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Verification and Modelling of Tsunami Arrival Time and Wave Height Along Thailand's Andaman Sea Coast Using an Enhanced TOAST

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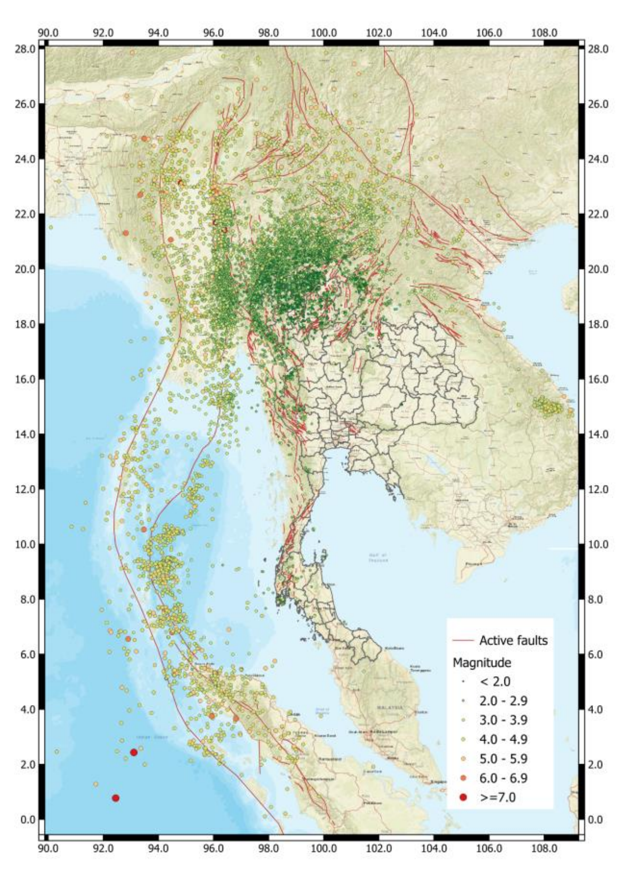
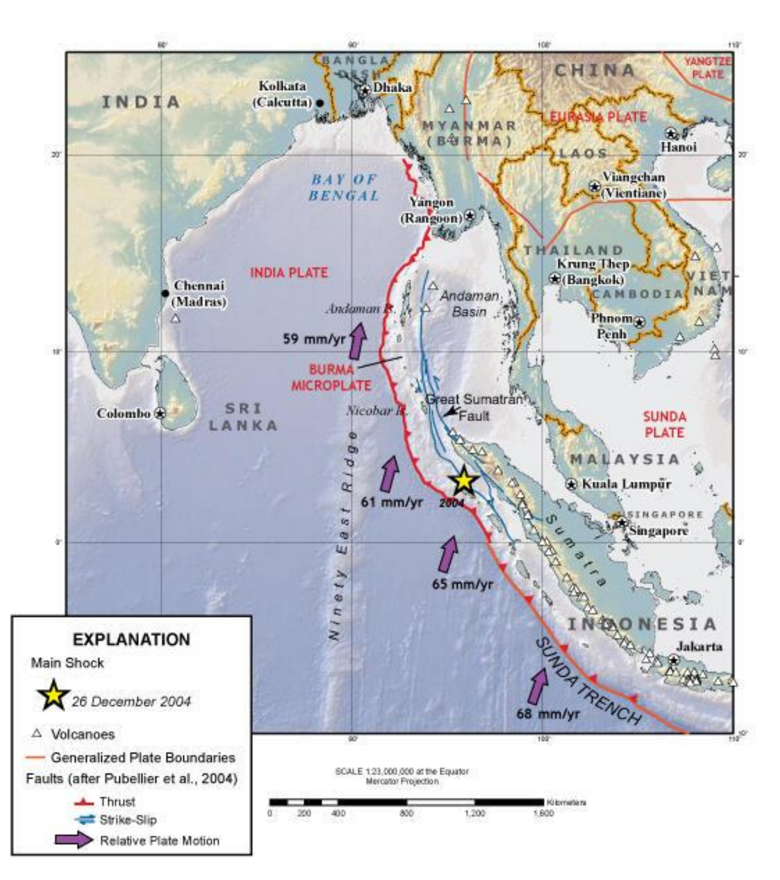
INTRODUCTION

- The Sumatra-Andaman subduction zone is a major source of tsunami risk to Thailand's Andaman Sea coast.
- Past megathrust earthquakes, especially the 2004 Indian Ocean tsunami, have caused severe impacts and long term public concern.
- The Thai Meteorological Department (TMD) operates a real-time earthquake monitoring system using SeisComP with the TOAST module for tsunami simulation.



