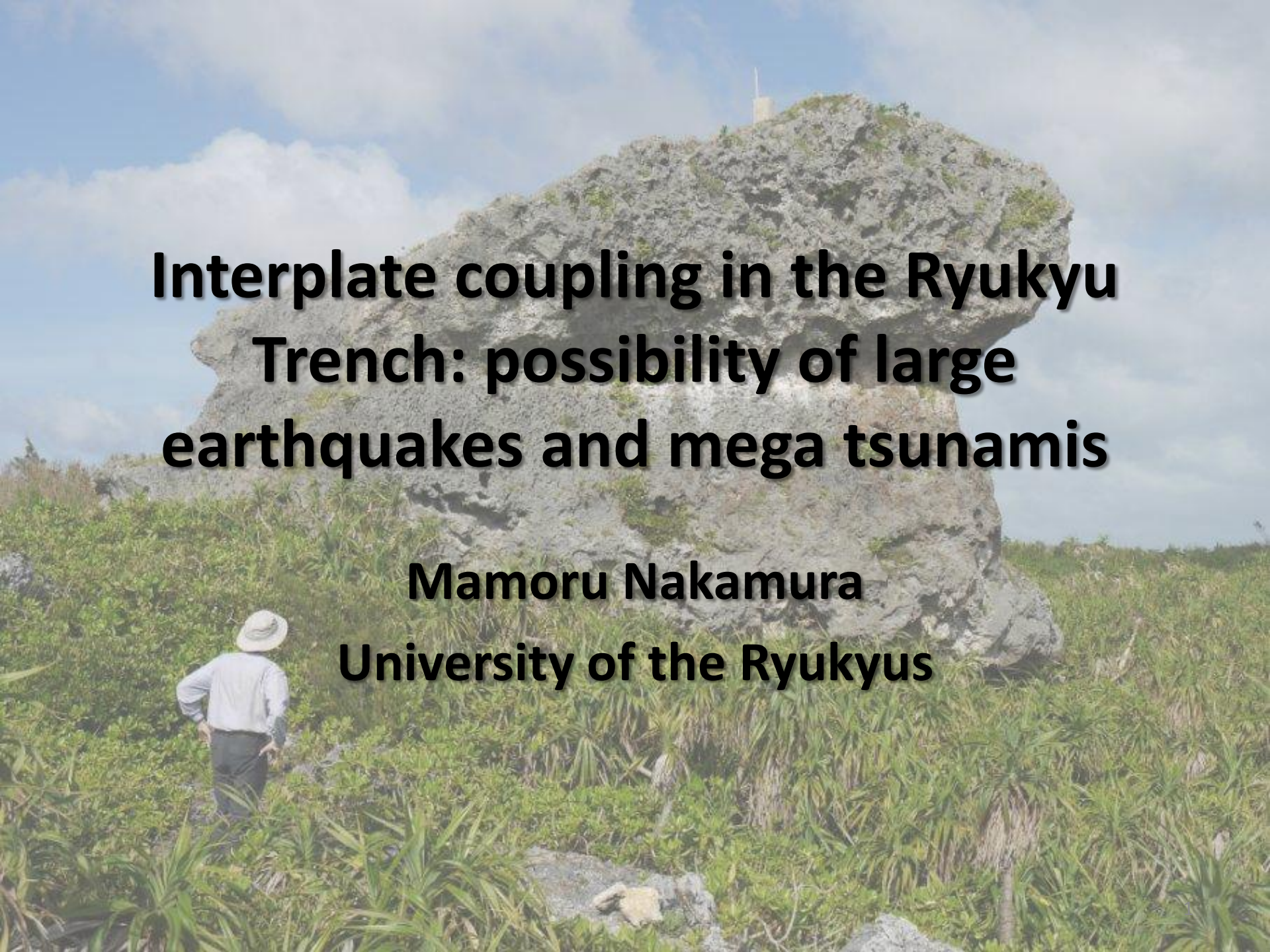


Interplate coupling in the Ryukyu Trench: possibility of large earthquakes and mega tsunamis

Mamoru Nakamura

University of the Ryukyus

Historical large earthquakes in the Ryukyu trench (1700-2010)

Damaged earthquakes in the Ryukyu area

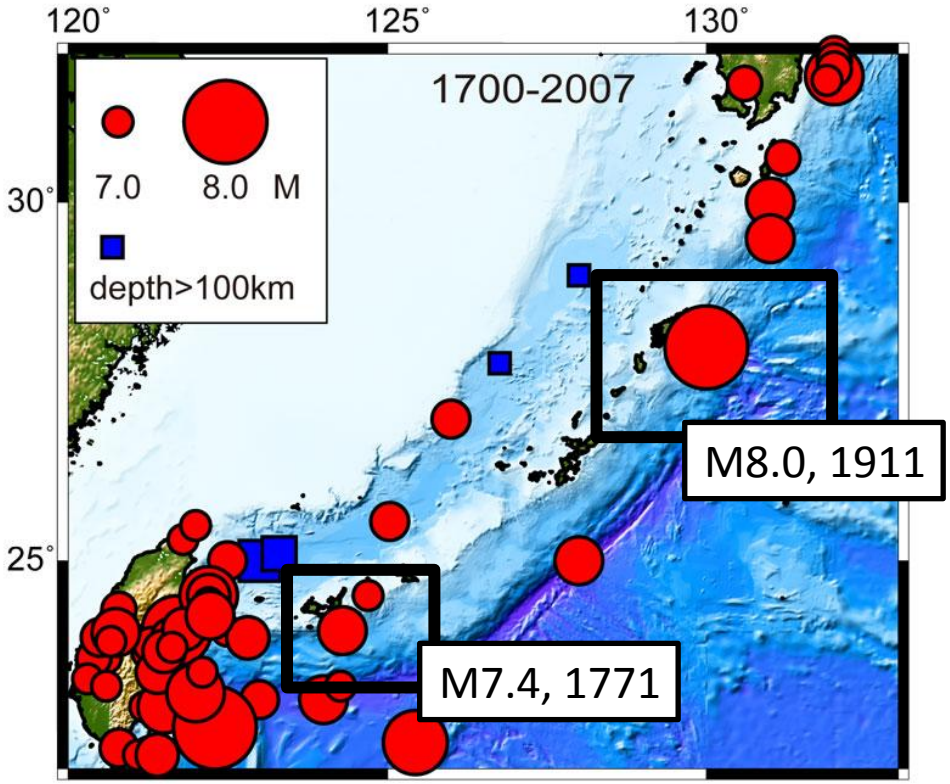
1771 Yaeyama earthquake (M7.4?) Mt8.5

1911 Kikaijima earthquake (M8.0)

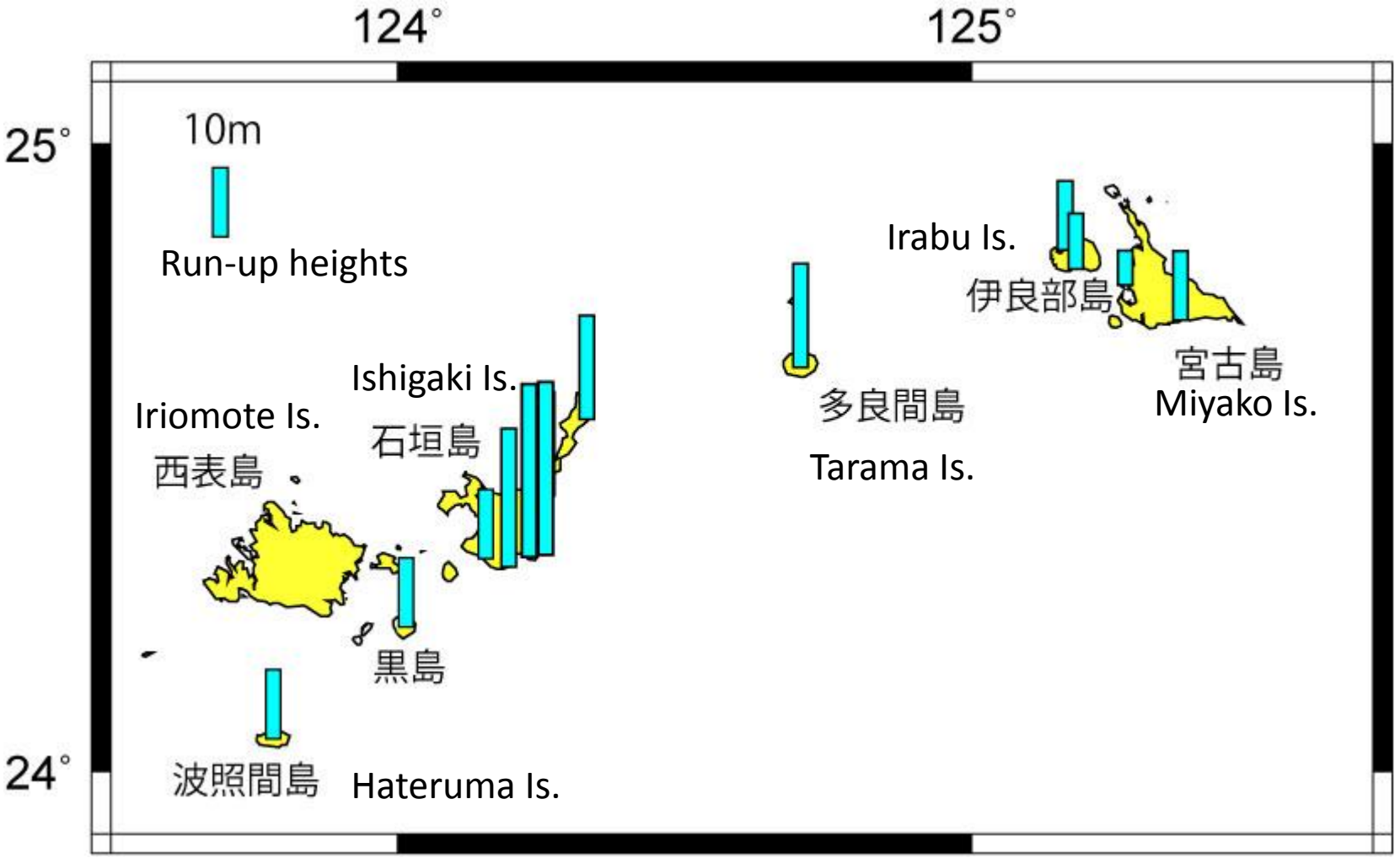
(Philippine Sea plate: intra-plate earthquake)

Thrust-type large earthquakes:

