Further Challenges for Warnings of Tsunamis

Satellite Activity - UN Ocean Decade Safe Ocean Laboratory

What do communities require

to be able to effectively respond to tsunamis generated by non-seismic and complex sources

07 April 2022

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The multiple manifestations of the tsunami threat

Type of Tsunami	Meteo-Tsunami	Earthquake induced tsunami	Landslide induced tsunami	Volcano induced tsunami	Meteorite impact
Triggering mechanism	Rapid changes in barometric pressure	Vertical displacement of the seabed	Mass movements in the water body: submarine landslides or subaerial land slumping into the ocean Causes are sudden, atmospheric (heavy rainfall) or seismic triggered slope failure or volcanic flank collapse. Landslides are often secondary phenomena and can amplify earthquake or volcano induced tsunami	Submarine eruption or phreatomagmatic explosion, pyroclastic flows and lahars entering the water, flank failure, collapse of lava domes, caldera subsidence and shock waves in the atmosphere from large explosions	Impact of extra-terrestrial objects in the ocean
Monitoring		**InaTEWS**	**No monitoring yet** (except recently around Krakatau: sea-level changes by tide gauges)		
Risk Assessment		**Risk assessment available**	**No risk assessment yet**		
Special features		Splay faults, Slow earthquakes, Outer rise events, Far Field		Mud volcanoes	
Relative frequency of occurrence	Less frequent	80+ % of all tsunamis	Less frequent	Relatively infrequent	Very rare
Timescales (impact after its origin)		Minutes to Hours	Usually Minutes In particular cases up to several hours		
Reach	Short range	From short range to trans-oceanic	Usually short range (near-field) In particular cases also trans-oceanic (far-field)		Trans-oceanic

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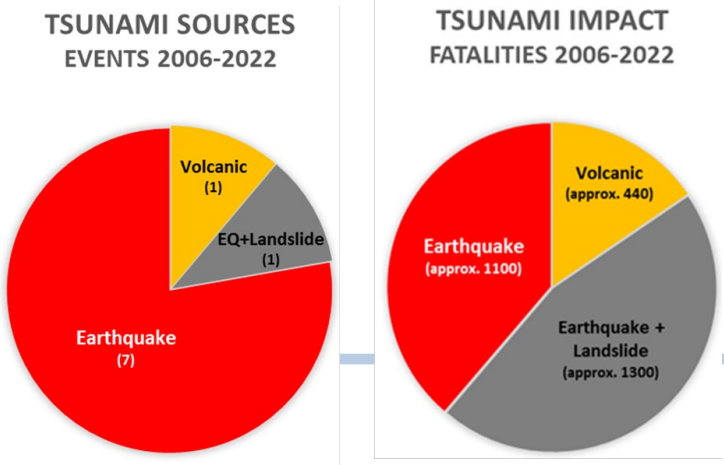
Understanding the Risk

"What do communities need to prepare for?"

What are the **relevant characteristics of non-seismically induced tsunami scenarios at the local level**: timelines, precursors, cascading effects, sequence and magnitude of impacts? Where are communities most at risk?