(TMD, 2025)



(USGS, 2008)

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OBJECTIVES

- Investigate tsunami arrival time and wave height along Thailand's Andaman coast.
- Enhance bathymetric resolution from 3.7 km → 0.46 km (GEBCO).
- Refine the impacted area to the subdistrict level.
- Validate simulation results with tide gauge observations.
- Produce maps and data of tsunami arrival time and wave height to support early warning and evacuation planning.

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Chutimon Promsuk, Patinya Pornsopin

STUDY AREA

No.	Lat. °N	Lon. °E	Mag.	Depth	
1	3.295	95.982	9.1	30	2004 Indian Ocean tsunami
2	5.377	94.224	8.5	10	Epicenter Simulation
3	6.910	92.958	8.5	10	Epicenter Simulation
4	8.879	92.375	8.5	10	Epicenter Simulation

A total of 97 subdistricts in Southern Thailand are located along the western coastline.

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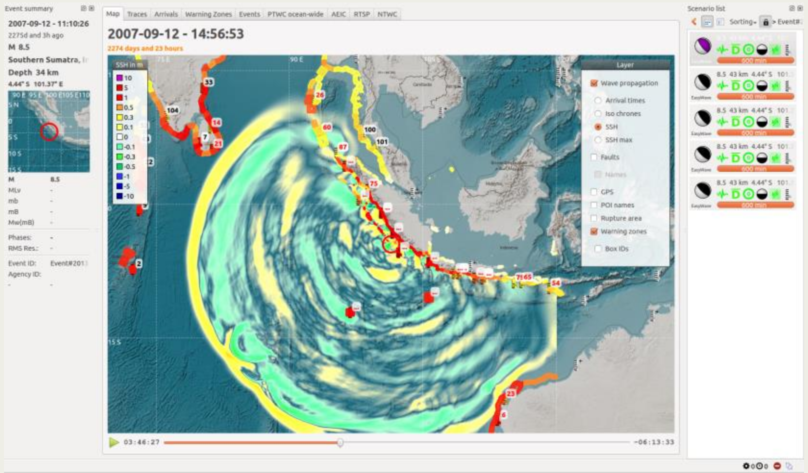
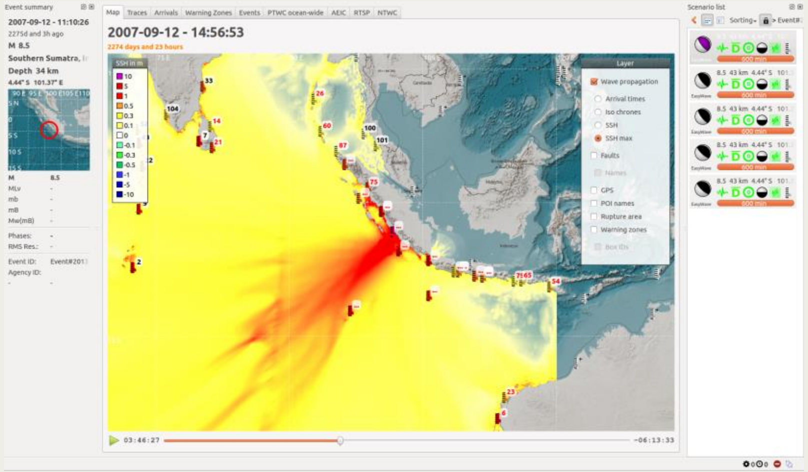
Chutimon Promsuk, Patinya Pornsopin

TOOLS & METHODS

- TOAST (Tsunami Observation and Simulation Terminal) is used for tsunami simulation by calculating the tsunami arrival time, the time of maximum wave height, and the maximum wave amplitude.

