# Variations in Slow Earthquake Features Along the Nankai Fault: A Comparative Study Using Observational Data and FEM Modeling

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## Introduction

During my two-month research visit to the Earthquake Research Institute (ERI) in Tokyo, I focused on studying the along-dip variation of observational features of slow earthquakes. This research aimed to provide a comparison between the observations in Nankai and a viscoelastic damage rheology of slow earthquakes (Dansereau et al. (2023)) obtained through my postdoctoral research at ISTerre. The primary datasets utilized in this study include epicenters and energy of deep low-frequency tremor reported by Obara et al. (2010) and a slow slip events (SSE) catalog reported by Okada et al. (2022). I investigated the correlation between locations and occurrence times of tremor and SSE, and analyzed their variation in the recurrence interval, event frequency and energy in the down-dip direction.

## Methodology

The tremor data used in this study were obtained using a clustering method of hourly tremor activity as described by Obara et al. (2010). This method involves a hybrid analysis using envelope correlation and amplitude, as detailed by Maeda and Obara (2009). The slow slip events (SSEs) analyzed in this research by Okada et al. (2022) were identified using global navigation satellite system (GNSS) data, which detects millimeter-order signals of short-term slow slip events (S-SSEs) and estimates their fault parameters, and duration.

## Results

Our analysis revealed several significant features:

1. **Tremor Energy Concentration:**

The concentration of tremor energy was observed to occur at certain depths within the Episodic Tremor and Slip (ETS) zone. This indicates that specific depth ranges are more active or conducive to tremor generation. In Figure 1 we presented all the tremor events from 2003 to 2019 and we are focusing on the energy values of each events in the red swath centered at longitude 133.5 and latitude 34.03. The down-dip variation of cumulative tremor energy is also reported in Figure 2. Considering the down-dip variation of tremor energy and recurrence interval, we tried to replicate the observational results through the FEM simulations by applying variable shear strength and healing effects (Figure 3).

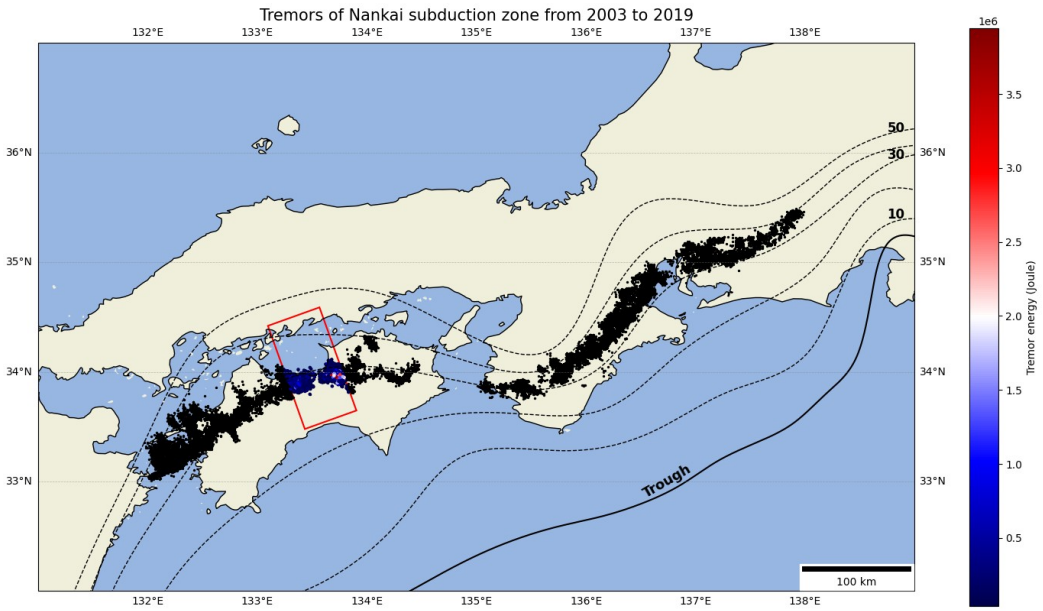


Figure 1: Spatial distribution of tremors between 2003 and 2019 in the Nankai subduction zone. The red rectangle shows an example of the swath to study the down-dip variation of tremor recurrence interval and energy. The energy of each selected event is also shown in color.

