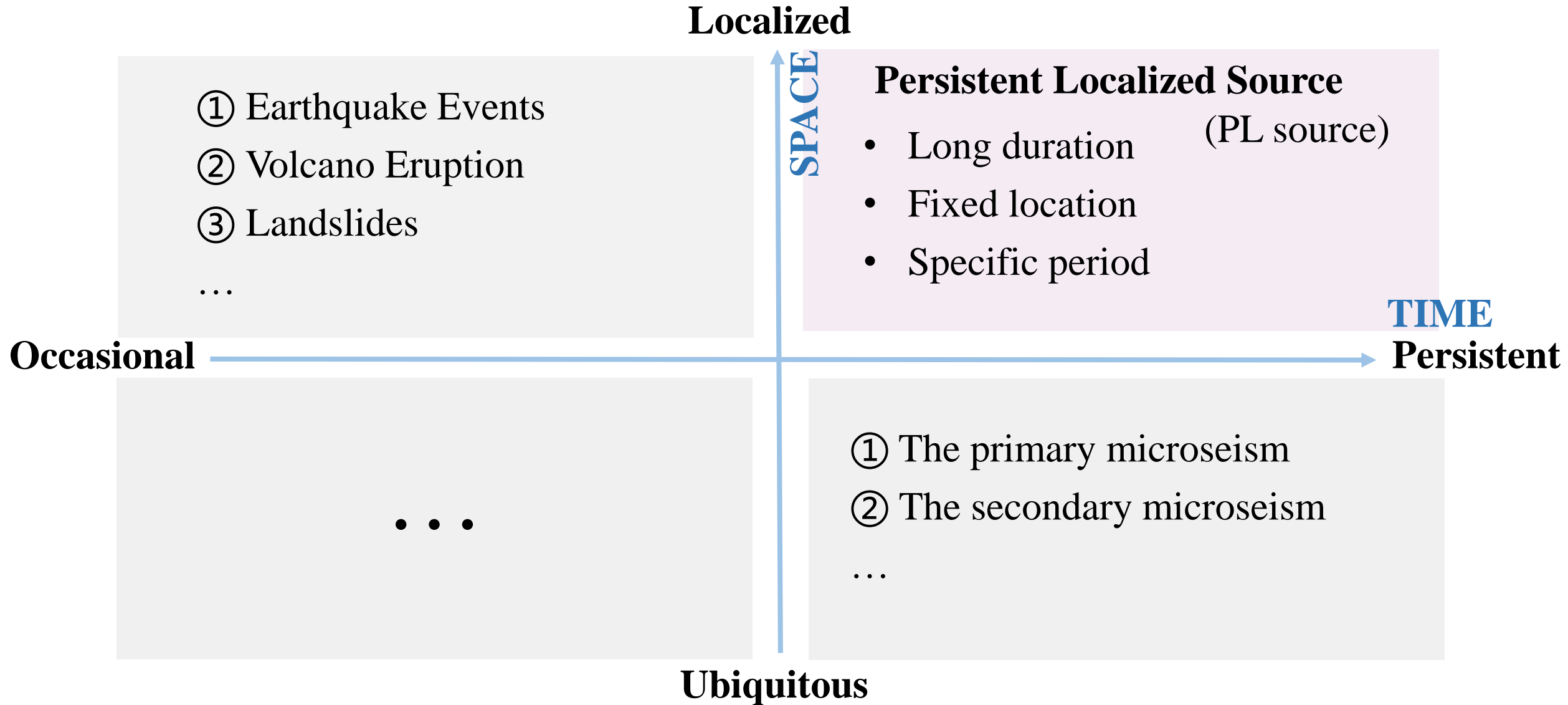
Distribution of PL source

(Kawakatsu, 1994)
(Zeng and Ni, 2010)
......

(Oliver, 1962)
(Xia et al., 2013)
(Xia and Chen, 2020)
......

(Zeng and Ni, 2014)
*(Shapiro et al., 2006)*
......

- The long-period signal of **26s** was first detected in the **Gulf of Guinea**

- Another **26s** signal was observed in Fiji Islands and it was first thought as a mirror of the 26s signal in the Gulf of Guinea but then was confirmed to be an independent source.

- The **8-14s** PL source around Aso volcano in Japan was detected.
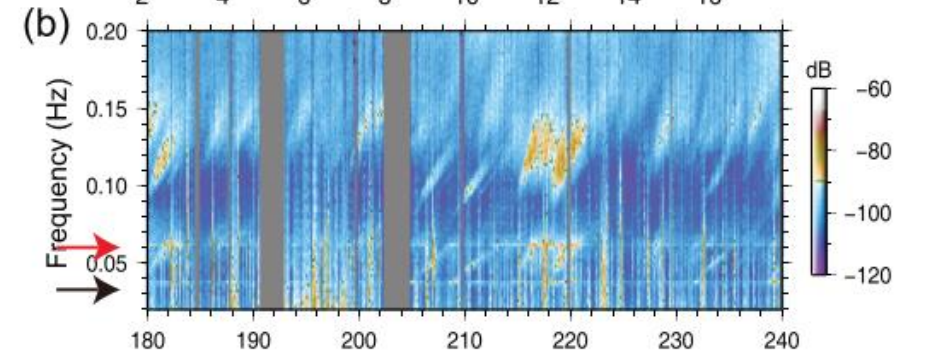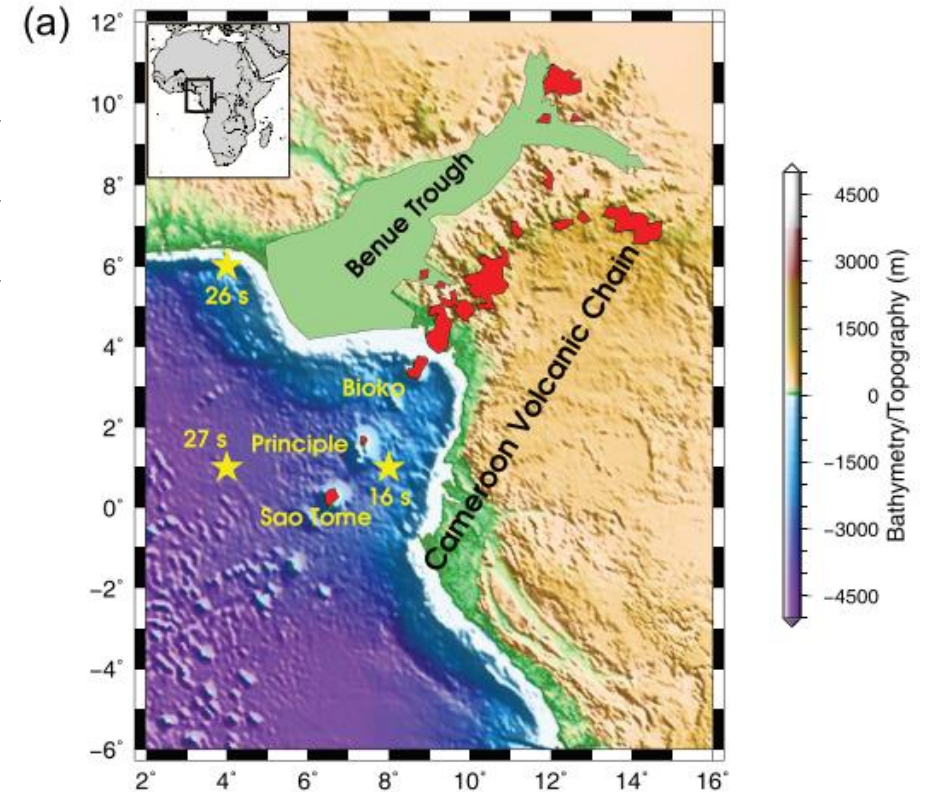
PL sources in the Gulf of Guinea