- The simulation model applied is EasyWave, introduced by Kowalik and Whitmore (1991), which uses fault parameters from Okada (1985). It is based on the two-dimensional shallow water equations, solved on a spherical coordinate grid system to determine wave propagation velocity and estimate the tsunami arrival time at the coast.





(gempa GmbH)

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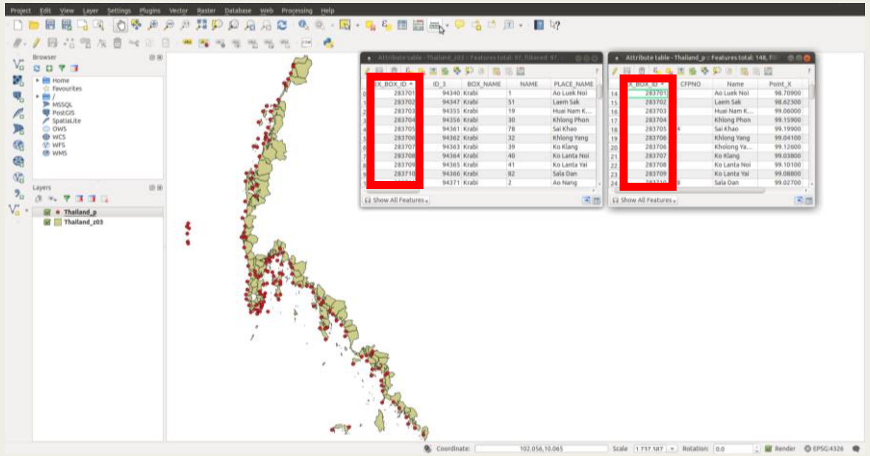
METHODOLOGY

Tools

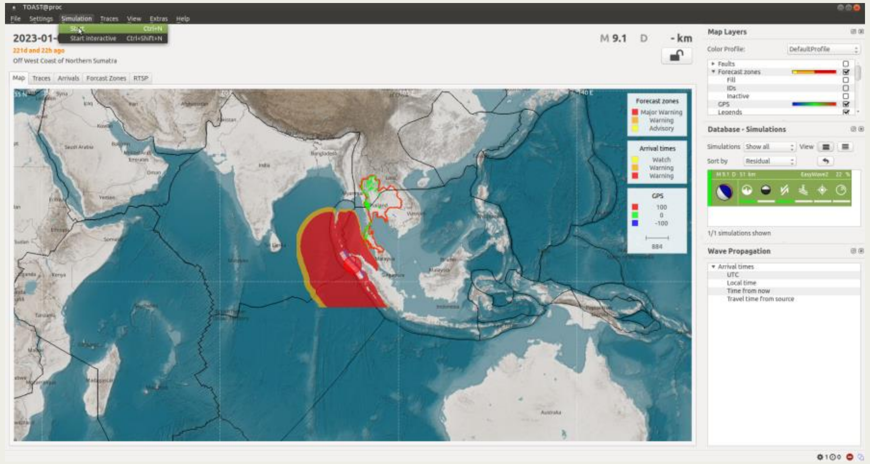
- SeisComP with TOAST module
- EasyWave simulation engine
- GEBCO bathymetry (0.46 km resolution)
- Subdistricts shapefile

Methods

- Define earthquake source (Sumatra–Andaman 2004, and along Sumatra subduction zone)
- Enhance bathymetry resolution for local area
- Run tsunami propagation simulation
- Compare with tide gauge data



