

Tsunami as Method? Recognizing Tsunami Waves, Reconfiguring Areas

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Abstract

While area studies scholars classically observe geographical connectedness, there is more on offer in science and technology studies to understand the entangled, yet complex social and earth systems; and how both realms are mediated by tsunami warning system technologies. This article aims at tracing knowledge and socio-technical flows of tsunamis exemplified in different imagined ‘areas’: tsunamis risk areas as red zone, tsunami modeling as trading zone, and tsunami warning center as high-tensions zone, situated in the vastly archipelagic and geologically active Indonesia. These three vignettes represent different ‘areas’ in different ways and meanings to different social groups, local and beyond local. More importantly, these different areas or zones are mutually interconnected, beyond geographical boundaries, through tsunamis. By approaching tsunamis as a metaphoric ‘method,’ it is argued that forms of human and non-human entanglements could be better analyzed, moving away from the narrative that tsunamis are merely a killing wave.

Keywords

Area studies; tsunami; Mentawai; tsunami modeling; operation room; risk zones

Introduction

It is common to think of tsunamis as purely disruptive events that affect people and environments negatively. That is why they are called natural hazards and understood as disasters exposing human livelihoods. In this ‘engagement,’ however, I will consider tsunamis, not only from the point of view of their destructive capacities, and the scientific knowledges that seek to understand them, but as material forces that shape different forms of knowledge and meanings in affected places. As Nigel Clark (2011) has argued, it is possible to imagine social science as taking up a different and less human-centered role with respect to the inhuman earth. In the case of tsunamis, this holds out the promise of making some forms of human and

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non-human entanglements more visible and vibrant. Thus, I seek to turn tsunamis into methods for gaining insight about collectivities and areas through the reverberating effects of the wave.

Today, tsunamis are associated with a whole cluster of terms relating to disaster: natural disaster, disaster management, disaster risk reduction; as well as probabilities, resilience, uncertainties, complex, cascading risks, and so forth. However, tsunamis propel other forms of knowledge—local and more-than-local—they facilitate knowledge across several boundaries, and their uncertainties spur new interdisciplinary knowledge formations. Some scientists see tsunamis as forces not just of death but also of life because they invigorate natural ecosystems and remake places, hence their regenerative capacities ([Rafliana 2025](#)).

In this engagement, I seek to engage tsunamis-as-method for eliciting entangled areas. To illustrate, I use three contact zones (freely adapted from [Pratt 1991](#)): an island coast that became a red zone after being severely hit by a tsunami, a trading zone of tsunami knowledges, and the operation room of the Indonesian Tsunami Warning Center (InaTEWS), which during emergencies becomes an affective high-tension zone. The engagement shows how tsunami areas are differently performed, and how the performances shape entangled areas.

Recognizing Tsunamis

I begin by tracing some material characteristics of tsunamis as they appear in explanations from geoscience, geophysics, and disaster studies. These are all valuable forms of knowledge, but the juxtaposition makes clear that understanding of the waves completely and comprehensively from a single perspective is not possible.

Tsunamis have had catastrophic effects on many populated urban coasts across the Earth: the Lisbon tsunami 1755, the Sanriku tsunami in 1869, the tsunami in Japan during 1933, the Chilean tsunami 1960, and then the 2004 Indian Ocean tsunami, the 2011 Great East Japan tsunami, the Tonga 2022 tsunami, just to name a few. In 1960, following the Chilean Tsunami, the Joint Tsunami Commission held its first meeting in Helsinki. From this moment, the gap between its original Japanese meaning, which simply is “harbor wave,” and various other meanings given to tsunamis in local vernaculars elsewhere, and “trans-oceanic waves” understood scientifically, kept widening.

Current science recognizes that many possible sources of water disturbances can generate tsunamis: underwater earthquakes, landslides, volcanoes, and meteorological sources ([Behrens et al. 2021](#)). Most famously, they are triggered by massive submarine earthquakes. This is what happened in the case of the Indian Ocean tsunami in 2004. At the “fault lines” of Eurasian and the Indo-Australian plate tectonics,



geologically ‘young’ and pliable¹ layers of interlocked lithosphere rub and push against each other over decades or centuries, and tension builds (Satake 2014; Okal 2015). When a layer breaks and the fault is torn open, an enormous amount of the earth’s crust is suddenly displaced under the water. The displaced sea floor disturbs the ocean column from the bottom to the surface of the ocean (Satake 2014). At this moment another earth is being materialized: the tsunami.

