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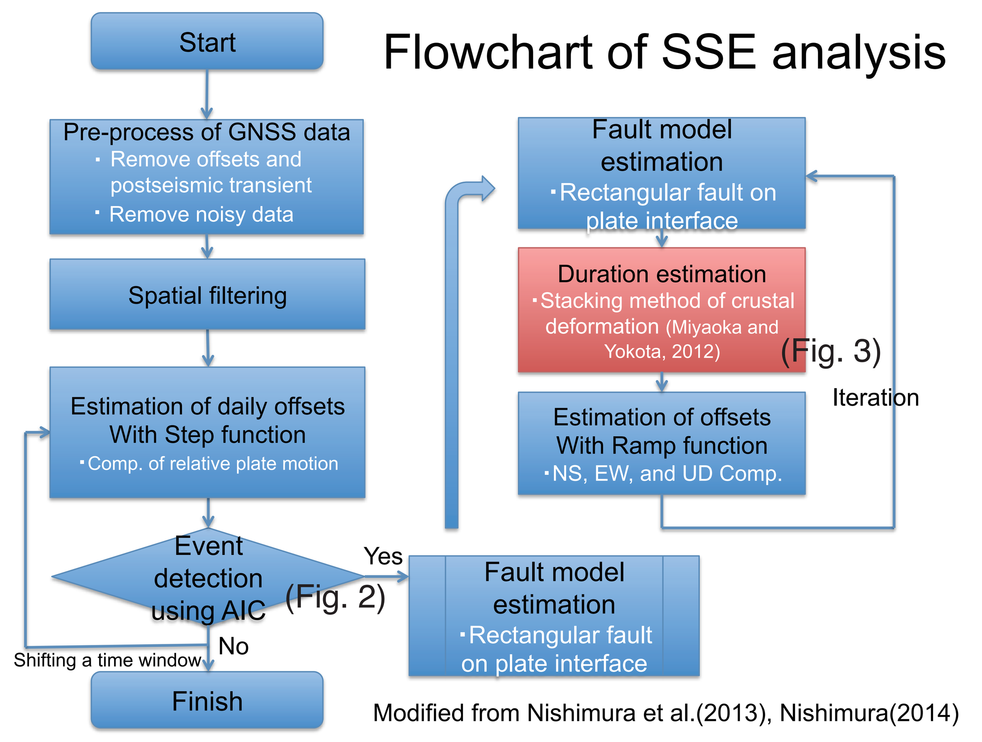
Short-term SSEs in the Kanto region, central Japan using GNSS data for a quarter century

Takuya NISHIMURA
Disaster Prevention Research Institute, Kyoto University
E-mail: nishimura.takuya.4s@kyoto-u.ac.jp

Key points

- More than 179 short- and imtermidiate- term SSEs (SSEs) with a duration of up to 80 day are detected using 26-years-long GNSS data in the Kanto region, central Japan.
- Two distinctive SSE clusters where relative plate motion is fully released by s-SSEs are found along the Sagami Trough.
- SSEs rarely overlap shallow tremors and regular M>7 earthquakes along the Japan Trench. However, they overlap M5-6 interplate earthquakes considerably.