1771 Yaeyama tsunami

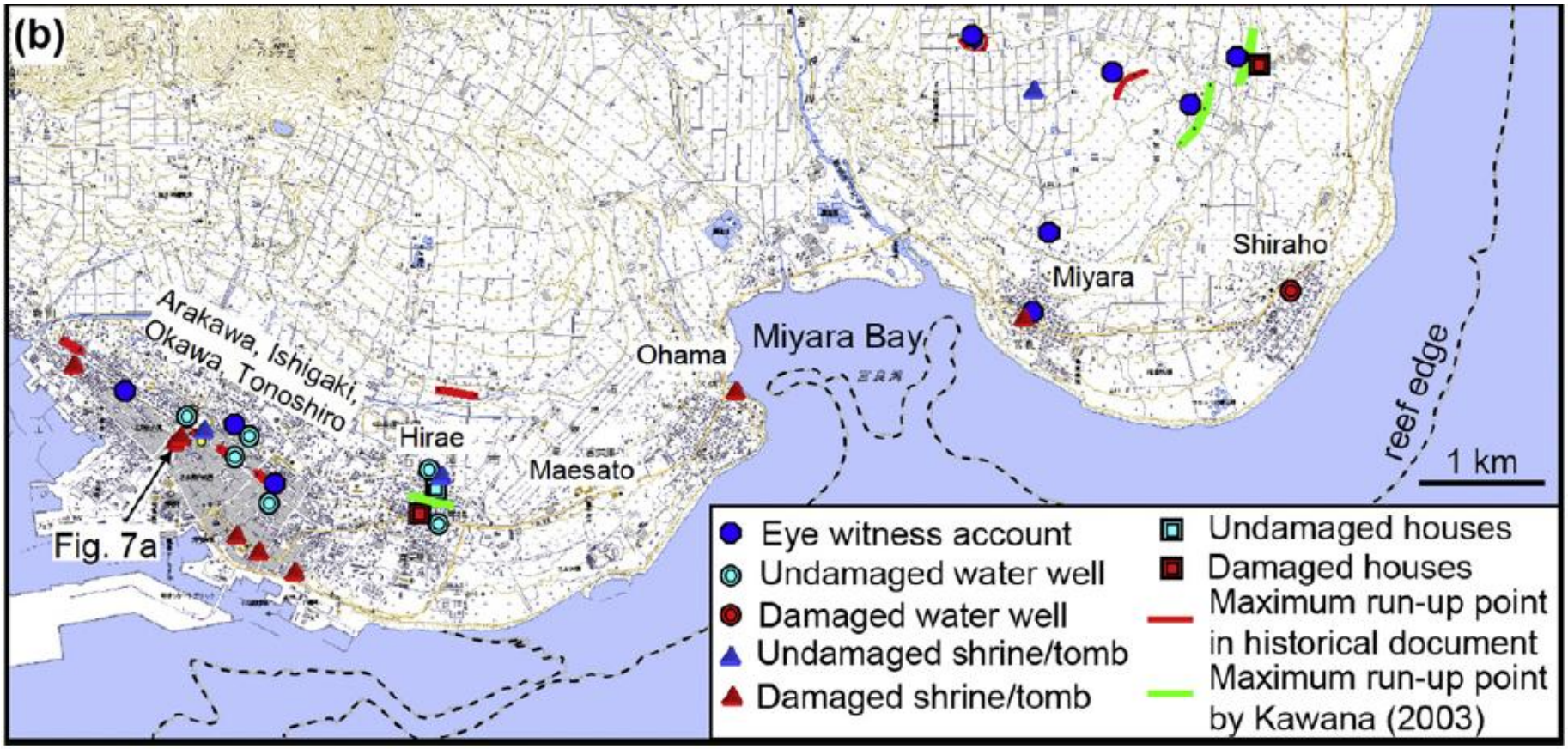


The 1771 Yaeyama tsunami



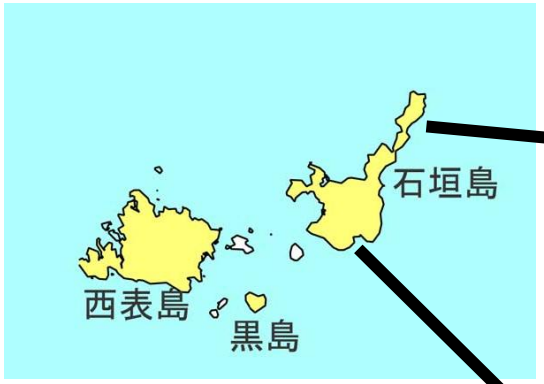
Kawana,2000; Goto et al., 2010

Inundation area of the 1771 Yaeyama tsunami in the south Ishigaki Island

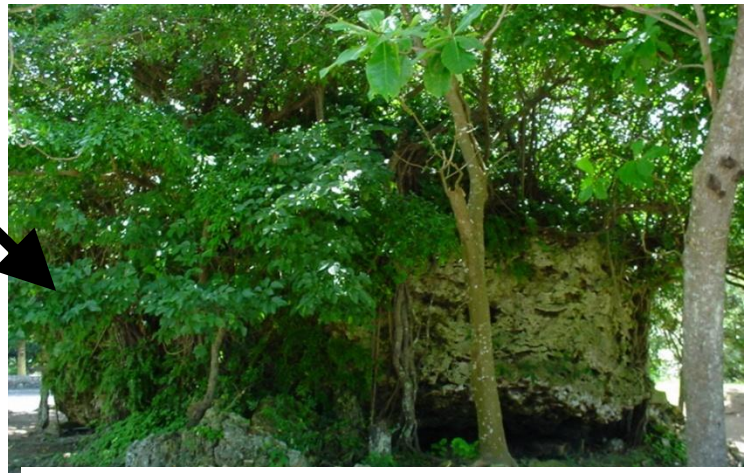


Goto et al., 2010

Tsunami boulders

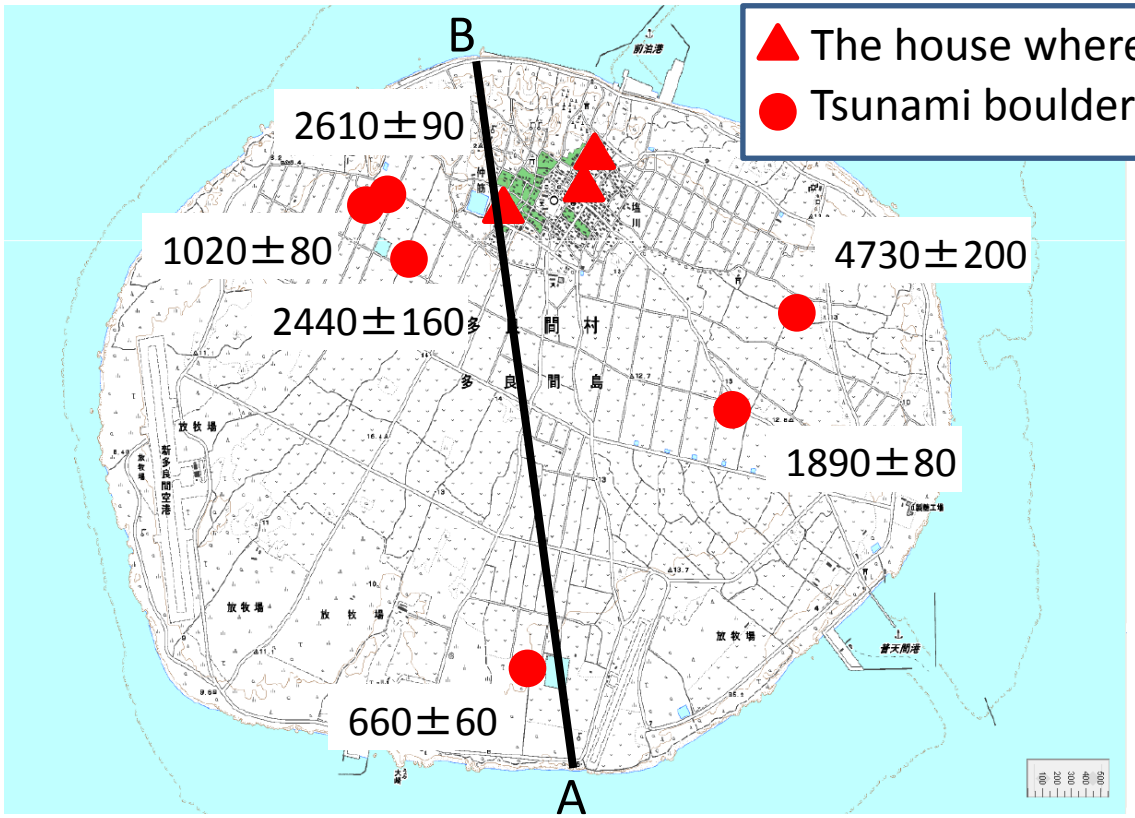


Tsunami boulder
(moved by the 1771 tsunami)



Tsunami boulder (coral)
(not moved by the 1771 tsunami)

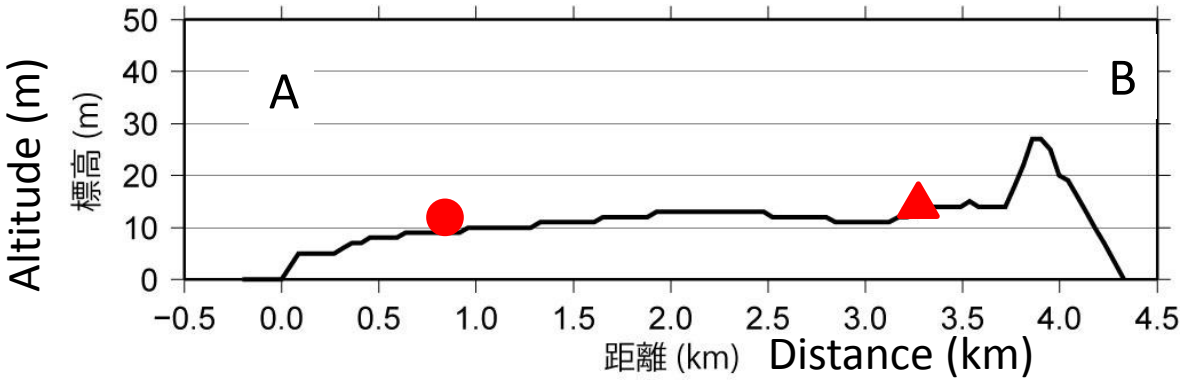
Inundation of the 1771 event in the Tarama Island



▲ The house where the tsunami reached
● Tsunami boulder and its age (coral fossil)

Tsunami inundation area :1~3 km from shoreline

（Nakata, 1990, Kawana & Nakata, 1994）



Trace of tsunami at the ruins in the Miyako Island

写真5　城辺町教育委員会調査の友利元島遺跡層序；
Ⅲ層が津波堆積か（宮古島市教育委員会提供）

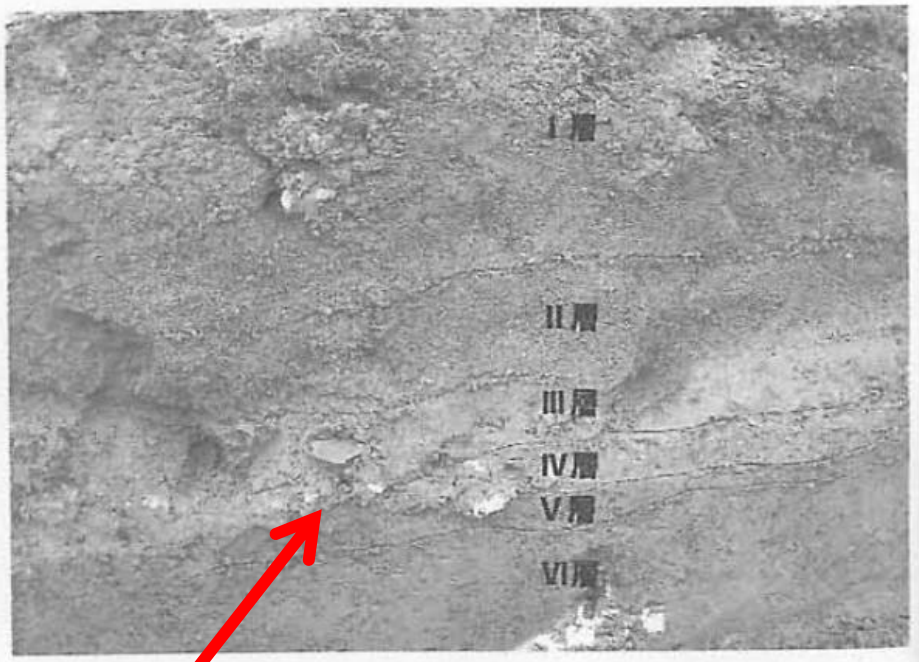
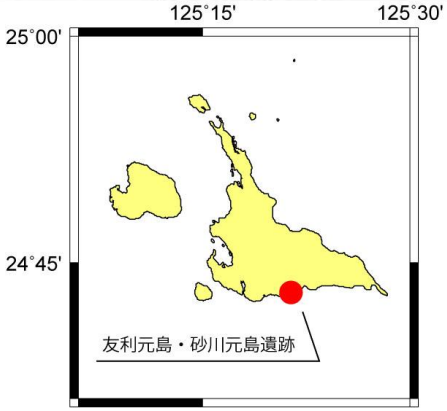


写真6　砂川元島遺跡試掘調査の層序；Ⅲ・Ⅳ層が津波堆積か
（宮古島市教育委員会提供）



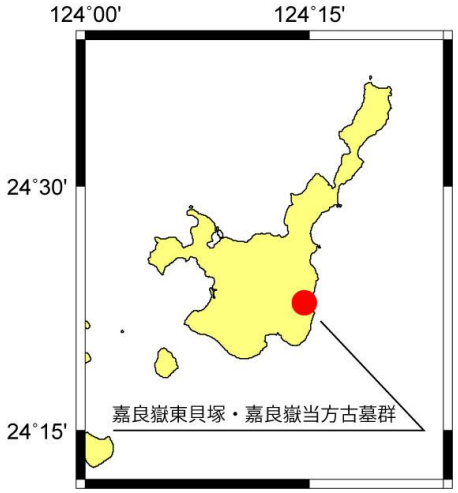
Tsunami sediments
of the 1771 event

Shimabukuro, 2008

Trace of ground shaking of the 1771 Yaeyama earthquake

Cracks and sand layer

（Okinawa Archeological center, 2009）

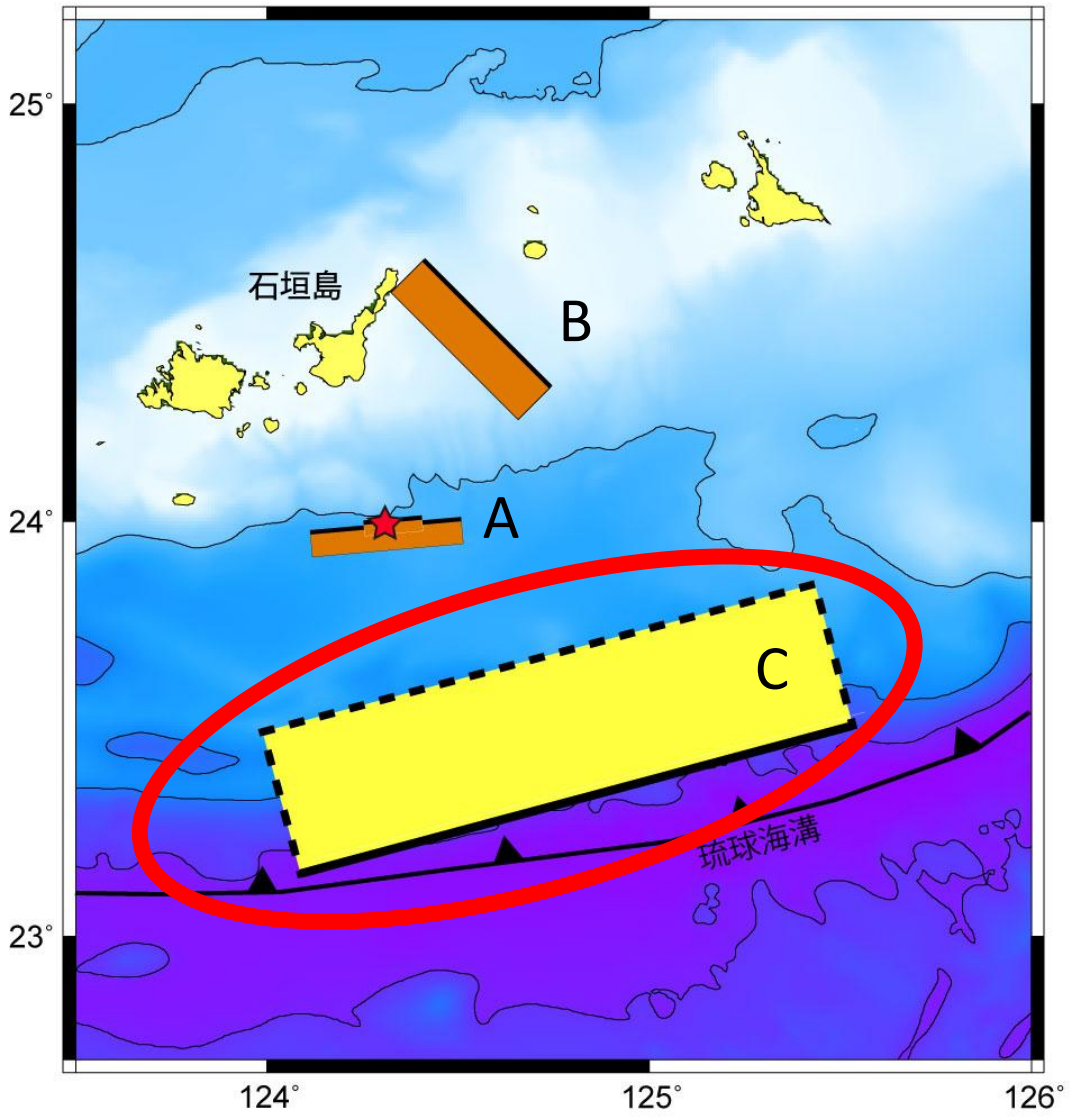


cracks by the ground shaking

inundation of tsunami

the tsunami attacked between 9 century and 1771

Source of the 1771 Yaeyama tsunami



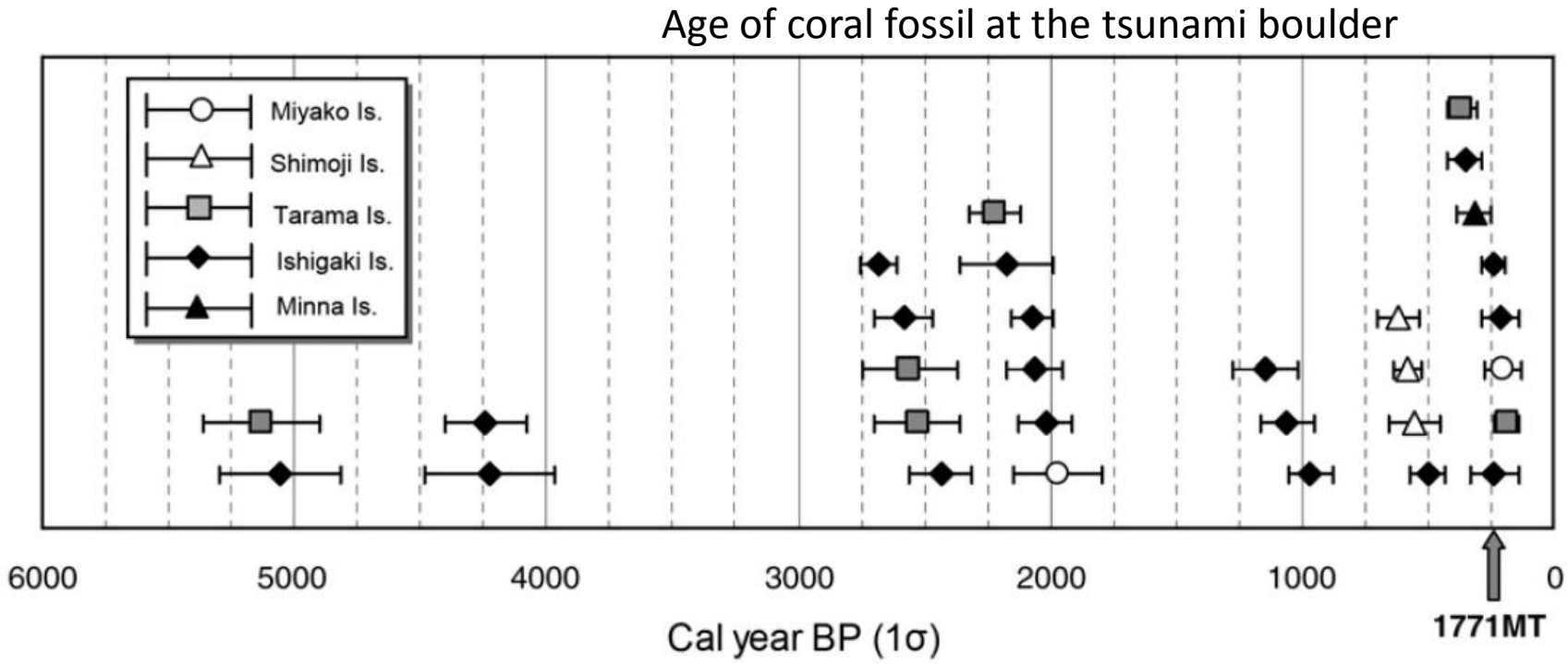
A : Intraplate eq. ＋ landslide
（Imamura et al., 2001,2008）
No evidence for landslides

B : Intraplate eq.
（Nakamura, 2006）
M8 intraplate earthquake?