1962 Detected the **26s** PL source in the Gulf of Guinea
2013 Detected the **28s** PL source in the Gulf of Guinea
2020 Detected the **16s** PL source in the Gulf of Guinea
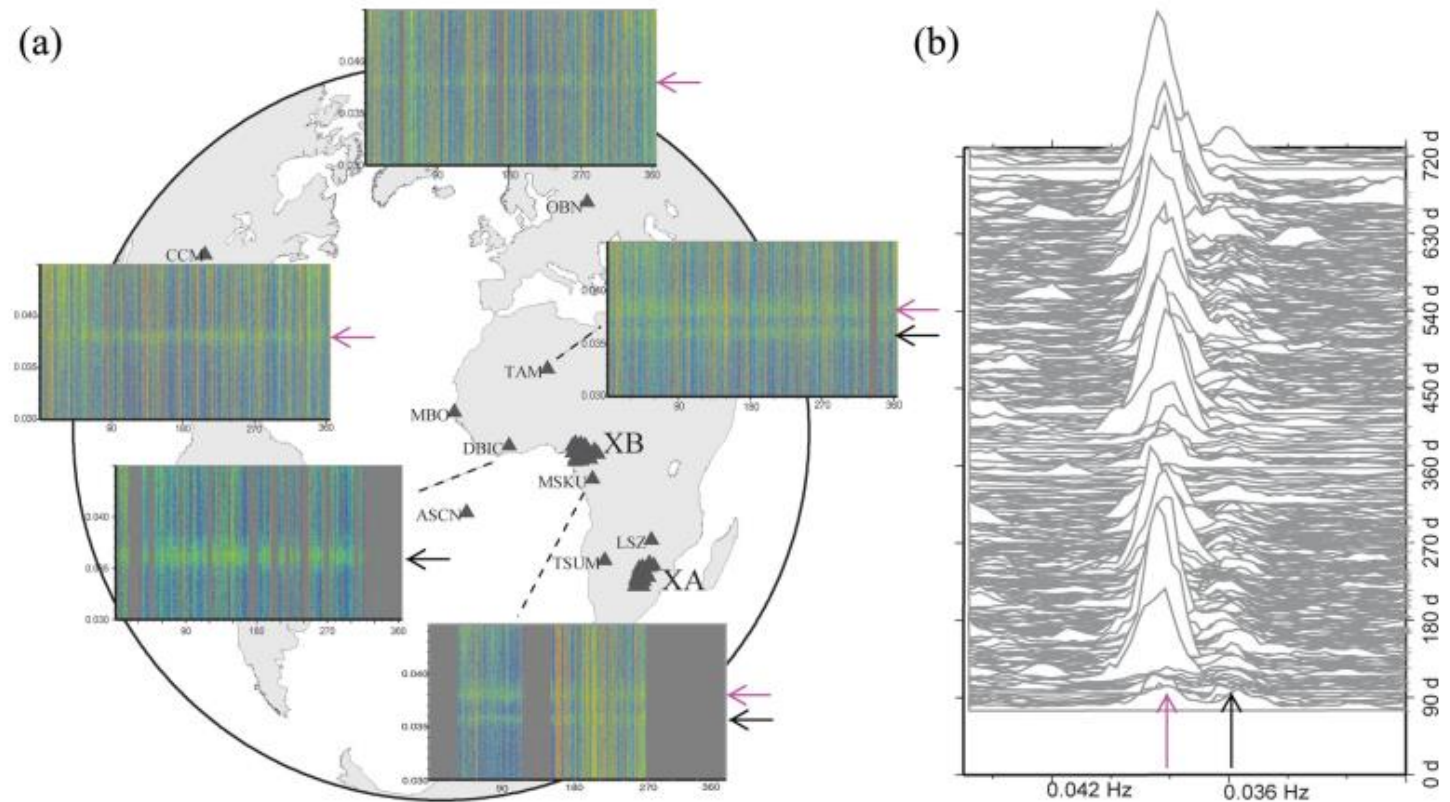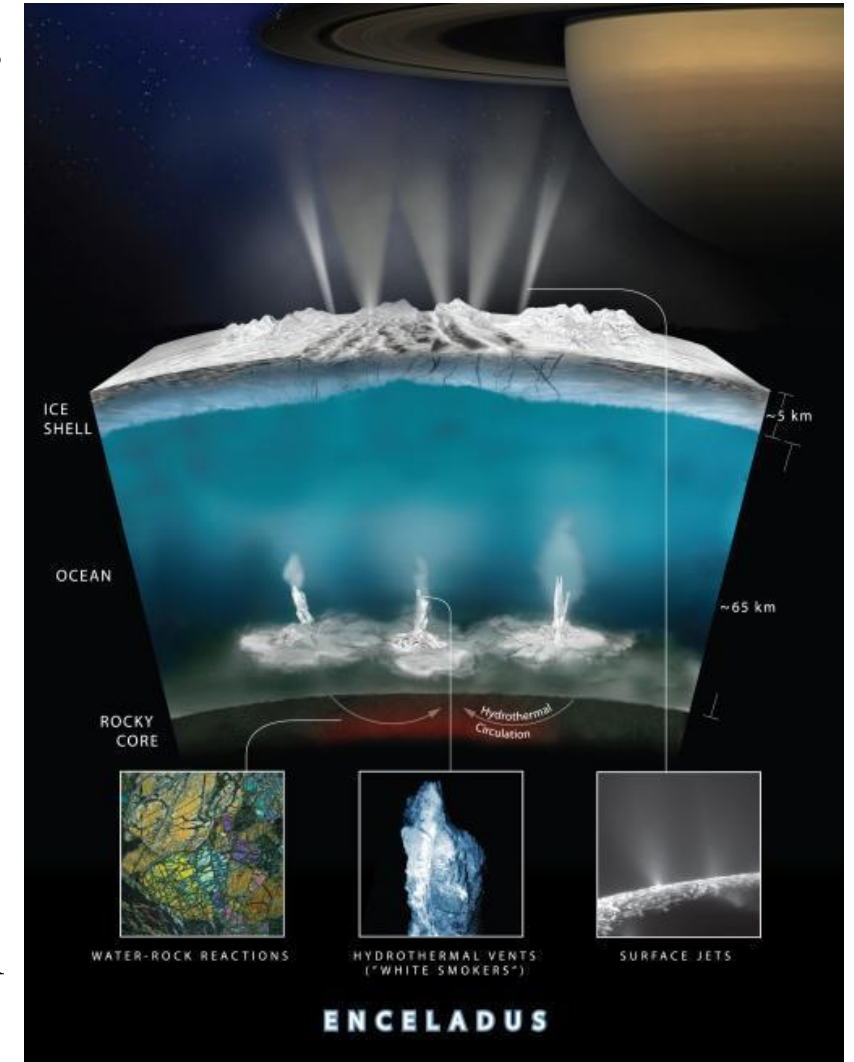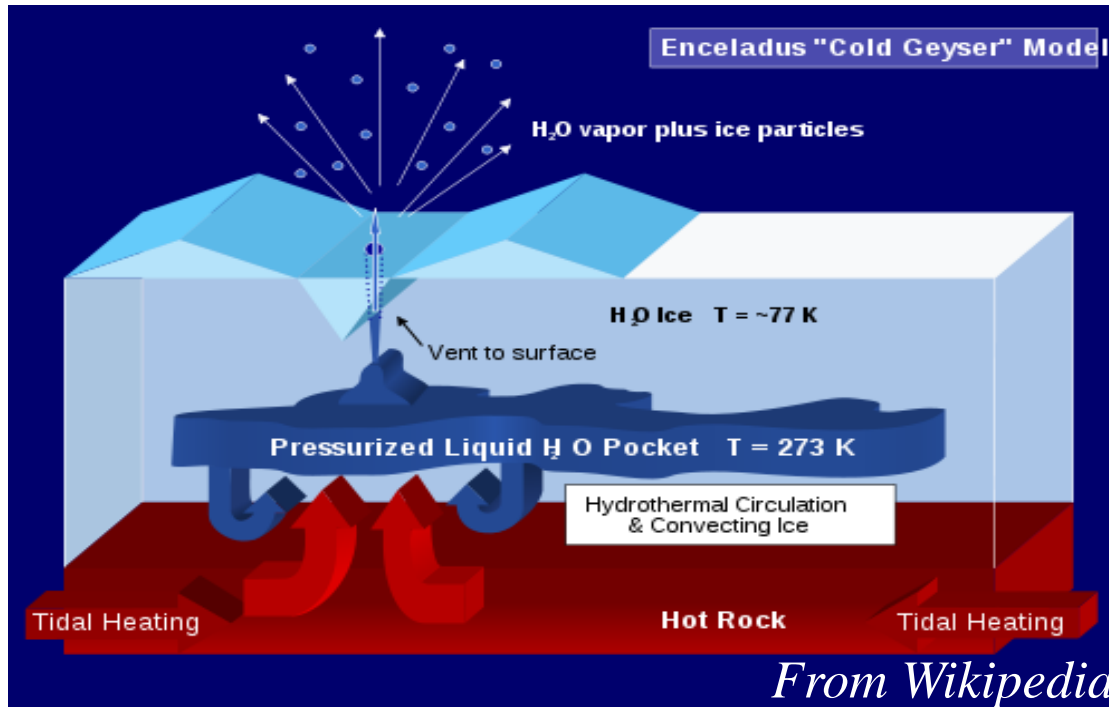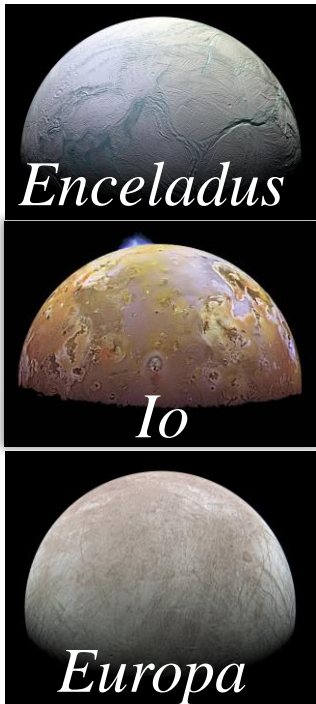

*(Xia et al., 2013)*

(Xia and Chen, 2020)

Probably Similar Sources on Earth-like Extraterrestrial Bodies

● Similar vibration may exist on Enceladus (Moon of Saturn), Io or Europa (Both moons of Jupiter).

Enceladus

Io

Europa

Enceladus "Cold Geyser" Model

H₂O vapor plus ice particles

H₂O Ice T = ~77 K

Vent to surface

Pressurized Liquid H₂O Pocket T = 273 K

Hydrothermal Circulation & Convecting Ice

Tidal Heating   Hot Rock   Tidal Heating

From Wikipedia

ICE SHELL
~5 km

OCEAN
~65 km

ROCKY CORE

Hydrothermal Circulation

WATER-ROCK REACTIONS   HYDROTHERMAL VENTS ("WHITE SMOKERS")   SURFACE JETS

E N C E L A D U S

● Analysing PL sources on earth can help explore the internal energy exchange process in other Extraterrestrial Bodies.