Detection of small short-term SSEs using GNSS Data



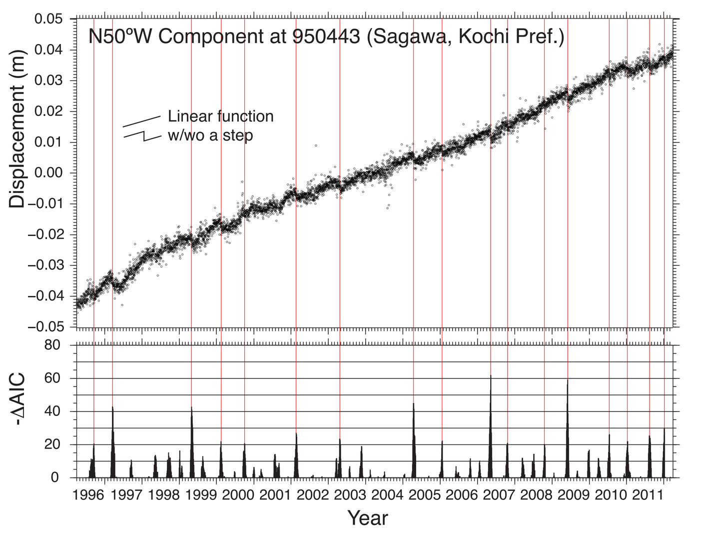


Fig. 1 Flowchart of SSE analysis

Fig. 2 Example of daily GNSS coordinates parallel to a relative plate motion and ΔAIC at 950443 station (Nishimura et al., 2013). Downward steps can be recognized, which is possibly caused by S-SSEs. Large -ΔAIC means significant step in time-series.

We apply the method of Nishimura et al. (2013) and Nishimura (2014) to detect a jump associated with short-term SSEs in GNSS time-series and estimate their fault models from observed displacements. A rectangular fault on the Philippine Sea or the Pacific plates is assumed for each SSE. The stacking of GNSS time-series based on the displacement predicted by the fault model [Miyaoka and Yokota, 2012] enable us to estimate duration of SSEs by fitting a ramp function.

Duration estimation by stacking of GNSS Timeseries

(Miyaoka and Yokota, 2012)

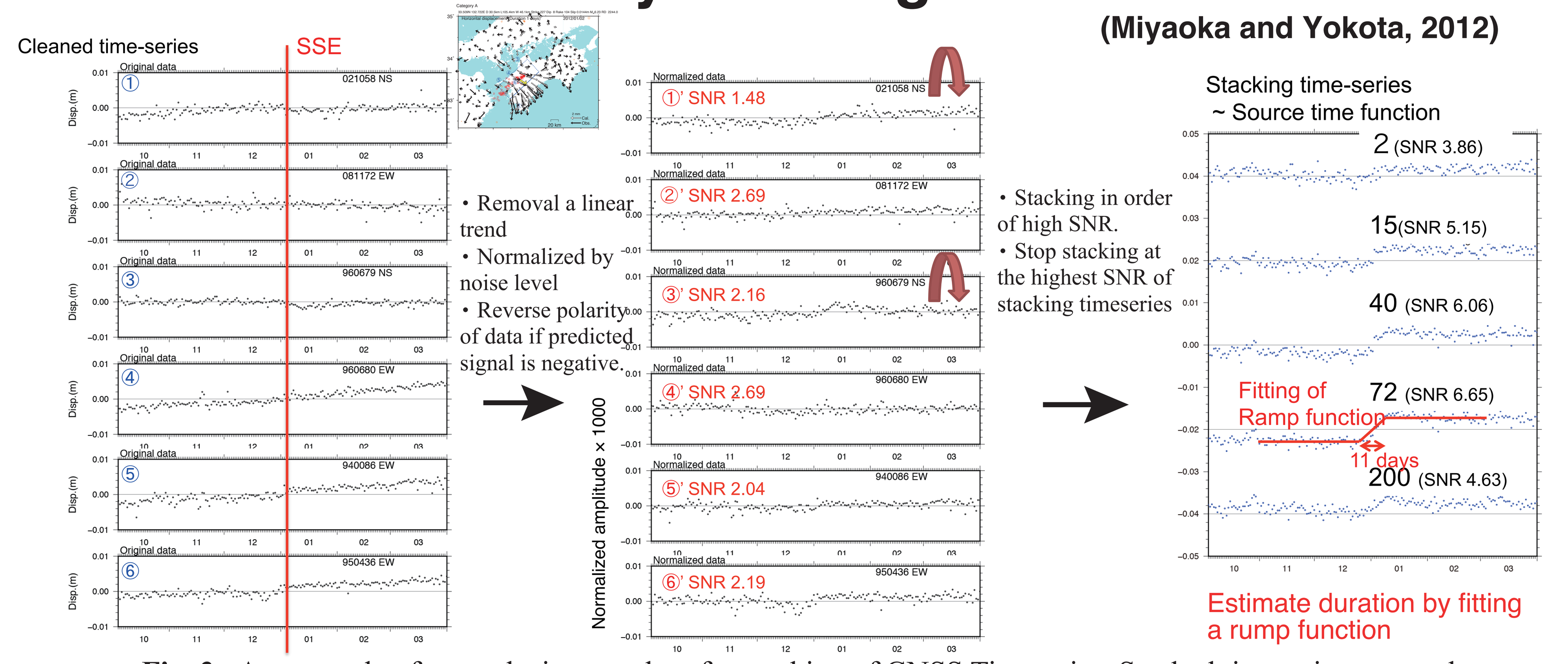


Fig. 3 An example of an analysis procedure for stacking of GNSS Timeseries. Stacked timeseries are used to estimate a source time function of small SSEs.

