Investigation on volcanic activity and sector collapse inducing the Sunda Strait tsunami in Indonesia

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Project operation

	Topic	Operation	Location
1	Elucidation of growth and collapse processes of Anak Krakatau volcano based on geological and geomorphological analyses	Geological survey	Krakatau Islands
2	Elucidation of the process where small scale eruption activities resulted in collapse of the mountains	Examination of seismicity in long-term	CVGHM
3	Elucidation of the collapse process of the mountains	Analysis broadband seismogram	CVGHM
4	Evaluation of possibility of future collapse	Operation fixed-wing UAV	POS
		Installation microphone	CVGHM

Topic 1: Elucidation of growth and collapse processes of Anak Krakatau volcano based on geological and geomorphological analyses

Geology group

Japan	Fukashi Maeno (ERI) Takayuki Kaneko (ERI) Masashi Nagai (NIED)	Study area: Krakatau Islands
Indonesia	Nugraha Kartadinata (CVGHM) Oktory Prambada (CVGHM)	

Objective: Clarify the cause and process of the flank collapse of Anak Krakatau volcano, based on geological and geomorphological data of the volcano.

Anak Krakatau Volcano before collapse

Size: ~2.1 km EW
~2.3 km NS
Height: > 300 m a.s.l.

Lava flows and a central cone

Anak Krakatau Volcano before collapse

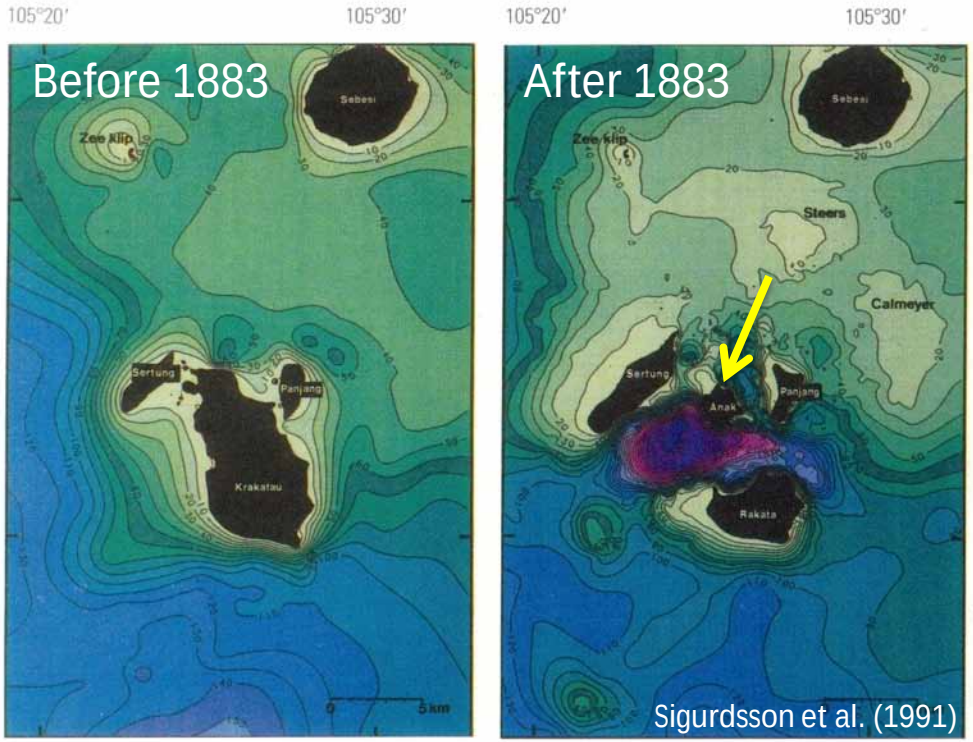
Size: ~2.1 km EW and ~2.3 km NS
Height: >300 m a.s.l.
Lava flows and a central cone

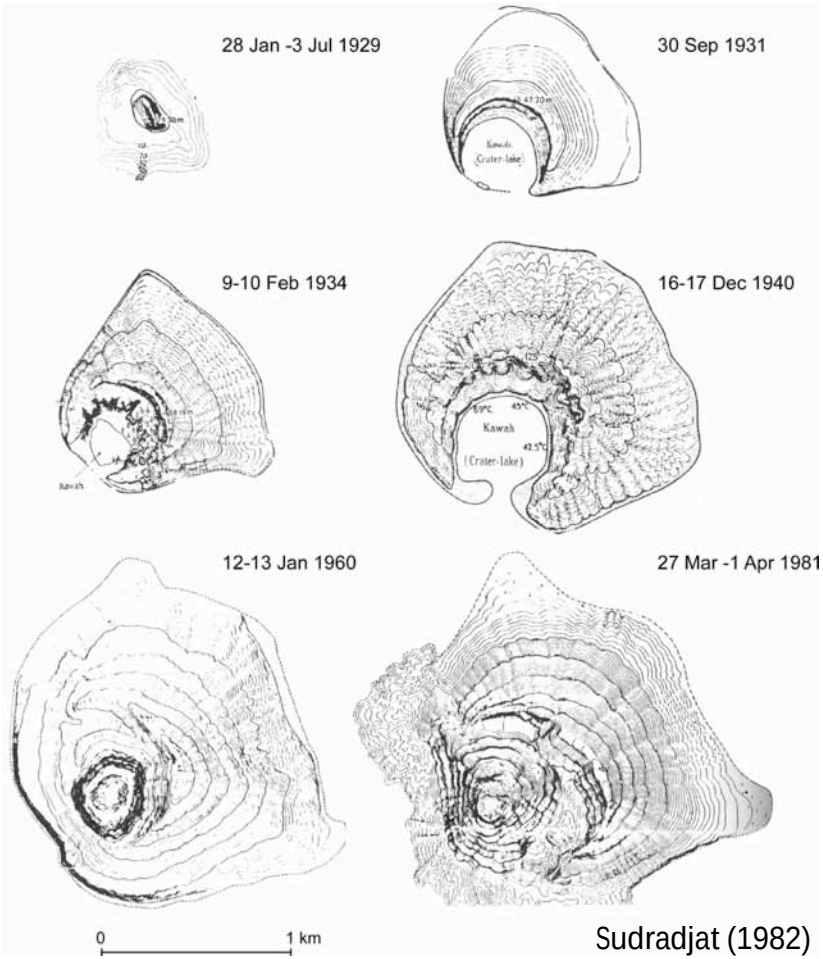
All photos were taken in September 2014

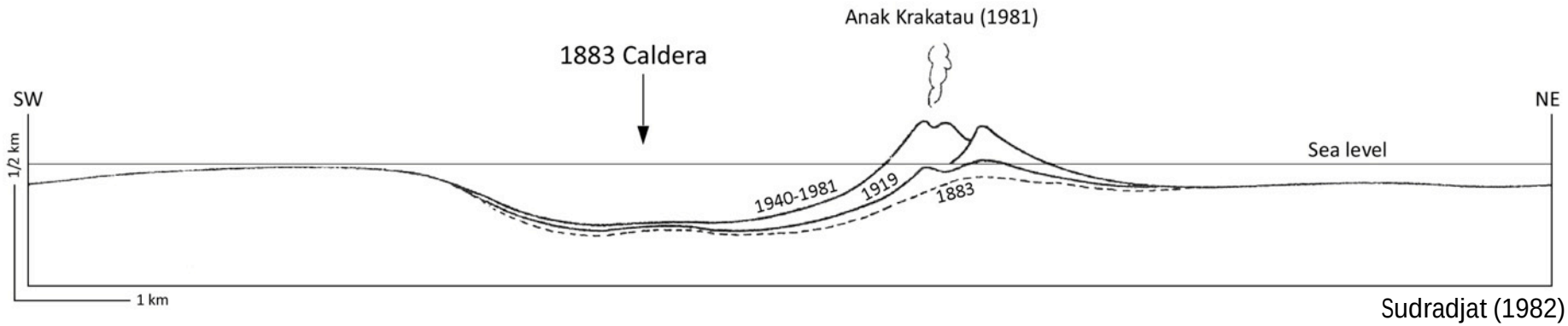
Accumulation of pyroclasts from
Strombolian and Vulcanian eruptions