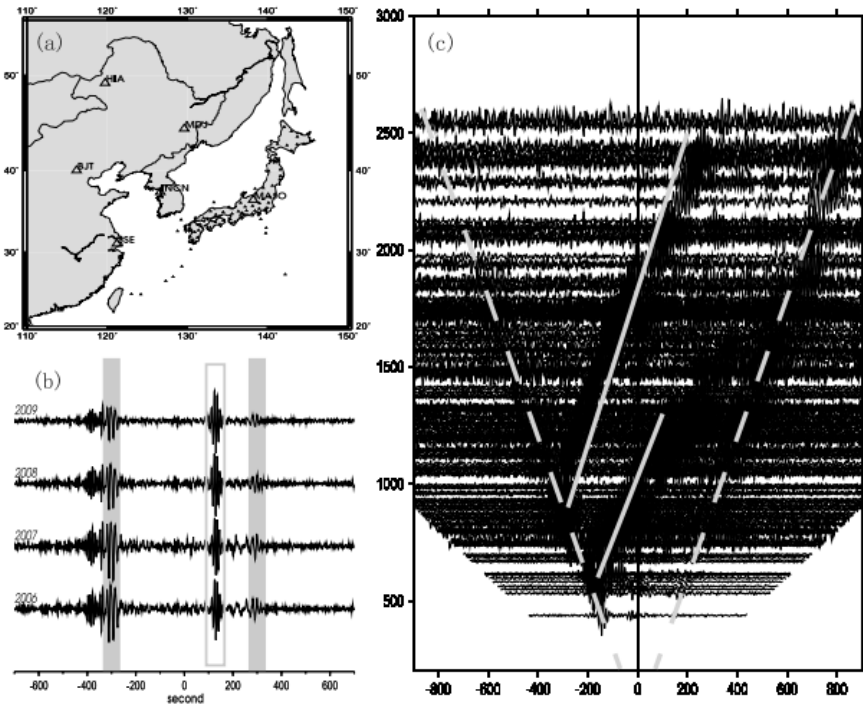# PL sources may cause severe contamination in ambient noise tomography
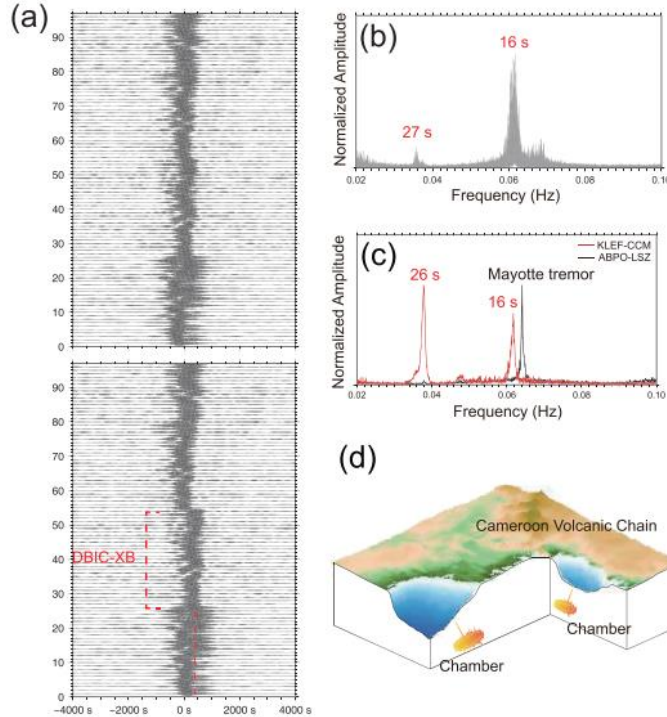

(Zheng et al., 2011)
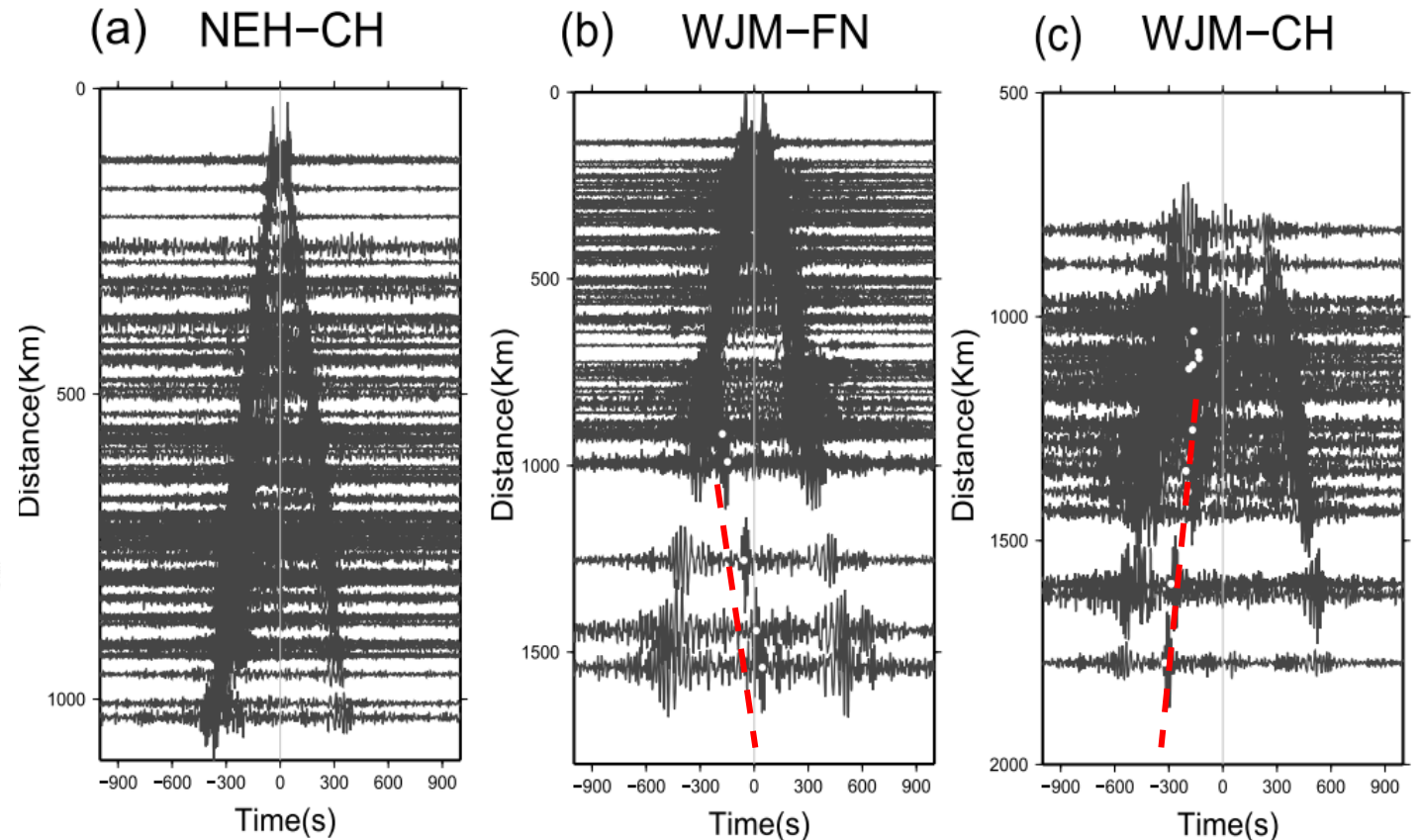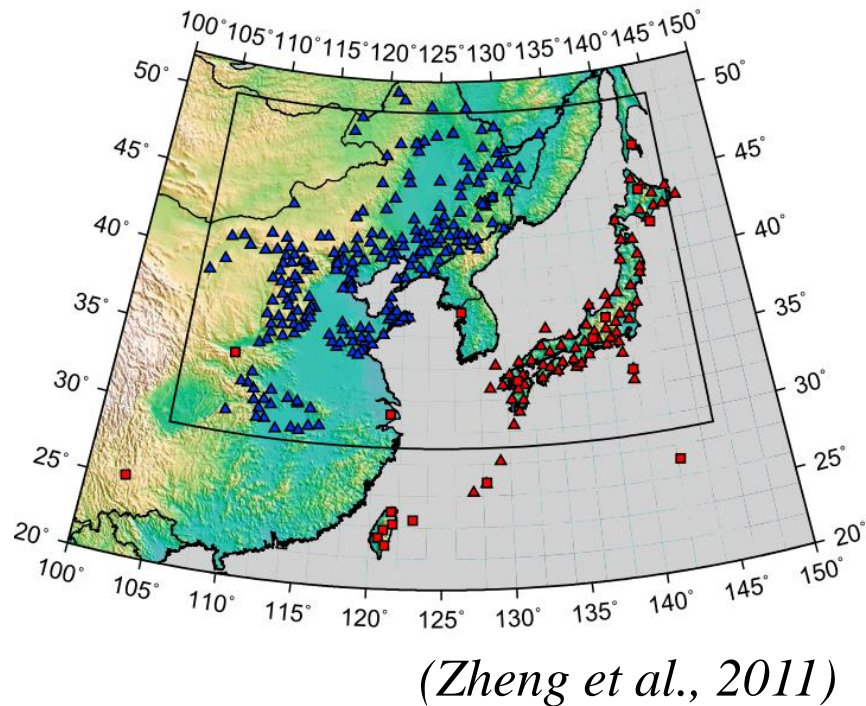
- The PL source appears as **precursory signals** on the cross-correlation waveforms.
- It is necessary to study PL sources to reduce their interference in ambient noise tomography.
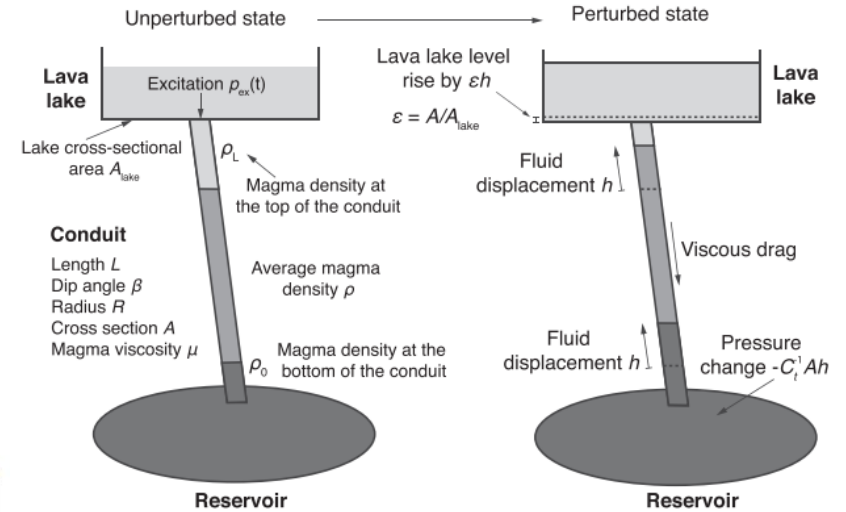
Location and generation mechanism studies of PL sources