There are ways in which the tsunami emerges differs from other waves that rhythmically ripple the surface, pulled and pushed by lunar gravity and climatic forces. It emerges massively—powerful and full-bodied from bottom to top, thrusting forward at a speed of 600–800 km per hour (Cummins and Goldberg 2006), building up higher waves as it reaches shallower slopes. By that time, coastal dwellers close to the earthquake source most likely would have already felt the ground shaking, seen water receding, and witnessed strange animal behaviors on land, for example fleeing towards higher hills. If such happenings are part of local memory and knowledge, people may also have sought refuge at higher grounds. But with changing mobilities and population patterns, these traditional knowledges are often absent.

Modern science engages with tsunamis in two general ways. First, in rapid mode with the purpose of saving lives through tsunami warning system technologies. Second, during longer periods of months or years, to comprehensively understand the tsunami event.

To respond quickly, it is important to have information about the type of earthquake that created the waves, their speed, and their estimated power at the time of impact. This requires observation instruments, which should be as close to the source of the tsunami as possible. Thus, warning systems are in a race against the wave—who will reach people on the coastline first?

To make forecasts and quick predictions, pre-computed scenarios are crucial: this is known as tsunami modeling. These models rely on a wide range of measurement devices and techniques. Seismometers to record seismic waves. Global Positioning System to observe in real-time the earthquake source and rupture behaviors. Seismic-modeling tools to compute magnitudes of the earthquakes and directions of the rupture. Tsunami buoys to record anomalous water behavior and traveling speed. Tide gauges to measure water movements and heights at coastal points. Then, a Tsunami Modeling and Decision Support System (DSS) to propose pre-computed scenarios of potential tsunami exposures. And finally, human operators to decide whether to issue and communicate warnings. But even with all the instrumentation in place and working, there are many complexities. For example, the earthquake sources might be too close, leaving too little time to warn of the tsunami, or a tsunami might emerge from an earthquake that is only vaguely felt by coastal

¹ These are not congruent with human time scales. Young earth plates or lithosphere layers could mean millions of years.



dwellers. There are also many other uncertainties and possibilities of error in the sociotechnical systems that underpin the warnings.

The longer-term scientific endeavors aim to comprehensively analyze tsunami events. This can take months or years and involves other sources of funding as well as diverse techniques and technologies. Among them are cross-disciplinary collaborations, which are known as ‘reconnaissance trips,’² and often combine multiple approaches: analysis and modeling through records from satellite imagery, ground-truthing with physical evidence from the tsunami, studies of historical events, and the collection of eye-witness accounts.

Scientists seek opportunities to identify and assess physical evidence of tsunamis right after the event. They search for signs of wave heights and strengths through ecological marks in broken trees and washed-away coastal plants, uplifted coral reefs and coastal plains, and damages to coastal infrastructure which must be documented before clean up and reconstruction commence.

These kinds of evidence are complemented by eyewitness accounts of survivors, which are also used to understand the behavior of the waves. Given ethical considerations relating to traumatic memories, this is a delicate and challenging procedure. Ethnographers and other scientists gather information through questionnaires and interviews. They take notes, and may use videos, photos, and recordings of voices. This kind of experiential knowledge includes descriptions of ripping forces, colors, sounds and smells, as well as other human bodily sensations and emotions. Artifacts are also collected. For example, wall clocks or watches are valued because they often precisely show the time of submergence in water, which is crucial to simulate the propagation and refraction of the tsunami.

As a forewarning of what might happen again in the future, palaeo-tsunami researchers excavate and carbon-date sedimentation layers that tell the stories of past tsunamis. By interpreting tsunami deposits coastal sands which provide unique timestamps, for example, Kruawun Jankaew et al. (2008) found evidence that a tsunami with a similar magnitude to the Indian Ocean Tsunami that reached the coast of Thailand had occurred around 550 to 700 years ago.

These advances in knowledge and improvements in warning systems are worth celebrating. Still, it is also worth noting that they tend to share a view of the tsunami as an “enemy.” In contrast, I proceed by experimenting with the idea that tsunamis can be approached differently, in terms of human and non-human entanglements, which also have the potentials for rethinking Southeast Asian areas.

