Mitigasi Tsunami Senyap

G S Prasetya. MSc.(Hons).PhD.

IATsI – Ikatan Ahli Tsunami Indonesia

Isi:

1. LATAR BELAKANG: Definisi Tsunami, Tsunami Disaster Management Fundamental

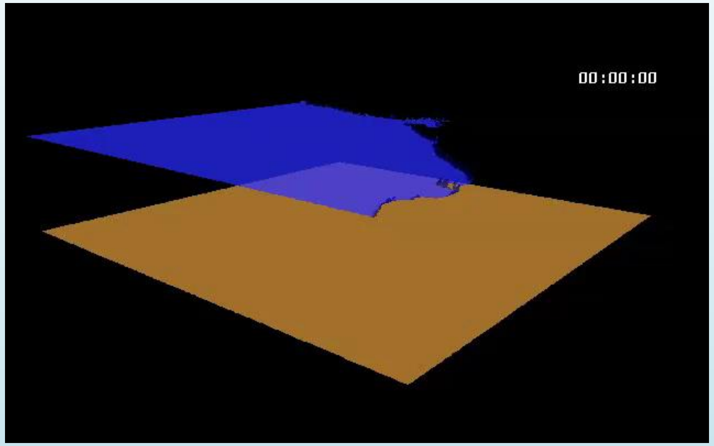
2. SUMBER TSUNAMI:
   2.1. TSUNAMIGENIC EARTHQUAKE
   2.2. VOLCANOGENIC TSUNAMI
   2.3. LANDSLIDE AND SUBMARINE SLUMP TSUNAMI

3.IMPLICATION FOR DISASTER MANAGEMENT
- Pentingnya pemetaan dan karakterisasi sumber tsunami
- Pengaturan Tata Ruang
- Preventions measures – soft and hard
- Early Warning for Tsunami ~ Tsunami-centric

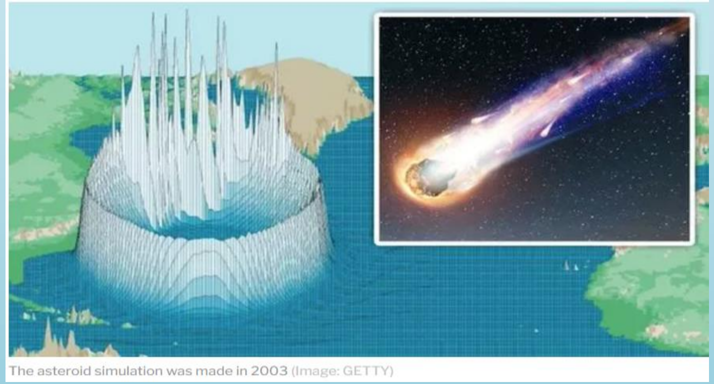
1. LATAR BELAKANG

DEFINISI TSUNAMI

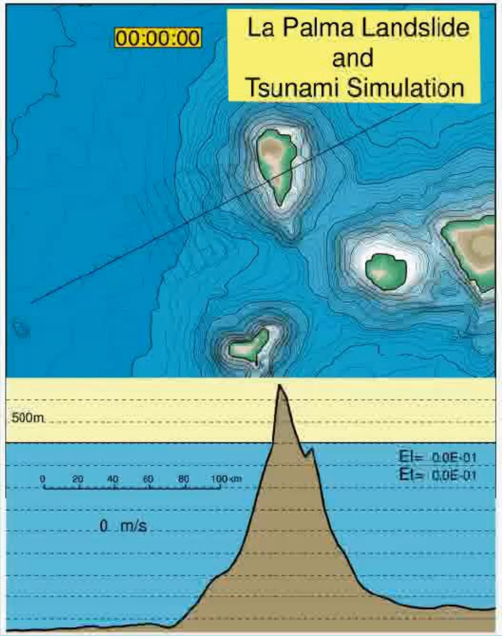
Tsunami merupakan gelombang laut yang terdiri dari 3-5 gelombang yang dibangkitkan oleh **gempa bumi**, **longsoran**, **aktivitas gunung api, Hantaman Asteroid** di Laut dan **Atmospheric pressures/Meteorologi Tsunami** (Rissaga).



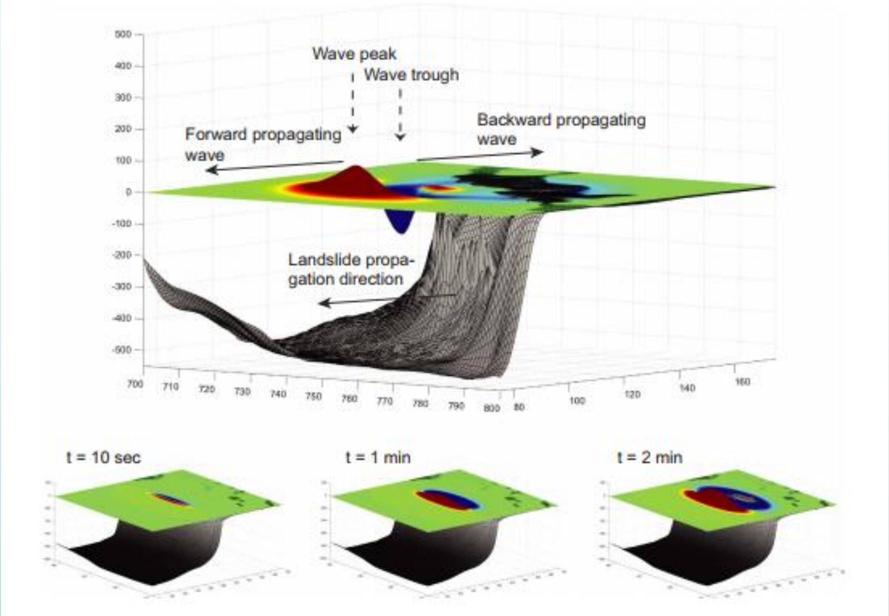
Submarine faulting sources (Imamura,DCRC)



Meteorite Tsunami (Express.co.uk)



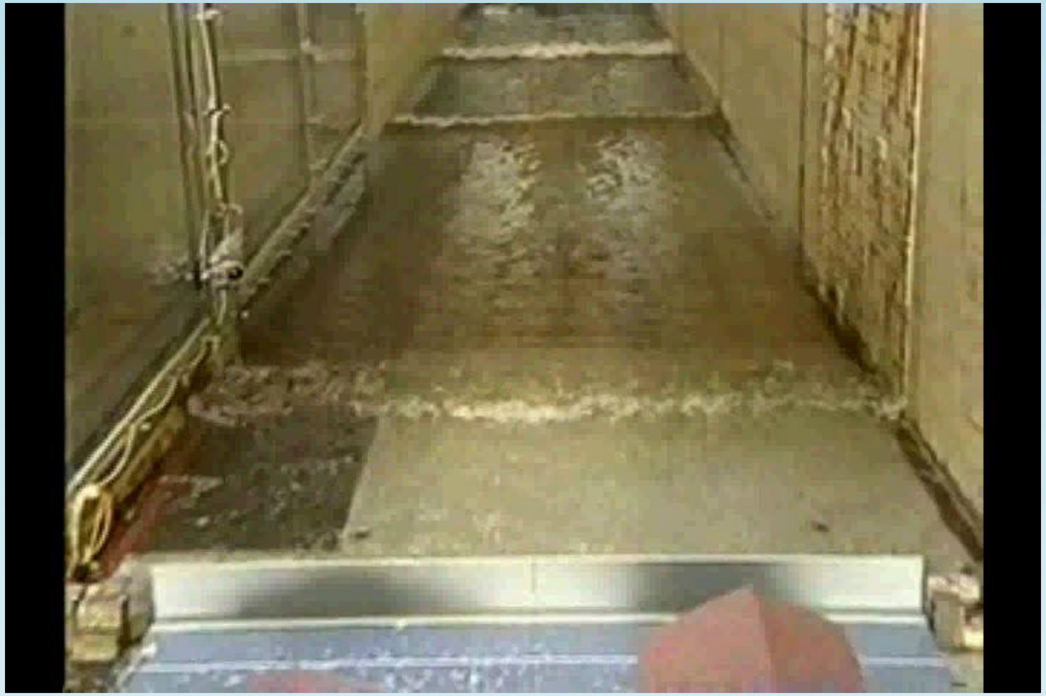
Flank Collapse sources (Ward, S.N)



(Schnyder etal (2016)).

PERBEDAAN MENDASAR
TSUNAMI DAN GELOMBANG LAUT (WIND WAVES)
DAN IMPLIKASINYA DALAM MITIGASI TSUNAMI

Tsunami



Wind Waves

Experimental Video Courtesy of
Dr. Taro Arikawa,
Tsunami Research Center, Port and Aiport
Research Institute, Japan

SKALA PRIORITAS DALAM SIKLUS MANAJEMEN BENCANA

Knowing the Risk and What to do about it

Memiliki pengetahuan mengenai resiko dan tahu apa yang harus dilakukan

Early Warning
Monitoring
Emergency Plan
Capacity Building

Disaster

Search & Rescue

Preparedness

Response

Humanitarian Aid

Mitigation/ Adaptation

Recovery

Damage Assessment
Rehabilitation & Reconstruction

Prevention Soft & Hard Solution
Land-use Planning
Risk Appraisal
Risk Analysis
Risk Identification

PRIORITAS UTAMA

MEMAHAMI PROSES-PROSES YANG TERJADI DI ALAM – MENUJU PEMBANGUNAN BERKELANJUTAN

~ DIBUTUHKAN RISET YANG TERUS MENERUS UNTUK MENGUPDATE KNOWLEDGE MENGENAI SOURCE CHARACTERISTIC~

Tsunami Sejak 1992 –

1992 Flores Tsunami, 1994 East Java, 1996 Tonggolobibi, 1996 Biak; 2000 Banggai……… *business as usual.*

2004, 26 December – Gempa dan Tsunami Aceh (Mw > 9.2) – Samudera Indonesia
(~250 ribu jiwa, total kerugian 42.7 Triliun Rupiah) ---- KESADARAN PERLUNYA TEWS-------
2005, 28 March – Gempa dan Tsunami Nias (Mw 8.5) – Samudera Indonesia
(~ 350 jiwa, total kerugian 10 Triliun Rupiah) ----- INATEWS DIMULAI--------------------
2006, 17 July – (Mw 7.6 – 7.7) Gempa dan Tsunami Pangandaran (Samudera Indonesia)
(~773 jiwa, total kerugian 650 Miliar Rupiah)
2007, 14 September – Mw 8.4 Bengkulu (Indian ocean) ~25 jiwa, total kerugian 1.5 Triliun Rupiah
BNPB didirikan 26 Januari 2008 ……………………………………………………………………….>
INATEWS OPERATION PADA 11 NOVEMBER 2008 --->

PERIODE SEBELUM ADA INATEWS/ BNPB

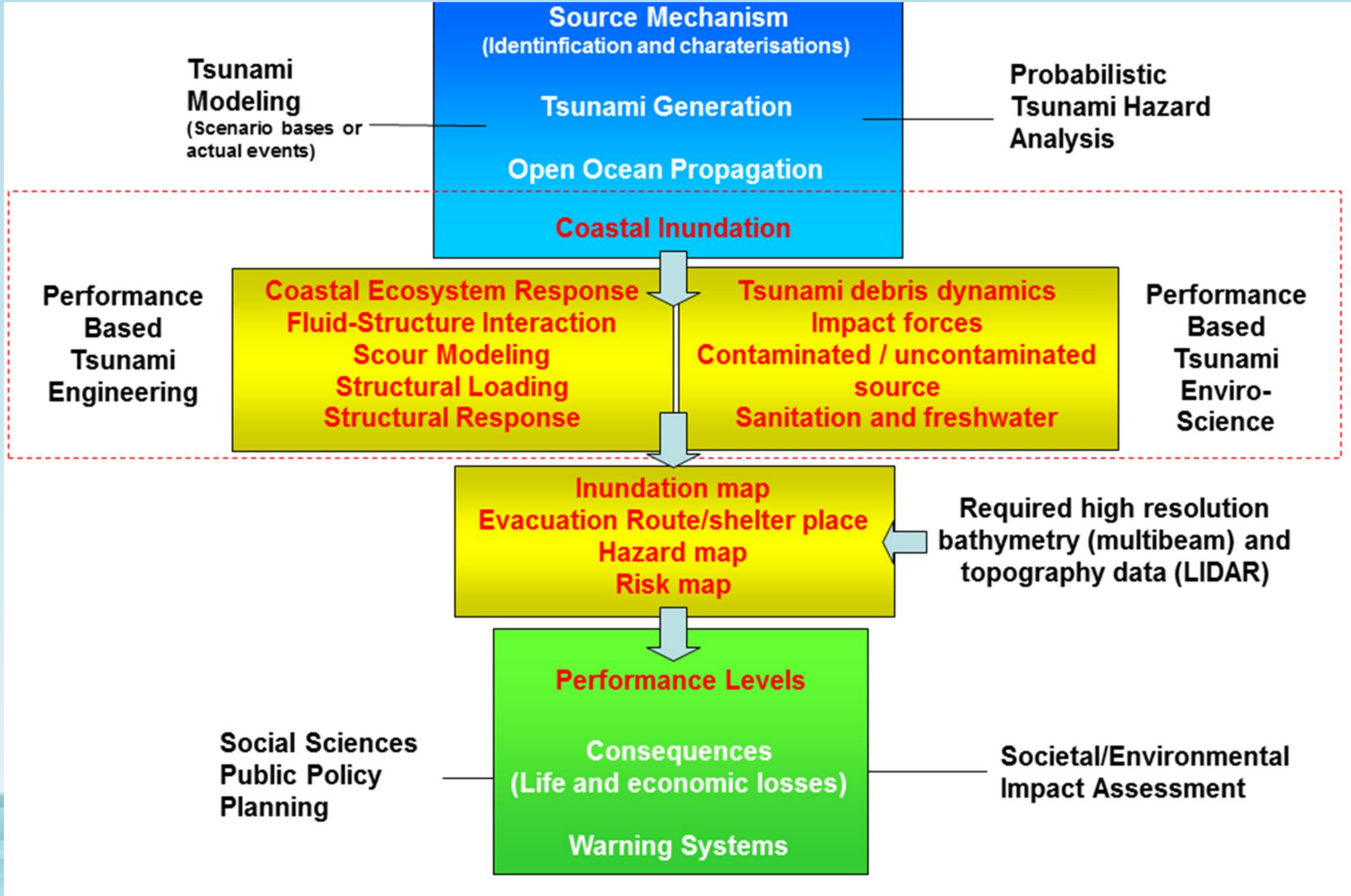
2010, 26 October – Mw 7.2 Mentawai (Indian Ocean) ~712 jiwa, total kerugian 10 Triliun Rupiah
2012, M 8.6 and M8.2 Couplet Earthquake and minor Tsunami – outer rise events! ~ No Tsunami !!!
2018, August - M7.0 Lombok – Local & Minor Tsunami ~564 jiwa, total kerugian 17 Triliun Rupiah
2018, September – M7.7 Palu - Strike Slip Event + Submarine Landslide+Liquefaction
(~ 3474 jiwa, total kerugian 18.4 Triliun Rupiah)
2018, December – Anak Krakatau Volcanic Eruption ~583 jiwa, total kerugian masih dihitung.

PERIODE SESUDAH ADA INATEWS /BNPB

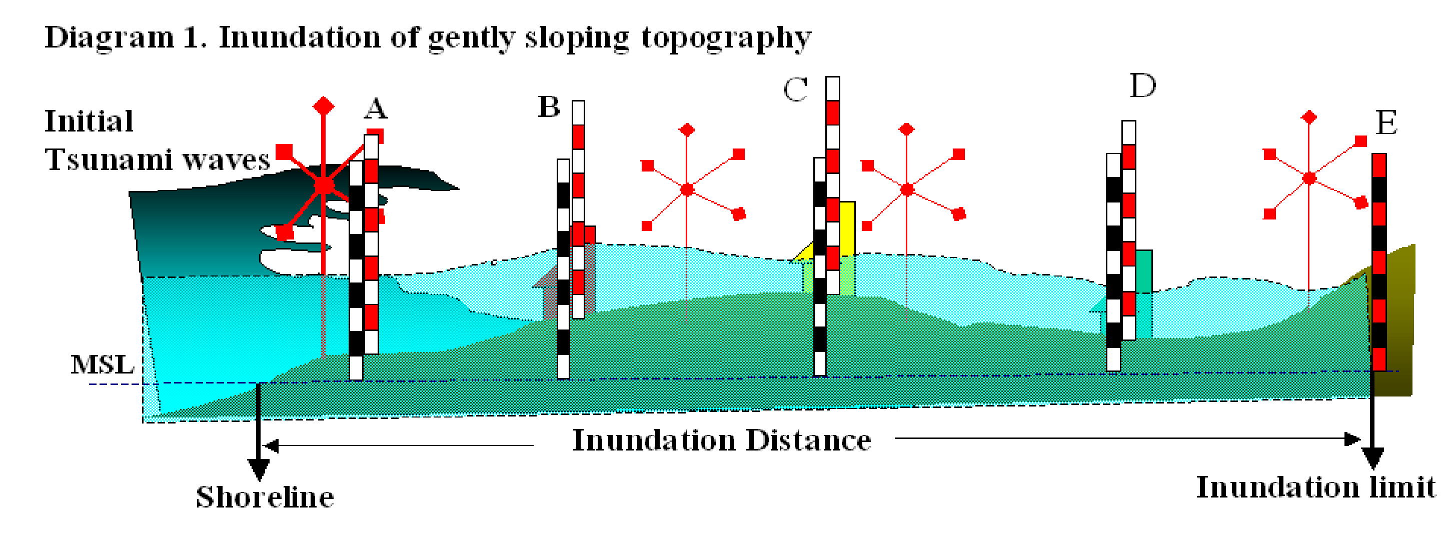
KORBAN JIWA DAN HARTA BENDA MASIH TERJADI
EARLY WARNING DAN ATAU UPAYA-UPAYA MITIGASI TIDAK BERJALAN ?

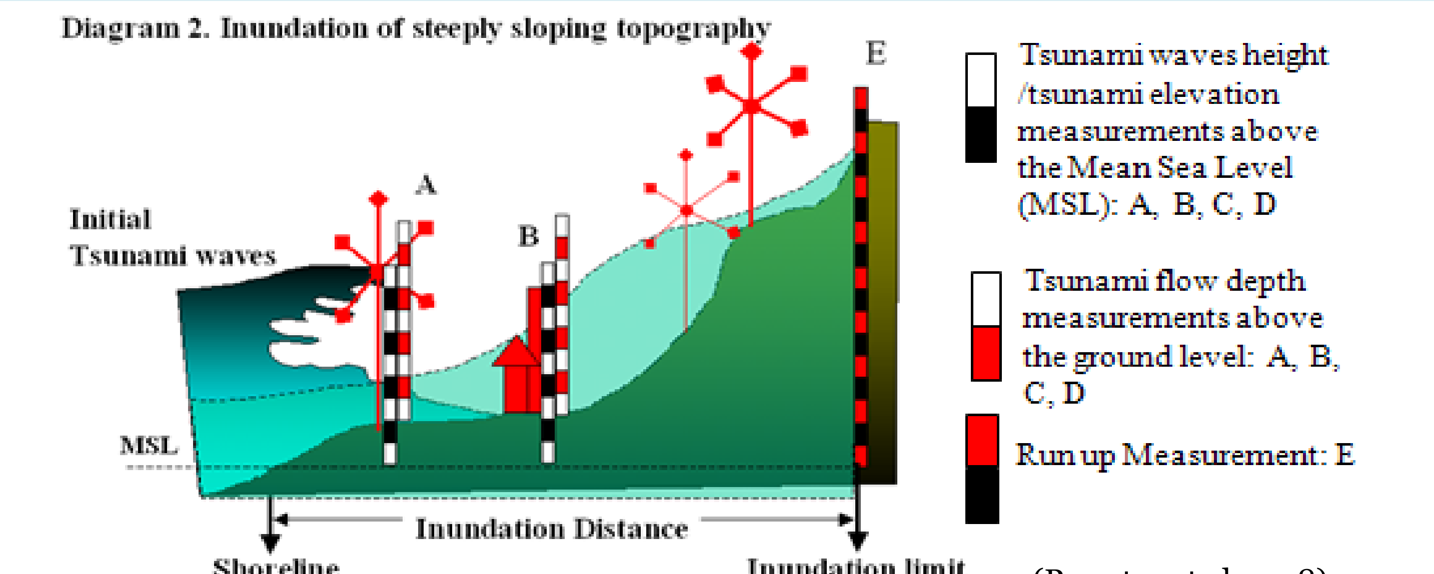
Tsunami Hazards and Disaster Management Fundamental Elements

(Source: G.Prasetya after Riggs and Robertson, 2010)



TSUNAMI TERMINOLOGY





(Prasetya et al.2008)

Tsunami Hazards is due to the forces of tsunami with their components:

- Tsunami height/inundation height/flow depth
- Inundation flow velocity – wavelenght
- Debris/flotsam carried by tsunami

Summary of changes using Linear Theory

Depth : 6.25 km → 10 m

- **Length, phase and group velocity: decrease** $\left(\frac{h_1}{h_2}\right)^{0.5} = \left(\frac{h_1}{h_2}\right)^{1/2}$ 25 x
- **Heigth / amplitude: increase** $\left(\frac{h_1}{h_2}\right)^{0.25} = \left(\frac{h_1}{h_2}\right)^{1/4}$ 5 x
- **Water velocity: increases** $\left(\frac{h_1}{h_2}\right)^{0.75} = \left(\frac{h_1}{h_2}\right)^{3/4}$ 125 x

Notes : Non-linearity can contribute a higher tsunami height and flow velocity

(Source: Prof.Tarmo Sommere).

KATEGORI TSUNAMI:

TSUNAMI YANG BERSUMBER DARI GEMPA BUMI:

- **Tsunami Dekat (NEAR_FIELD):** tsunami yang terjadi dengan sumber yang dekat dengan pantai. Umumnya penduduk didaerah pesisir merasakan goncangan gempanya. **Waktu tempuh tsunami < 30 menit**.
- **Tsunami Jauh (FAR FIELD):** tsunami yang terjadi dengan sumber yang jauh dari pantai. Umumnya penduduk daerah pesisir tidak merasakan goncangan gempa. **Waktu tempuh tsunami > 3 jam, tsunami ini dikenal pula sebagai *'TSUNAMI SENYAP'***
- **TSUNAMI EARTHQUAKE :** Tsunami ini dikenal sebagai ***'TSUNAMI SENYAP'*** arti secara harfiah nya, gempa dengan magnitudo yang relative kecil namun mampu membangkitkan tsunami yang lebih besar dari seharusnya.

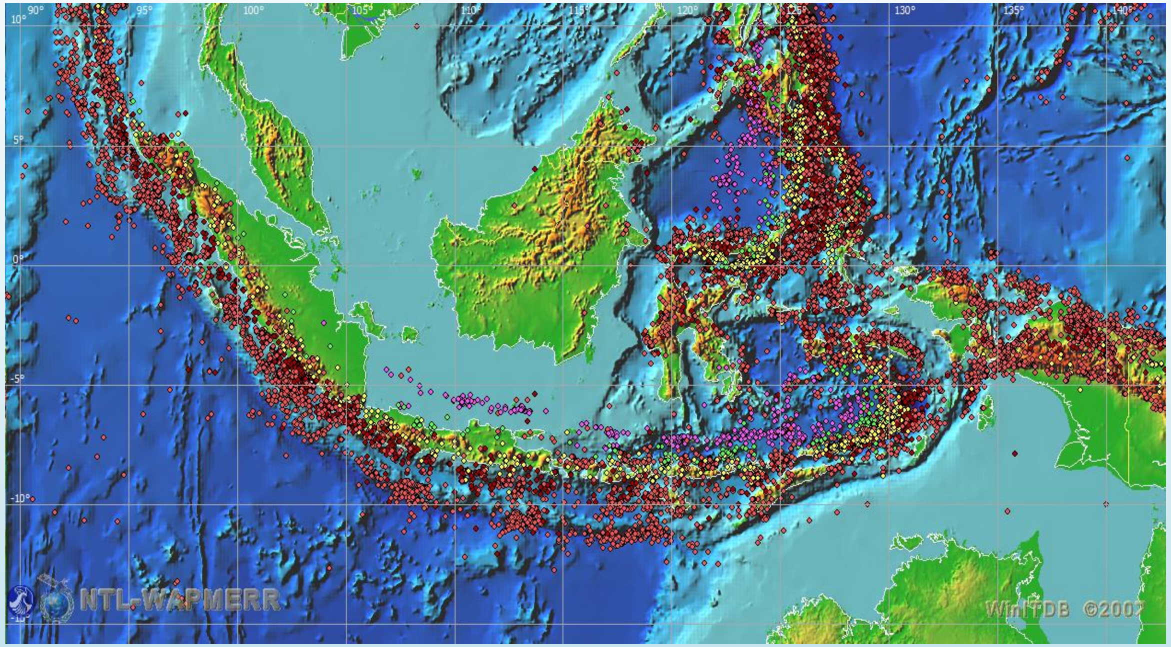
TSUNAMI AKIBAT AKTIVITAS GUNUNG BERAPI:

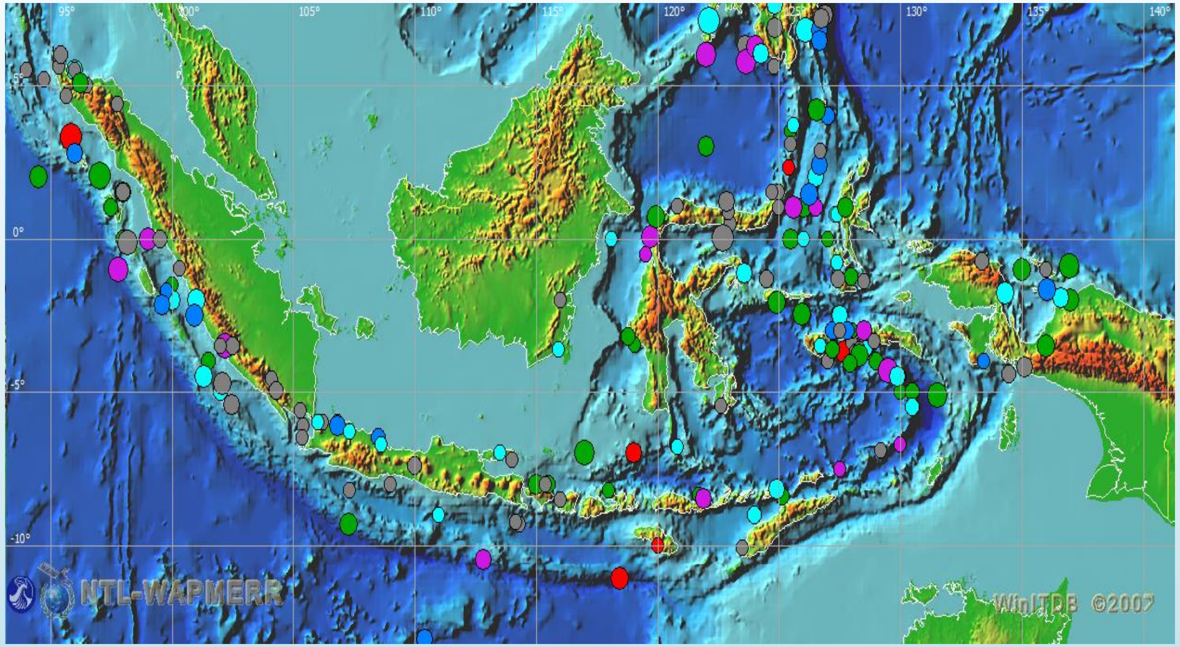
- Tsunami akibat runtuhnya setengah dari badan gunung Api/flank collapse
- Tsunami akibat runtuhnya Kaldera
- Tsunami akibat luncuran aliran pyroclastic
- Tsunami akibat ledakan/explosion dari gunung api
- Tsunami akibat adanya *lateral blast*.

Sebagian mekanisme tsunami dari aktivitas vulkanik ini dapat dikategorikan sebagai ***'TSUNAMI SENYAP'***

TSUNAMI LONGSORAN (LANDSLIDE, SLUMPS): tsunami yang terjadi akibat longsoran bawah laut yang diakibatkan oleh adanya gempa bumi ataupun erupsi gunung berapi. Tsunami akibat longsoran ini juga dapat dikatergorikan sebagai ***TSUNAMI SENYAP***.

SECARA HISTORIS – Sejak Tahun 416 tercatat 215 tsunami.



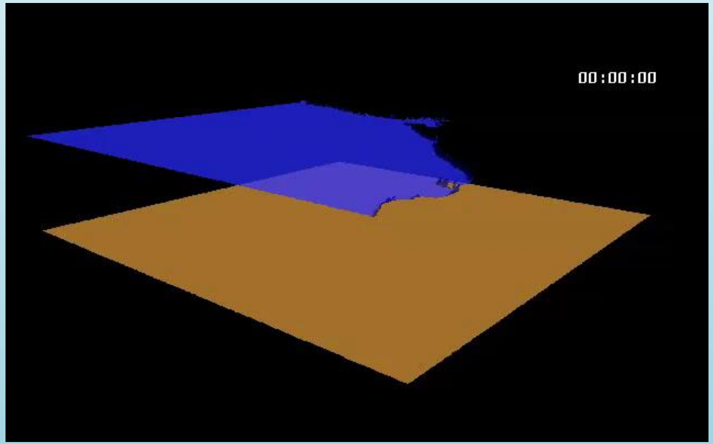


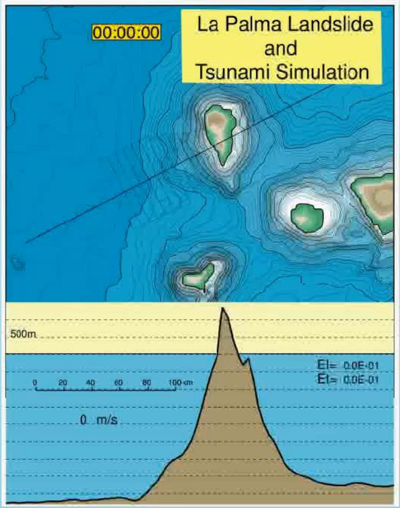
Data Historis Gempabumi, Jarak zona gempa bawah laut <300km , waktu tempuh tsunami < 30 menit.