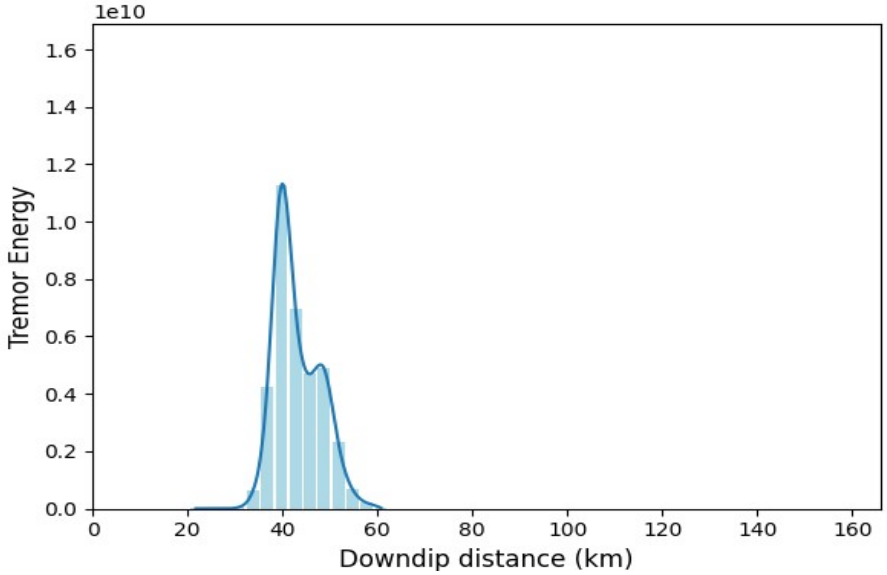


Figure 2: Variation cumulative tremor energy from 2003 to 2019 along the down-dip distance in the swath presented in Figure 1

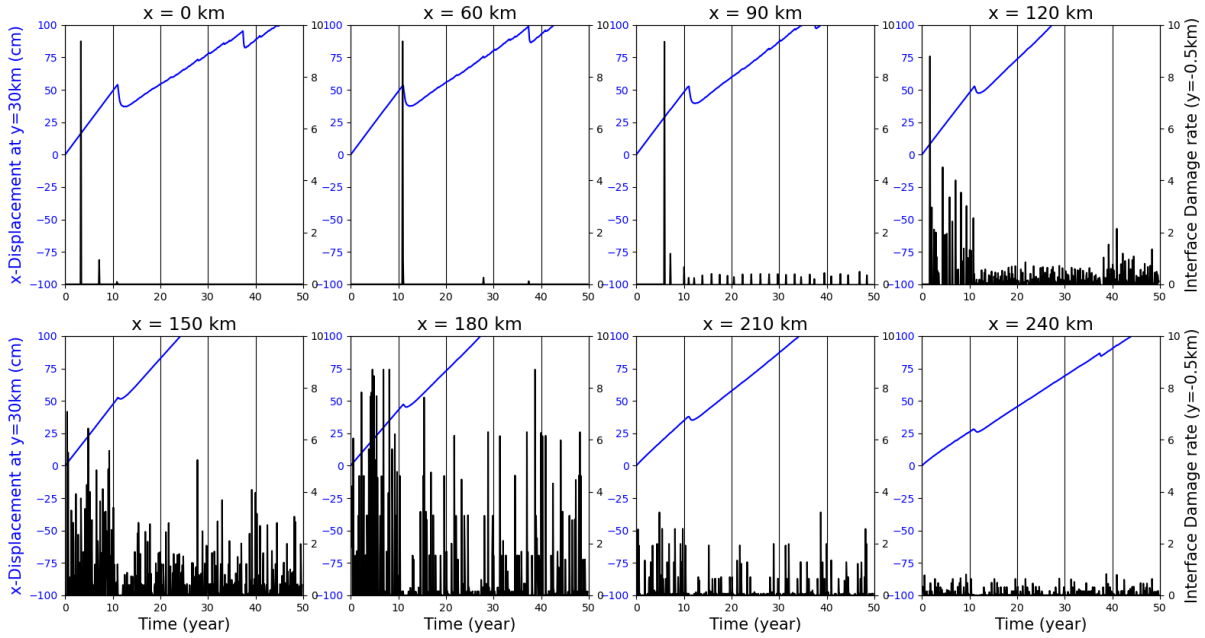


Figure 3: The results of surface displacement (SSE proxy) and damage rate (tremor proxy) determined along the fault of the slow earthquake model. Results at different down-dip distances from the shallowest part (0 km) to the deepest part (240 km) are shown. The results are obtained through the viscoelastic damage model by considering the various pore-pressure effects on healing and shear strength.

