Toward Indonesia Dense Ocean Floor Network System For Earthquake and Tsunami (INA-DONET) for Seismic Hazard Mitigation in Indonesia

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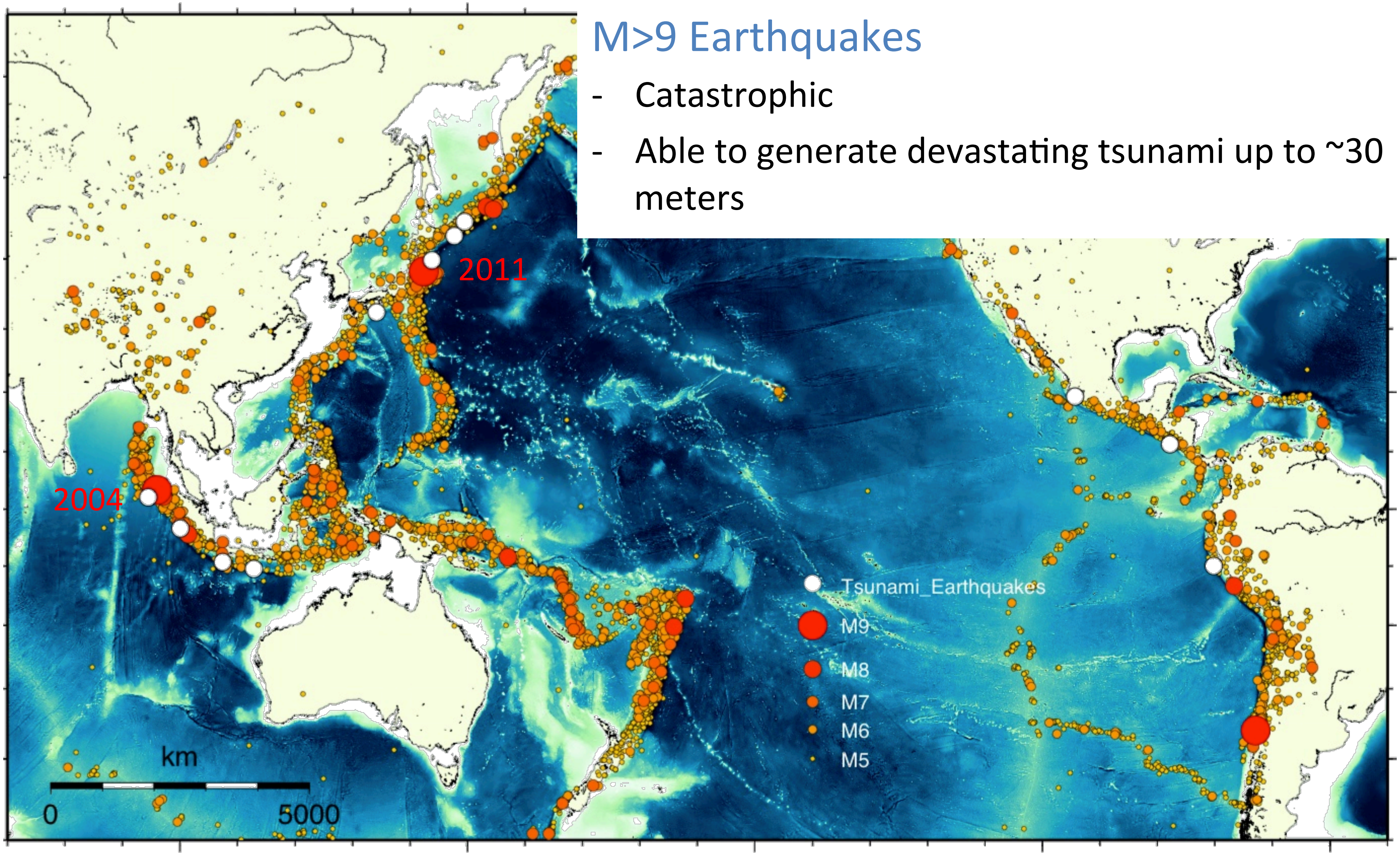
Unexpected and Unusual Events



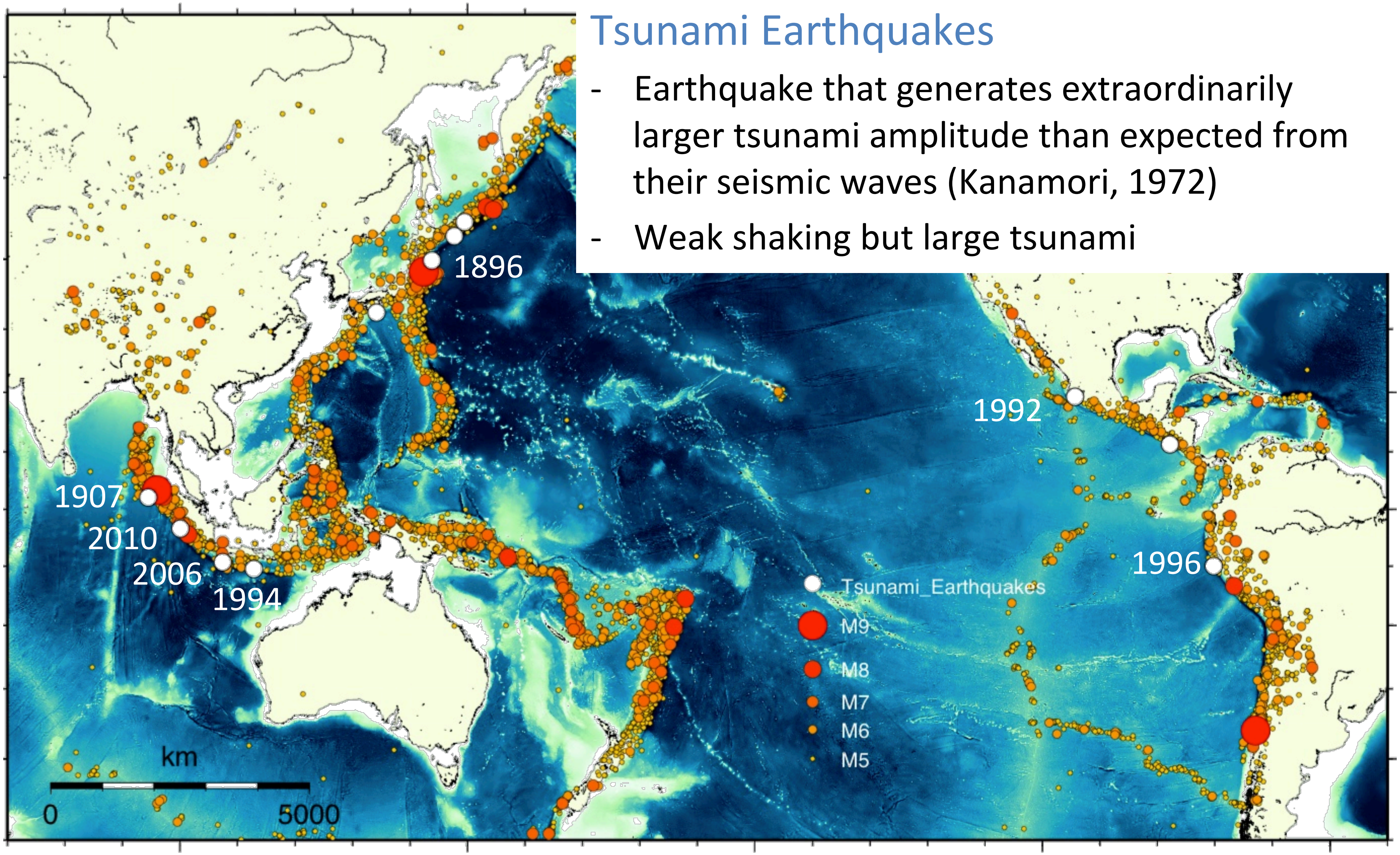
M>9 Earthquakes

- Catastrophic
- Able to generate devastating tsunami up to ~30 meters

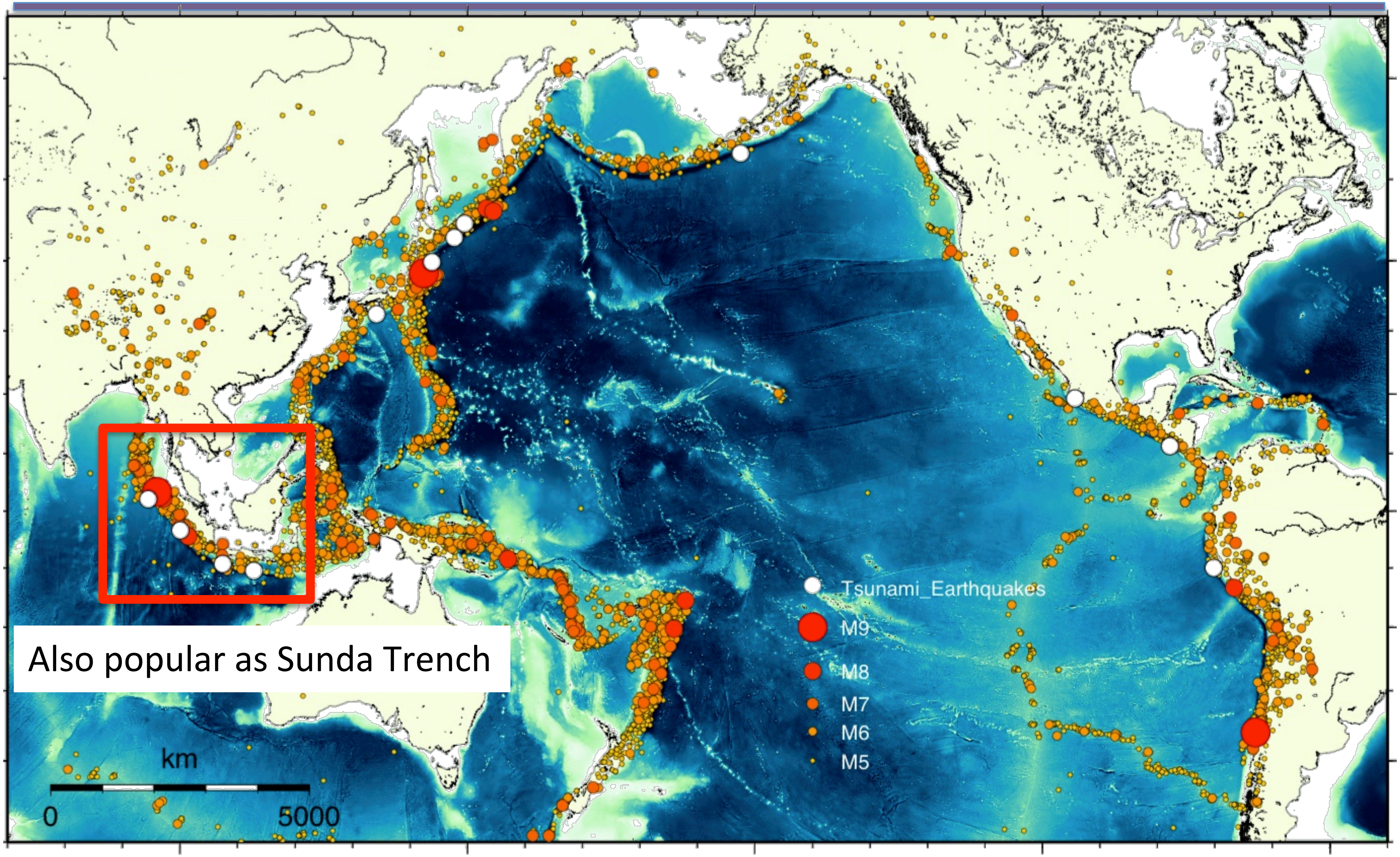
Unexpected and Unusual Events

Tsunami Earthquakes

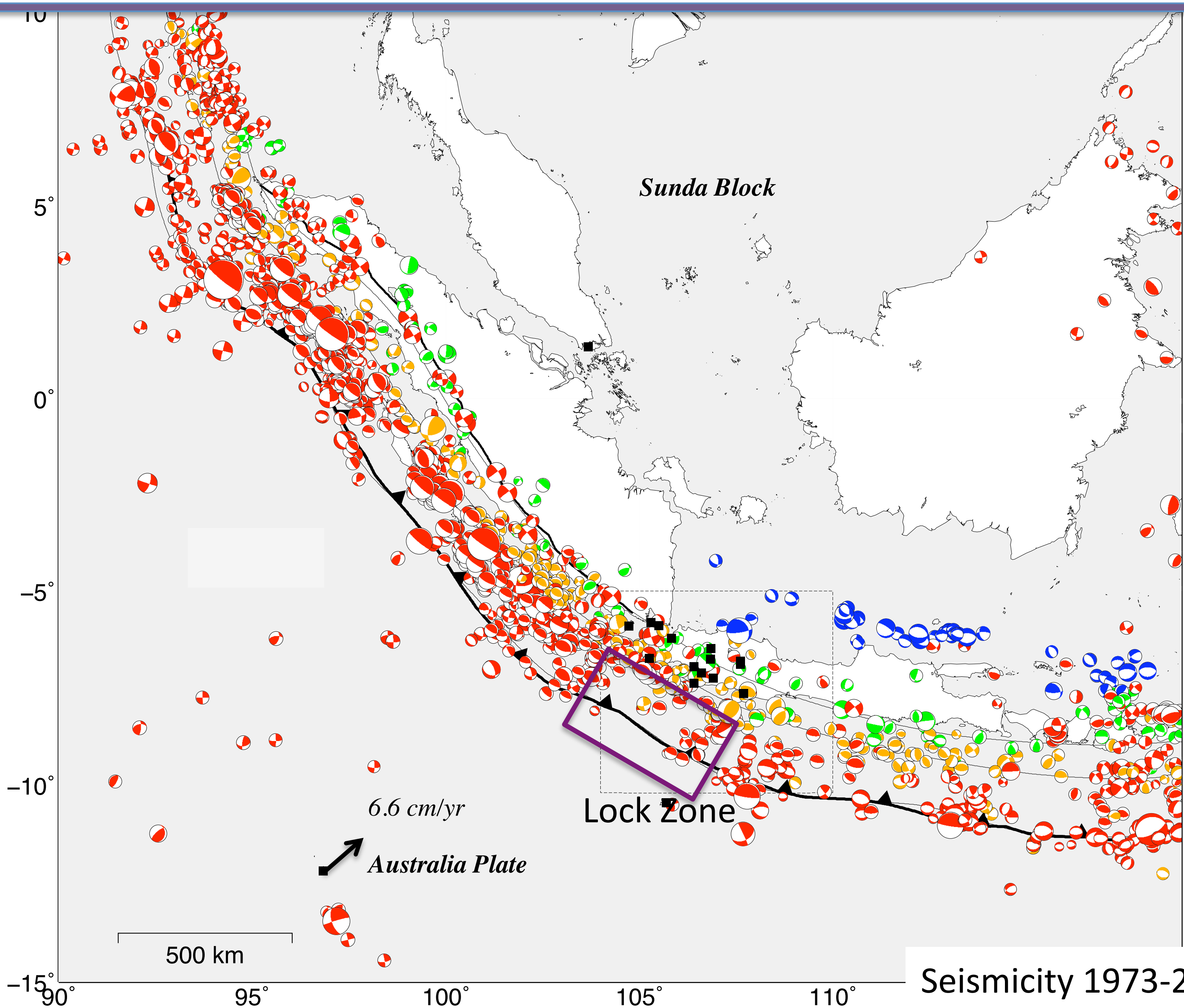
- Earthquake that generates extraordinarily larger tsunami amplitude than expected from their seismic waves (Kanamori, 1972)
- Weak shaking but large tsunami



A search for possible unexpected/unusual interplate earthquake: **Java Trench**



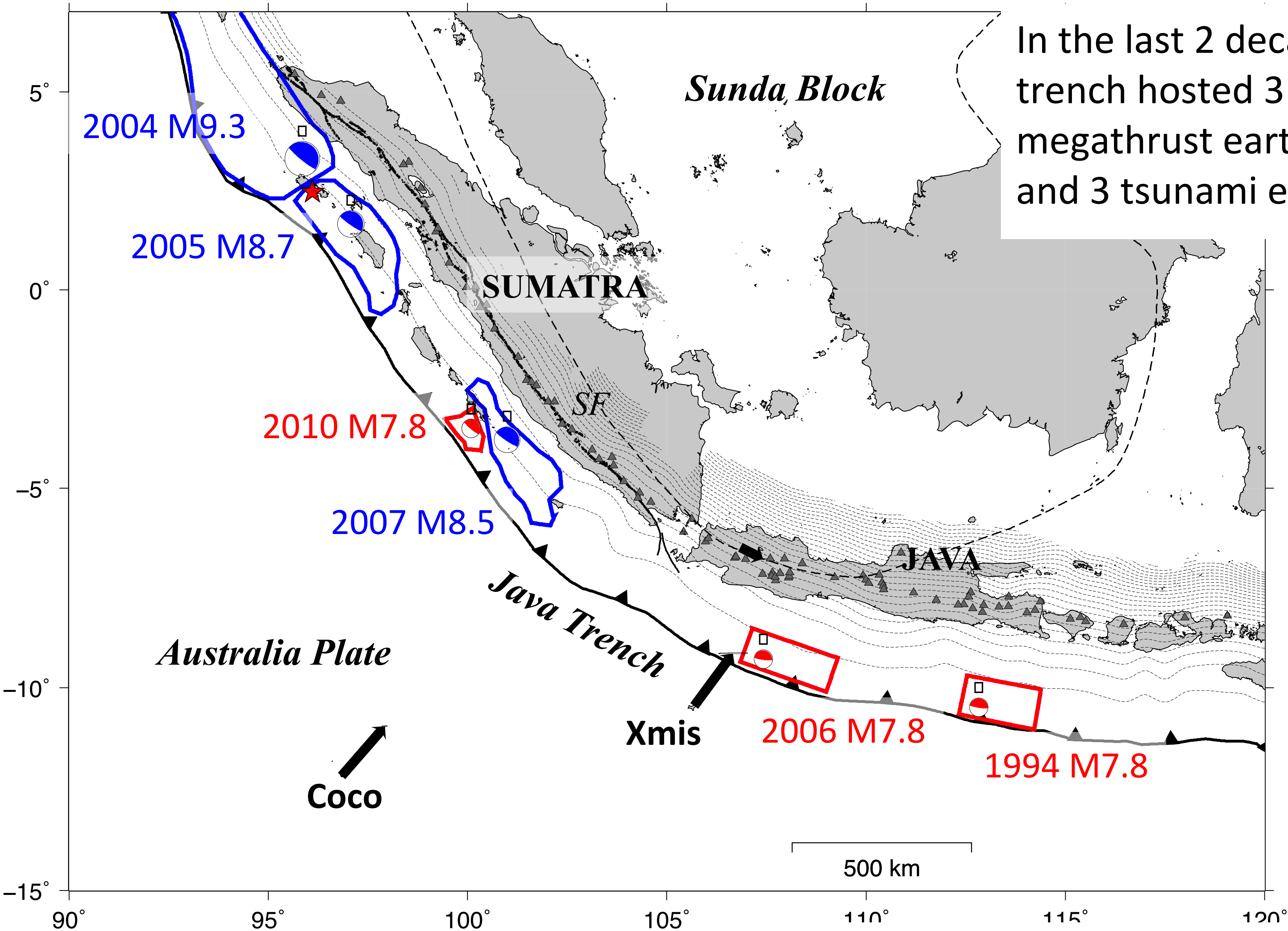
Seismicity along Sunda Trench



Seismicity 1973-2014, USGS

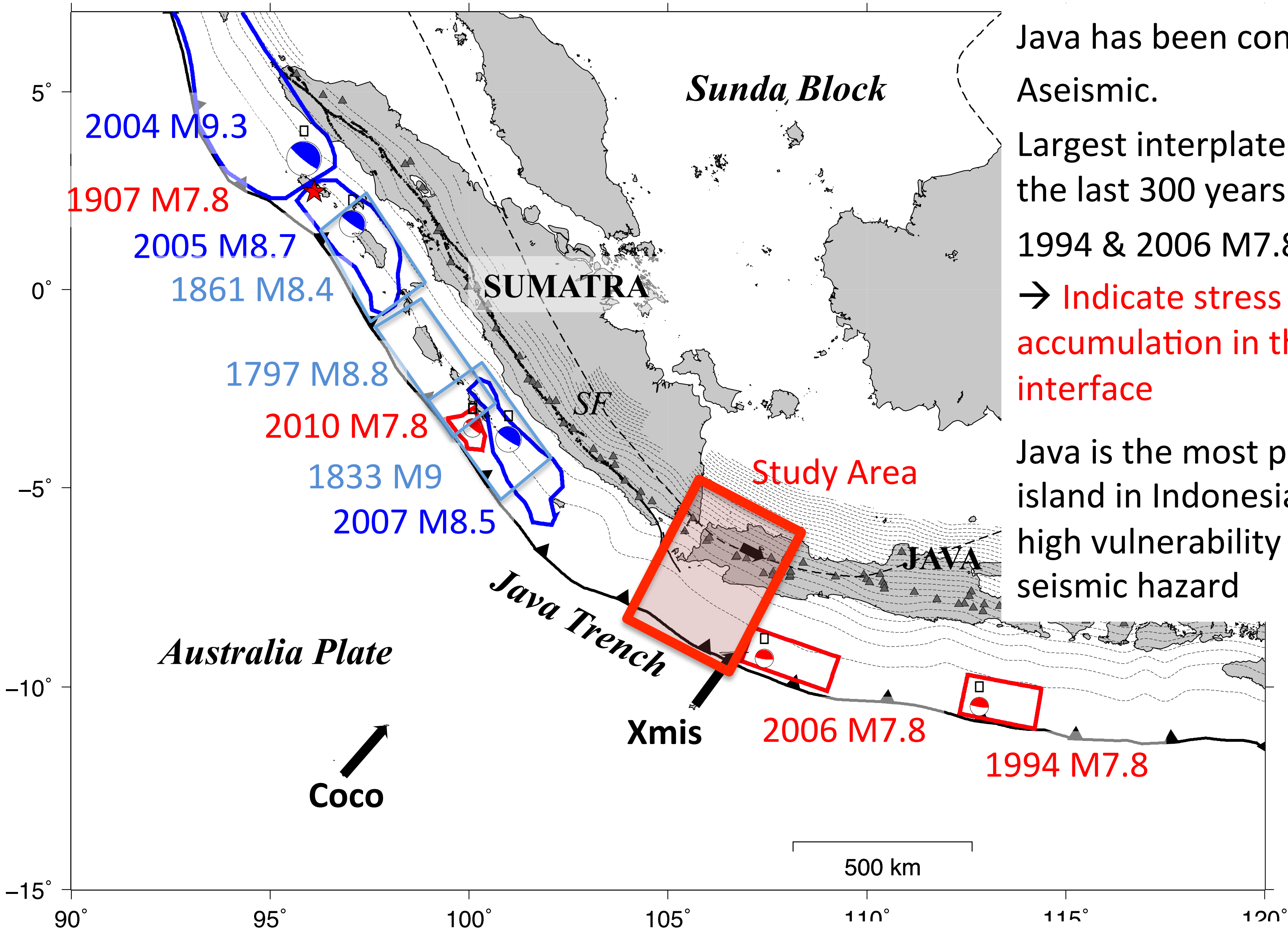
Java Trench

In the last 2 decades Java trench hosted 3 M>8.5 megathrust earthquakes and 3 tsunami earthquake