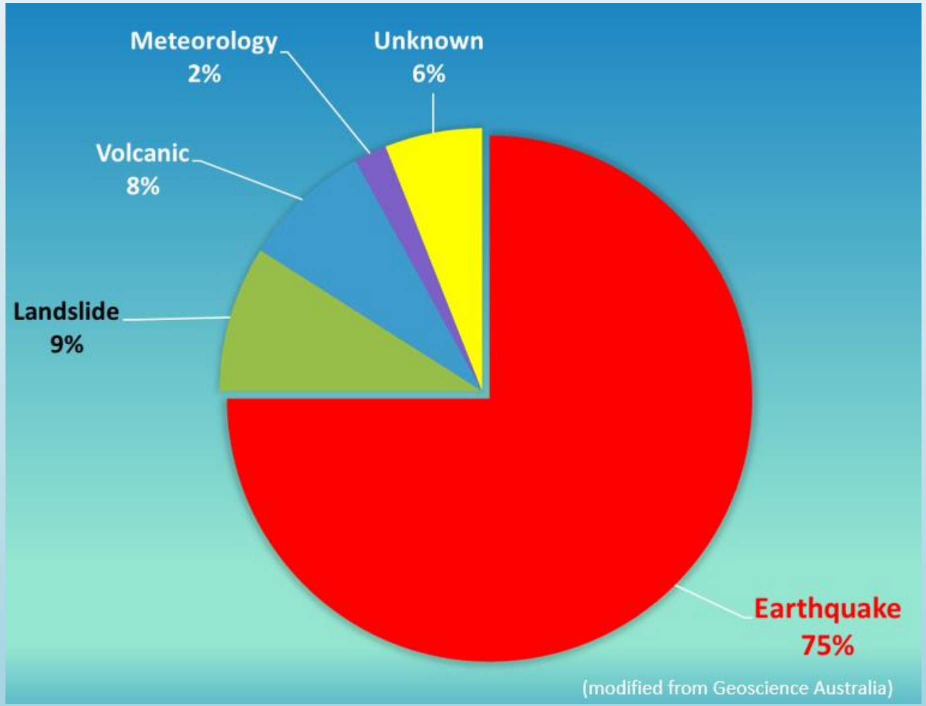
Data Historis Tsunami, menunjukan sumber tsunami dari tektonik dan non tektonik (gunung api contohnya Krakatau 416,1883, Tambora 1815 dan Bande Api , submarine landslide – Flores 1992, Banda 1979)

2. SUMBER TSUNAMI

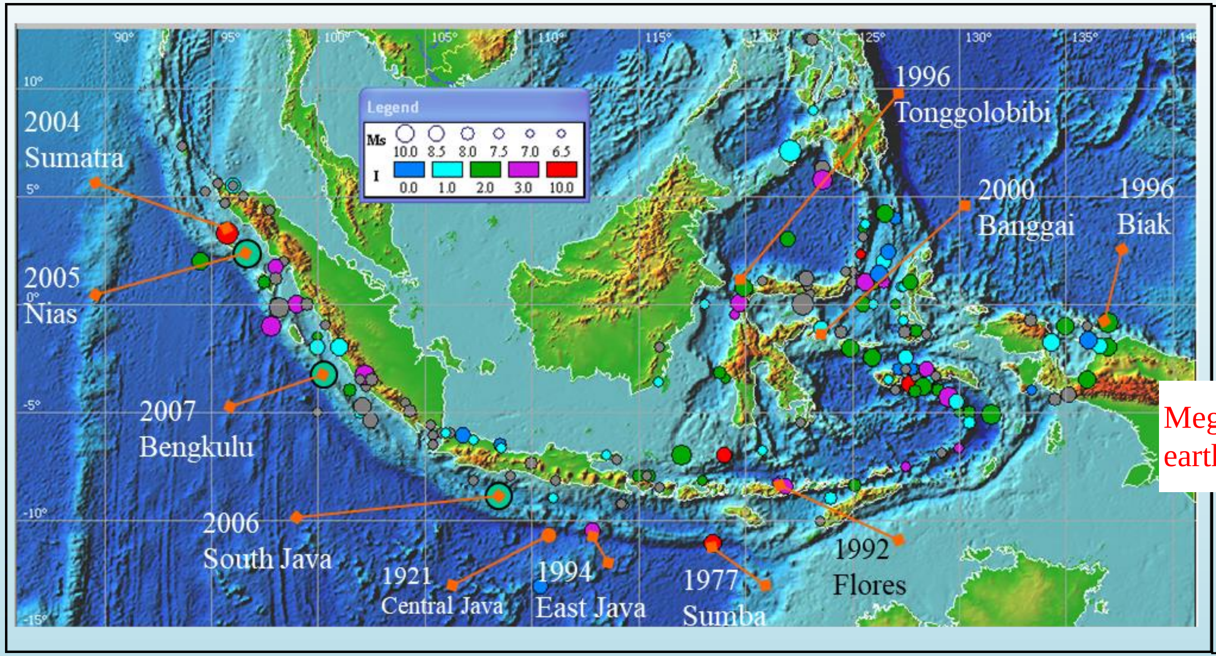
- **Gempabumi (Earthquake): 75%**
- **Longsoran Bawah Laut (Submarine Landslide): 9%**
- **Aktivitas Gunung Berapi (Volcanogenic Tsunami): 8%**
- **Meteorologi (Rissaga): 2%**
- **Unknown Source:6%**
  (~ hantaman meteorit)

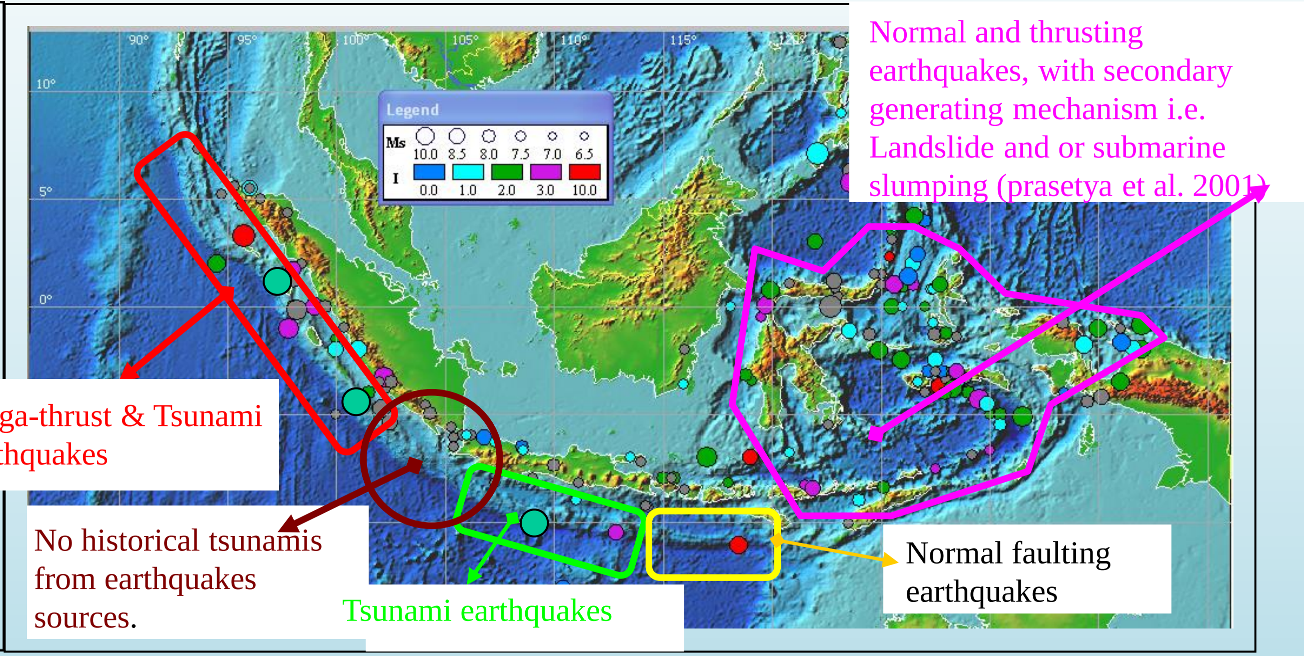






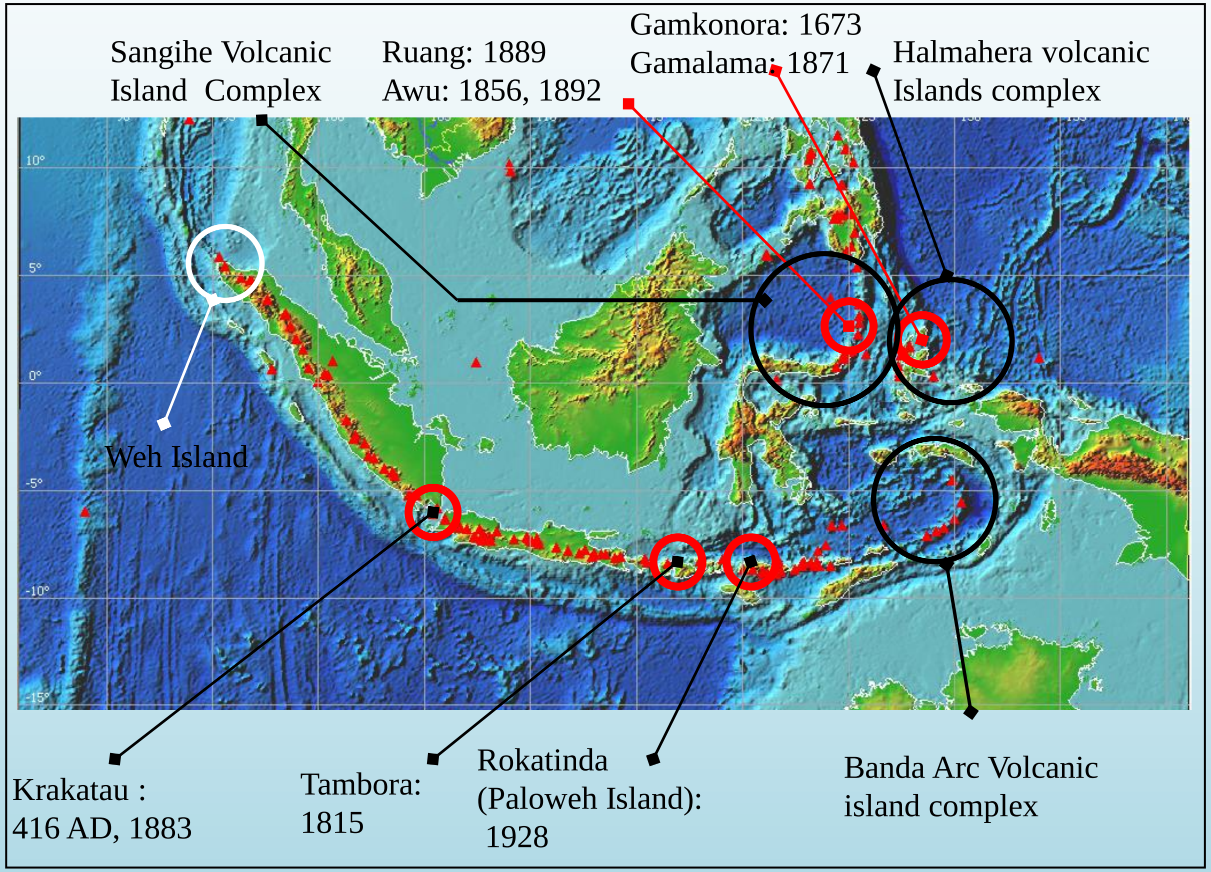
2.1. TSUNAMIGENIC EARTHQUAKE SOURCE





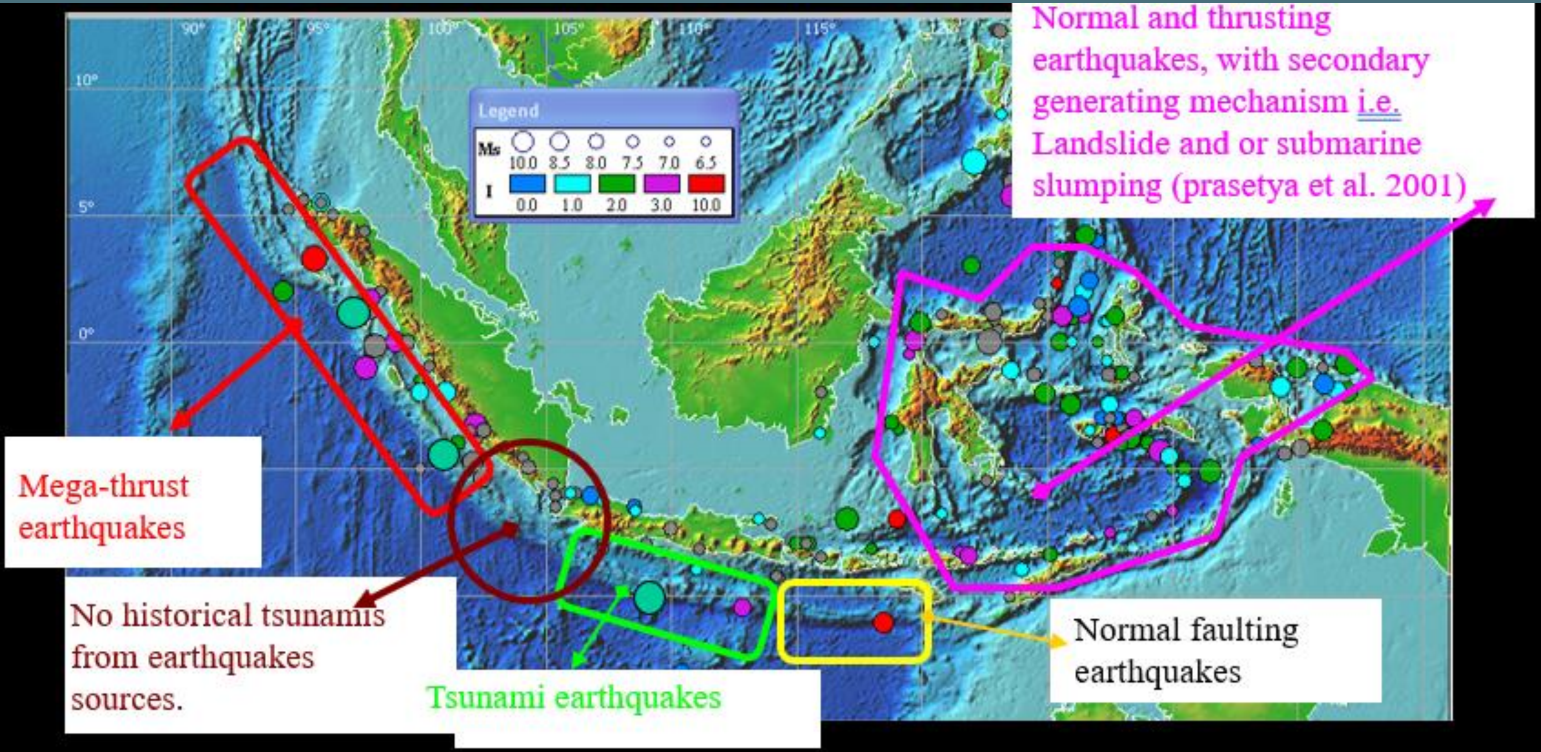
(Prasetya et.al 2009)

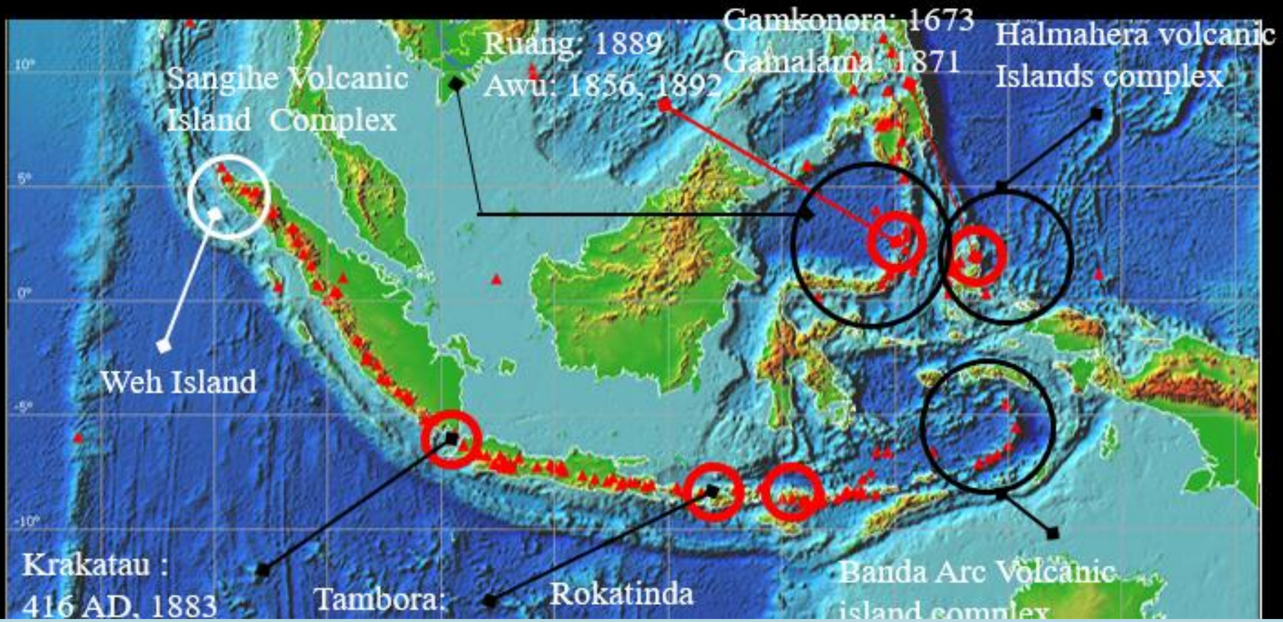
2.2. VOLCANOGENIC TSUNAMI SOURCE



(Prasetya et.al 2009)

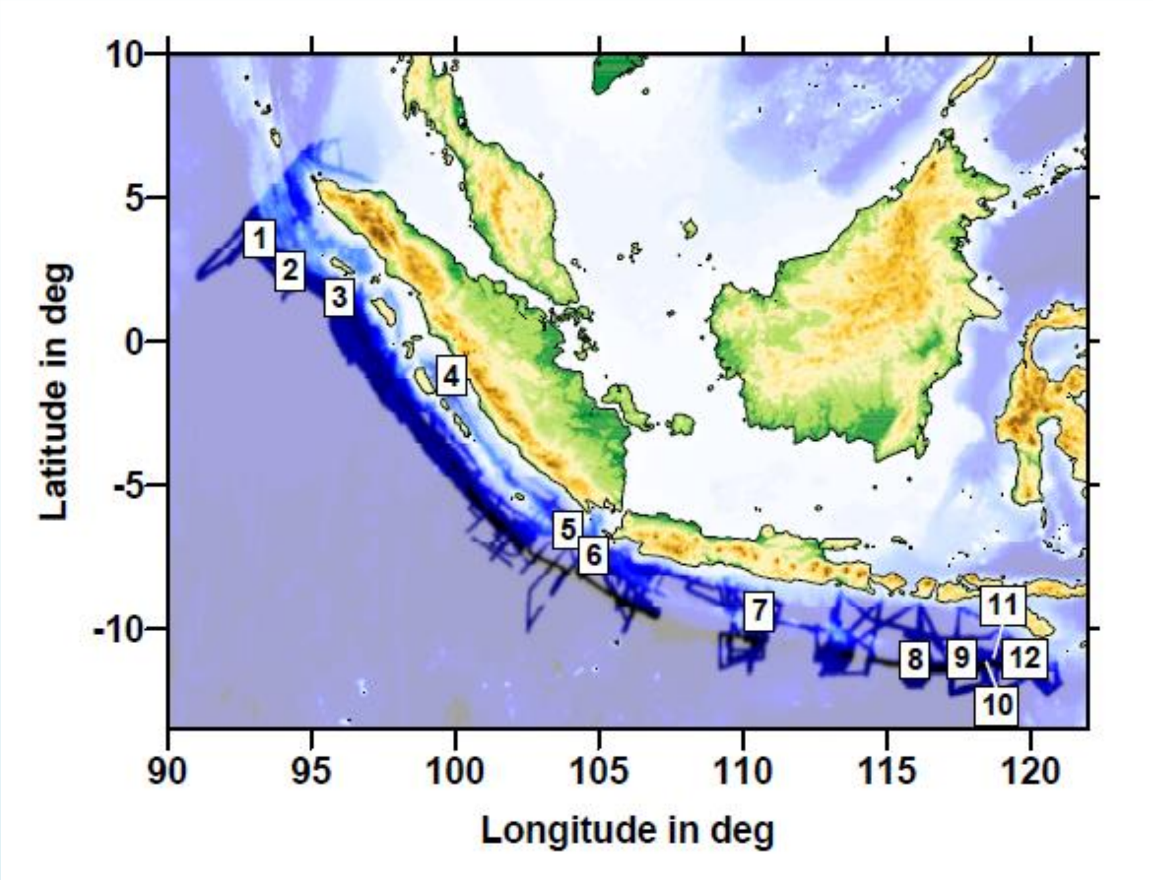
CLUSTER Tsunamigenic Earthquake Vs Volcanogenic Tsunami

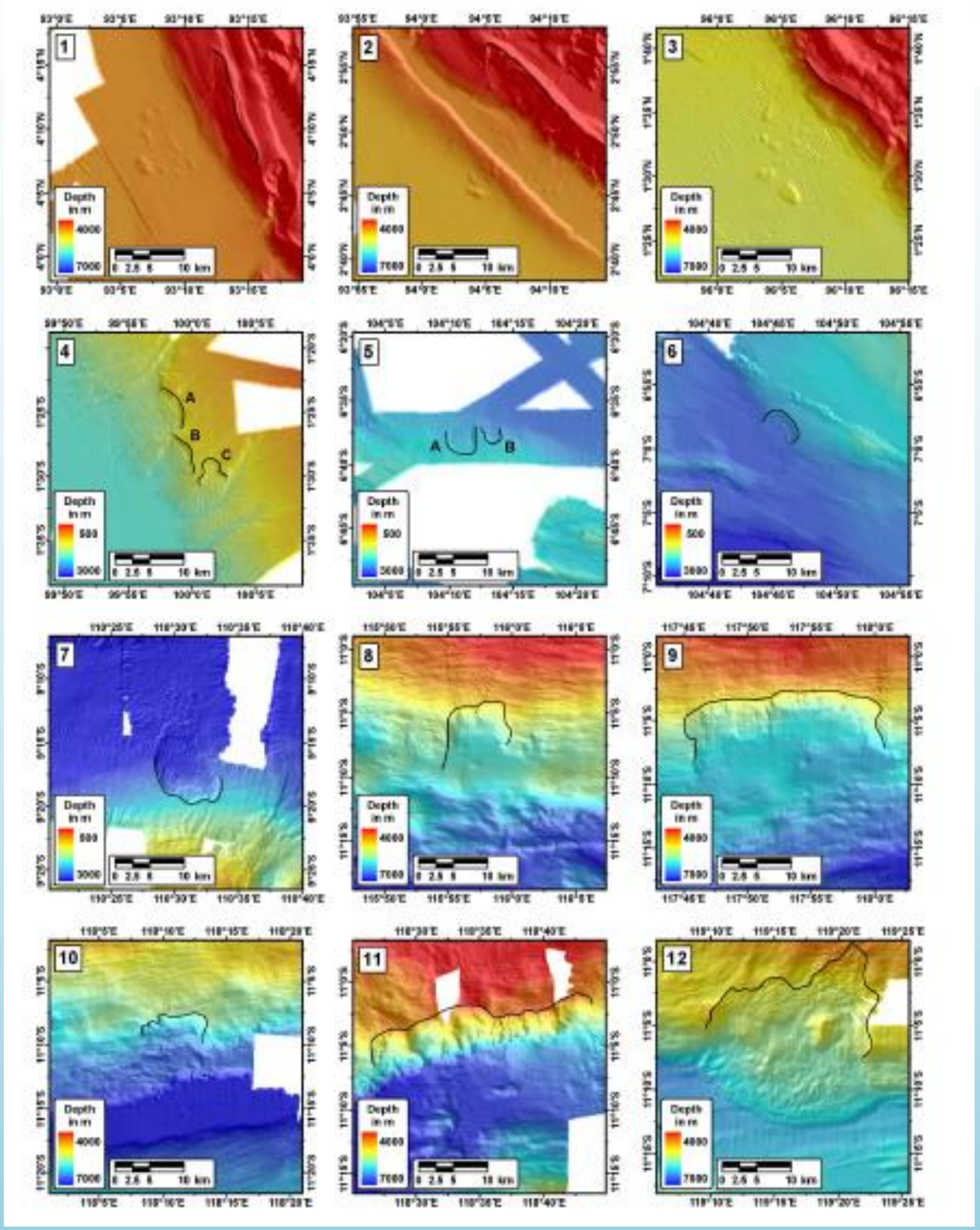




Prasetya et al. (2009).

2.3. LANDSLIDE TSUNAMIGENIC SOURCE

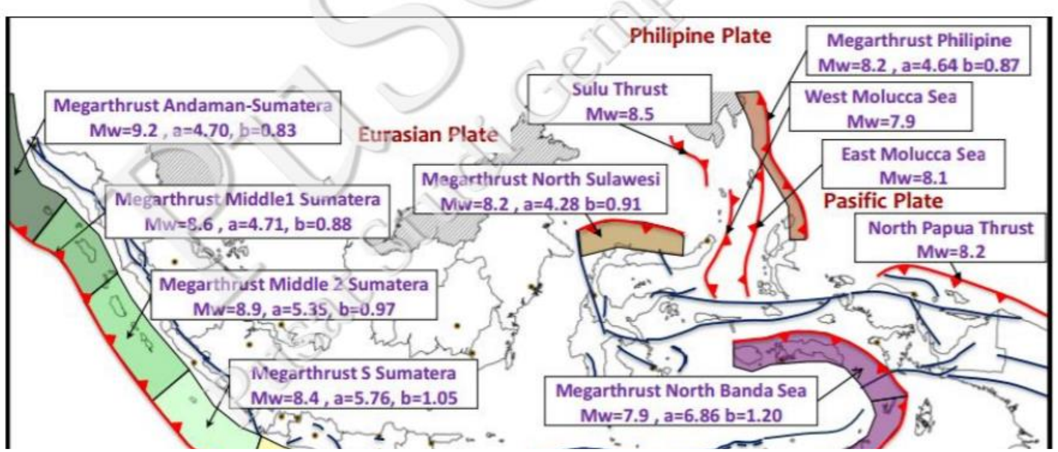




Bathymetry images of the landslides. Head scarp interpretations are marked as black lines. Locations are mapped in 1, 2, 3, and 4 have been previously published by Moran and Tappin (2006), Henstock et al. (2006), Kopp et al. (2008, 2006), respectively. Note: the different depth scales for slides in for-arc basins (3000 to 500 m) and near the trench (7000 to 4000 m) (source: Brune etal.2010).

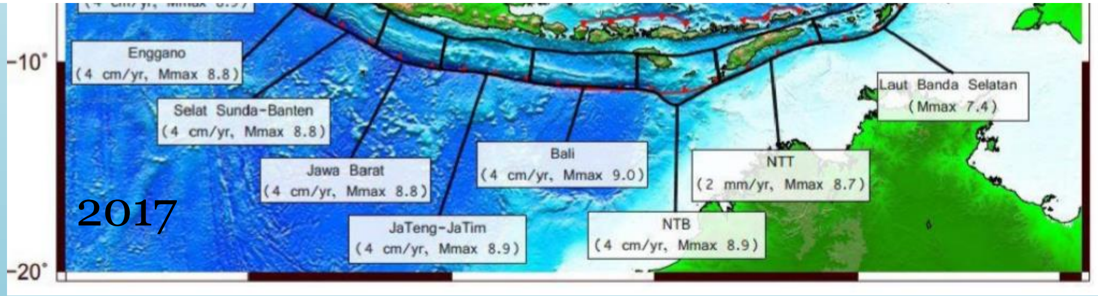
2.1.1. TSUNAMIGENIC EARTHQUAKE

MEGATHRUST EARTHQUAKE:
Didefinisikan sebagai gempa yang terjadi di zona subduksi dengan Magnitudo M>8.0



PELAJARAN YANG DIAMBIL ADALAH:
BESAR KECILNYA MAGNITUDO GEMPA TIDAK SELALU BISA DIJADIKAN ACUAN ATAU UKURAN BESAR KECILNYA TSUNAMI YANG TERJADI !

tsunami yang dibangkitkannya memberikan dampak yang besar/destruktif. Kanamori (1972) pertamakali memperkenalkan istilah Tsunami Earthquake ini untuk Tsunami yang terjadi di Sanriku Jepang.