Kanto Double Subduction Zone and Boso SSEs

The Kanto region, central Japan is situated under complex tectonics where the Philippine Sea and the Pacific plates subduct from the Sagami Trough and the Japan Trench, respectively (Fig. 4).Several SSEs were reported by the previous studies [e.g., Ozawa et al., 2014]. Recently, Nishikawa et al. found tremors along the Japan trench However, spatiotemporal distribution of SSEs on both plates still remains unclear.

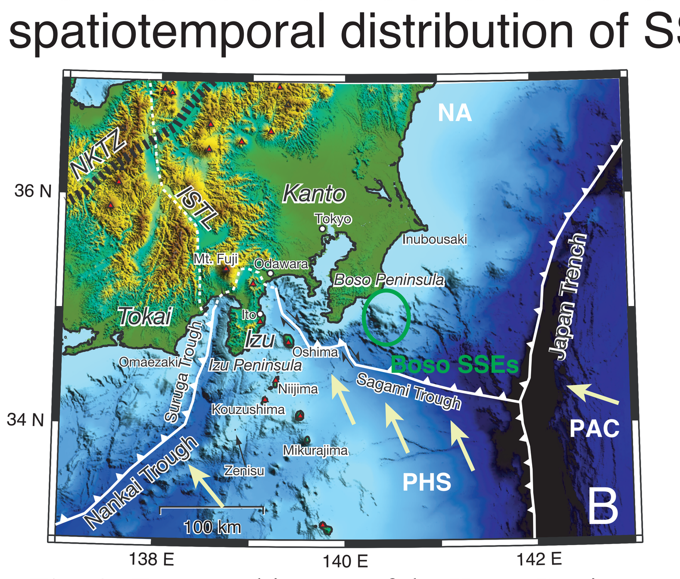


Fig. 4 Topographic map of the Kanto Region. Modified from Nishimura et al.(2007)

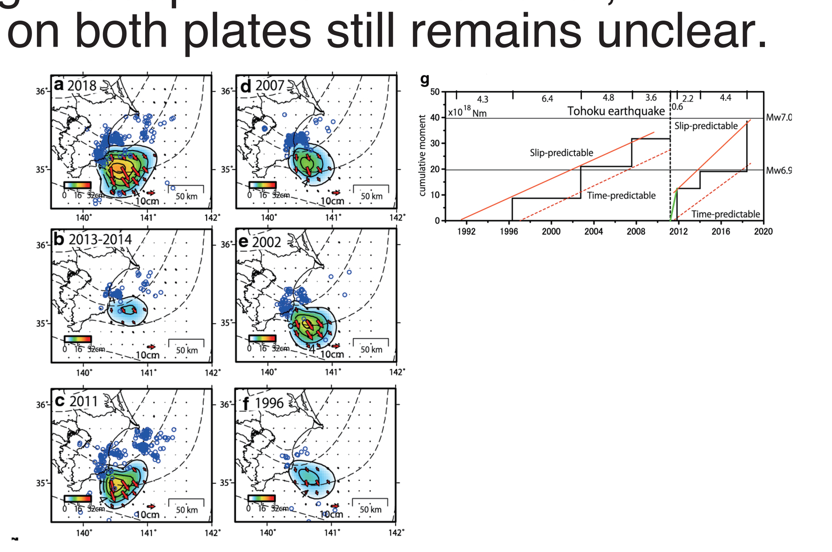


Fig. 5 Slip distribution of past 6 Boso SSEs (a-f) and their recurrence intervals (g). (Ozawa et al., 2019)