Interplate earthquake with M>7 since 1973

Java Trench



Interplate earthquake with M>7 since 1700

Java has been considered Aseismic.

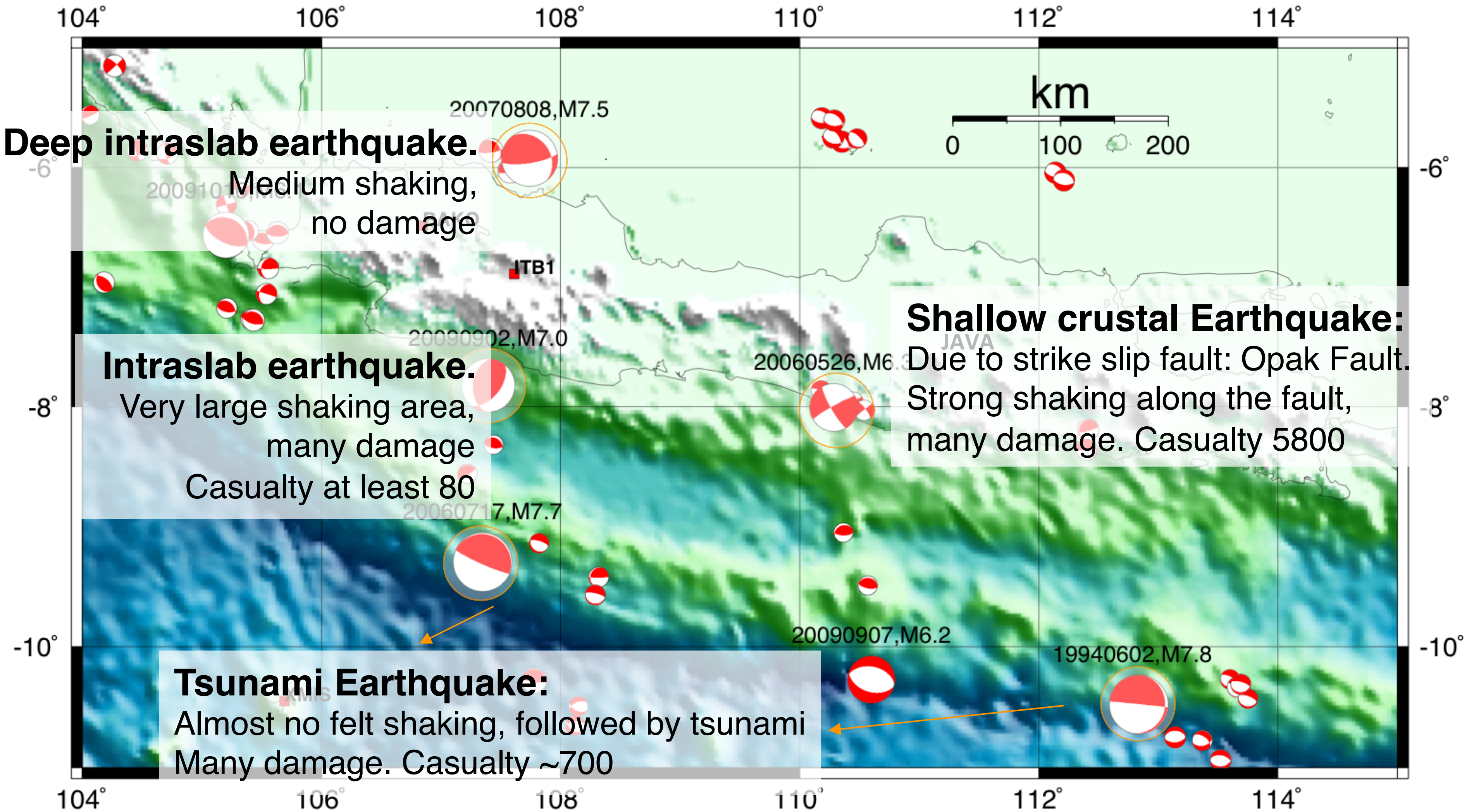
Largest interplate events in the last 300 years:

1994 & 2006 M7.8

→ Indicate stress accumulation in the plate interface

Java is the most populated island in Indonesia with high vulnerability to seismic hazard

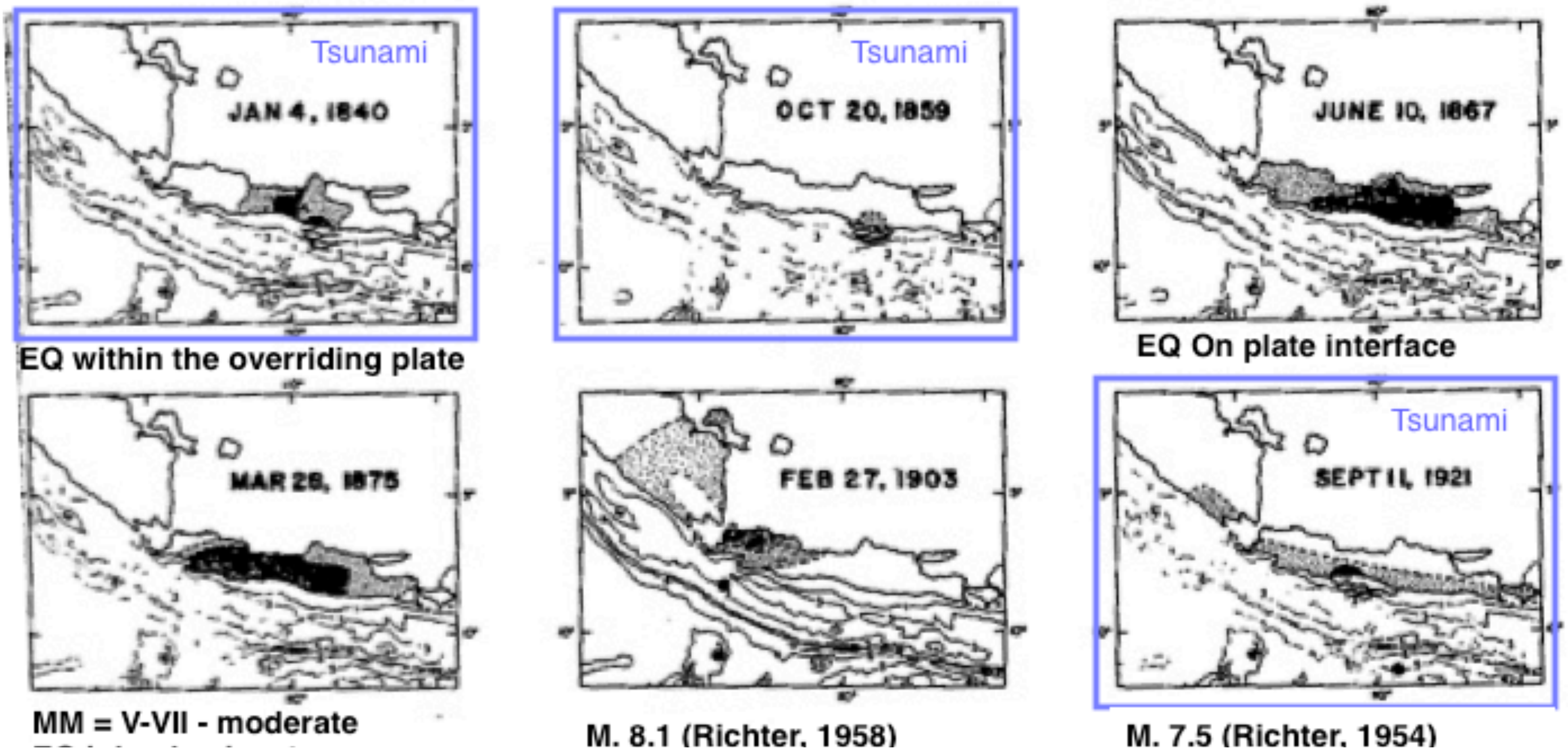
Modern seismicity in Java



CMT data from USGS catalogue (1973-Oct 2009) with M > 5.

Historical Seismicity

Available from ~1700 A.D. Reviewed by Newcomb and McCann 1989 and Okal, 2012



Most historical earthquakes were intraplate events. One event was an outer rise event (1921).

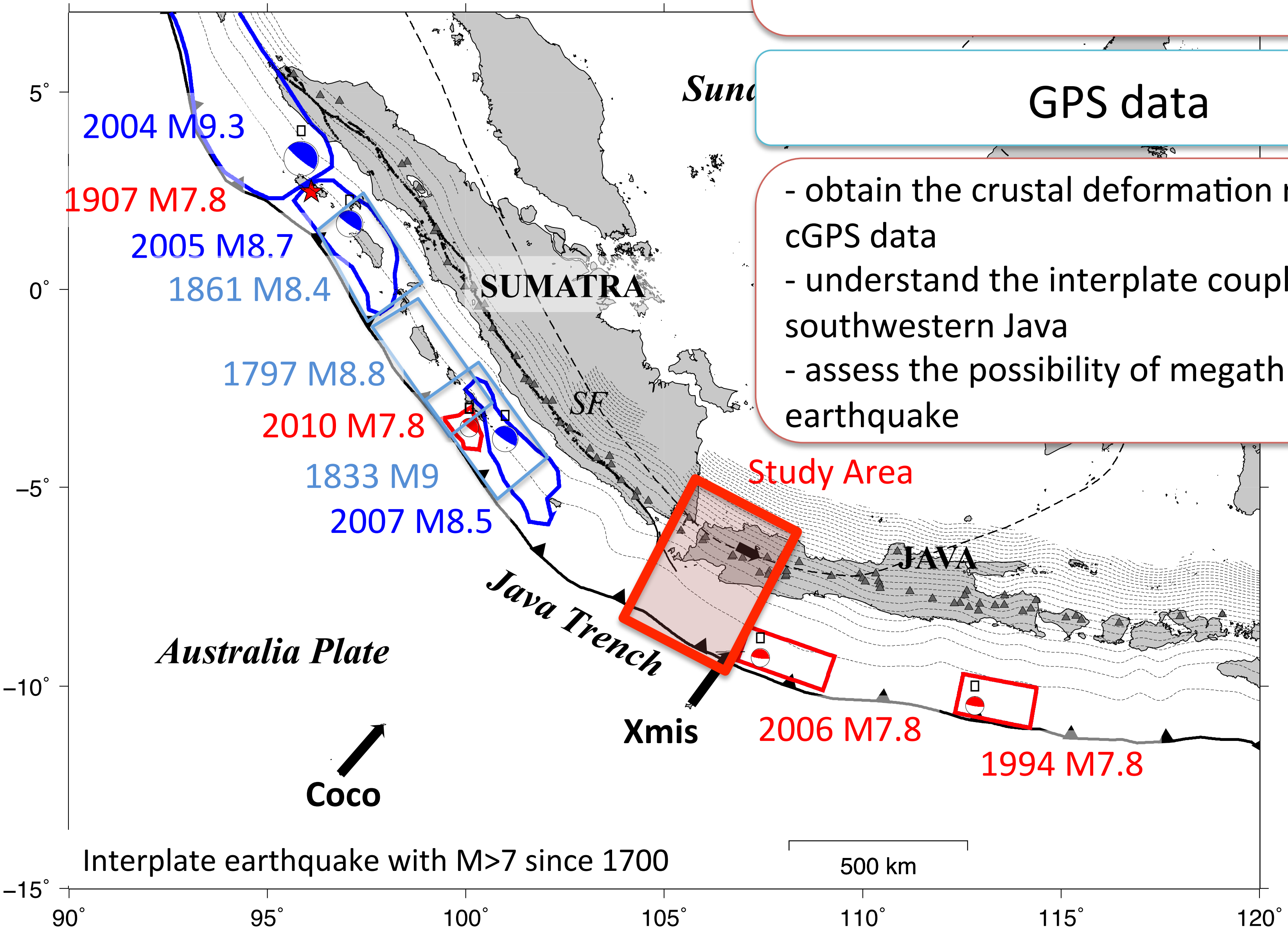
⇨ No M>7 interplate earthquake events, in the last 300 yrs (except 1994 & 2006 earthquakes)

Java Trench

Existence of interplate coupling and possibility of occurrence of megathrust earthquake southwestern off Java?

GPS data

- obtain the crustal deformation rate from cGPS data
- understand the interplate coupling off southwestern Java
- assess the possibility of megathrust earthquake

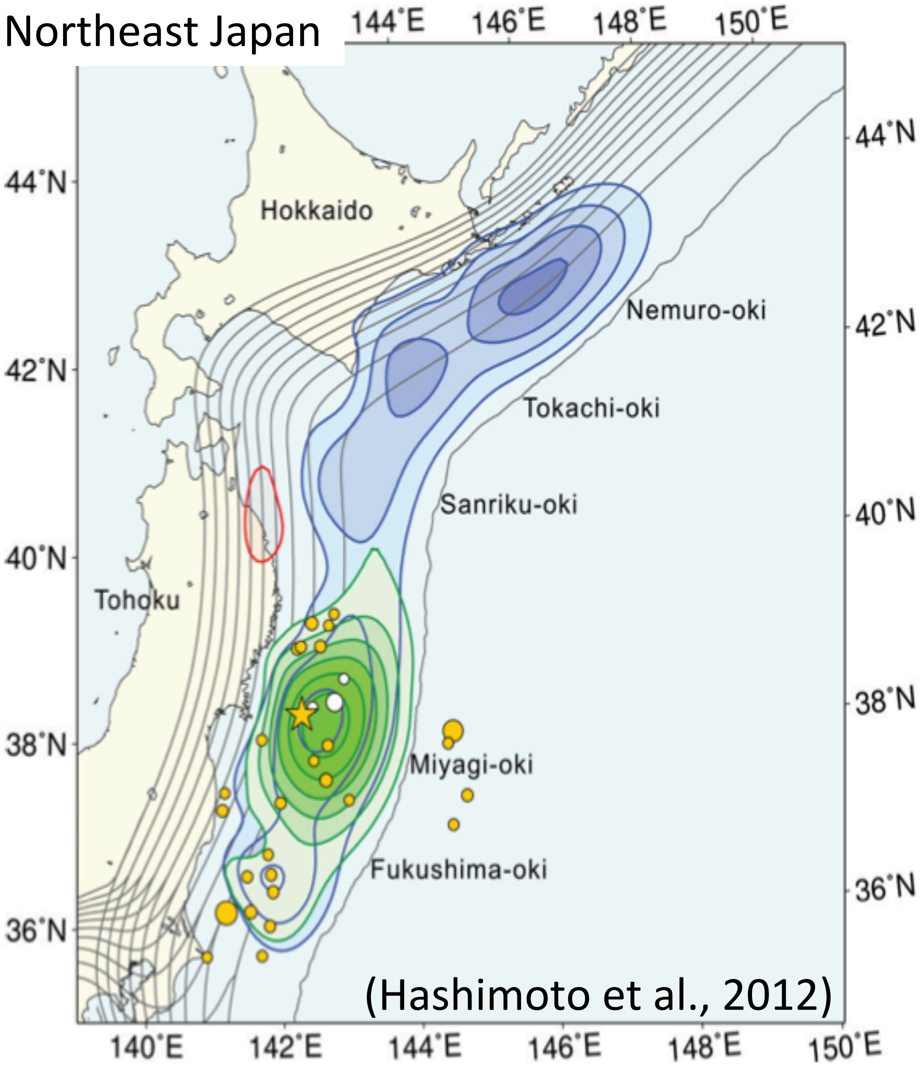


Interplate earthquake with M>7 since 1700

GPS contribution to estimate interplate coupling

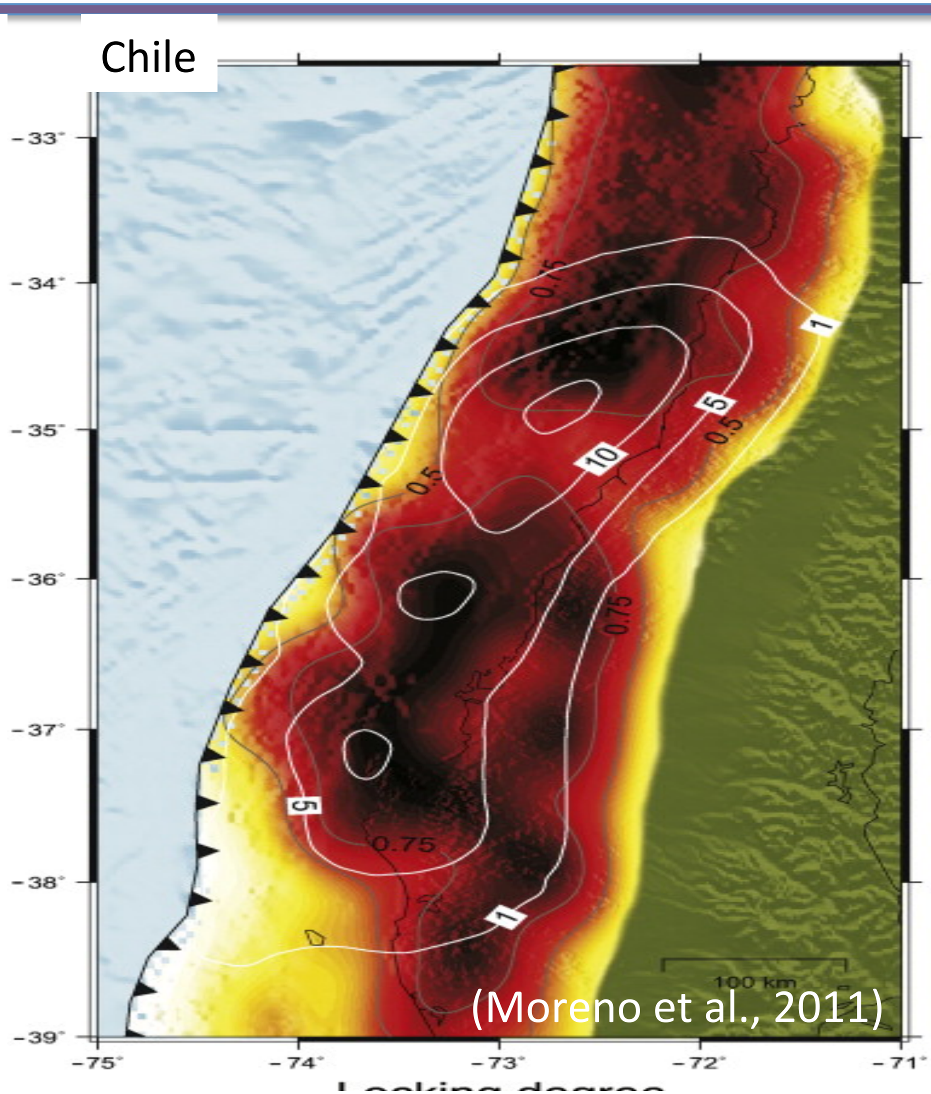
Case of 2011 M9.0 Tohoku and 2010 M8.8 Chile earthquakes