CONTOH TSUNAMI EARTHQUAKE DI INDONESIA

- TSUNAMI JAWA TIMUR 2004, M7.8 – ketinggian runup mencapai >12m.
- TSUNAMI PANGANDARAN 2006, M7.7 – ketinggian runup mencapai 10-21m
- TSUNAMI MENTAWAI 2010, M7.8 – ketinggian runup mencapai >10m

Secara teoritis M7.8 menghasilkan tsunami runup <5m

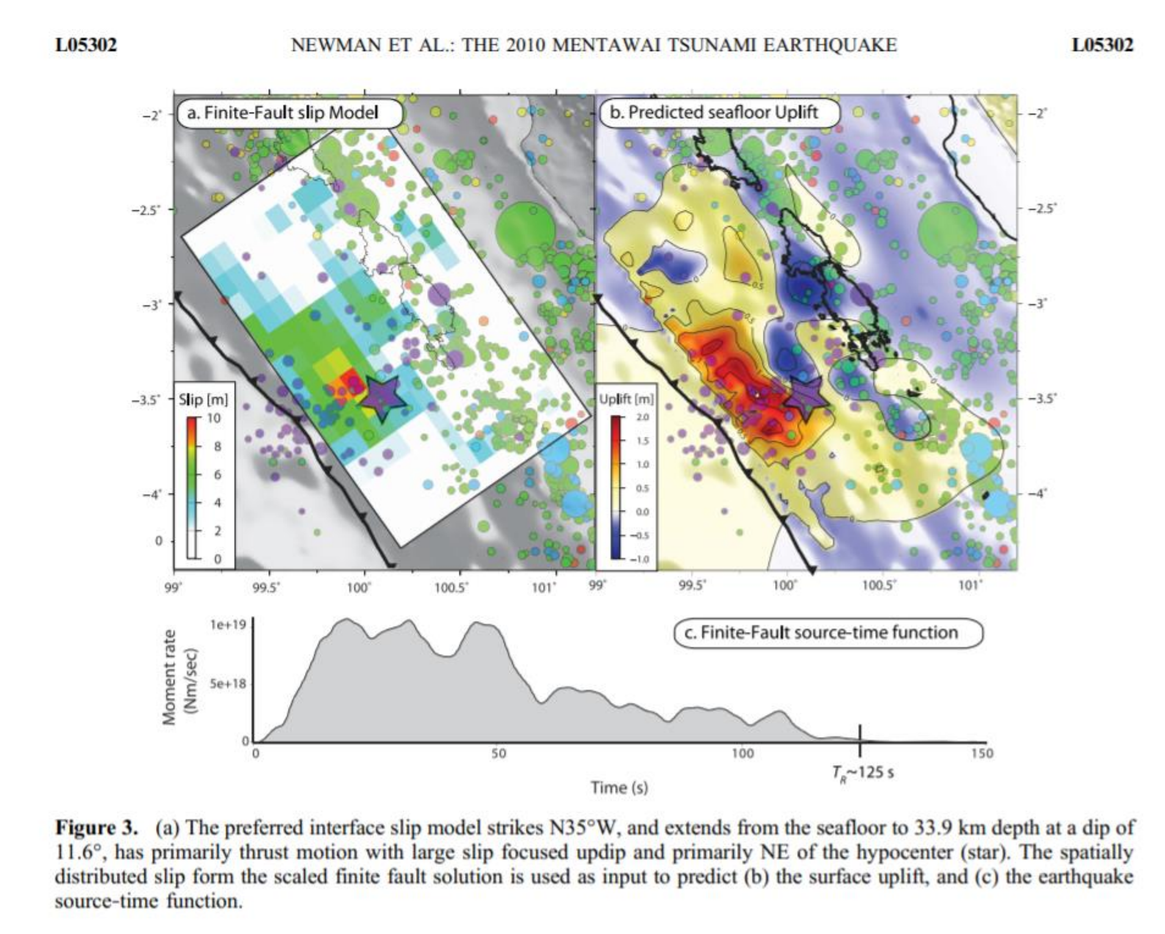
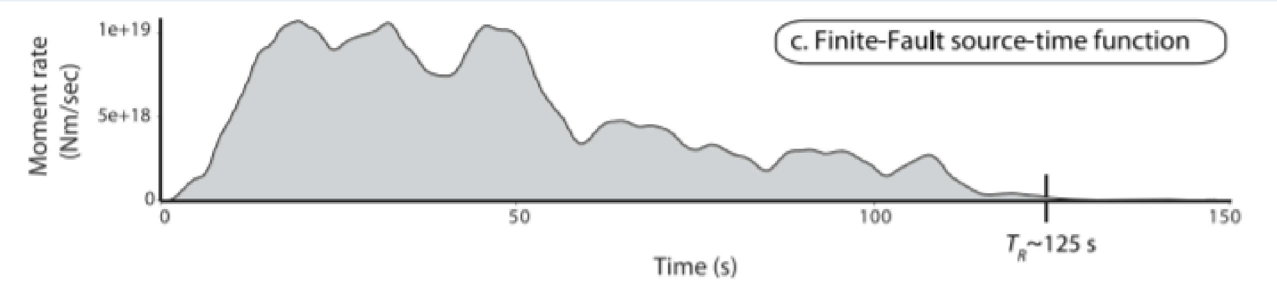
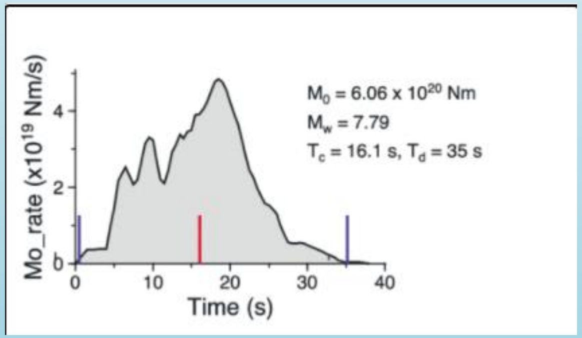

L05302 NEWMAN ET AL.: THE 2010 MENTAWAI TSUNAMI EARTHQUAKE L05302

Figure 3. (a) The preferred interface slip model strikes N35°W, and extends from the seafloor to 33.9 km depth at a dip of 11.6°, has primarily thrust motion with large slip focused updip and primarily NE of the hypocenter (star). The spatially distributed slip form the scaled finite fault solution is used as input to predict (b) the surface uplift, and (c) the earthquake source-time function.

Perbedaan source-time function antara Tsunami Earthquake dengan Earthquake biasa untuk M7.79

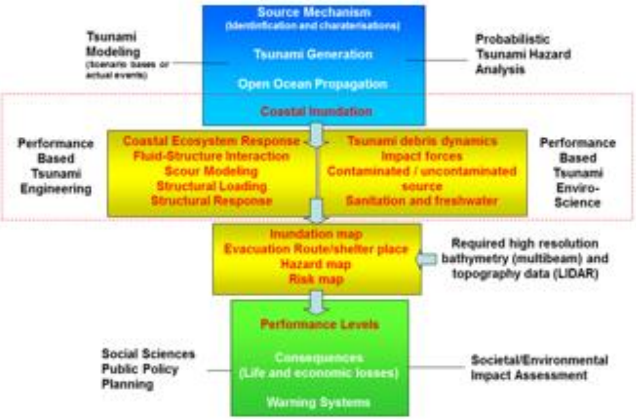


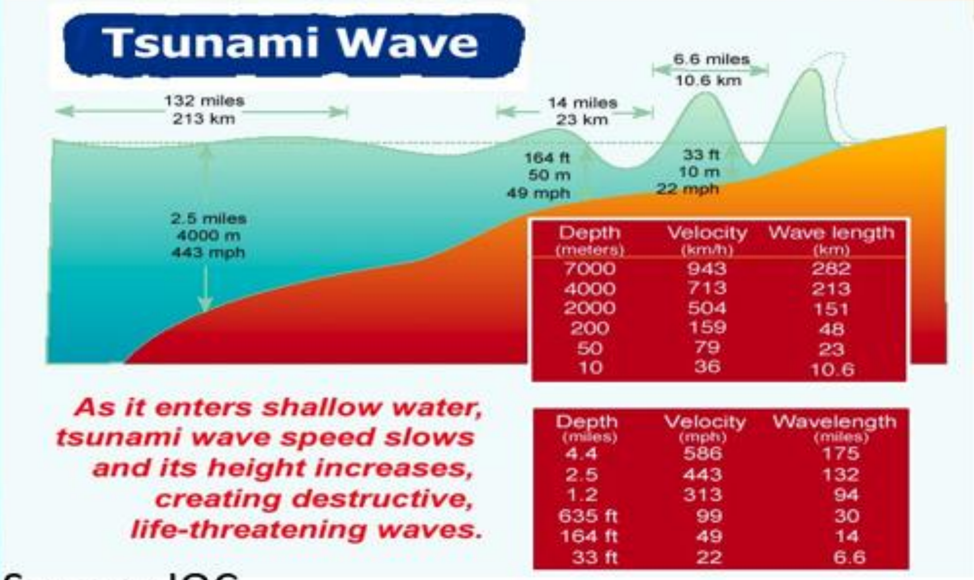
Tsunami Earthquake dengan M7.79



Gempa biasa dengan M7.79

SIKLUS HIDUP TSUNAMI

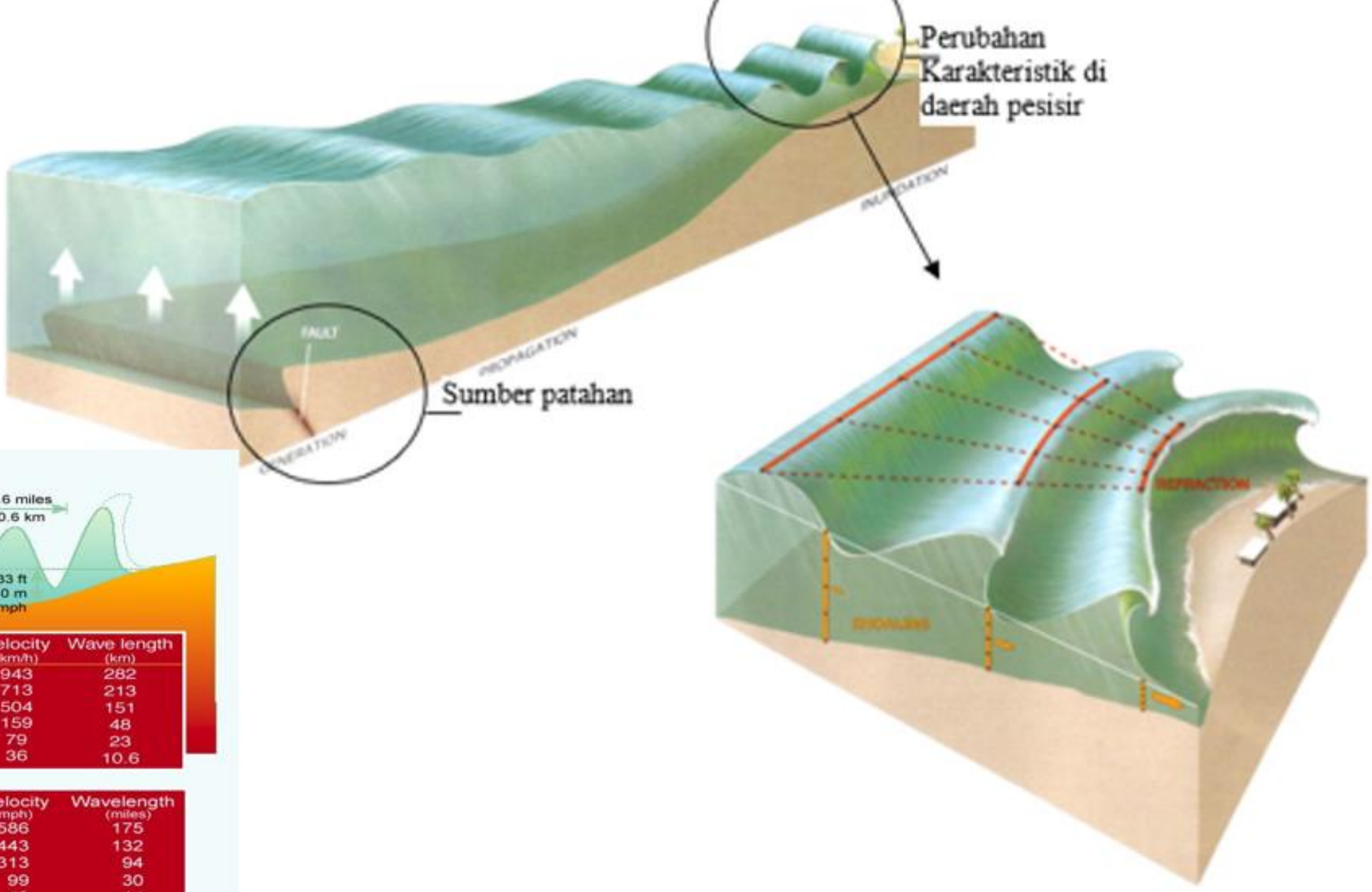




Depth (meters)	Velocity (km/h)	Wave length (km)
7000	943	282
4000	713	213
2000	504	151
200	159	48
50	79	23
10	36	10.6

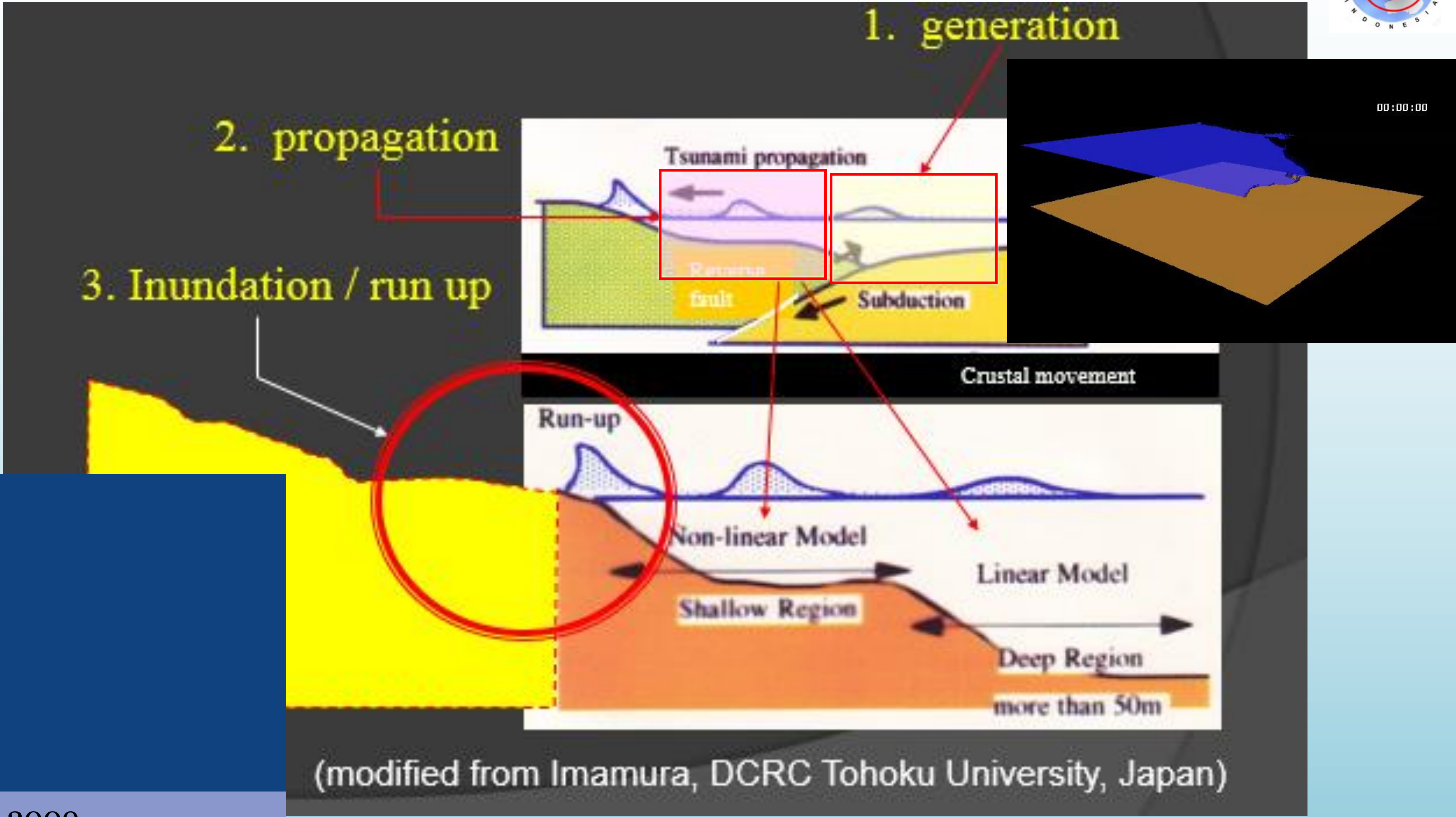
Depth (miles)	Velocity (mph)	Wavelength (miles)
4.4	586	175
2.5	443	132
1.2	313	94
635 ft	99	30
164 ft	49	14
33 ft	22	6.6

Source: IOC



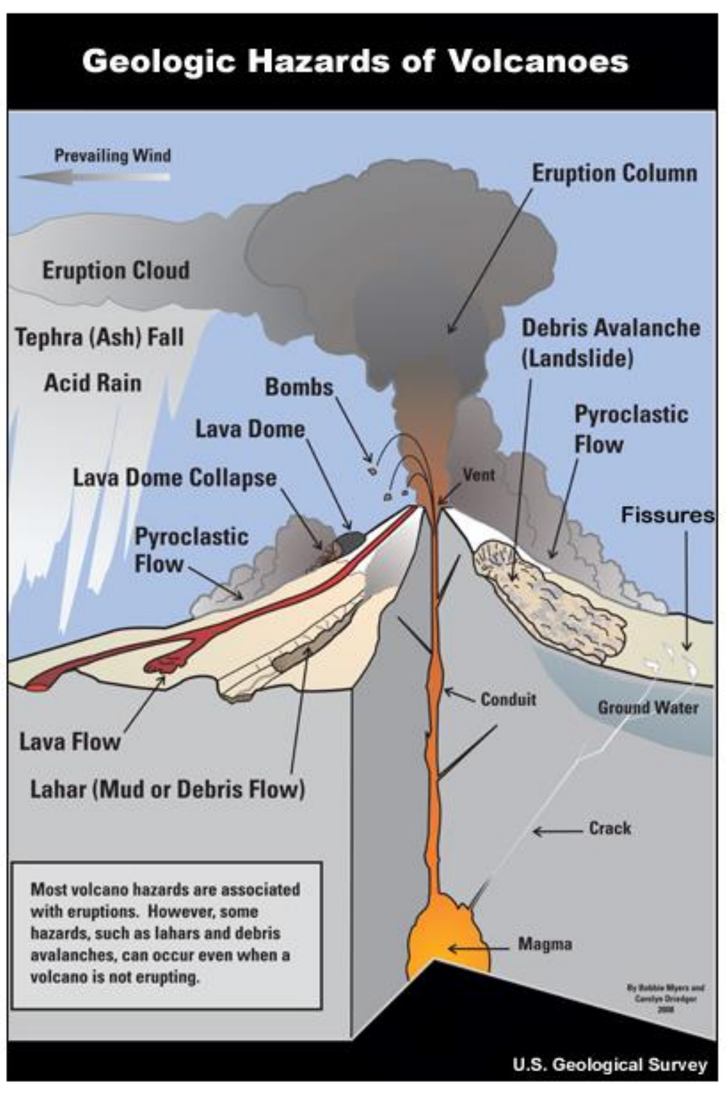
Source: Gonzales, 1990

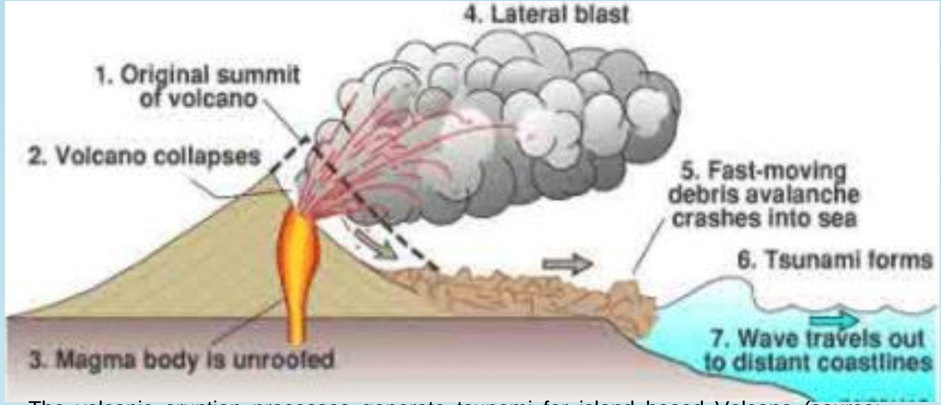
TSUNAMI LIFE CYCLES FROM EARTHQUAKE SOURCES



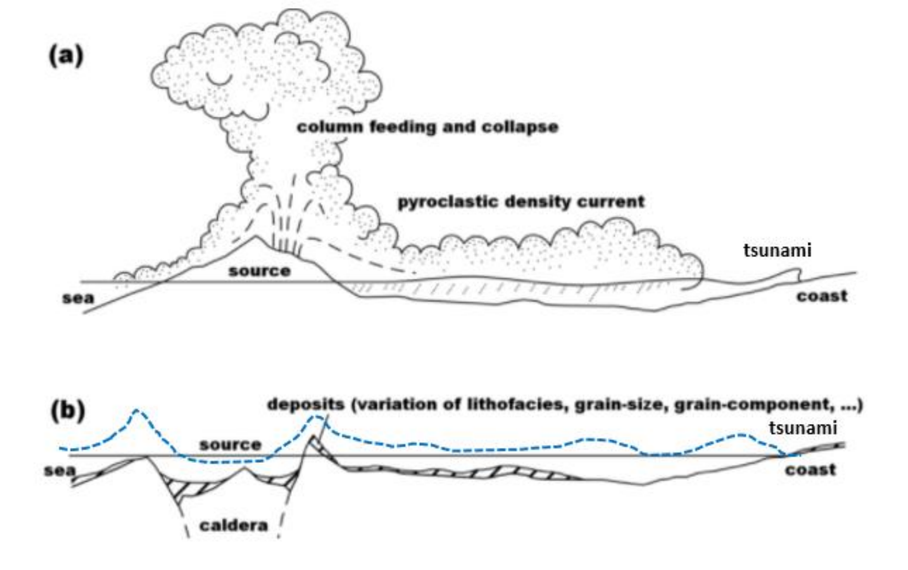
Prasetya et.al 2009

2.2.1 Volcanic Tsunamis – the complexities and uncertainties





The volcanic eruption processes generate tsunami for island based Volcano (source: http://academic.evergreen.edu/g/grossmaz/springle/)



Tsunami generated by volcanic island eruption where (a) is representing the process of pyroclastic flow, which is in similar case like lateral blast or flank collapse in Figure above, and (b) is representing the caldera collapse and also submarine explosion tsunami generation mechanism (Source of sketch: Maeno F, 2006).

The Processes

Latter (1981), with particular reference to Krakatau event in 1883 recognised 10 distinct processes with 8 main processes whereby volcanic activities may generate tsunamis as follows:

- pyroclastic flows or nuees ardantes (impacting on water): 20 %
- earthquake accompanying eruptions: 22%
- landslides and avalanches of cold rock: 7%
- submarine explosions: 19 %
- caldera collapse or subsidence: 9 %
- basal surges and accompanying shock waves: 7%
- avalanches of hot rock: 6%
- lahars: 4.5 %
- air waves associated with large explosion: 4.5%
- lava flows: 1%

It was noted that the ***efficiency of these processes varies***, depending primarily ***on the amount of seawater displaced, the direction of displacement and the duration of the disturbance*** (Latter, 1981; Sigurdsson and Carey,1991; de Lange and Hull, 1994; de Lange et al., 1997, Prasetya 1998).




Laboratory experiment ~ reference to Krakatau 1883 and future event of Anak Krakatau

Laboratory Setting for three hypotheses:

- ***Submarine explosion,***
- ***Pyroclastic Flow,***
- ***and Caldera Collapse***



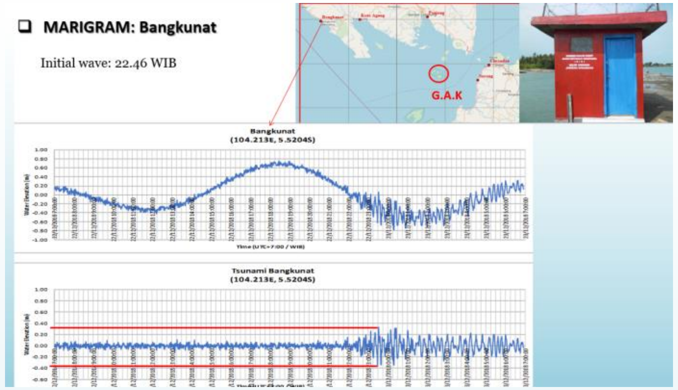

The 3-dimensional wave basin arrangement at Coastal Engineering Laboratory BPPT Yogyakarta (Now BPDP) for this undistorted model experiment (Prasetya, 1998)

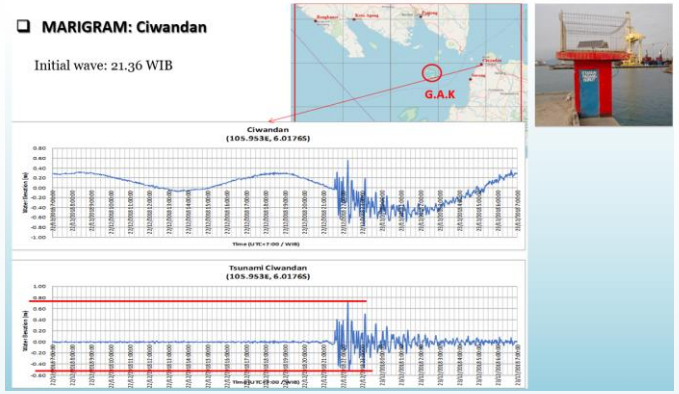


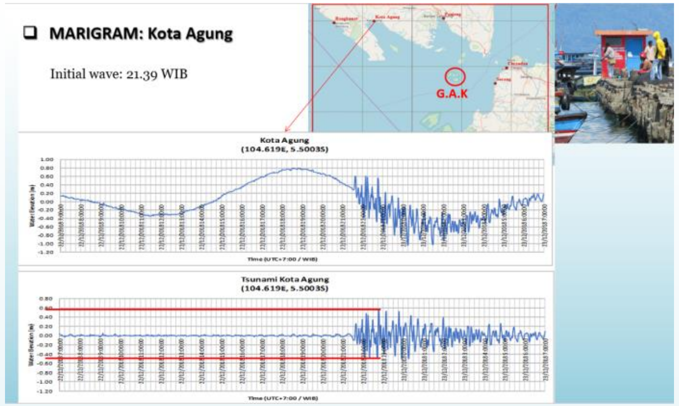

(Prasetya, 1998)