Data and Preprocessing

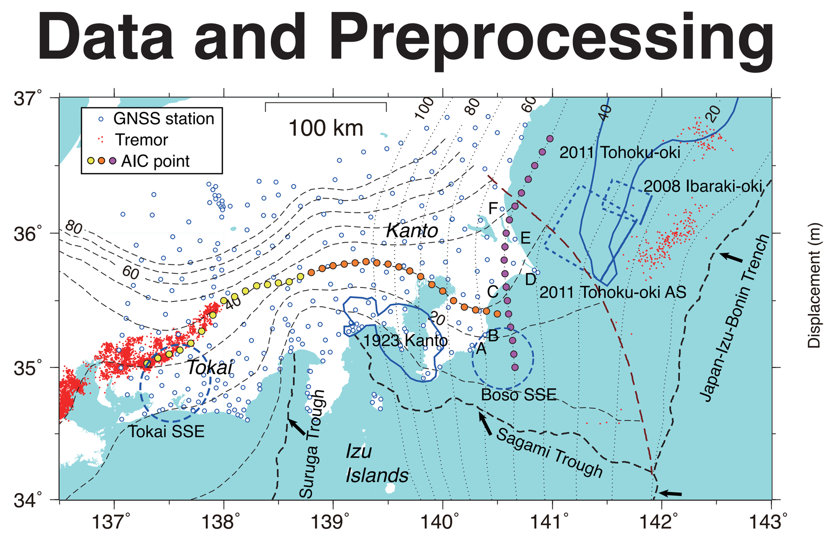


Fig. 6 Used GNSS stations and assumed slab geometry. The geometry is based on the model complied by Dr. F. Hirose. Time-series of A-E stations are shown in Fig.8.

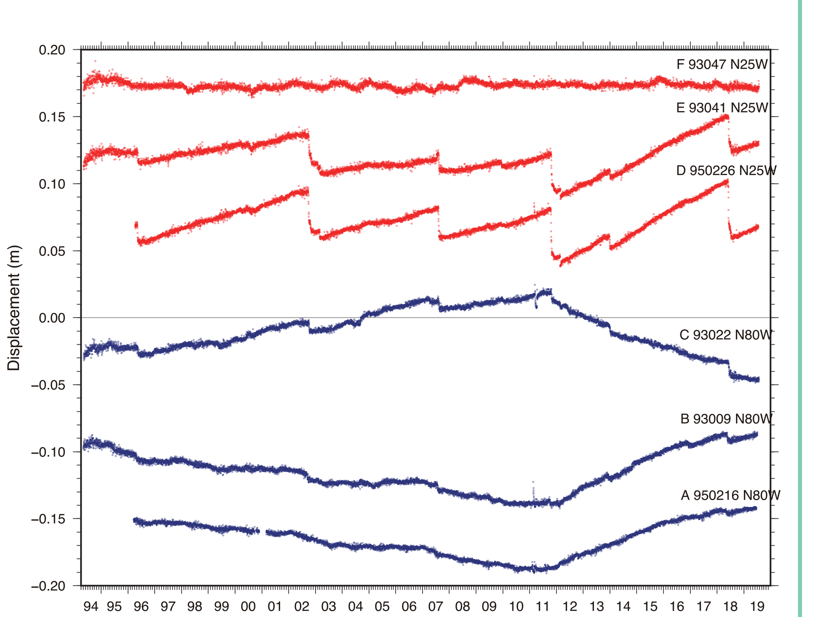


Fig. 7 Time-series of daily GNSS displacements for 26 years. Six Boso SSEs (black arrows) have been identified by previous studies. A linear trend is removed. See Fig. 6 for station location.

The used daily coordinates at 294 stations from April 25, 1994 to February 21, 2020 are estimated using GIPSY 6.4 software. Offsets related M≥6 earthquakes and maintenance are removed. Although co- and post- seismic displacement of the 2011 Tohoku-oki earthquake is removed by fitting Heaviside, logarithmic, and exponential functions, we excluded a period from December 11, 2010 to September 11, 2011 for the SSE detection because of large scattered data. The transient displacement related the 2000 Miyake-Kouzu volcanic event is also removed by using the model prediction (Nishimura et al., 2001). N80W, N25W, and N40W components are used to detect steps for SSEs along the Japan Trench, Sagami Trough, and Suruga Trough, respectively.