Northeast Japan



(Hashimoto et al., 2012)

Chile

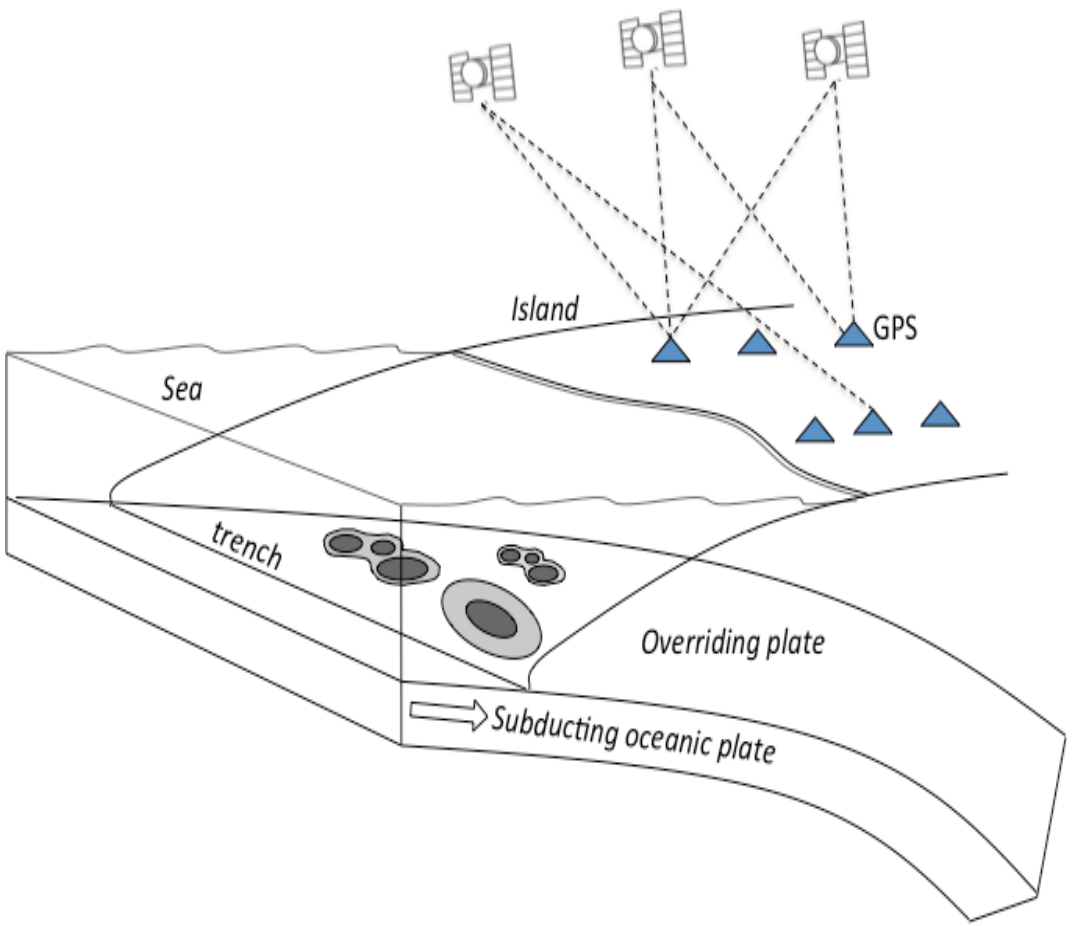


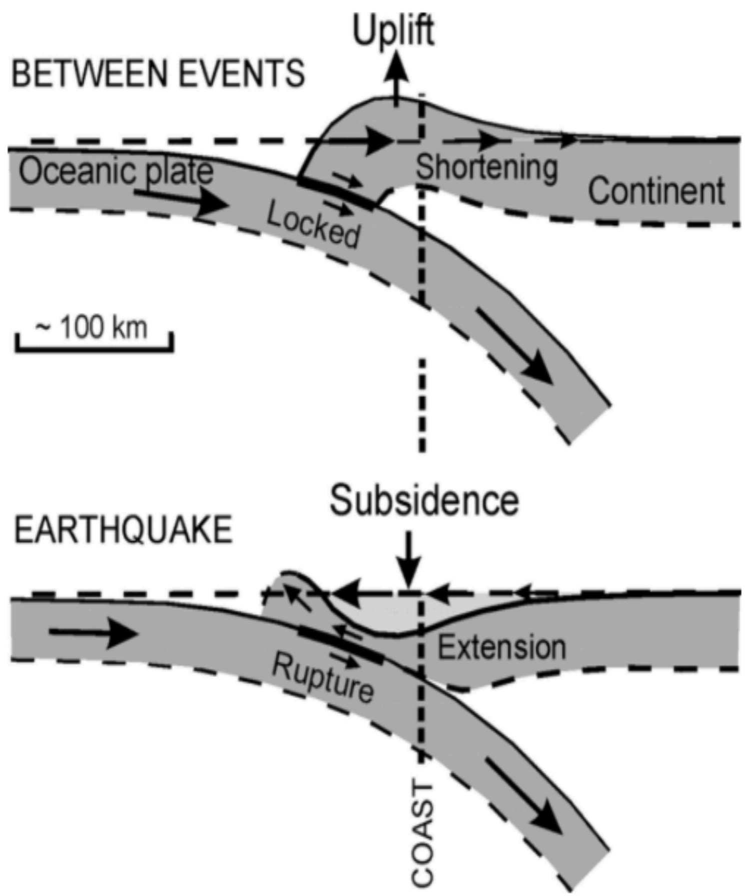
(Moreno et al., 2011)

Blue: Interseismic coupling
Green: Coseismic patches

There is spatial correlation between locked patches and coseismic patches

How GPS contribute to estimate interplate coupling?

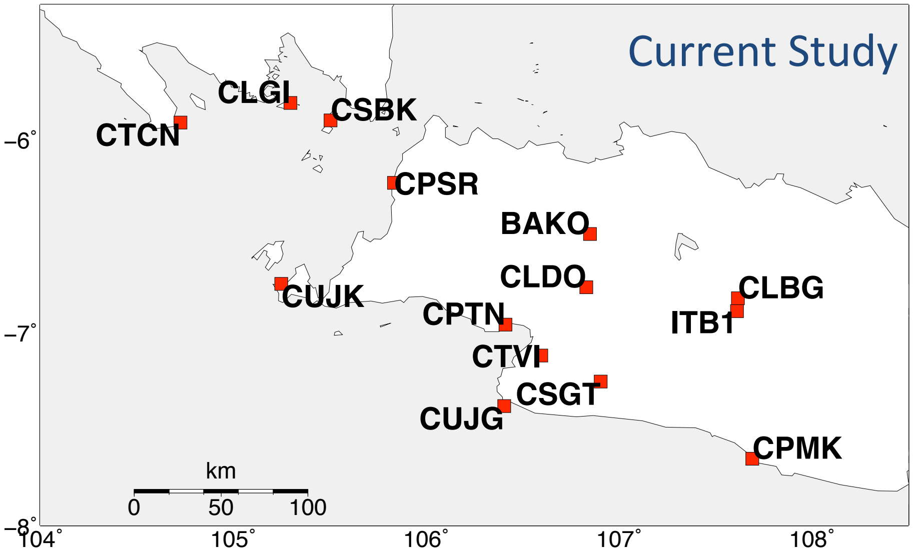




Re-draw with modification from Wang et al., 2012

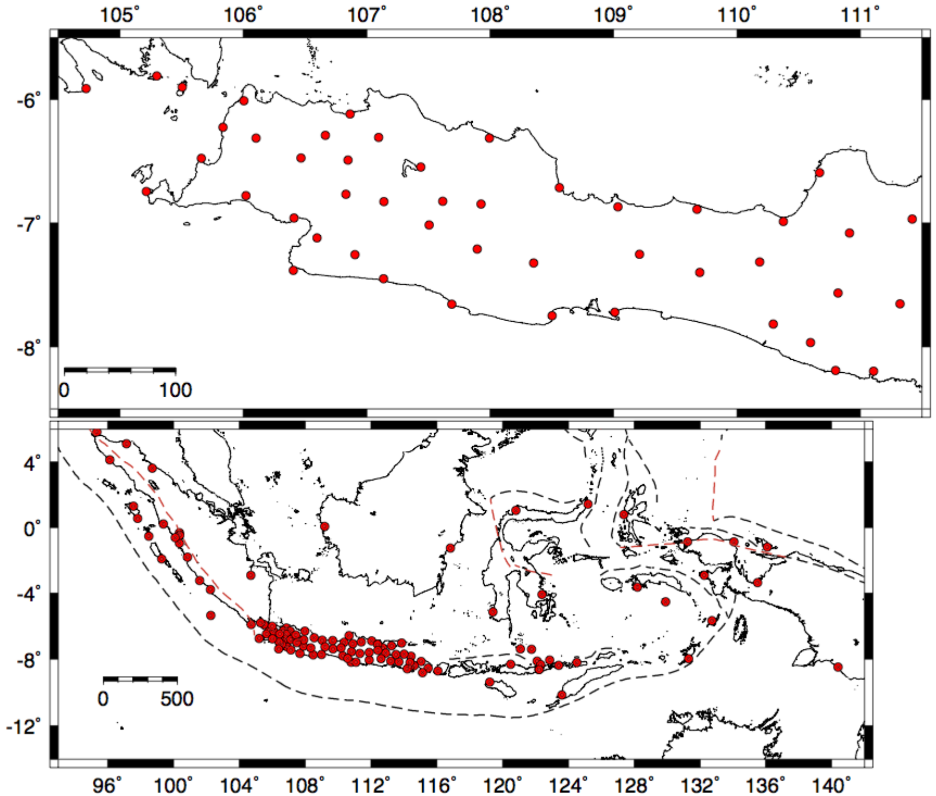
Leonard et al., 2004

Indonesian Permanent GPS Station Network (IPGSN)



In the end of 2007 BIG (Geospatial Agency of Indonesia) established IPGSN, and ITB installed CORS-GPS in ITB.

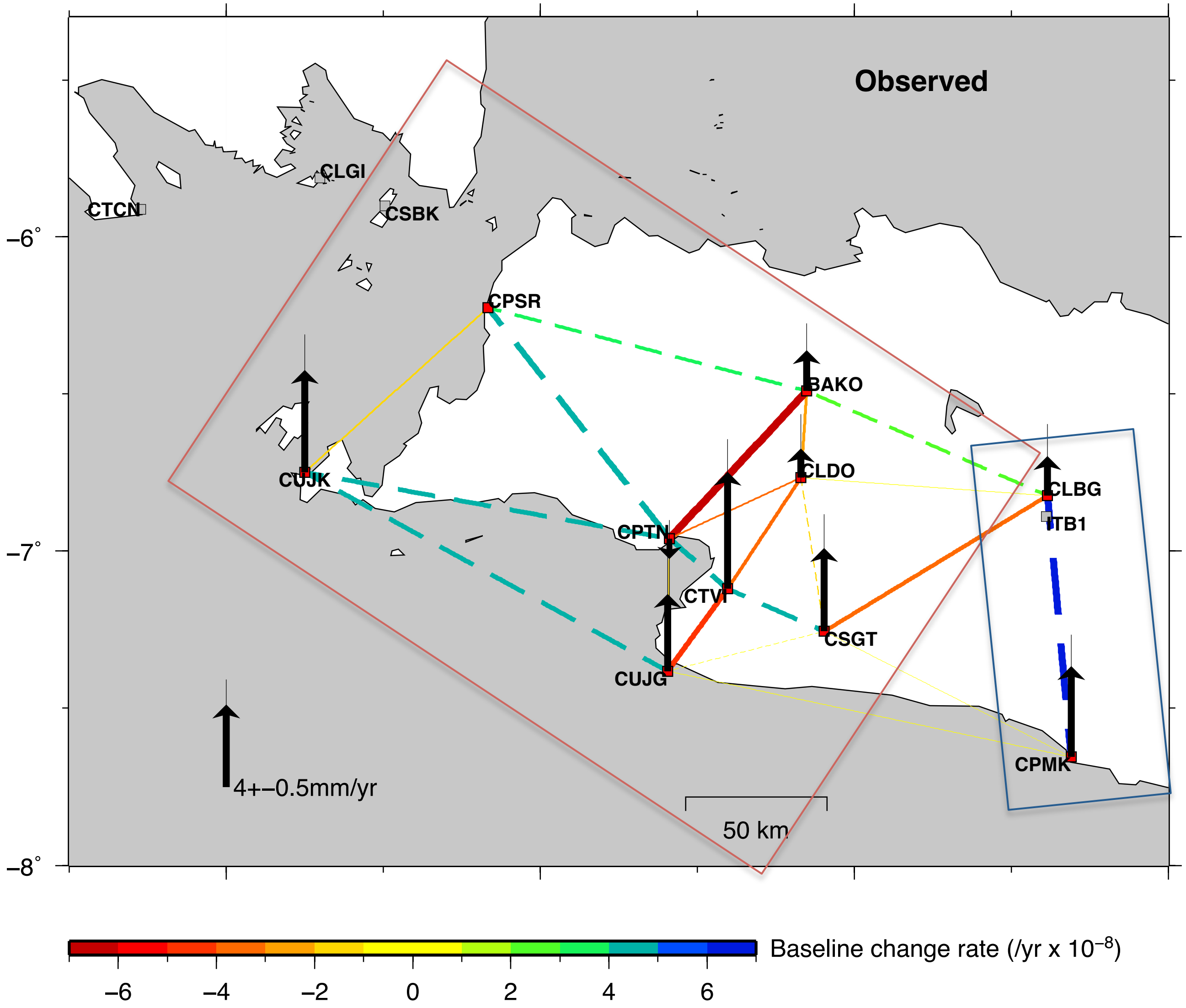
IPGSN Status in 2010-2012



(Subarya, 2013)

Observed Baseline change and Vertical displacement rate

- 21 baselines from 10 cGPS sites + vertical displacement rate



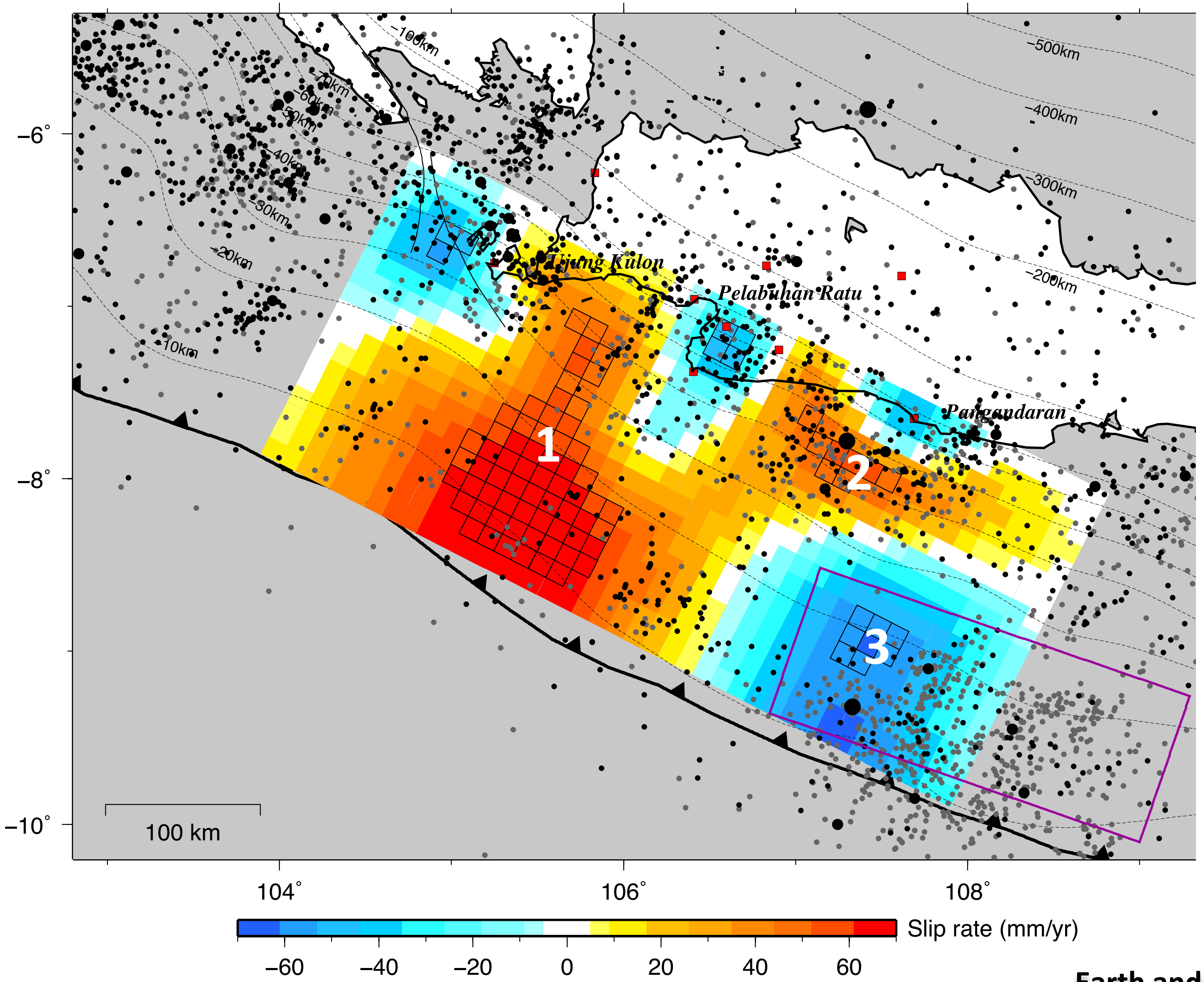
north-south shortening + uplift
→ might reflect some amount of interseismic locking in the plate interface at its downdip limit

north-south extension
→ possibly reflect postseismic effect of the 2006 Java earthquake

Solid = shortening
Dash = extension

Hanifa,N.R., et. al., Earth and Planetary Science Letter (2014)

Interplate coupling result from GPS data inversion



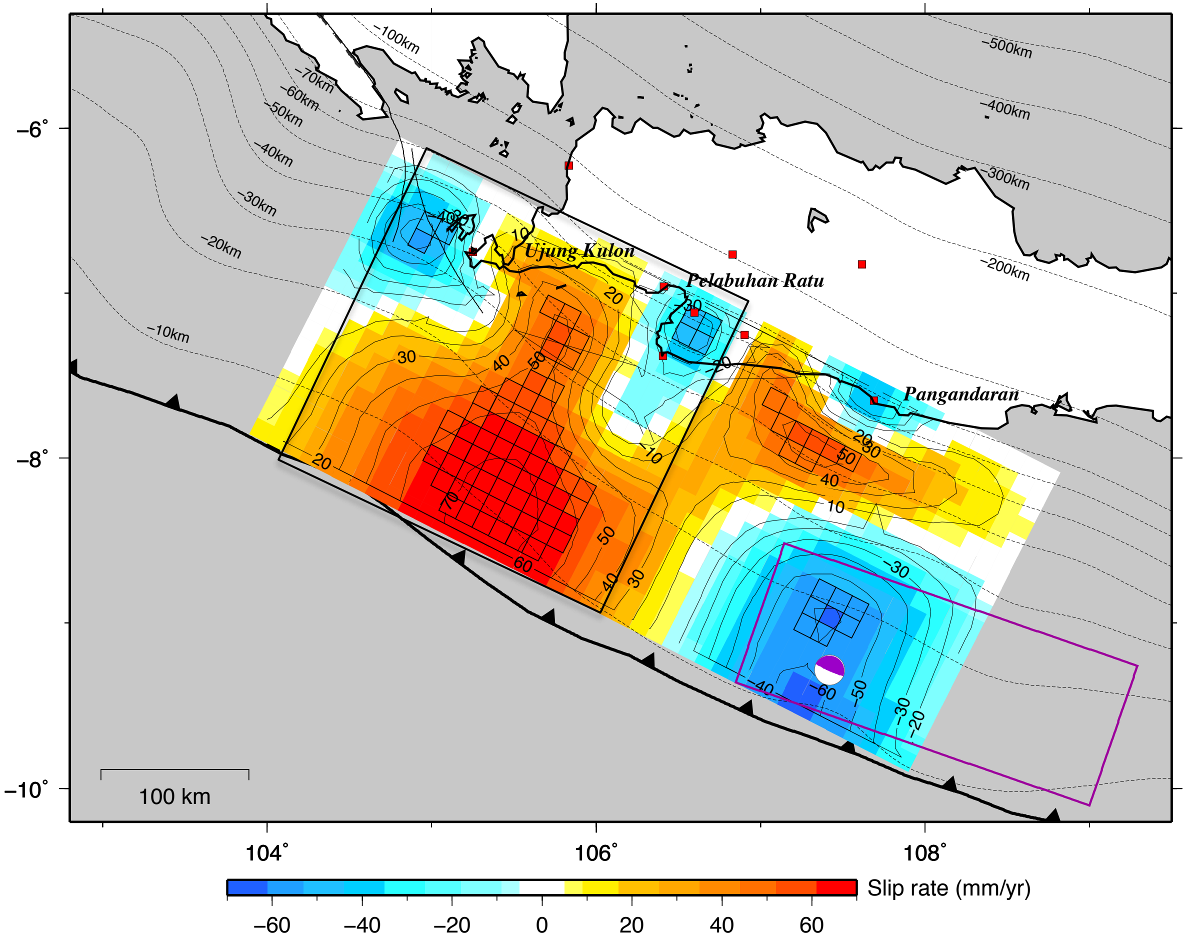
3 significant pathes:

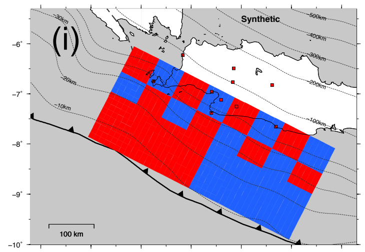
1. Slip deficit off Pelabuhan Ratu - Ujung Kulon (~M8.7 for 300 yr)
2. Slip deficit off Pangandaran (~M8.3 for 300 yr)
3. Slip excess off Pangandaran.