(Zeng and Ni, 2014）　　　*(Xia and Chen, 2020）*　　　*(Liang et al., 2020)*

Observation: Cross-correlation　　　**Lack connection**　　　Simulation
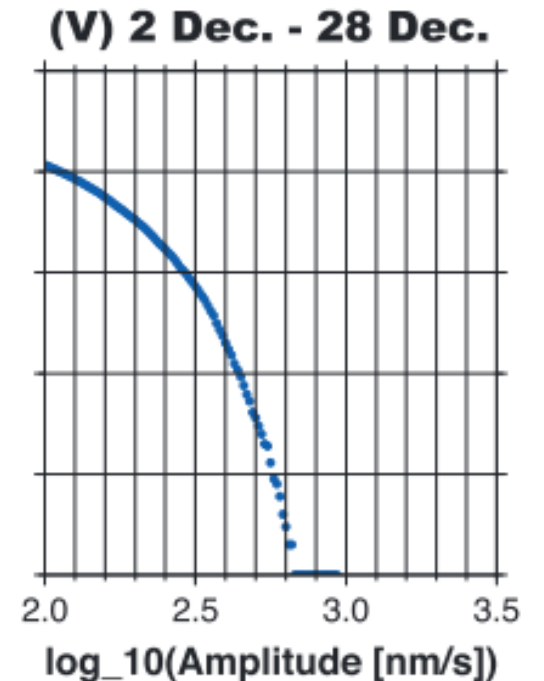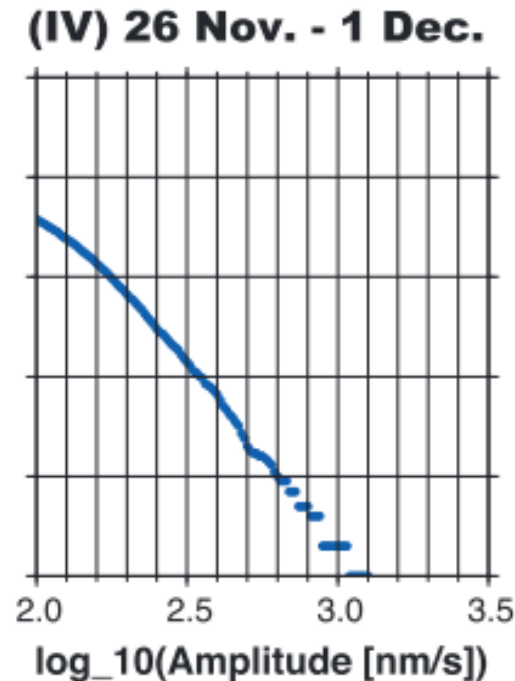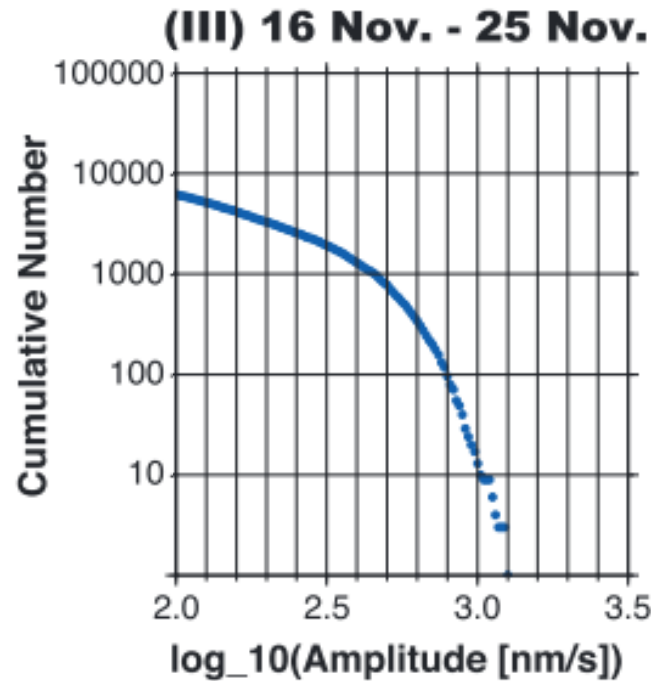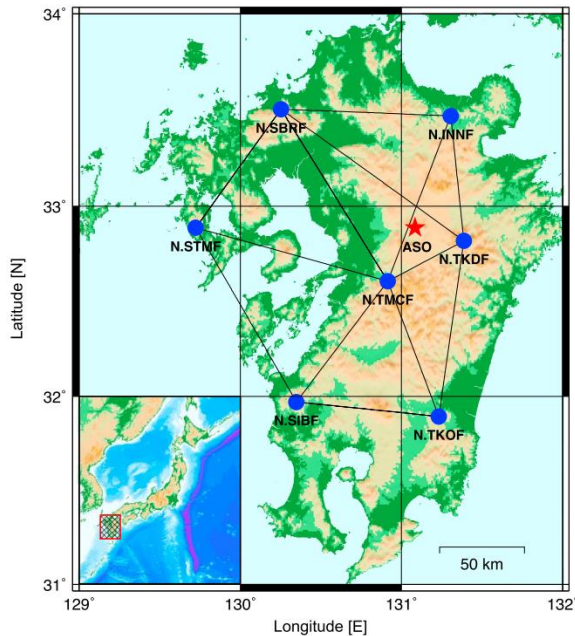
Characteristics　　　Location　　　…　　　Generation mechanism

Statistical Method are effective in studying generation mechanism of PL sources

(Osamu Sandanbata et al.,2015)

Amplitude-frequency Distribution   Exponential ➡ Power law ➡ Exponential

The eruption style of Aso volcano   Phreatic ➡ Magmatic ➡ Phreatic

The 26s (0.038Hz) and 28s (0.036Hz) source in the Gulf of Guinea
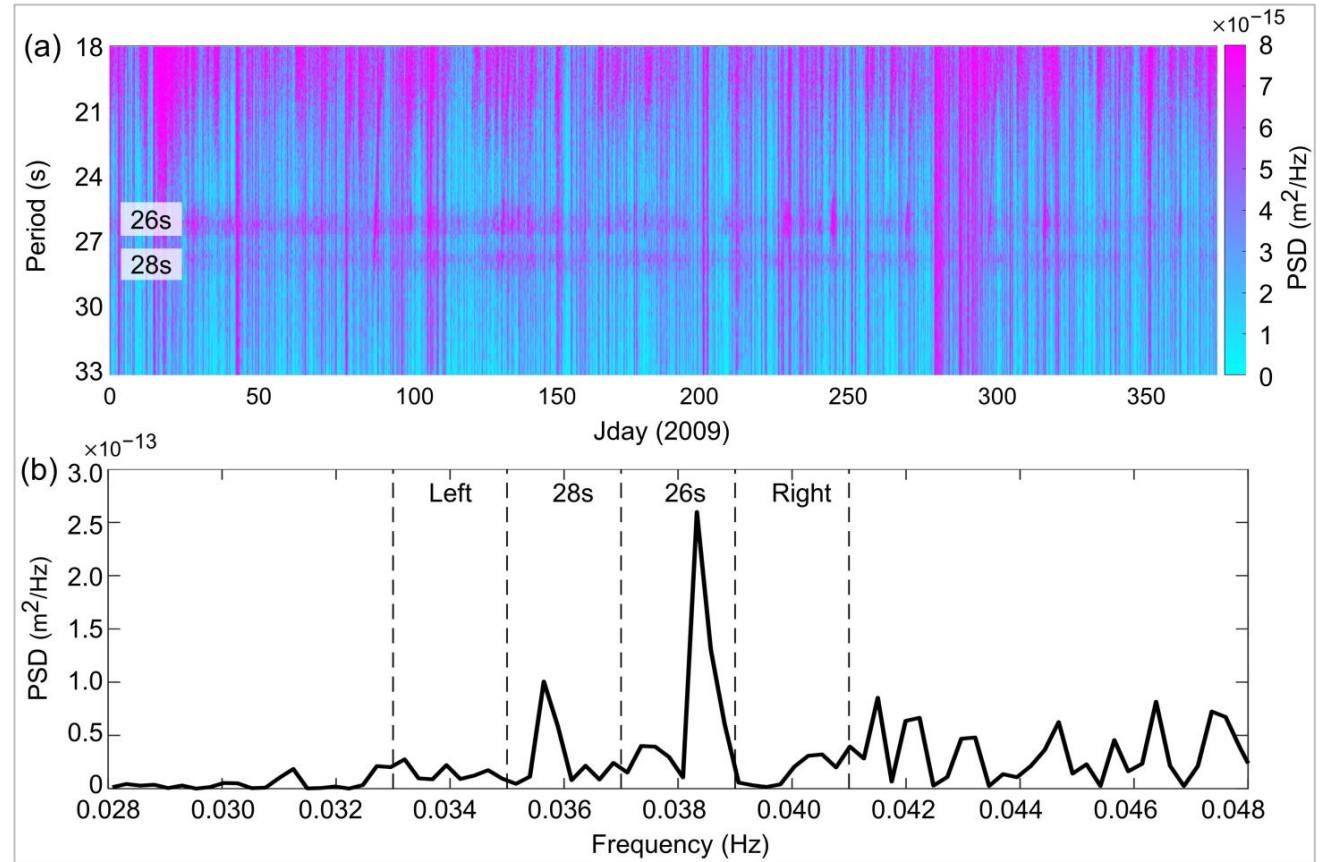
- The strongest signal-to-noise ratio
- Complete data for 30 years coverage