SSEs detected on the PHS

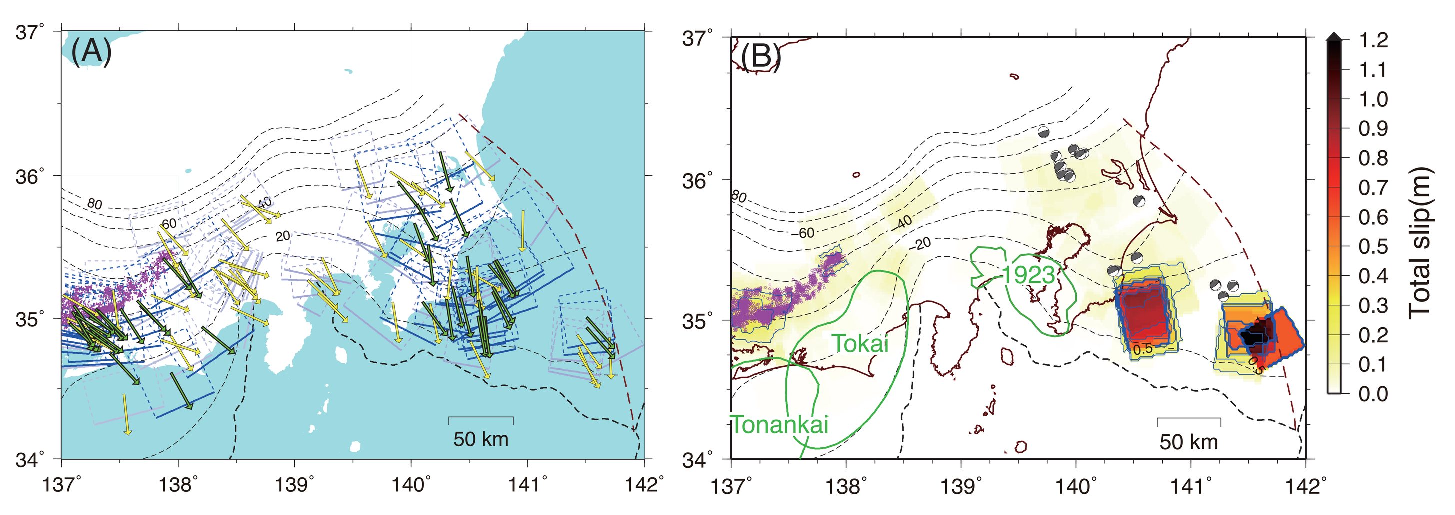


Fig. 8 Fault models for detected S-SSEs on the Philippine Sea plate. (a) Rectangular fault models (blue rectangles) and their slip vectors (yellow vectors). (b) Cumulative slip of SSEs. Focal mechanism is plotted for M_W>4.6 interplate earthquakes (240º ≤ Strike ≤ 300º, 0º ≤ Dip ≤ 30º, and 45º ≤ Rake ≤ 135º) during 1997-2019. Green regions represent source regions of the past megathrust earthquakes.

Findings and Implications

- Two distinctive SSE patches (Regions A and B)
- Total slip on these patches is equal to the relative plate motion.
- Medium-size interplate earthquakes occur at a downdip edge of SSEs patches.
- Small cumulative slip in the region of past megathrust

