Tidal sensitivity of shallow tectonic tremors in northeastern Japan

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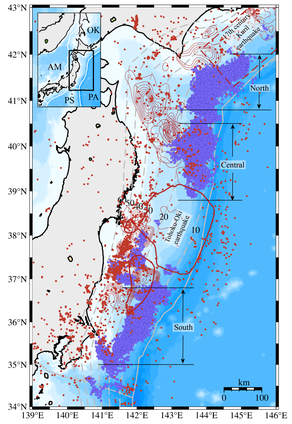
1.Background

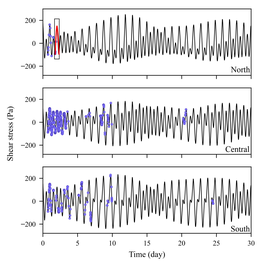
❑Tidal sensitivity of tremor

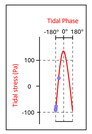
- Tectonic tremor is tidally modulated, and its tidal sensitivity provides a probe of fault conditions.
- Tidal sensitivity has been shown to increase during tremor migration or slow slip events in Nankai and Cascadia subduction zones[1,2], but its behavior in northeastern Japan and its relationship with seismicity remain unclear.
- Tidal sensitivity analysis methods[3]: phase-based analysis and amplitude-based analysis.

❑Map of northeastern Japan



❑Tides stress in study regions





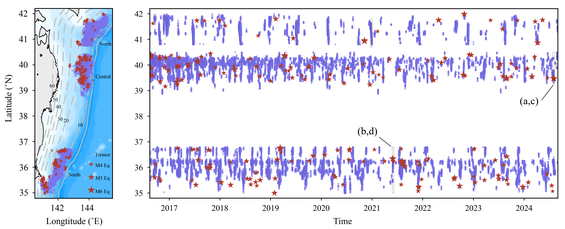
$$\frac{P_{obs}(\Delta\tau)}{P_{ref}(\Delta\tau)} = C\, e^{\alpha\Delta\tau}$$

❑Research question

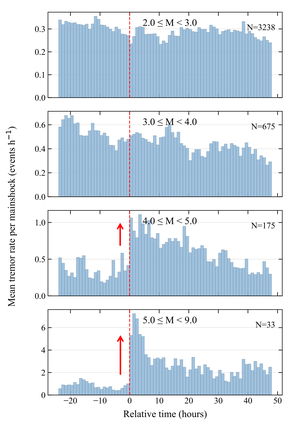
How does the tidal sensitivity of shallow tremor[4] in northeastern Japan reflect fault conditions?

A study of spatial variations associated with seismicity and temporal variations during tremor migration.

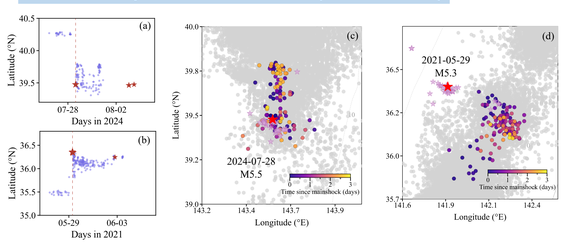
2. Spatiotemporal distribution of tremors and earthquakes



❑Tremor rate changes before and after earthquakes of different magnitudes



❑Post-earthquake tremor increase (“aftertremor”)

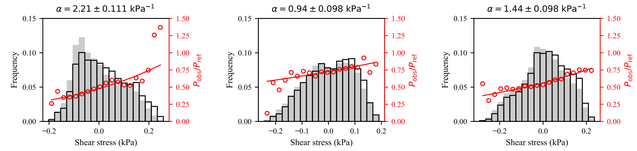


❑Main findings from this section

Characteristic	North	Central	South
Tremor migration	Yes[5]	No	No
EQ rate density ($yr^{-1}\,deg^{-2}$)	~40	~170	~260
Typical Post-EQ tremor pattern	Rare post-EQ tremor	EQ and post-EQ tremor both occur within the tremor belt	Edge EQ; post-EQ tremor remains confined to the tremor belt