2. **Down-Dip Recurrence Interval Variation:**

As we analyzed the deeper parts of the ETS zone, we found that the recurrence interval of tremor events decreased. This means that as we go deeper, tremor events occur more frequently. This pattern suggests a gradient in the mechanical properties or stress conditions along the downdip direction. Figure 4 represents the recurrence interval of each events for different depth of ETS zone and the average recurrence interval. Figure 5 shows that the concentration of tremor events number for the chosen swath is located at depth 40 km.

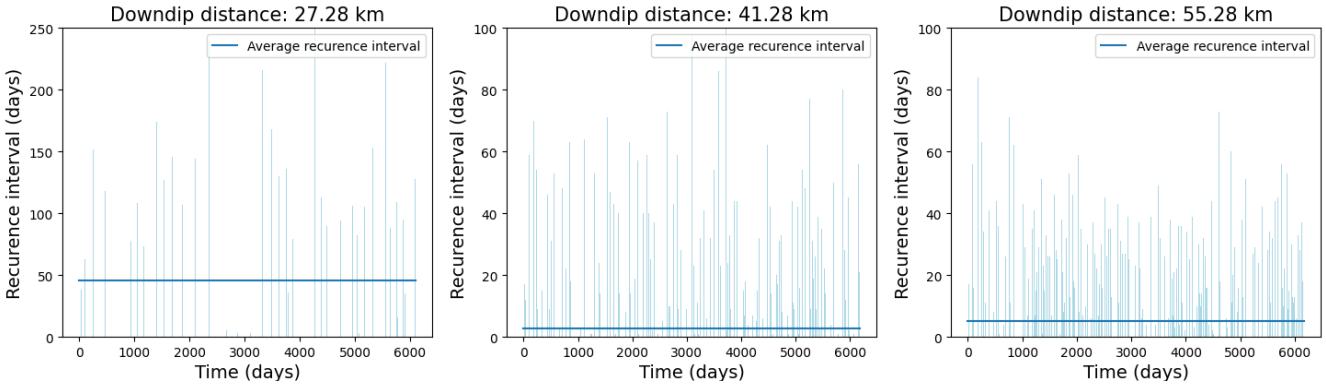


Figure 4: Variation of recurrence interval for various downdip distances for the seismic events between 2003 and 2019 for the selected region shown in Figure 1

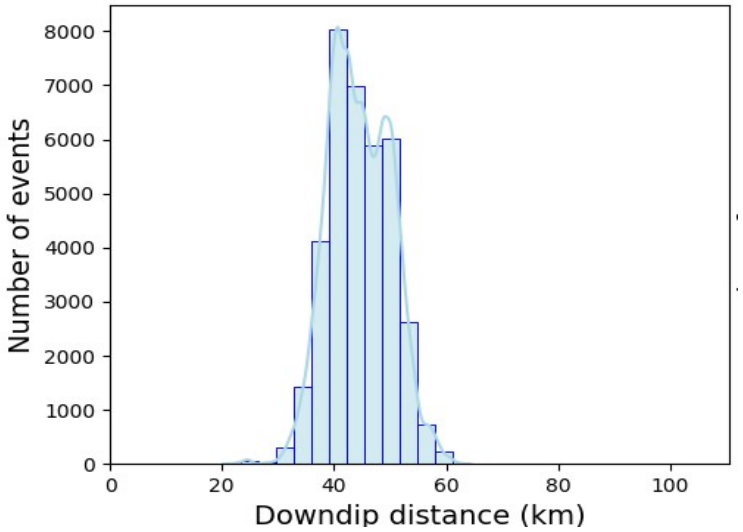

Figure 5: Down-dip variation in cumulative number of tremors in the red swath in Figure 1

## Discussion and Conclusions

The observed spatiotemporal correlation between tremors and SSE suggests a potential interaction between these phenomena, which may provide insights into the mechanics of slow earthquakes. The down-dip variation in the recurrence interval highlights the complexity of fault behavior and the need for further investigation into the factors influencing these patterns. The down-dip variation in tremor event frequency and energy could indicate the stress changes along the fault, offering a valuable change in pore pressure and healing time based on the viscoelastic damage rheology model. This study underscores the importance of integrating tremor and SSE records to enhance our understanding of slow earthquake mechanisms through the modeling of their characteristics. The results also highlight several important features hinting at the variation of pore pressure, viscosity, and healing time along the ETS zone, which could be tested through the FEM simulations.

## References

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