Geological background

A young volcanic island growing since 1927

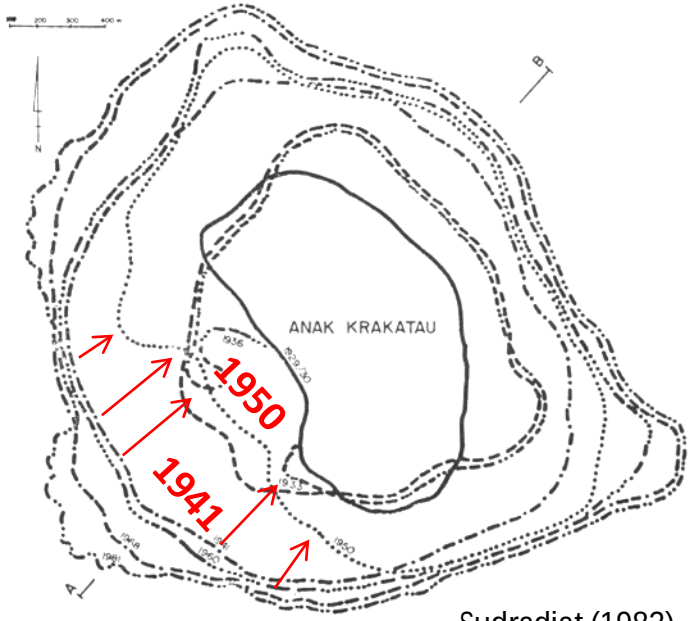




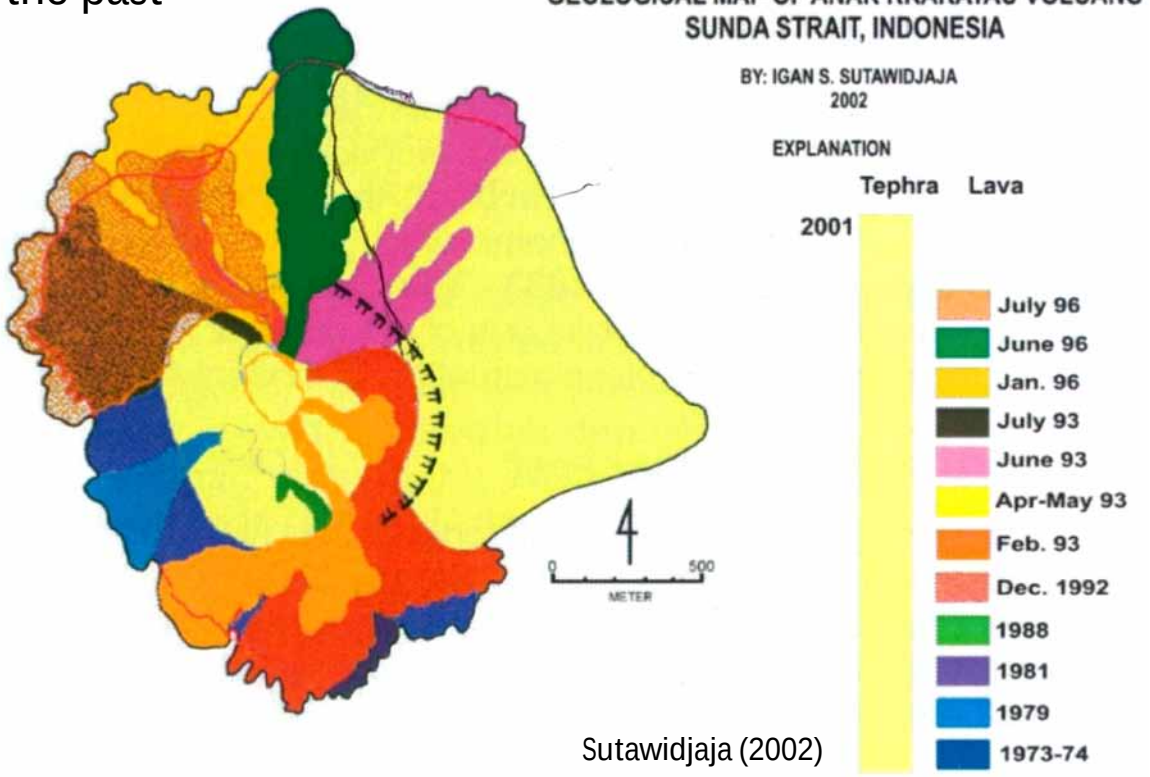


Geological background

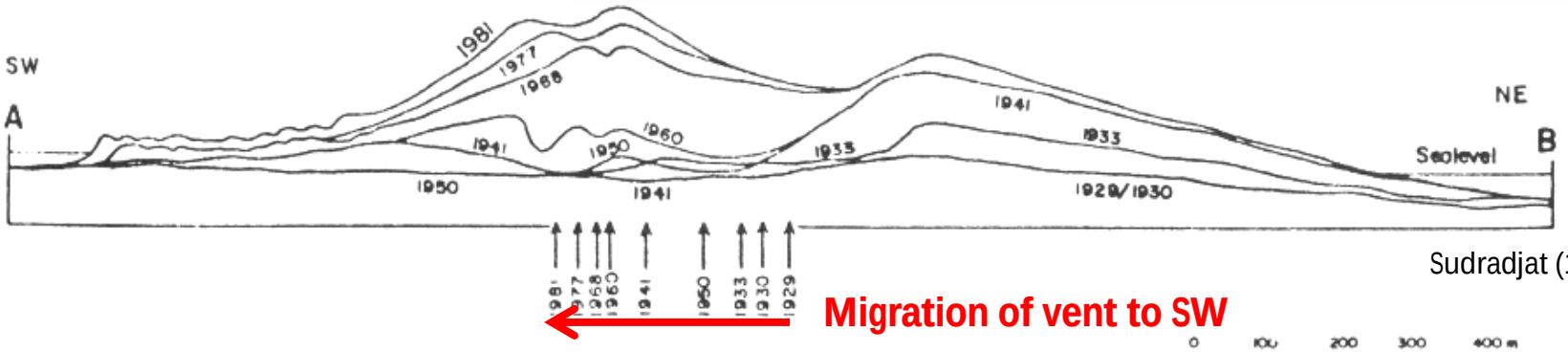
At least 3 small-scale collapses in the past



Sudradjat (1982)