C : Interplate eq.
（Nakamura, 2009）

★ : epicenter by the earthquake catalogue.

Mega-tsunami before the 1771 event

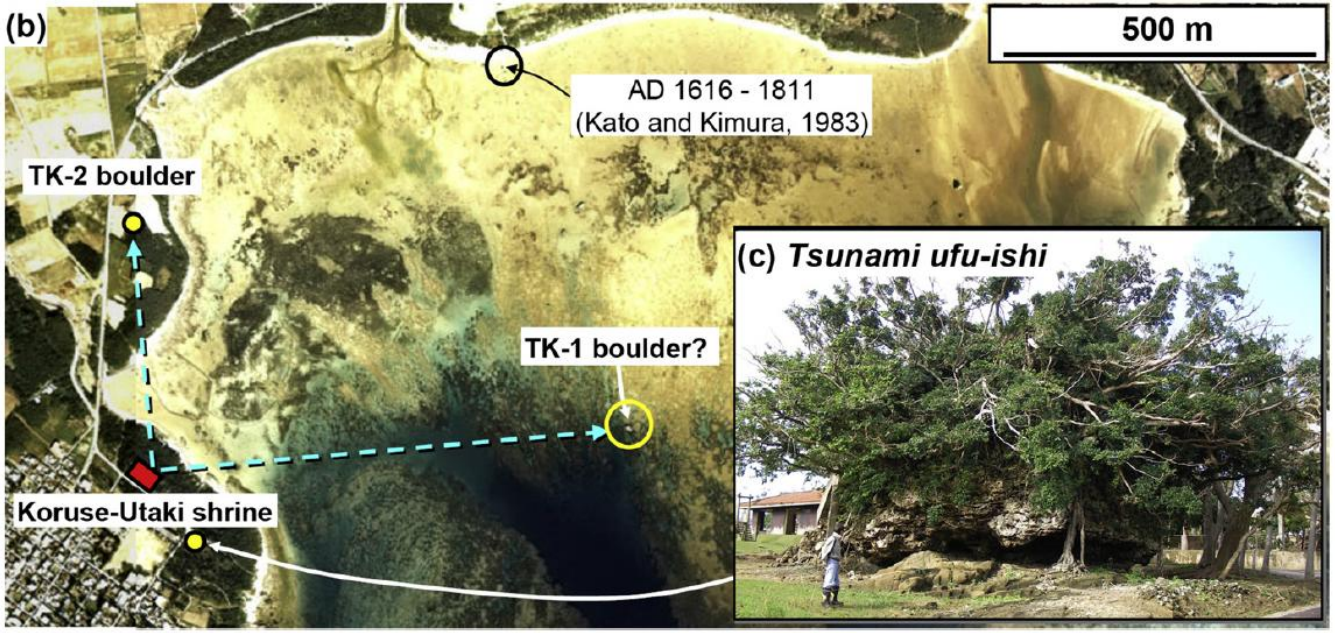


Goto et al., 2010

Occurrence of mega tsunami : 200, 500, 1000,2000,2500 yrs. BP.

5 times for 3000 years.

Evidence of mega-tsunami before 1771 event



Goto et al., 2010

The tsunami boulder moved from Koruse-shrine to east and north direction by the 1771 tsunami. (written in the old documents)（大波之時各村之形行書）

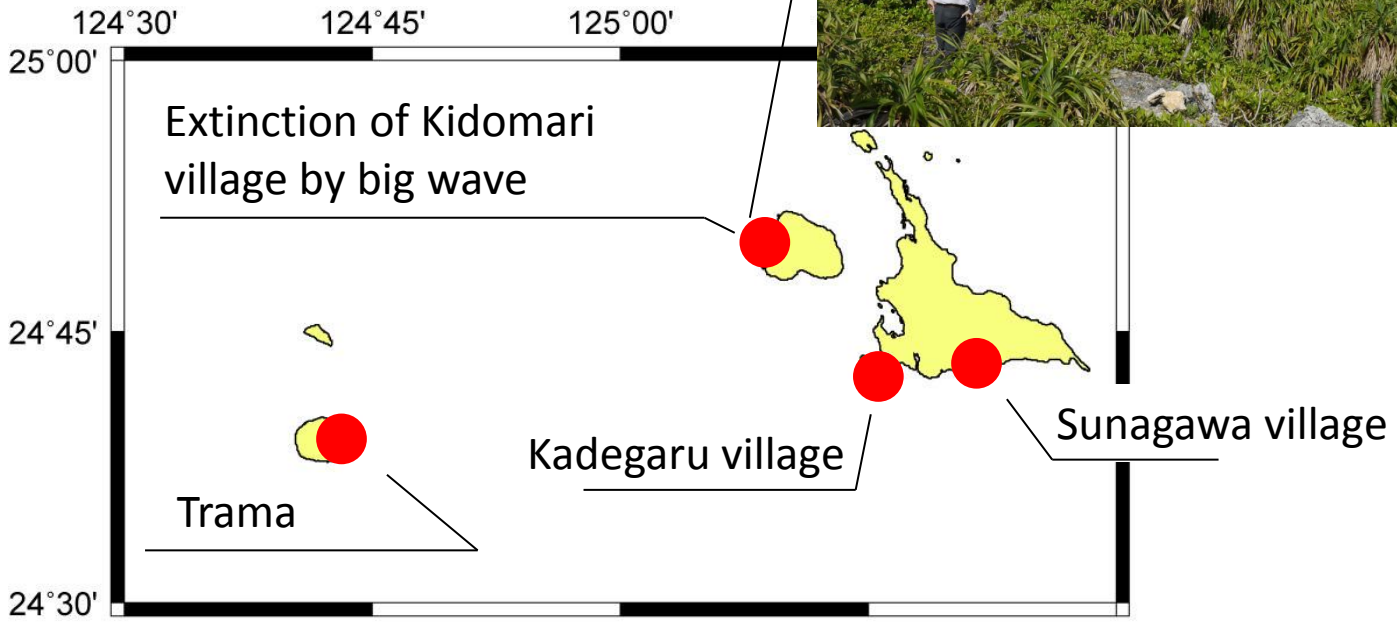
14C age of the coral fossil of the tsunami boulder（TK-2）2110～2390 yBP

2000 yrs BP. : the boulder moved from reef to land.

1771: the boulder was broken and moved.

Tsunami Folklores in the Miyako area

Obi-Iwa
(tsunami boulder)



Tsunami Folklores : 13~15 century

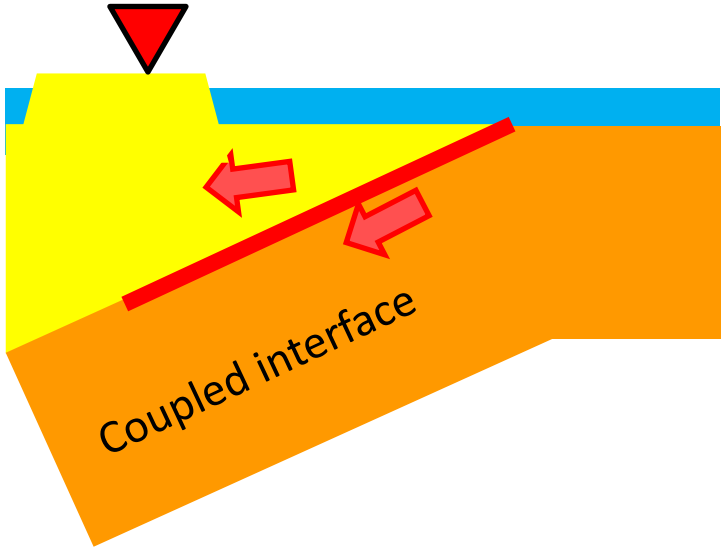
documented in the old literature (Miyako-kyuki, 1748)

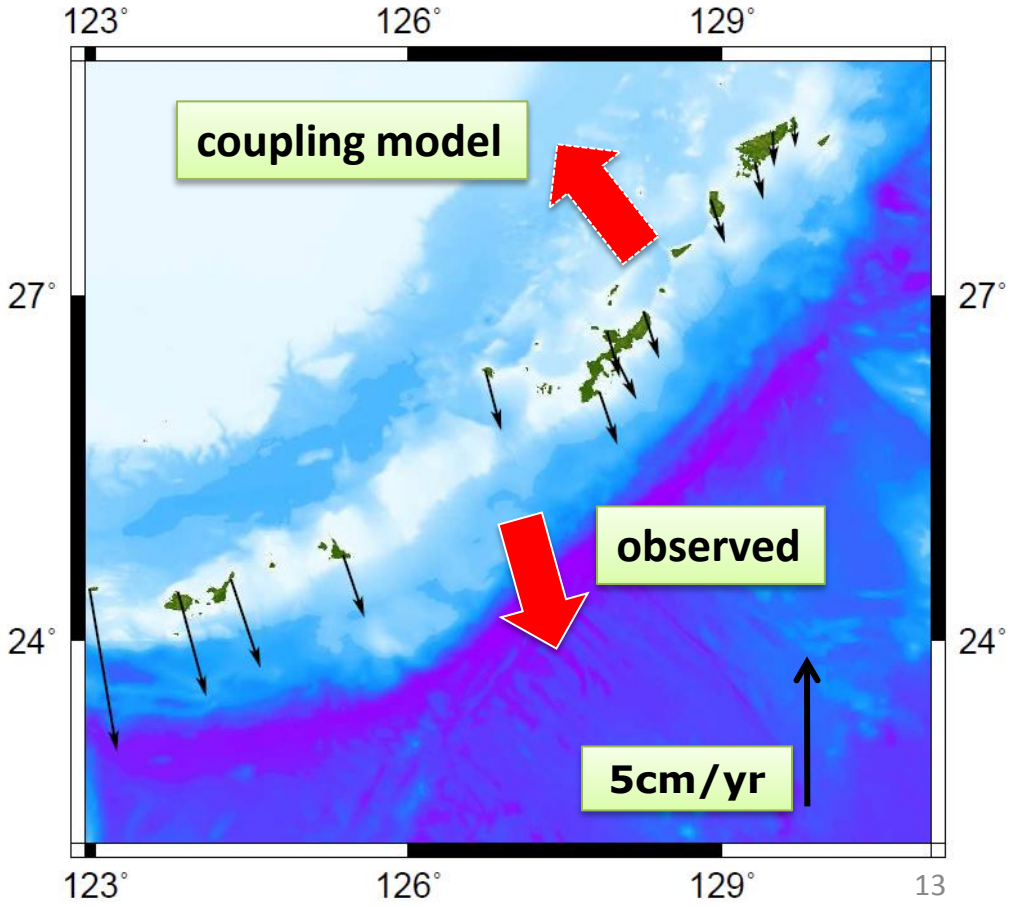
The Ryukyu Trench is coupled?

Stress accumulation

Southward movement of Ryukyu Islands -> weak coupling

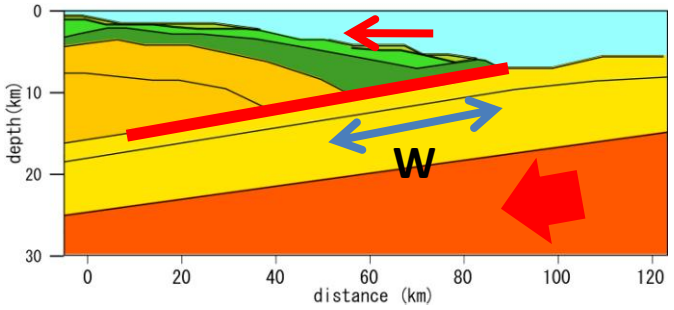
Inter-seismic coupling: 5% (Paterson & Seno, 1984)