Shapefile data processed with QGIS



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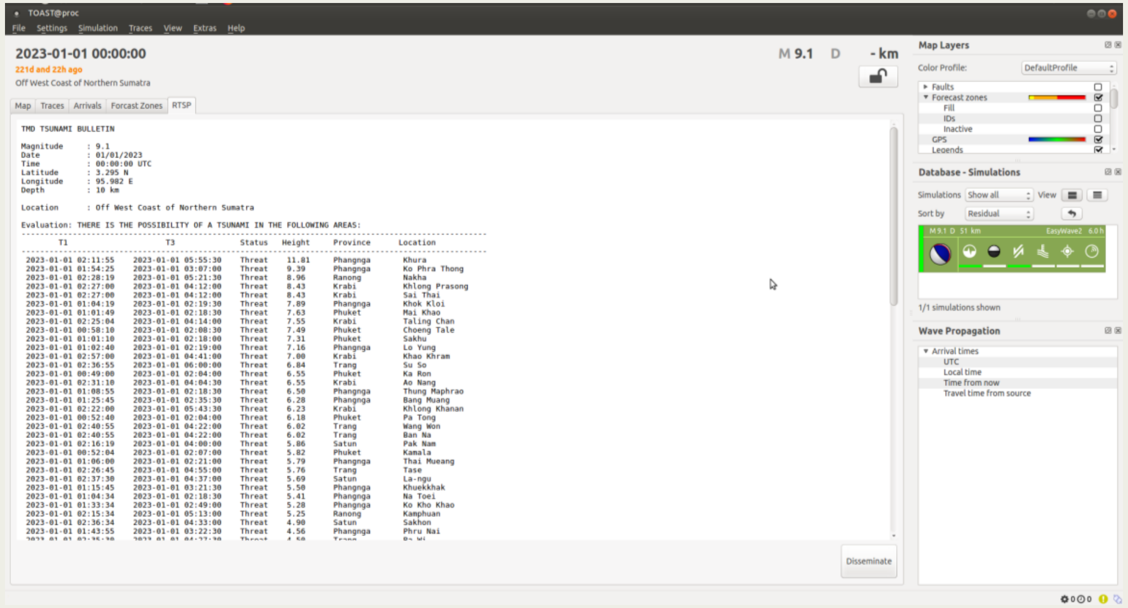
Chutimon Promsuk, Patinya Pornsopin

RESULTS

Simulation results are displayed within the RTSP (Regional Tsunami Service Providers).

T1 Time of exceedance of the detection threshold
T2 Time of first exceedance of the threat threshold (50cm)
T3 Time of maximum positive amplitude
T4 Time of last exceedance of the threat threshold

Status **Thread** Wave height exceeding 50 cm
Height Tsunami wave height
Province, Location Province and sub-district



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Chutimon Promsuk, Patinya Pornsopin

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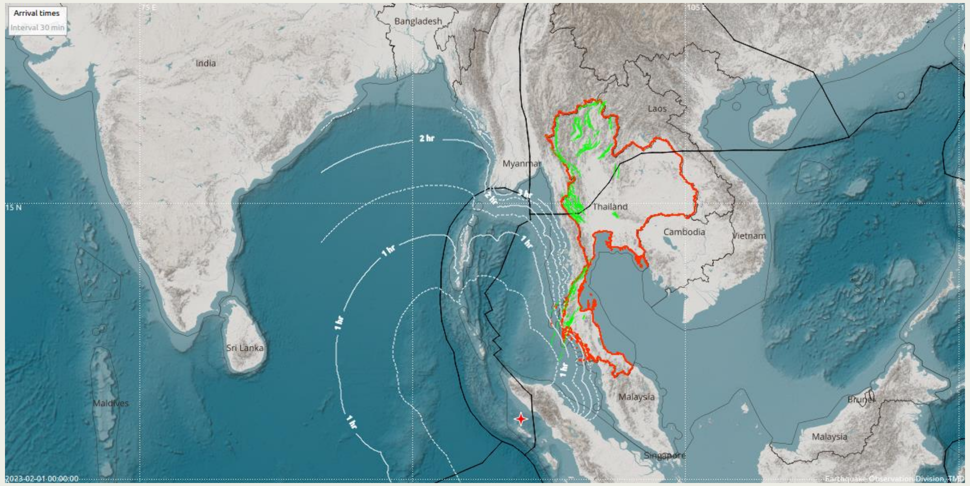