² The most common, collective way of doing tsunami reconnaissance is through the International Tsunami Survey Team (ISTS) mechanisms under the coordination of UNESCO. The traditions of ITST emerged in the 1990s, particularly after the Nicaragua and Flores tsunami in 1992.

Red Zone: Siberut and South Pagai, Mentawai Islands

On Siberut island, Mentawai, earthquakes were traditionally met with gentle chants “*Moile-moile, Teteu...* [Please be gentle, grandfather/earthquake].” A documentary film titled *Repdeman*, released on October 25, 2016 ([Watch Doc 2016](#)) shows a Siberut shaman speaking softly to the earthquake in such a manner. No panic, no rush. The spirits will take care of us.³ This was also what Melki Sanene told me, when I stayed at his family home in rural Siberut island, Mentawai around 2014 for some weeks to learn about the connectedness of earthquakes, spirits, and villagers on this island. On Siberut, housings were built from logs and timbers, constructed to withstand tremors and ground shakes. Aside from that, one would only ask for the earthquake spirits to be gentle. Nowadays, admittedly, demands for bricks are growing, since half masonry and two-story houses akin to those of urban people suggest wealth and success.

On the island, I was hunting for memories and stories about relations with earth beings. One elder villager, Sem Sagaragara, recalled a story his mother had told him about a dugout canoe, which had tipped over on a day when the rivers went wild after an earthquake ([Rafliana 2015](#)). This might suggest a tsunami, but it was impossible to tell. I got the impression that tsunami stories barely exist anymore in his village. Perhaps haunting stories of devastation are not encouraged? Forced resettlements was part of the history of the islands from the 1950s. At the time, island dwellers were pushed closer to coastlines with schools and health clinics as part of the state’s development and modernization project ([Simaepa and Rafliana 2023](#)). Perhaps, then, as time passes and people resettle, it is better to unlearn and forget? ([Tulius 2020](#)).

When the 2010 tsunami hit the islands of Sipora and Pagai in the southern part of Mentawai the villagers were caught by surprise. This occurred at around 10 pm in the evening on a pitch-black October night. At least 7 villages and 18 hamlets ([Purwoko 2010](#)) were exposed to the tsunami waves, which yielded 546 fatalities, as recorded by the National Disaster Management Agency ([Yulianto et al. 2023](#)). Surprisingly, among this devastation all the villagers of Tumalei were saved by preparedness skills and knowledge, which had been introduced by an NGO called *Surfaid* several years before. Minutes before the entire village washed away, the Tumalei youths who had been trained managed to get everyone safely to the closest hill. A few weeks later, the survivors began to build temporary housing with support from local non-government organization ([ibid.](#)).

However, after the event the government categorized the area as a high-risk ‘red zone’ (see [figure 1](#)). According to the classification, this meant any area that a future wave could potentially inundate by more than three meters. Those places were no longer allowed for living. Over the following months, the Tumalei villagers were made to join survivors from the neighboring village in temporary shelters in the interior. The

³ See also the documentary on perceived tsunami risks among local dwellers and experiences of 25 October 2010 tsunami Mentawai in *Repdeman* ([Watch Doc, 2016](#)).

classification of the Mentawai area as an uninhabitable red zone represents a top-down and asymmetrical form of decision-making, where quantitative risk-profiling determined the fate of local people who were given no say in the matter. When asking Siberut island communities if they were afraid of future tsunamis, I was often told was that “*bukan tsunami yang saya takutkan, tapi waspada [what is frightful is not the tsunami but the admonition to ‘be aware’]*”. Thus, scientific conceptions of risk can be used politically to override local actors’ agency.

