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A New Approach to Clarify Slow Earthquake Source Regions: Multi-band Receiver Function Analysis Including Local Deep-focus Events

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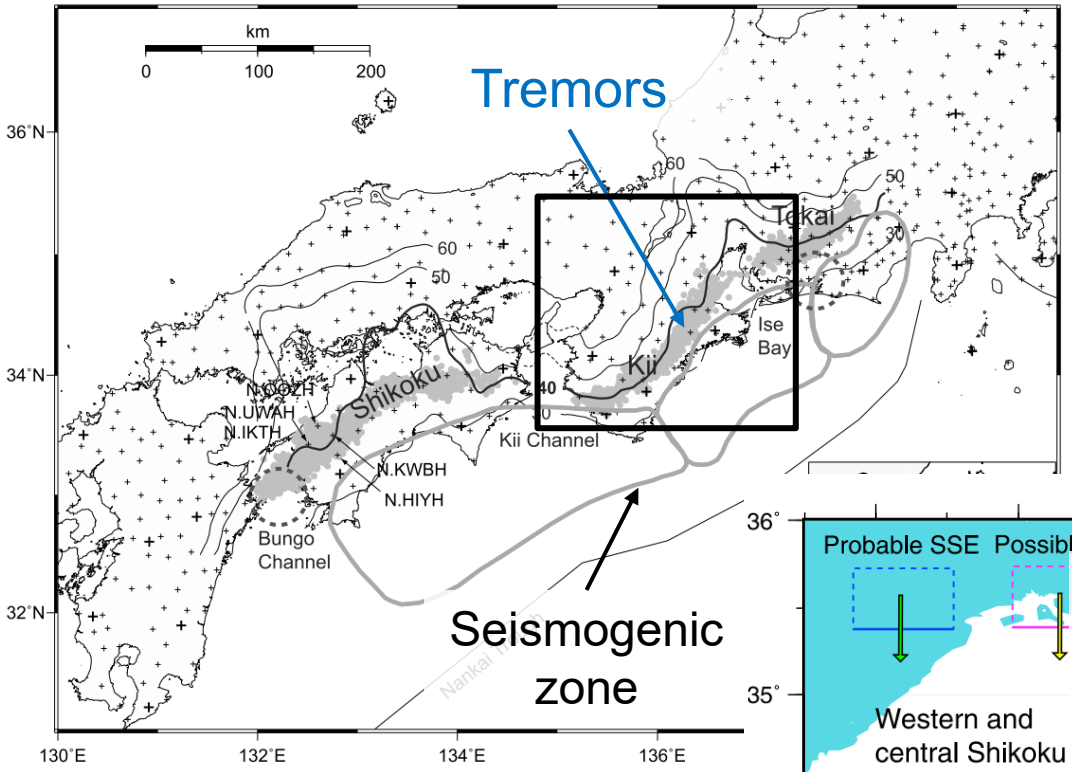
Deep Slow Earthquake Activities in SW Japan



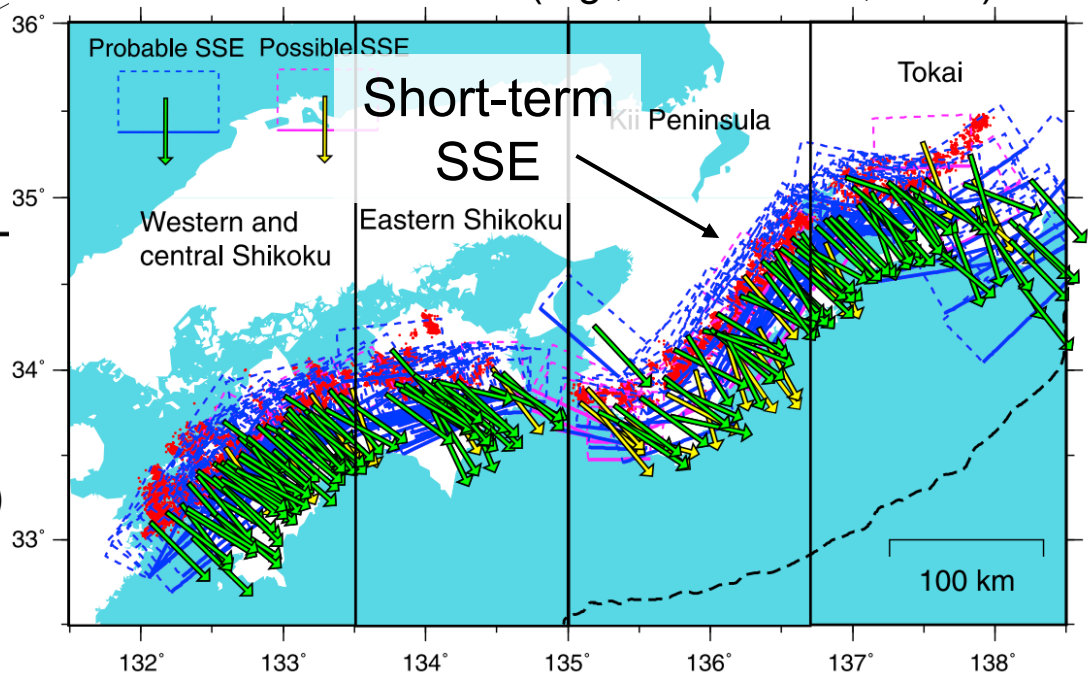
[Modified from Obara (2010, *JGR*)]

Tremors accompanied with SSEs
⇒ Episodic Tremor and Slip (ETS)
(e.g., Obara et al., 2004)

Episodic Tremor -> Index of slips

Slow earthquake activities on deeper portions of seismogenic zone

- Slow Slip Event (SSE)
  (e.g., Ozawa et al., 2001)
- Low-frequency tremor
  (e.g., Obara et al., 2002)



[Nishimura et al. (2013, *JGR*)]