THE 22nd DECEMBER 2018 EVENT

Source: Crew of Susi Air/23rd December 2018

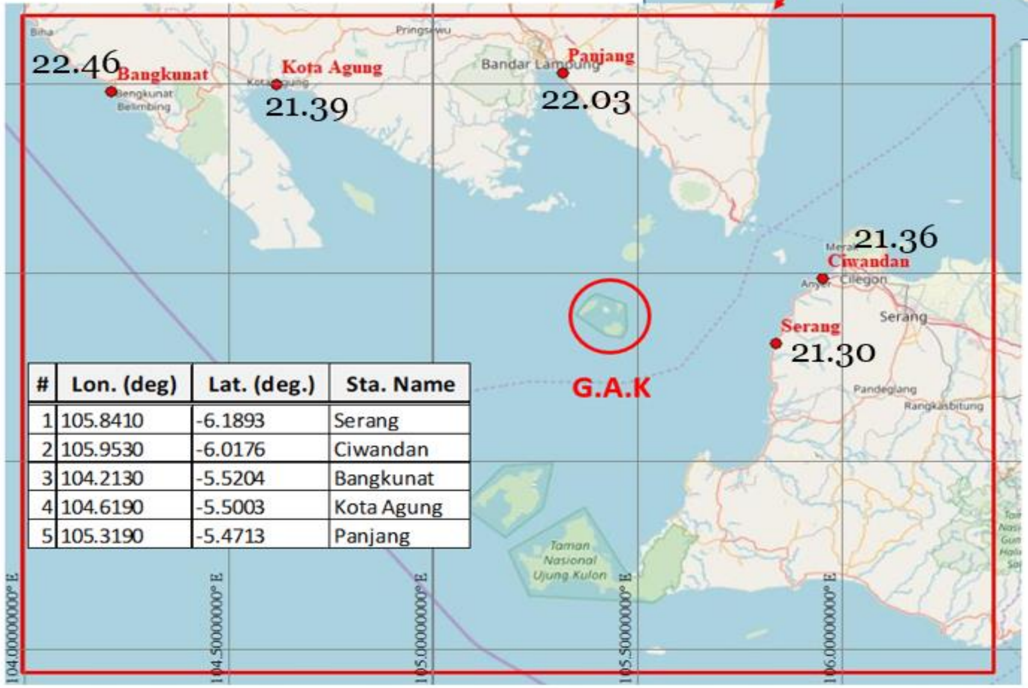




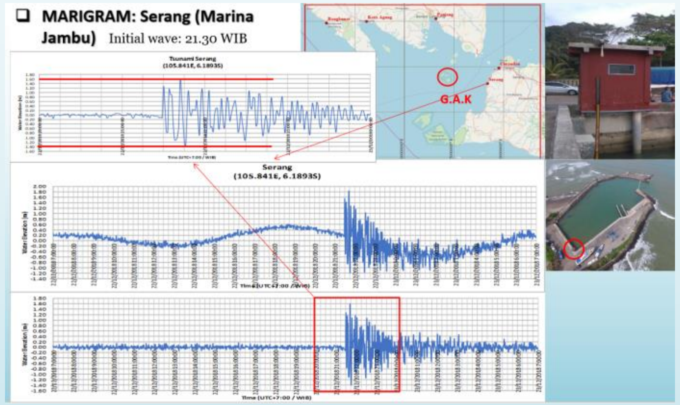


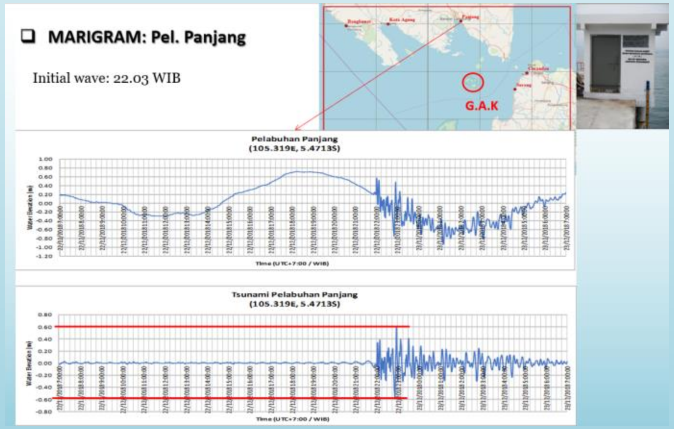
TIDE STATION POINTS

GAK: Anak Krakatau Volcano



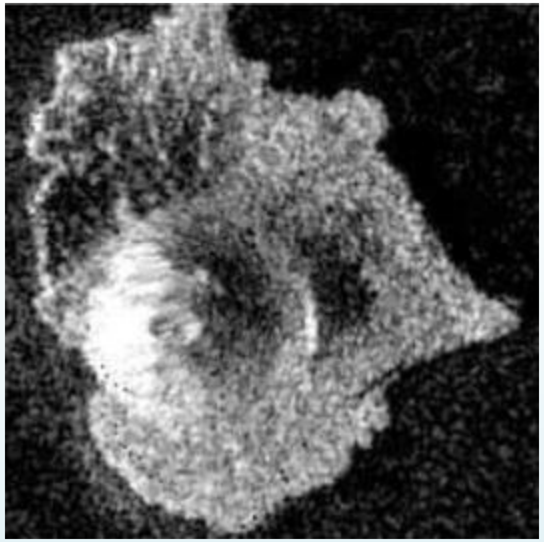
#	Lon. (deg)	Lat. (deg.)	Sta. Name
1	105.8410	-6.1893	Serang
2	105.9530	-6.0176	Ciwandan
3	104.2130	-5.5204	Bangkunat
4	104.6190	-5.5003	Kota Agung
5	105.3190	-5.4713	Panjang



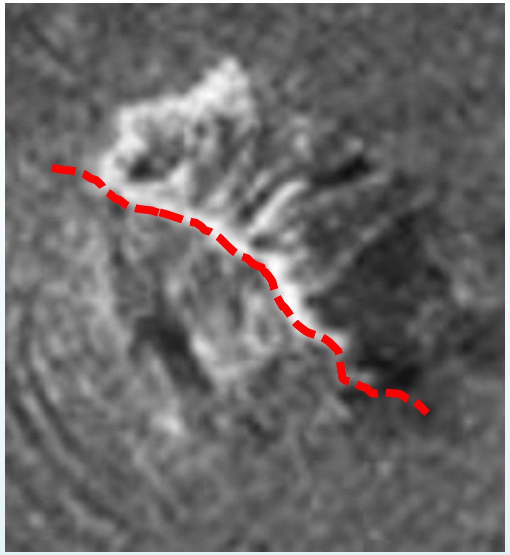


(Prasetya et.al 2019)

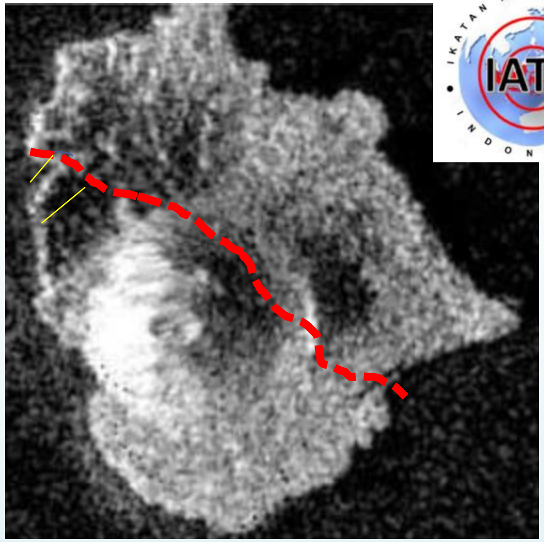
Typical eruption from the top
(source: Discovery Volcano)



19 December 2018
(Source: Sentinel -1)

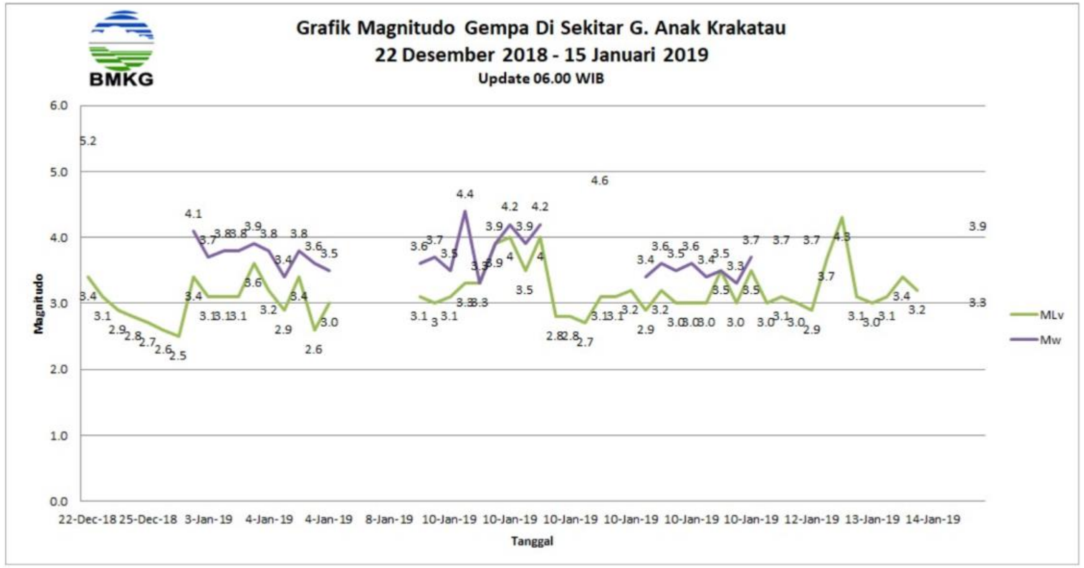


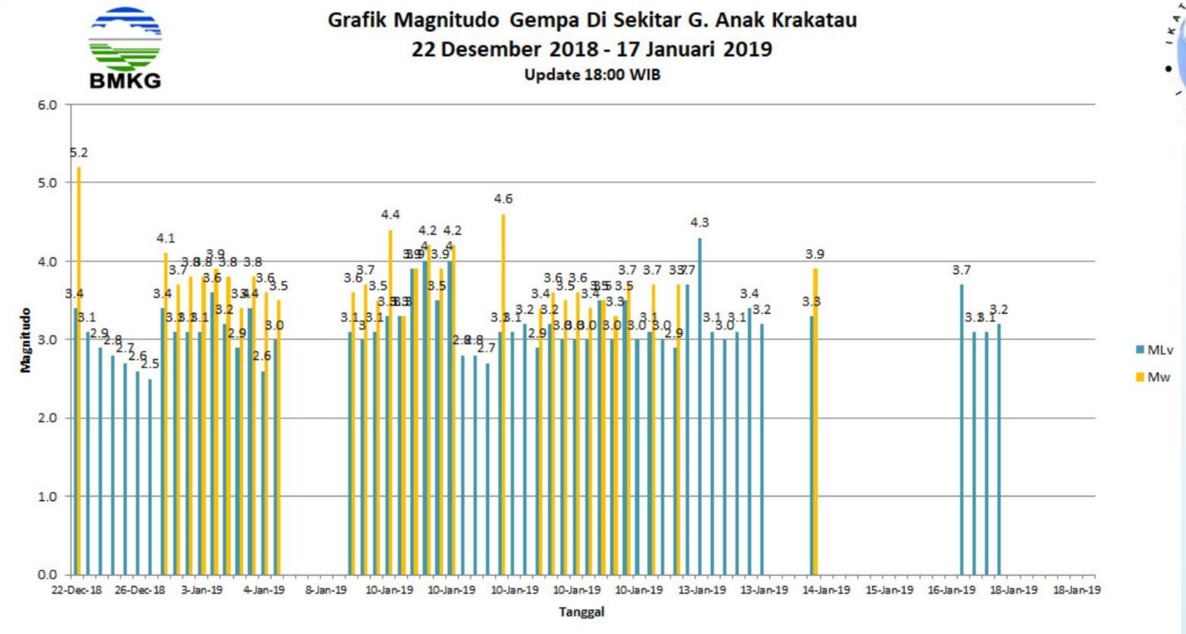
22 December 2018
(source: JAXA)

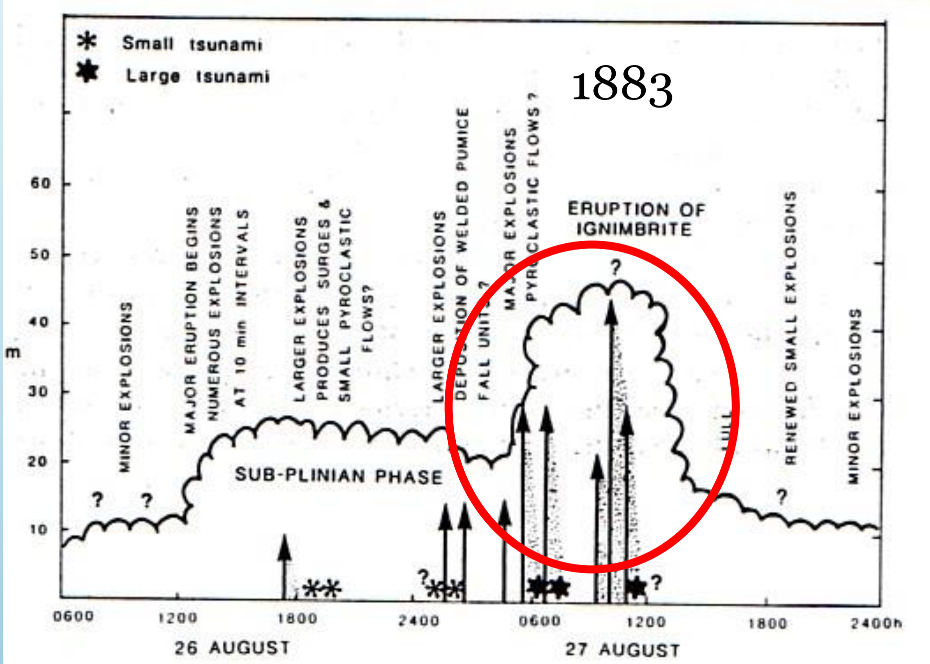


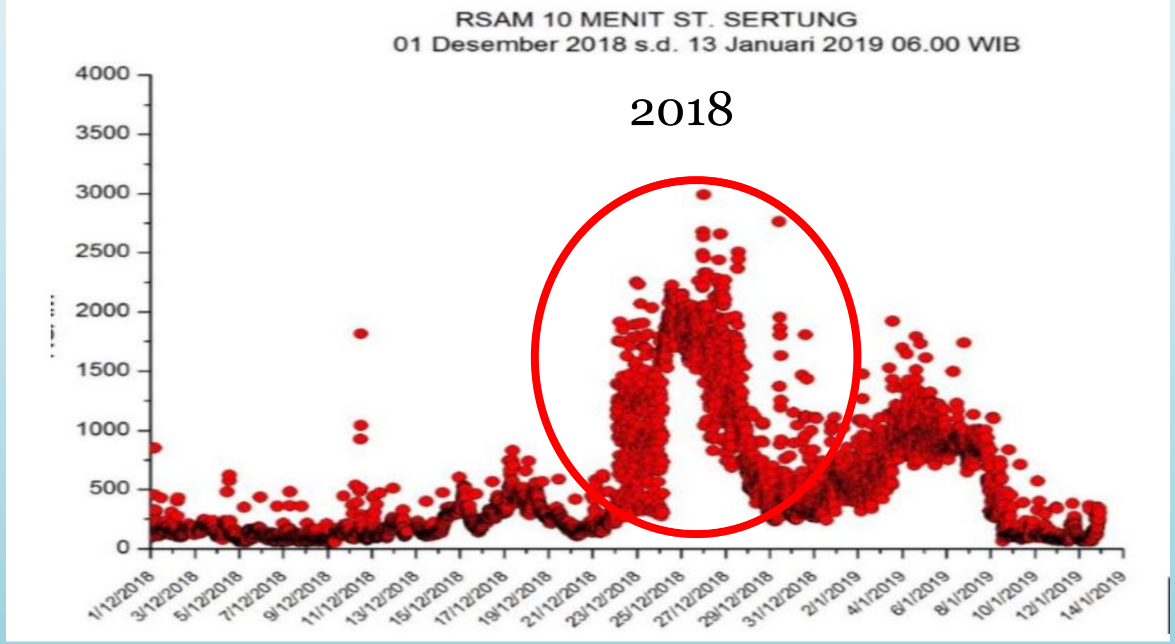
The missing part
~ 1.21 km2

Eyewitnesses account: ' **the volcano was erupted from the side** (lateral blast?) not from the top as usual, and the top was collapse after eruption and the volcano was divided into two – the tsunami generate shortly after its erupted and collapse – there are 3 waves. (Prasetya et.al 2019)

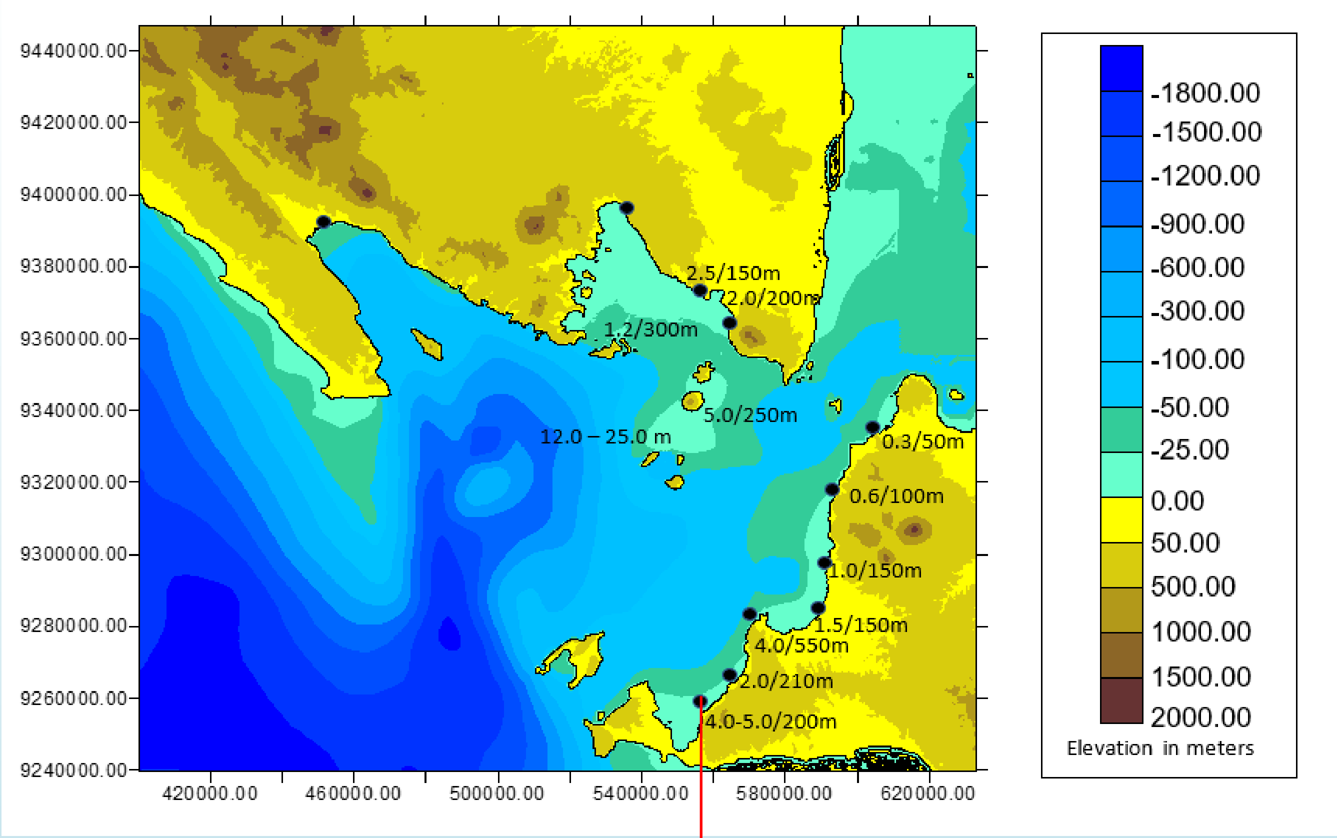

BMKG
Grafik Magnitudo Gempa Di Sekitar G. Anak Krakatau
22 Desember 2018 - 15 Januari 2019
Update 06.00 WIB
Magnitudo
Tanggal
MLv
Mw
22-Dec-18 25-Dec-18 3-Jan-19 4-Jan-19 4-Jan-19 8-Jan-19 10-Jan-19 10-Jan-19 10-Jan-19 10-Jan-19 10-Jan-19 10-Jan-19 12-Jan-19 13-Jan-19 14-Jan-19

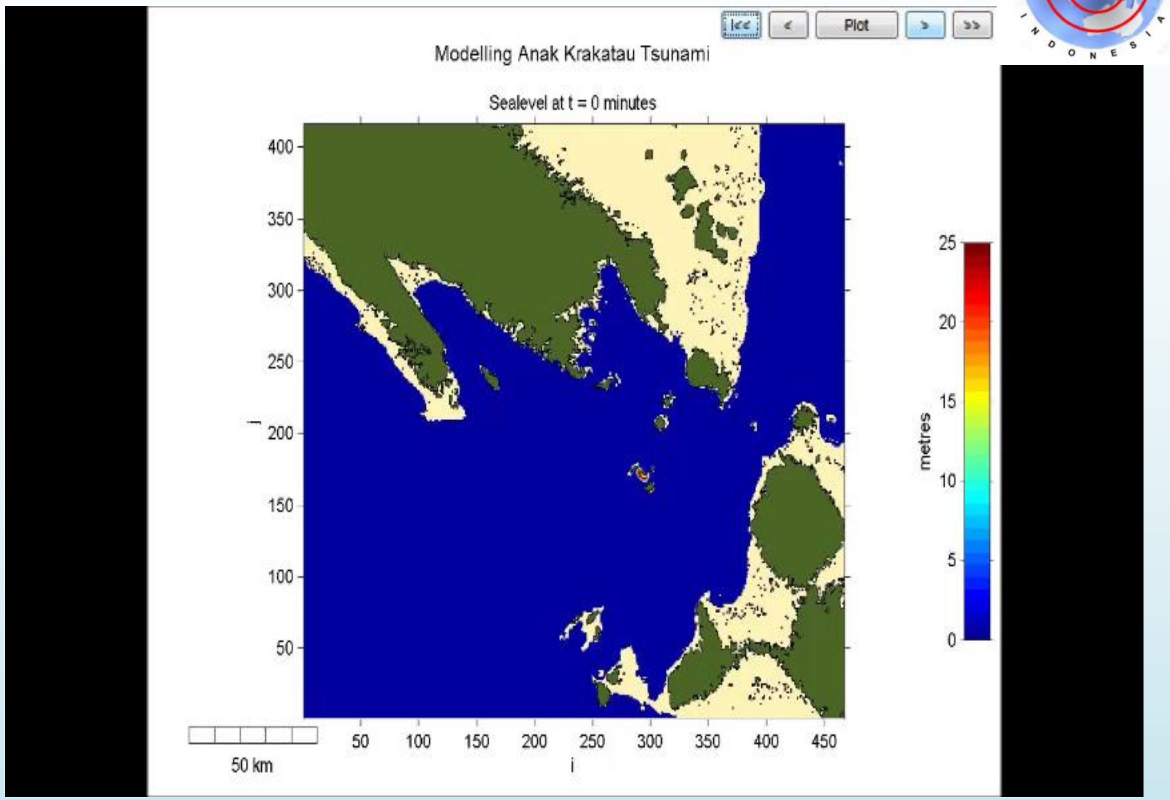

BMKG
Grafik Magnitudo Gempa Di Sekitar G. Anak Krakatau
22 Desember 2018 - 17 Januari 2019
Update 18:00 WIB
Magnitudo
Tanggal
MLv
Mw
22-Dec-18 26-Dec-18 3-Jan-19 4-Jan-19 8-Jan-19 10-Jan-19 10-Jan-19 10-Jan-19 10-Jan-19 10-Jan-19 13-Jan-19 13-Jan-19 14-Jan-19 15-Jan-19 16-Jan-19 18-Jan-19 18-Jan-19


Small tsunami
Large tsunami
1883
MINOR EXPLOSIONS
MAJOR ERUPTION BEGINS NUMEROUS EXPLOSIONS AT 10 min INTERVALS
LARGER EXPLOSIONS PRODUCES SURGES & SMALL PYROCLASTIC FLOWS?
LARGER EXPLOSIONS
ERUPTION OF IGNIMBRITE
RENEWED SMALL EXPLOSIONS
MINOR EXPLOSIONS
SUB-PLINIAN PHASE
km
0600 1200 1800 2400 0600 1200 1800 2400h
26 AUGUST
27 AUGUST

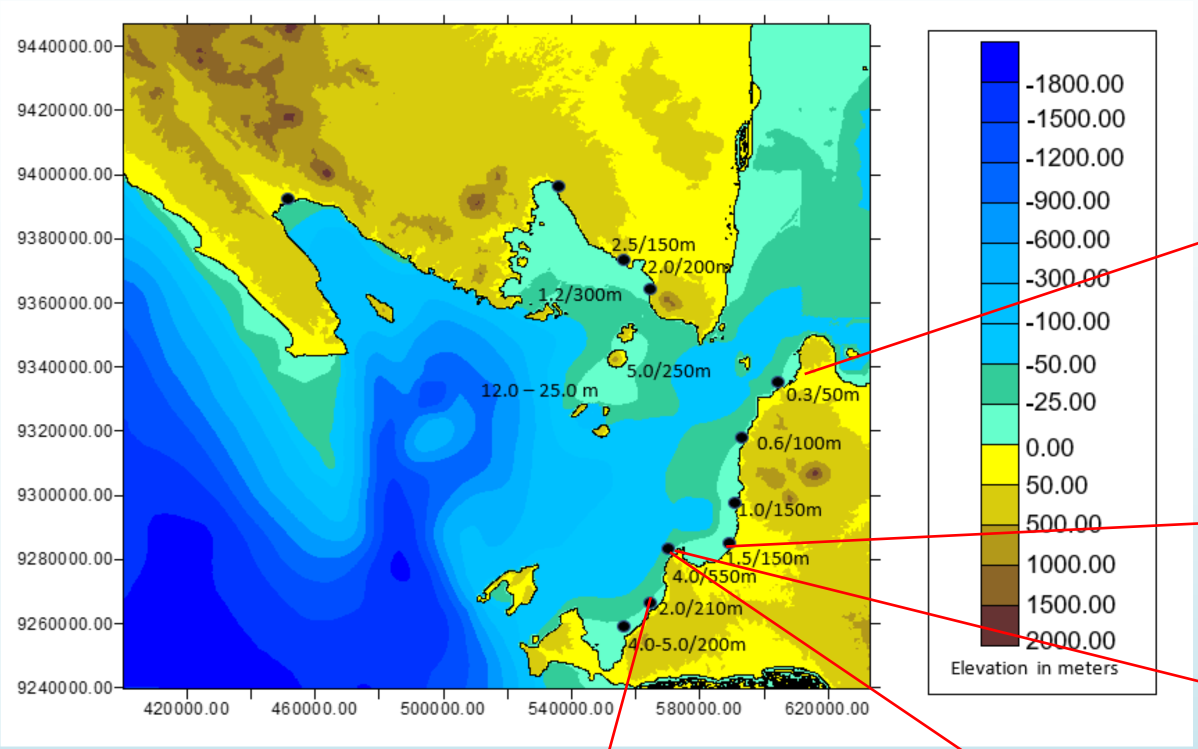

RSAM 10 MENIT ST. SERTUNG
01 Desember 2018 s.d. 13 Januari 2019 06.00 WIB
2018
1/12/2018 3/12/2018 5/12/2018 7/12/2018 9/12/2018 11/12/2018 13/12/2018 15/12/2018 17/12/2018 19/12/2018 21/12/2018 23/12/2018 25/12/2018 27/12/2018 29/12/2018 31/12/2018 2/1/2019 4/1/2019 6/1/2019 8/1/2019 10/1/2019 12/1/2019 14/1/2019

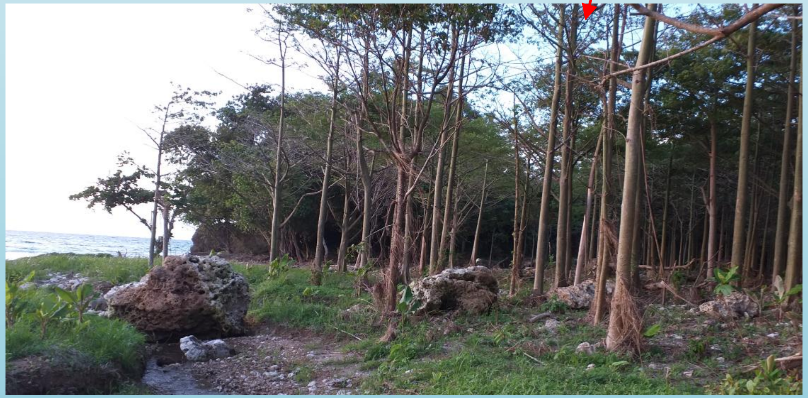
SURVEY RESULTS BASED ON RAPID SURVEY 26-27 December 2018 AND DAMAGE LEVEL





SURVEY RESULTS BASED ON RAPID SURVEY 26-27 December 2018 AND DAMAGE LEVEL

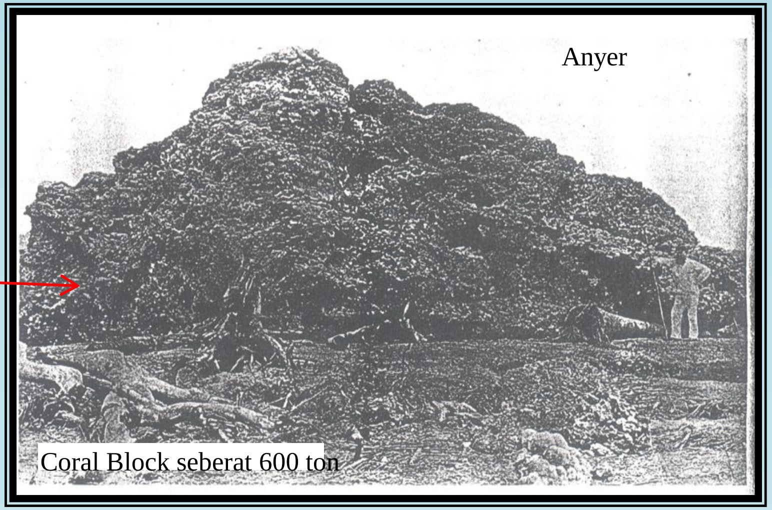




SIMILARITY OF 1883 AND 2018 EVENT ON COASTAL IMPACT

The Evidence:

Coral Boulder carried out by Tsunami 1883



Ujung Kulon – 2.5 km inland

Anjer – 600 inland

Labuan

The Evidence:

Coral Boulder carried out by Tsunami 2018

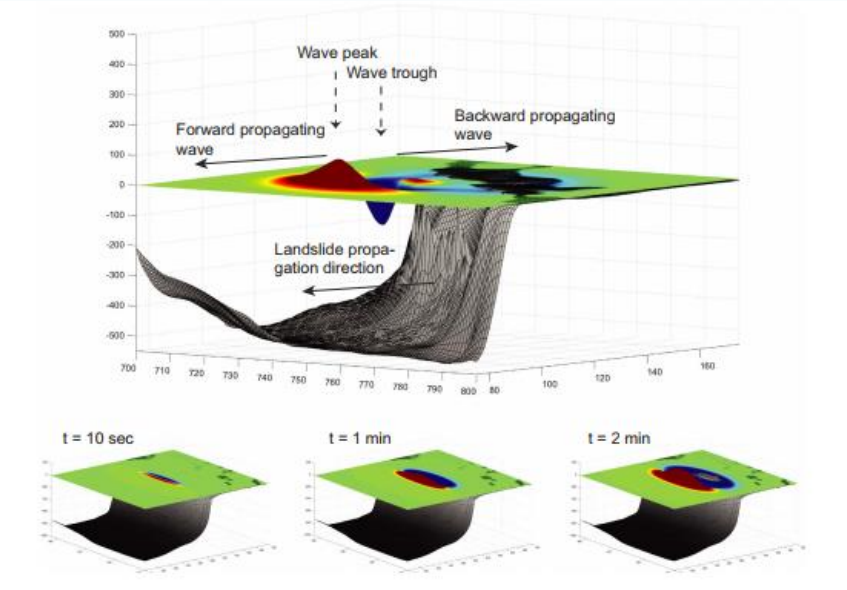
2.3.1. LANDSLIDE AND SUBMARINE SLUMPS/FLANK COLLAPSE

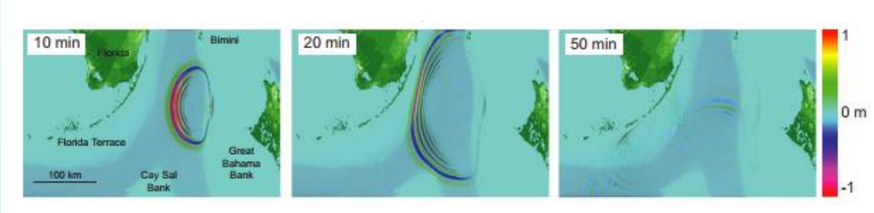
Landslides and submarine slumps generate tsunamis can occur ***from various causes, and may take place in the open ocean, bays or inlets.***

Generally, landslide tsunamis ***have much smaller horizontal scale*** than tsunamis generated by earthquake and have ***been considered as point sources with local characteristics*** (Kulikov et al., 1996).