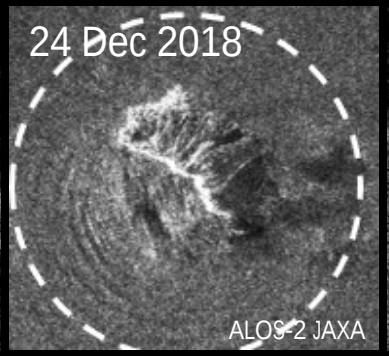


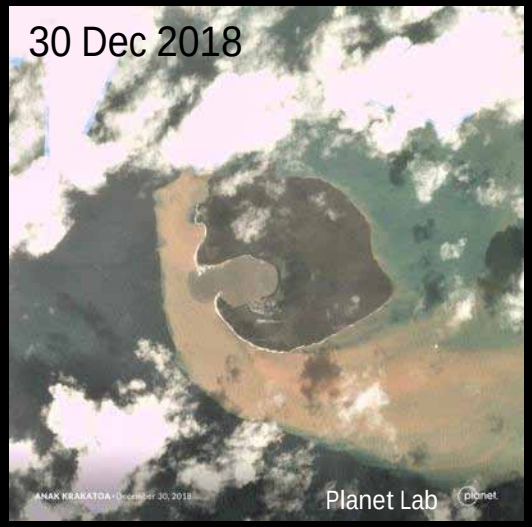
Sutawidjaja (2002)



Sudradjat (1982)

Evolution of Anak Krakatau (SAR, Optical)





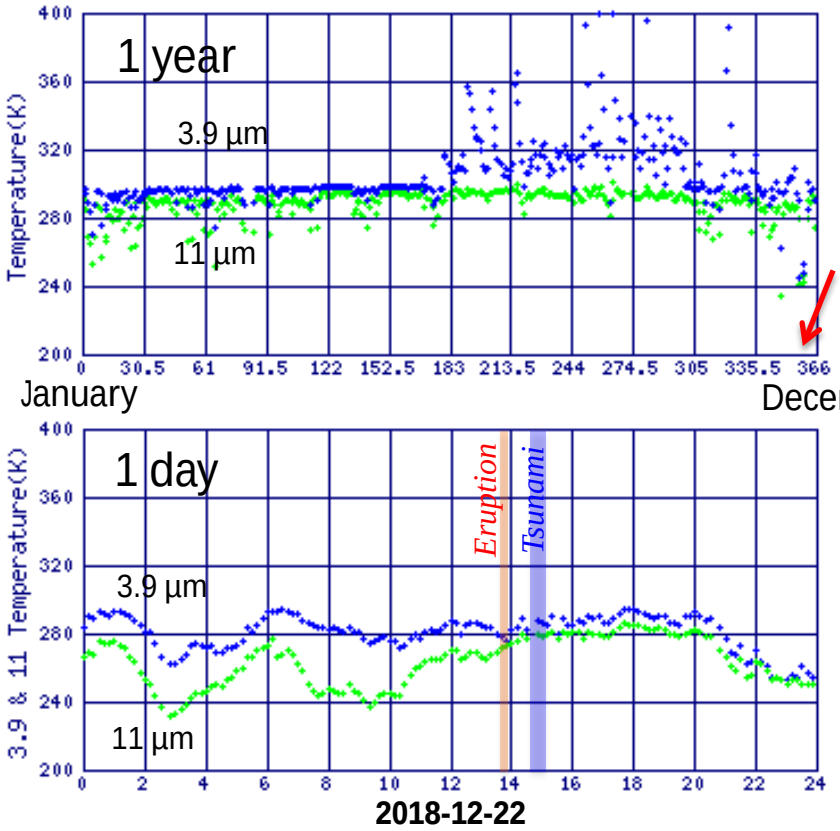
Collapse

⬇

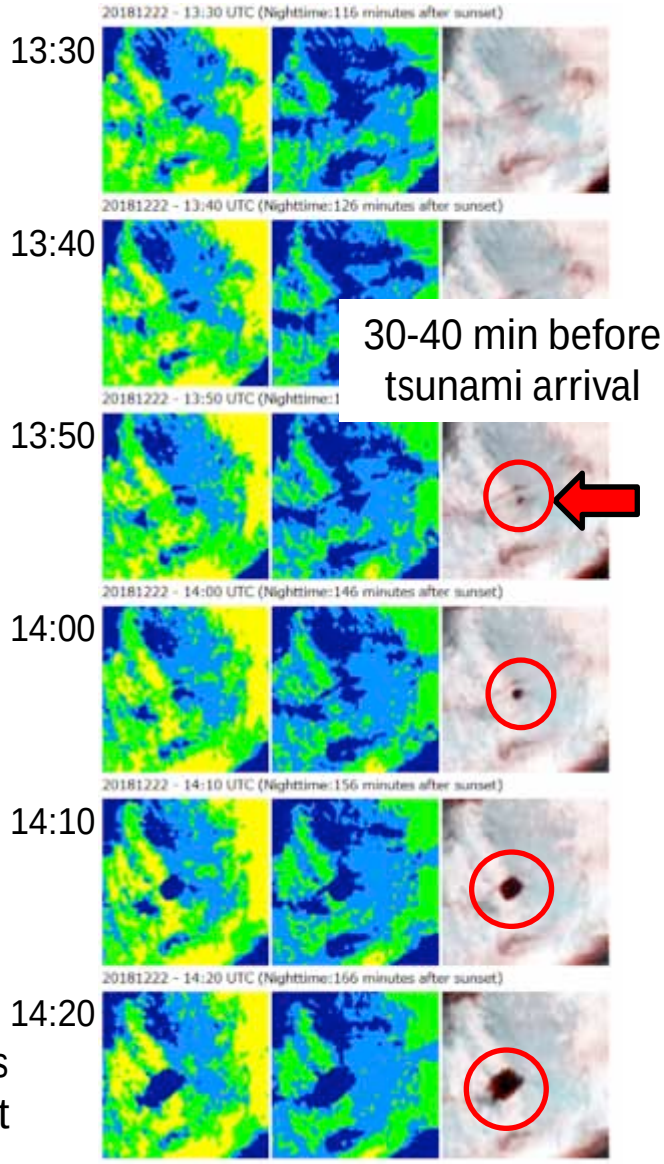
Growth

Activity in 2019: Himawari-8 data (Thermal anomaly)

Variation of thermal anomaly in 2018 (only night)