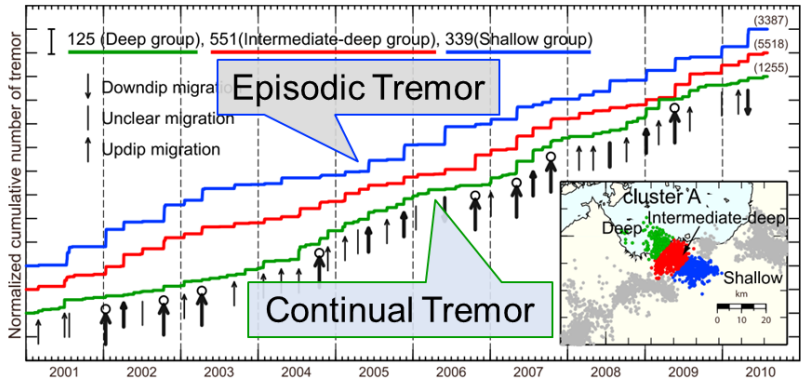
Bimodal Tremor Distribution

[Obara et al. (2010, *GRL*)]

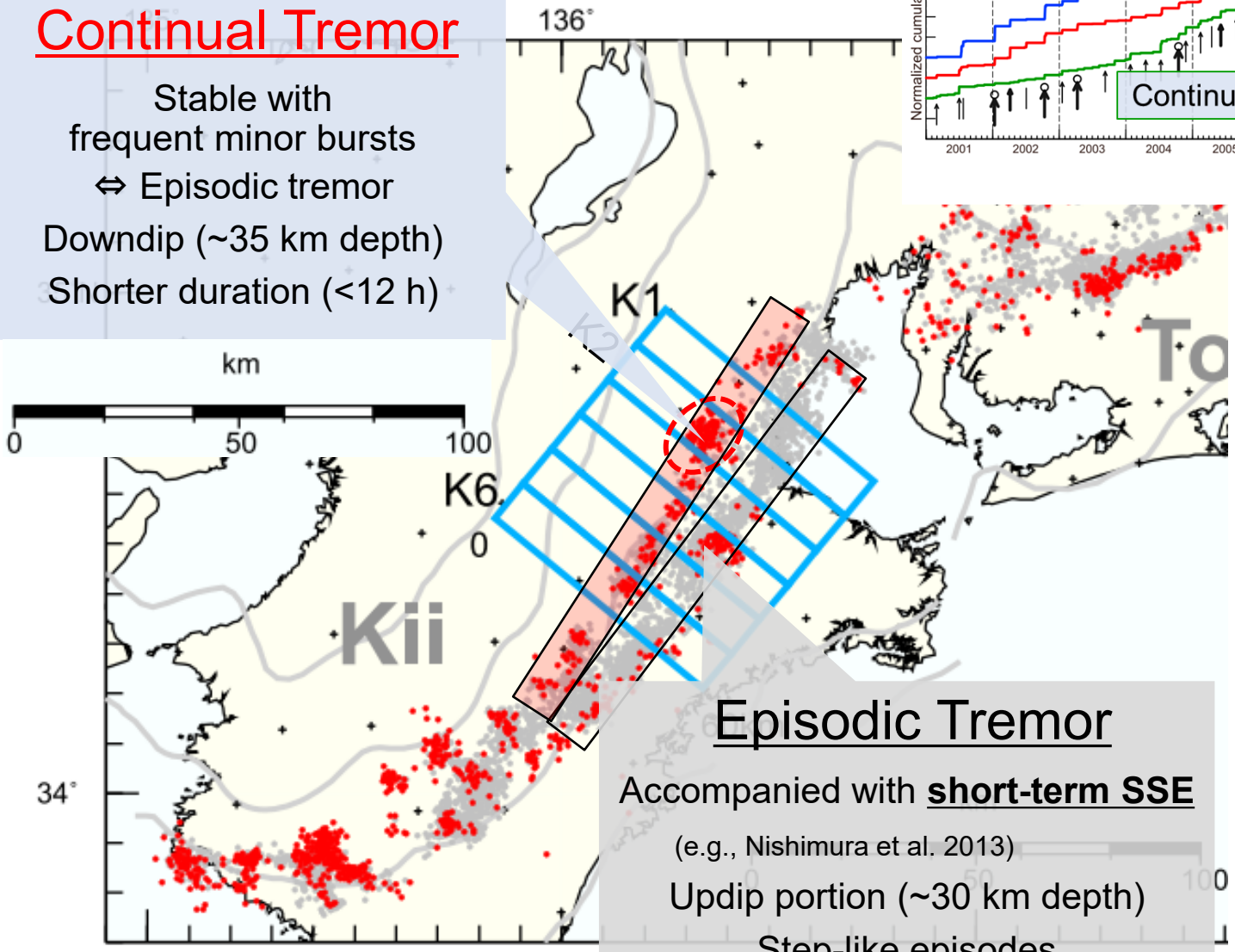
Continual Tremor

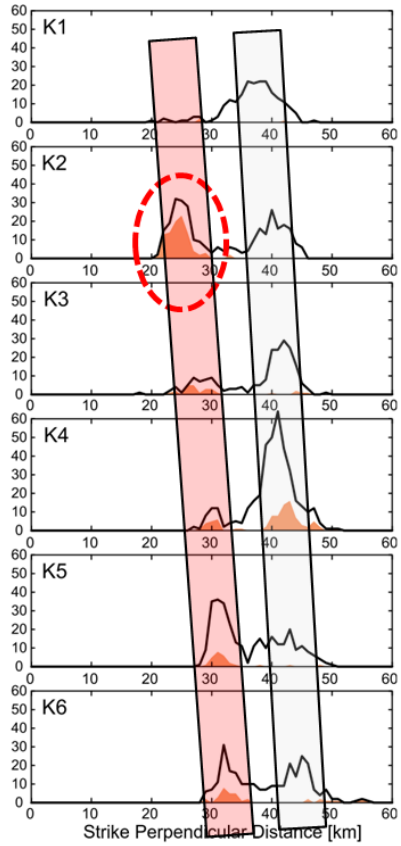
Stable with
frequent minor bursts
⇔ Episodic tremor
Downdip (~35 km depth)
Shorter duration (<12 h)