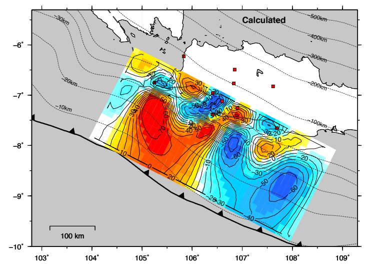
:: Seismicity 1973.01.01 – 2014.08.20

Hanifa, et. al., Earth and Planetary Science Letter (2014)

1: Slip Deficit off Ujung Kulon – Pelabuhan Ratu







From shallow to ~43 km depth
Rate 48 to 73 mm/yr.

Reliable result:
At depth 20 ~ 43 km,
→ coupling ratio 70-82%
(convergence rate 68 mm/yr)

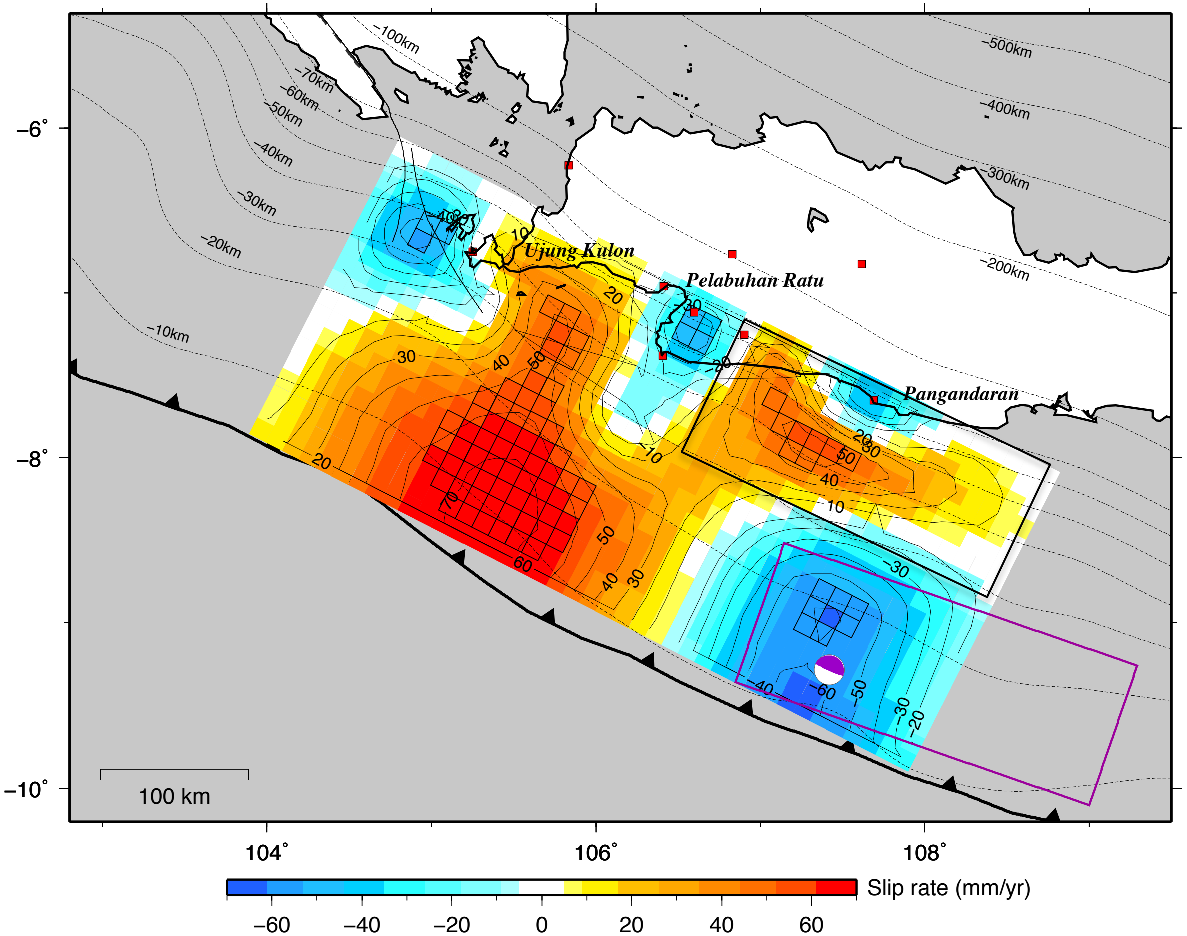
Integrated seismic moment accumulation rate
5.4 x 10^{19} Nm/yr

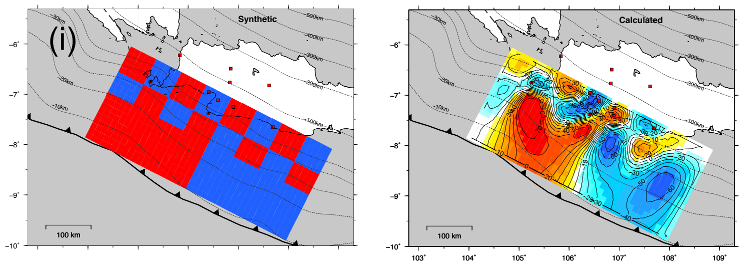
If steady within 300 years
~ 1.6 x 10^{22} Nm (Mw 8.7)

Can be released by earthquake,
Or by repeated slow slips
(without causing great earthquakes)

Hanifa, et al., EPSL 2014

2: Slip Deficit off Pangandaran





Reliable result:

At depth 37 - 45 km,

Rate: 48 - 55 mm/yr.

→ coupling ratio 75-80%

(convergence rate 68 mm/yr)

Integrated seismic moment accumulation rate

1.3×10^{19} Nm/yr

If steady within 300 years

~ 3.9×10^{21} Nm (Mw 8.3)

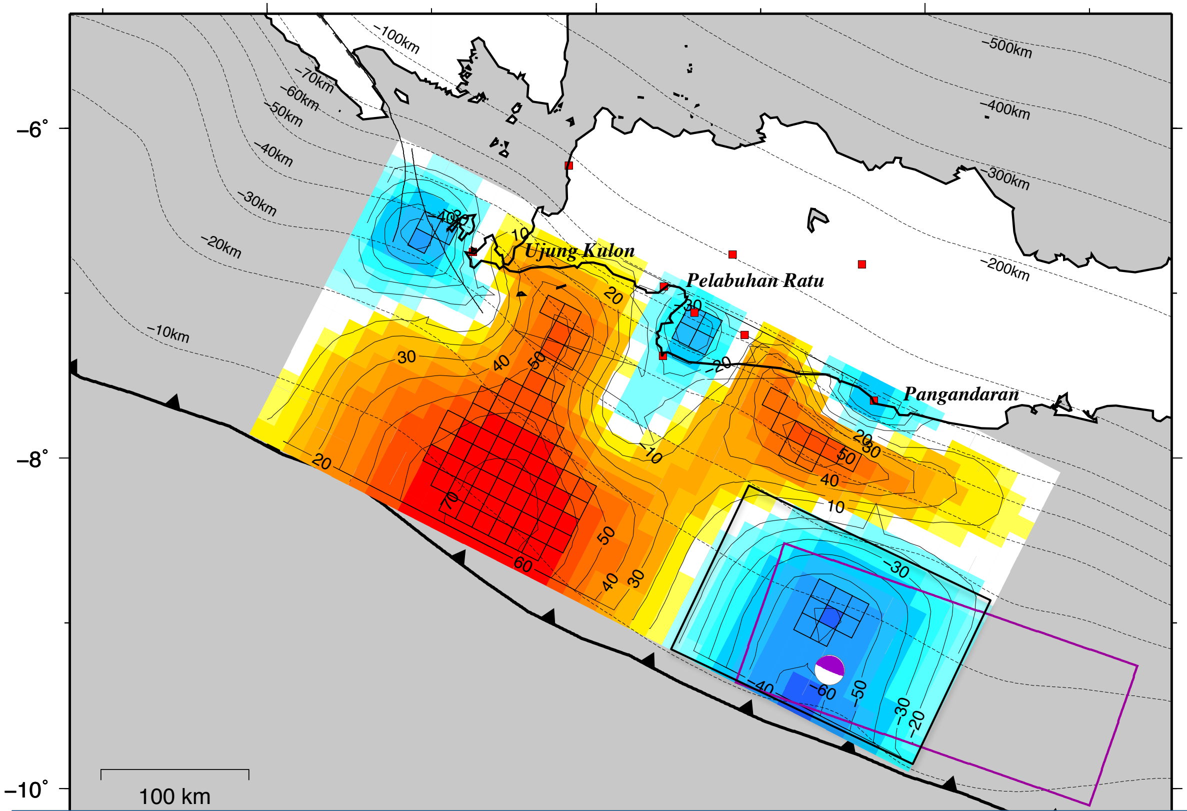
Can be released by earthquake,

Or by repeated slow slips

(without causing great earthquakes)

Hanifa, et al., EPSL 2014

3: Afterslip off Pangandaran



In shallow portion <30 km

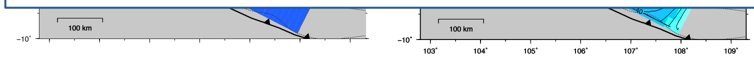
→ detailed slip distribution could not be resolved by the on-land GPS.

→ with larger patch we are able to detect signal from shallow portion.

We are sure that there is ongoing afterslip of the 2006 M7.8 earthquake, 4.5 years after the mainshock

We cannot resolve whether the afterslip occurs inside the mainshock rupture area or in the adjacent downdip area.

Afterslip could extend further to the east because of the absence of GPS data to the east of CPMK



Hanifa, et al., EPSL 2014

Lack of seismicity in Southwestern Java: Locking

300 years historical record & instrumental period → too short

Case in Northeast Japan,
Misunderstand lack of seismicity in the shallow portion as creeping.
Great earthquake prior 2011 M9.0 Tohoku Earthquake → A.D. 869 Jogan earthquake (~1100 yrs)

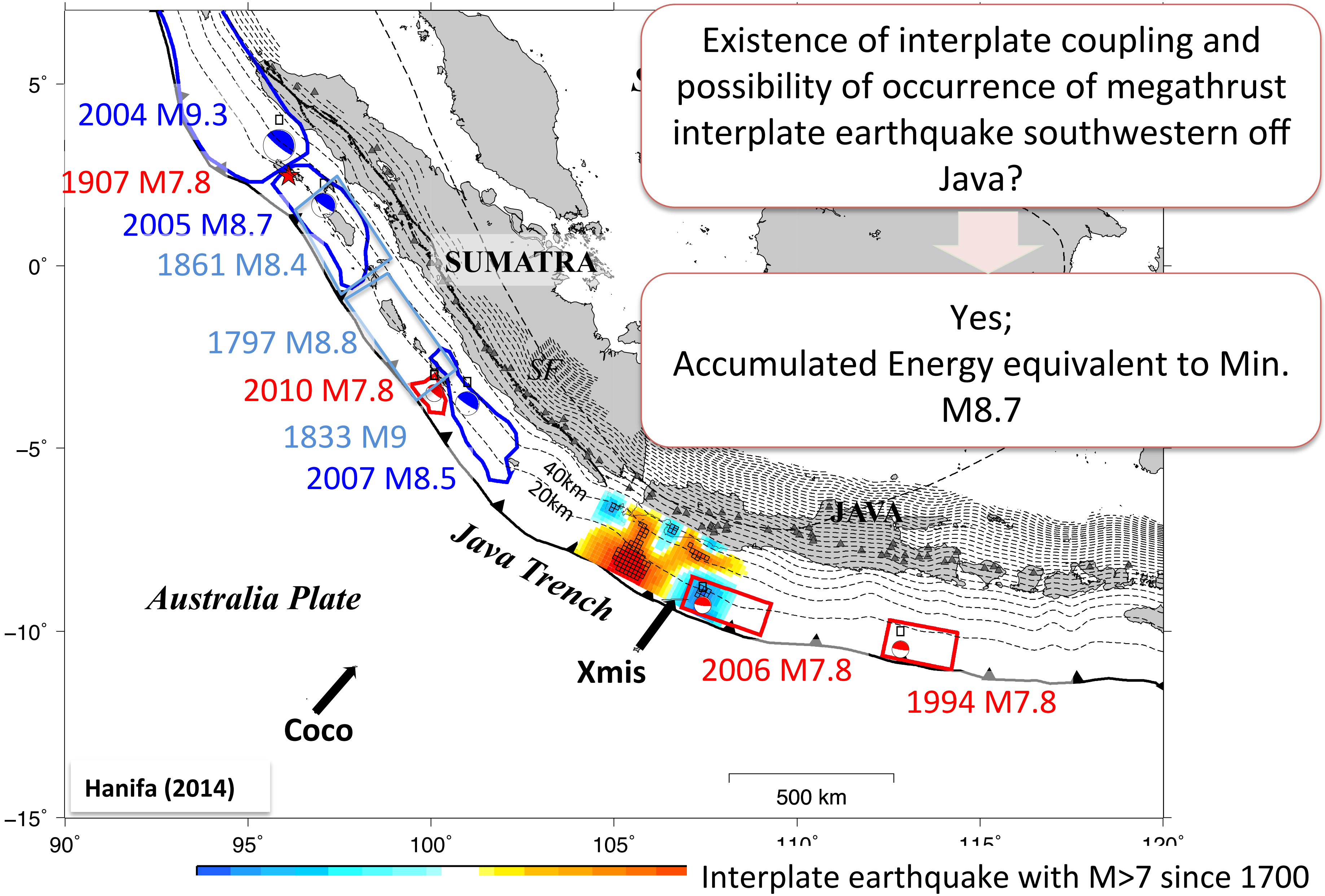
Case in 2004 Sumatra-Andaman,
Lack of seismicity : creeping or seismic gap? → no GPS data in northern Sumatra before 2004
Great earthquake prior 2004 M9.3 Aceh–Andaman earthquake: A.D. 1390–1455 (~600 yrs) (Meltzner et al., 2010)

Off Western Java:

Lack of seismicity + Interplate coupling = Seismic Gap

Hanifa, et al., 2014

Megathrust Earthquake Potential

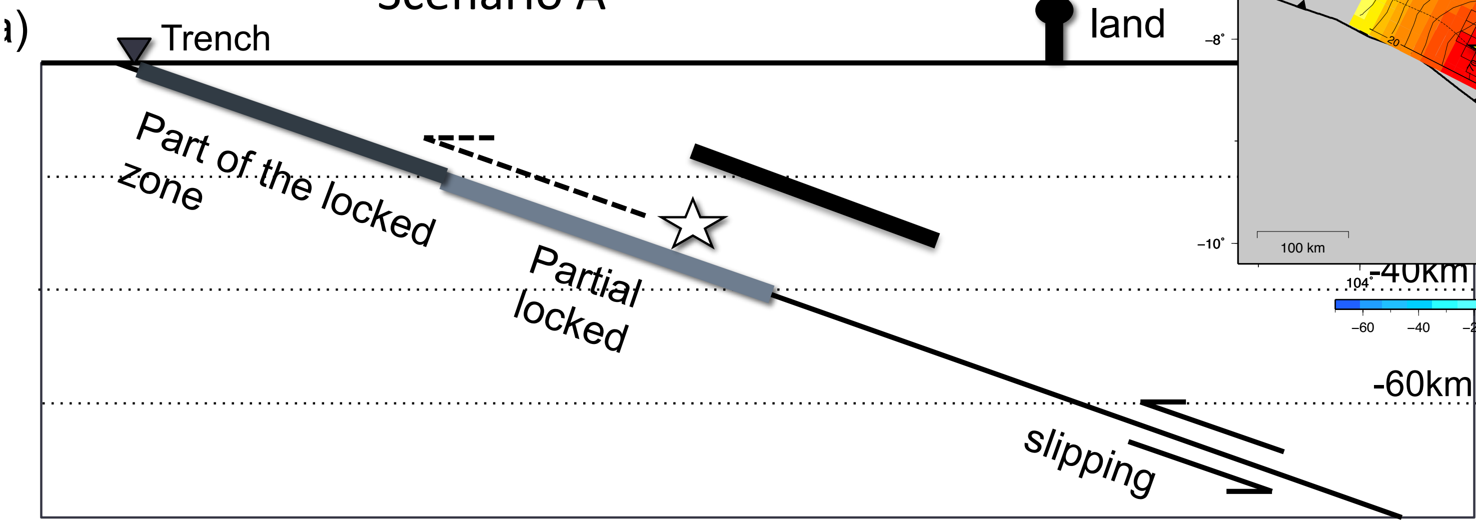


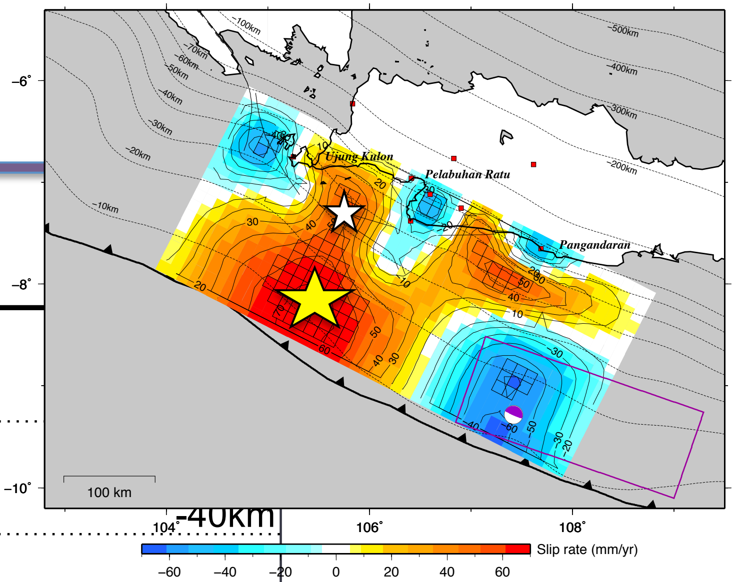
Existence of interplate coupling and possibility of occurrence of megathrust interplate earthquake southwestern off Java?