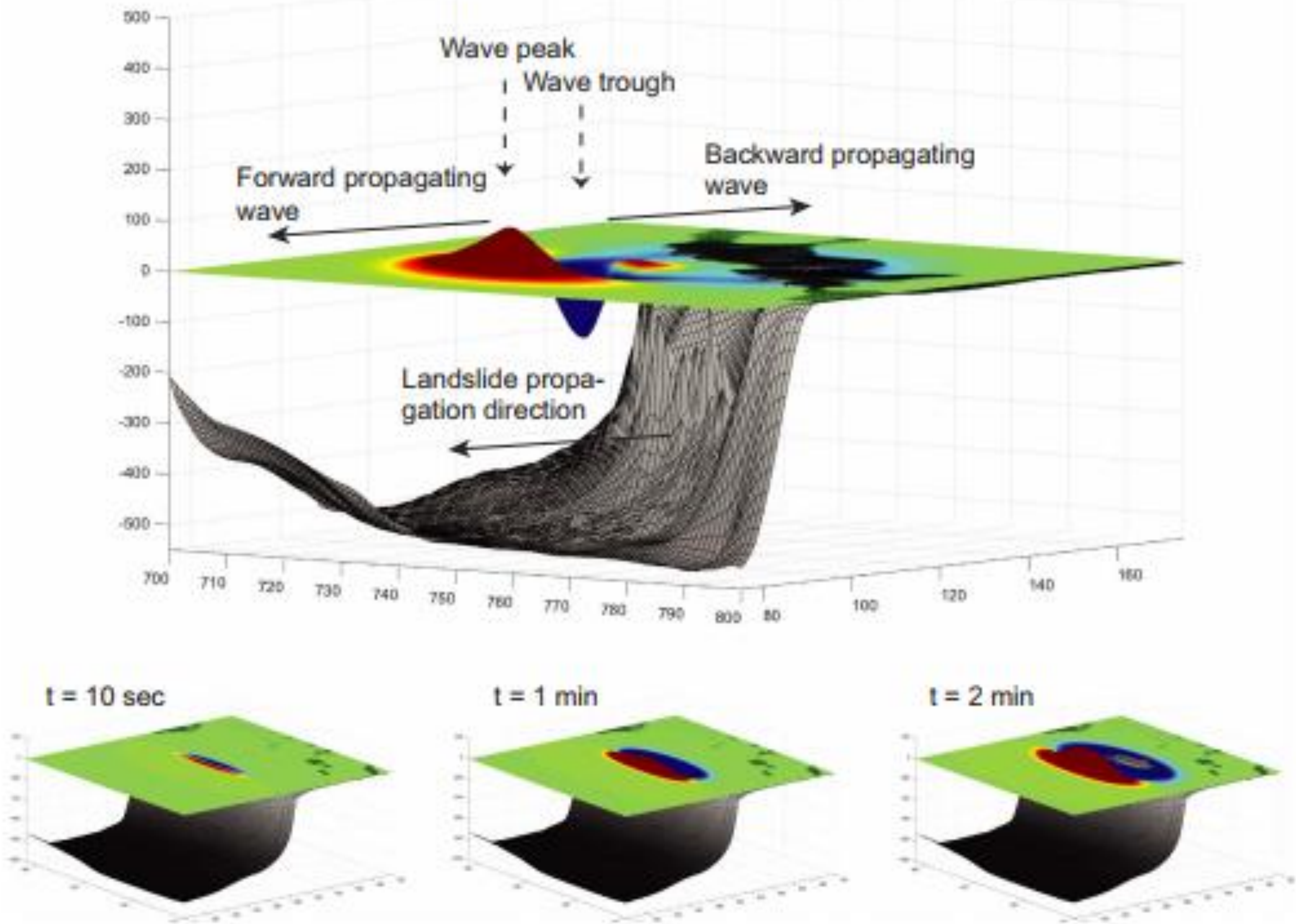
Landslide generated tsunami depend ***on the volume, velocity, and coherence of the slide mass. The local water depth and the fraction of the slide volume that is subaerial or submarine are also important factor*** (Bornhold and Thomson in Clague and Steads, 2012).

Most documented tsunamis associated with known slumping, have involved large masses of sediment moving down relatively steep slopes, usually the continental slope (de Lange, 1983; de Lange and Hull, 1994, Brune etal.2010).

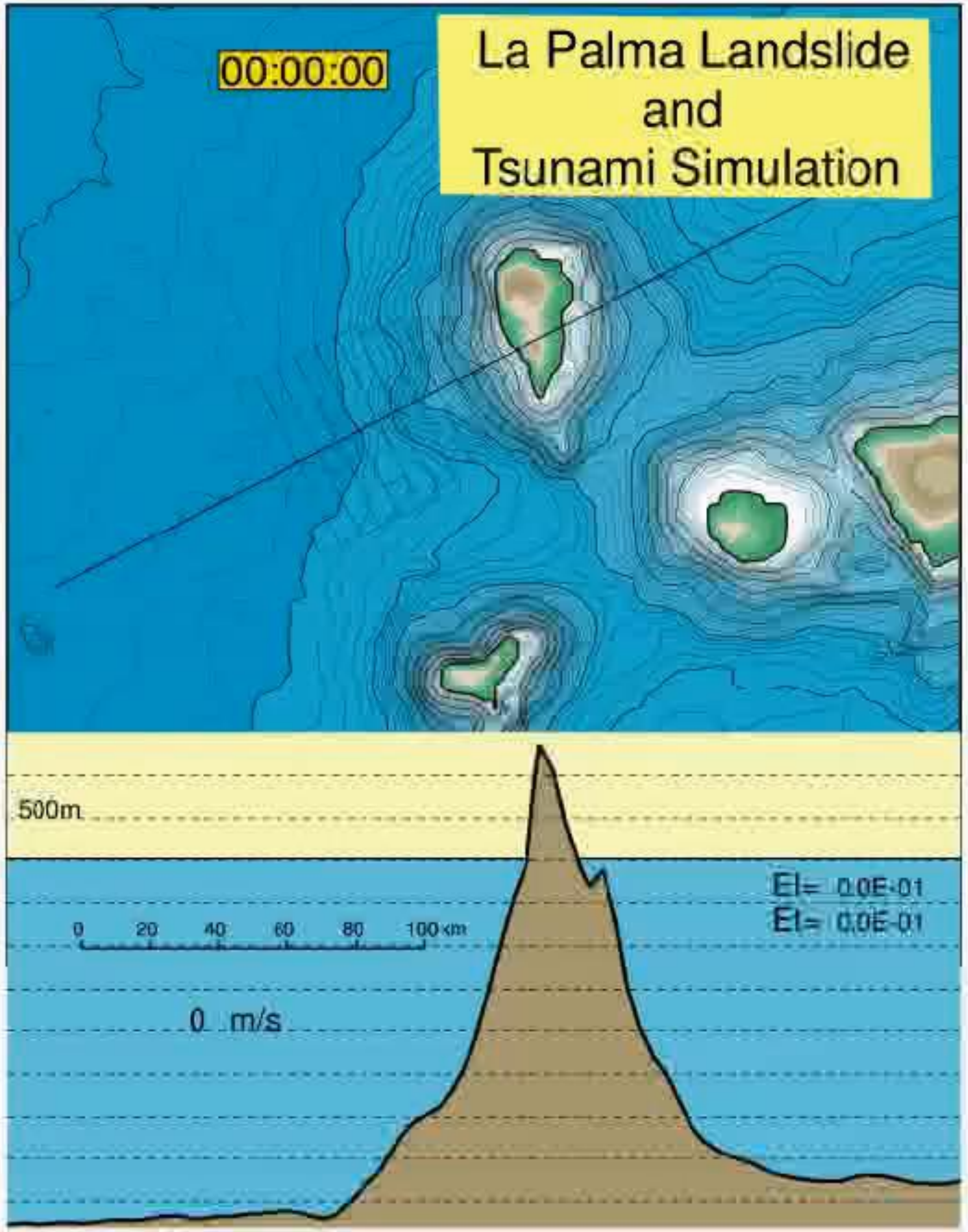




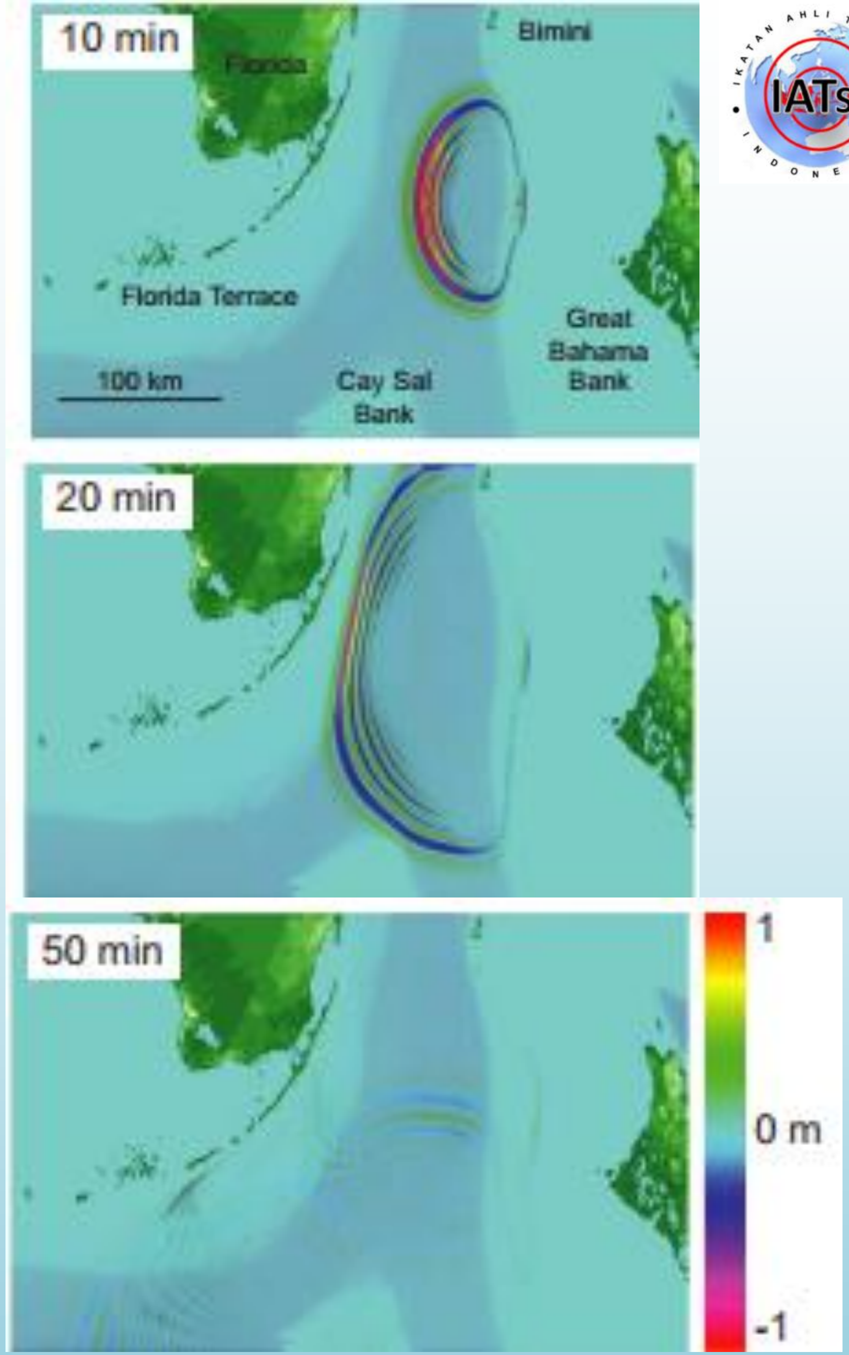
(Schnyder etal (2016)).



(Schnyder etal (2016)).

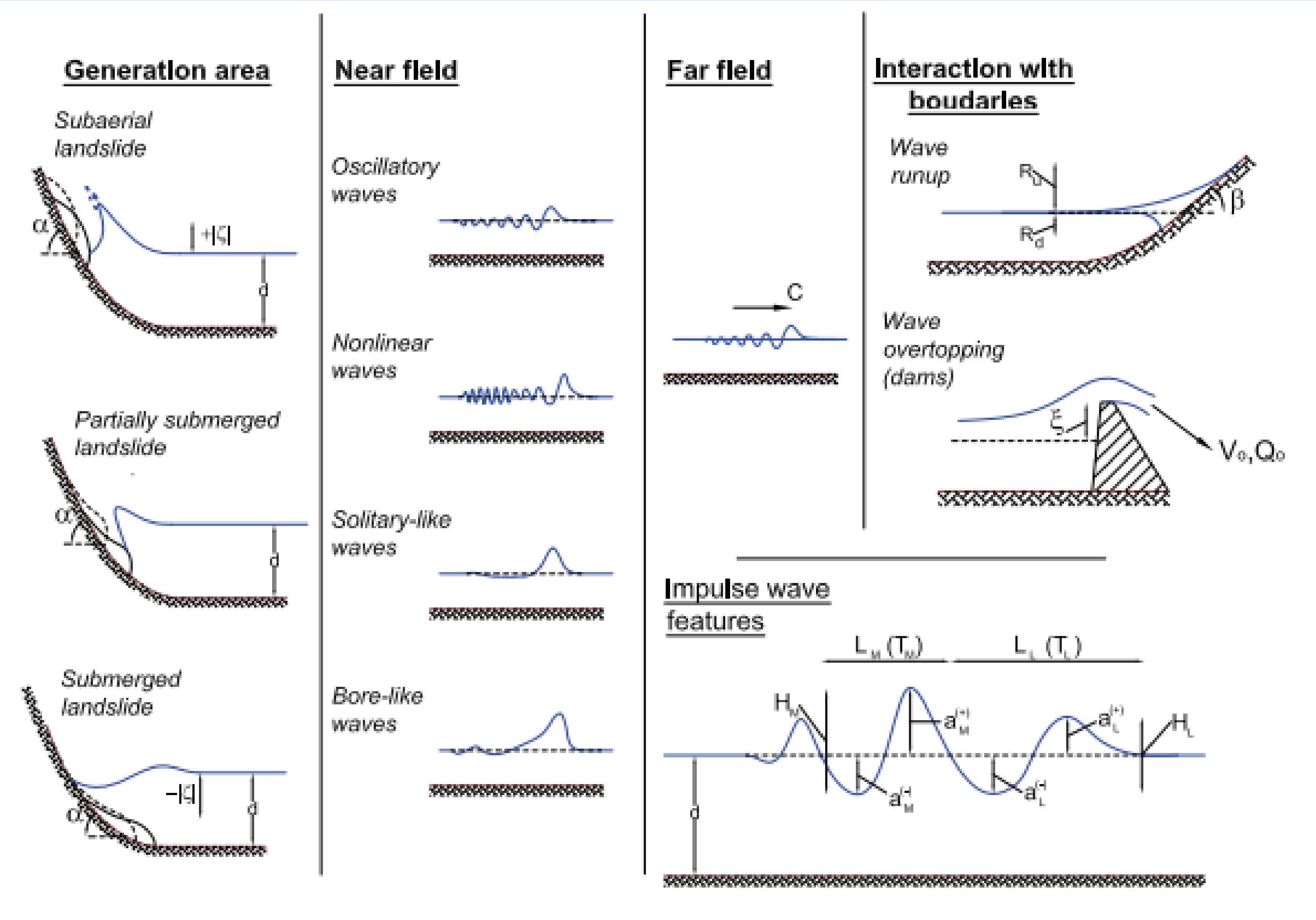


Flank Collapse sources (Ward, S.N)

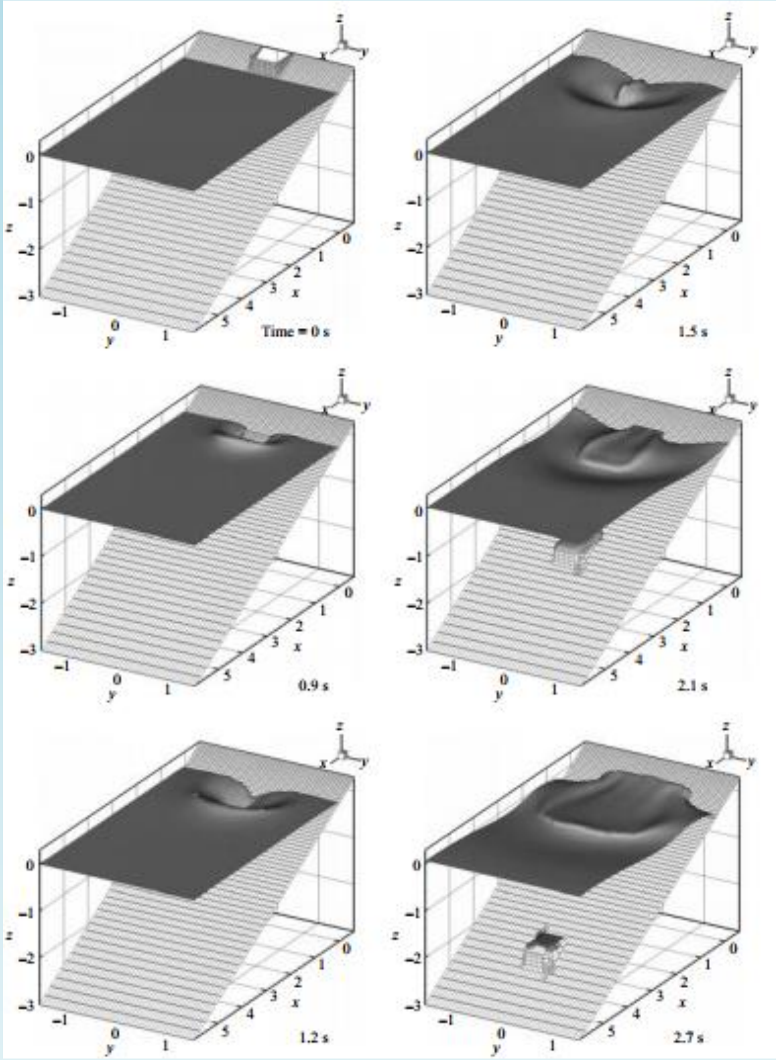


(Schnyder etal (2016)).

INITIAL WAVES, PROPAGATION AND RUNUP

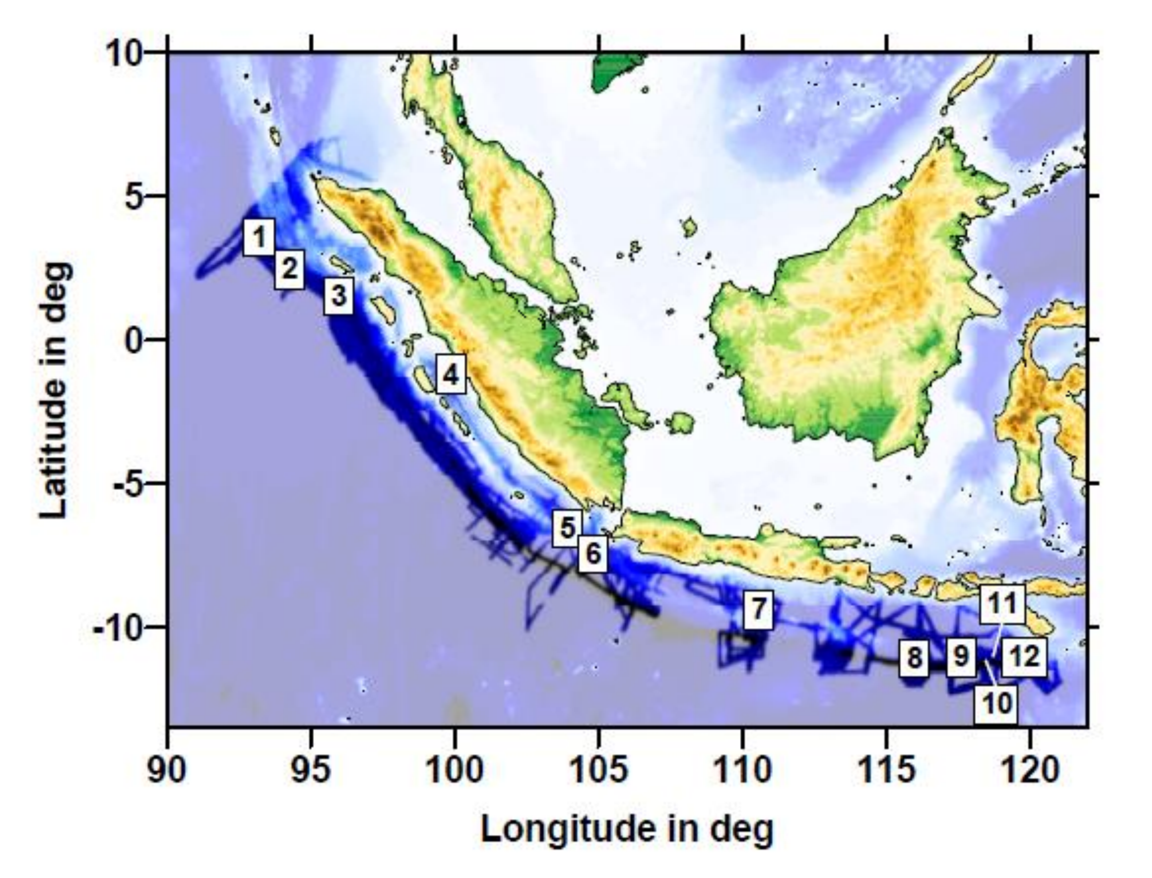


Qualitatif sketch of landslide generate impulsive wave (Di Risio and Berthami 2006).

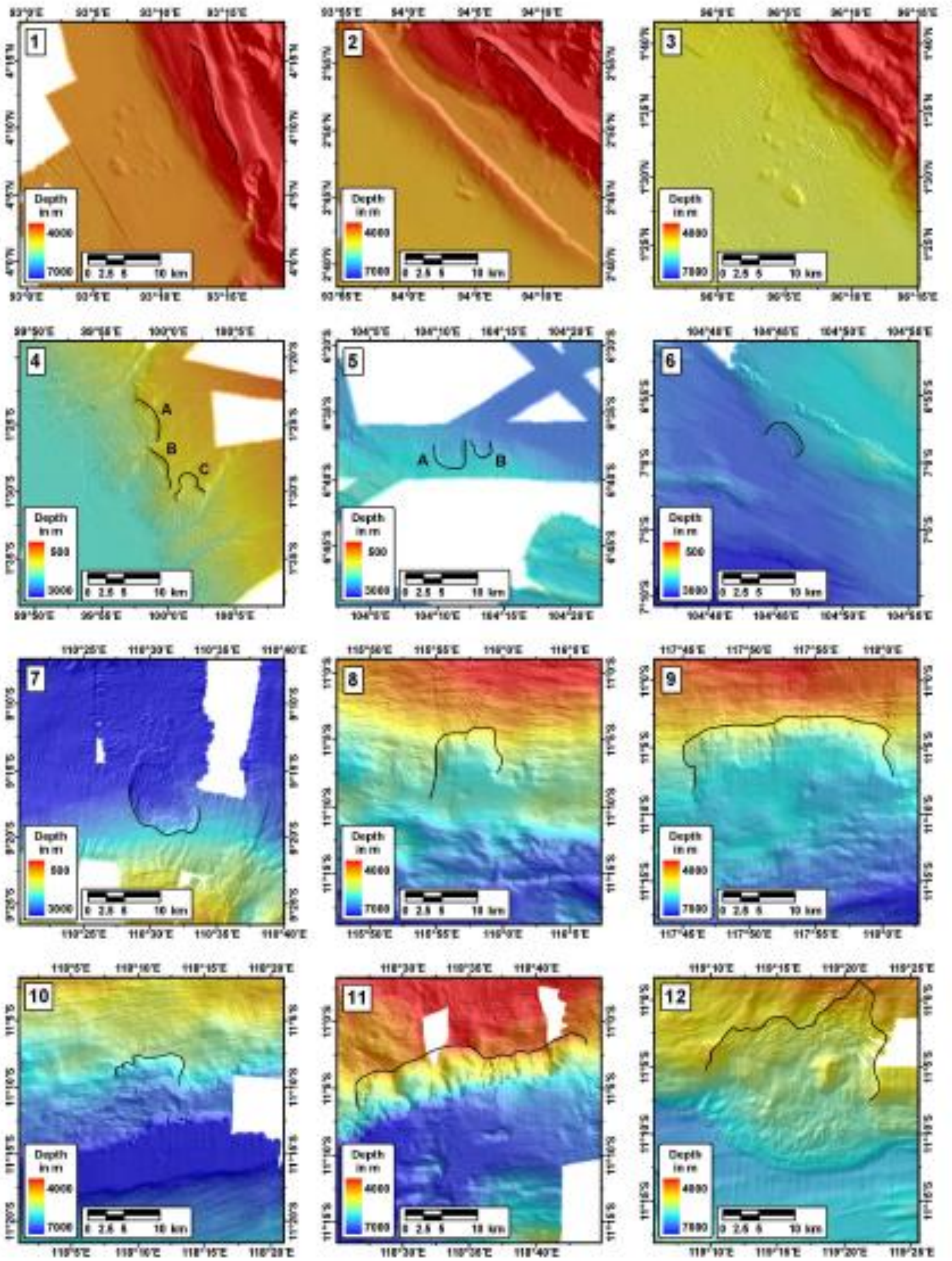


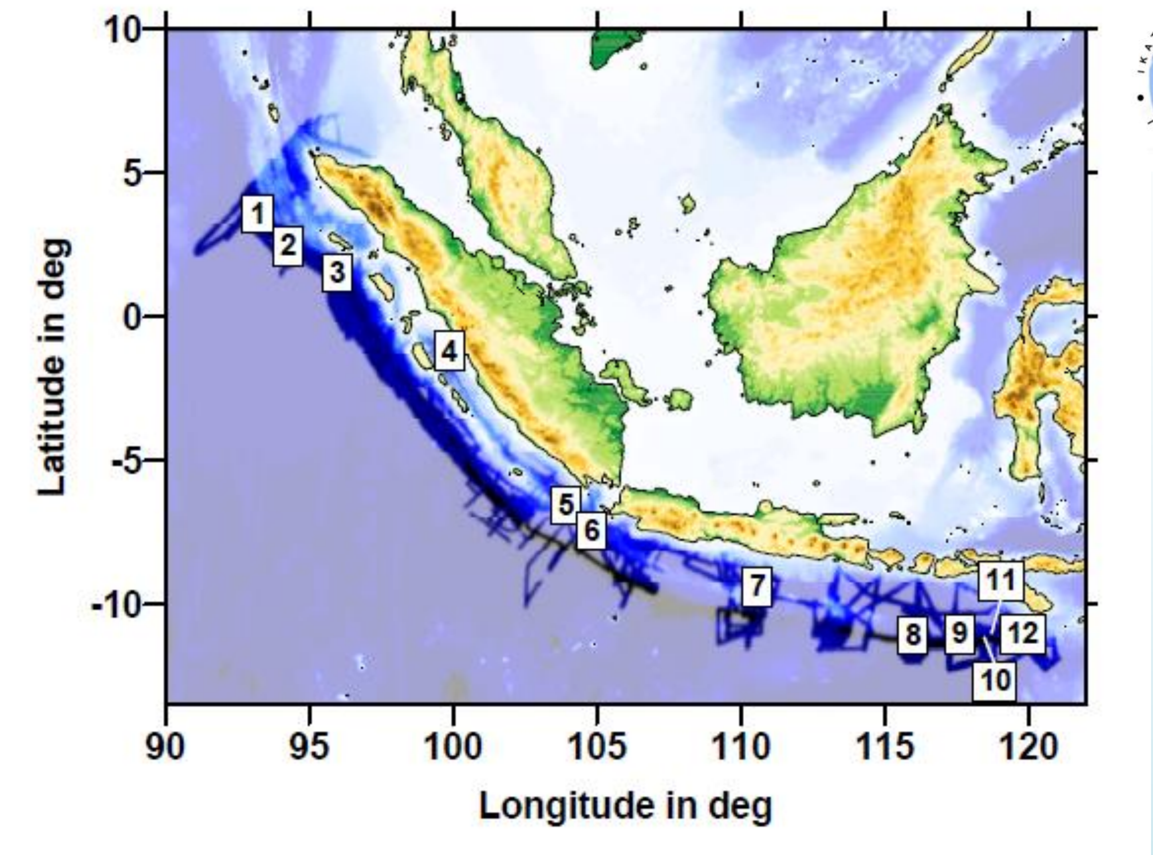
The snapshot of the numerical model results (Liu etal.2005)

The contribution of detail Bathymetry Survey in submarine landslide identification



Brune etal (2010) visually analysed the bathymetry data for characteristic landslide features: cauliflower-shaped escarpments and mass movement deposits. Evidence for fifteen slope failures has been found at 12 distinct locations (Figure 26). The submarine slide at site 1-3 are located at the trench off Northern Sumatra which describe as bloky debris avalanches. Site 4-7 located at depth between 1.3 ro 2 km at the foot of the foreach basins. There are three event on site 4, two event on site 5. The largest event are situated at sites 8 to 12 near the eastern end of the Java Trench.