Cumulative # of tremors in north Shikoku



[Obara et al. (2011, *GRL*)]





Episodic Tremor

Accompanied with **short-term SSE**

(e.g., Nishimura et al. 2013)

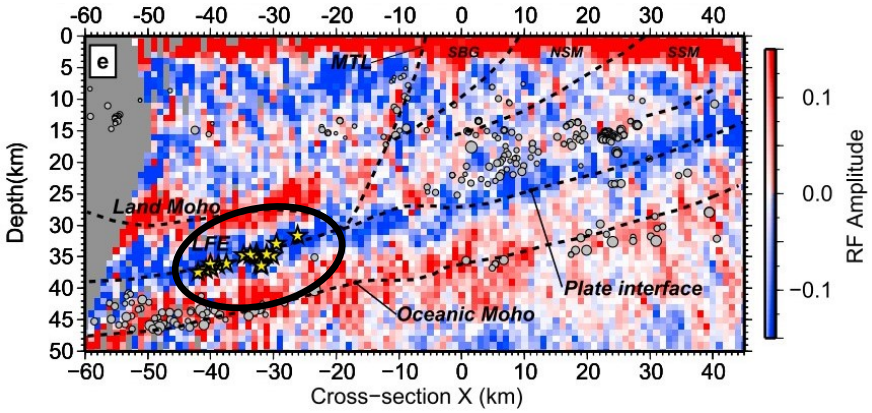
Updip portion (~30 km depth)

Step-like episodes

Source Region of Low-frequency Earthquake (LFE)

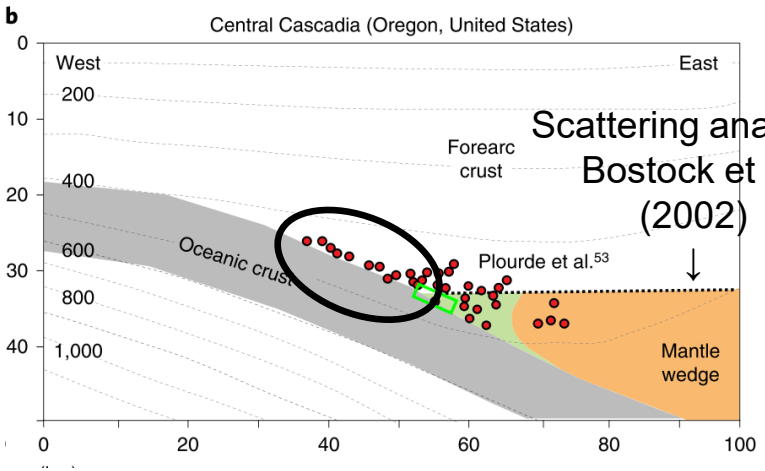
Velocity structure estimated by seismic analysis

- ➢ Mantle wedge regions
  - Tokai: Kato et al. (2010)
  - West Shikoku: Hikita et al. (2019)



[Kato et al. (2010, *GRL*)]

- ➢ Crust / Crust boundary
  - Cascadia: e.g., Plourde et al. (2015)

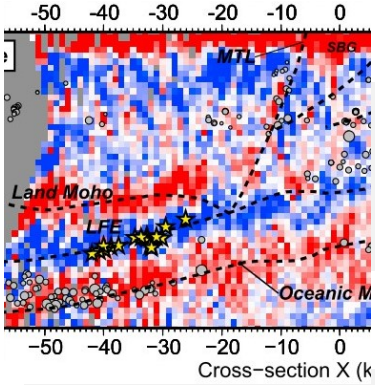


[Tarling et al. (2019, *Nature Geoscience*)]

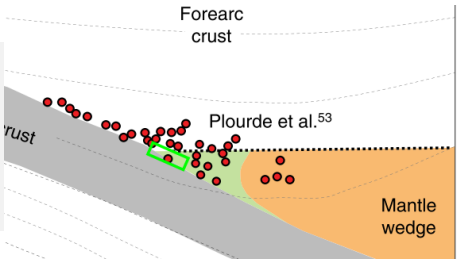
High resolution seismic structure NOT analyzed in NE Kii.

⇒ Essential for constraining mechanisms of Slow-EQ

Purpose



Bimodal distribution of tremors
…Seismic structure still unknown



Episodic tremor and continual tremor are close
→ High resolution analysis for seismological structure
⇒ **Multi-band** receiver function including deep-focus EQs

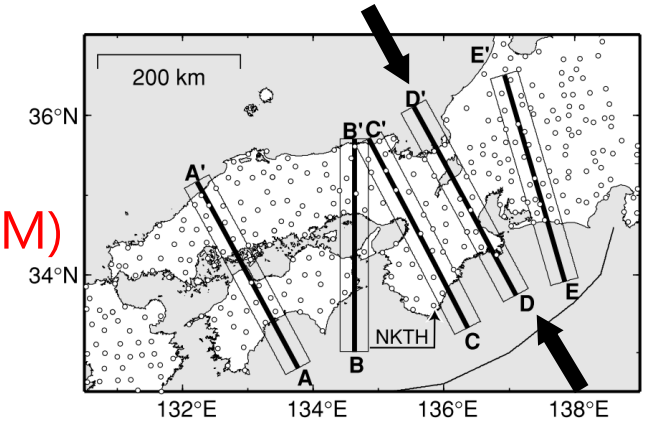
Estimation of source regions of tremor
to detect high-resolved seismic structure
by multi-band receiver function (RF) analysis