Yes;
Accumulated Energy equivalent to Min. M8.7

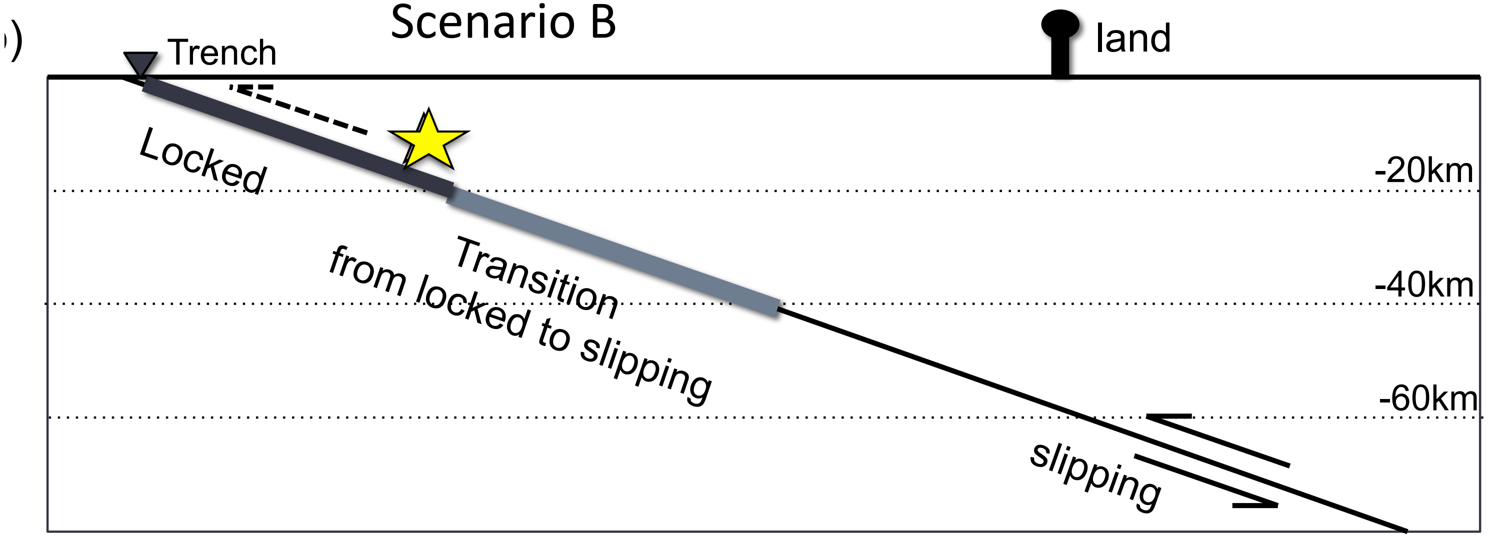
Scenarios

Scenario A





Scenario B



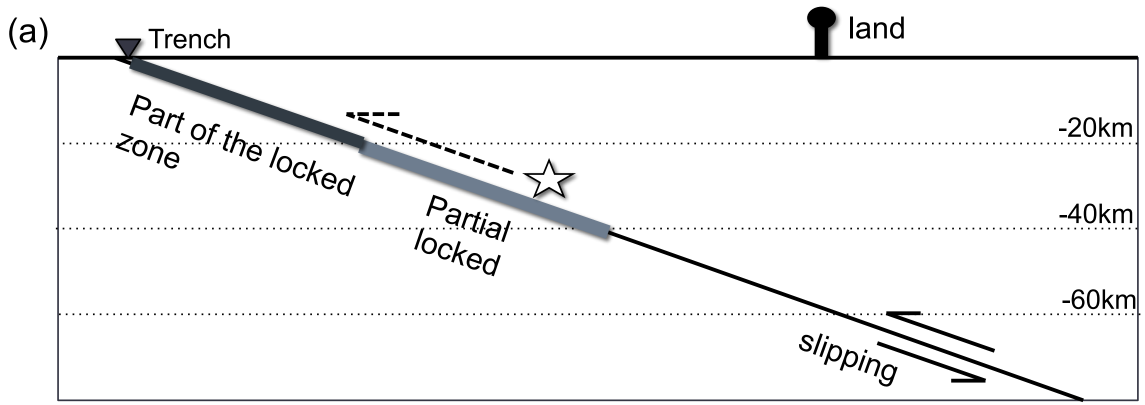
Disaster Mitigation in Western Java: Case of Scenario A

Initiates at intermediate depth (20-40 km) within normal rigidity,

→Potential to trigger strong ground motion in Java island.
e.g. Case of 2007 M8.5 Bengkulu earthquake: strong ground shaking felt until ~500 km away.
Might cause collapse of buildings and infrastructures, causing casualties, structural damage and economic loss.

→Potential rupture to near-trench, generating massive tsunami
e.g. The 2011 M9.0 Tohoku Earthquake

Future research:
Our source model can be use to calculate strong ground motion and tsunami modeling.



Hanifa, et al., EPSL 2014

Disaster Mitigation in Western Java: Case of Scenario B

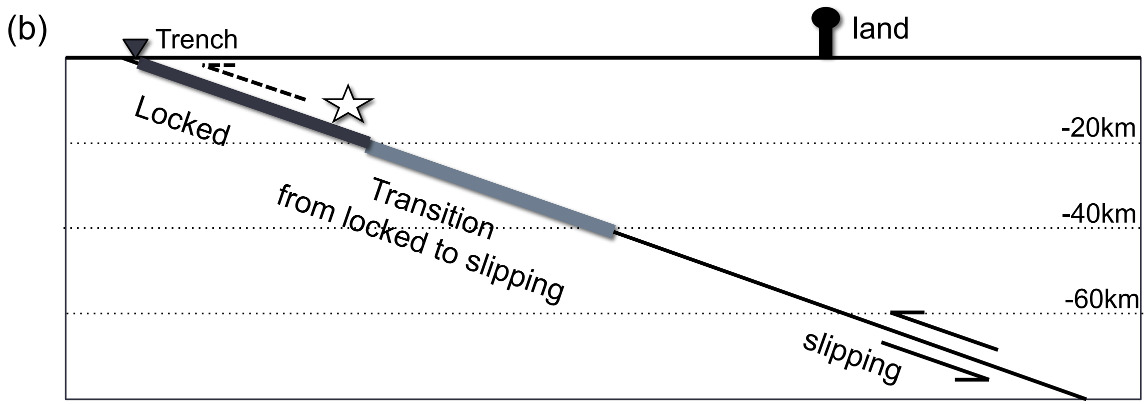
Initiates at shallow depth (<20 km) within low rigidity,
→ Cause weak shaking in Java island.
→ Rupture to near-trench may cause massive tsunami
e.g. 2006 Java & 2010 Mentawai Tsunami Earthquakes

→ No natural warning of tsunami

- An adequate early tsunami warning system should be improved.

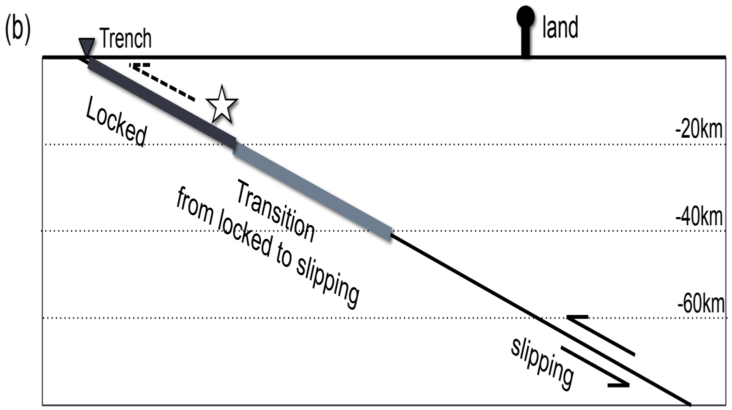
GPS can play an important to supplement seismic data because it can provide coseismic displacement in real time (e.g. Ohta et al., 2012).
(expected coseismic displacement along the coast: ~1m)
There will be enough time (~30-40 minutes) for local people along the coastline to evacuate if the earthquake information is delivered in a timely manner.

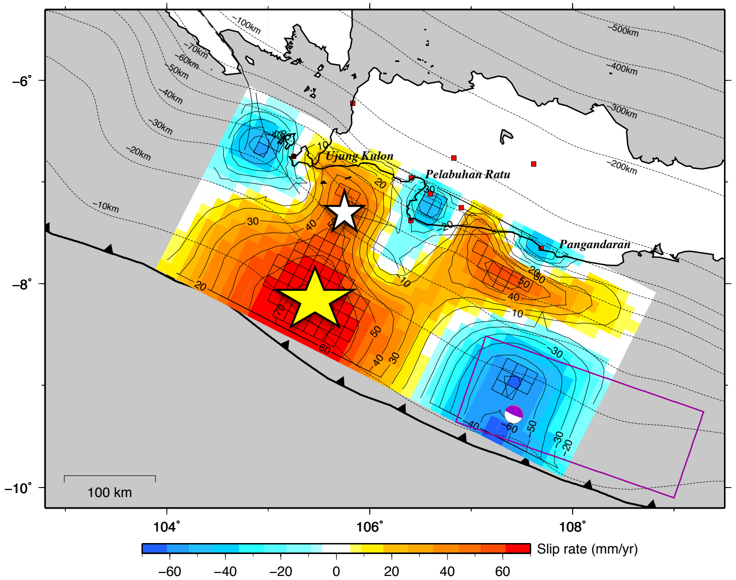
- Tsunami education and awareness campaign should be improved to local people along the coast.

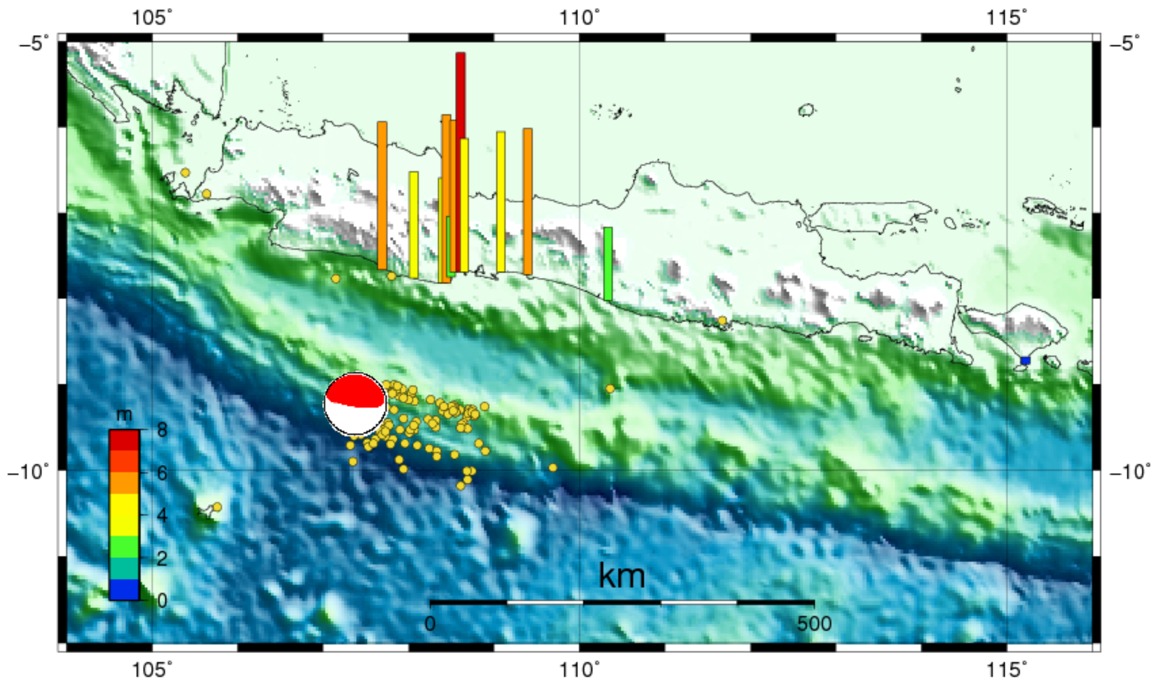


Hanifa, et al., EPSL 2014

Scenario B example: THE 2006 M7.8 JAVA TSUNAMI EARTHQUAKE







-Very slight shaking

-Tsunami of 3-8 m, max of 21 m.

- Inundation of 200 m

- Almost 700 deaths

- destructions

Hypocenter distribution of main shock and aftershocks of July 2006 Java Earthquake in the period within 2 days after the mainshock by USGS. Focal mechanism of the main shock by Harvard CMT solution. Observed tsunami heights by Geodesy Research Division of ITB and BMG compiled in Kato, 2006.

TIMELINE OF THE 2006 M7.8 JAVA TSUNAMI EARTHQUAKE

Photos of Hasanuddin

Timeline

15:19	Earthquake
~15:30	BMG (Geophysics and Meteorology Agency of Indonesia) announces that there is no danger of a tsunami (M6.8)
15: 36	Pacific Tsunami Warning Center issues local watch for Indonesia and Australia (M7.2)
15:46	JMA issued tsunami watch for Indian Ocean (same as PTWC message)
~16:05	Tsunami wave hits Pangandaran

Source compile from BMG(2006) and Jim Mori(2007)

FAILURE TO GIVE WARNING

1. Underestimate possibility of tsunami due to its “low” seismic moment (M 6.8)
2. Unready Tsunami Early Warning System

Tsunami Earthquake

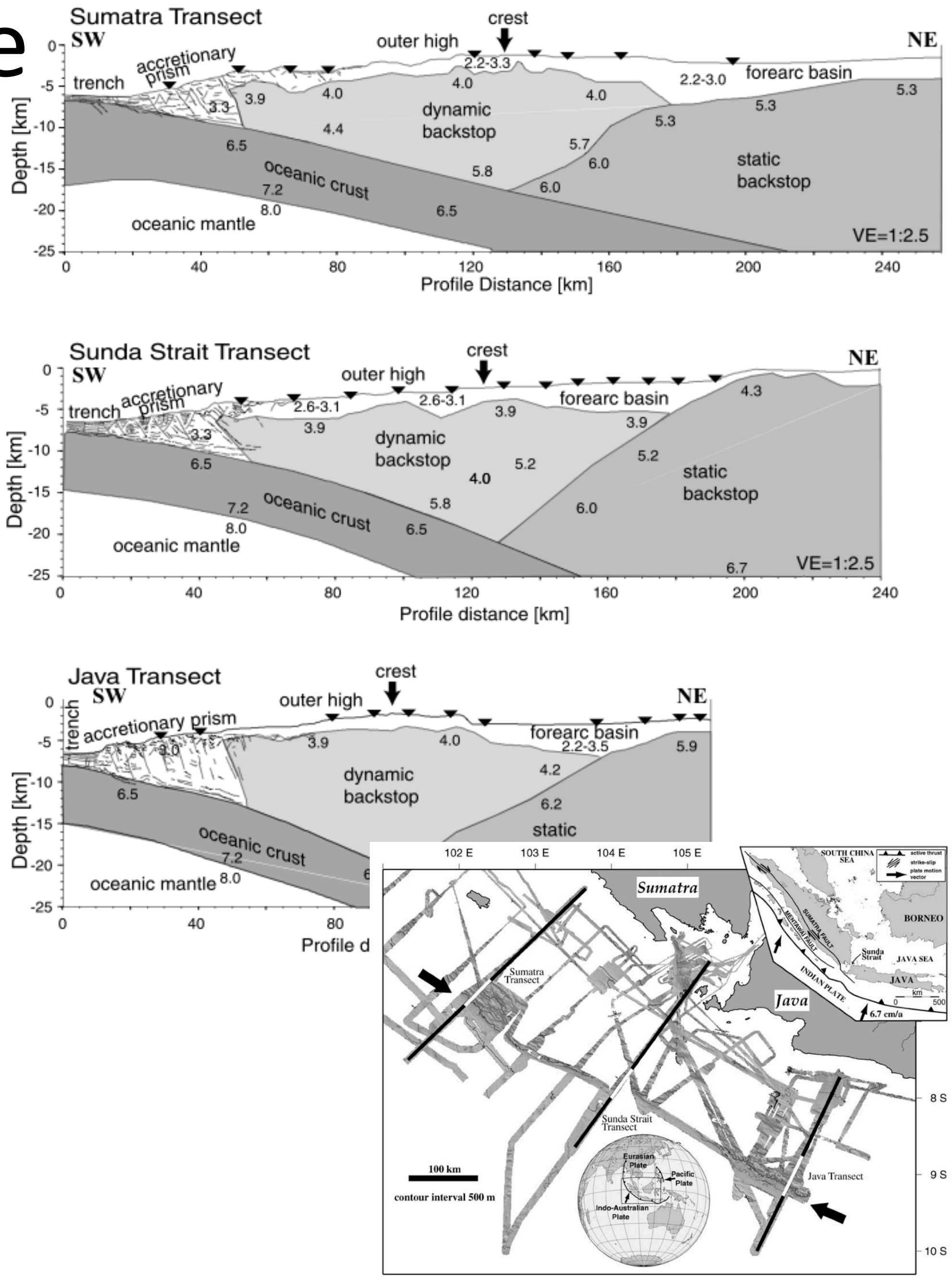
This study cannot resolve existence interplate coupling of a tsunami earthquake from land-base GPS observation.

Tsunami earthquake can occur everywhere in subduction zone or only in specific subduction zone?

It can occur regardless of interplate coupling estimated from land-base GPS.

Indication:

- Existence of soft sediments/ accretionary prism along the trench
- Rupture to near-trench slip along the Java Trench, causing larger vertical displacement
- Weaken the shaking

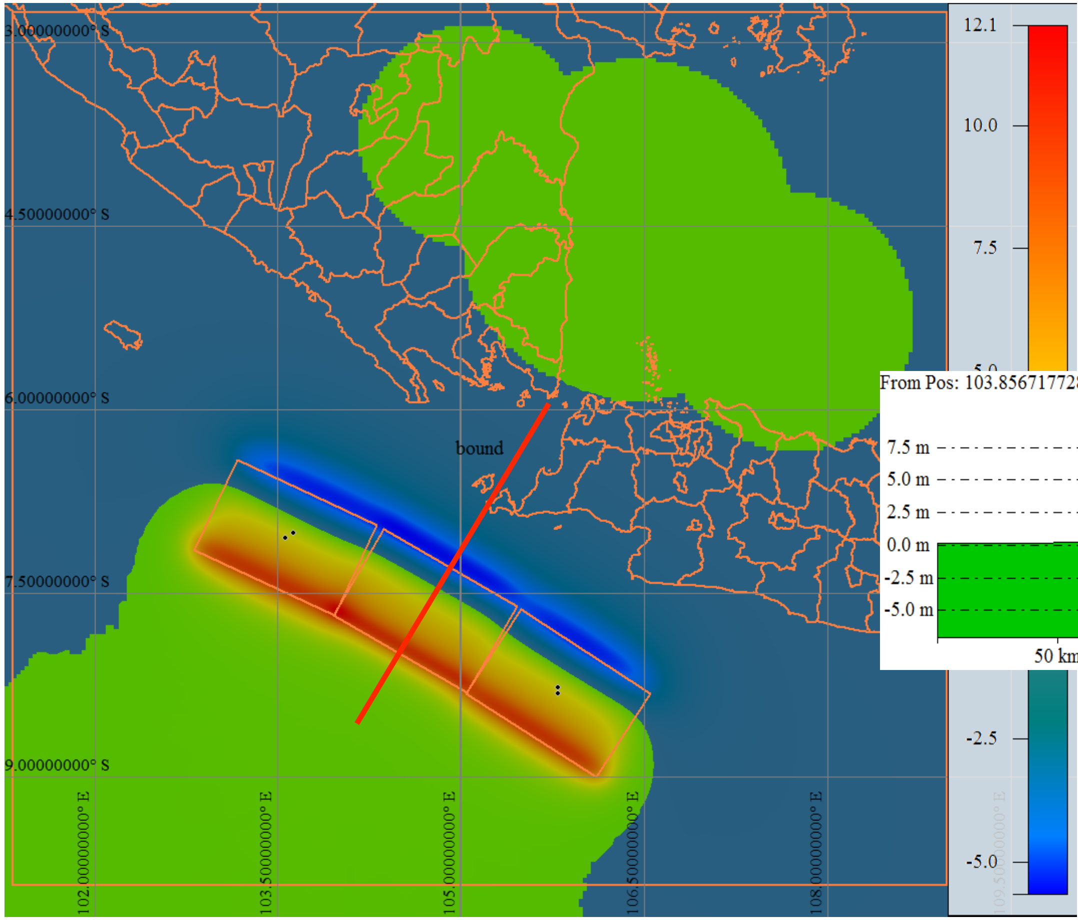


- Kopp, H., and N. Kukowski (2003)

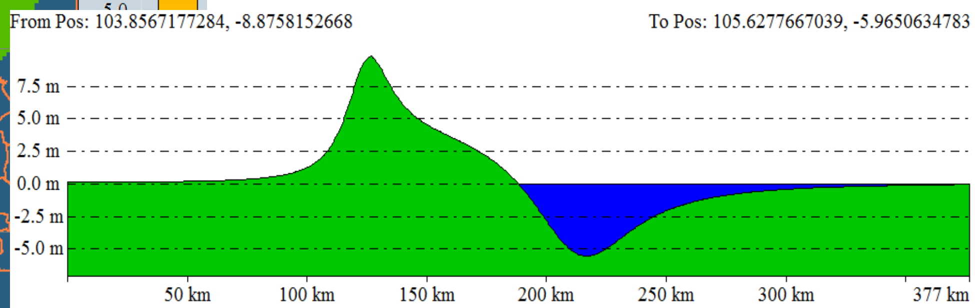
Tsunami scenario

Tsunami model: set-up & initial condition of tsunami source

•Numerical model of TUNAMI 1 (LSWE), leapfrog scheme, finite different, time step 6s, grid 2” arc, time simulation 6 hours. The geometric data is Gebco08.