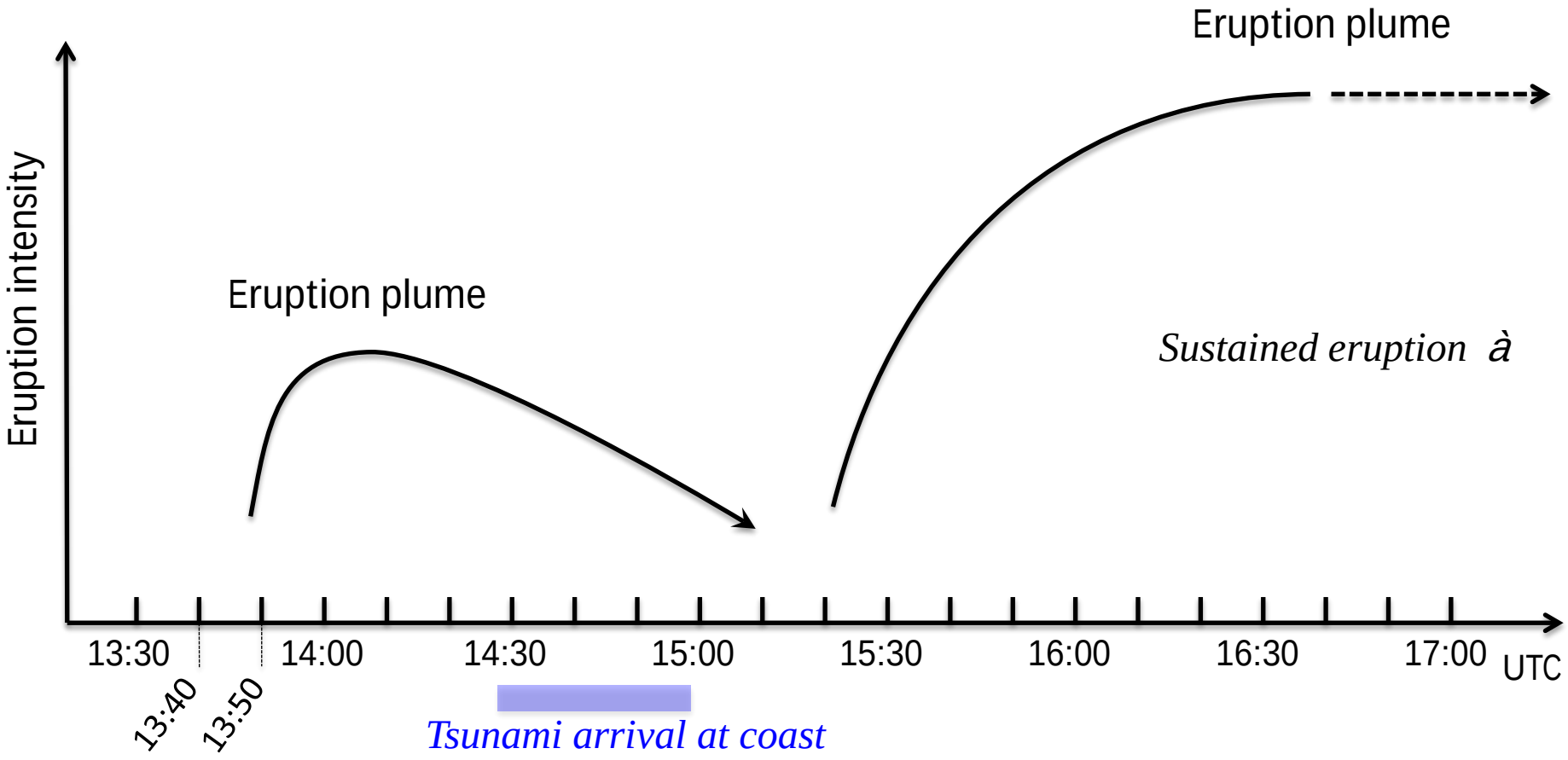
The last eruption before the event was the 13:51 21 Dec.



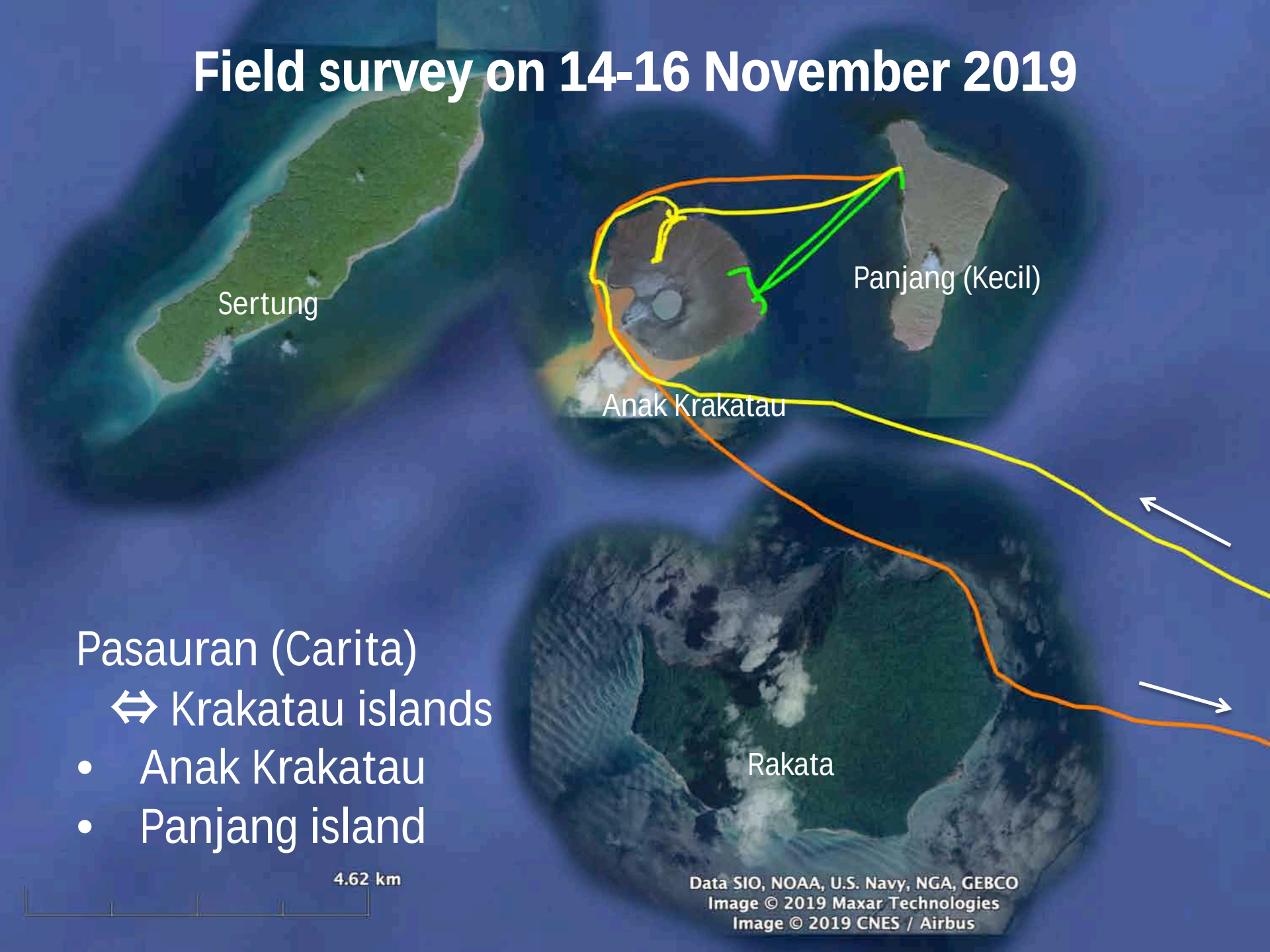
⬆☐Continuous thermal anomaly has been detected since the middle of June. No specific higher anomaly toward the eruption.

è The eruption began ~13:50 UTC, 22 December 2018. This time is 30-60 min before tsunami arrival around Sunda Strait (~14:30-15:00 UTC). Length of a side is 200 km.

