Plate coupling along the Manila subduction zone between Taiwan and northern Luzon

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Key Questions

• What is the plate coupling ratio between subducting Sunda Plate and the Philippine Sea plate?

• What are the relationship among trench-parallel gravity anomaly, bathymetry, and giant earthquake rupture?
Tectonic setting

GPS horizontal velocity w.r.t the Sunda Plate gradually decrease from north to south along the western Luzon at rates of 81 to 50 mm/yr in the west-northwest direction.
Seismicity (1900-1999)

(Engdahl and Villasenor, 2002)
GPS array in the Luzon area

1996-2008
(8 surveys)

1996-2000:
surveyed annually

3 additional surveys:
2004/4, 2006/12, 2008/8

in collaboration with the Philippine Institute of Volcanology and Seismology, Philippines

(Yu et al. 2011)
Modeled and predicted velocities along three transects

(a) A-A'
85° / 15 km

(b) B-B'
89° / 15 km

(c) C-C'
70° / 28 km

(Yu et al. 2011)
Convergence rate along the Manila Trench

- Velocities w.r.t to the Sunda Plate
- The fault locking effect on the Philippine Fault is removed from GPS velocity field (Yu et al. 2010)

- GPS horizontal velocities decrease from north to south suggesting a southward decrease of convergence rate along the Manila Trench.
The interseismic deformation can be represented as the sum of the long-term block motion across the plate boundary, i.e. plate convergence rate, and backslip distribution on the locked fault segment.
Plate coupling ratio derived from inversions of GPS data

\[ \frac{\text{slip deficit rate}}{\text{plate convergence rate}} \]

\[ \chi^2 = 4.6 \]
Trench Parallel Gravity Anomaly (TPGA)

The subduction earthquakes occur predominately on the plate interface beneath forearc basins and in areas with a strongly negative TPGA [Song and Simons, 2003; Wells et al., 2003].

(Seismicity, 1900-1999 Engdahl and Villasenor, 2002)
Method

1. TPGA values (-100~100 mGal)
2. Normalized (0~1, different scaling law)
   e.g. -100 mGal → coupling ratio = 1 (fully locked)
       100 mGal → coupling ratio = 0 (creep)
3. Slip-deficit distribution
   predicted surface velocity
4. Compare with GPS observations
Locked asperities defined by negative TPGA

Locked asperities inferred from GPS data

\[ \chi^2 = 9.7 \]

\[ \chi^2 = 4.6 \]

\[ \text{coupling ratio } (c) \propto (-\text{TPGA}_{FA})^3 \]
1994 Java tsunami earthquake: slip over a subducting seamount

M7.6

Decoupled Aseismic slip Seamount Aseismic slip

Normal faulting No seismicity Normal faulting

1994 Java Mw 7.6 EQ

Cross-section
(Abercrombie et al. 2001)
Seismicity between 1973 and 2010
NEIC (M$_w$ 4.6-7.7)
Bathymetry and fault rupture behaviors

The Costa Rican subduction zone

Bilek et al. (2003)

- M7.0
- M6.9
- M7.4

The Nankai Trough

The 1946 Nankaido earthquake:
brittle rupture in the eastern part and slow slip in the western part of the Tosa-bae

Kadoira et al. (2000)
E-W transects of GPS horizontal velocities
Seafloor Crustal Deformation Observation System

1) Kinematic GPS for positioning a survey vessel

2) Acoustic ranging for measuring distances to seafloor transponders

(Courtesy of M. Ando)
Slip behaviors on the fault

(Courtesy of M. Ando)
Conclusions

1. The seismogenic behaviors offshore northern Luzon remain poorly constrained.

2. The plate interface between the Manila Trench and the western Luzon is possibly predominately aseismic.

3. The seafloor roughness and subducted sediments may complicate the slip behavior at subduction zones. The great subduction zone earthquake propagates beneath the Scarborough Seamount seems to be unlikely.

4. We need more data to resolve the details of plate coupling and validate present best TPGA-based coupling models.
Thank you for your attention

Oct. 2009, Luzon GPS survey