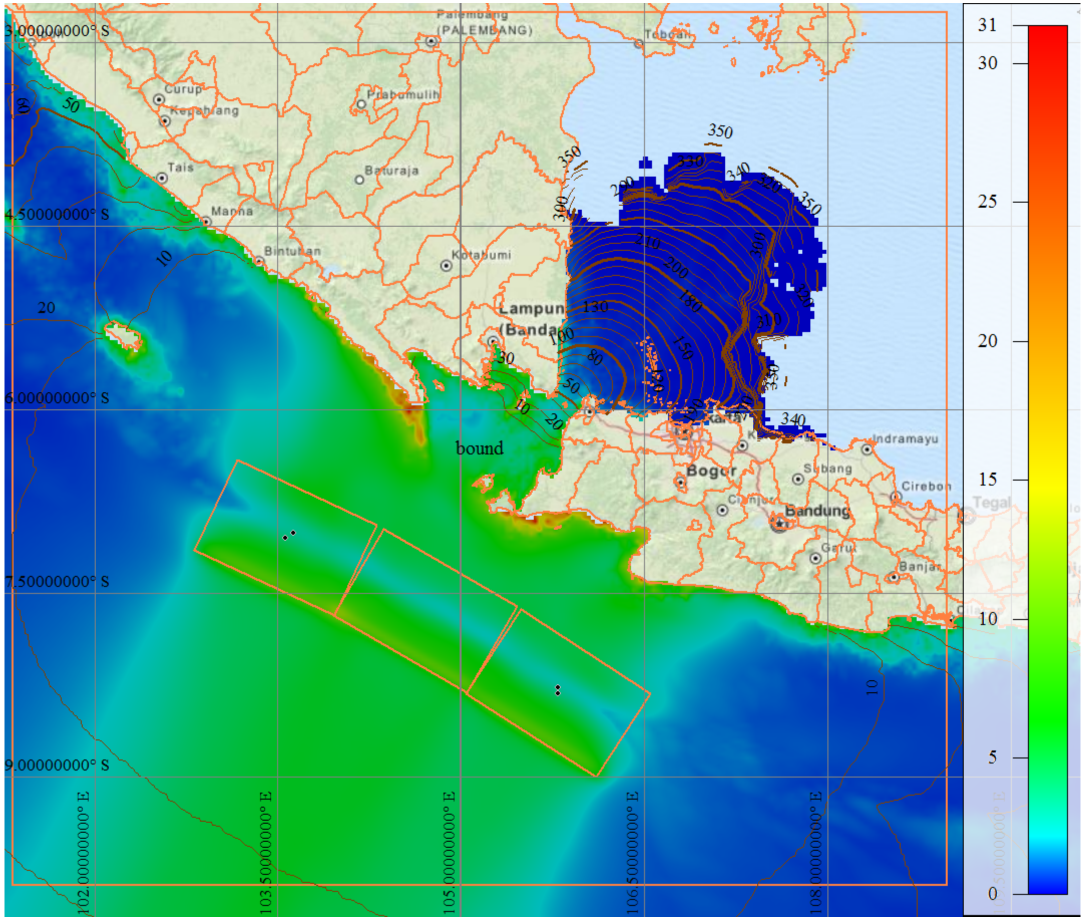
•The maximum/minimum initial source ~12 m and ~ -5.5 m.



Widjokongko, 2015

Tsunami scenario

Tsunami model: height distribution, estimated time arrival (eta)



- The maximum height ~30 m (along coastline of lampung barat, pandeglang),
- >15 district affected by tsunami height >5m.
- The first ETA is within 10 min (threshold, 10 cm)

Widjokongko, 2015

Need Seafloor Observation System for Earthquake and Tsunami

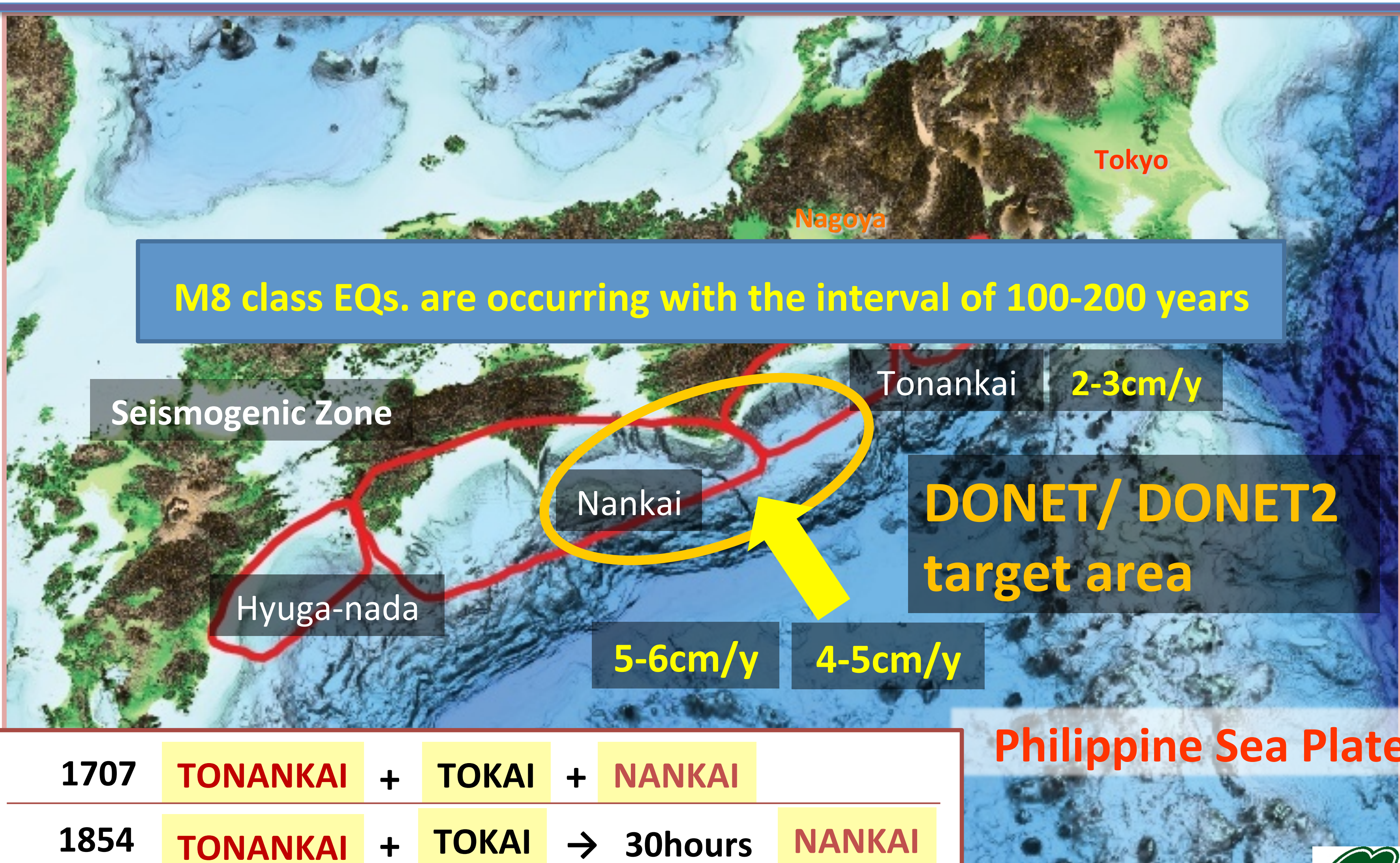
Objectives:

- to evaluate a more accurate estimation of state of interplate coupling near the trench,
- to improve a faster a more accurate earthquake and tsunami early warning system for disaster risk reduction purpose.

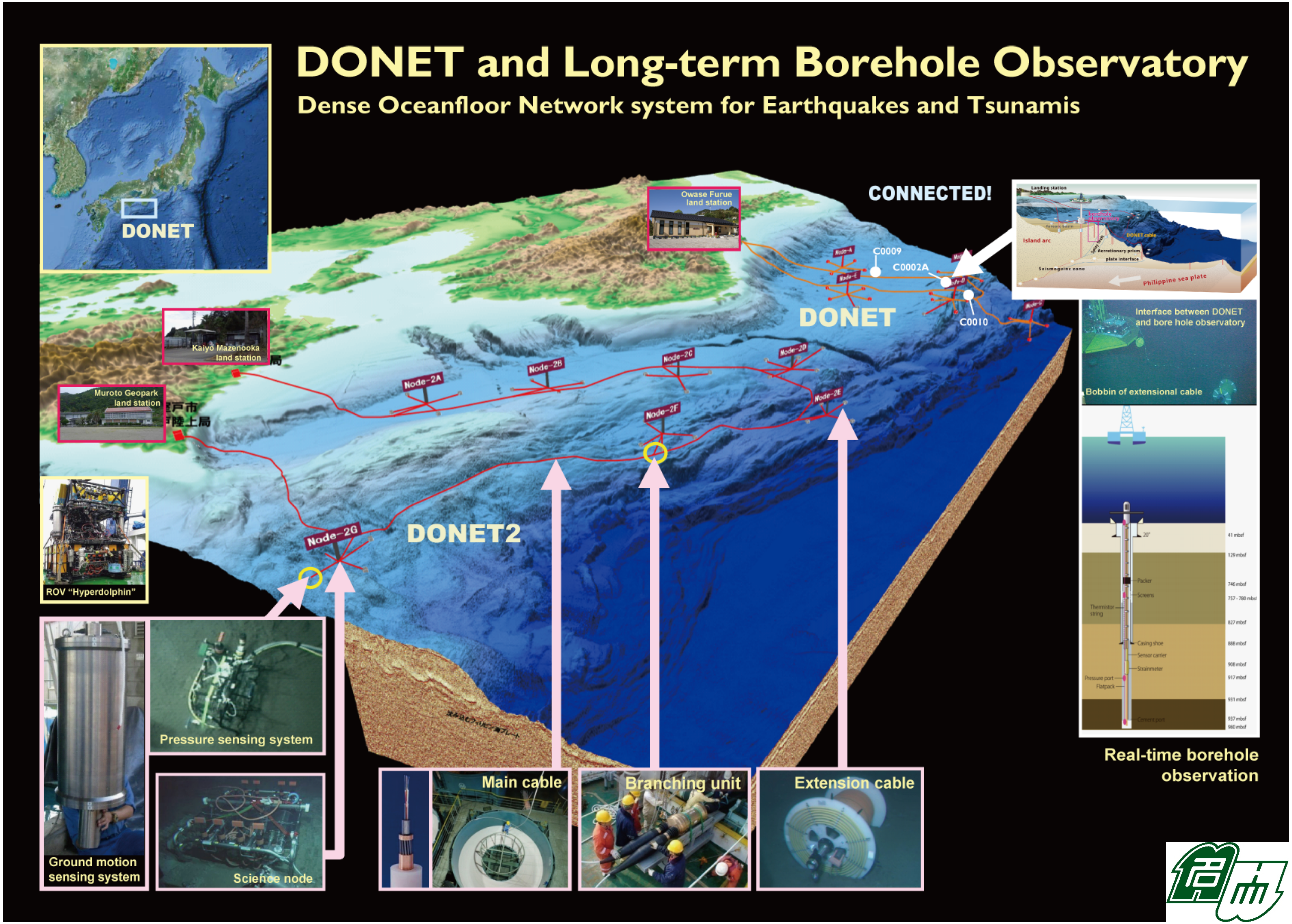
The propose technology is to employ Indonesia Dense Ocean Floor Network System For Earthquake and Tsunami (INA-DONET)

- in the offshore of southwestern Java up to south Sumatra
- adapting DONET system employ in Nankai Through by JAMSTEC.

Target Region:
Nankai Subduction Zone



1707	TONANKAI	+	TOKAI	+	NANKAI	
1854	TONANKAI	+	TOKAI	→	30hours	NANKAI
1944 1946	TONANKAI			→	2years	NANKAI

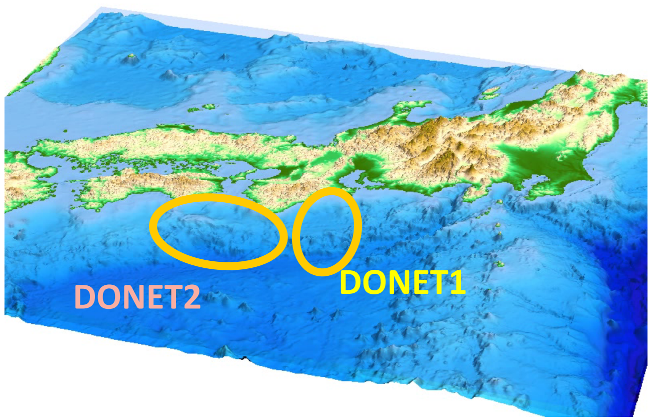

DONET and Long-term Borehole Observatory
Dense Oceanfloor Network system for Earthquakes and Tsunamis
DONET
CONNECTED!
Owase Furue land station
Kaiyo Mazenooka land station
Muroto Geopark land station
C0009
C0002A
C0010
DONET
DONET2
Node-2A
Node-2B
Node-2C
Node-2D
Node-2E
Node-2F
Node-2G
Island arc
Philippine sea plate
Interface between DONET and bore hole observatory
Bobbin of extensional cable
ROV "Hyperdolphin"
Pressure sensing system
Ground motion sensing system
Science node
Main cable
Branching unit
Extension cable
Real-time borehole observation

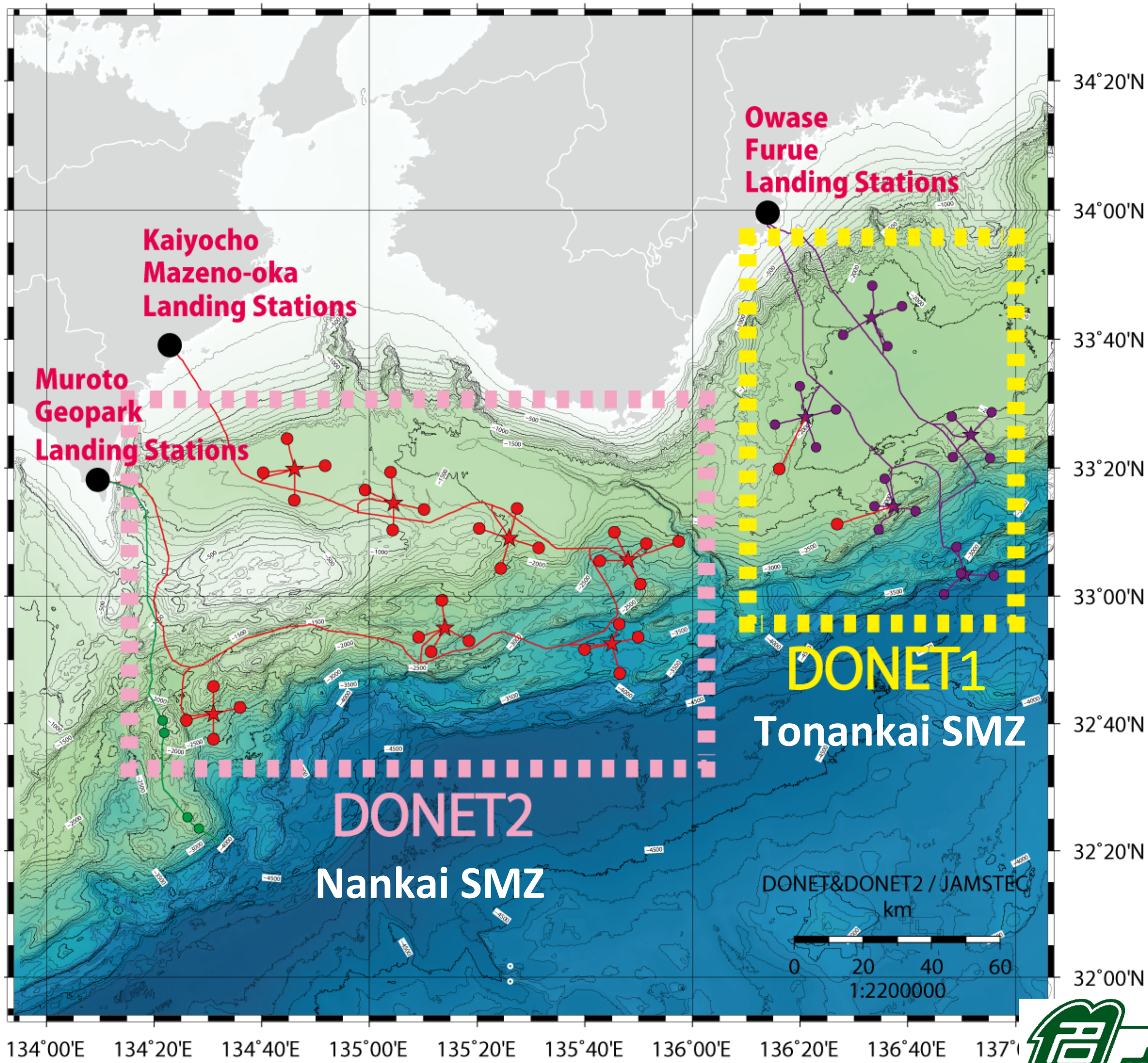
New Real-time Monitoring System in the Nankai Trough (DONET2)

DONET2 fact sheet
(in ( ) is DONET1)

Backbone cable length : ~350km(~250km)
# of Branching Unit : 7 (5)
# of Node : 7 (5)
# of Observation system : 29 (20+2)