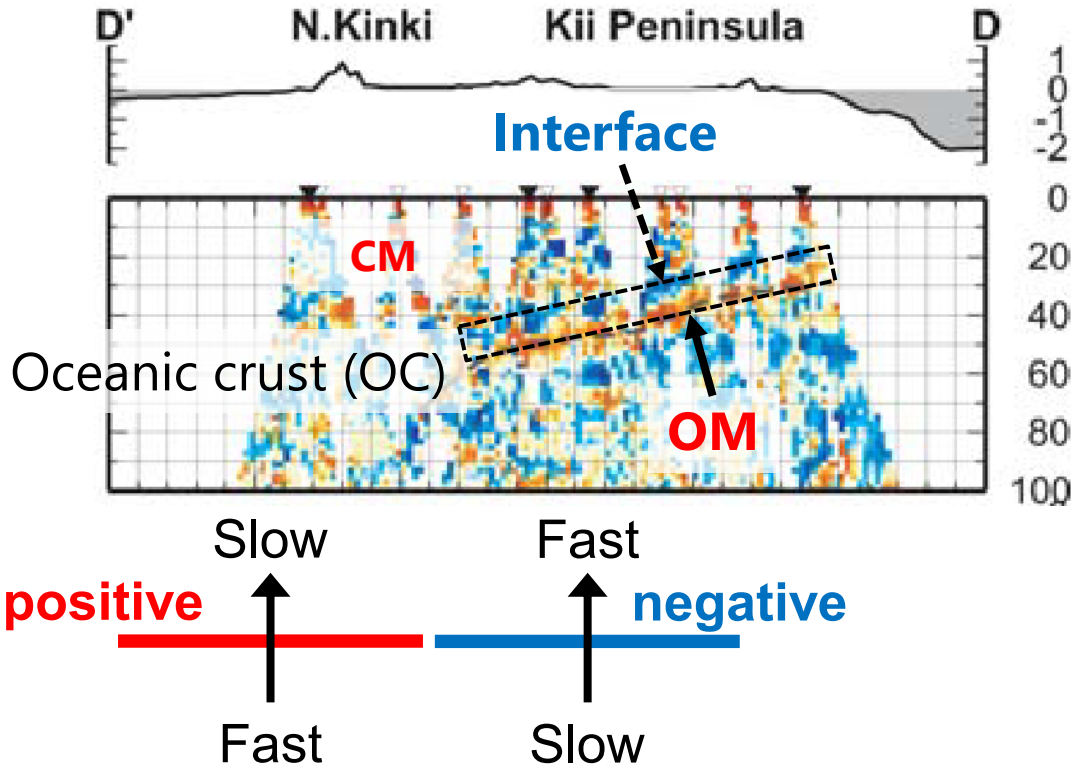
Seismic Structure of Oceanic Crust (OC)

[Shiomi et al. (2008, *GJI*)]

Receiver Function: <u>Velocity contrast</u>

- Depth conversion of RFs (<0.6 Hz)
  - ⇒ Oceanic Moho(OM), Continental Moho(CM)
  - ⇒ Plate Interface





✓ Low-freq. RF

⇒ Only to detect the shapes of primary phases (e.g., OM)

⇕

Detailed structure for source regions of slow EQ

⇐ <u>High-freq.</u> image

Multi-band RF & Local Deep-focus EQ

100 Hz sampling
⇒ No decimation
Bandpass filtered of
[0.05, 50](Hz)
Azimuthal correction of
horizontal components
(Shiomi et al., 2003)

Epicentral distance
Δ : 30° - 90°

Hi-net
Inland observation

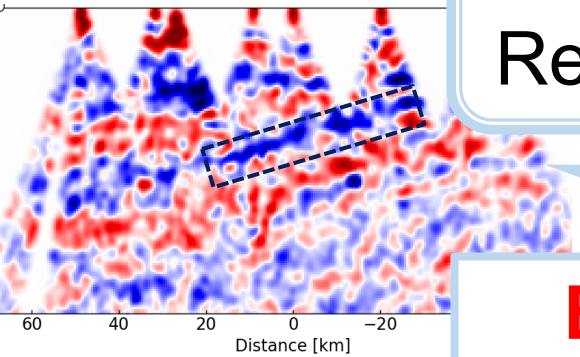
Tele-seismic events

New
Local Deep EQ
(Pacific slab)

- Higher S/N
- Many events
- Localized distribution
⇒ Broadening

Multi-band
Receiver Function

Tapering method:
Extended-Time Multitaper
[Helffrich (2006, BSSA);
Shibutani et al. (2008, BSSA)]



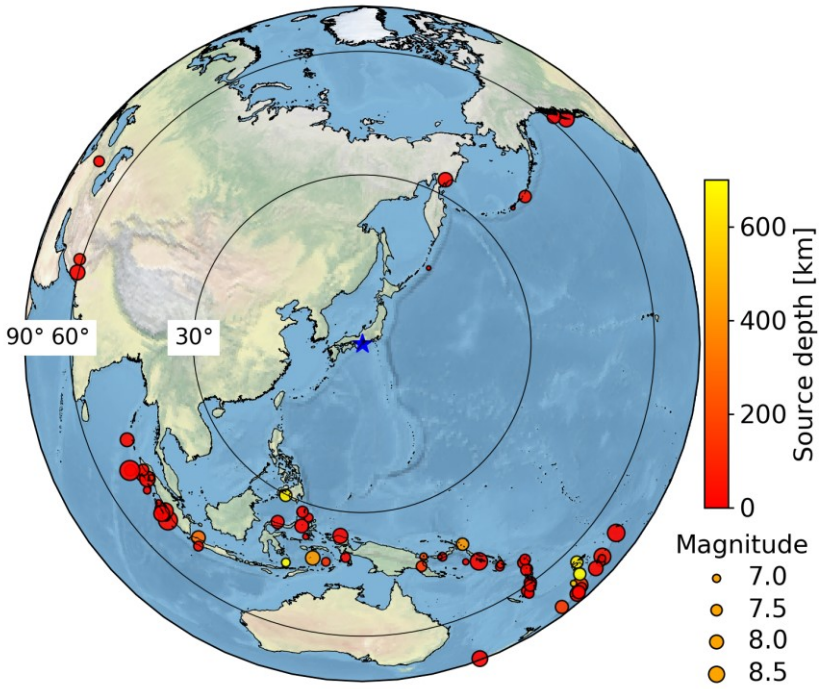
[Depth conversion by 1D velocity model (JMA2001)]