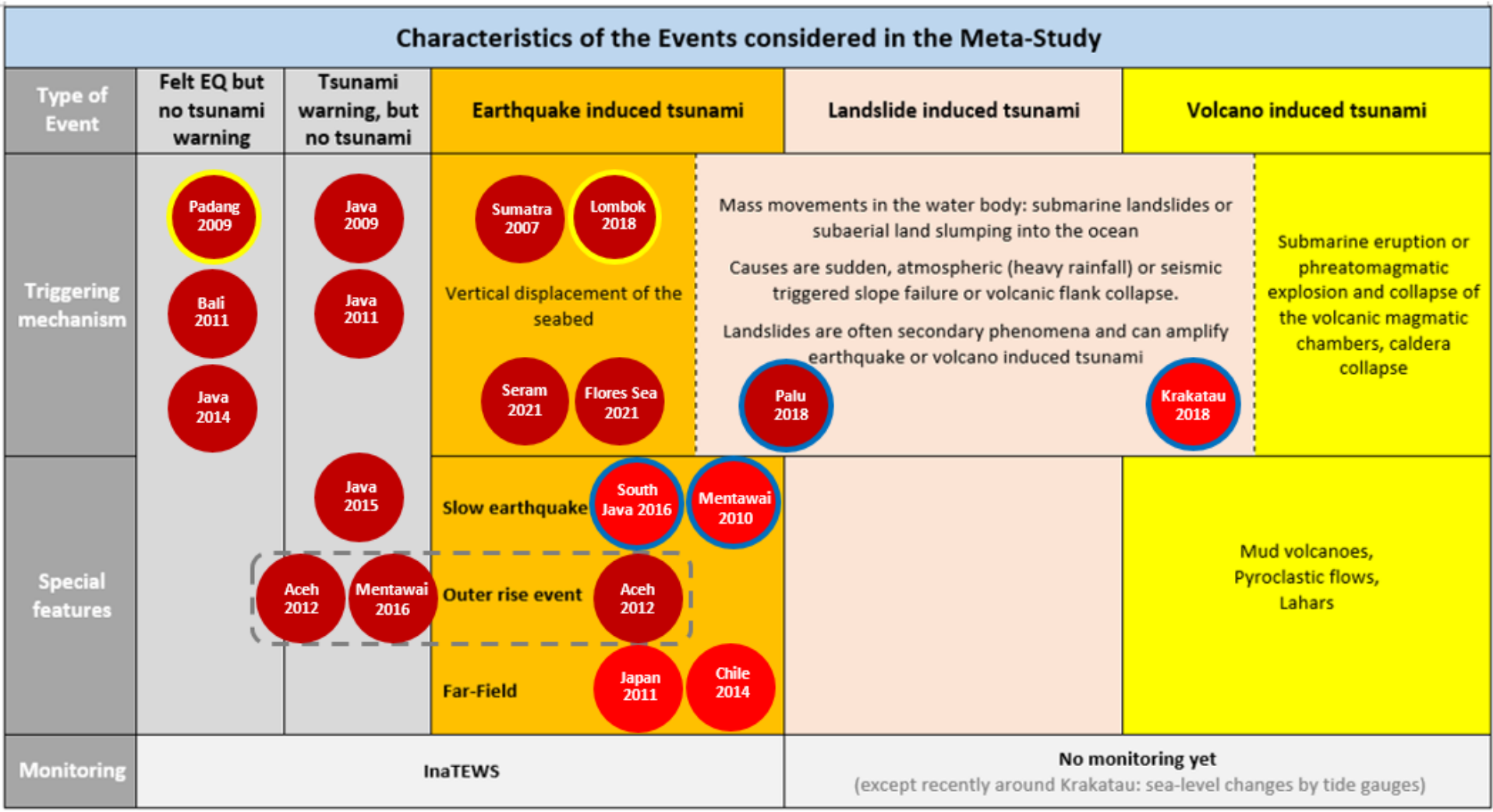
Tsunamis are usually triggered by primary natural hazards:

Communities often face a multi-hazard threat situation



Understanding the Risk

What can we learn from past experiences?



Date of the Event & Location of the Case		Type of Event	Earthquake Magnitude	NTWC Warning	Natural Warning	Tsunami Impact	Earthquake Impact
Earthquake location within the Indonesian archipelago							
2006-07-17	Pangandaran	Slow EQ	7,7	No Warning		High	
2007-09-12	Sumatra/Padang	EQ	8,0	Warning		Medium	High
2009-09-02	Java/Bantul	EQ	7,3	Warning			High
2009-09-30	Padang	EQ	7,7	No Warning			Very high
2010-10-25	Mentawai	Slow EQ	7,0	Warning		High	
2011-04-04	Southern Java	EQ	6,7	Warning			
2011-10-13	Bali	EQ	6,1	No Warning			Medium
2012-01-11	Aceh	Outer Rise	7,1	Warning			
2012-04-11	Aceh	Outer Rise	8,6	Warning		Low	Low
2014-01-25	Java	EQ	6,1	No Warning			
2016-03-02	Mentawai/Sumatra	Outer Rise	7,7	Warning			
2017-12-15	West-Java	EQ	6,7	Warning			Medium
2018-08-05	Lombok	EQ	6,9	Advisory		Low	Very high
2018-09-28	Palu/Sulawesi	EQ / Landslide	7,5	Warning		High	Very high
2021-12-14	Flores Sea	EQ	7,3	Warning		Low	Medium
Earthquake location outside the Indonesian archipelago							
2010-02-27	Chile Tsunami (Maule)	Far Field	8,8				
2011-03-11	Japan Tsunami (Tohoku)	Far Field	9,0	Warning		Low	
2014-04-02	Chile Tsunami (Iquique)	Far Field	8,2	Advisory			