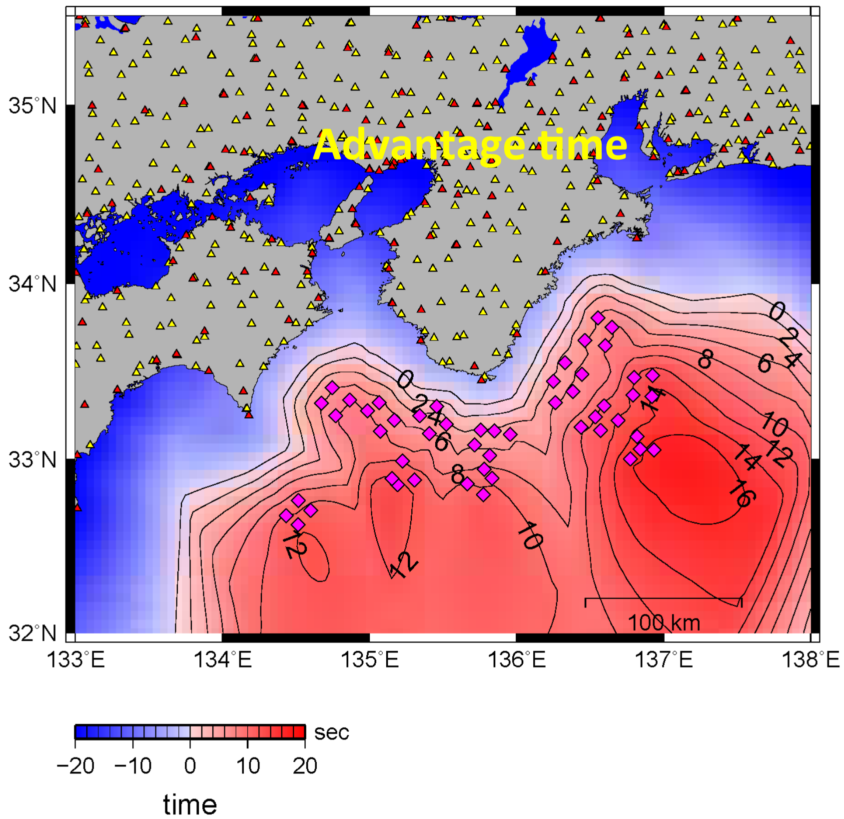
Total 51 Observatories



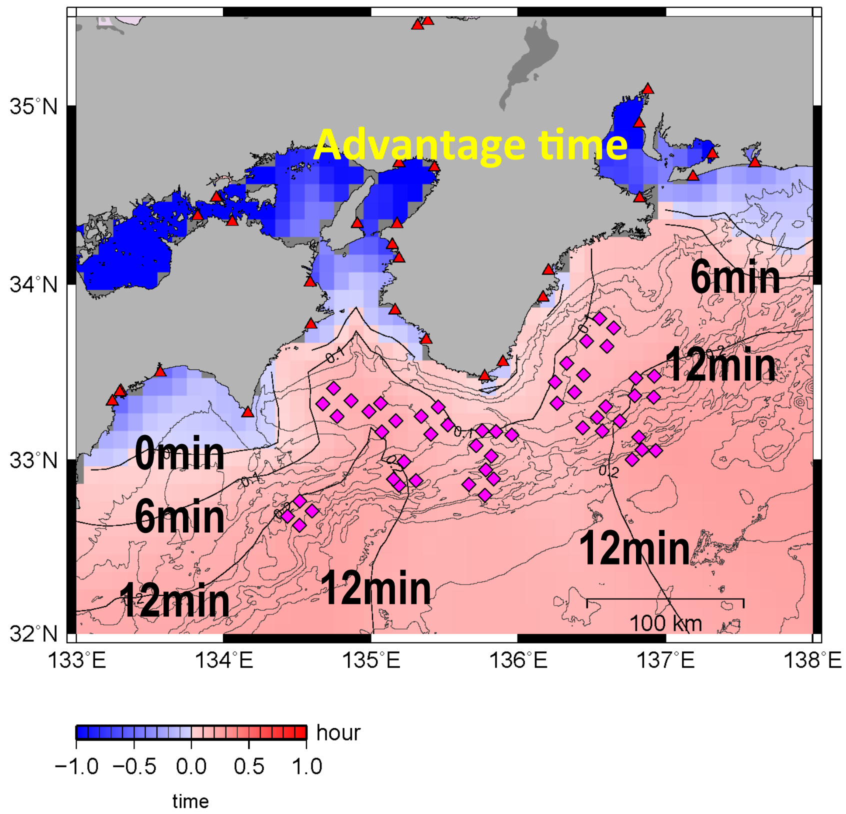


Early Detection of Earthquake and Tsunami by DONET1/DONET2

Seismic waves

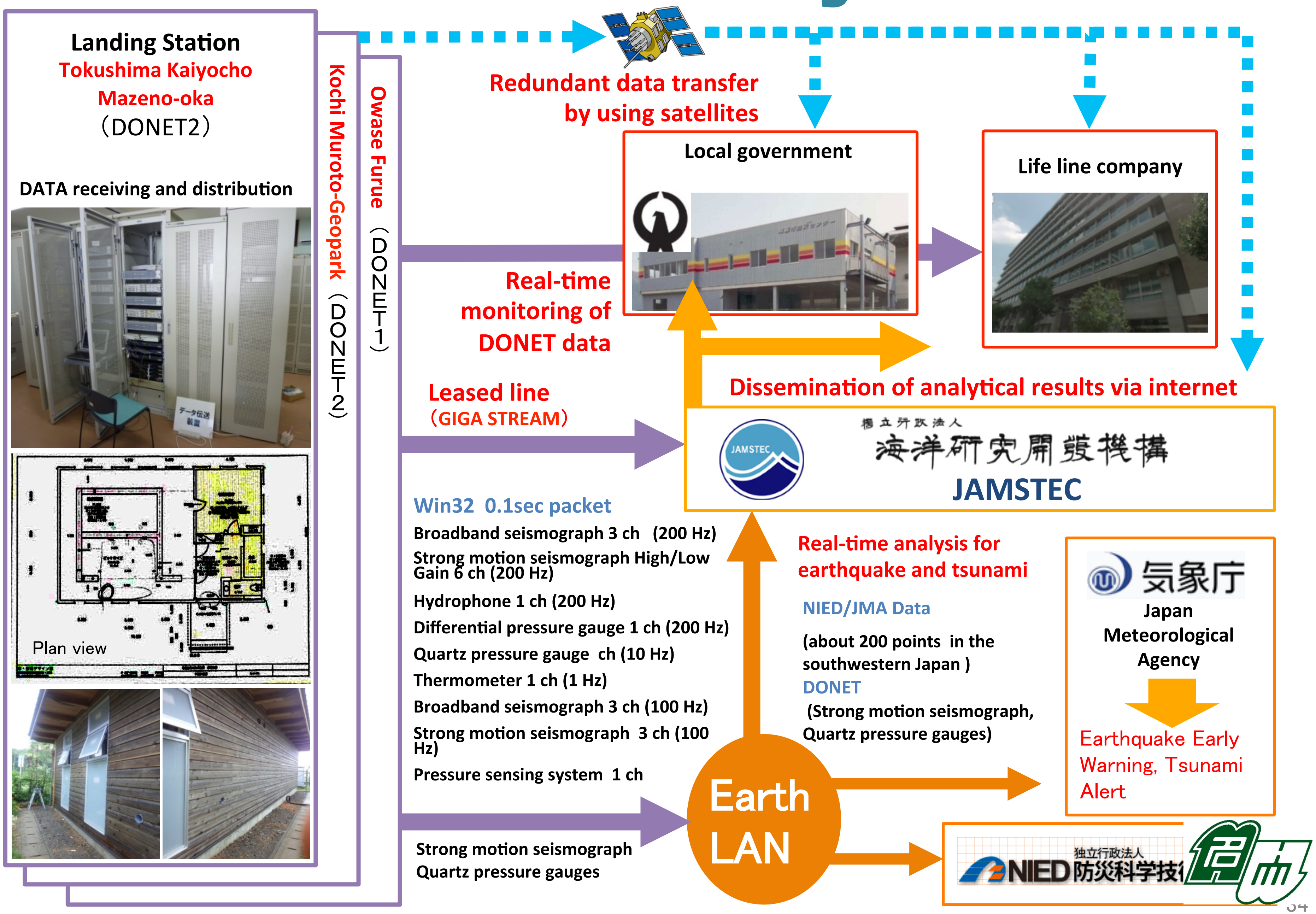


Tsunami



The red parts show the **DONET/DONET2** detects earthquakes and tsunamis earlier than the land stations.

Data Transfer System



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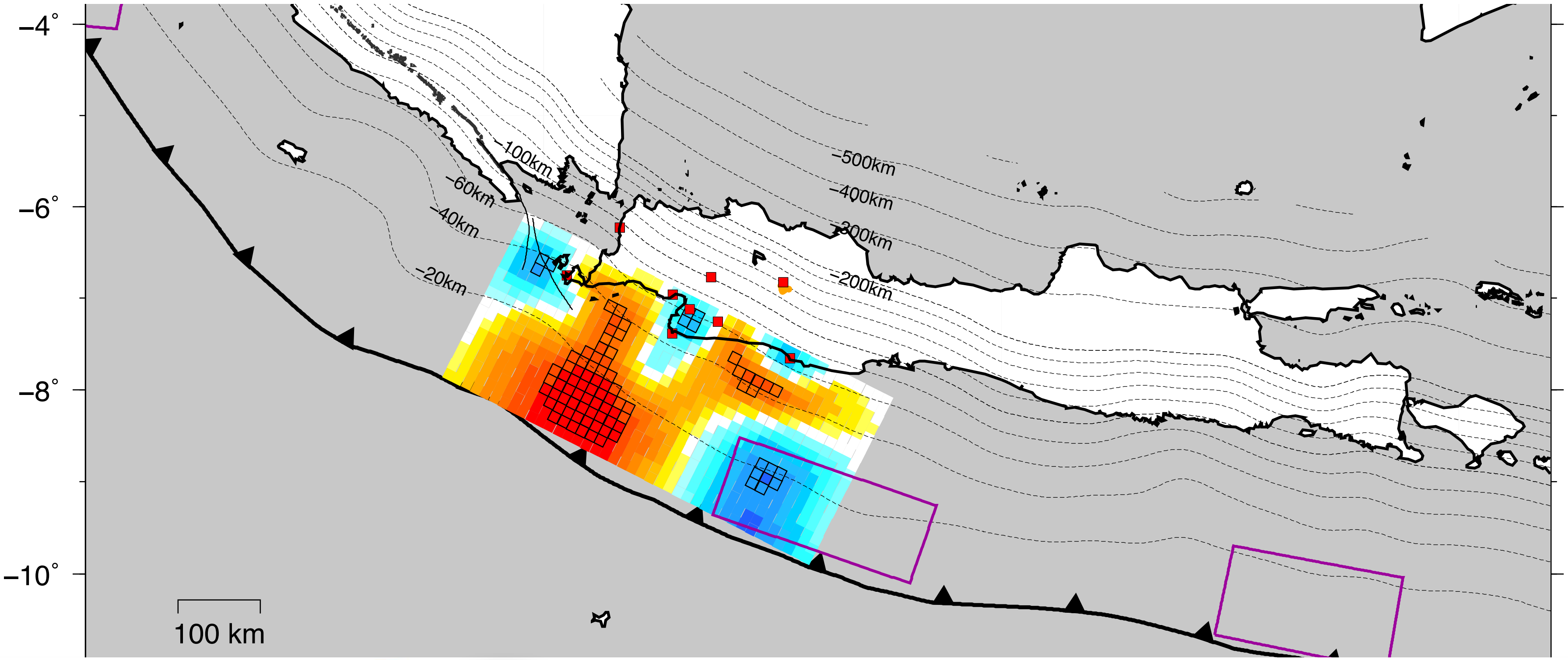


BMKG

BNPB

RISTEKDIKTI

JAMSTEC

NEC

Propose INA-DONET Desain

Expected advantage of the INA-DONET

- (1) parameter determination of earthquakes under the sea would be faster and more accurate.
- (2) consequently, information of the earthquake and tsunami early warning system will be faster and more accurate.
- (3) understanding of the characteristics of earthquakes and earthquake prediction will be improved.

INA-DONET TIMELINE

2016 | 2017 | 2018 | 2019 | 2020

- Approval
- Institutional Support from Both Countries
- Funding
- Feasibility Study and Data Completeness
- Preliminary Survey
- Capacity Building of Indonesia Researchers

- Proceed the Survey
  - Bathymetry, Current, Seismic survey, etc
  - Core Sampling
  - Architectural design of INA-DONET
  - Capacity Building of Indonesian Human Resources
  - Development of Supporting Infrastructure

- Final Test Stage
- Readiness of Infrastructue on Land
- Telecommunication systems
- Installation of INA-DONET

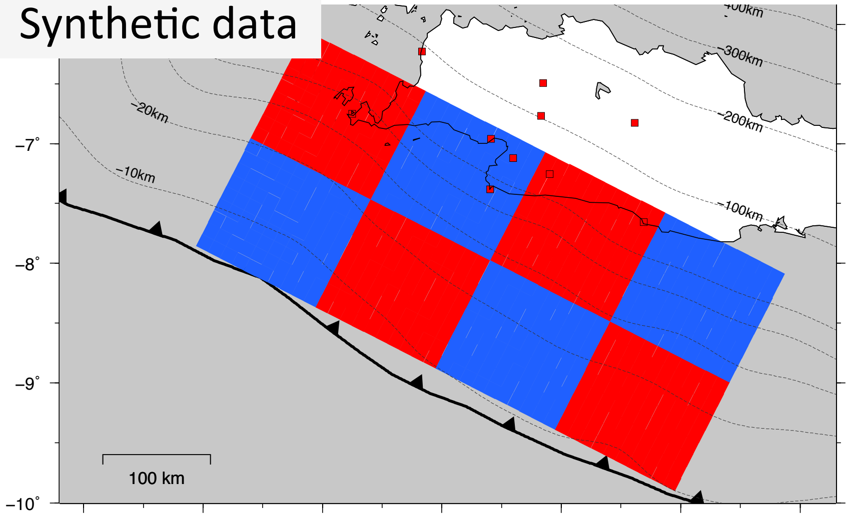
- Finalization of INA-DONET Installation
- System Testing and Evaluation
- Development of BMKG-BNPB connectivity
- Development of Dissemination System

First Training: 30 November – 15 December 2015

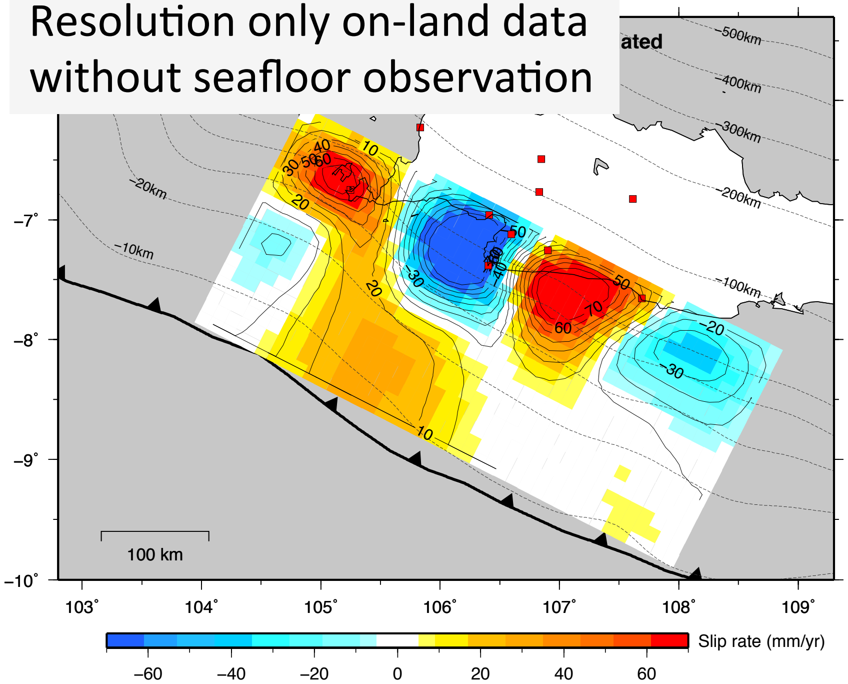
- **JAMSTEC**
- **NIED**
- **NAGOYA UNIVERSITY**
- **DONET STATION OWASE**
- **JMA**
- **NEC**
- **HOUSE OF THE REPRESENTATIVEs**

Numerical simulation: Resolution Improvement with GPS seafloor measurement

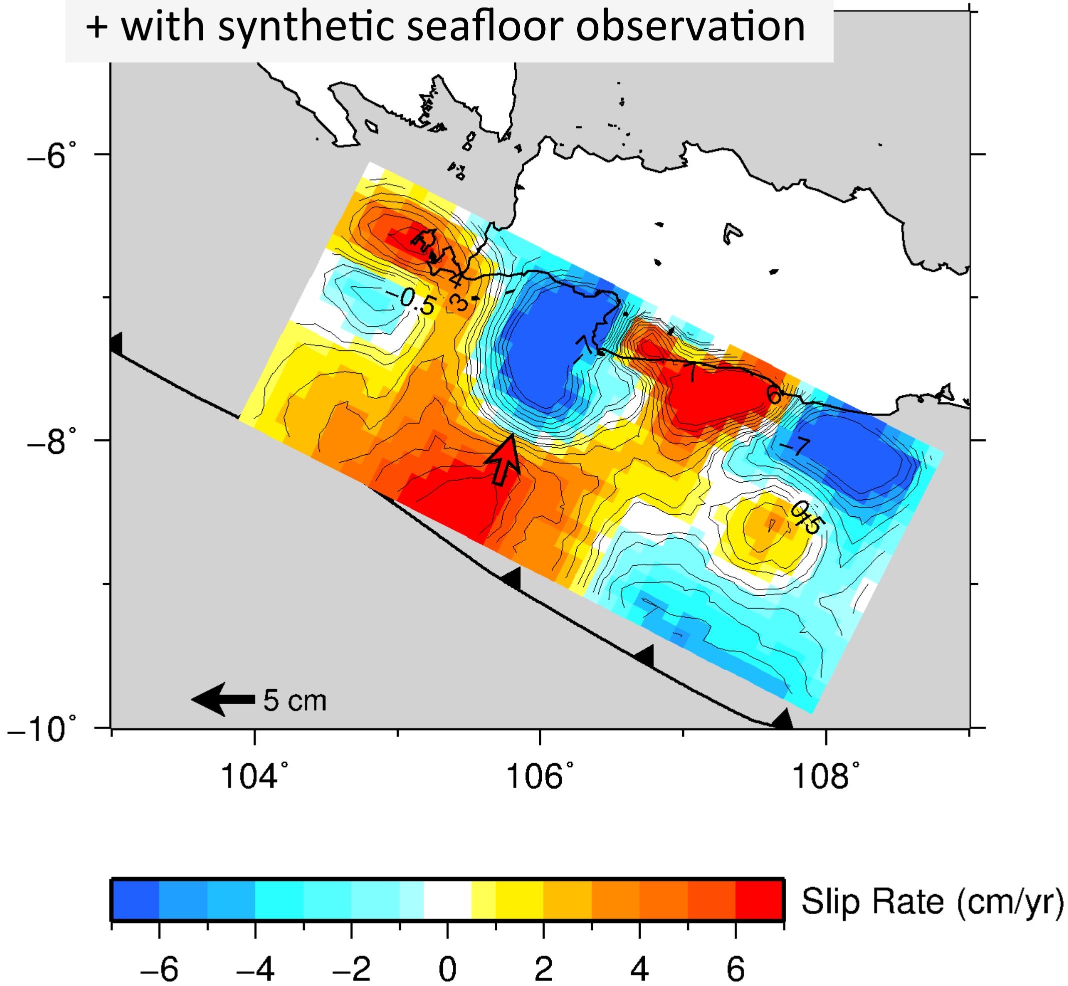
Synthetic data



Resolution only on-land data
without seafloor observation



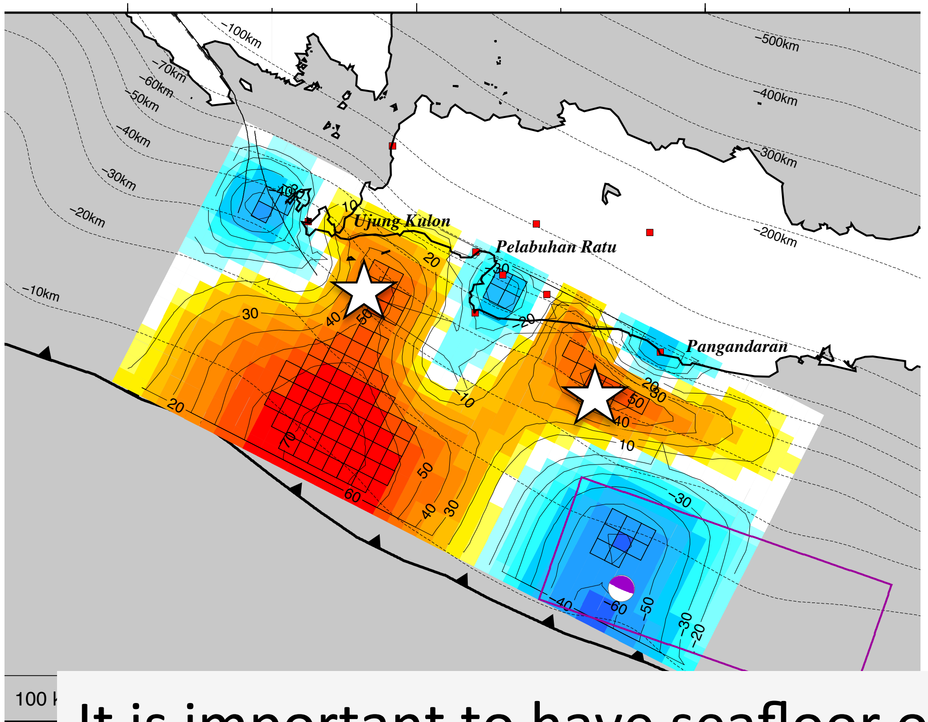
Resolution on-land data
+ with synthetic seafloor observation