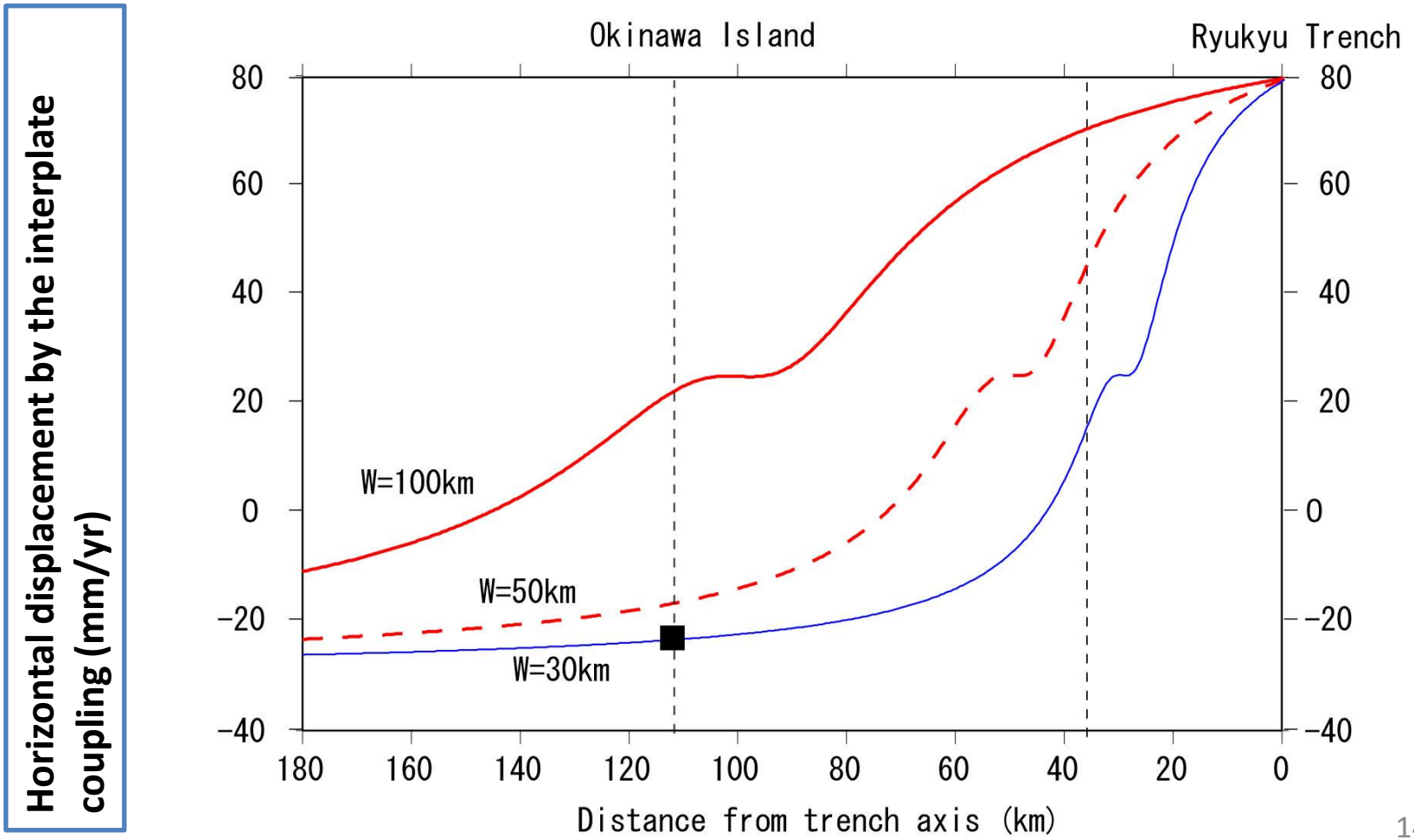


GPS horizontal velocity
(GSI, 1997-2006)
Tsushima is fixed

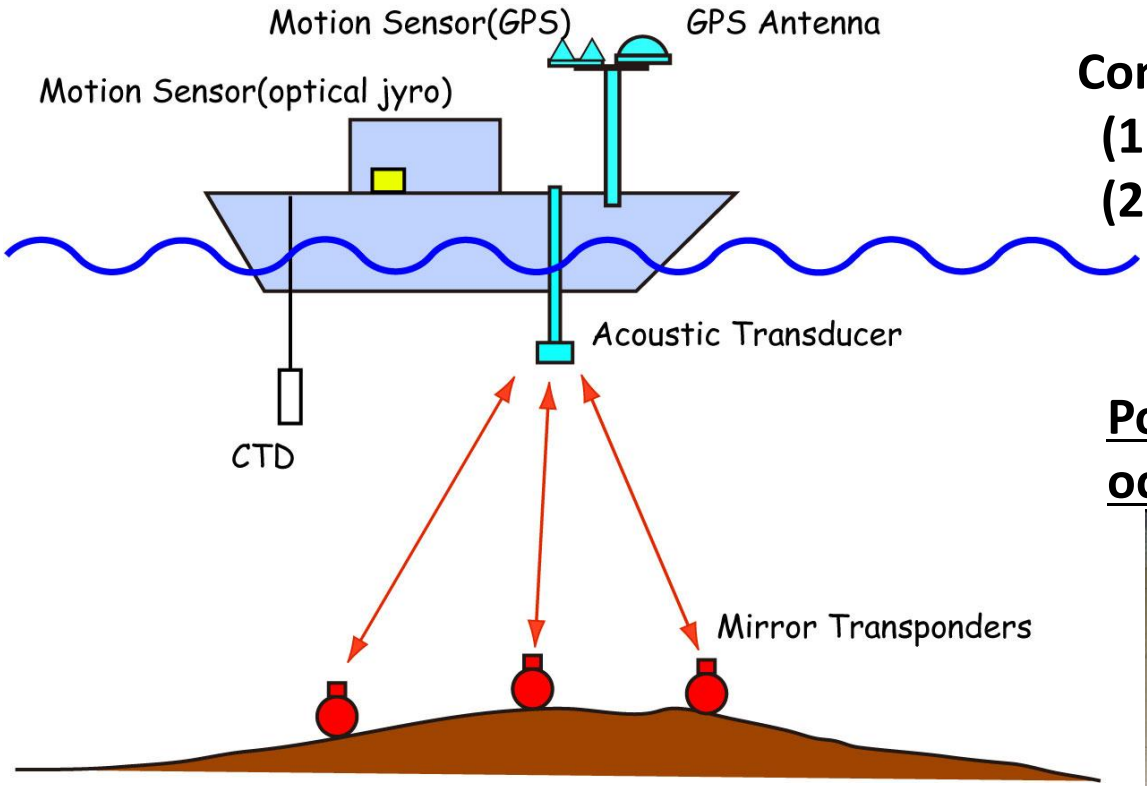
Width of the coupled zone



Horizontal velocity relative to the Amurian plate (NW direction: positive)



Ocean Bottom Crustal Movement Measurement System



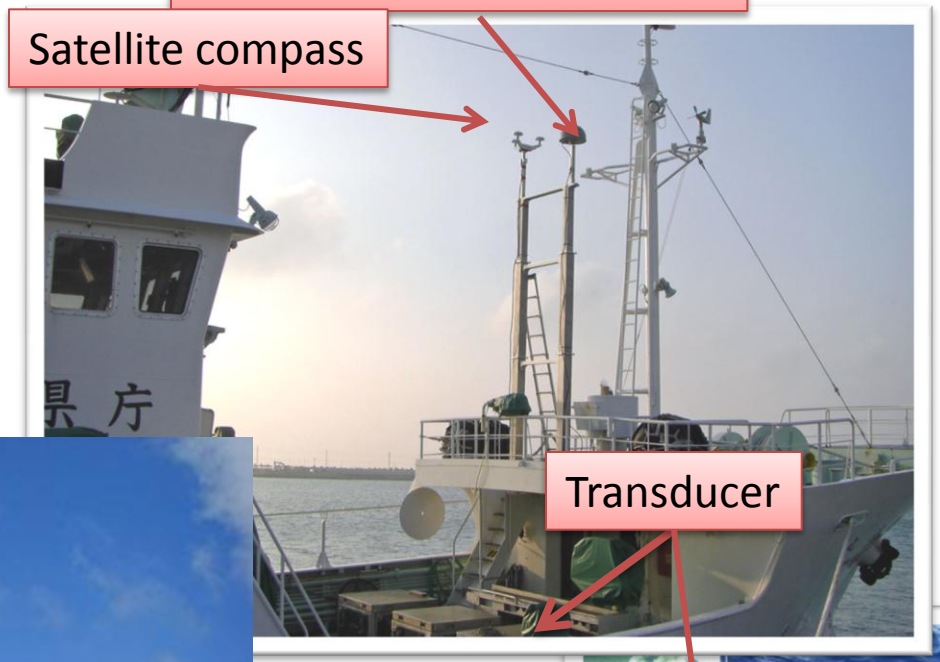
Combination of
(1) Kinematic GPS (5Hz sampling)
(2) Acoustic ranging system

Position determination of ocean-bottom benchmarks

University of the Ryukyus
Nagoya University
IES, Academia Sinica

Tonan-Maru (176t)

(Okinawa Prefectural Fisheries and Ocean Research Center)