Broadening & Clarification

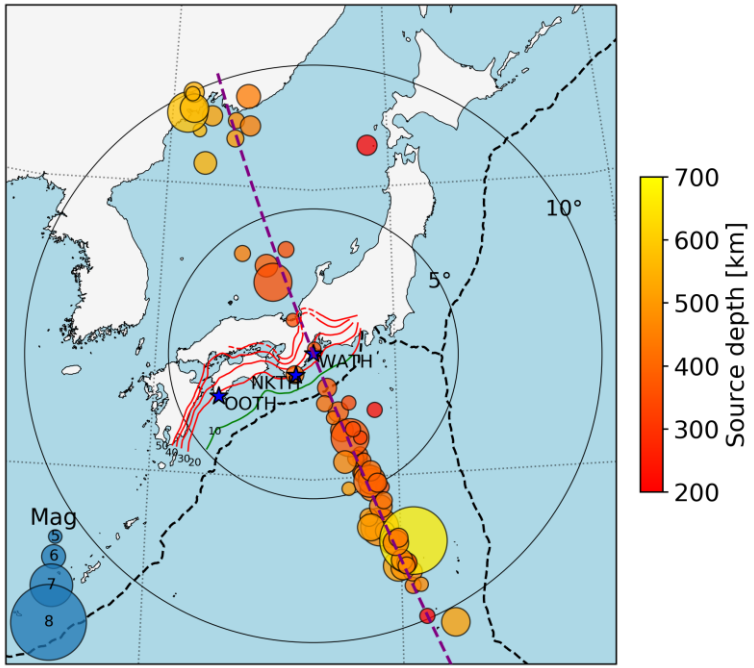
Compare freq. bands of
[0.05, **0.6**] [Hz]
[0.05, **2**]
⇒ Freq. dependence

Tele-seismic events & Deep EQs

Tele-seismic events



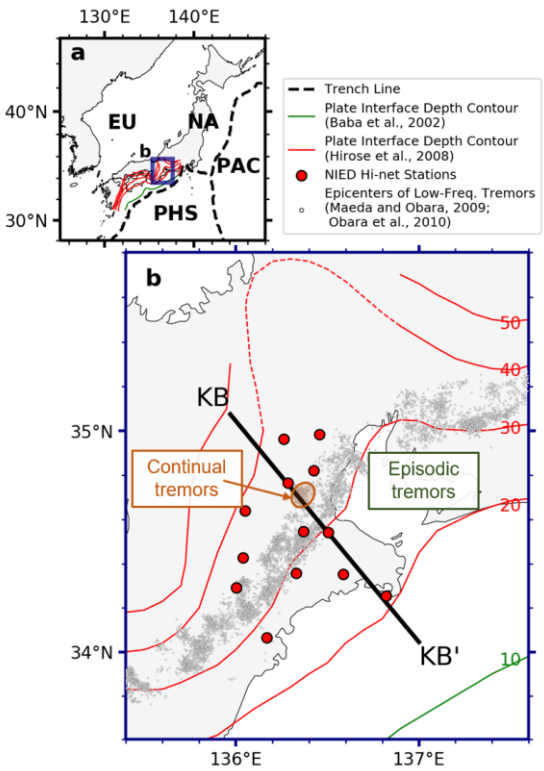
Deep-focus events

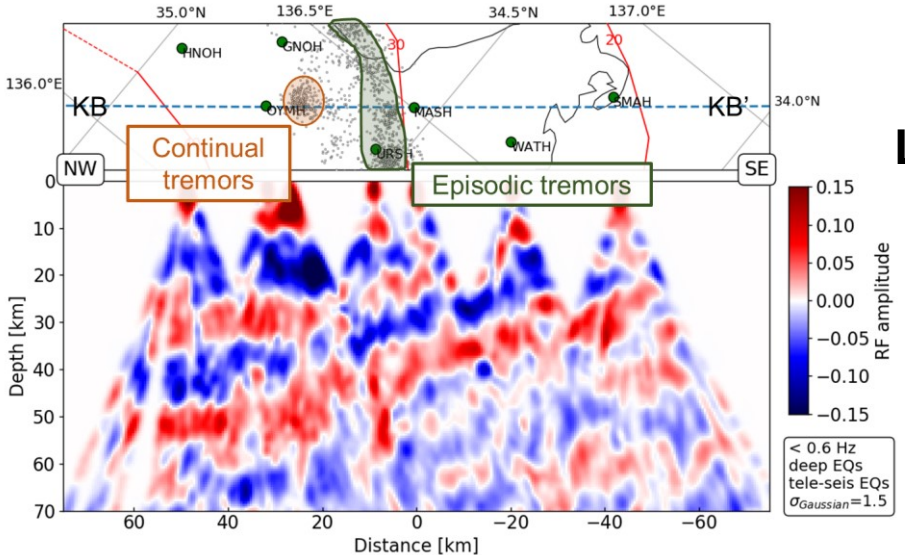


Jan. 2006 – Dec. 2016	**Period**	Jan. 2005 – Dec. 2018
30° – 90°	**Epicentral distance**	Up to 10°
6.6 – 8.6	**Magnitude (Mw)**	**5.3** – 8.3