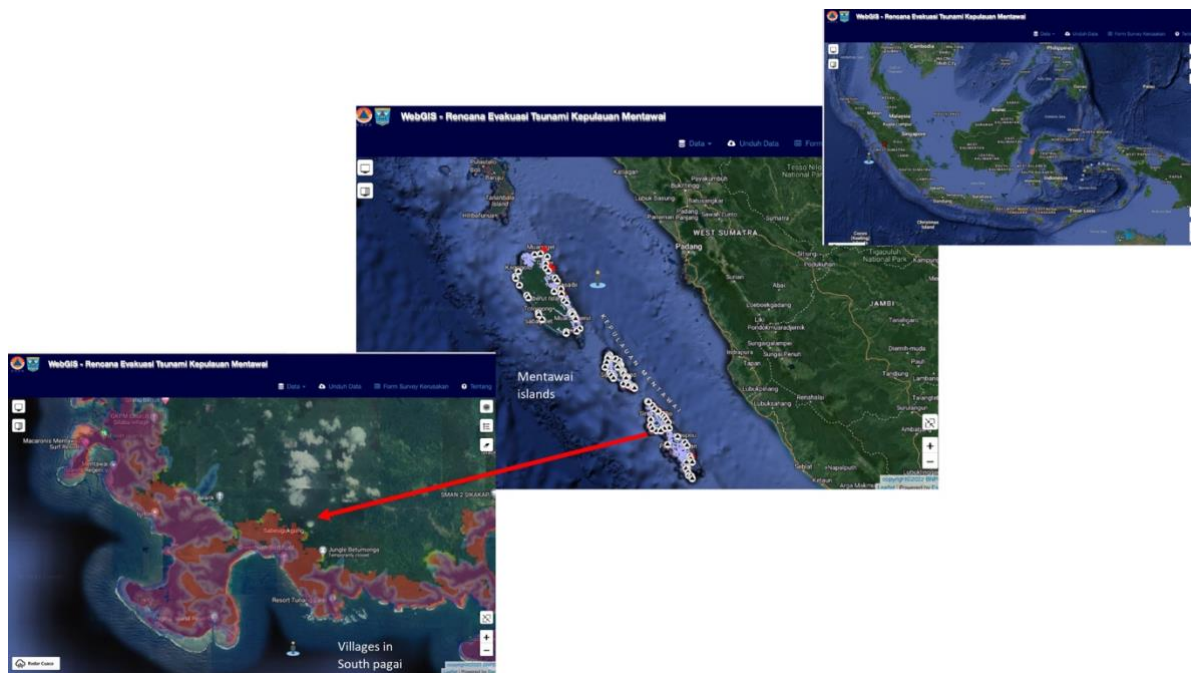


Figure 1. Red Zone in South Pagai island, Mentawai suggesting at high tsunami risks with possible inundation more than 3 m. Source: IRBI

After Mentawai, advocacy for zoning the coastal plains based on threats and the risk exposure of people and physical assets increased across Indonesia. A good example is the Central Java tsunami evacuation map displayed in [figure 2](#).