Ocean-bottom crustal deformation measurement in the central Ryukyu trench

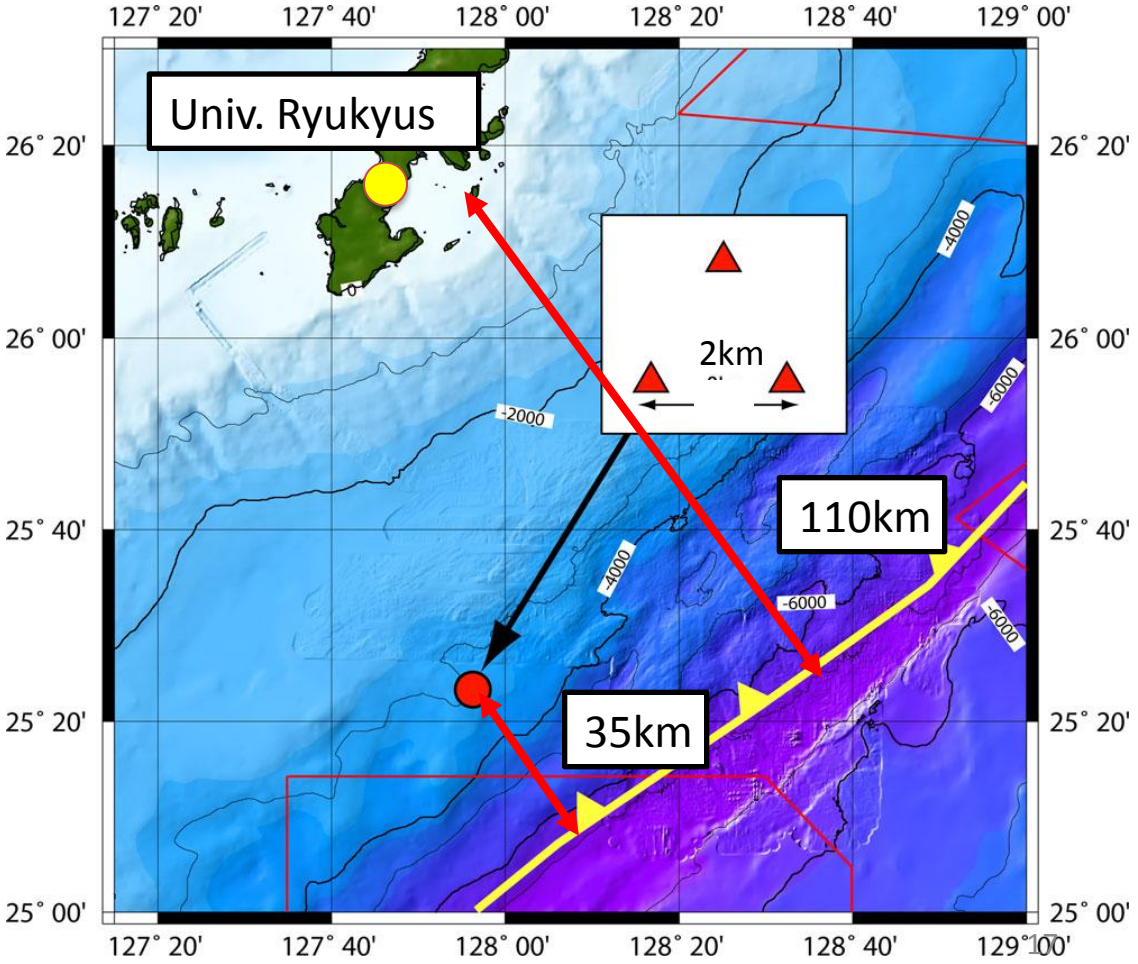
Benchmarks

35km land-side from Ryukyu Trench

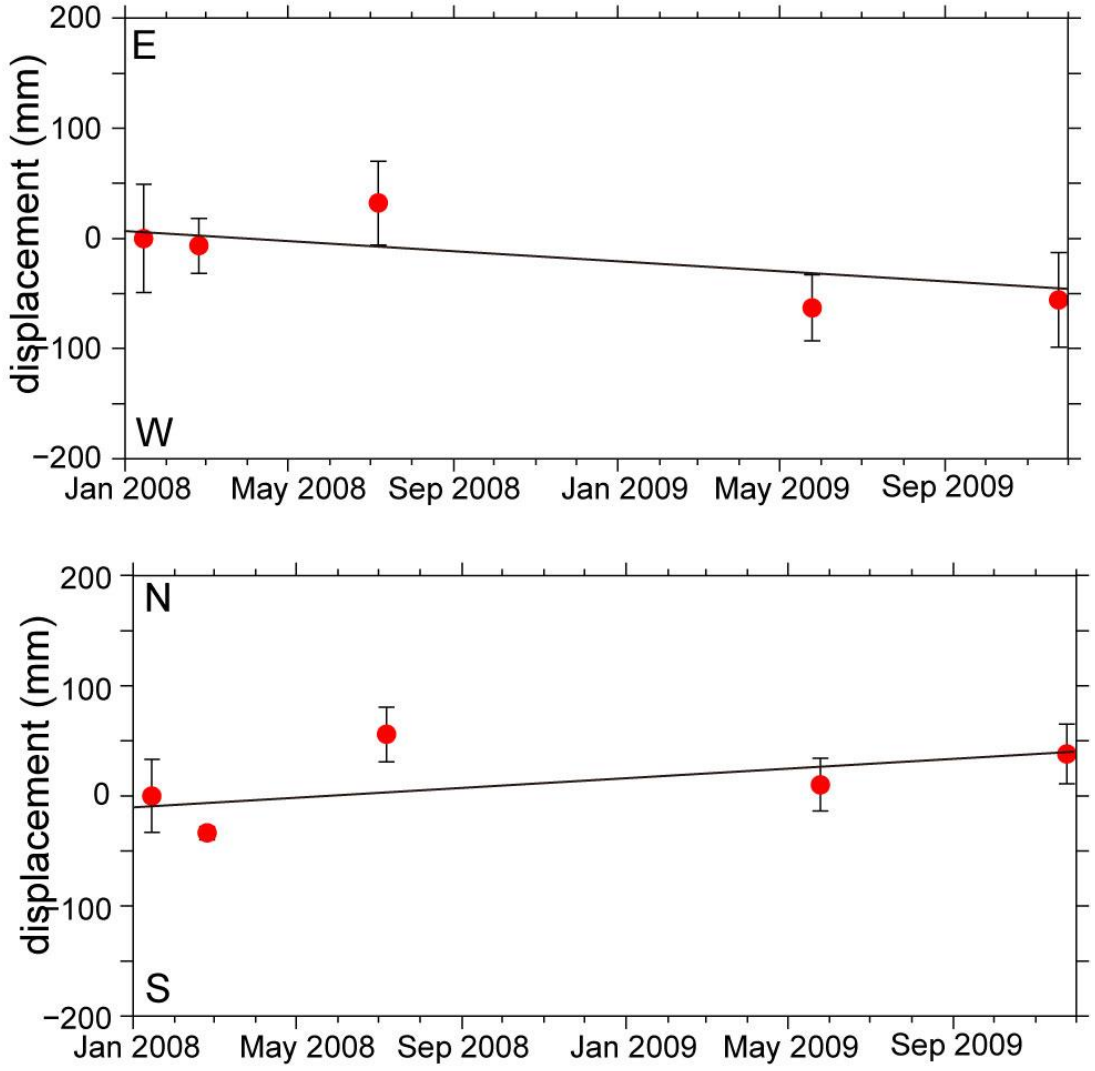
interval: 2km

Reference of kinematic GPS

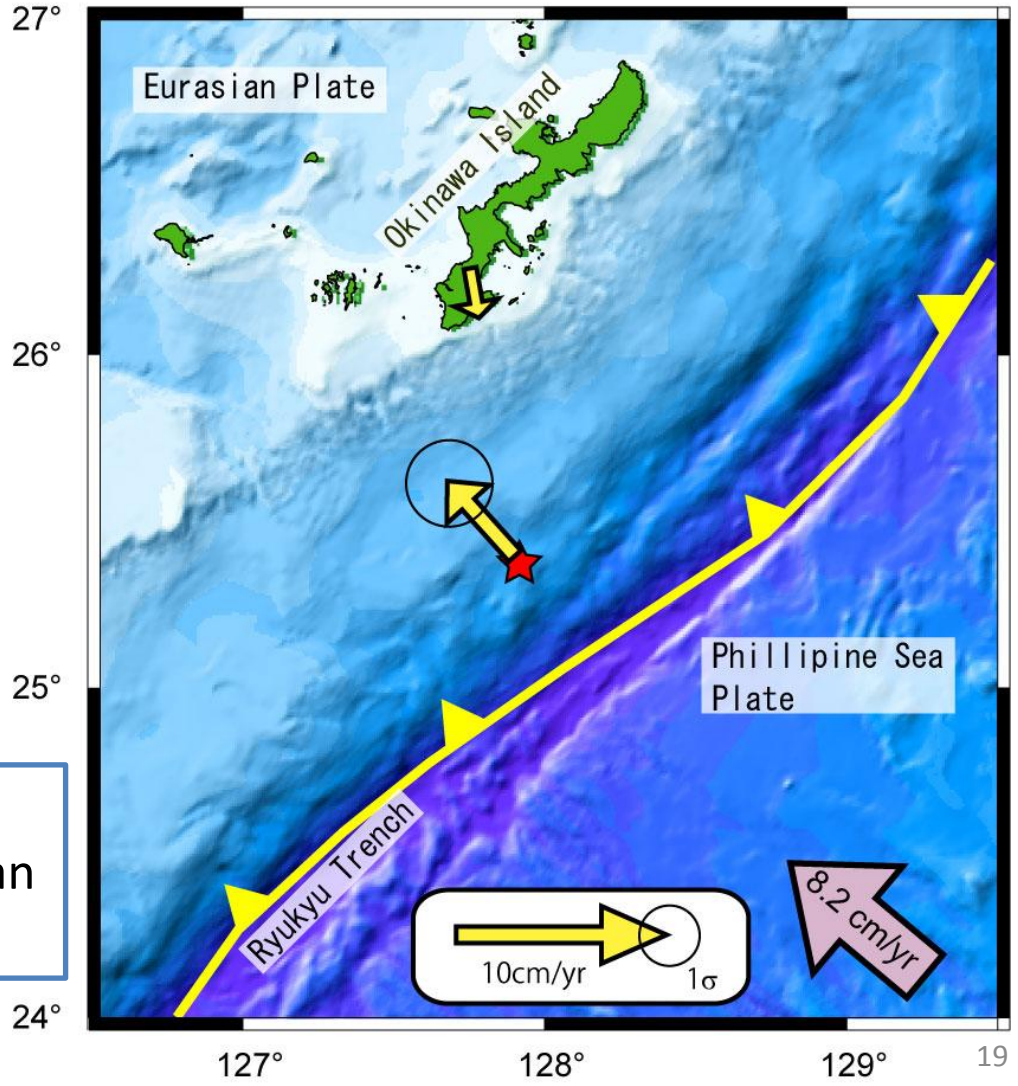
Univ. Ryukyus



Result of the observations

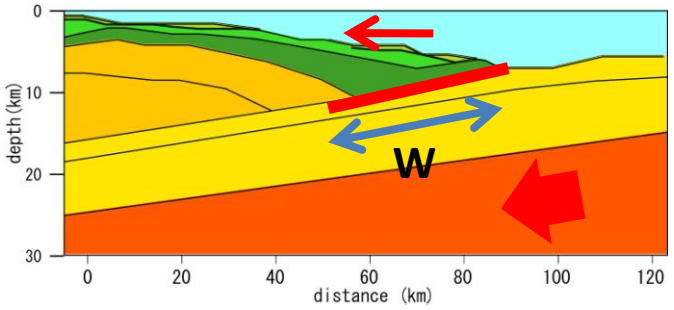


Velocity of the benchmark

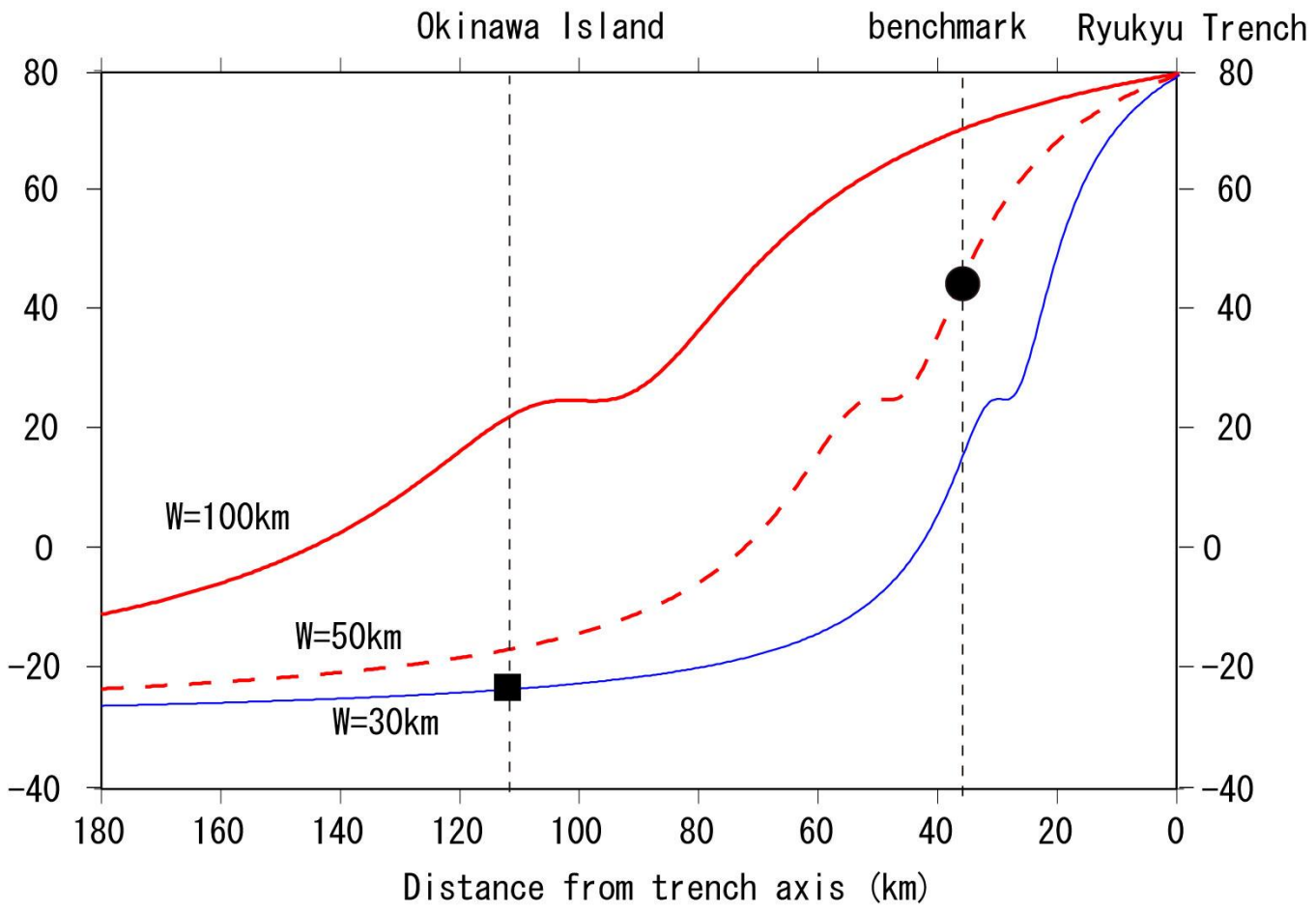


Horizontal velocity of the benchmark relative to the Amurian plate

Width of the coupled zone

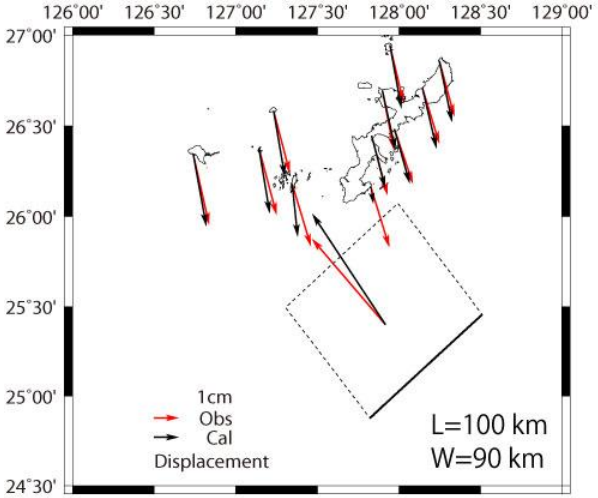


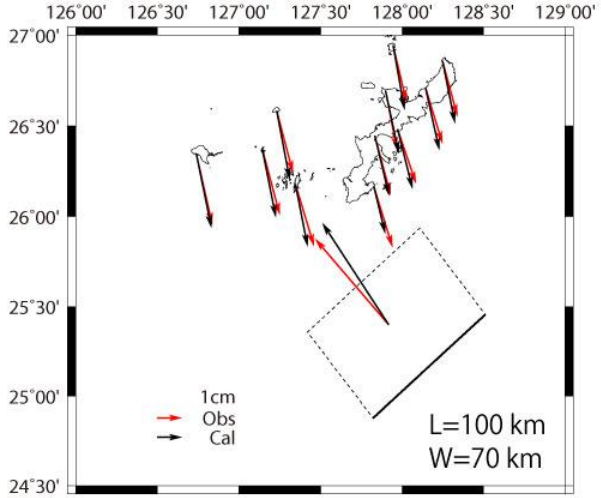
Horizontal velocity of the benchmark relative to the Amurian plate (NW direction: positive)

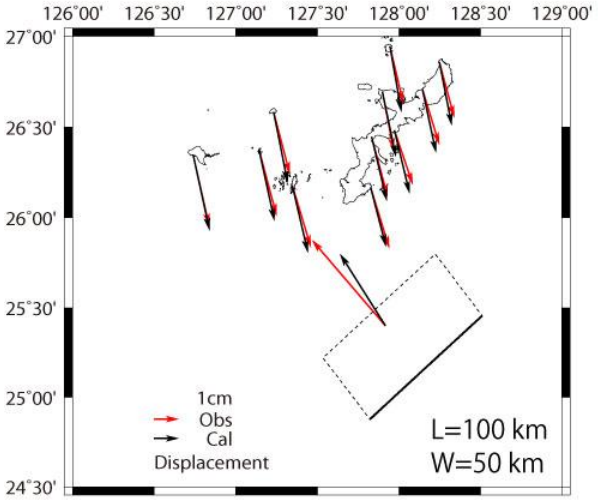


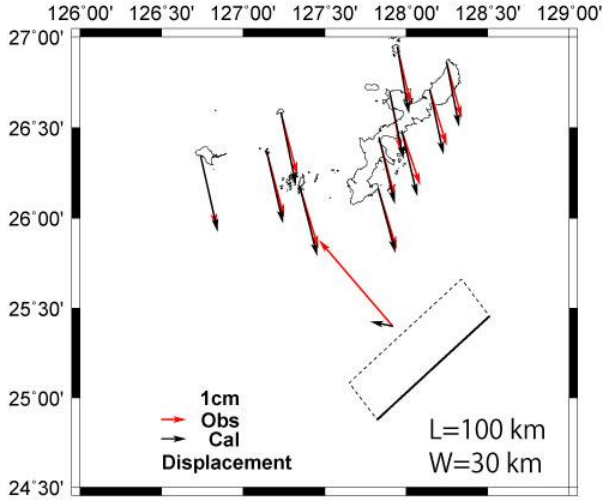
Horizontal displacement by the interplate coupling (mm/yr)

Backslip model (2)