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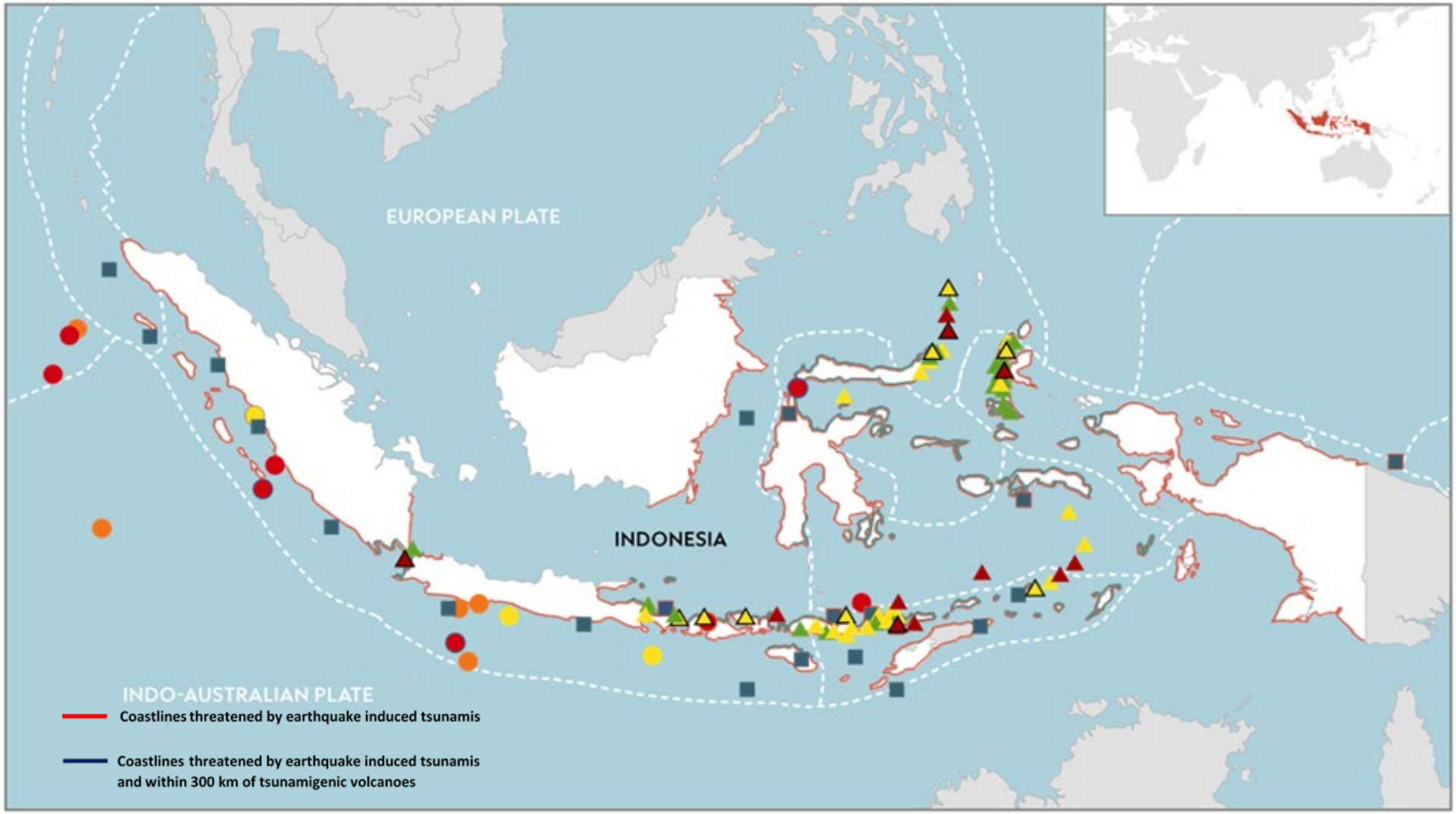