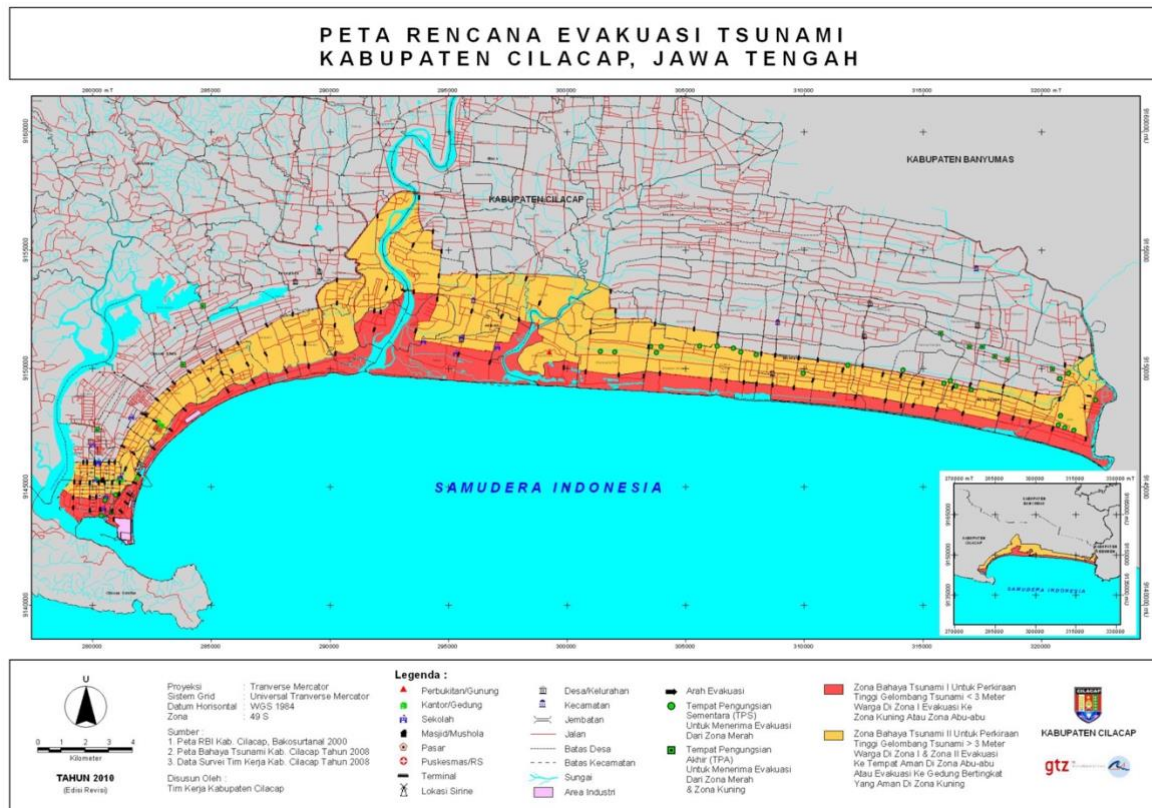


Figure 2. Red zones indicating tsunami risks exposing coastal dwellers and industrial complex of Cilacap, South coast of Jawa. Source: German Indonesian Tsunami Early Warning System Project—GITEWS ([N.d.](#)).

With forced migrations from hinterlands to coastlines and back, the establishment of red zones are bound to be painful for many local people. Once opened as a red zone (in analogy with how STS had advocated for opening the black box), it no longer appears as a natural geographical repository of danger but as a site of political contestation, which ought to be available for negotiations between science, government, and island dwellers. The red zone might then potentially transform into a compromise between local knowledges and spiritual beliefs, traditional land rights and tenures, local livelihoods, and critical infrastructures. While recognizing that another tsunami is a persistent possibility, perhaps the red zone might even become a new green (safe) zone. The zones are, therefore, subject to change depending on tsunamis in the past and their potential recurrence. Areas are changed by symbolic as well as material tsunamis.

Trading Zone: Tsunami Modeling

When it comes to recognizing and forecasting tsunami events, modeling is a significant knowledge practice, exemplified in [figure 3](#). The historian of science Peter Galison and philosopher of science David Stump in their book *The Disunity of Science: Boundaries, Contexts, and Power* (1996) showed that computer simulations, including modeling, often establish ‘trading zones’ where diverse scientific disciplines meet and exchange techniques, observations, and understandings. Claus Pias (2011) has also examined the epistemologies of

computer simulations, which creates particular relations between forms of mathematics, engineering, and various other sciences. With inspirations from these scholars, tsunami modeling can be understood as an uneven trading zone where German and Indonesian scientists with different forms of expertise and interests exchange knowledge and resources. At the beginning of the GITEWS project, the German scientists were predominantly experts in seismology science and mathematical modeling, whereas there were more Indonesian scientists with expertise in tsunami research. While some of the latter were able to develop and run modeling, they were missing the critical infrastructure. However, the delivery from Germany to Indonesia came packed with an epistemic hierarchy that tended to valorize mathematical expertise over more grounded tsunami knowledges. To these geopolitical and epistemic aspects of the trading zone must be added ontological uncertainties of tsunamis, which can be triggered by events that are very difficult to predict, for example from volcanic eruptions, underwater landslide to asteroids penetrating the earth's atmosphere.

The Indonesian Tsunami Warning System (InaTEWS), which was inaugurated on November 11, 2008, one and a half decades ago, was predominantly shaped by a German-led technology project.⁴ The system initially was designed to focus on the Sunda arc, where two major tectonic plates, the Eurasian and the Indo-Australia plate, collide and generate waves like the Indian Ocean tsunami in 2004. The entire Sunda arc goes from the north tip of Sumatra down to southern Java and onwards to East Timor. This choice was also geopolitical since the earthquake sources of this arc threaten the Indian Ocean region beyond Indonesian territories. Choosing the Sunda arc as a reference for the establishment of the tsunami modeling and warning system thus facilitated various knowledge and economic exchanges with other Indian Ocean countries.⁵

Meanwhile, the specification of the system involved difficult trade-offs. For example, the system might be oriented mainly towards the threats posed by the Sunda arc, but less to the complex geological settings in the eastern part of Indonesia, or to volcano and underwater tsunamis, or sources that are not from the major fault lines. Or it might be designed with less attentiveness to situations where the tsunami size is disproportionate to the earthquake from which they originated as is the case with so-called 'tsunami earthquakes' such as the one that hit Mentawai ([Polet and Kanamori 2009](#); [Satake et al. 2013](#)).