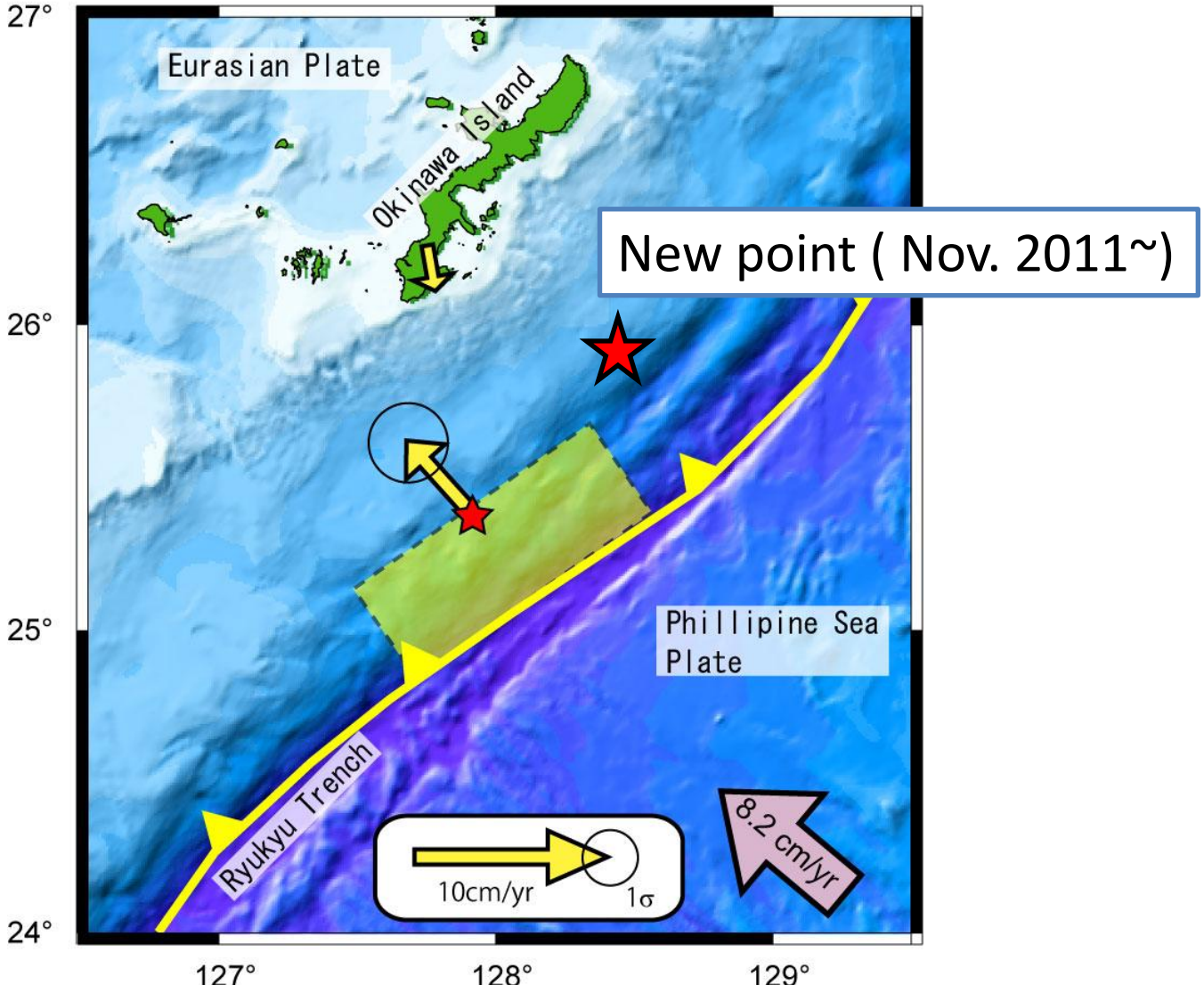




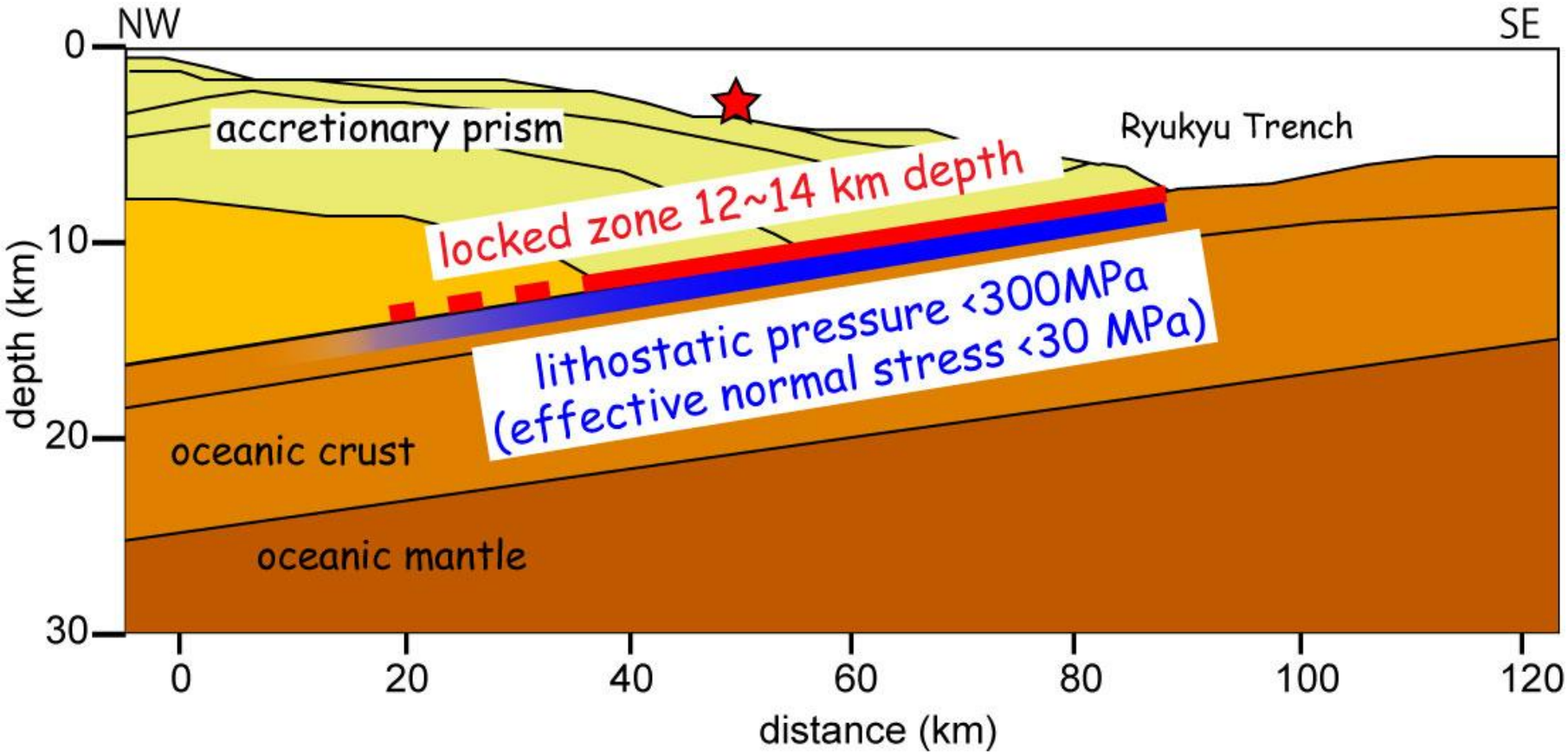


Coupled zone from trench to 50~70 km widths

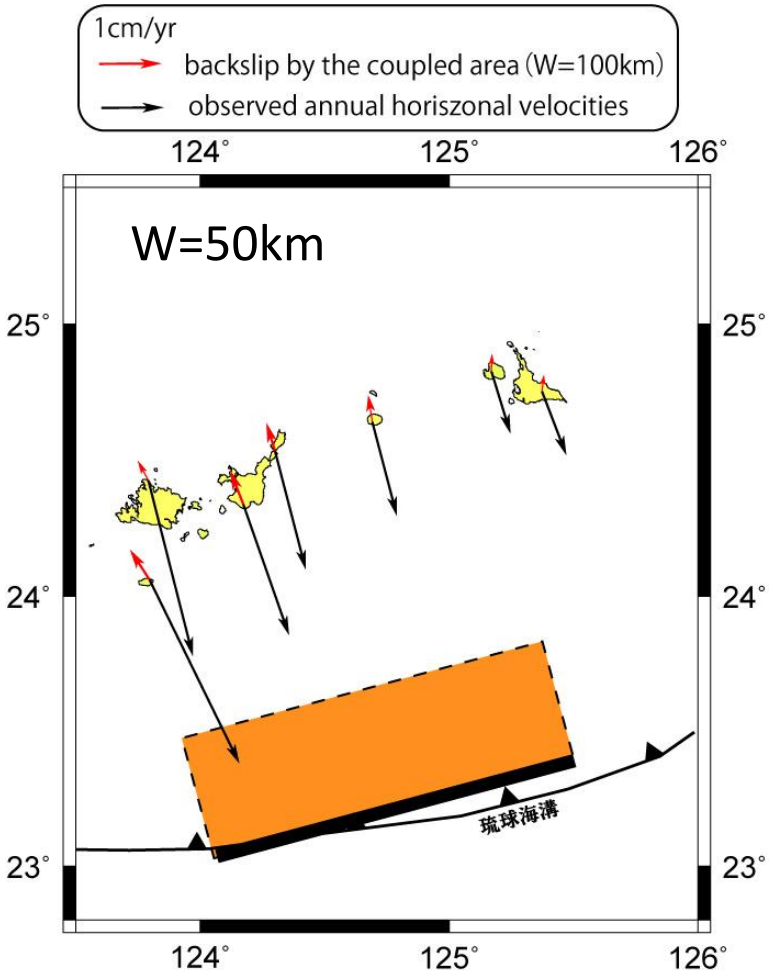
Model of coupling area

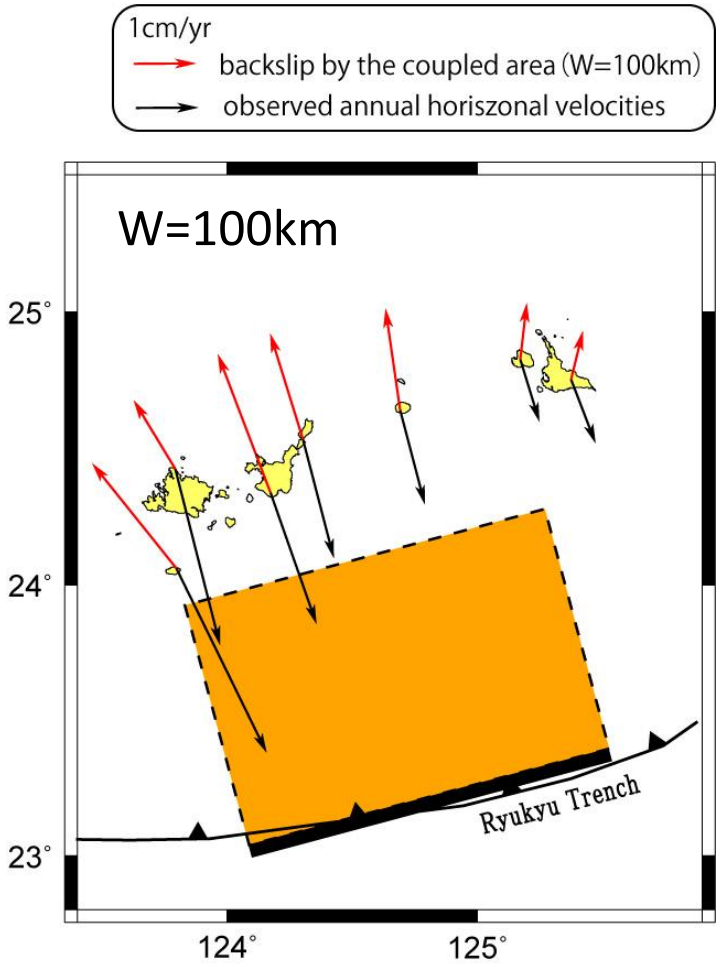


Vertical cross-section of the central Ryukyu Trench

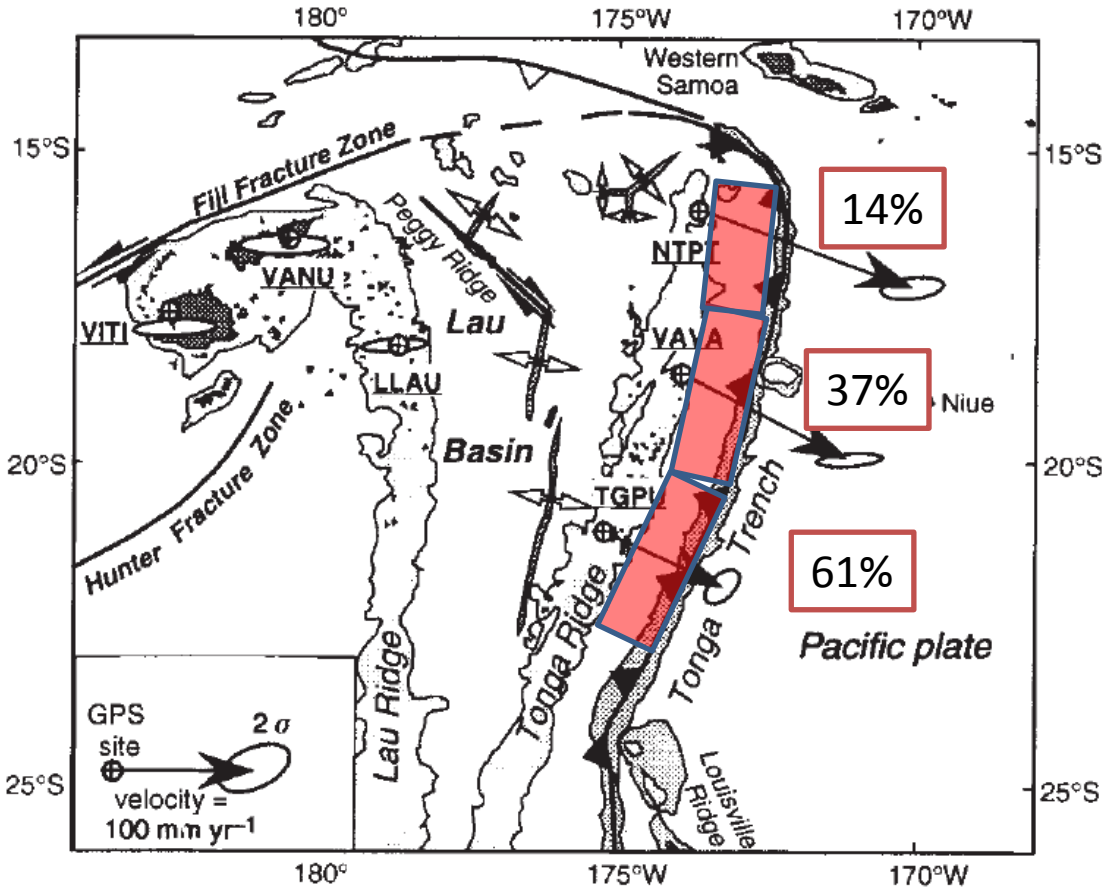


Backslip by the coupled area in the south Ryukyu Trench





Tonga region



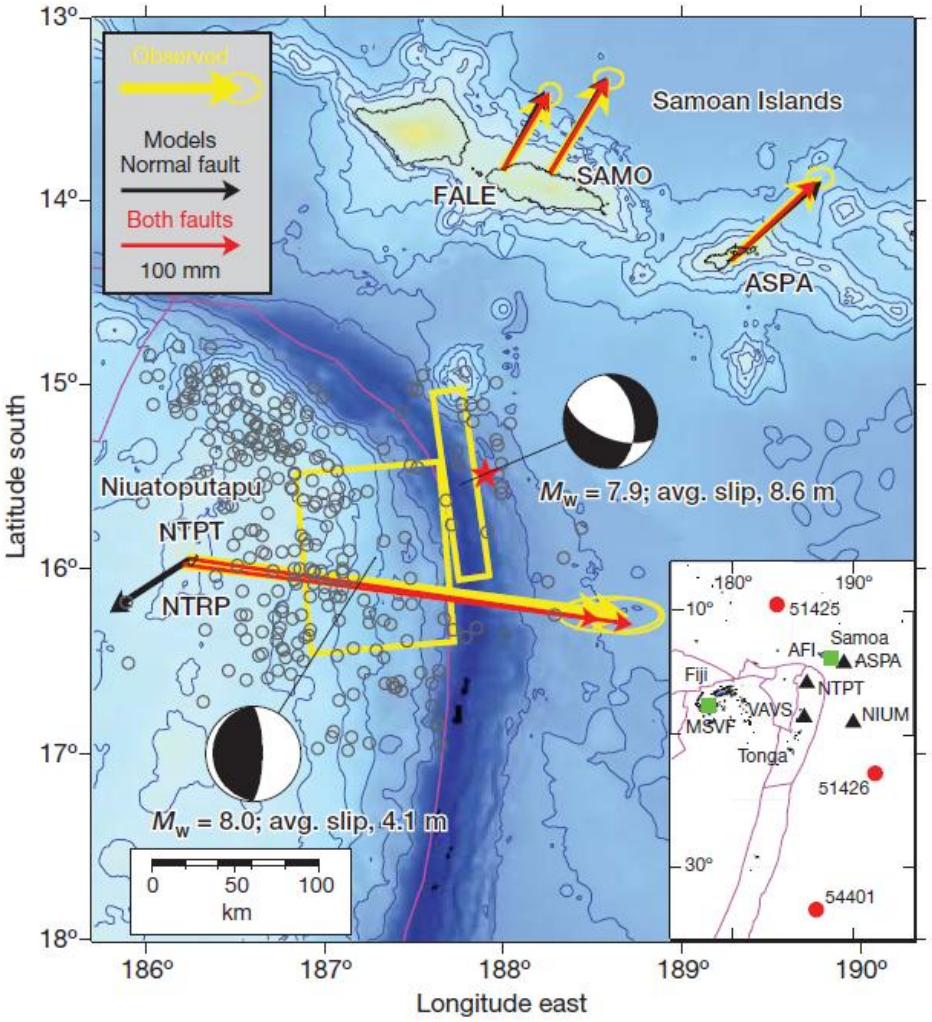
(Bevis et al., 1995, Nature)