- Analyze data via Fast Fourier Transform (FFT)
- Calculate the power spectral density (PSD)

Magnitude-Number (M-N) Analysis and Time interval-Number (T-N) Analysis

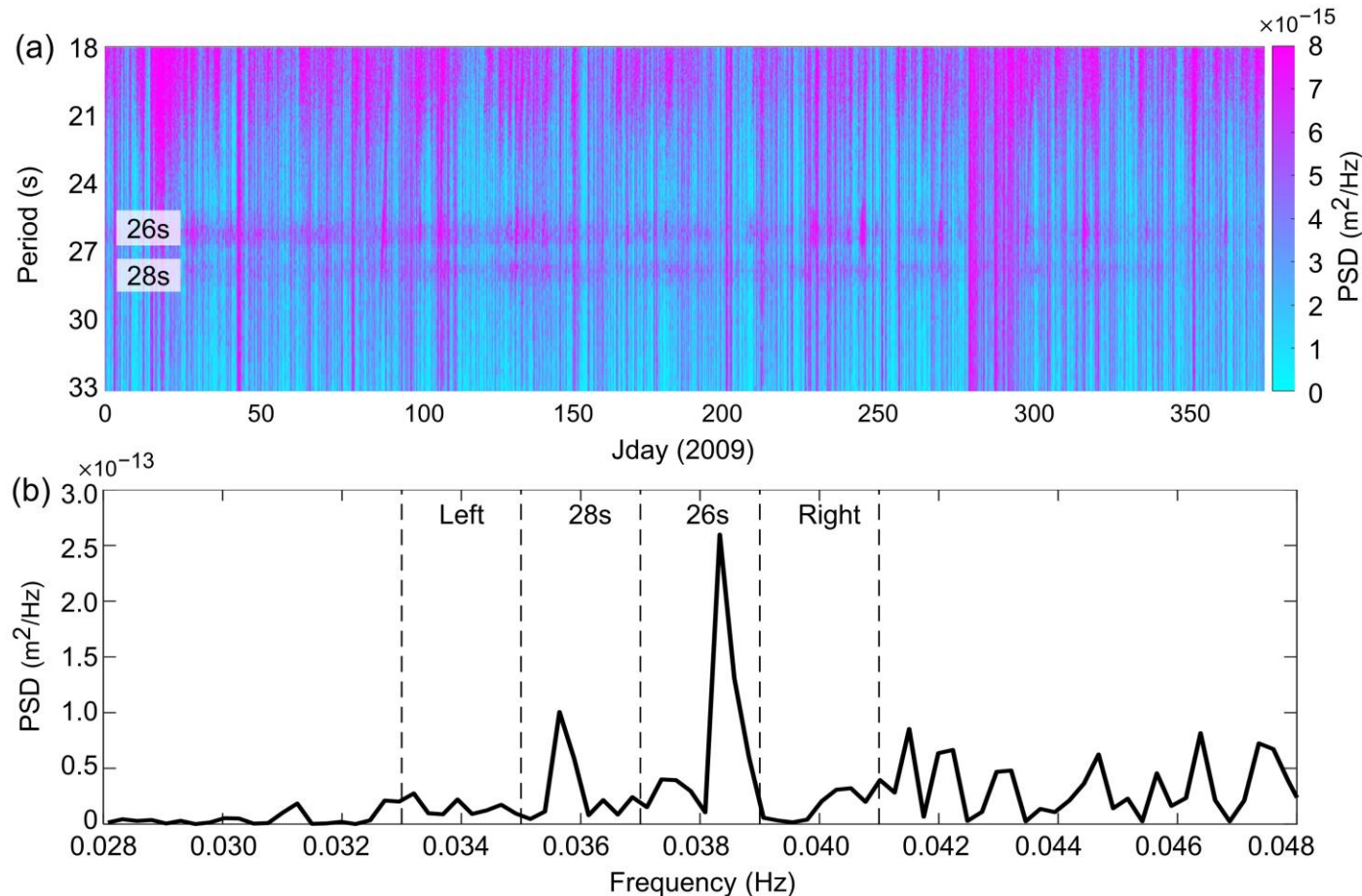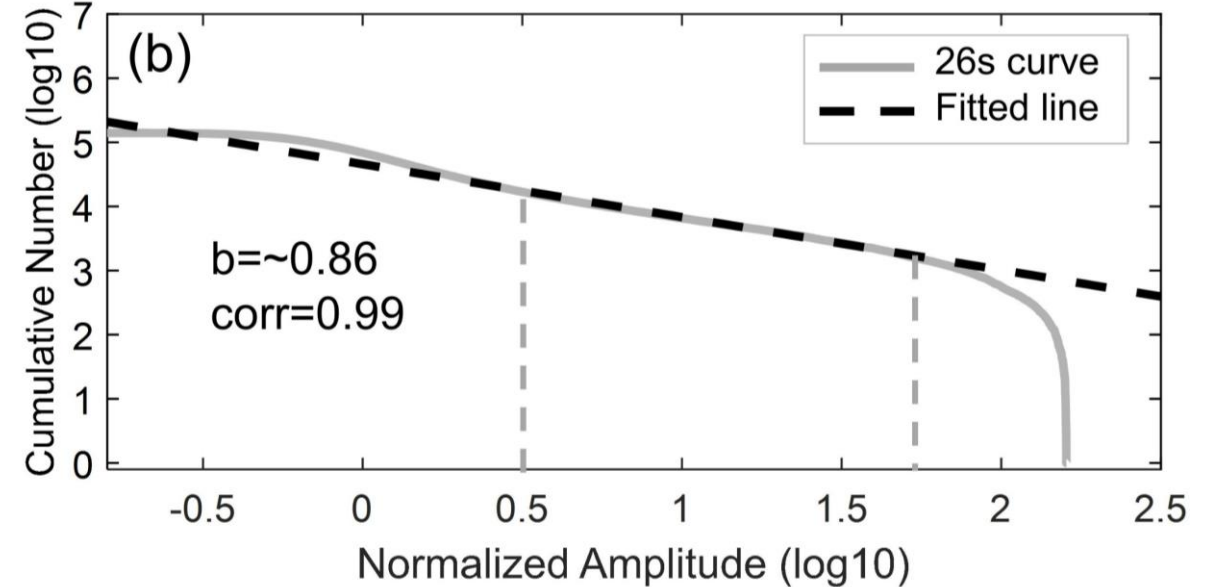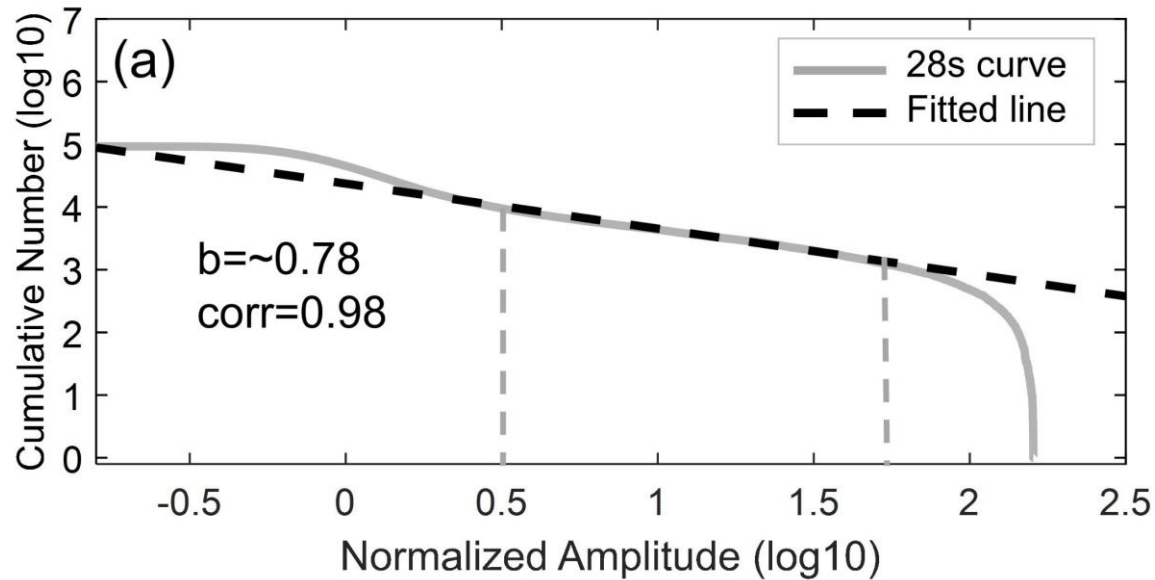1990-2019 TAM(z component)

M-N Analysis

Taking 0.01 as the statistical grid, we counted the **accumulative numbers** of data for each grid of amplitude.