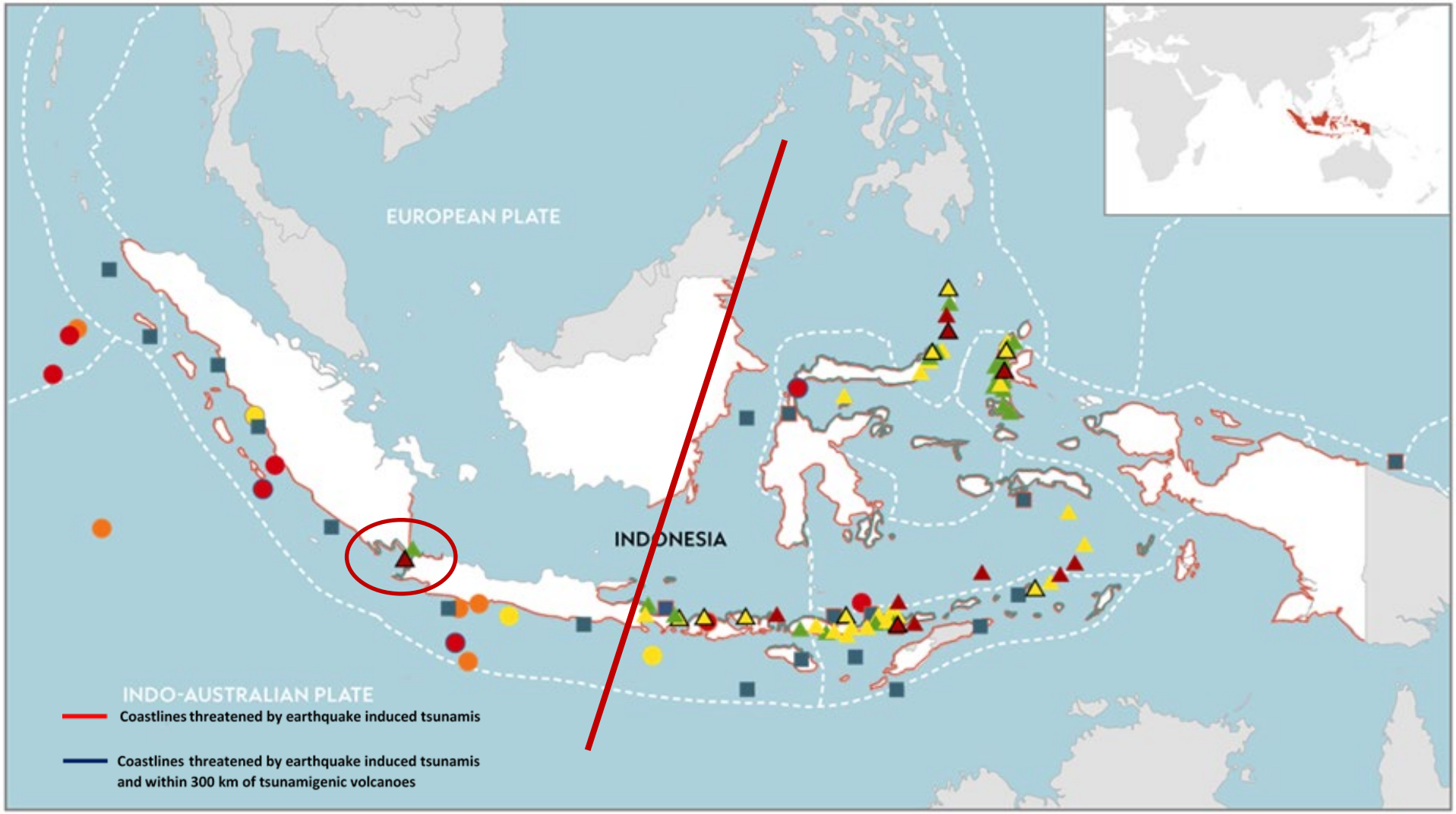
No “typical” tsunami here!