Sequence of the 2018 event



Field survey on 14-16 November 2019

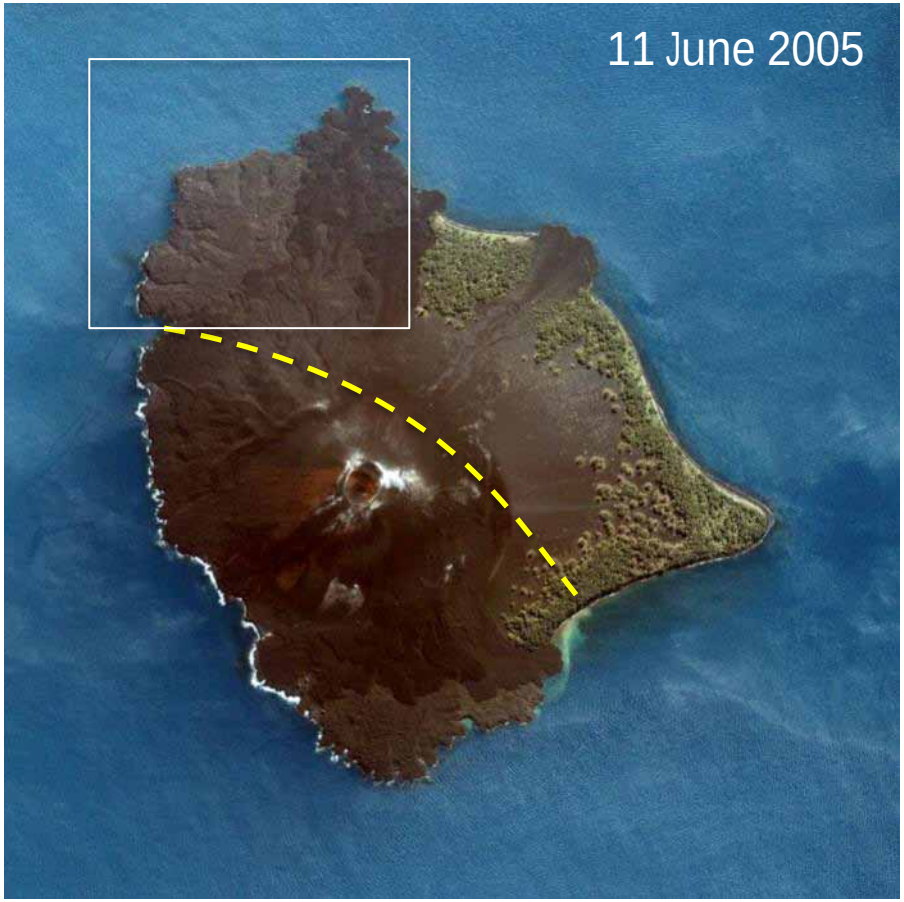


Pasauran (Carita)

⇔ Krakatau islands

- Anak Krakatau
- Panjang island

Before and after the event



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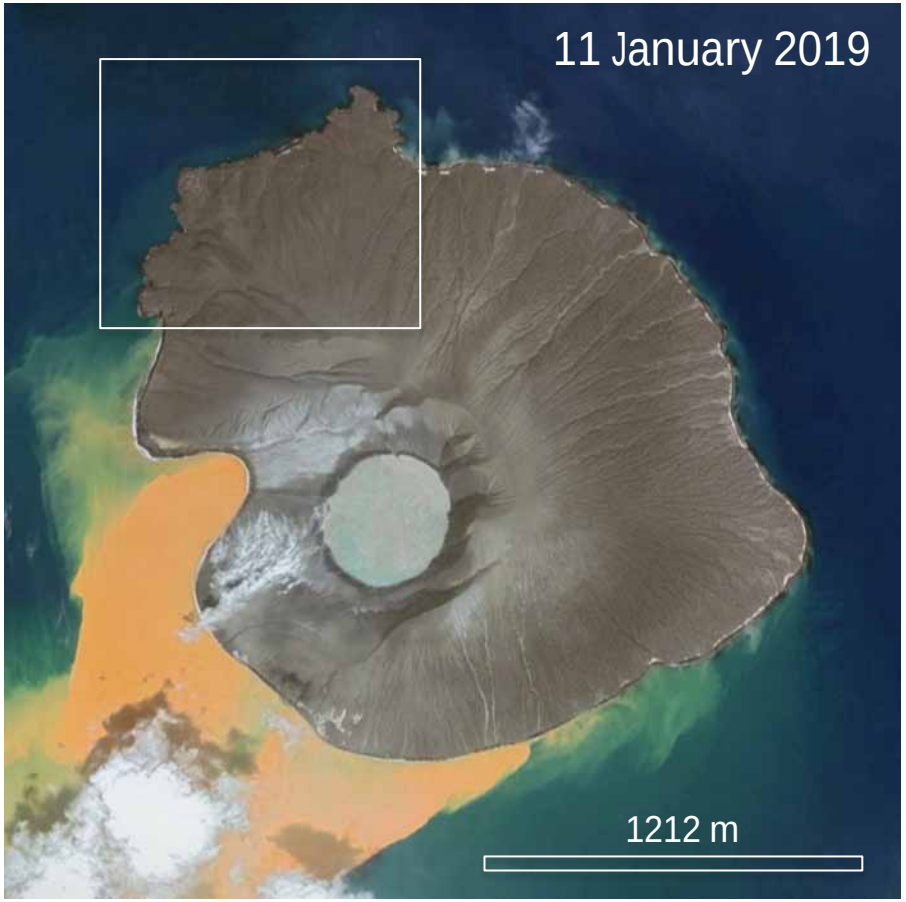
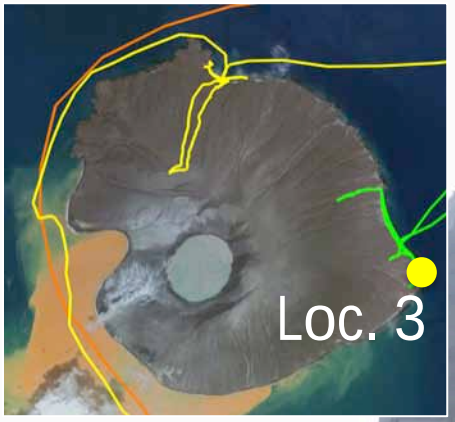


Google Earth

Intermittent small-scale explosions are continuing
(Surtseyan-type eruption by magma-water interaction)



Bread-crust scoria, indicating a product by magma-water interaction

Stratified-cross stratified deposits, suggesting origin of pyroclastic surges, consists of main cone

Summary of geological study

- Anak Krakatau has collapsed several times through its eruptive history.
- Satellite data suggest that a small eruption began at around 13:50 (UTC) 22 Dec 2018, which is 30-40 minutes before tsunami arrival at coasts along Sunda Strait. Then it was followed by the main sustained eruption.
- We found various types of deposits associated with the 2018 collapse-eruption event at Krakatau islands.
- The eruption started with pyroclastic surge generation.
- Distribution, facies, and grain characteristics of deposits will be important clues to constrain the process of 2018 event.

Future works

- Grain component and size distribution analyses for deposits.
- Geochemical analysis of essential products and comparison with the past products.
- Discuss collapse and eruption processes.