T-N Analysis

With the statistical grid as 0.05 (day), the **numbers** of tremor events within each grid of interval time are counted.

1990-2019 Magnitude-Number (M-N) Analysis Results

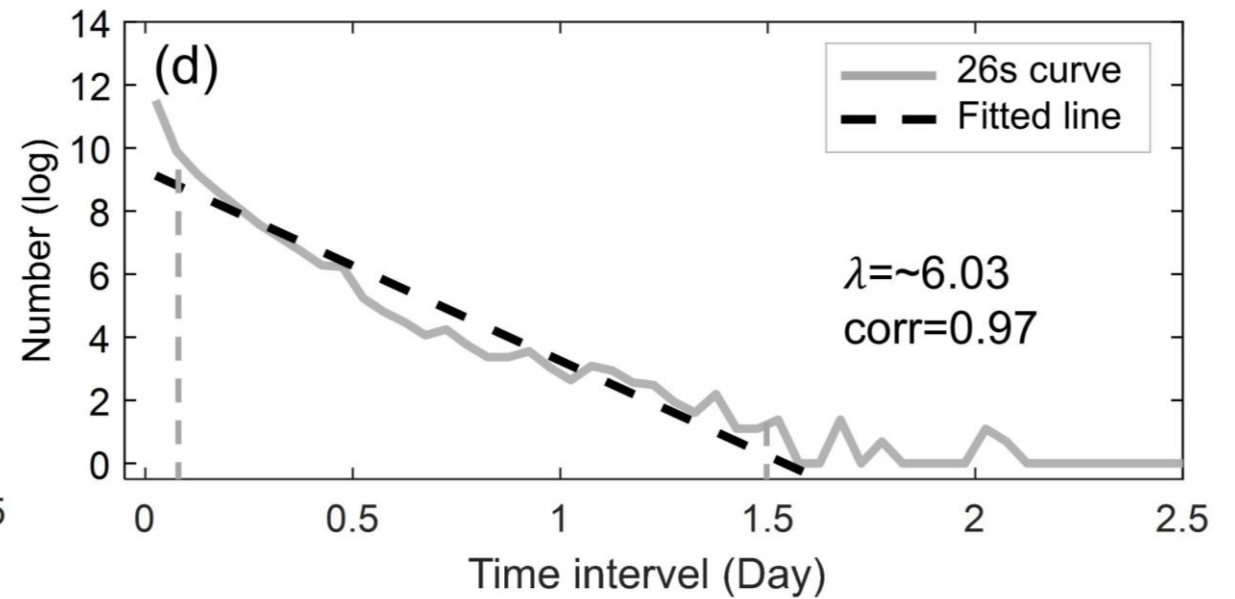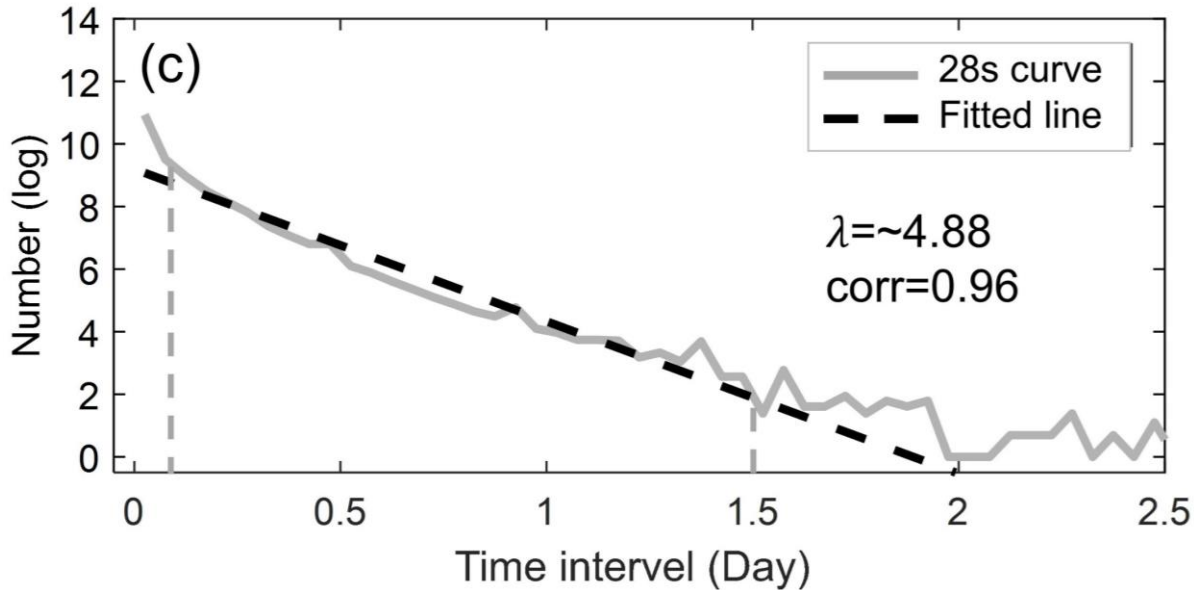**G-R Relationship** $Log_{10}N = a - bM = a - bLog_{10}A$

A: Amplitude   M: Magnitude N: accumulative number

- ● M-N curve: almost linear trend, similar to the **G-R relation** for tectonic earthquakes.

- ● may be related to some **underground structural networks without a characteristic scale**.

1990-2019 Time interval-Number (T-N) Analysis Results

Poisson Distribution

$$P(T > t) = e^{-\lambda t} \quad (t > 0)$$

$$\boldsymbol{logP}(T > t) = -\lambda \boldsymbol{t} \quad (t > 0)$$

T: inter-arrival time
P: Probability
λ: average occurrence rate

- The T-N curve : almost linear trend with negative slope, similar to the **Poisson process**

- The 26s and 28s sources : **behave randomly**

The influence of Swell
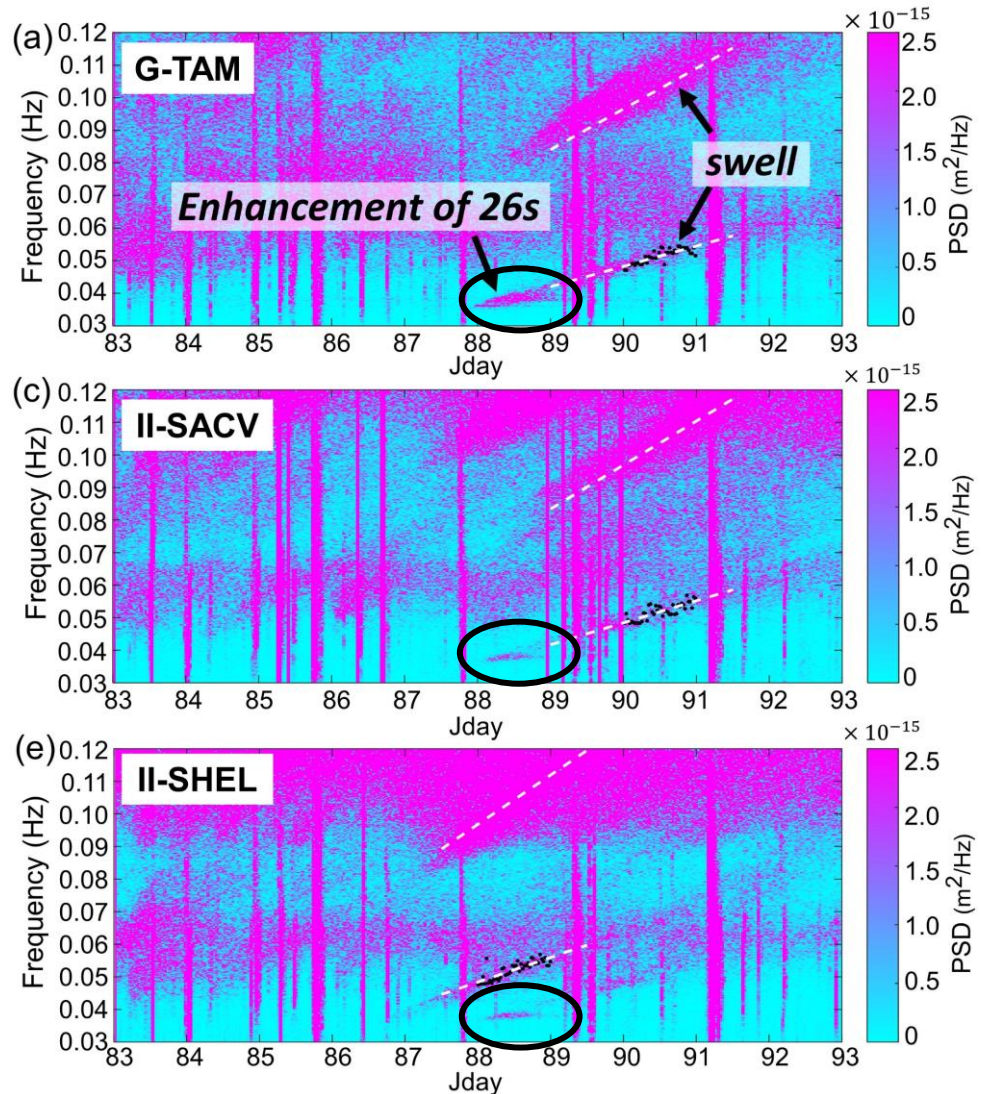
Strong effects of oceanic swells on **26s** source