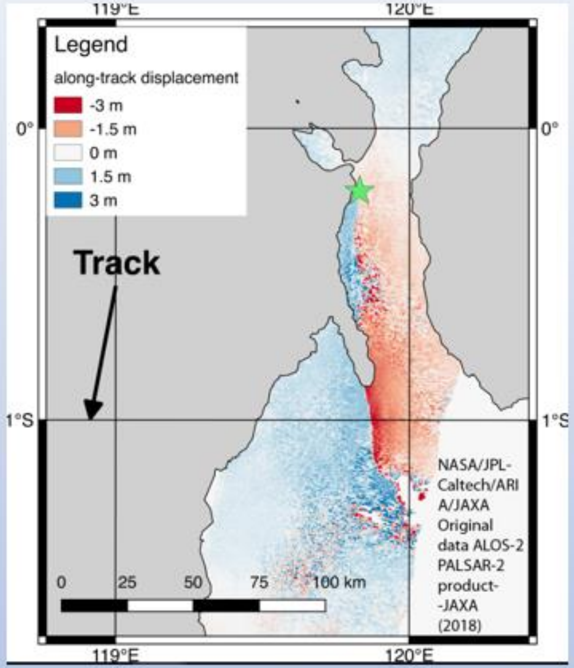




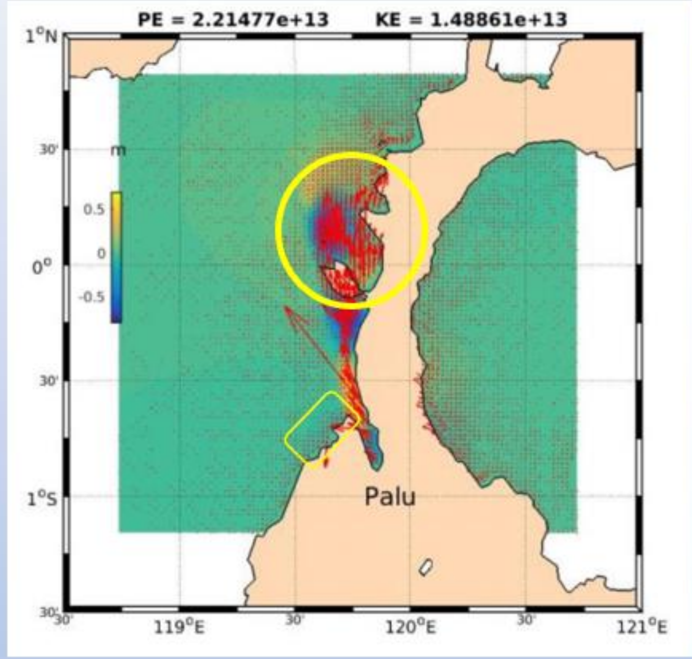
Bathymetry images of the landslides. Head scarp interpretations are marked as black lines. Locations are mapped in 1, 2, 3, and 4 have been previously published by Moran and Tappin (2006), Henstock et al. (2006), Kopp et al. (2008, 2006), respectively. Note: the different depth scales for slides in for-arc basins (3000 to 500 m) and near the trench (7000 to 4000 m) (source: Brune etal.2010).

PALU EVENT 2018

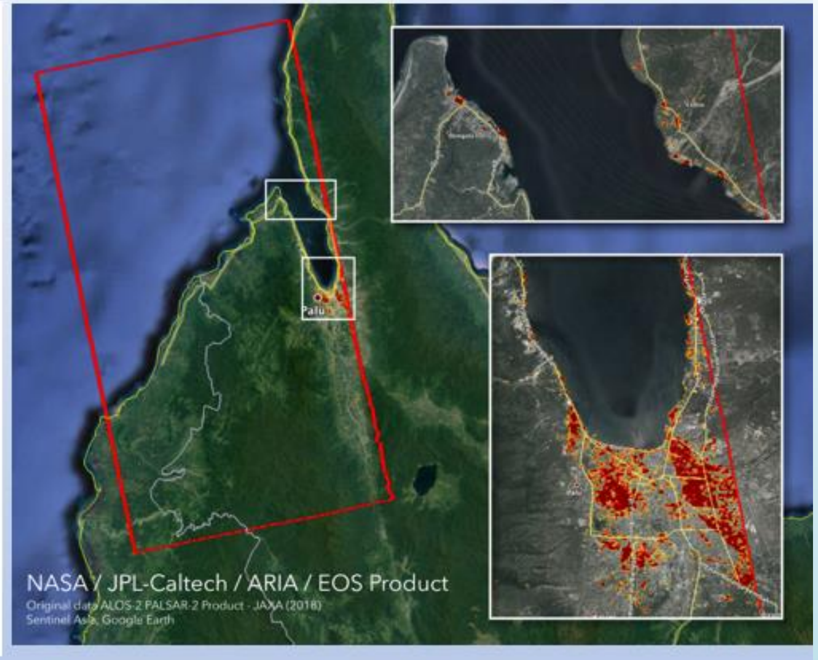
From the source to the impact……………………………..



ARIA Along-track Deformation Map of the M7.5 September 28, 2018 Sulawesi earthquake, Indonesia (https://disasters.nasa.gov/sulawesi-island-indonesia-earthquake-and-tsunami-2018/aria-along-track-deformation-map-m75-September)



Two tsunami source energies were derived: Potential Energy (PE) due to seafloor uplift and Kinetic Energy (KE) due to horizontal seafloor displacement. **However, no tsunami had been observed at the yellow circle and square box.** (https://disasters.nasa.gov/sulawesi-island-indonesia-earthquake-and-tsunami-2018/nasa-system-detects-two-tsunami-energies-0)



Damage area based on satellite image

A history of International Tsunami Survey Team (ITST) In Indonesia

POST TSUNAMI FIELD SURVEY SANGAT PENTING UNTUK KEPERLUAN MITIGASI

1992 Flores – **1994** East Java – **1996** Tonggolobibi – **1996** Biak - **2000** Banggai – **2004/5** Aceh – **2006** Pangandaran –2007 Bengkulu-**2010** Mentawai – **2018** Palu

Survey team members shown, from left to right: S. Diposaptono, G. Prasetya, S. Han, C. Synolakis, M. Usman, F. Imamura, B. Cook, H. Matsutomi, Y. Tsuji, S. Harada, M. Jumadi, and K. Arai. The following people also participated in the 1994 survey: T. Adronio, A. Agus, A. Bottero, K. Budi,Y. Chandra, L. Dona, Z. Dupe, K. Frans, A. Maramai, N. Puspito, T. Rivai, T. Takahashi, W. Takin, S. Tinti, W. Triyoso, and F. Warianto.

West Sumatra International Tsunami Survey Team
(Post 2004 M9.2 and 2005 M8.5 - ITST2)

Leg 1 (30 March -12 April 2005)
Gegar Prasetya (BPPT)- Leg 1 Co-Leader
Jose Borrero (USC)- Leg 1 Co-Leader
Rahman Hidayat (BPPT)
Bretwood Higman (UW)
Etienne Kingsley (USGS)
Lukiyanto (BPPT)
Brian McAdoo (Vassar)
Bob Peters (USGS)
Widjokongko (BPPT)
Vasily Titov (NOAA PMEL)

Leg 2 (13 April -26 April 2005)
Bruce Jaffe (USGS)- Leg 2 Leader
Lori Dengler (Humboldt State)
Guy Gelfenbaum (USGS)
Bretwood Higman (UW)
Andy Moore (Kent State)
Bob Morton (USGS)
Peter Ruggiero (USGS)
Widjokongko (BPPT)
Eko Yulianto (LIPI)

evolve

Survey team members shown, from left to right:
Prof. Philip F Liu, Prof. Costas, Prof. Herman Fritzs, G..Prasetya,PhD.

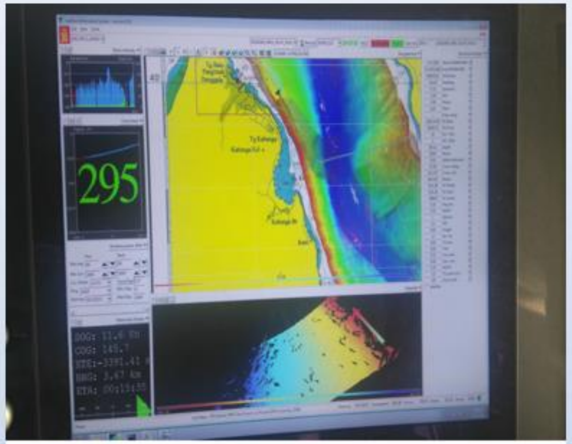
Perlu SEGERA melakukan survey lapangan setelah terjadinya Tsunami untuk memahami proses terjadinya tsunami dan dampaknya sebagai upaya mitigasi di masa datang !!!

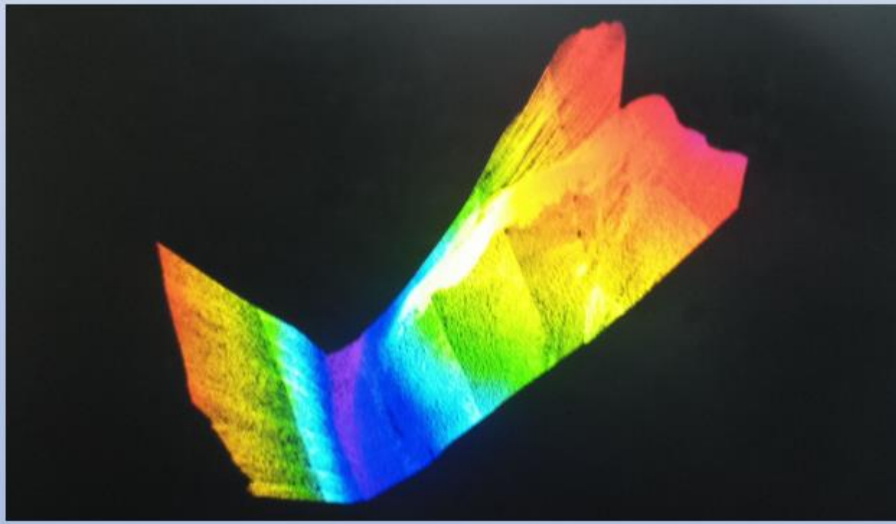
post-tsunami investigations

Data Collected:

- Eyewitness Reports
- Water Levels
- Flow Directions
- Water and Sand Inundation
- Topo-bathy Profiles
- Subsidence or Uplift
- Coastal Morphology and Response
- Deposit Thickness
- Sediment Samples

RESULTS OF NATIONAL TSUNAMI SURVEY TEAM – SUPPORTED BY NAVY HYDROGRAPHIC OFFICE.





Submarine slumps/slide

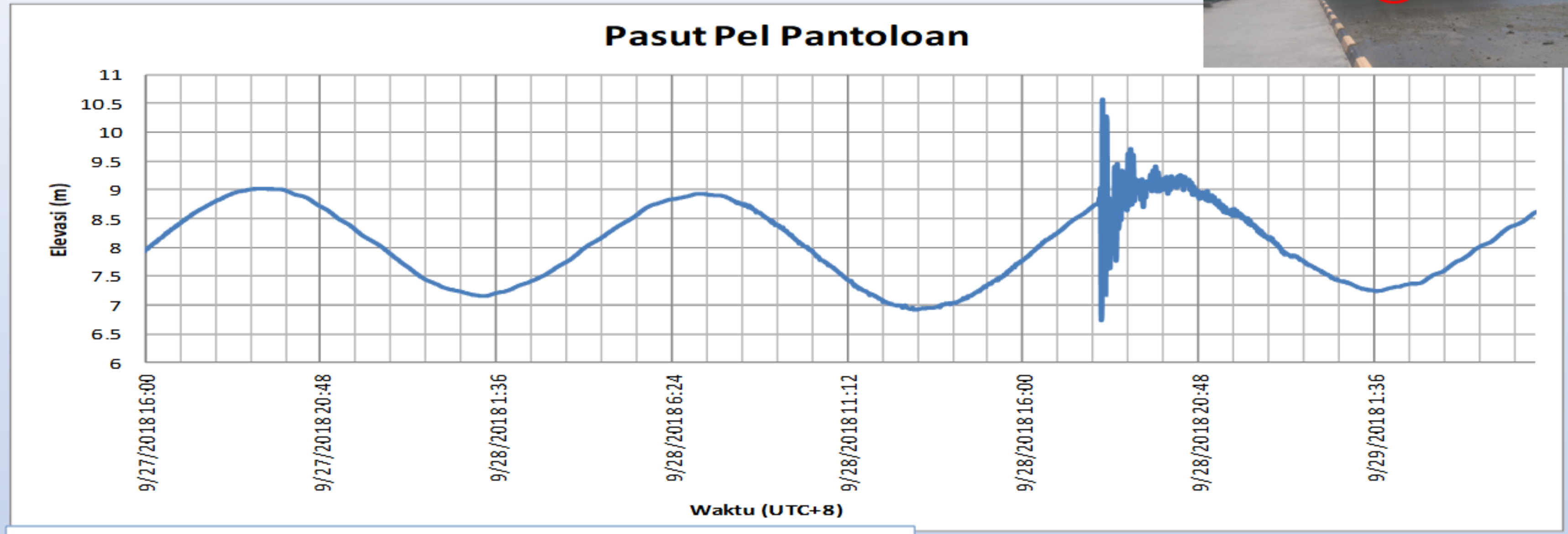
Constraint Source:

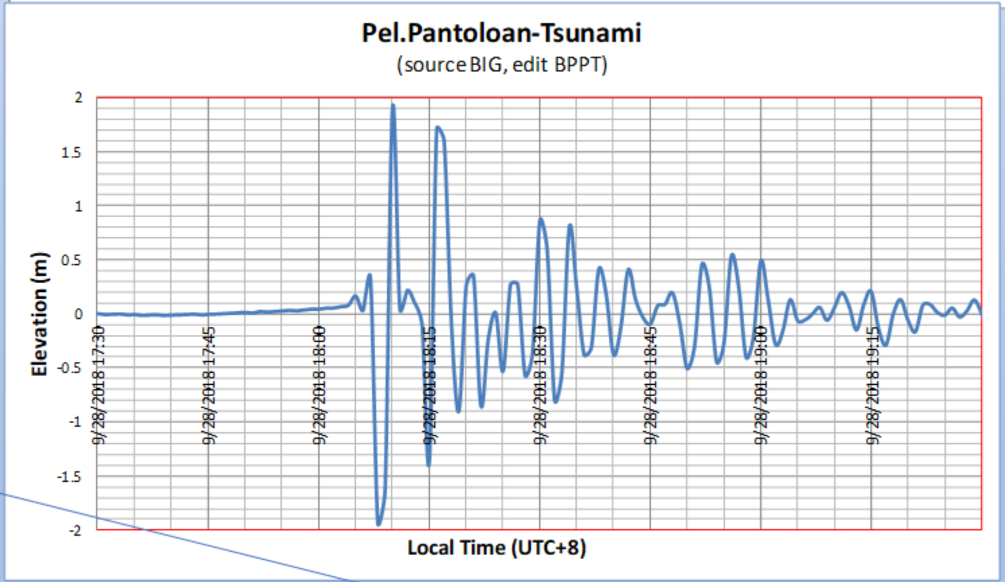
❑Marigram at Pantoloan & Mamuju

Minor Tsunami

Wani – Major Tsunami

Eyewitnesses Tsunami arrive: 3 minutes 40 sec after the quake





Tsunami Pantoloan		
First Positive Wave	1.90	m
ETA	9/28/2018 18:10	WITA
Periode	3.53	Minute
(Source BIG, detide BPPT)		

(Prasetya et.al 2018)

Pantoloan– Major Tsunami

Tsunami arrive: 5 minutes 20 sec after the quake

Constraint Source:

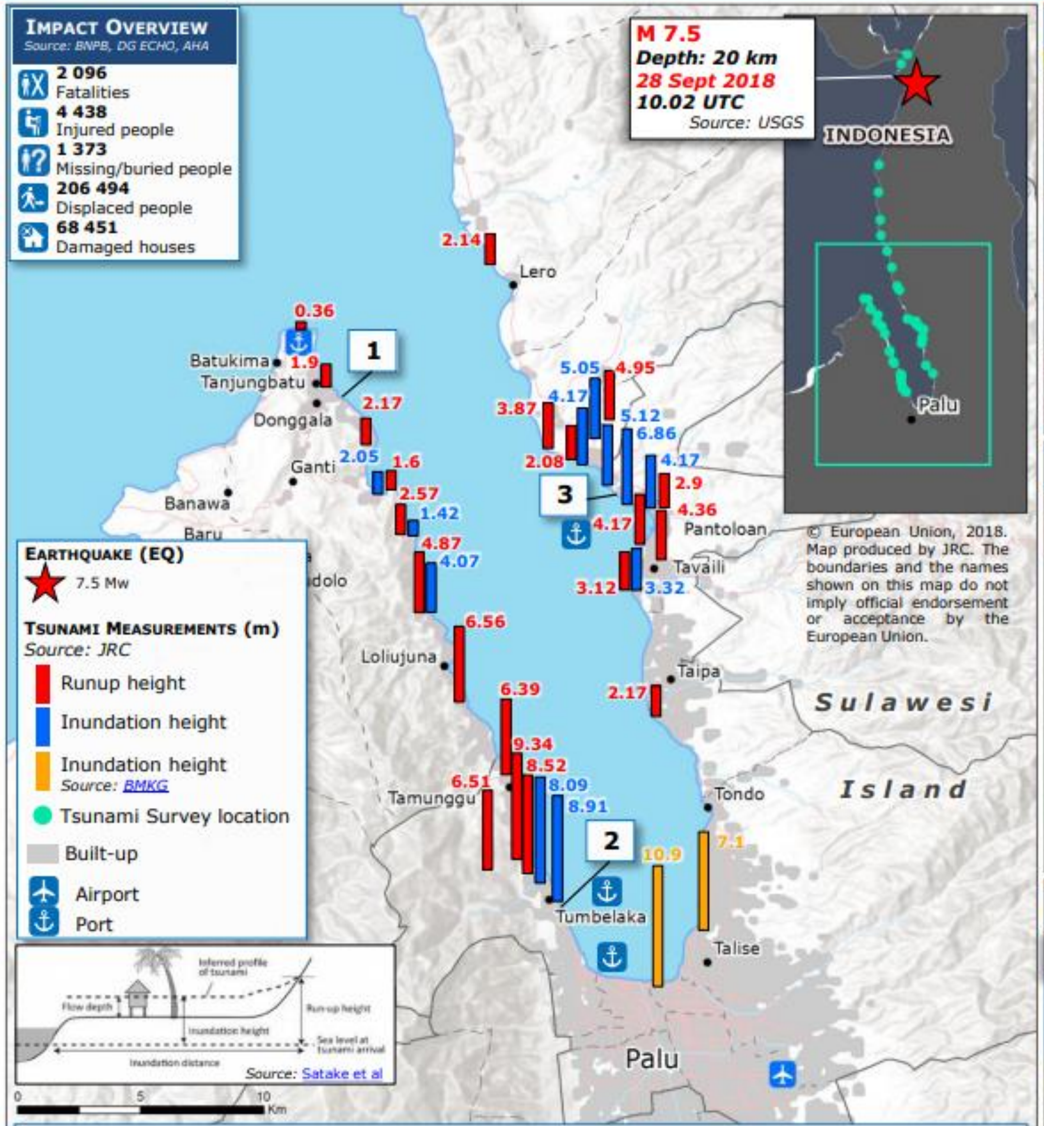
Minor Tsunami

Pantai Tanjung Karang - Donggala

Emergency Response Coordination Centre (ERCC) – DG ECHO Daily Map | 16/11/2018

Indonesia | Post event Tsunami Survey | 7.5 M Earthquake (28 Sept 2018)

European Commission



European Commission | METU | YOKSEL PROJE | INSTITUTO DOM LUIZ | IPMA | LIPI | BMKG | BPPT | IATsI

1 DONGGALA AREA: COASTLINE MODIFICATION

2 TUMBELAKA AREA: COASTAL COLLAPSE

3 NGAPA (WANI) AREA

OVERVIEW

- The September 28, 2018 Palu Mw7.5 Earthquake in Sulawesi Island in Indonesia triggered an unexpected tsunami that caused damage and loss of lives in the region. A field survey by the UNESCO International Survey Team composed of scientists from Turkey, Indonesia, Russia, Portugal, Italy, Austria and the European Commission's Joint Research Centre (JRC) has been performed between November 07 and 11, 2018 covering the entire coast of Palu Bay up to the earthquake epicenter region.
- The survey aimed at understanding and document the tsunami effects and also the tsunami generation mechanisms through measuring and observing the tsunami impact.

Original Paper

Landslides
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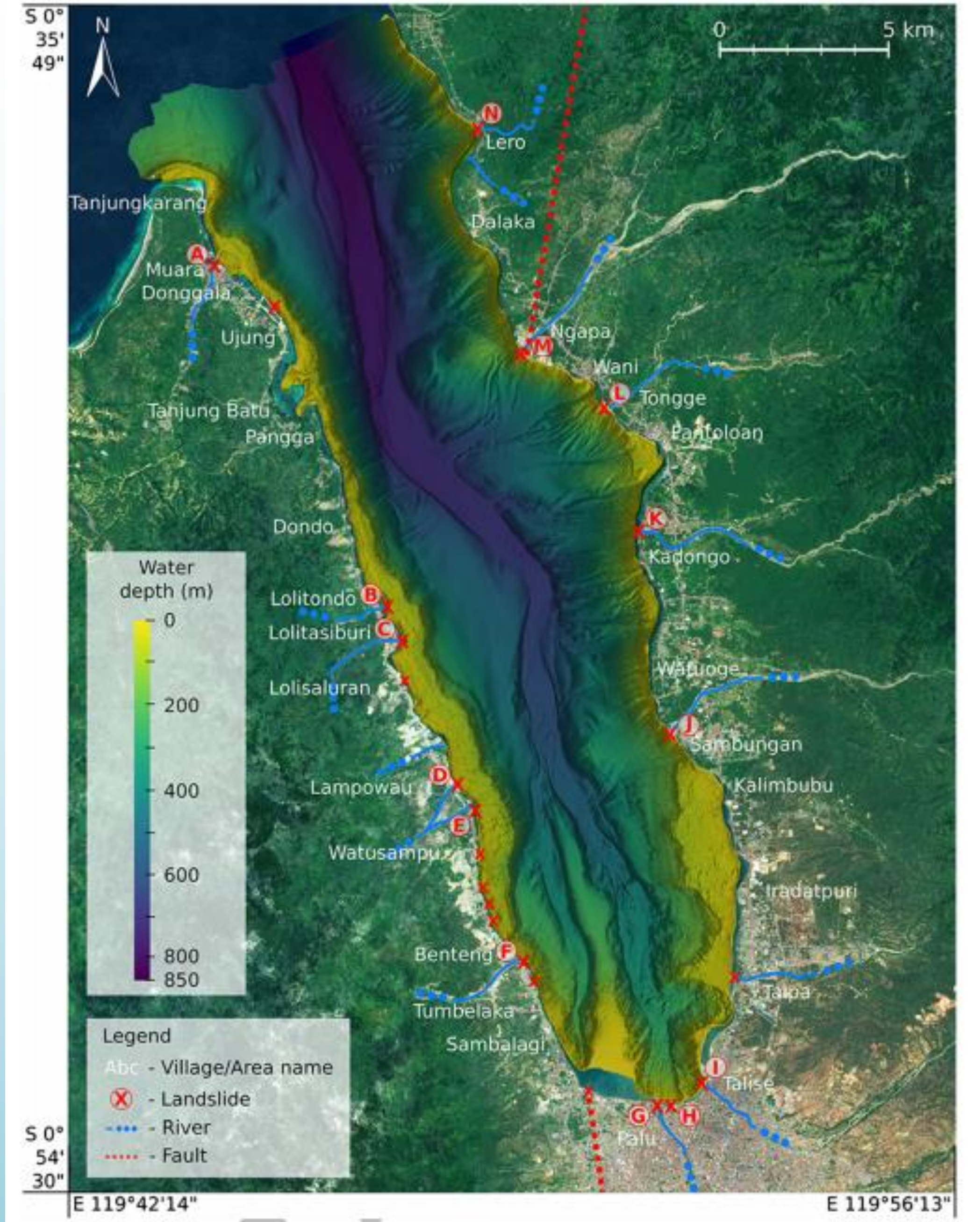
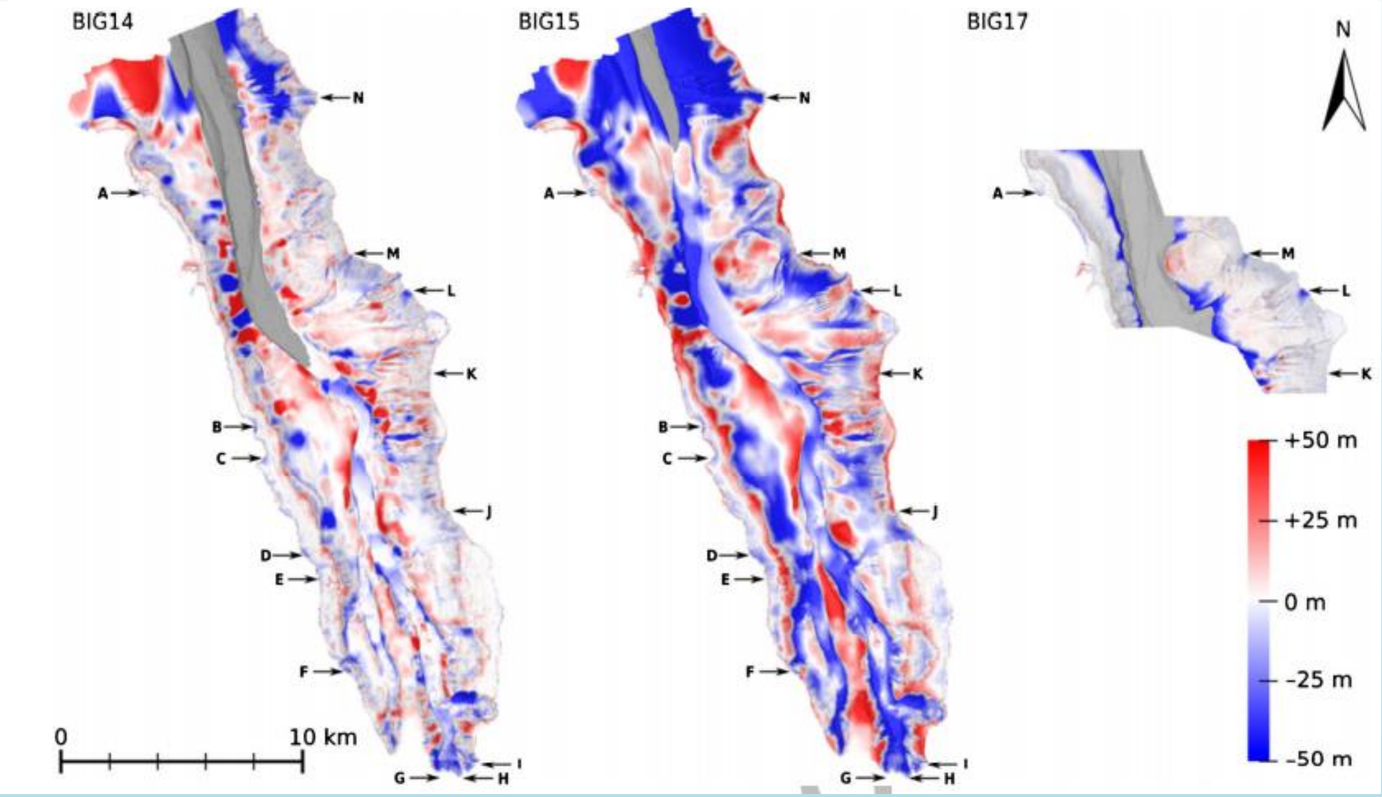
Received: 23 August 2019
Accepted: 21 April 2020