Backarc spreading

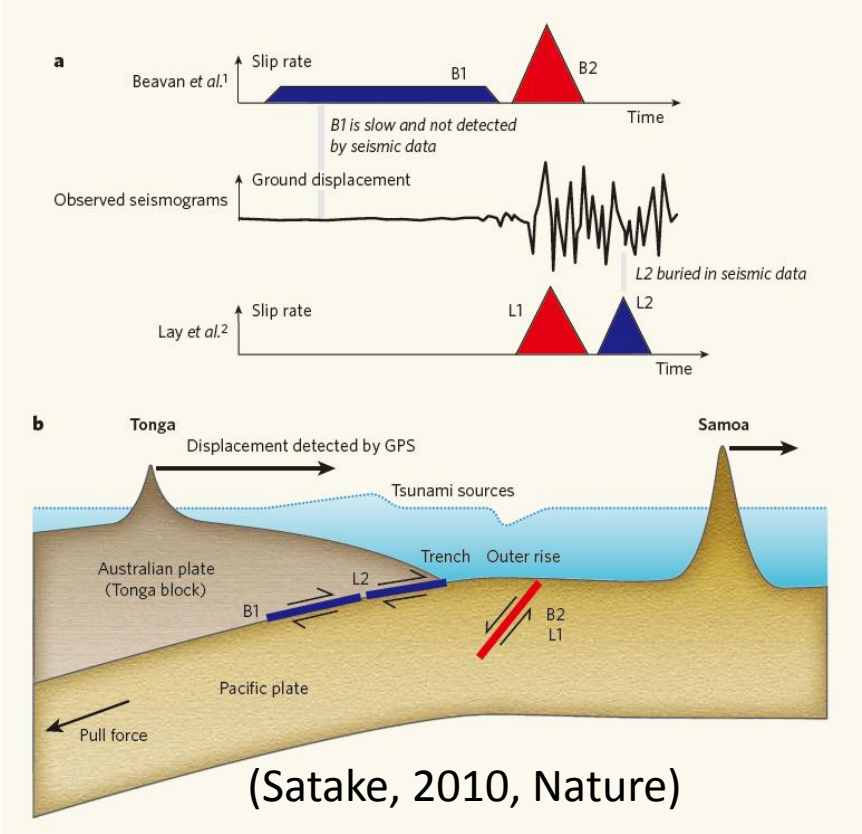
Weak interplate coupling ?

Seismic coupling
(motion of the backarc spreading is not included in the calculation)
(Pachenco& Sykes, 1993 JGR)

The 2009 Samoa–Tonga earthquake



(Beavan et al., 2010, Nature)

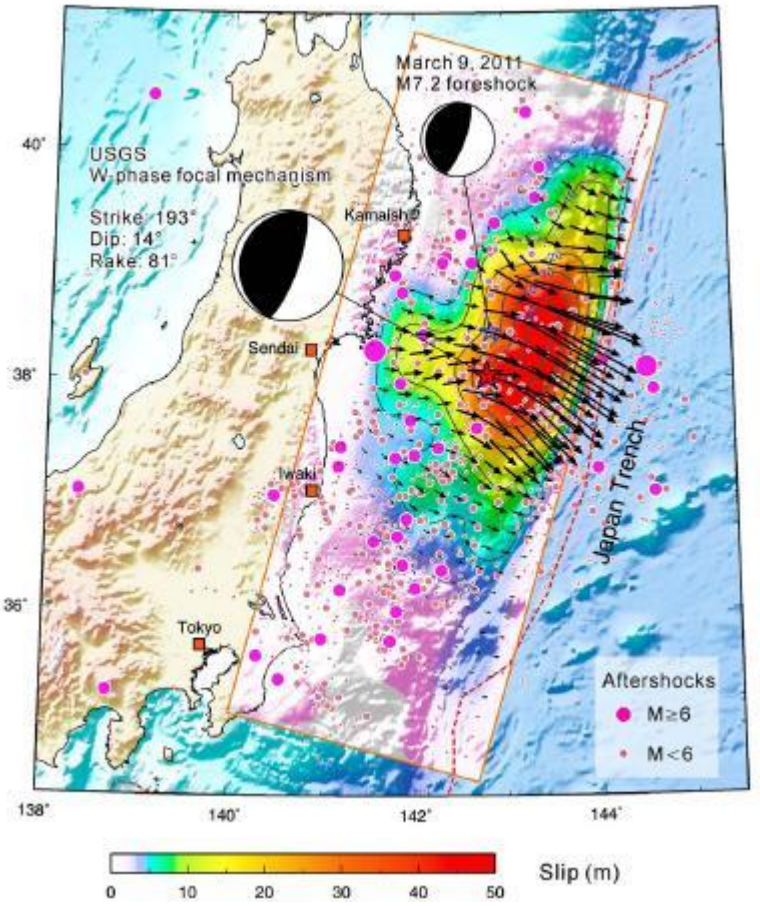


(Satake, 2010, Nature)

2011 Tohoku earthquake

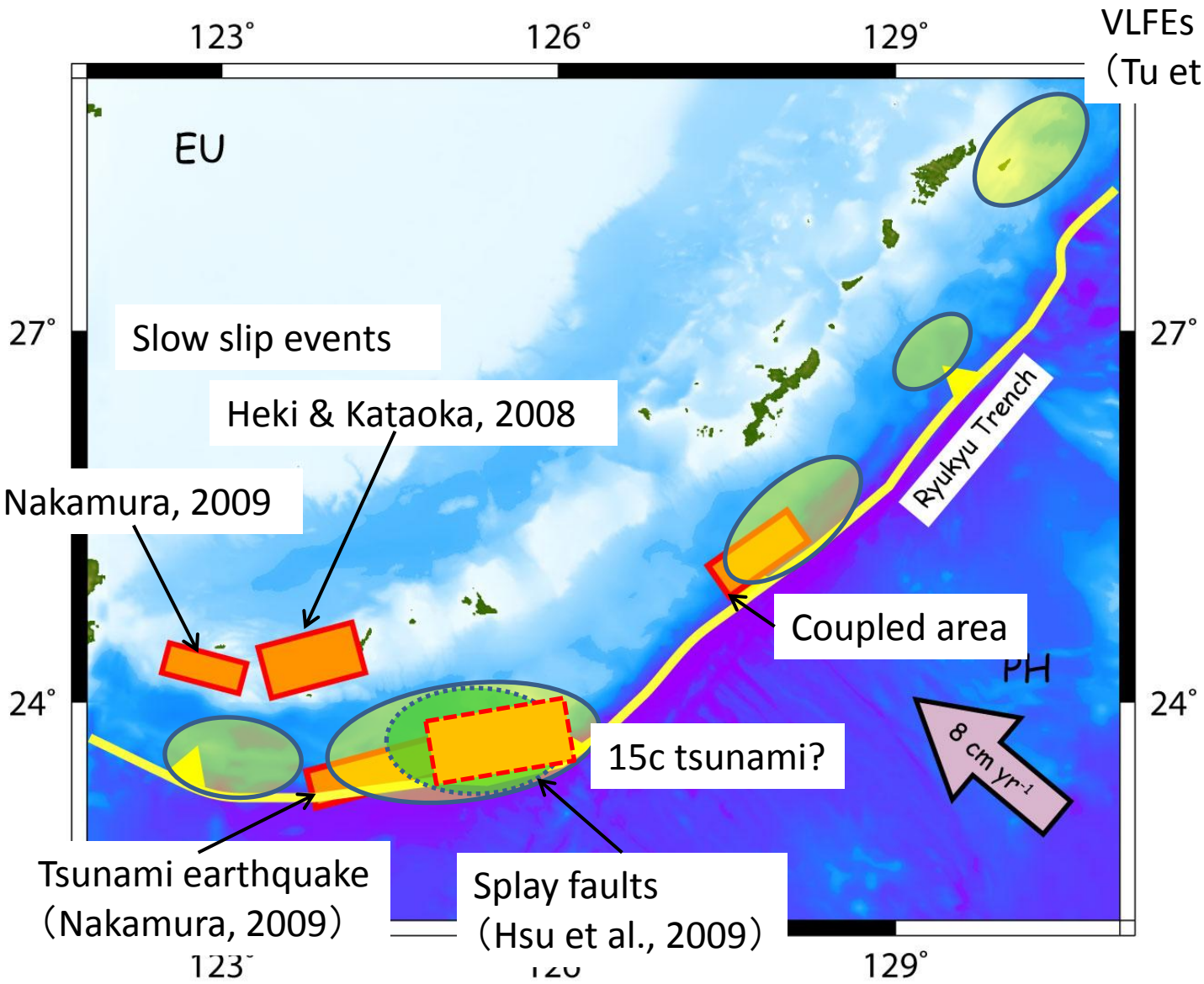
Large slip near the Trench axis

Coupled zone in the shallow part of Japan Trench



(Lee et al., 2011)

Distribution of coupled area, splay faults, and source of earthquake in the Ryukyu Trench



Tsunami hazard mitigation in Okinawa

Display the elevation of location

School
(opened on Apr. 2011)

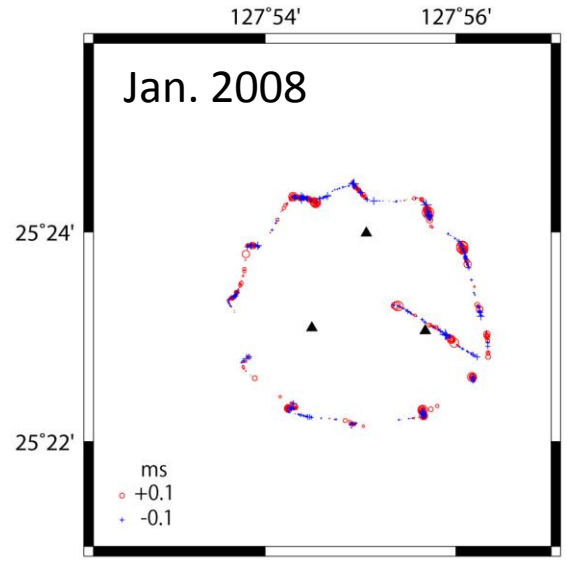
Started to evacuation drill to the tsunami safe zone

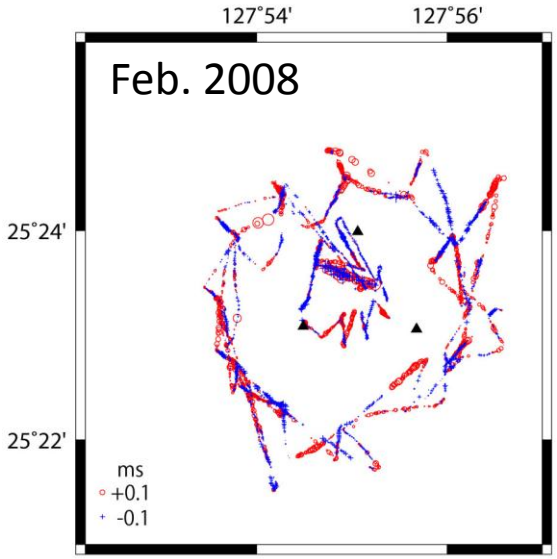
School: moved from terrace area to landfill area.
People did not pay attention to tsunami disaster.

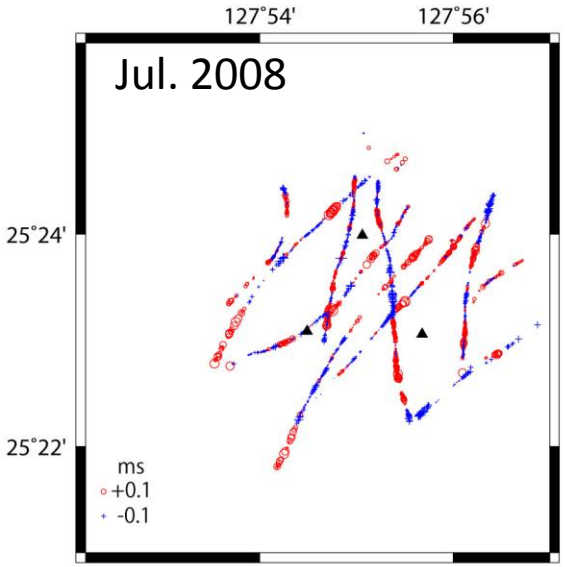
Conclusions

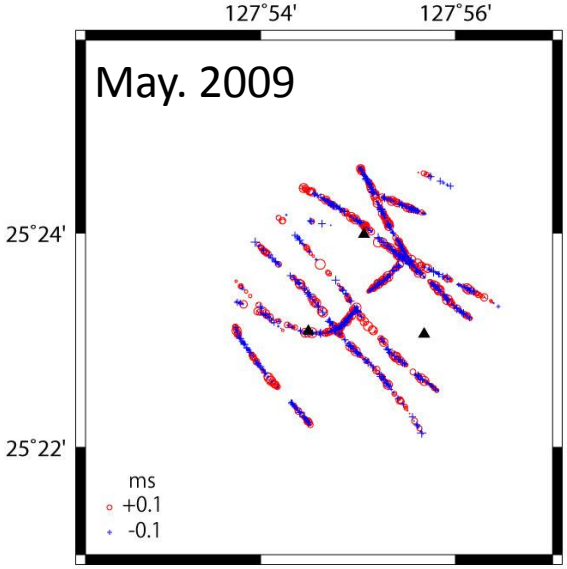
- Occurrence of Mega-tsunami in the southern Ryukyu Trench:
  - 5 times during 3000 years
    - 200, 500, 1000,2000,2500 years BP
  - Source faults: Ryukyu Trench
- Shallow part of the coupled area in the central Ryukyu Trench
  - 50~70 km in width
  - 100~ km in length
- Shallow part of the Ryukyu Trench
  - Full-coupled?
  - Cause of large earthquakes and tsunami?