What kind of tsunami threat are communities facing?

The spatial distribution of the tsunami threat in Indonesia

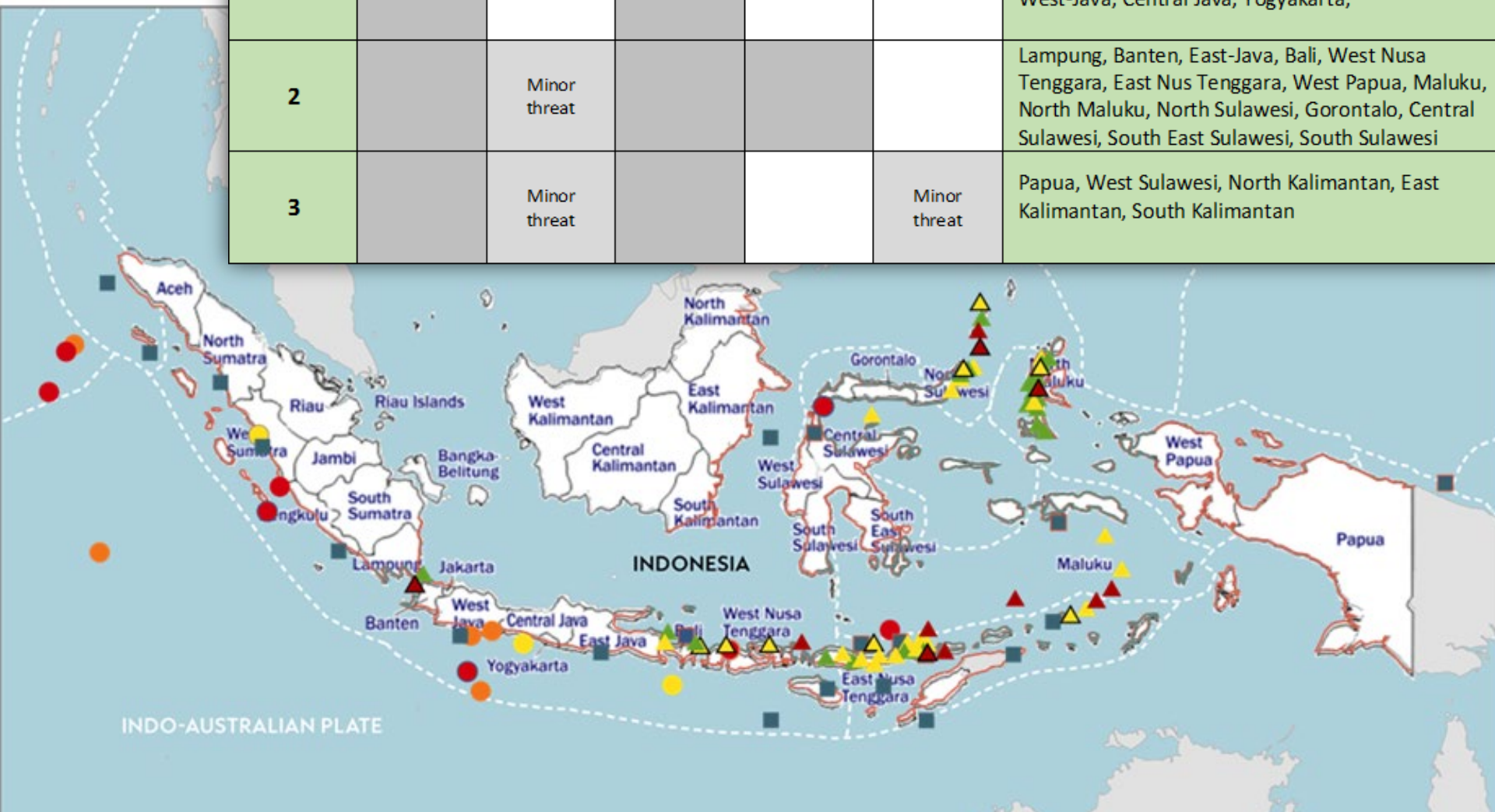


The spatial distribution of the tsunami threat in Indonesia



Supporting communities through strategies for specific threat scenarios!

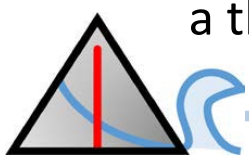
Threat Scenario	EQ Near-field	EQ Far-field	Land-slide	Volcanic < 300 km	Volcanic > 300 km	Provinces
1						Aceh, North Sumatra, West Sumatra, Bengkulu, West-Java, Central Java, Yogyakarta,
2		Minor threat				Lampung, Banten, East-Java, Bali, West Nusa Tenggara, East Nus Tenggara, West Papua, Maluku, North Maluku, North Sulawesi, Gorontalo, Central Sulawesi, South East Sulawesi, South Sulawesi
3		Minor threat			Minor threat	Papua, West Sulawesi, North Kalimantan, East Kalimantan, South Kalimantan



Rules of thumb to better understand the threat

Example: Landslide induced tsunamis in Indonesia

- Landslides that generate tsunamis are **mostly triggered by earthquakes**
- Landslide tsunamis **can even be caused by minor earthquakes** that do not themselves have the potential to trigger a tsunami.
- The **strength of a felt earthquake does not provide conclusive indications** about the occurrence and magnitude of an imminent threat from a landslide triggered tsunami
- In rare cases a landslide tsunami **can occur without a preceding earthquake**
- The documented historical landslide tsunamis all occurred in the **near field** and are usually **localized events**
- Landslide tsunamis often have **catastrophic consequences for the immediate vicinity**
- Whether tsunamis from landslides originating in the **far field** could pose a threat to Indonesian communities remains to be determined



What should be tackled next?

- **More detailed hazard and risk assessments with a community perspective**: mapping coastlines that are exposed to different types and sources of non-seismic tsunamis, timelines, magnitude of impact, inundation areas at local level
- **Exploring the possibilities and limits of early warning** for these phenomena and what can be practically implemented in this regard on the short run and in the near future
- **Discussion on specific strategies for communities how to prepare for non-seismic tsunamis** considering the limitations of monitoring and warning as well as the complexity of the sources