Topic 3: Analysis broadband seismogram

Elucidation of the collapse process of Anak Krakatau:
Landslide movement history estimated from seismic waveforms

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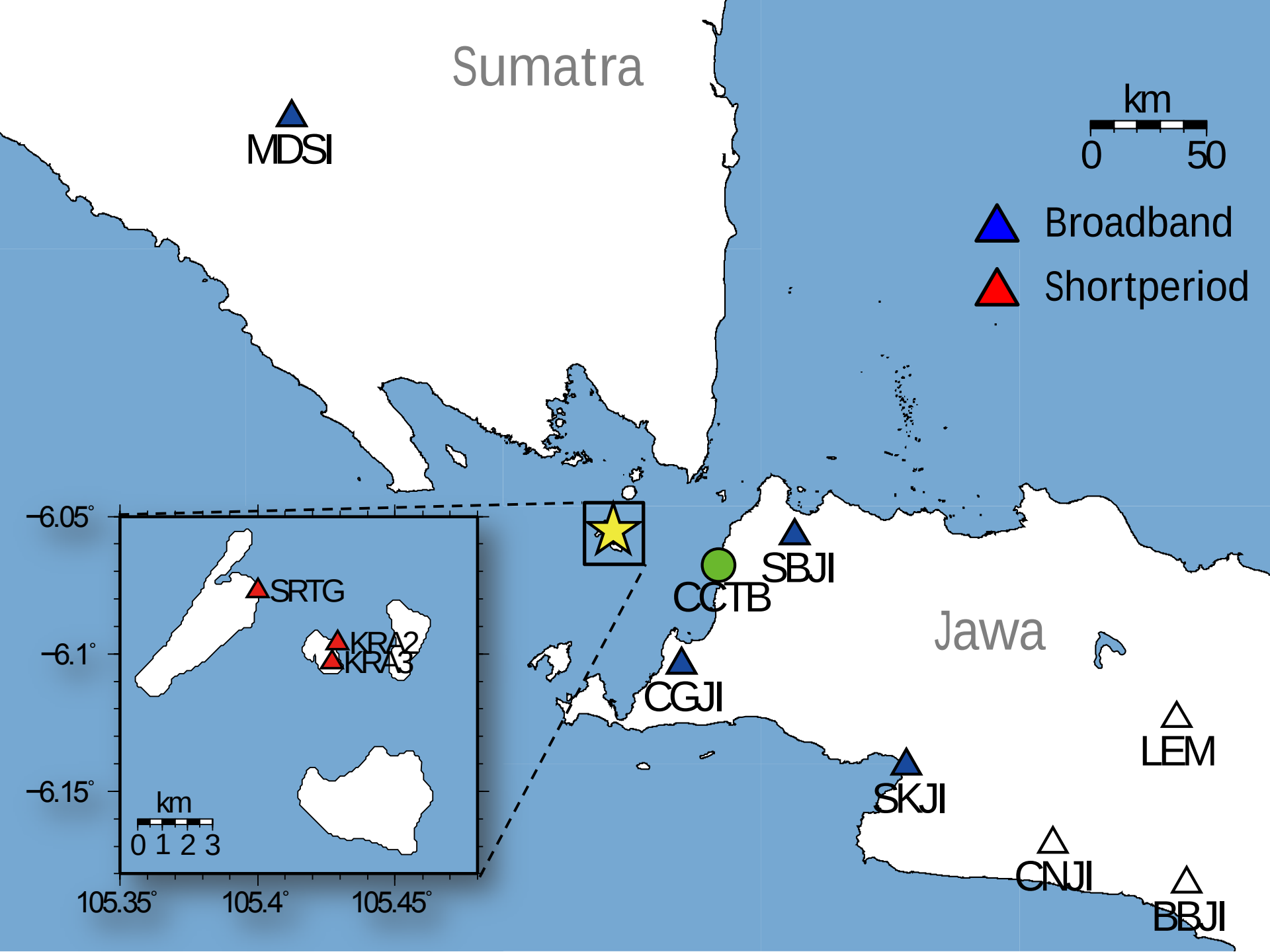
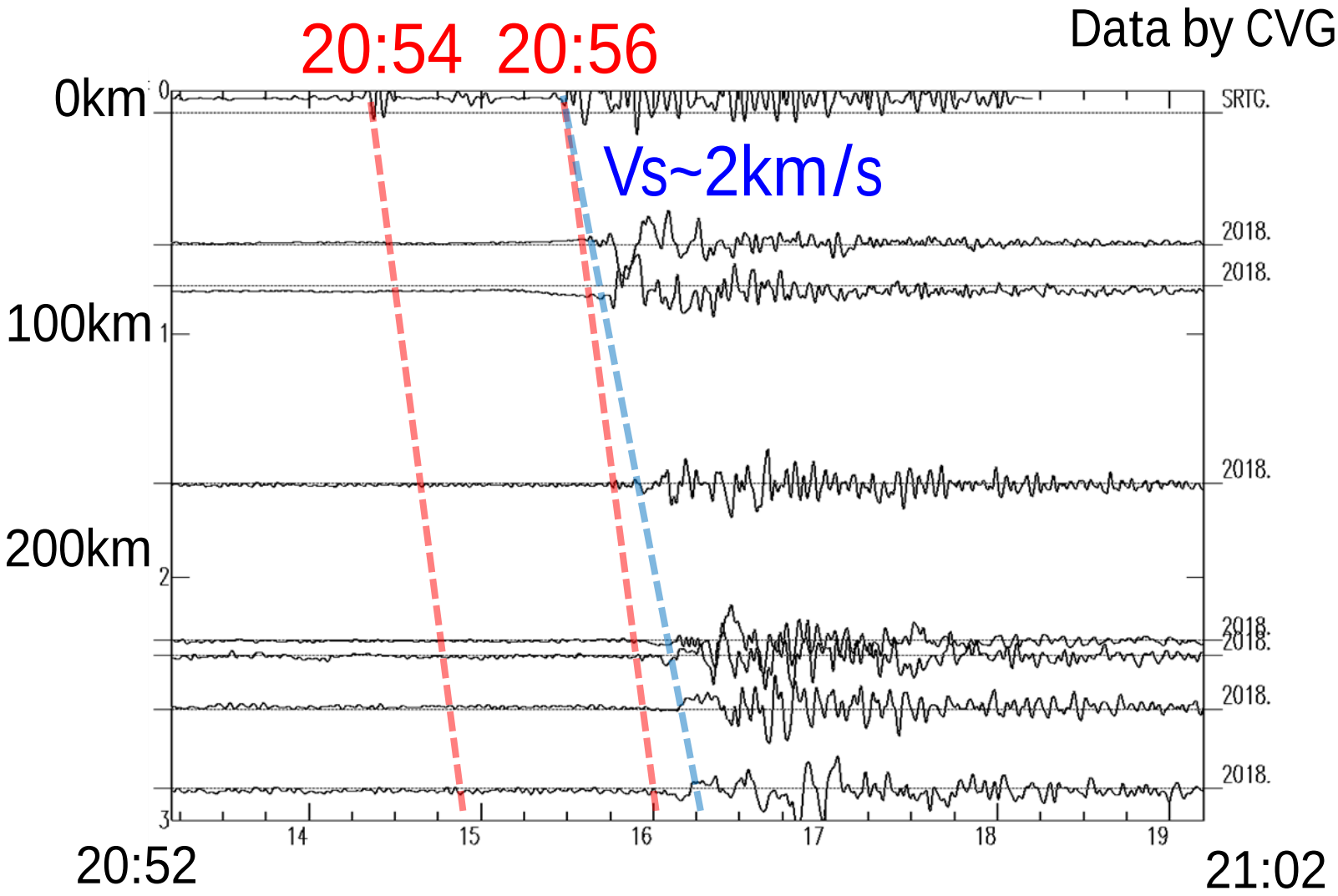
Mulia, I., Karyono (CVGHM)

Time of Eruption

Dec. 22 (WIB)	CCTV	Event	Seismic Signal
12:00	Not clear 		
18:30	Plume 		
19:00	Erupting 		
21:03		Eruption? (official)	Signal lost
21:30		Tsunami	


Sumatra
MDSI
km
0
50
Broadband
Shortperiod
SBJI
CCTB
Jawa
CGJI
LEM
SKJI
CNJI
BBJI
−6.05°
−6.1°
−6.15°
SRTG
KRA2
KRA3
km
0 1 2 3
105.35°
105.4°
105.45°