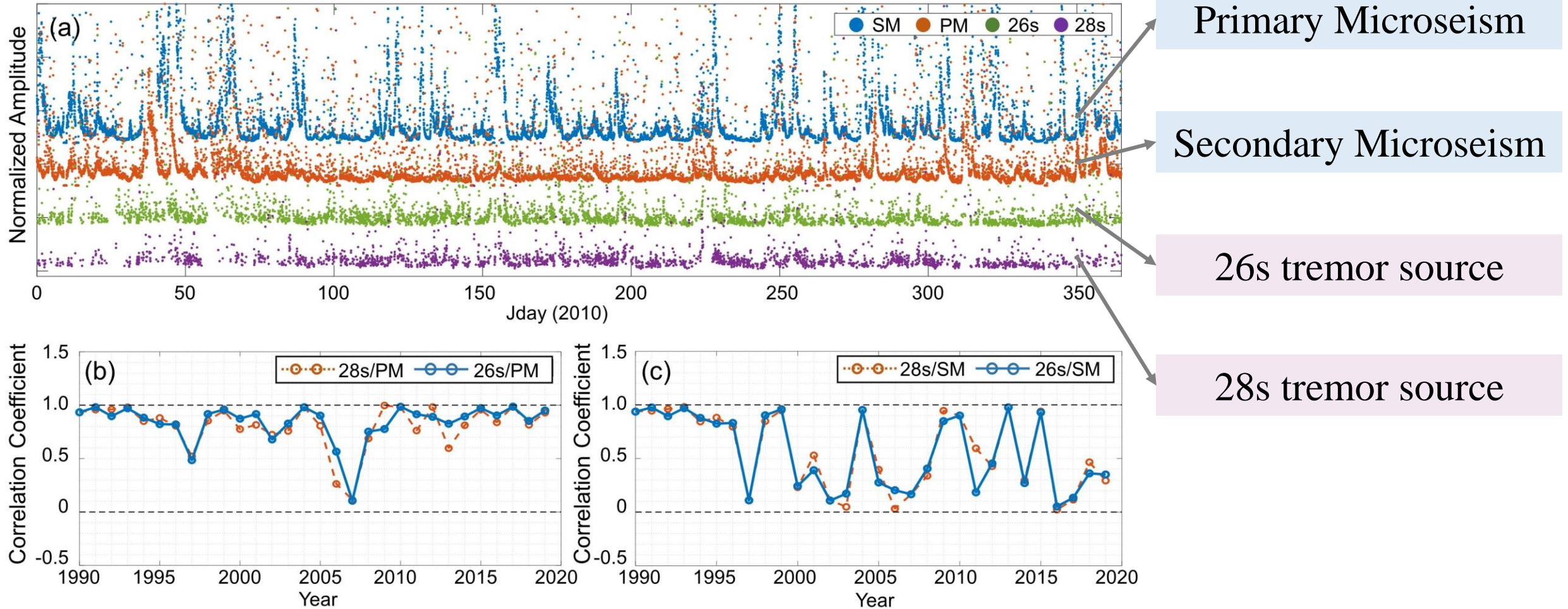located at a **shallower depth**

like sediment layer

Weak effects of oceanic swells on **28s** source

located at a **deeper depth**

like the bedrock

The influence of Microseism

Primary Microseism

Secondary Microseism

26s tremor source

28s tremor source

● 26s and 28s signals are mainly modulated by the **primary microseism (PM)**

Probable generation mechanisms of 26s tremor source

1. Related to the volcanic tremor beneath the South Atlantic

??? However, there are no extant volcanoes around the 26s source

Remain to be verified.

2. Related to the oceanic waves (swell or seas)
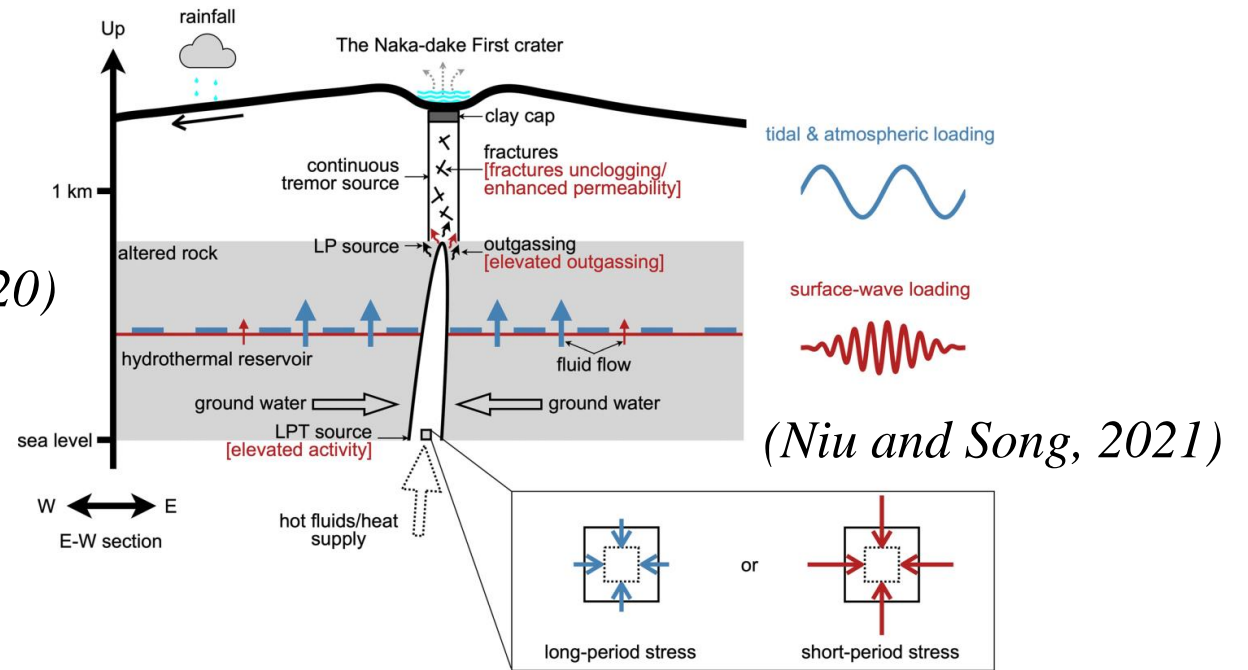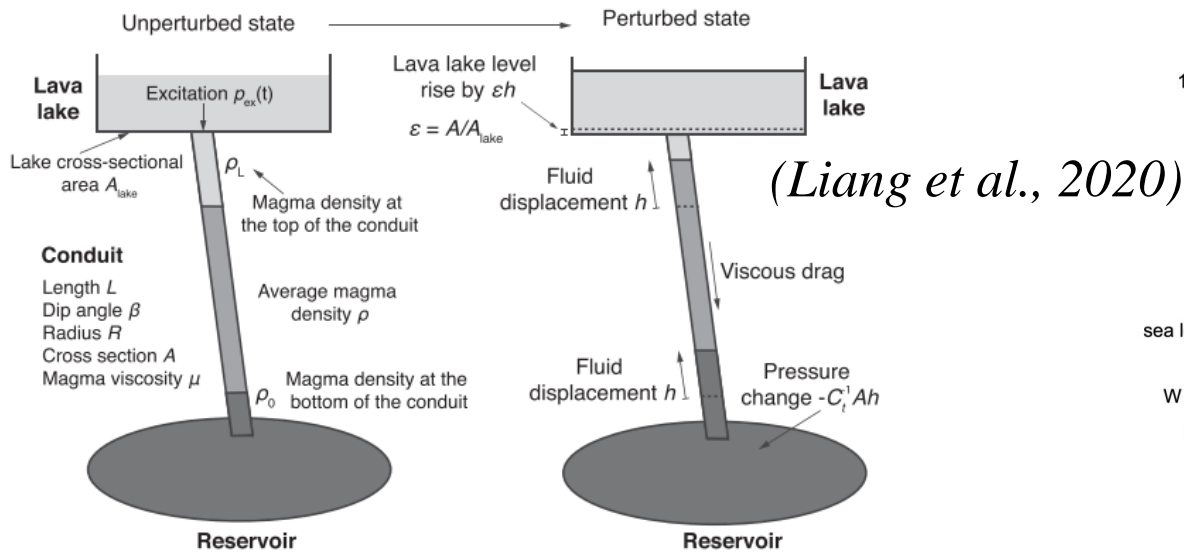
??? However, oceanic waves are weak during period above 20s and have

dispersive characteristics, they cannot excite monochromatic signals.