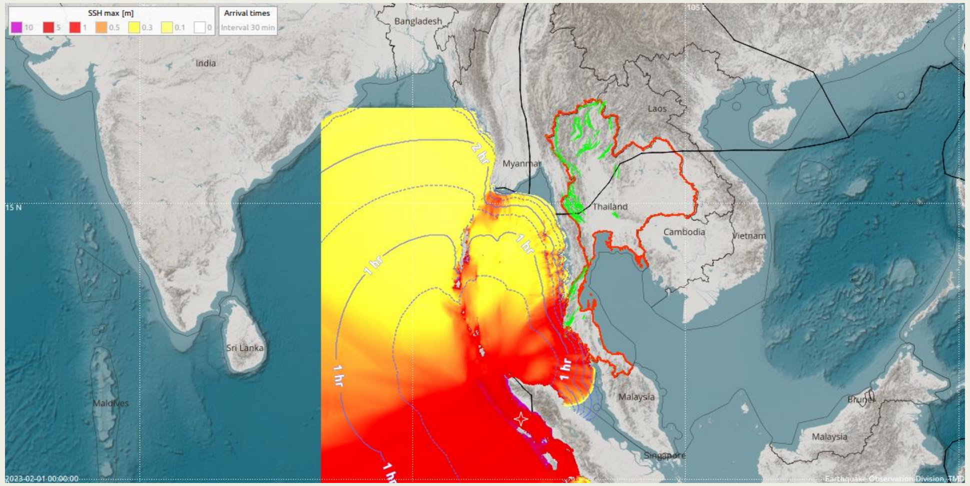

Tsunami arrival time and wave height maps

TMD TSUNAMI BULLETIN

Magnitude : 9.1
Date : 01/02/2023
Time : 00:00:00 UTC
Latitude : 3.295 N
Longitude : 95.982 E
Depth : 30 km

Location : Off West Coast of Northern Sumatra

Evaluation: THERE IS THE POSSIBILITY OF A TSUNAMI IN THE FOLLOWING AREAS:

T1	T3	Status	Height	Province	Location
2023-02-01 01:54:40	2023-02-01 02:44:00	Threat	10.92	Phangnga	Thung Maphrao
2023-02-01 02:00:22	2023-02-01 02:45:30	Threat	8.11	Phangnga	Ko Kho Khao
2023-02-01 02:23:55	2023-02-01 03:10:00	Threat	7.86	Phangnga	Bang Nai Si
2023-02-01 01:26:33	2023-02-01 02:16:00	Threat	7.85	Phuket	Mai Khao
2023-02-01 01:57:16	2023-02-01 02:43:30	Threat	7.82	Phangnga	Bang Muang
2023-02-01 01:47:55	2023-02-01 02:33:00	Threat	7.33	Phangnga	Khuekkhak
2023-02-01 01:26:43	2023-02-01 02:18:30	Threat	6.68	Phuket	Chalong
2023-02-01 02:28:40	2023-02-01 03:30:30	Threat	6.48	Krabi	Sai Thai
2023-02-01 02:33:16	2023-02-01 03:26:00	Threat	6.42	Krabi	Khlong Prasong
2023-02-01 02:04:58	2023-02-01 02:50:00	Threat	6.17	Phangnga	Ko Phra Thong
2023-02-01 01:14:25	2023-02-01 02:05:00	Threat	6.13	Phuket	Choeng Tale
2023-02-01 02:17:16	2023-02-01 03:25:00	Threat	6.08	Phangnga	Bang Wan
2023-02-01 02:27:10	2023-02-01 03:12:00	Threat	6.00	Phangnga	Khura
2023-02-01 01:10:30	2023-02-01 01:59:00	Threat	5.97	Phuket	Pa Tong
2023-02-01 02:09:46	2023-02-01 03:03:00	Threat	5.89	Krabi	Ko Klang
2023-02-01 02:15:10	2023-02-01 03:08:00	Threat	5.66	Krabi	Ko Siboya
2023-02-01 01:27:28	2023-02-01 02:16:00	Threat	5.49	Phangnga	Khok Kloi
2023-02-01 02:40:19	2023-02-01 03:30:30	Threat	5.14	Ranong	Nakha
2023-02-01 01:11:03	2023-02-01 02:00:00	Threat	5.14	Phuket	Kamala
2023-02-01 02:40:13	2023-02-01 03:29:00	Threat	5.03	Krabi	Khao Khram
2023-02-01 01:17:31	2023-02-01 02:06:30	Threat	4.75	Phuket	Sakhu
2023-02-01 01:56:40	2023-02-01 02:50:00	Threat	4.71	Krabi	Sala Dan
2023-02-01 01:32:40	2023-02-01 02:21:30	Threat	4.70	Phangnga	Thai Mueang
2023-02-01 01:30:40	2023-02-01 02:18:30	Threat	4.67	Phangnga	Na Toei
2023-02-01 02:27:40	2023-02-01 03:30:00	Threat	4.55	Ranong	Kamphuan
2023-02-01 01:55:39	2023-02-01 02:48:30	Threat	4.53	Krabi	Ko Lanta Yai
2023-02-01 02:31:55	2023-02-01 03:34:30	Threat	4.46	Phuket	Thep Krasatti
2023-02-01 02:30:39	2023-02-01 03:29:00	Threat	4.34	Ranong	Muang Klang
2023-02-01 01:10:10	2023-02-01 01:59:30	Threat	4.23	Phuket	Ka Ron
2023-02-01 02:30:34	2023-02-01 03:35:00	Threat	4.07	Krabi	Taling Chan
2023-02-01 02:01:58	2023-02-01 03:00:30	Threat	4.02	Phuket	Si Sunthon
2023-02-01 02:12:37	2023-02-01 03:07:00	Threat	3.94	Trang	Ko Libong
2023-02-01 02:42:42	2023-02-01 03:33:00	Threat	3.89	Ranong	Bang Hin

