Slow earthquake families on the subducting Philippine Sea plate in southwest Japan:

Non-volcanic tremor •, slow slip ○, and very low-frequency earthquake ○

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Tremor and Slip
- Time sequence of Tremors
  - Periodicity, Migration, Triggering
- Slow slip event detected by tiltmeter
  - Coherency with tremor activity
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  - along the belt-like distribution of tremor

Very Low Frequency (VLF) earthquake
- Waveform
- Seismicity
1 hour continuous seismograms observed at 3 stations in the western part of Shikoku
4 am, 17 August 2001
3 days envelope traces in Shikoku

20010816 BPF: 2-16Hz

20010817 BPF: 2-16Hz

20010818 BPF: 2-16Hz

Time (hour)

IKTH
KWBH
TBEH
YNDH

Parallel to the strike of subducting Philippine Sea plate

1944 Tonankai Eq. (M7.9)

1946 Nankai Eq. (M8.0)
Clustering of tremor activity

Shikoku

Kii

Tokai
Periodic activity of tremors in Shikoku
Migration of tremors (27 Aug – 2 Sep, 2003)

- Daily distribution of tremors determined by envelope correlation method for each one-minute as shown in bottom envelope traces.

Migration velocity = 10km/day

Example of envelope traces and detection of tremors

- LF events listed in JMA catalog
- LF tremor detected by this method
Horizontal component of high-sensitivity accelerometer

(Tiltmeter)

equipped in all NIED Hi-net stations

Tidal effect is removed by Baytap-G
Tremor and Tilt change in the western part of Shikoku

Tilt change [μ rad.] \(\rightarrow\) S.E down

2001 /1

2001 /8

2002 /2

2002 /8

5 days

5 days

5 days

6 days

(HIYH.N)

(HIYH.E)

(Time window: 14 days)
Relationship between migration of tremor and tilt

**[Winter]**
- Tilt vector: S-down → E-down
- Tremor: NE → SW

**[Summer]**
- Tilt vector: SE-down → S-down
- Tremor: SW → NE
ETS (Episodic Tremor and Slip) on both sides of the Pacific Ocean; Shikoku (SW Japan) and Cascadia
Observed Tremor and Slow slip

W. Shikoku

- Recurrence Rate: 6 months
- Duration: a few days ~ 1 week
- Deformation: ~ 0.1 micro radian (tiltmeter)

Cascadia

- Recurrence Rate: 13 ~ 16 months
- Duration: 10 ~ 20 days
- Deformation: ~ 5mm (GPS)

- Short-term slow slip
- Long-term slow slip

Tokai Slow Slip: a few years
Short-term and long-term slow slip event (SSE) with tremor from August 2003

Long-term SSE in 1997

Long-term slow slip and Tremor
Tilt change and tremor in Kii area

MASH.E

MASH.N

2001 / 3 - 4

2002 / 10

2003 / 12 - 2004 / 1

3 days

4 days

Tilt (μ rad.) → SE down

Hourly count of tremor

Time window: 28 days

Day (Time window: 28 days)
Distribution of short- and long-term slow slip events in SW Japan

- Short-term slow-slip and Tremor
- Long-term slow-slip
- 1944 Tonankai Eq. (M7.9)
- 1946 Nankai Eq. (M8.0)
Tremor triggered by M2.4 microearthquake

30-min. Envelopes (BPF: 2-16Hz) from 2002/08/11 08h00m in Mie

M2.4
Tremors
Tremor triggered by M7.6 Indonesia earthquake

1-hour Envelopes (BPF:2-16Hz) from 2002/10/10 19h50m in Tokai

T-phase

Tremor activity
Epicenter of tremor within 30 min.

2002/10/10 19:50
1.7S 134.1E
10km M7.6

Surface wave
Tremor energy release in the active stage with short-term slow slip in west of Shikoku

The periodicity of 12 hours == effect of earth tide
- Non-volcanic deep tremor
  - at the down dip of the seismogenic zone
  - sometimes triggered by seismic wave

- Major Tremor and short-term slow slip event
  - occurs periodically
    (6 months in W. Shikoku, 3 months in E. Shikoku).
  - continues for days ~ weeks.
  - migrates along the strike of subducting slab.

- Tremor and long-term slow slip event
  - detected in Bungo Channel.
  - Unclear in Tokai
Very Low-Frequency earthquake near the Nankai trough
1 hour broadband seismograms (2003/7/6 03h)

10-100s Band-pass filtered traces

Time [min]
Seismograms along the Pacific coast line

VLF event: 2003/06/26 06h30m--07h00m

Apparent Velocity ~ 3.5km/s

Nothing in JMA catalog
Estimation of epicenter
Epicentral distribution of VLF events

- **VLF in 2003**
- **5/8-5/11, 2004**
- **9/9--, 2004**
- ○ Tremors

**M7.4**

9/5/2004
Relocation and CMT analysis

Depth: 2-10 km

Reverse fault type
Summary of VLF events

1. VLF events generate only surface wave.
2. The source depth is very shallow.
3. The mechanism is reverse fault type.
4. VLF events might occur in the accretionary wedge or the plate boundary.
Conclusions

1. Deep tremors occur in a narrow belt at the down dip of the seismogenic zone.

2. Slow slip events occur in some parts of the tremor zone.

3. The style of the coupling phenomena has regional differences.

4. VLF events are located along the Nankai trough.

5. Both events might be related to the subduction of the Philippine Sea plate.
Slow events on the Nankai subduction zone

- Deep Low-f Tremor
- Short-term Slow Slip
- Long-term Slow Slip

VLF event
Locked zone