Probable generation mechanisms of 26s tremor source

3. Related to hydrologic motion

(Liang et al., 2020)
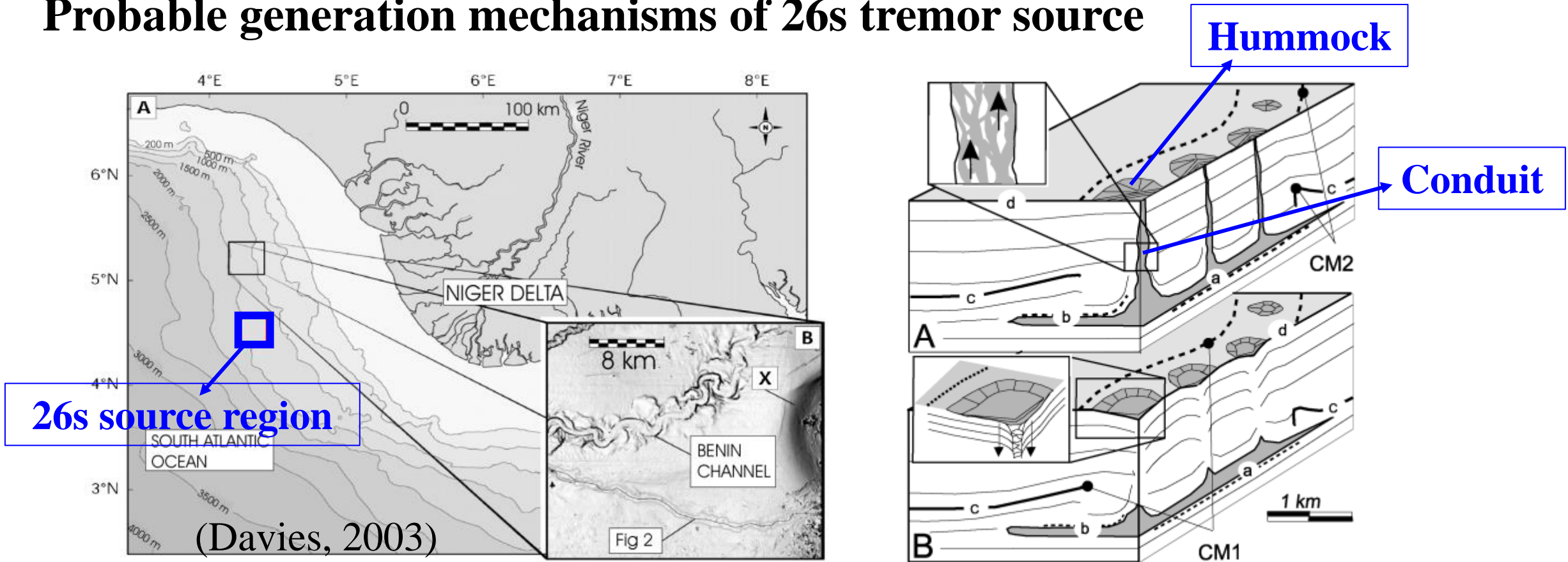

(Niu and Song, 2021)

The Hawaiian VLP : the resonance caused by the fluid passing through an underground conduit inserted to a reservoir below.

The Aso volcano VLP : the pressure change monitored by resonance in a crack-like conduit embedded within a hydrothermal reservoir.

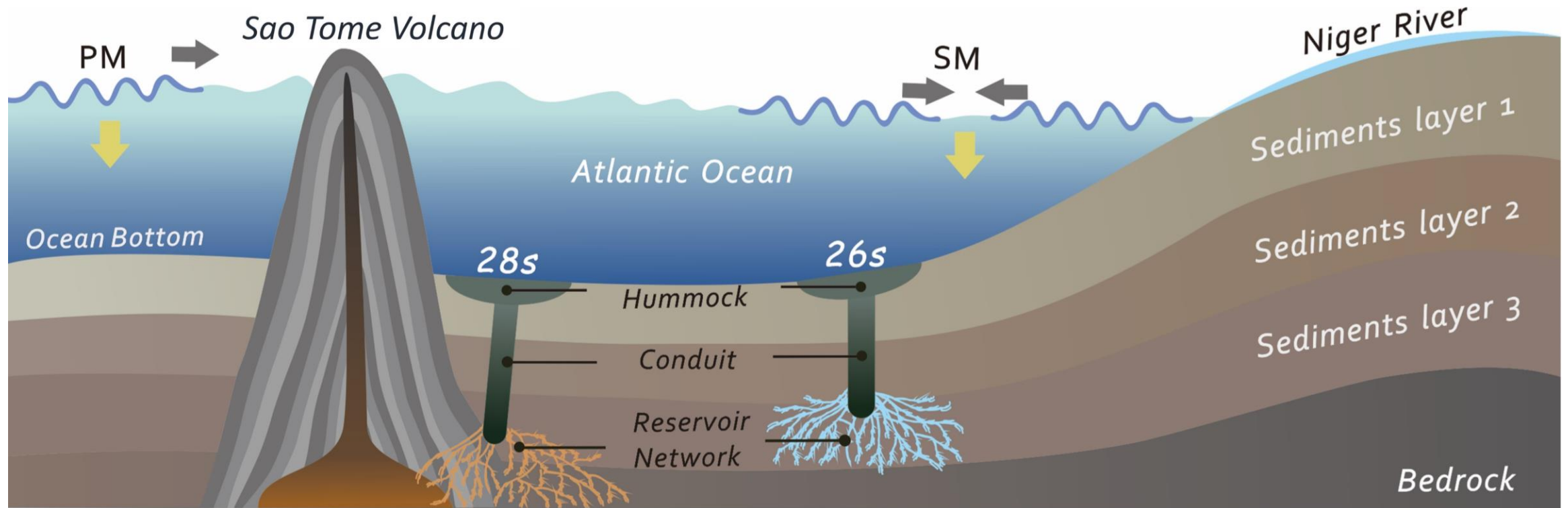.......

Probable generation mechanisms of 26s tremor source

(Davies, 2003)

- There are **hummock-depression structures** in the Gulf of Guinea close to the 26s source.

- Hummocks: ~0.2-1.5km wide / Conduits : ~1-1.5km wide and ~2-3 km long

Probable generation mechanisms of 26s tremor source

- Upper a **hummock** in sediment layer
- Middle connecting a **conduit**
- Lower **reservoir networks** composed of lots of tiny cracks without characteristic scale
- Resonance of **Fluids** passing through the conduit generates monochromatic signals
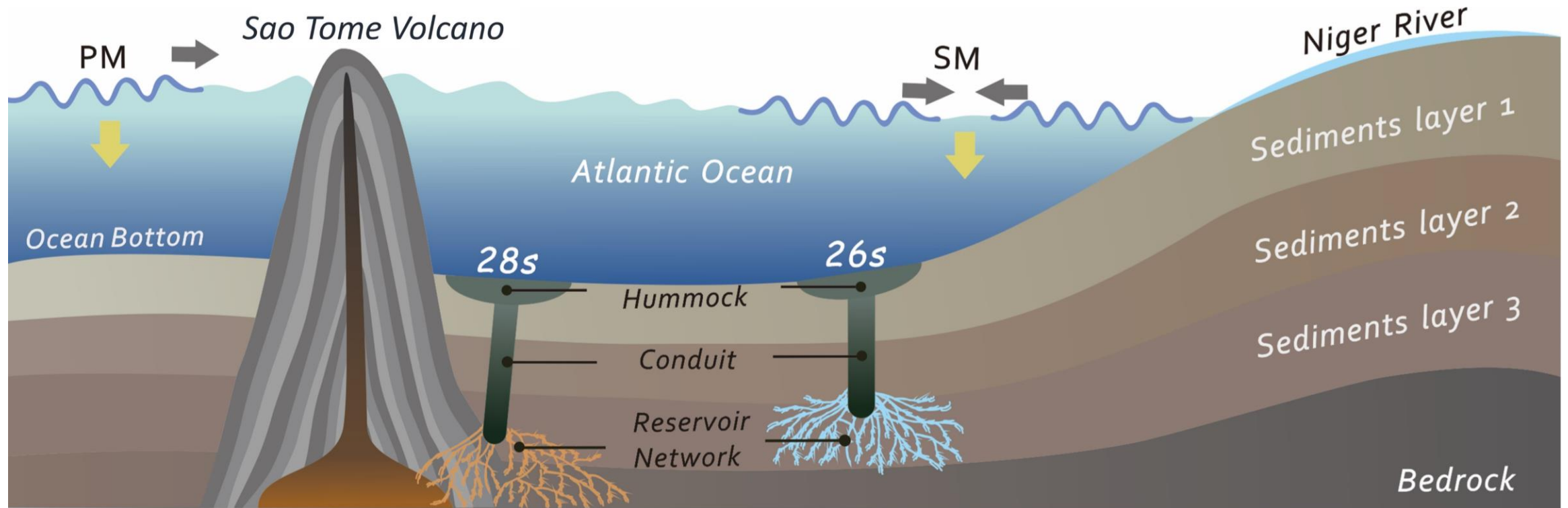
Probable generation mechanisms of 28s tremor source

- Upper a **hummock** in sediment layer
- Middle connecting a **conduit**
- Lower **reservoir networks** composed of cracks **in bedrock** without characteristic scale
- Probably **magma** related fluids passing through the conduit and generate 28s signals

Signal Characteristic long duration, fixed location, specific period

Magnitude-Frequency Analysis   similar to the **G-R relation**; may be related to some underground structural networks without a characteristic scale.

Time interval-Frequency Analysis   similar to the **Poisson process**; behave randomly.

Influence Factor   Strong short-time effects of oceanic swells on 26s tremors, weak correlation with 28 tremors; modulate by primary microseism.

Excitation Mechanism   a **hummock**, middle connecting a **conduit** and lower **reservoir networks** composed of lots of tiny cracks without characteristic scale

SnT 2023

Thanks for your attention!

Chen, Y., Xie, J., & Ni, S. (2022). Generation mechanism of the 26 s and 28 s tremors in the Gulf of Guinea from statistical analysis of magnitudes and event intervals. Earth and Planetary Science Letters, 578, 117334.

Acknowledgements

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