SSEs detected on the PAC

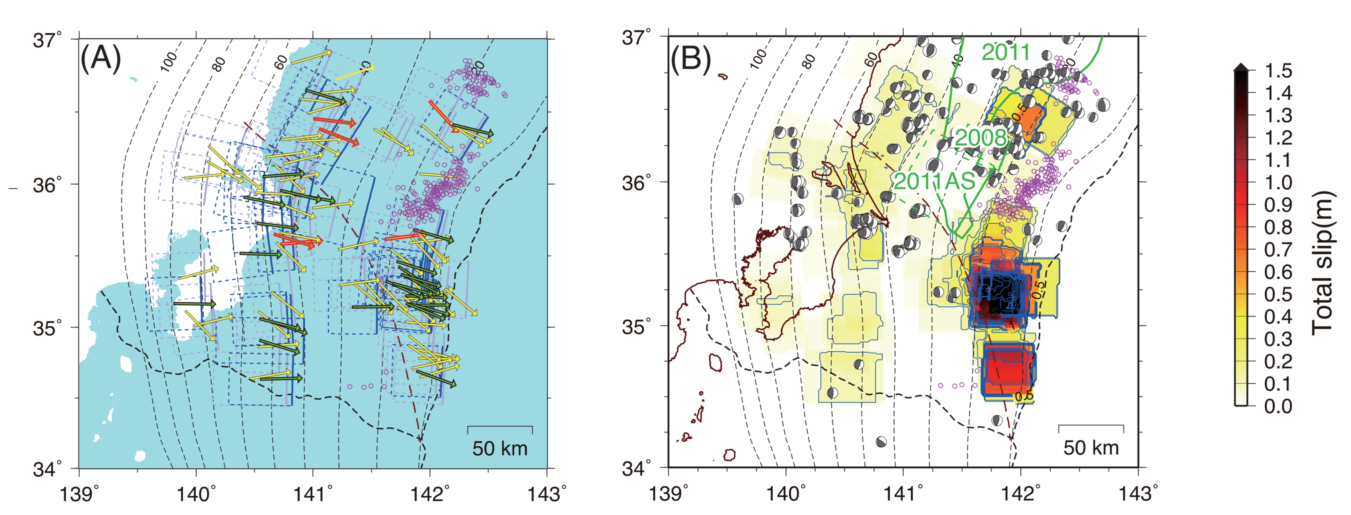


Fig. 9 Fault models for detected S-SSEs on the Pacific plate. (a) Rectangular fault models (blue rectangles) and their slip vectors (yellow vectors). (b) Cumulative slip of SSEs. Focal mechanism is plotted for M_W>4.6 interplate earthquakes (160º ≤ Strike ≤ 220º, 0º ≤ Dip ≤ 30º, and 45º ≤ Rake ≤ 135º) during 1997-2019. Green regions represent source regions of the past megathrust earthquakes.

Findings and Implications

- Many SSEs occur in two depth ranges, i.e., 10-20 km and 40-60 km.
- Little overlapping of S-SSEs and tremor regions in the shallow(10-20 km) depth range.
- Both SSEs and fast earthquakes coexist in the deep depth range (40-60 km). It is partly attributed to detected SSEs include co- and post-seismic slip events of M~6 earthquakes.
- No significant change of SSE slip behavior at the 2011 Tohoku-oki earthquake (Fig. 10).
- Small cumulative slip in the region of past megathrust earthquakes.

PAC SSEs controlled by subducting sea-mounts and overriding plates

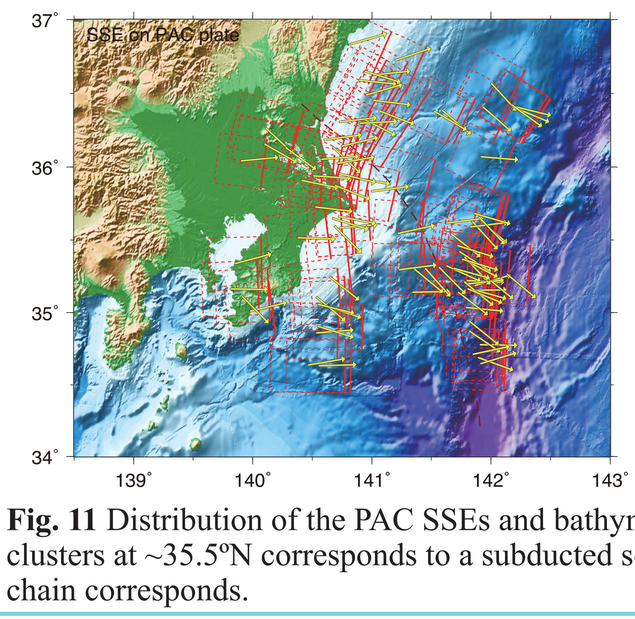


Fig. 11 Distribution of the PAC SSEs and bathymetry. SSE clusters at ~35.5ºN corresponds to a subducted sea-mounts chain corresponds.