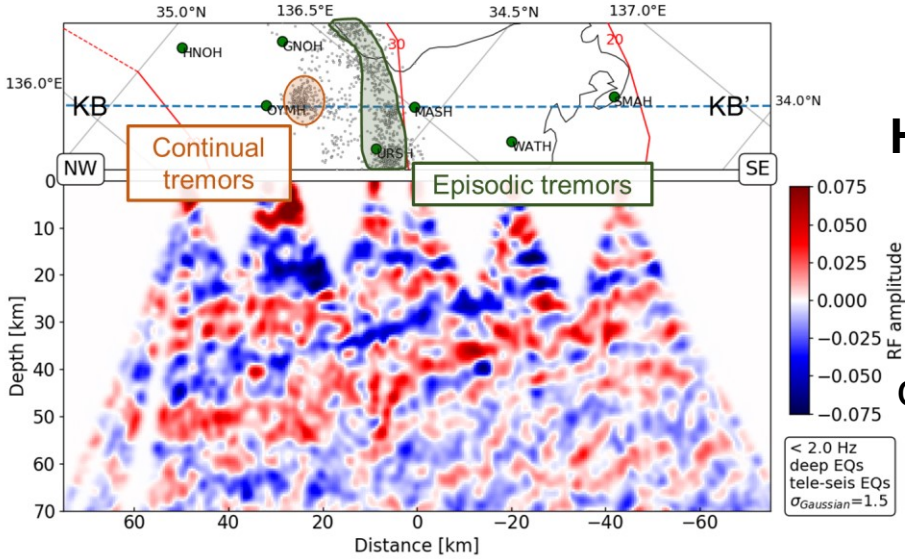
- Shorter S-P time
- Triplication phases

Cross-sections of Multi-band RF (NE Kii Peninsula)





Low-frequency
(< 0.6 Hz)
⇓
Shape of
Oceanic Crust

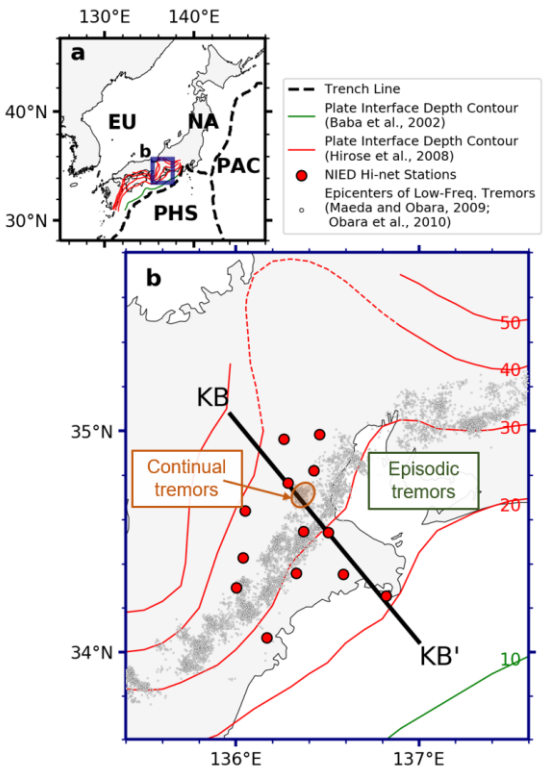


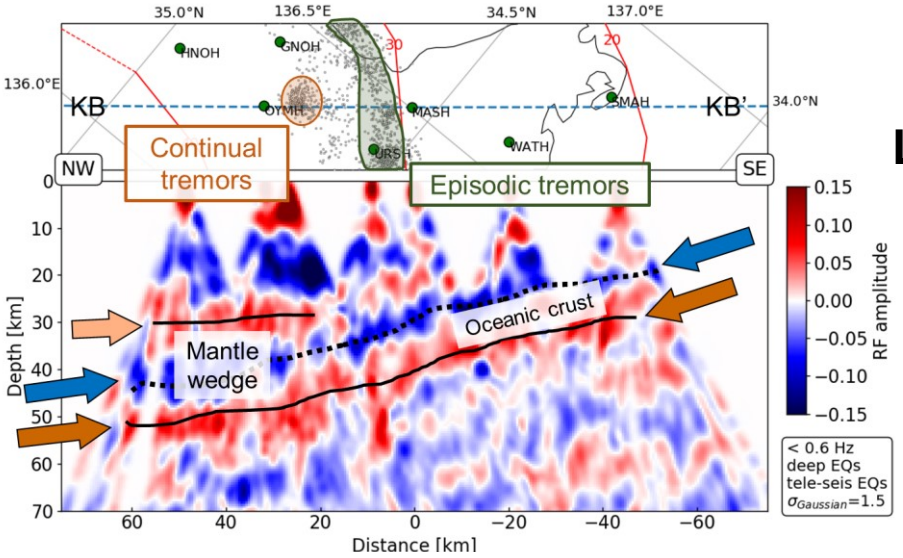
High-frequency
(< 2 Hz)
⇓
Depth
dependence of
Upper OC

Oceanic Moho → Plate interface → Continental Moho

[Depth conversion using 1D velocity model (JMA2001)]

Cross-sections of Multi-band RF (NE Kii Peninsula)

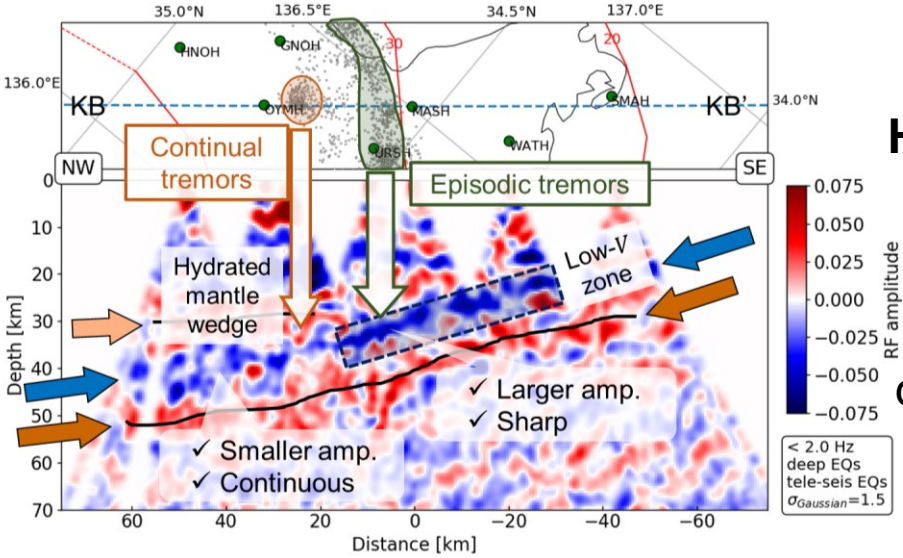




Low-frequency (< 0.6 Hz)