During development, it was considered economically unfeasible and impractical to establish a dense monitoring network of real-time offshore sensors and observation instruments along Indonesia's enormous

⁴ The German-Indonesian Tsunami Warning System Project (GITEWS) was established to develop the Indonesian Tsunami Warning System (InaTEWS). The project started in 2005 after the Indian Ocean tsunami 2004, with significant fundings from the German government; it was led by GFZ; a German research institute with experiences in seismic hazards.

⁵ Such inter-dependencies are negotiated, for example, through the Intergovernmental Coordinating Group of the Indian Ocean Tsunami Warning and Mitigation System (ICG IOTWMS), under the coordination of IOC UNESCO.

coastline. To fill the voids and escape the limitations of physical and real-time observations, the project therefore relied on modeling, where warnings might be issued based on many different scenarios.⁶ The aim was to enable the warning system to make ‘quick and dirty’ estimations of tsunami arrival times, which could be used to make decisions about evacuations in risky areas.

By choosing the Sunda arc as the pivot and assuming the arrival of tsunami waves within 30 minutes or less, the warning system tried to maintain a moderately short lead time, which would still be sufficient for a chain of reactions. First, it is necessary to identify the earthquake source and size, and to establish potential tsunami-generating mechanisms. Second, one must determine a relevant tsunami scenario and the magnitude of the waves. By developing a library of scenarios, the models can run calculations and issue a ‘proposal’ for the event, which operators use for decisions about issuing a warning. Warnings are immediately disseminated to the public, close to the area at risk. They include running texts or stop–press in electronic media, siren activations at coastal points, and information by short messaging texts and other means.

Two years after the inauguration, the devastating October night at Mentawai provided a series of object lessons for the warning system. Clearly, the system had not worked according to plan. The specific type had not been included among the modeling scenarios (see [figure 3](#)). After 2010, there was a gradual expansion of scenarios, which has since grown to around 18,000 different combinations, likelihoods, and effects ([Harig et al. 2020](#)).

⁶ The thousands of pre-calculated tsunami scenarios are matched with the data from the seismic stations closest to the earthquake sources, once the earthquake parameters are defined (magnitude, hypocenter and the earthquake rupture mechanisms) and the onset of tsunami occurrence arrived at the warning center (from tide gauges or tsunami buoys). Operators in the warning center then decides which scenario fits best to be published as a tsunami warning ([Harig et al. 2020](#)).