Many shallow SSEs on the PAC locate in a region where the overriding plate is the North American plate, not the Philippine Sea plate (Fig. 11). This may reflect on a difference of interplate coupling controlled by geology of the overriding plate [Uchida et al., 2009]. It is also suggested that the SSE cluster at ~35.5ºN corresponds to a subducted sea-mount induced from a bathymetry and gravity anomaly.

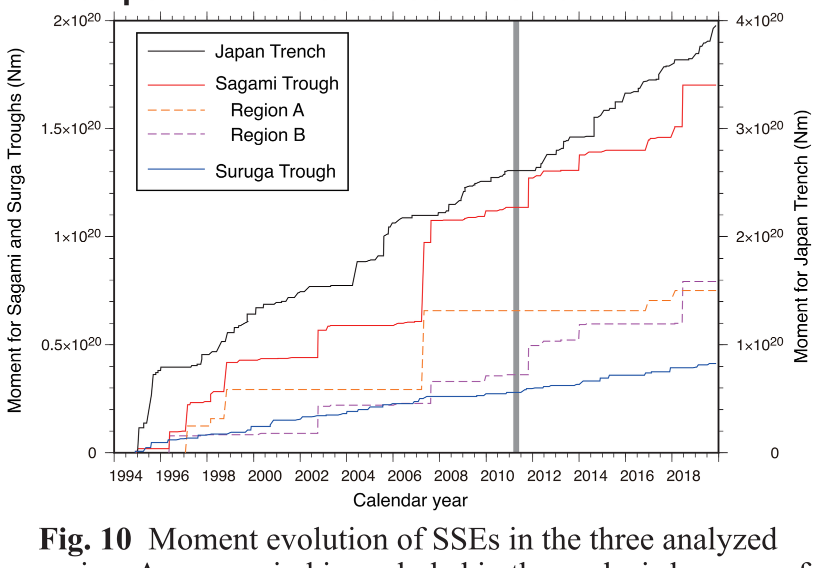


Fig. 10 Moment evolution of SSEs in the three analyzed region. A gray period is excluded in the analysis because of postseismic deformation of the 2011 Tohoku-oki earthquake.

Acknowledgements

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Reference

Miyaoka, K. and T. Yokota, Development of stacking method for the detection of crustal deformation -Application to the early detection of slow slip phenomena on the plate boundary in the Tokai region using strain data, J. Seismol. Soc. Jpn. (Zisin), 65, 205-218, 2012.

Nishikawa, T., Matsuzawa, T., Ohta, K., Uchida, N., Nishimura, T., and Ide, S. The slow earthquake spectrum in the Japan Trench illuminated by the S-net seafloor observatories. Science, 365(6455), 808-813, 2019.

Nishimura, T., Ozawa, S., Murakami, M., Sagiya, T., Tada, T., Kaidzu, M., and Ukawa, M. Crustal deformation caused by magma migration in the northern Izu Islands, Japan. Geophysical Research Letters, 28(19), 3745-3748, 2001.

Nishimura, T., T. Sagiya, and R. S. Stein, Crustal block kinematics and seismic potential of the northernmost Philippine Sea plate and Izu Microplate, central Japan, inferred from GPS and leveling data, J. Geophys. Res., 112, B05414, doi:10.1029/2005JB004102, 2007.

Nishimura, T., T. Matsuzawa, and K. Obara, Detection of short-term slow slip events along the Nankai Trough, southwest Japan using GNSS data, J. Geophys. Res. Solid Earth, 118, 3112-3125, doi:10.1002/jgrb.50222, 2013.

Nishimura, T., Short-term slow slip events along the Ryukyu trench, southwestern Japan, observed by continuous GNSS, Progress in Earth and Planetary Science, 1:22, doi:10.1186/s40645-014-0022-5, 2014.

Ozawa, S., Shortening of recurrence interval of Boso slow slip events in Japan. Geophysical Research Letters, 41(8), 2762-2768, 2014.

Uchida, N., Nakajima, J., Hasegawa, A., and Matsuzawa, T. What controls interplate coupling?: Evidence for abrupt change in coupling across a border between two overlying plates in the NE Japan subduction zone. Earth and Planetary Science Letters, 283(1), 111-121, 2009.