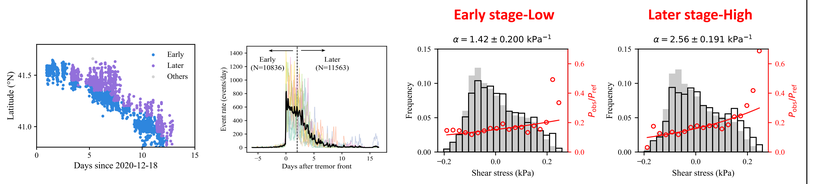
3. Tidal sensitivity analysis

❑ Along-strike variations in tidal sensitivity

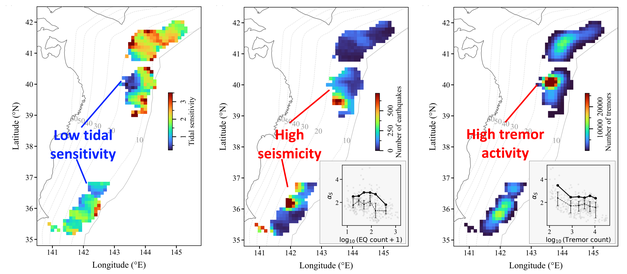


❑ Temporal evolution of tidal sensitivity in northern clusters

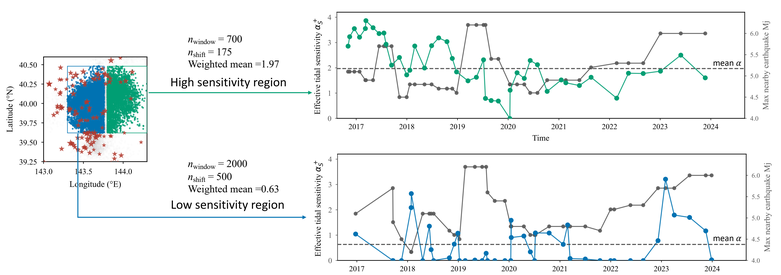
- Threshold of migration front 30 events/day
- later stage: 2days after migration front
- Early stage: 2days before migration front



❑ Spatial patterns of tremor tidal sensitivity, seismicity, and tremor activity



❑ Temporal evolution of tidal sensitivity in representative high- and low-sensitivity regions



❑Main findings from this section

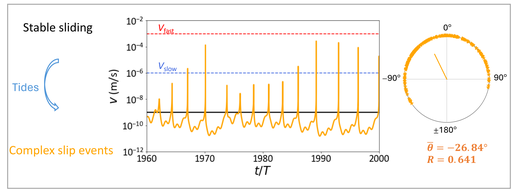
Characteristic	North	Central	South
Tidal sensitivity of tremor	Highest (higher during later migration)	Lowest (weak in the western part)	Moderate (weak at the western edge)

4. Discussion

❑ Previous structural and regional observations for the three regions

Characteristic	North	Central	South
Aseismic slip	SSEs and afterslip[6]	Post-EQ SSEs[5]	Abundant SSEs[5]
Structural constraints	Change in trench strike	Strong structural heterogeneity[7]	Half-graben structure, possible fluid effects and seamount effects[5,7]

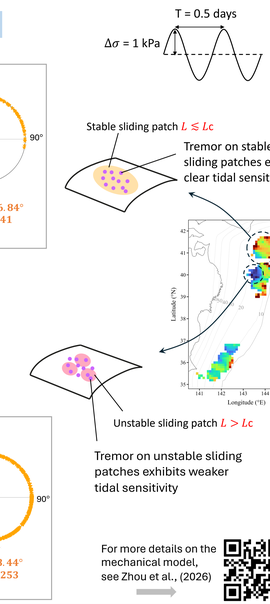
❑Mechanical interpretation of tremor-generating patches



Stable sliding patch $L \lesssim Lc$

Two end-member tremor-generating patch regimes
(Assume tremor occurs on VW patch)

Unstable sliding patch $L > Lc$



For more details on the mechanical model, see Zhou et al., (2026)

Take-home messages

❑ What We Found in Northeastern Japan Tremor:

- **Aftertremor** is mainly observed after Mj ≥ 4 earthquakes.
- **Aftertremor patterns** typically differ by region: central earthquakes and aftertremor both occur within the tremor belt; southern edge earthquakes are often followed by belt-confined aftertremor.
- **Along strike,** highest tidal sensitivity occurs in the north, lowest in the central region, and intermediate levels in the south.
- **During northern tremor migration,** higher tidal sensitivity in the later stage.
- **With seismicity,** weak tidal sensitivity coincides spatially with high seismicity, but short-term earthquake activity does not simply explain its temporal evolution in the central region.

References

[1] Yabe, S., Y.Tanaka, H.Houston, and S.Ide (2015), Tidal sensitivity of tectonic tremors in Nankai and Cascadia subduction zones, J. Geophys. Res. Solid Earth, 120, 7587–7605.

[2] Hirose, F., Kobayashi, A. Tidal correlation of deep tectonic tremors increases during long-term slow slip events in the Bungo Channel, southwest Japan. Earth Planets Space 77, 18 (2025).

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