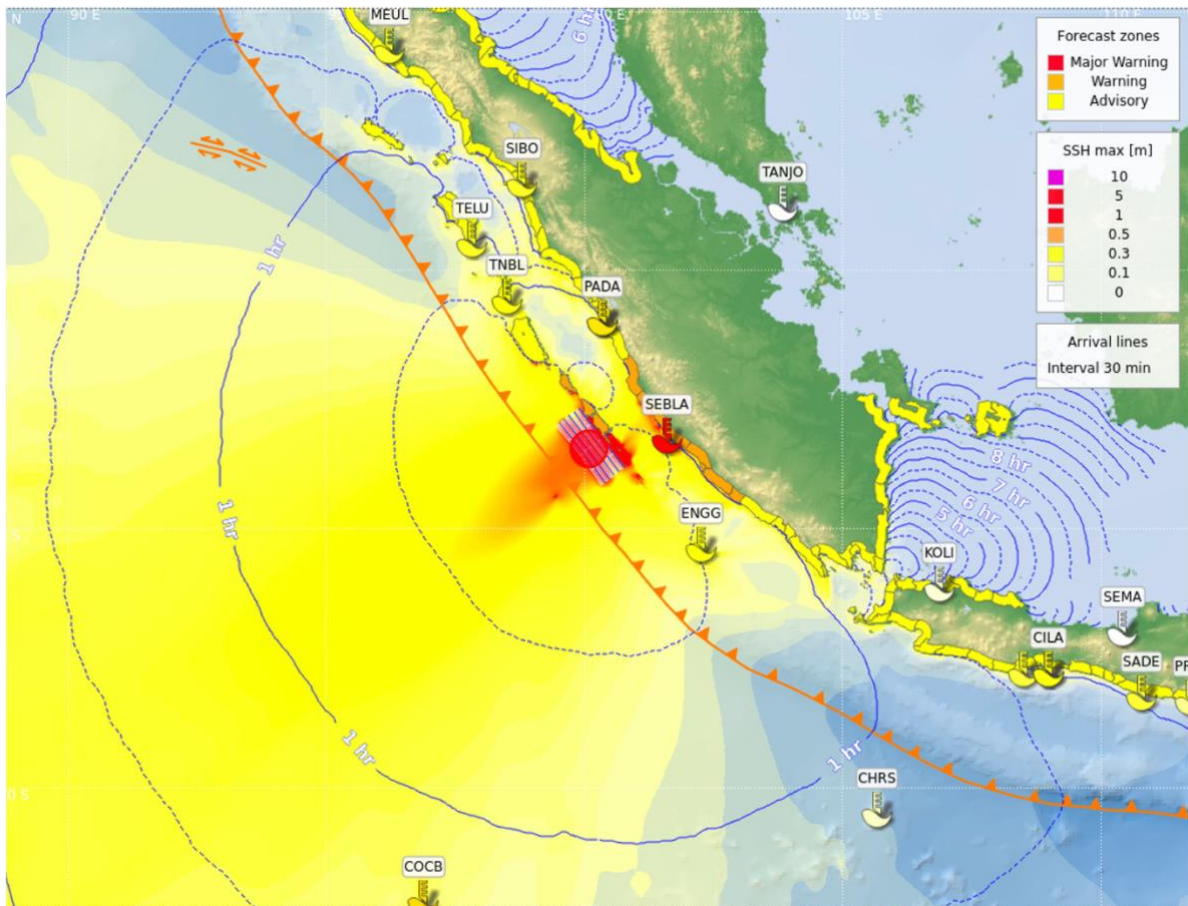


Figure 3. Snapshot of the tsunami scenario modeled using TOAST suggesting the event close to the 7,8-magnitude earthquake followed by tsunami in Mentawai October 25, 2010. Source: [ibid.](#)

As exemplified by the Mentawai disaster, tsunamis create ontological uncertainties that require continuous improvements in knowledge. They create homework, so to speak, for Indonesian scientists and operators, who are also supposed to take charge and become less dependent on the Germans. Simulations and models become particularly important because Indonesia has limited scientific and infrastructural resources but very complex and active geological realities. On the one hand, it is not realistic to aim for comprehensive offshore and real-time instrumentation along Indonesia's very long coastlines. Yet, on the other hand, empirical cases have shown that model-based warning systems relying on seismic monitoring are vulnerable to false positives, which can compromise the trust of the public ([Babeyko et al. 2010](#)). In this complex situation, there is no ideal solution that will solve all the problems. In the trading zone, everything involves risky trade-offs.

High-Tension Zone: Tsunami Warning Center (InaTEWS)

Tsunami simulations create virtual areas which affect real ones. But, entangled with others, the operating room of the Indonesian Tsunami Warning Center is also its own contact zone. The warning system is a spaced

around 144 square meters with high ceilings, neatly surrounded with different size screens on the walls and monitors on the desks of the operators. With no windows to the outside, it resembles a monad, a totally closed world expected to synchronize information about tsunamis from many instruments in a manner that facilitates quick life and death decisions.

Created by the German-Indonesian Tsunami Warning System Project (GITEWS), the design of the operation room intentionally resembles the German Aerospace Center operation room, which remotely monitors German astronauts. In both rooms, there is a total disconnect from the immediate surroundings: the external world is only present as giant screens and monitors. Both operate round the clock, 24 hours, 7 days a week. If something anomalous happens, both are responsible for issuing warnings. But while the former observes astronauts working in outer-space vehicles, the eyes of the latter are firmly fixed on seismic activities in and around Indonesia. And there is another significant difference. While preventing loss of life in the case of a tsunami is the highest priority, there is also a strong pressure not to issue false warnings, because evacuations are extremely costly. These conflicting pressures turn the operating room into a high-tension zone.

The Indonesian tsunami warning system is an assemblage of seismic sensors, various ocean observation instruments, a decision support system for issuing warnings, and warning receiver systems at provincial or district levels, as well as multi-modal transmissions to television, radio, mobile application, and social media. The situation of the operators is defined by information about the tsunamis made available by the entire array of sensors and instrumentation. The better the information, the lower chance of issuing false warnings to the public, and the less uncertain their position.