P. L.-F. Liu · P. Higuera · S. Husrin · G. S. Prasetya · J. Prihantono · H. Diastomo · D. G. Pryambodo · H. Susmoro

Coastal landslides in Palu Bay during 2018 Sulawesi earthquake and tsunami

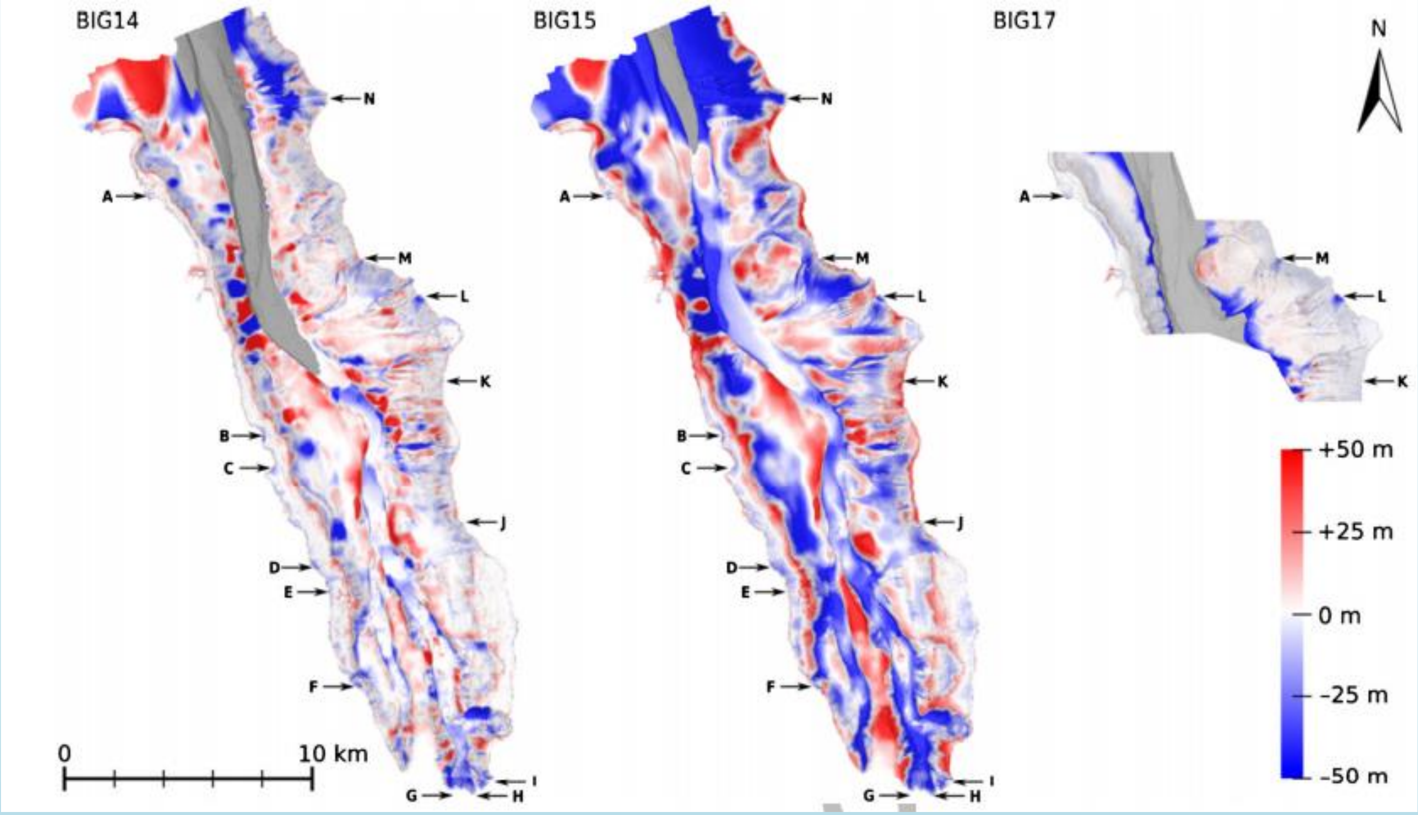


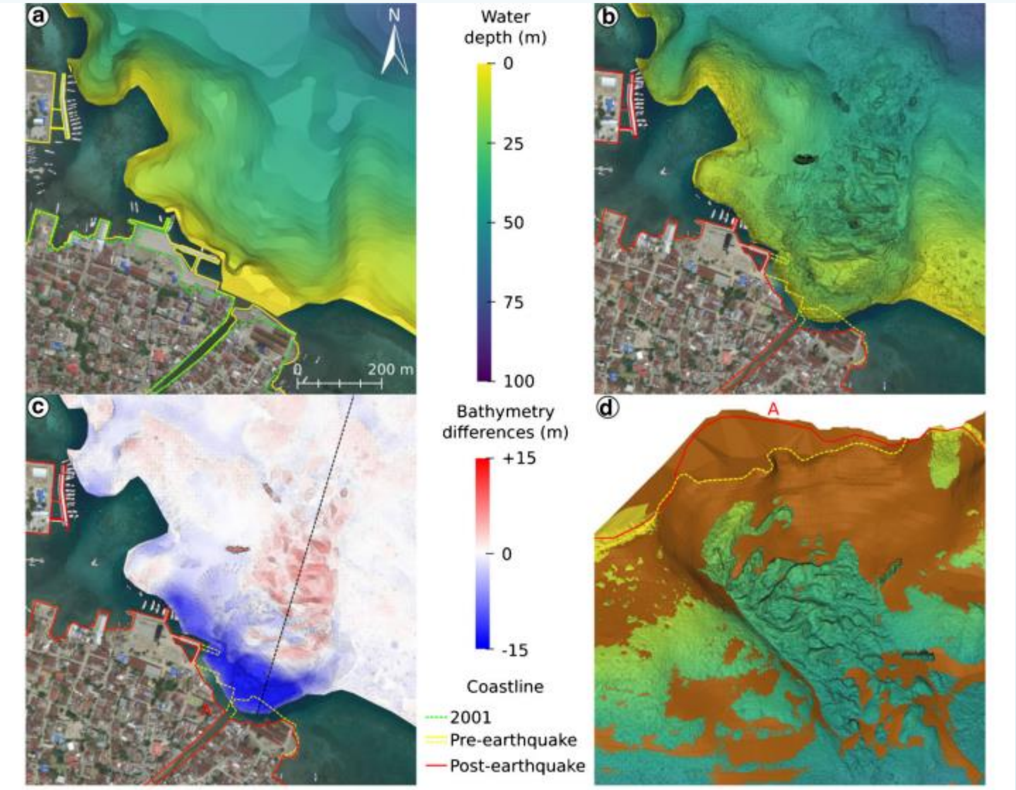
Hasil survey Multibeam (Liu etal.2020)



Perubahan Batimetri di dalam Teluk Palu hasil survey Multibeam (Liu etal.2020)

Kerjasama National University Singapore (Prof. Phil.Liu) – IATsI – BRSDM KKP melakukan survey multibeam dari garis pantai sampai kedalaman 200m di Teluk Palu

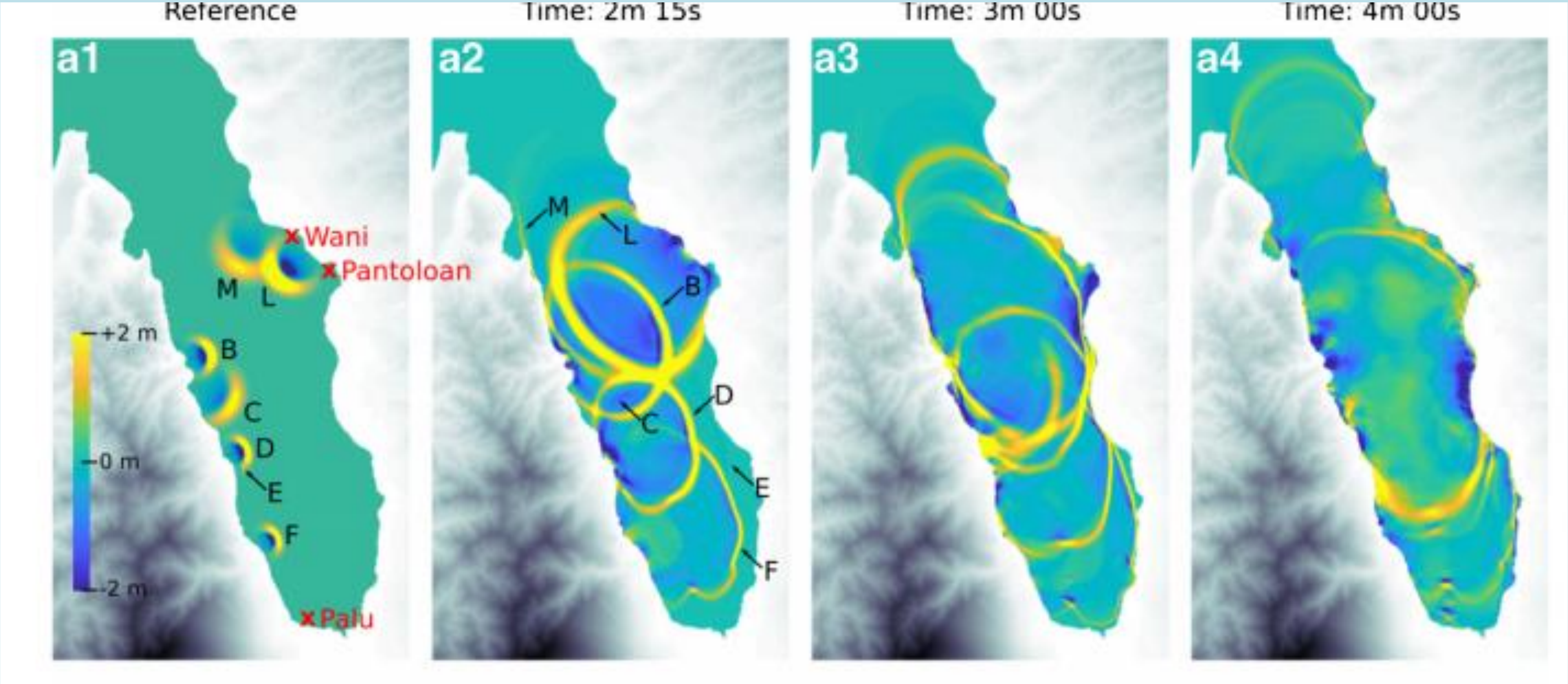




Perubahan Batimetri di dalam Teluk Palu hasil survey Multibeam (Liu etal.2020)

Perubahan Batimetri di titik A hasil multibeam survey (Liu etal.2020)

Multiple submarine landslide generated tsunami inside Palu Bay (Liu et al.2020).



3. SOLUSI MITIGASI BENCANA TSUNAMI

SKALA PRIORITAS DALAM SIKLUS MANAJEMEN BENCANA

Knowing the Risk and What to do about it

Memiliki pengetahuan mengenai resiko dan tahu apa yang harus dilakukan

Early Warning

Monitoring

Emergency Plan

Capacity Building

Disaster

Search & Rescue

Preparedness

Response

Humanitarian Aid

Prevention Soft & Hard Solution

Land-use Planning

Risk Appraisal

Risk Analysis

Risk Identification

Mitigation/ Adaptation

Recovery

Damage Assessment

Rehabilitation & Reconstruction

PRIORITAS UTAMA

MEMAHAMI PROSES-PROSES YANG TERJADI DI ALAM – MENUJU PEMBANGUNAN BERKELANJUTAN

~ DIBUTUHKAN RISET YANG TERUS MENERUS UNTUK MENGUPDATE KNOWLEDGE MENGENAI SOURCE CHARACTERISTIC~

3. SOLUSI MITIGASI BENCANA TSUNAMI

Berdasarkan karakteristik tsunami yang terjadi di wilayah kepulauan Indonesia yang tergolong kedalam TSUNAMI DEKAT (NEAR FIELD – WAKTU TEMPUH < 30 menit) dan sebagian dikategorikan dalam TSUNAMI SENYAP, maka SOLUSI MITIGASINYA adalah dengan PERENCANAAN TATA RUANG DAN OPSI PREVENTION MEASURES.

3.1. PERENCANAAN TATA RUANG

Dua (2) Kategori:

3.1.1. Untuk daerah yang sudah terlanjur terbangun (well-built environment)

3.1.2. Untuk daerah yang belum terbangun (green-field)

3.2. PREVENTION MEASURES ~ SOFT AND HARDS SOLUTION

3.2.1. Natural Protective function of Coastal Features

3.2.2. Man-made Structures

3.1. PERENCANAAN TATA RUANG

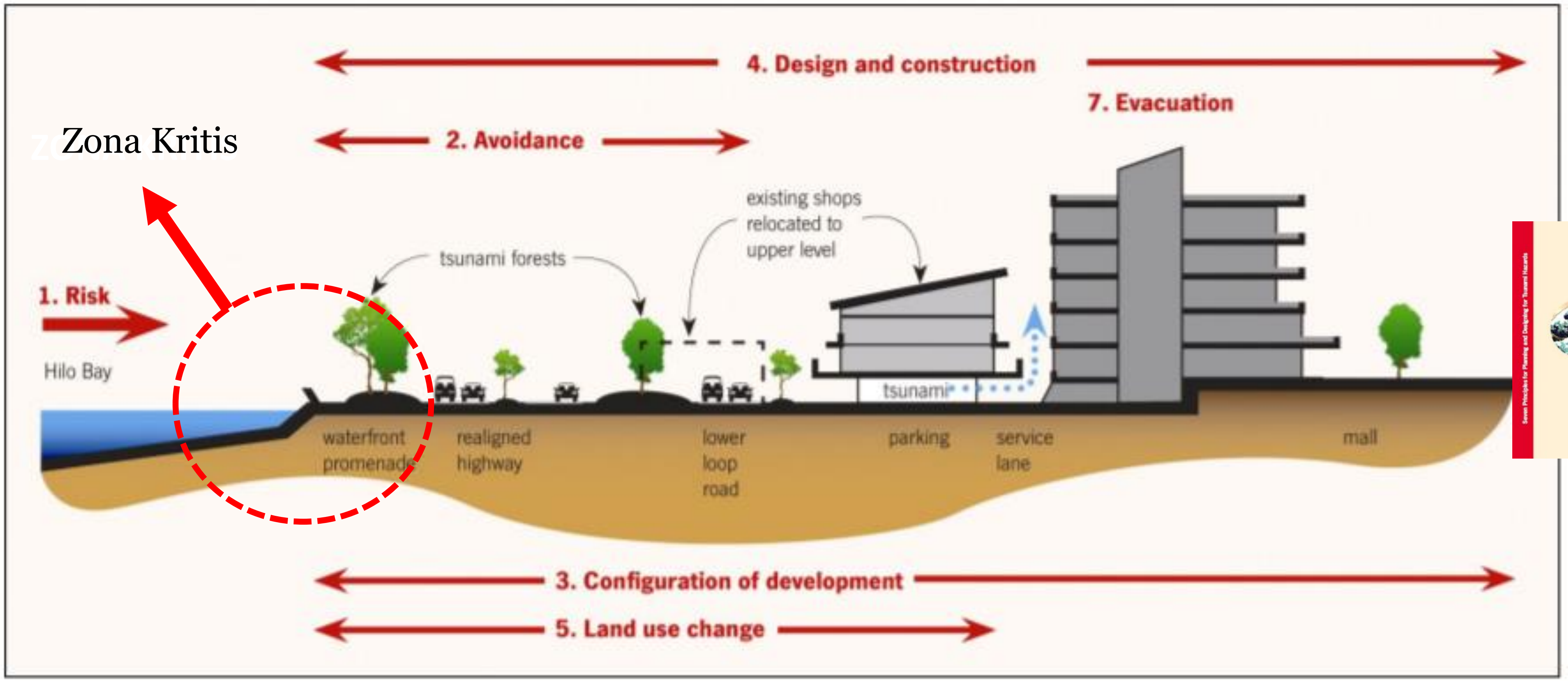
PERLU PENGATURAN TATA RUANG DAN IMPLEMENTASINYA:

1. UNTUK DAERAH YANG SUDAH TERLANJUR TERBANGUN (WELL BUILT ENVIRONMENT): OPSINYA LEBIH KOMPLEKS

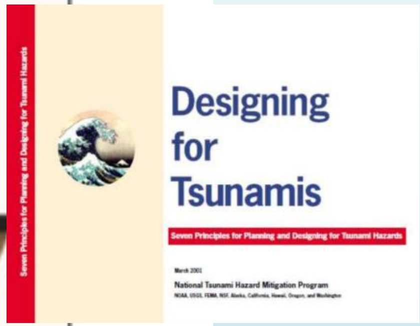
CONTOH : KAWASAN INDUSTRI PETROCHEMICAL CILEGON BERKAITAN DENGAN SECONDARY DISASTER

2. UNTUK WILAYAH YANG BELUM TERBANGUN (GREEN FRIELD) – OPSINYA LEBIH MUDAH

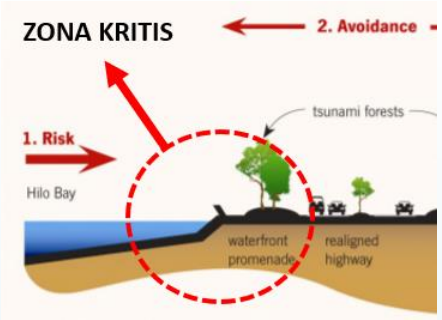
Contoh Penataan Ruang berdasarkan Guidelines di Amerika Serikat – (Designing for Tsunamis – National Tsunami Hazard Mitigation Program) 2001



Seven principles for planning and designing for tsunami hazards in Hilo, Hawaii (adapted from National Tsunami Hazard Mitigation Program, 2001, p27).



ZONA KRITIS



Hindari membangun bangunan/struktur yang bersifat temporary atau tidak permanen dan mudah terbawa gelombang karena akan menjadi debris – yang mematikan. BUILDING CODE untuk ZONA MERAH harus dipatuhi.

Bongkahan batuan di Selat Sunda

Bongkahan seawall yang terbawa gelombang Tsunami di Palu

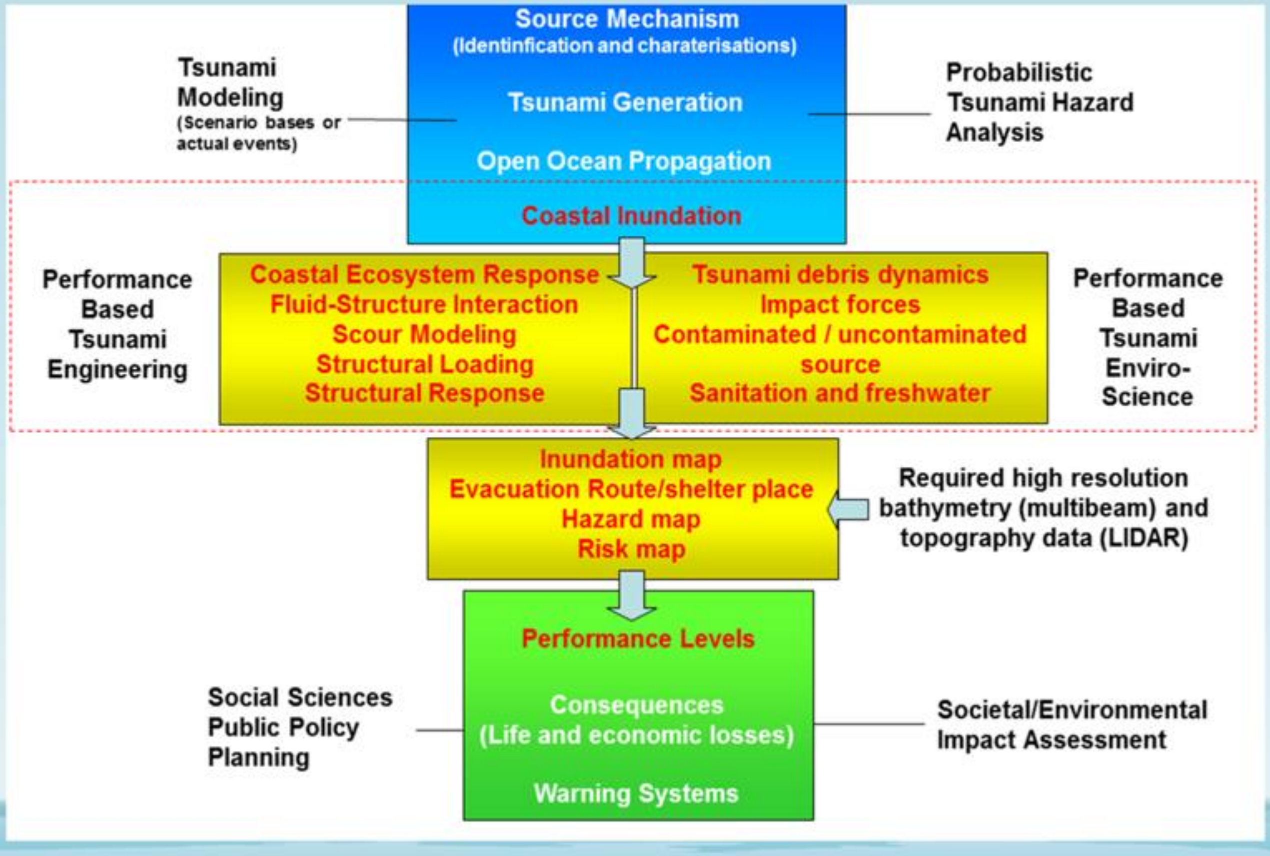
Debris yang terbawa tsunami di Banda Aceh

3.2. PREVENTION MEASURES ~ SOFT AND HARDS SOLUTION

DIAGRAM PENGELOLAAN ANCAMAN TSUNAMI

Tsunami Hazards and Disaster Management Fundamental Elements

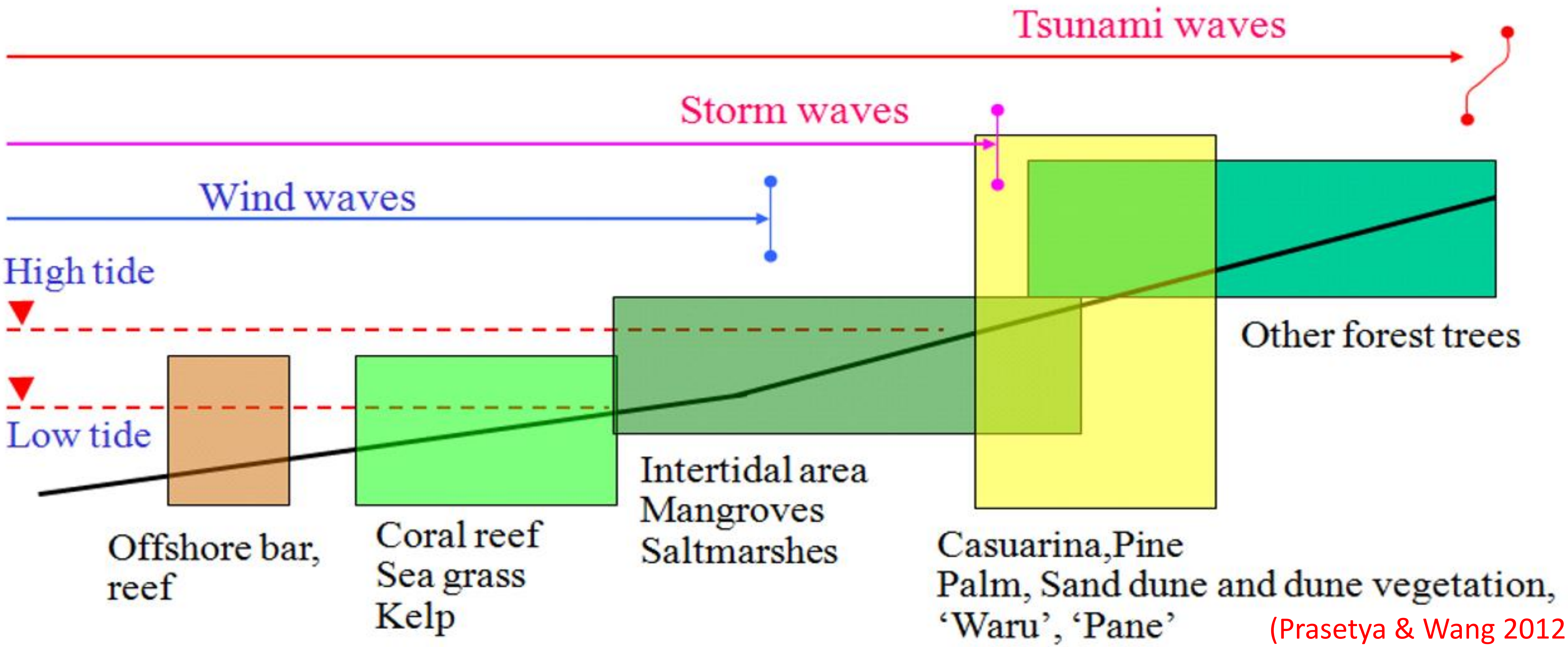
(Source: G.Prasetya (2010) after Riggs and Robertson)



BELAJAR DARI ALAM – SOFT SOLUTIONS

KONSEP MITIGASI DAN ADAPTASI TERHADAP *'NATURAL FORCES '*

A NATURAL PROTECTIVE FUNCTION OF NATURAL ECOSYSTEM – *A SUSTAINABLE INVESTMENT*

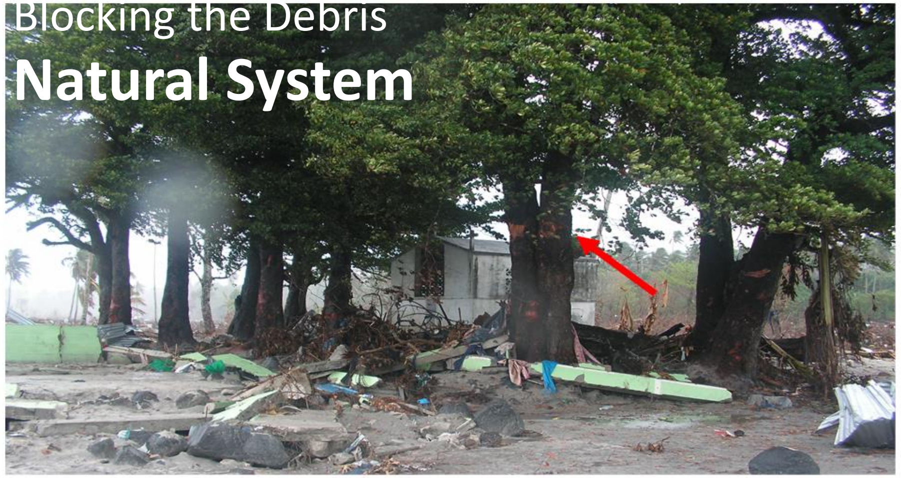


(Prasetya & Wang 2012)

Coastal Forest and Tsunami ~ THE SHIELDING/SHELTERING EFFECTS

Mangrove in Simeulue Island post 26 December 2004 event >Mw 9.2

THE SHIELDING EFFECTS



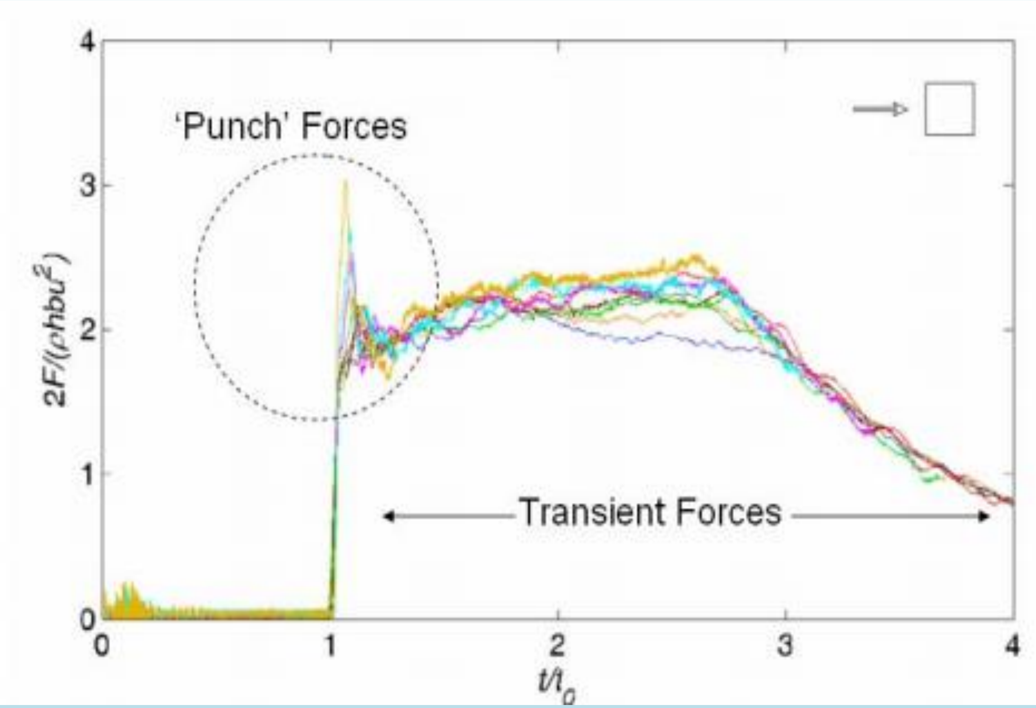
Local Panee Trees in Samoa during the Samoa 2009 events;

(Sumber: Prasetya et al, 2009)

PERFORMANCE BASE TSUNAMI ENGINEERING

Tsunami Force (Punch Forces + Transient Forces)

(source: Arikawa, T 2009)



Source: Arnason, 2005

PERFORMANCE BASE TSUNAMI ENGINEERING

Bangunan/struktur dengan BUILDING CODE yang sesuai tidak menjadi debris bahkan memberikan shielding effect.

BANGUNAN GEDUNG ATAU STRUKTUR YANG DIBANGUN DI ZONA KRITIS HARUS TAHAN TERHADAP GAYA GEMPA DAN TSUNAMI (BUILDING CODE).