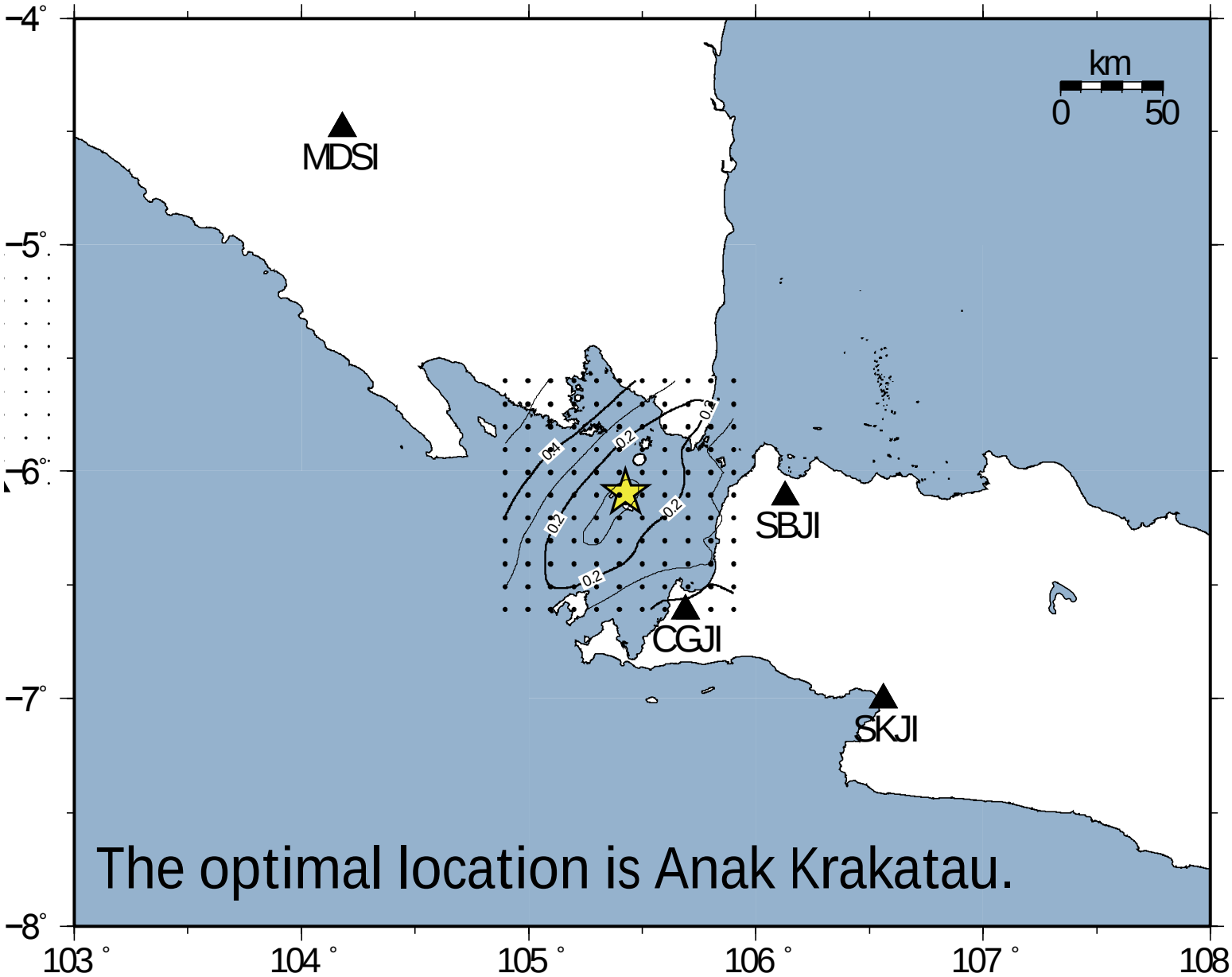
Long-period waveforms (> 5 s)



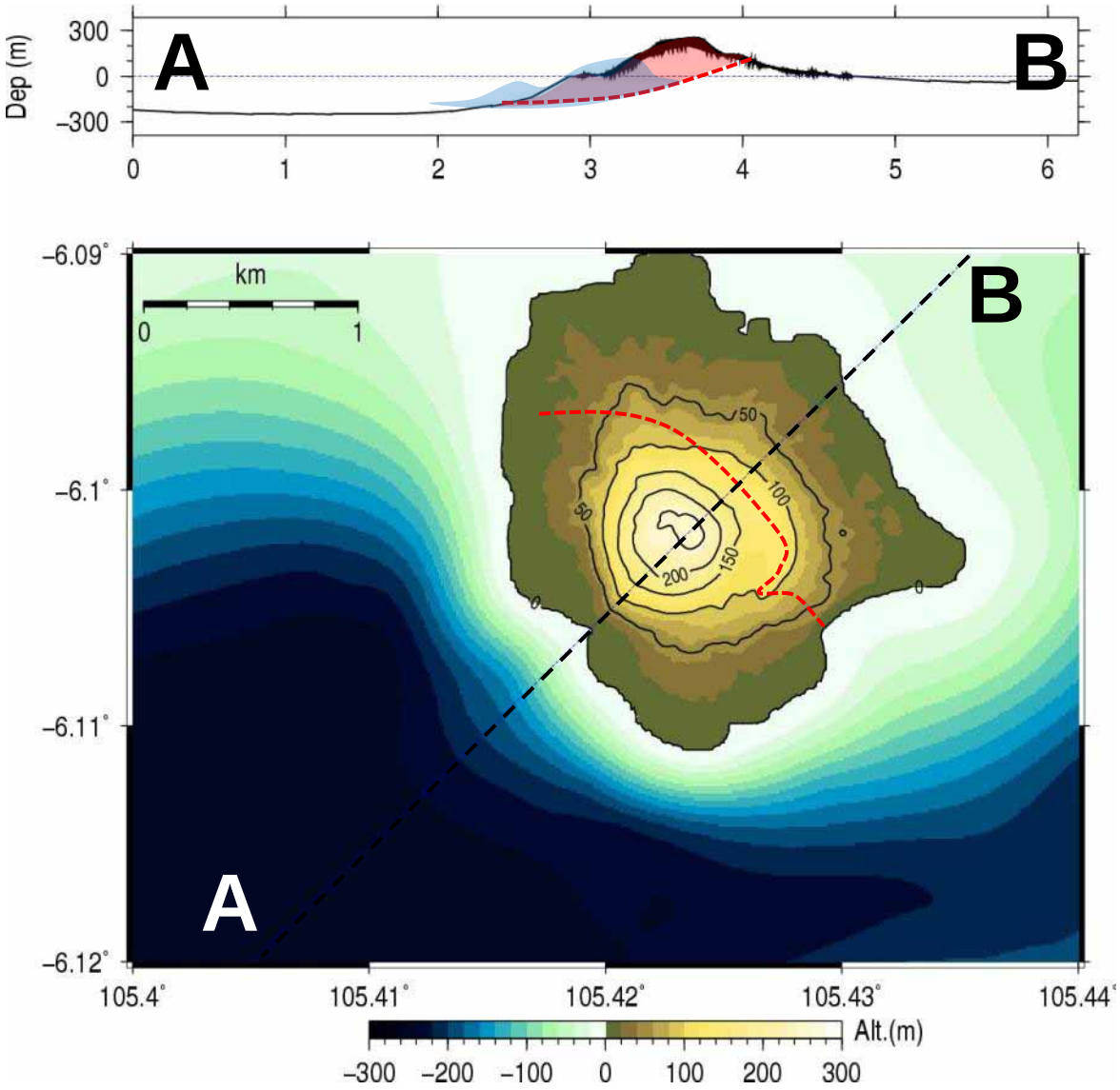
Time of Eruption

Dec. 22 (WIB)	CCTV	Event	Seismic Signal
12:00	Not clear		
13:30			Amplitude increase
18:30	Plume		
19:00	Erupting		
20:54			Small collapse
20:56			Large edifice collapse
21:03		Eruption? (official)	Signal lost
21:30		Tsunami	