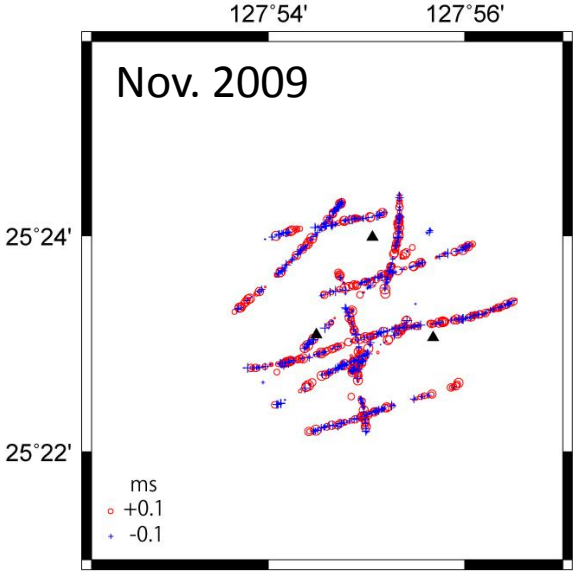
Distribution of travel time residuals





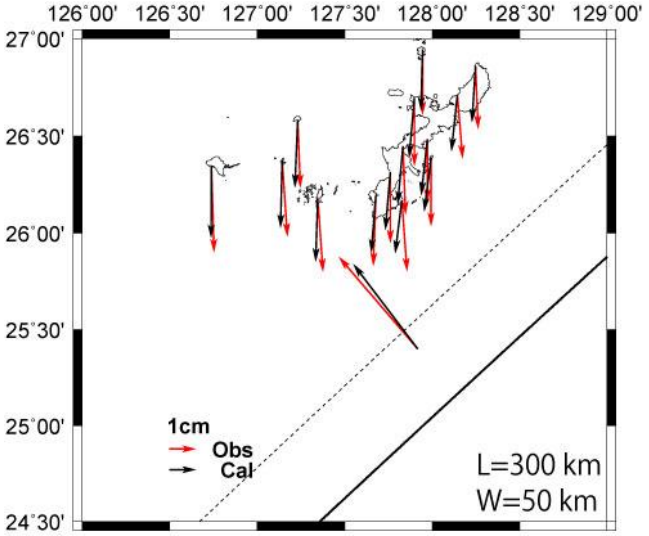


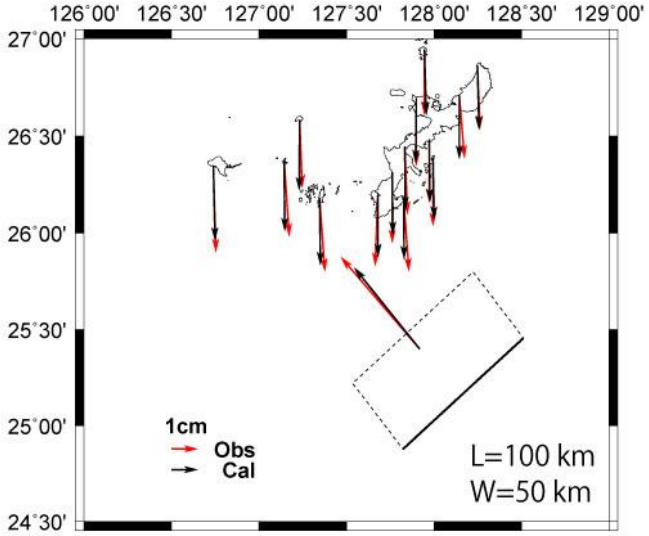


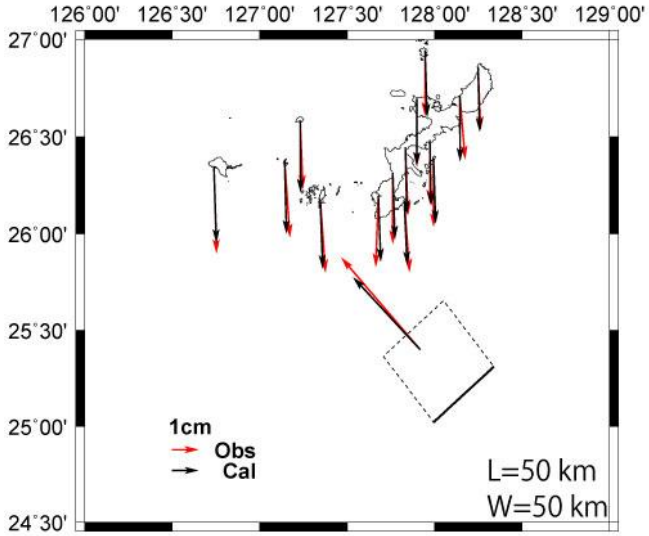


Rms: 70 micro-sec

Backslip model (1)

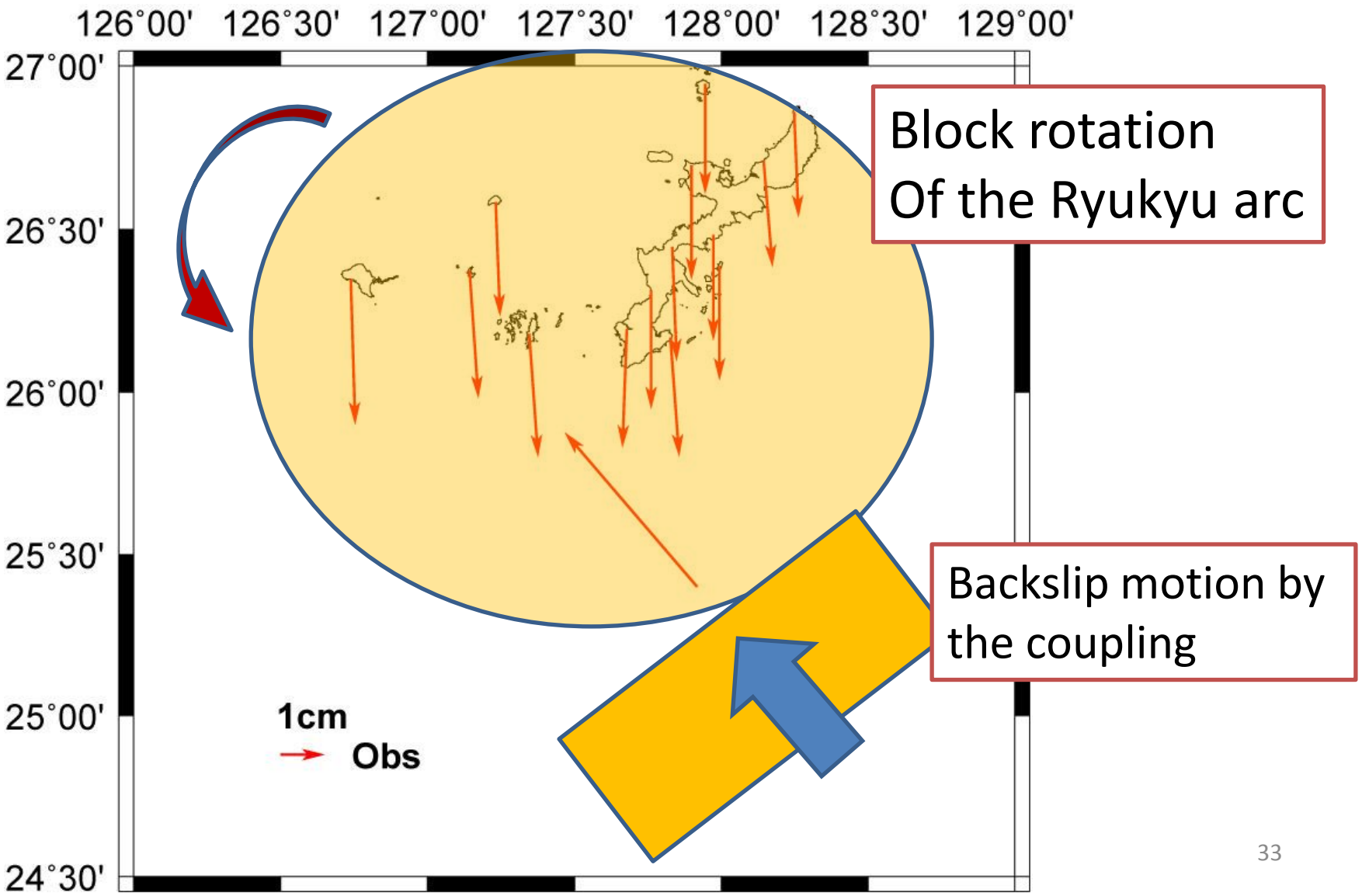




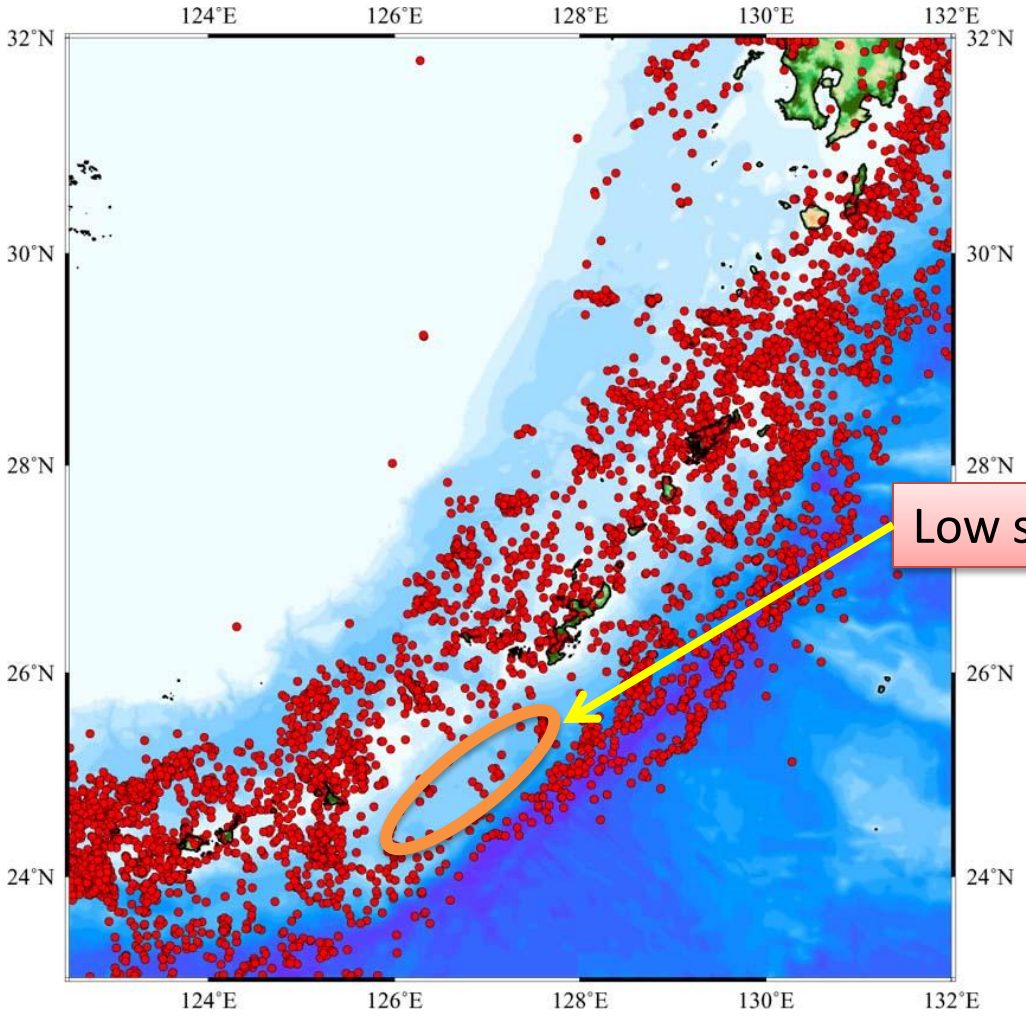


No slips from trench to 50 km width

Calculation of displacements

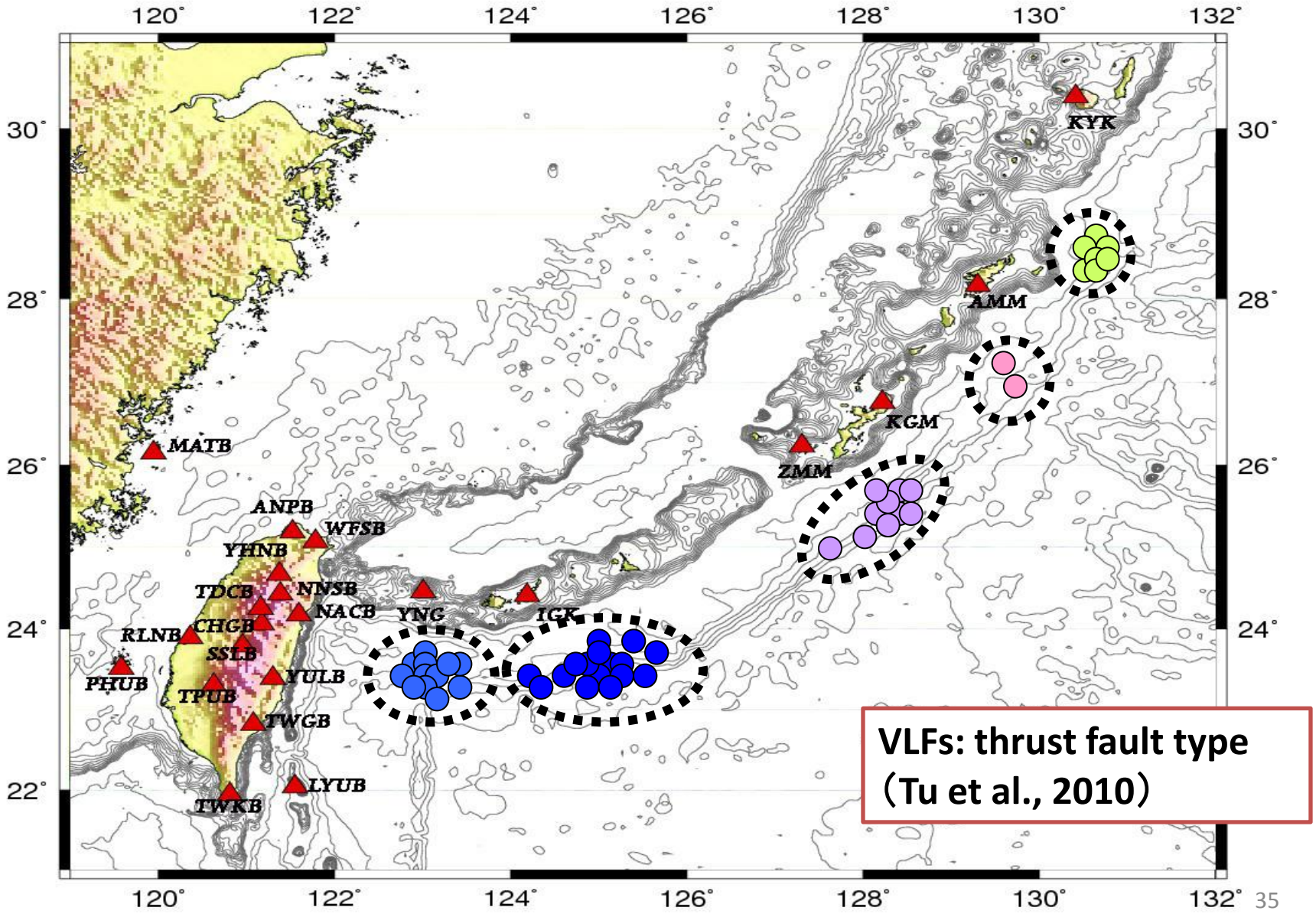


Seismic gap (?) in the central Ryukyu Trench



Low seismicity (> M 5) for 100 years.

The locations of VLF events in 2007 (Tu et al., 2009)



Interplate coupling and possibility of large earthquakes in the Ryukyu region