BANGUNAN INI DAPAT AKAN MEMILIKI FUNGSI SEBAGAI *THE SHIELDING/SHELTERING EFFECTS*

Scouring at the corner of building

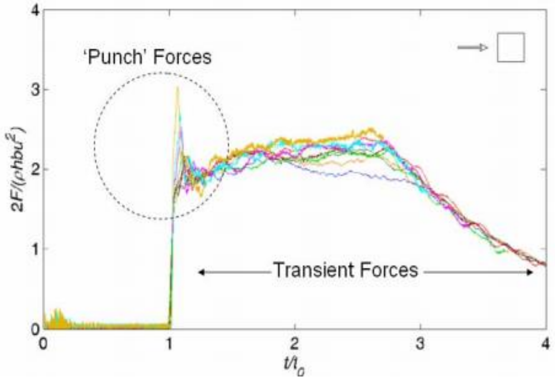
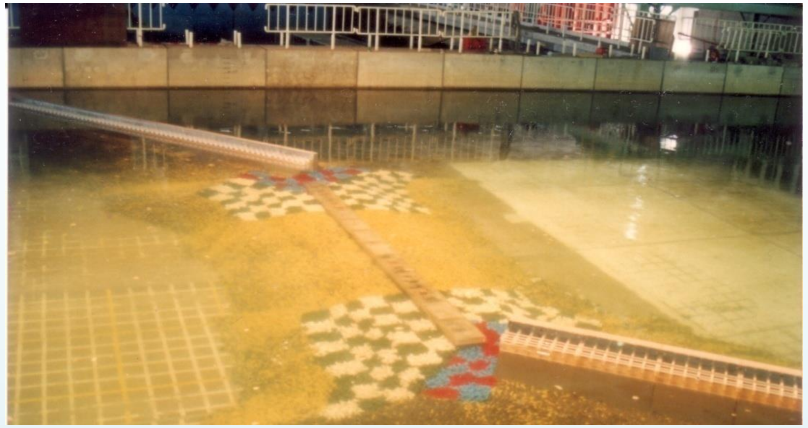


Figure 4 Typical damage to different types of houses due to tsunami with different flow depths in Banda Aceh and Nias Island after the 26 December 2004 event. Most of the 3 storey reinforced concrete structures survived the tsunami with flow depths greater than 10m (photo 5 and 6) whereas other buildings which surrounded these were completely wiped out. With this flow depth, no sheltering effects from the buildings or trees reduced the tsunami impact. A simple house with a palm tree roof was resistant to the earthquake shaking (photo 1) when compared to the neighbouring concrete house (photo 2). However, this house suffered damage from the tsunami with a flow depth of 1.8 m or half of the height of the house (Modified from: Prasetya et al. 2008).

LESSON LEARN FROM ACEH 2004 AND SAMOA 2009

HARD SOLUTIONS


(Source: Prasetya, 1992)

LESSON LEARN FROM JAPAN

Design Test Offshore Tsunami Breakwater – Kamaishi, PHRI 1992
(Source: Prasetya, 1992)
Construction completed in March 2009 ~ $1.5 billion

-------------------FAILED DURING THE 2011 EVENT--------------------

Seawall/Dyke Terlimpasi !!!!

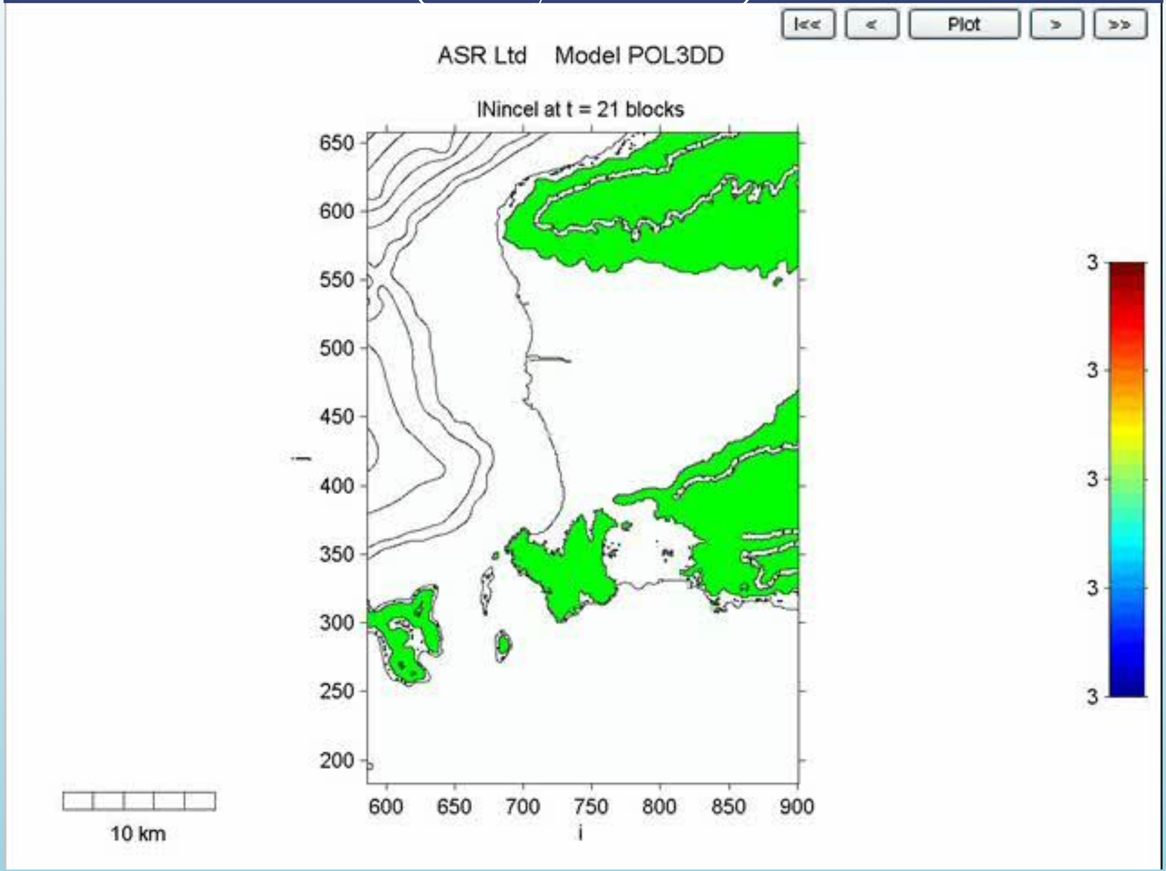
TSUNAMI DRILL dan TANGGUL

(Source: New York Times)

PERFORMANCE BASE TSUNAMI ENVIRO-SCIENCE

Tsunami membawa semua material/debris......

Modelling pergerakan debris di Banda Aceh
(Prasetya etal. 2010)



PERFORMANCE LEVEL:
PENGUATAN SISTEM PERINGATAN DINI TSUNAMI

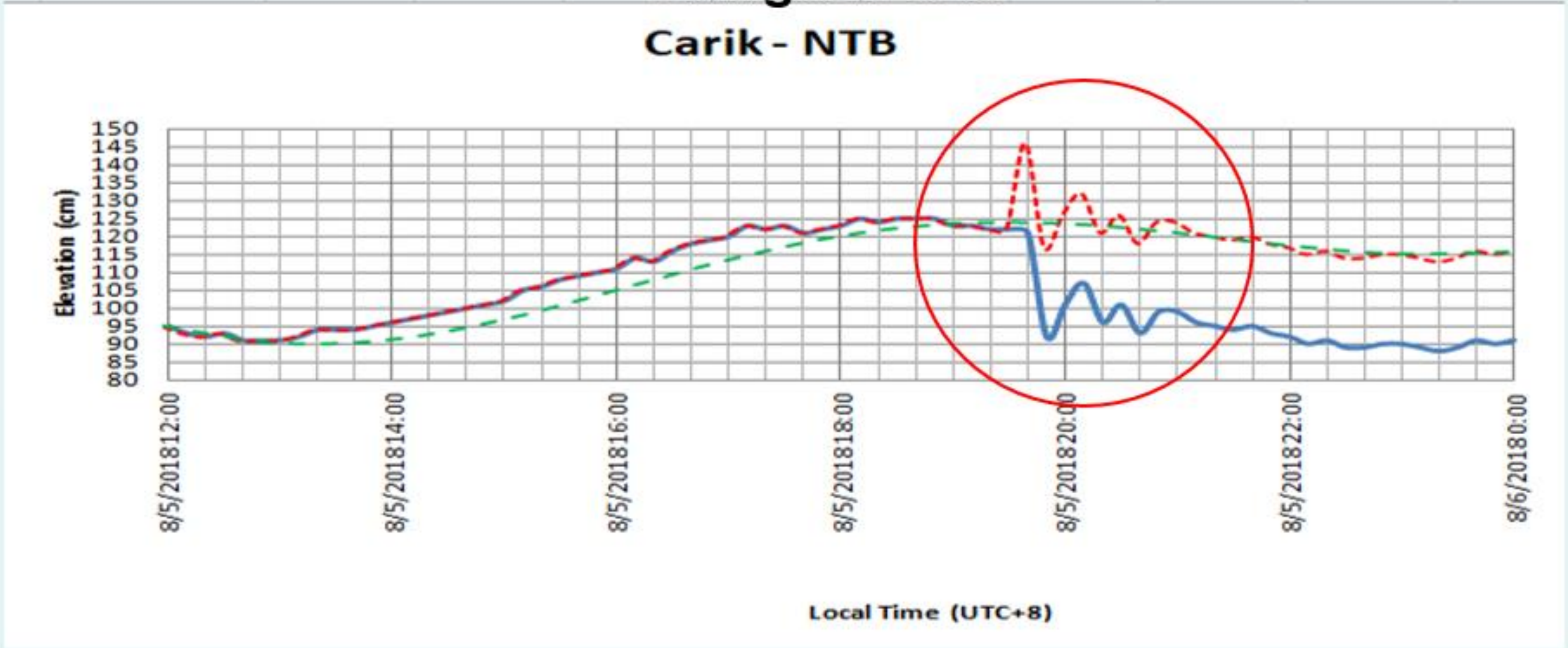
TSUNAMI YANG DIBANGKITAN OLEH AKTIVITAS GEMPA BUMI ~ *shifting paradigm from Earthquake-centric to tsunami centric:*

- Indonesia merupakan negara kepulauan
- Jarak sumber gempa/tsunami dengan daratan cukup dekat
- Deformasi awal dari aktivitas tektonik juga terjadi di daratan – terjadi perubahan elevasi vertikal di darat: naik (uplift) atau turun (subsidence)
- Tsunami dapat di deteksi dengan mudah dan cepat dengan alat ukur perubahan permukaan laut yang dipasang di darat
- Sistem Peringatan Dini harus berubah dari Earthquake-Centric ke Tsunami-Centric

Sumber: Danny Hilman Natawidjaja

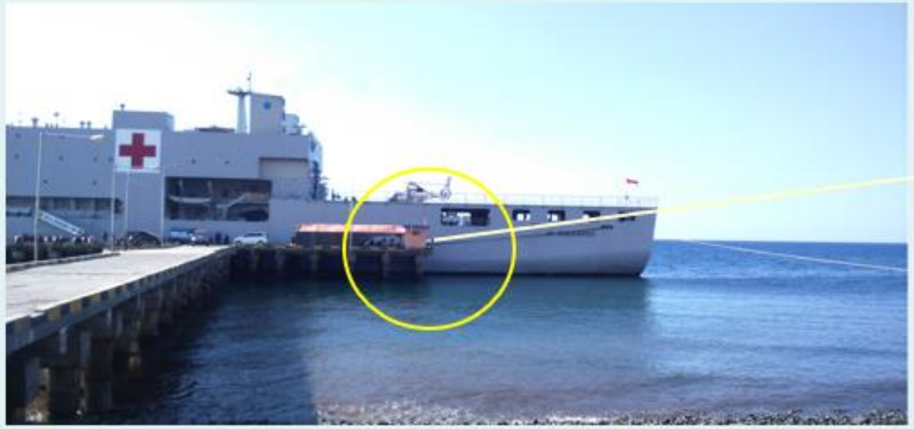
Sumber: Danny Hilman Natawidjaja

Example of uplift recorded at Tidal Station during Lombok Earthquake M7.0 5 August 2018



(Prasetya et al. 2019 AGU Meeting Washington, USA)

Microatoll coral reef



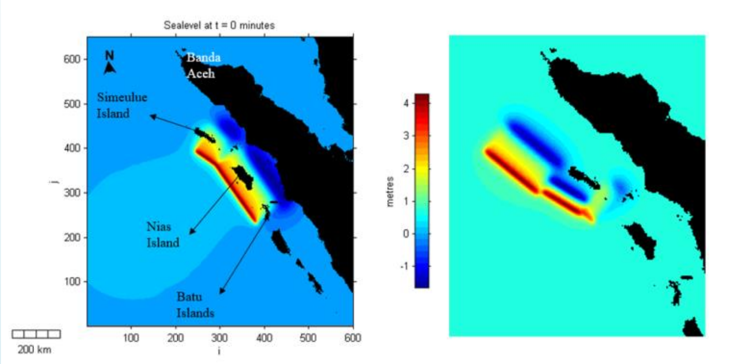
Tide Station at Carik Port (yellow circle)

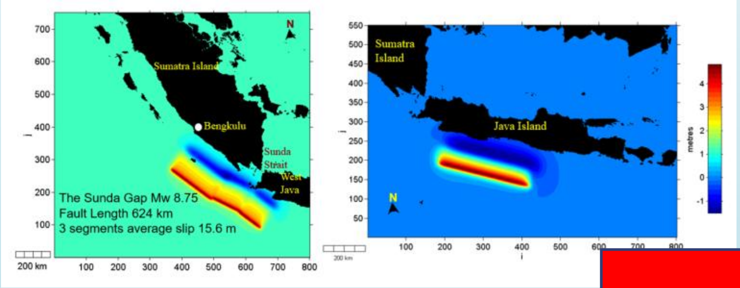
PROGRES SOLUSI TEKNOLOGI PERINGATAN DINI YANG DI TAWARKAN

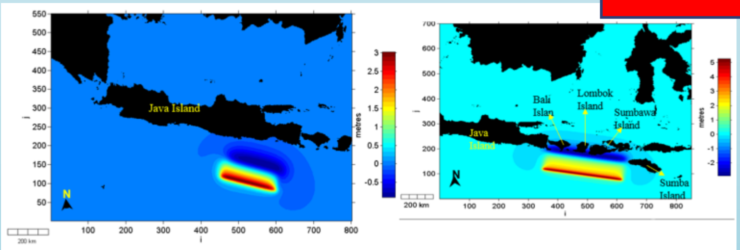
SOLUSI ALTERNATIF SENSOR PENGUKURAN PERUBAHAN MUKA LAUT UNTUK MEGATHRUST DAN VOLCANIC TSUNAMIS (KOMPLEMENTARI DATA PASUT BIG).

- Inexpensive Device for Sea Level measurement – (IDSL (JRC – EU)/PUMMA(INA))

Megathrust event





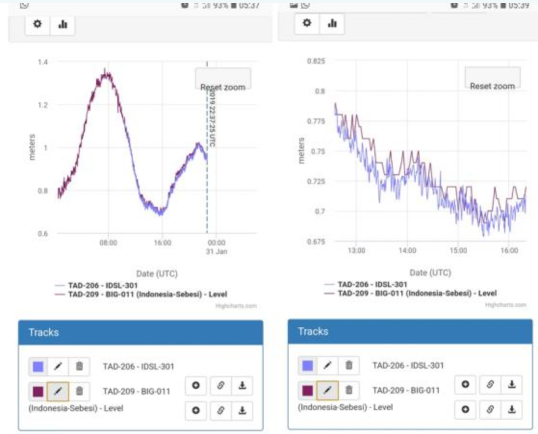


Daratan ikut terdeformasi....

Mengapa IDSL (Inexpensive Device for Sea Level measurement)

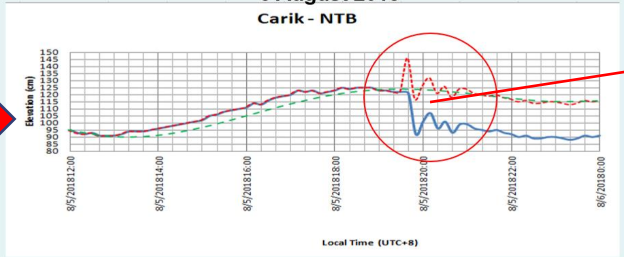
- ✓Dikembangkan oleh Uni Eropa (JRC-EC) didukung oleh IOC/UNESCO
- ✓Mengukur anomaly muka air (tsunami)
- ✓Murah, memanfaatkan sistem eksisting, komponen di pasaran, biaya pulsa (60rb/bln)
- ✓Operasional 10 tahun di Kawasan Mediterania→ Tsunami jarak pendek
- ✓Mudah dipasang →sederhana
- ✓Cepat→ transmisi data dan kerapatan data+CCTV Camera

IDSL (2/8) Terpasang (31 Januari 2019)

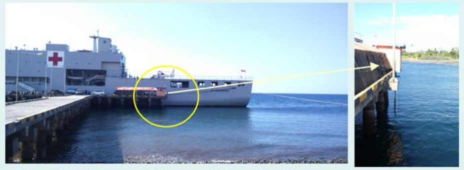


Data IDSL jauh lebih rapat (setiap 5 detik Vs setiap 2 menit)

Example of uplift recorded at Tidal Station during Lombok Earthquake M7.0 5 August 2018



Microatoll coral reef



Tide Station at Carik Port (yellow circle)

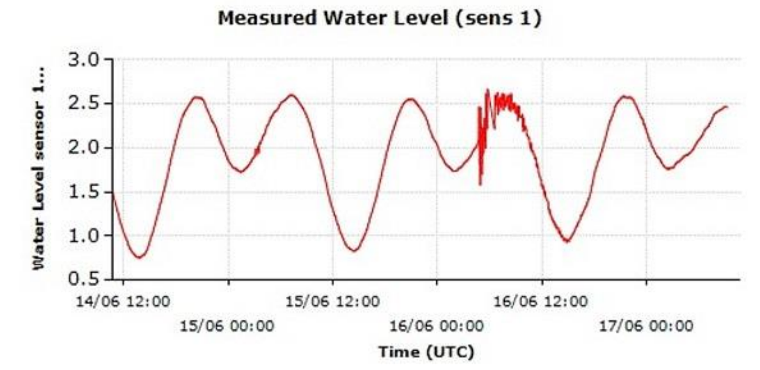
webcritech.jrc.ec.europa.eu/TAD_server/Home

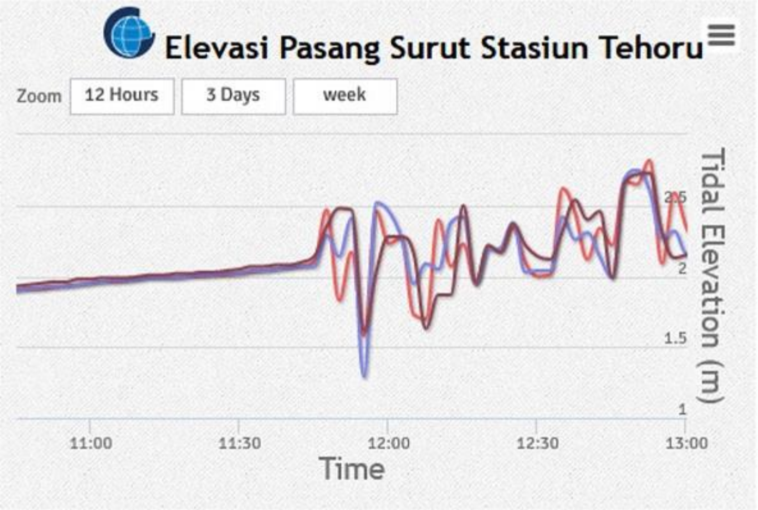
Indonesia

191	BIG-001	RAD	ToliToli	Indonesia (Sulawesi)	BIG	7.420	04 Feb 2019 00:35:00	6 Min.
192	BIG-002	RAD	Mamuju	Indonesia (Sulawesi)	BIG	0.870	04 Feb 2019 00:35:00	6 Min.
193	BIG-003	RAD	Pantaolan	Indonesia (Lampung)	BIG	1.330	04 Feb 2019 00:35:00	6 Min.
194	BIG-004	RAD	Kota Agung	Indonesia (Lampung)	BIG	1.230	04 Feb 2019 00:35:00	6 Min.
195	BIG-005	RAD	Krui	Indonesia (Banten)	BIG	1.030	04 Feb 2019 00:35:00	6 Min.
196	BIG-006	RAD	Bengkunat	Indonesia (Banten)	BIG	0.630	04 Feb 2019 00:35:00	6 Min.
197	BIG-007	RAD	Pelabuhan	Indonesia (Banten)	BIG	1.090	04 Feb 2019 00:35:00	6 Min.
201	BIG-008	RAD	Binuangeun	Indonesia (Banten)	BIG	8.280	04 Feb 2019 00:35:00	6 Min.
200	BIG-009	RAD	Ciwandan	Indonesia (Banten)	BIG	1.620	04 Feb 2019 00:35:00	6 Min.
190	BIG-010	RAD	Marina Jambu	Indonesia (Banten)	BIG	0.500	04 Feb 2019 00:35:00	6 Min.
209	BIG-011	RAD	Sebesi	Indonesia (Banten)	BIG	1.020	04 Feb 2019 00:35:00	6 Min.
206	IDSL-301	RAD	Sebesi	Indonesia (Sumatra)	JRC-MMAF	1.004	04 Feb 2019 00:41:29	15 Sec.
207	IDSL-302	RAD	Marina Jambu	Indonesia (Java)	JRC-MMAF	0.648	04 Feb 2019 00:41:31	13 Sec.

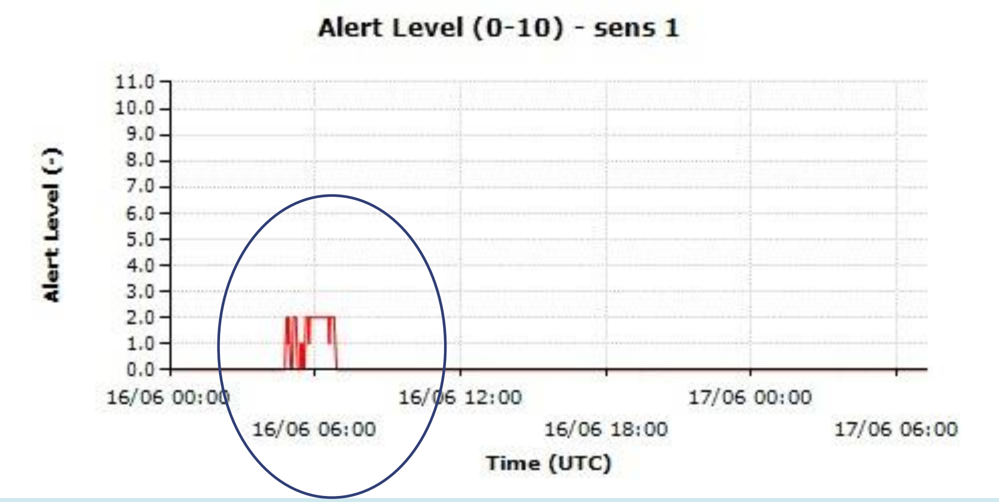
15 detik Vs 6 menit

REAL-TIME APPLICATION – KEJADIAN TSUNAMI MALUKU 16 JUNI 2021 PERINGATAN DIKELUARKAN ALGORITM IDSL





Peringatan Dikeluarkan Algoritm IDSL



Maluku				
4418	0017TUAL03	Tual	10 Min.
4415	0107NAML03	Namlea	10 Min.
4414	0108BULA03	Bula	10 Min.
4413	0126BNDA03	Banda	10 Min.
4523	0184THRU03	Tehoru	1 Hours

Sumber: https://kkp.go.id/brsdm/pusriskel/artikel/31546-pelajaran-penting-dari-tsunami-maluku-16-juni-2021

APLIKASI IDSL/PUMMA UNTUK TSUNAMI EARTHQUAKE

DEFORMASI MENTAWAI 2010 DAN PANGANDARAN 2006 DAPAT DIDETEKSI OLEH IDSL/PUMMA

MENTAWAI 2010, M7.8

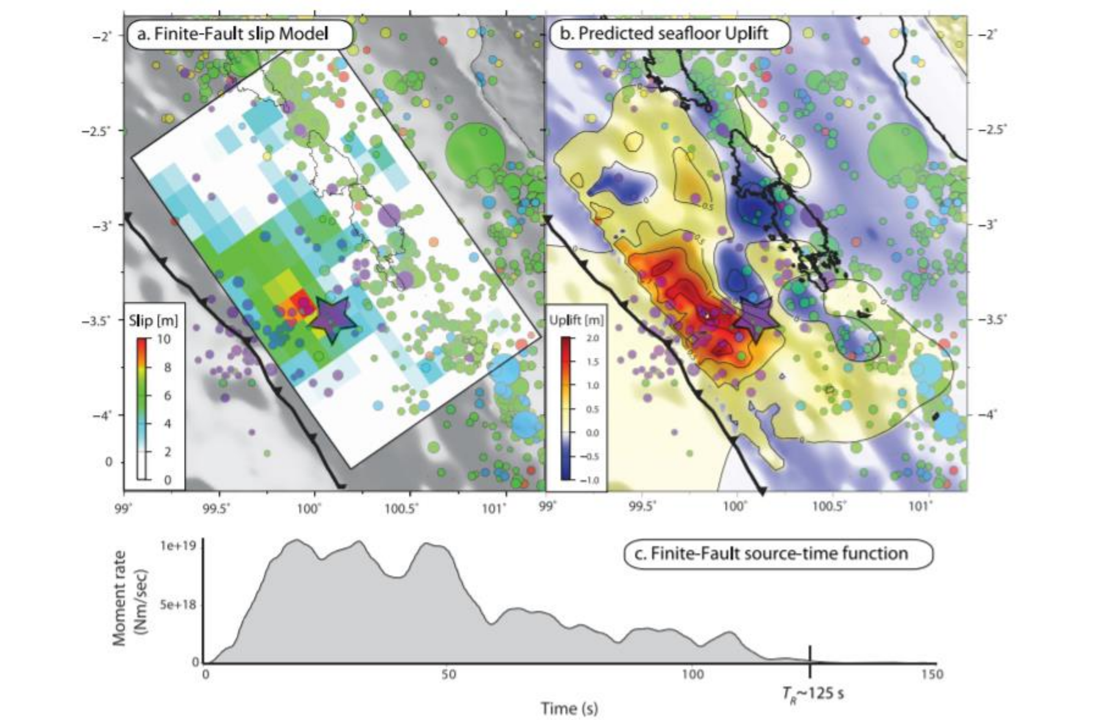


Figure 3. (a) The preferred interface slip model strikes N35°W, and extends from the seafloor to 33.9 km depth at a dip of 11.6°, has primarily thrust motion with large slip focused updip and primarily NE of the hypocenter (star). The spatially distributed slip form the scaled finite fault solution is used as input to predict (b) the surface uplift, and (c) the earthquake source-time function.

(Newman et al. 2011)

PANGANDARAN 2006, M7.7

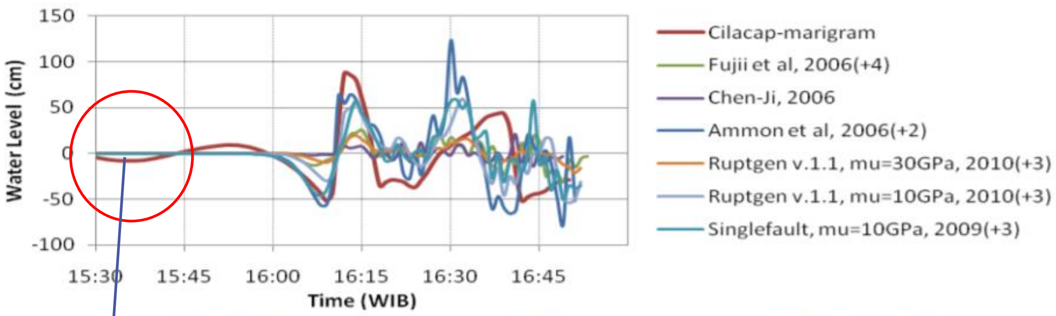


Figure 10. Marigram vs. water level at tide gauge of cilacap (109.019E, 7.753S)

(Widjo Kongko et al. 2010)

Initial deformation dari Cilacap-Marigram

PENUTUP

- **Indonesia sebagai negara kepulauan dimana jarak sumber gempa dan daratan sangat dekat, sehingga perubahan elevasi muka air ketika terjadi gempabumi atau turun dan naiknya daratan ketika gempa bumi terjadi dan proses geologi lainnya *dapat langsung tercatat di stasiun pasut dan cGPS*. Stasiun Pasut yang real-time (seperti IDSL/PUMA) terbukti handal, murah dan mudah dalam pengoperasiannya sesuai dengan kondisi ekonomi Indonesia saat ini.**
- **Kombinasi *real-time tide gauge*, *cGPS* *dan* *seismograf* merupakan salah satu solusi yang bisa dilakukan sekarang untuk efektif TEWS sebagai salah satu Upaya didalam memitigasi tsunami.**
- **Penataan Ruang yang diikuti dengan aturan building code berdasarkan kajian karakteristik tsunami yang mungkin terjadi bersama-sama dengan integrated TEWS (kombinasi real-time tide gauge, cGPS, dan Seismograf) merupakan solusi mitigasi tsunami near-field baik itu dari sumber megathrust maupun tsunami yang dikatergorikan kedalam kategori Tsunami Senyap.**

Thank You
Terima Kasih