⇓

Shape of Oceanic Crust



High-frequency (< 2 Hz)

⇓

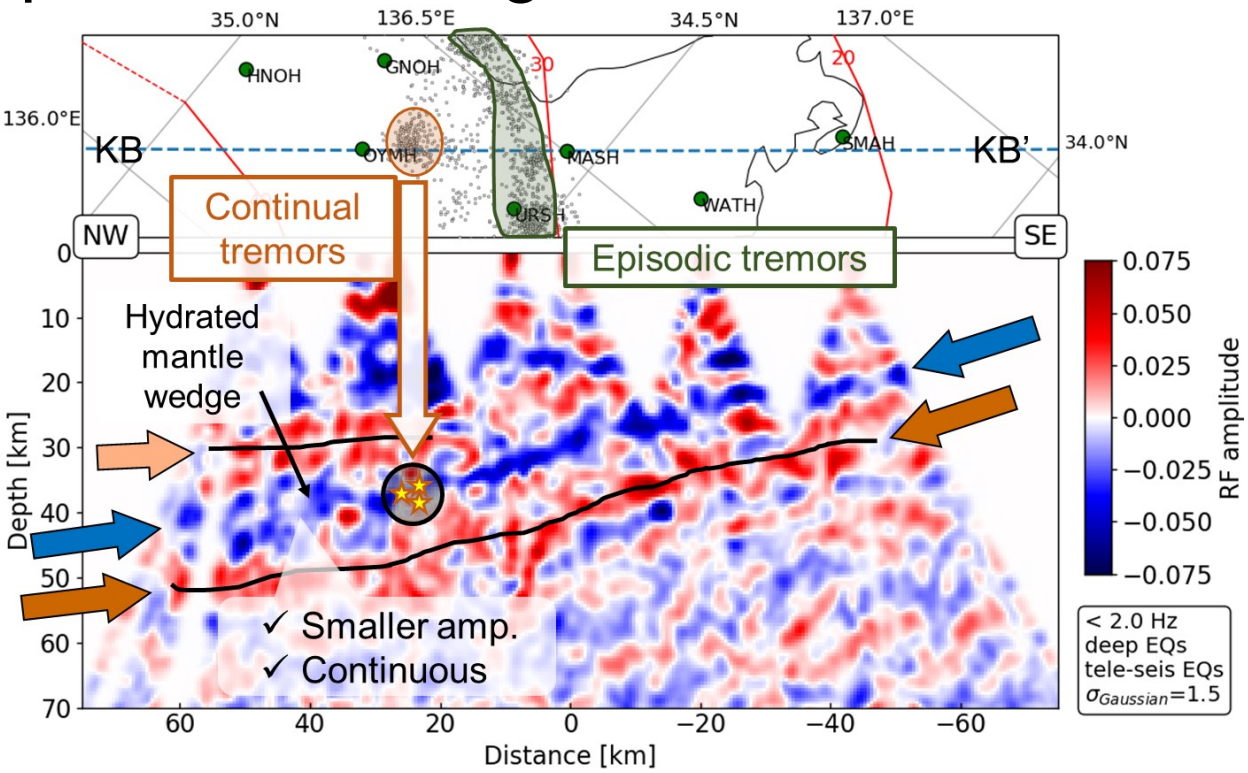
Depth dependence of Upper OC

Oceanic Moho → Plate interface → Continental Moho

[Depth conversion using 1D velocity model (JMA2001)]

Discussion

Downdip: Mantle Wedge Corner



- Hydrated mantle wedge (e.g., Bostock et al., 2002)
- Epicenters of Continual tremor are above mantle wedge corner