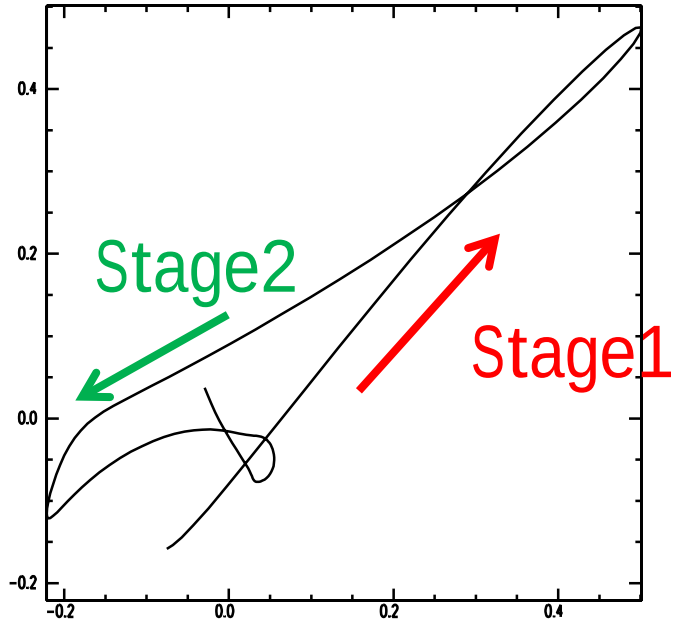
Residual Surface of the Inversion



Estimation of the Collapsed mass



Force in horizontal plane



Summary of seismic waveform analyses

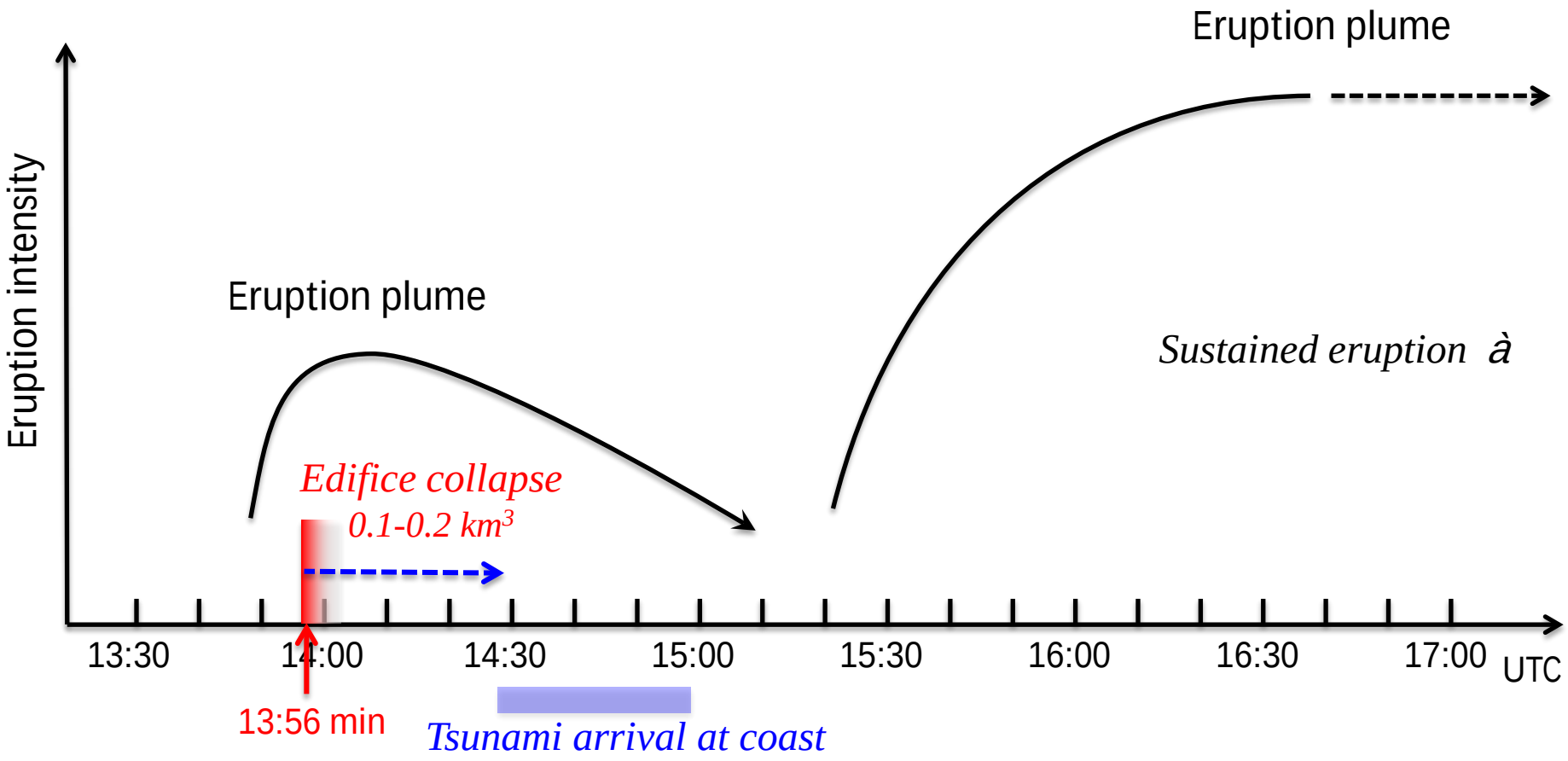
We analyzed the near-source seismic data of the 2018 Anak Krakatau volcano eruption

- Origin time 20:56 (local time)
- Collapsed from NE à SW, about 1min, low dip angle
- Mass 2.5-5.0 × 10^{11} kg
- Small coefficient of friction

n The volcanic eruption may trigger edifice collapse.

n A warning from seismic signals may be possible if infrastructure is well-prepared.

Sequence of the 2018 event



Eruption start ~ Edifice collapse à Main eruption start

Summary

We investigate volcanic activity and sector collapse inducing the Sunda Strait tsunami on 22 Dec 2018.

- Small-scale eruptions had repeated in the eruption day. Satellite data shows no large eruption before the event but a significant eruption began at around 13:50 (UTC).
- We found deposits from the collapse/eruption event at Krakatau islands.
- The eruption started with pyroclastic surge generation.
- Seismic waveform inversion suggest that origin time of collapse was 20:56 (local time), collapse direction NE à SW, and collapse duration about 1 min.
- Collapse volume is estimated to be 2.5-5.0 × 10^{11} kg (~0.1-0.2 km^3).
- Collapse occurred with an eruption then followed by a main sustained eruption.

Issues: Relationship between collapse and eruption. Detail process and mechanism are still problematic.

Implication to volcanoes in Japan

Evaluation of collapse potential and mass movement will be important.