Any earthquake event in Indonesian territory sets off alarms, blinking lights, and pre-recorded messages. The higher the earthquake magnitude received from the real-time monitoring system, the more anxious the atmosphere grows, until the tsunami assemblage has turned all the data from instruments, sensors, and stations into recommendations. As the operators huddle closely, all eyes converging on the screens, tensions rise.

The Mentawai tsunami of 2010 was the second big test for the new warning system. Afterwards, it was described as something of a worst-case scenario. Since the earthquake magnitude of 7.8 crossed the threshold, a tsunami warning and evacuation recommendation was issued and disseminated on several channels including national television. But no corroborating evidence from the ground arrived at the control room to suggest that a tsunami followed. There were no tsunami buoys nearby, and the closest tide gauge station on the Sumatran mainland far from the epicenter showed only minor anomalies. Moreover, island dwellers had received no preparedness training or public education about different kinds of tsunami risks ([Yulianto et al. 2023](#)), and the slow-swaying earthquake was barely felt. Nothing sufficiently alarming for sleeping people to flee in the dark of the night.



Since no information about a significant tsunami reached the control room, the warning was called off. Meanwhile, the Mentawai islands were totally devastated on this dark night. Officials would later publish a statement clarifying that all decisions made during the event were in accordance with standard operating procedures.⁷ Unfortunately, the control room had been blinded. Decisions were indeed made, but they cost of hundreds of human lives. During critical moments when the alarms go off in the control room today, some operators silently pray. Amidst the high-tech machinery, they are haunted by the presence of death.

Tsunami as Method?

I have presented three contact zones—the red zone of Mentawai, the trading zone of tsunami modeling, and the high-tension zone of the warning center—as performing different versions of both tsunamis and area. Each of the zones has their own entanglements but they are also mutually entangled. The different zones speak to human relations with technologies and geological realities, and stretched, patchy geographical and political relations between Indonesia and Germany, as well as simulated, virtual areas that are yet capable of moving real humans. All are interlinked by both the imaginary and physical forces of the tsunami waves.

The red zone showed that knowledge of tsunamis is variably shaped by contexts, and that they can be forgotten, brought together from different territories, or be reinvented, as exemplified by villagers learning from *SurfAid*. But they can also be integrated in state-based forms of power and dominance, as when the tsunami risk classification became the basis for forced resettlement. The trading zone of tsunami modeling showed a virtual space, which is also an uneven space of exchanges between German and Indonesian scientists with different disciplinary backgrounds, interests, and constraints. Moreover, the performance of the warning system, including the quality of modeling, is no longer fit in a contained space or area within Indonesian geographical territories. As much as tsunami science also influenced Germany's contemporary epistemic spaces, tsunamis in Indonesia have been and always will have affects.

Finally, I showed how the control room becomes an affective high-tension zone, where pressures of many kinds converge. The tsunami areas performed by these zones are entangled. The trading zone of modelling sits in the background of decisions to demarcate red zones, while the operation room is a high-tension zone because it must always stay ahead of the curve and make difficult decisions about areas that are at risk. But the traffic of knowledge between the zones is far from symmetrical. There are not many efforts to learn from coastal dwellers how they know tsunamis, or how they would like to be informed, or whether their risk as understood by science is more important than living by the coast, perhaps trying to cultivate other ways of living with dangerous waves.

⁷ This statement was claimed by the Deputy Head for Geophysics/National Tsunami Warning Center (National Agency for Meteorology, Climatology and Geophysics), responding to the public criticism that the warning system had failed to forecast the Mentawai 2010 tsunami event, and that the warning was terminated despite the tsunami occurrence ([Detiknews 2010](#)).

In line with STS scholarship, Anna-Katharina Hornidge (2007) has argued that knowledge is profoundly shaped by national legal and scientific infrastructures. This certainly is true of the Indonesian tsunami warning system, where forms of German scientific expertise and imaginaries interact with very different Indonesian areas and knowledges. Jensen et al. (2017), even more so, inspired this article by underlining the diverse ontologies and ways of recognizing tsunamis, as expressed in the three vignettes.

In these brief vignettes, I have used the tsunami as a method to elicit how these interactions perform several versions of area, which become entangled in turn. This raises questions about other possible tsunami performances, which might create different, and perhaps more generative, entanglements. It might be possible to imagine tsunamis with capacities that are not only destructive, but also regenerative, where these earthly processes connect humans beyond their geographical boundaries.

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