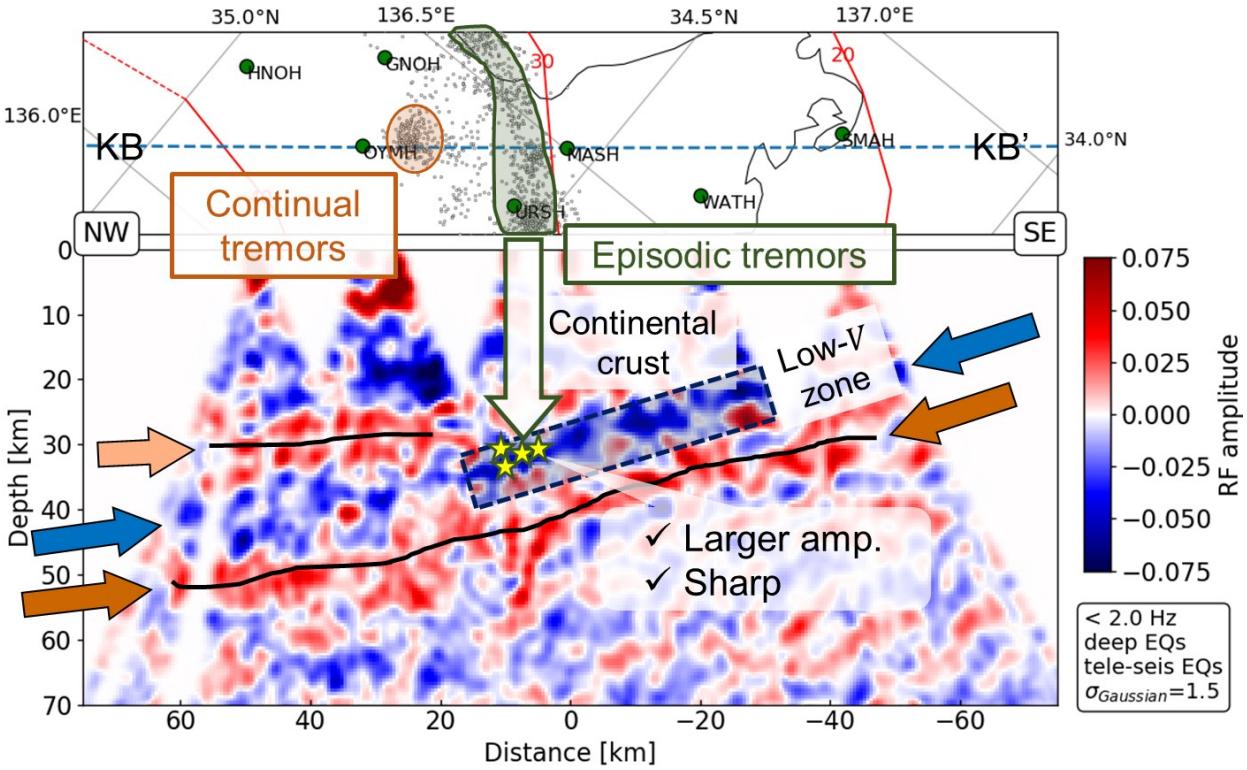
  ⇒ Continental crust composed of low-permeable gabbro (Katayama et al., 2012)

  ⇒ **Continuously** high fluid pressure sealed by continental crust

  ↑ Crustal seal is stable due to no slip at CM

Continual Tremor in Mantle Wedge Corner

Updip: Oceanic Crust & **Continental Crust**

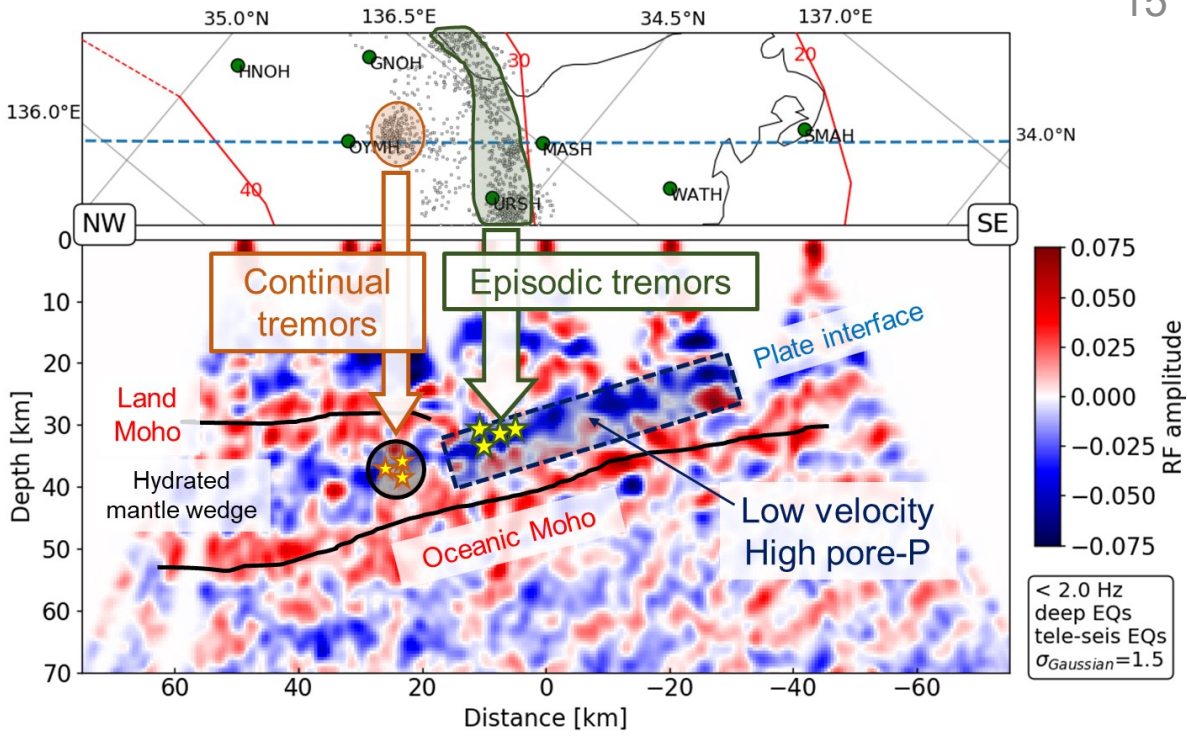


- Sedimental OC (containing pore fluid and fluid-rich clay) (e.g., Akuhara et al., 2017)
  ⇒ Upper OC is fluid-rich due to dehydration (e.g., Hacker et al., 2003)
- Larger contrast: Contact with **continental crust** ⇒ High pore pressure (Katayama et al., 2012)
  ⇒ Active ETS (e.g., Yabe and Ide, 2014) (Gosselin et al., 2020)
  ☐ SSE breaks the seal ⇒ Fluid migration and tremor generation?

Episodic Tremor below Continental Crust

Conclusions

- ✓ First apply local deep-focus events in Pacific slab to multi-band receiver function analysis around NE Kii.



- ✓ Structural difference on tremor-genic zones.
  - ✓ Clear and sharp phase of plate interface on updip portion.
    - ⇒ High fluid pressure and low effective stress on the interface
      - ⇒ Episodic tremor below **continental crust**
  - ✓ Obscure and continuous phase on downdip portion.
    - ⇒ Continual tremor in **mantle wedge corner**

- Unclear relationship of fluid migration and tremor generation.