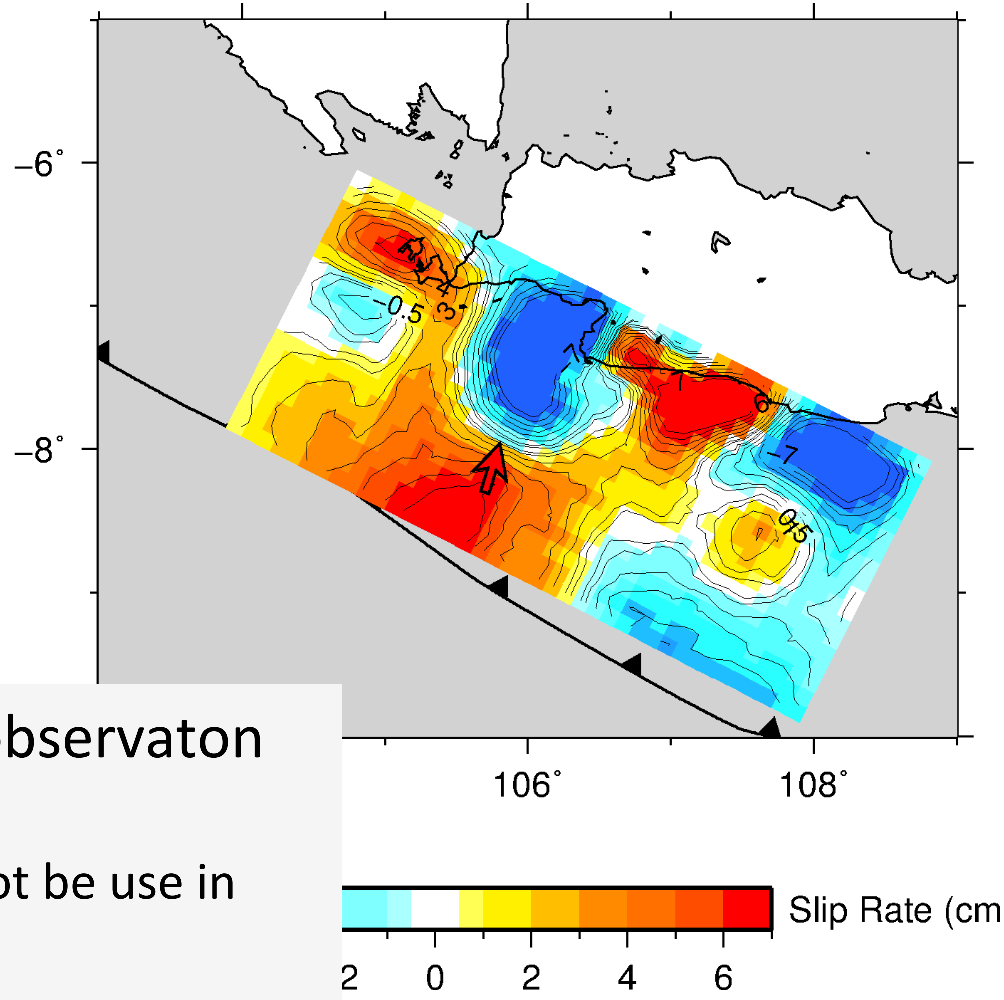
Hanifa, et al., ISEDM 2015

Numerical simulation: Resolution Improvement with GPS seafloor measurement

GPS Data 2008-2010



Numerical simulation with synthetic data



It is important to have seafloor observaton system.

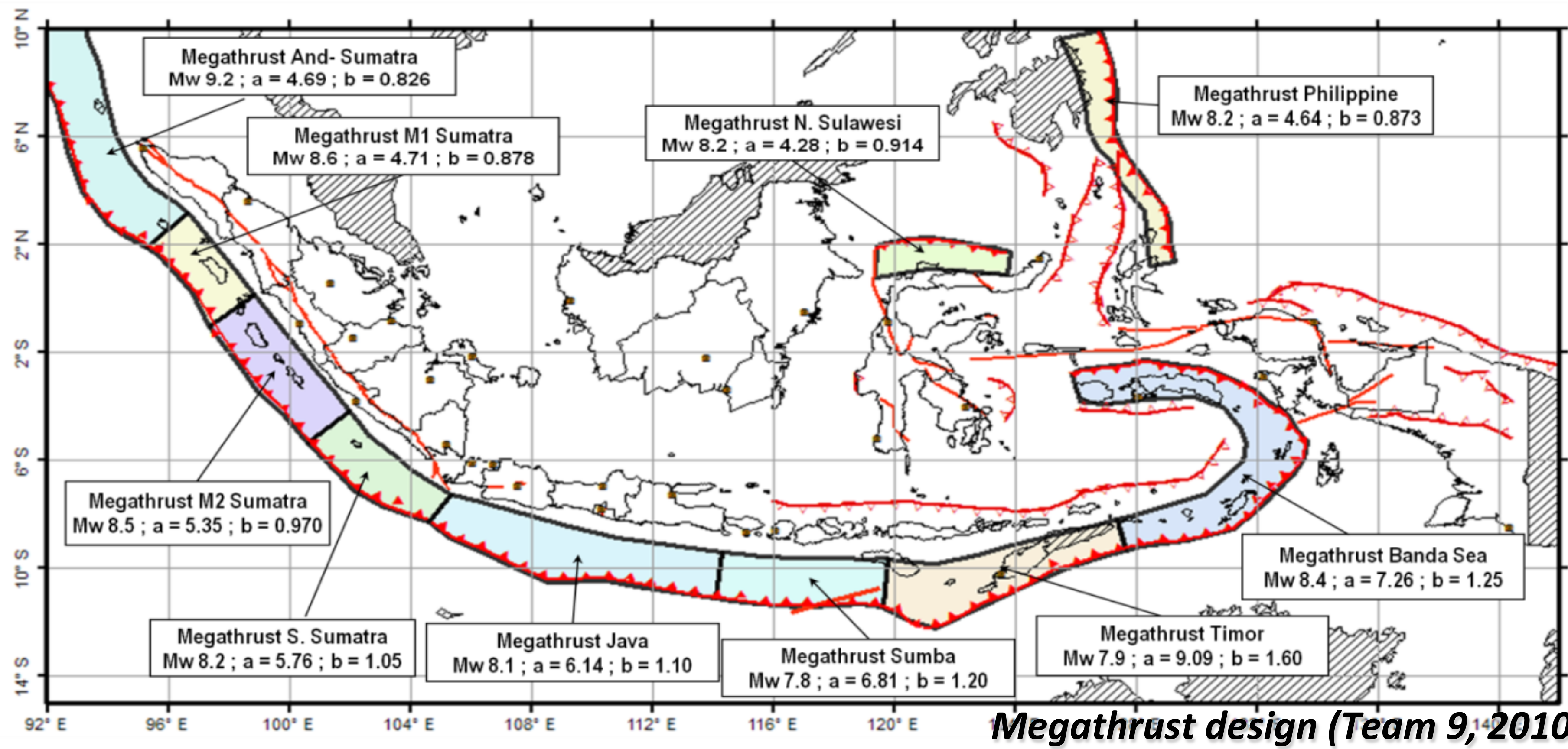
Current GPS Seafloor Technology cannot be use in real-time mode.

INA-DONET is plan to be real-time

Hanifa, et al., ISEDM 2015

Other Activity
Research Center for Disaster Mitigation

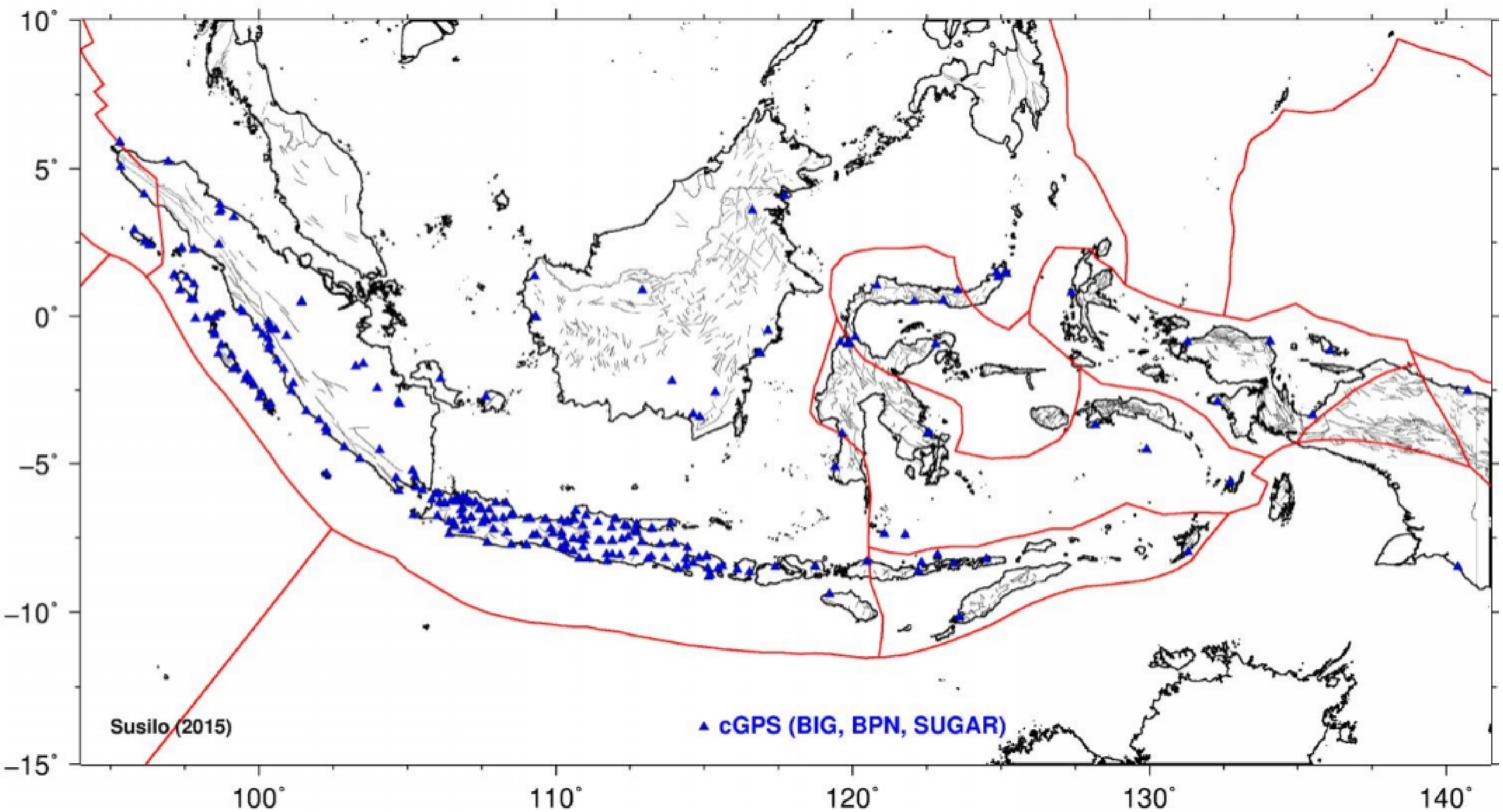
- Development of University Strengthening Program for Enhanced Contribution in Disaster Risk Reduction in Eastern Indonesia



***Megathrust design (Team 9, 2010)*:**

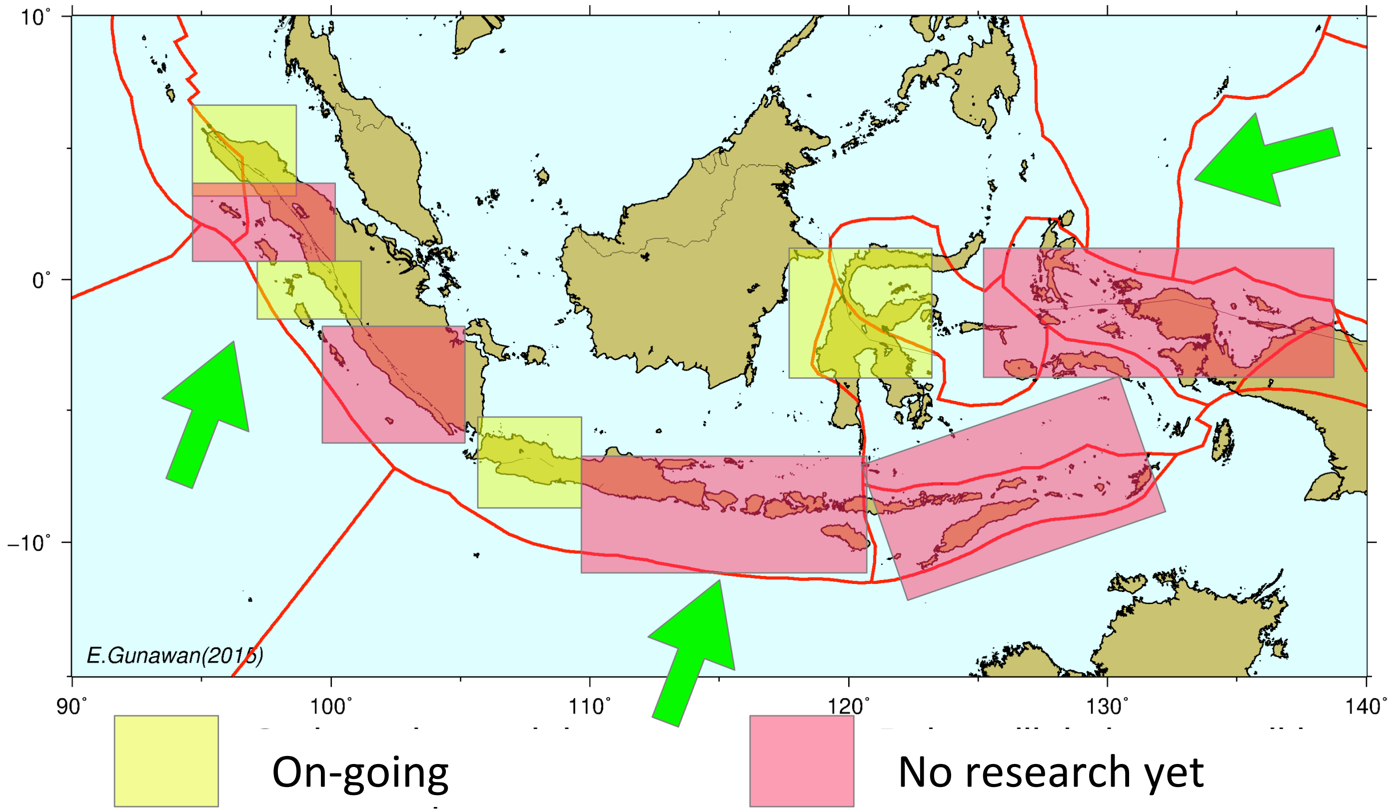
Other Activities:
Graduate Research on Earthquake and Active Tectonics

- Implementation of Deformation Model for Economic Risk Reduction due to Earthquake Hazard

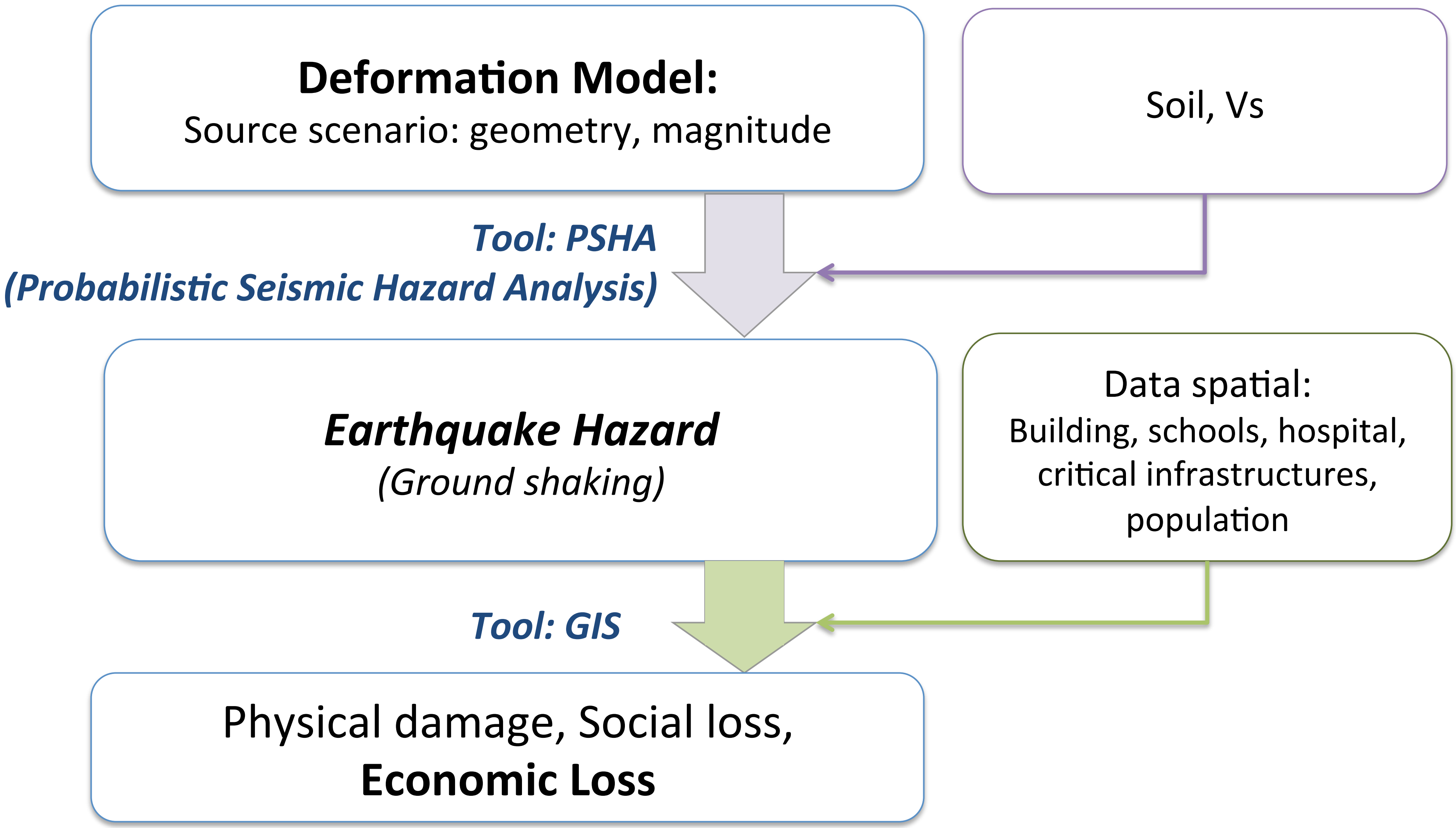


Other Activities:
Graduate Research on Earthquake and Active Tectonics

- Deformation Model: To understand tectonic process before (interseismic phase), during (coseismic phase) and after (postseismic phase) earthquake.



Implementation of Deformation Model for Economic Risk Reduction due to Earthquake



Summary

- CGPS detect strain accumulation off southwestern coast of Java equivalent to at least M8.7.
- Earthquake can rupture to the shallow portion and trigger tsunami.
- Calculated Earthquake intensity is VI MMI in Jakarta.
- The hypothetical tsunami model show that tsunami maximum height up to 30 m in several districts. More than 15 districts affected by 5 m tsunami. ETA for 10 cm tsunami height within 10 minute after EQ.

Summary

- Indonesia propose installation of INA-DONET to
  ① to increase capacity building of earthquake and tsunami disaster mitigation,
  ② to enhance research capacity building.

- The expected advantage of the INA-DONET are
  ① parameter determination of earthquakes under the sea would be faster and more accurate.
  ② information of the earthquake and tsunami early warning system will be faster and more accurate.
  ③ understanding of the characteristics of earthquakes and earthquake prediction will be improved.

International Collaborations are very important for Under water Technology and Ocean Science

Especially, real time monitoring systems and simulation researches are indispensable for disaster mitigation in Indonesia/Japan

(Kaneda, 2015)

Looking forward for
Japan – Indonesia Collaboration

どうもありがとうございました