Chutimon Promsuk, Patinya Pornsopin

RESULTS

Earthquake epicenter Point 1 (3.295° N, 95.982° E)

The epicenter is the same as the Mw 9.1 earthquake that occurred in 2004. A comparison is made regarding the improvement of bathymetry parameters, validated against observational data from tide gauge stations (Suppasri et al., 2010).

Tide gauge stations	First wave arrival time (T1)			Highest wave arrival (T3)		
	Recorded	Modeled	Difference	Recorded	Modeled	Difference
Kuraburi station	3:01	2:22	0:39	3:21	5:55	2:34
	3:01	2:27*	0:34	3:21	3:12*	0:09
Taphaonoi station	2:00	1:27	0:33	2:01	4:14	2:13
	2:00	1:26*	0:34	2:01	2:29*	0:28

Note: * Indicates data based on improved bathymetry

Chutimon Promsuk, Patinya Pornsopin

RESULTS

Earliest Arrival

Epicenter	Bathymetry	Location	First wave arrival time (T1)	Highest wave arrival (T3)	Maximum Wave Height (m)
1	Original	Lam Kaen Subdistric, Thai Mueang District, Phang Nga Province	00:51:10	04:51:30	3.40
	Improved		00:58:07	02:48:00	3.58
2	Original		01:04:04	02:24:00	2.37
	Improved		01:12:03	01:27:30	3.26
3	Original		01:12:04	01:43:30	2.11
	Improved		01:21:31	01:53:30	2.26
4	Original		01:10:40	02:42:00	3.04
	Improved		01:18:04	02:39:30	4.28

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Chutimon Promsuk, Patinya Pornsopin

RESULTS

Maximum Wave Height

Epicenter	Bathymetry	Location	Highest wave arrival (T3)	Maximum Wave Height (m)
1	Original	Tambon Kura, Amphoe Kuraburi, Phang Nga Province	05:55:30	9.45
	Improved	Tambon Thung Maprao, Amphoe Thai Mueang, Phang Nga Province	02:44:00	10.92
2	Original	Tambon Choeng Thale, Amphoe Thalang, Phuket Province	02:04:30	4.16
	Improved	Tambon Tha Kham, Amphoe Palian, Trang Province	03:20:30	5.84
3	Original	Tambon Thai Mueang, Amphoe Thai Mueang, Phang Nga Province	05:45:30	3.78
	Improved	Tambon Khuek Khak, Amphoe Takua Pa, Phang Nga Province	02:36:30	3.34
4	Original	Tambon Choeng Thale, Amphoe Thalang, Phuket Province	02:31:00	5.57
	Improved	Tambon Thung Maprao, Amphoe Thai Mueang, Phang Nga Province	02:52:00	8.84

Chutimon Promsuk, Patinya Pornsopin

CONCLUSIONS

- The modified TOAST model, with improved bathymetry resolution, new forecast zones, and forecast points at the subdistrict level, was evaluated against real tidal gauge observations from the 2004 Indian Ocean Tsunami.

- Arrival time of first waves showed no significant difference between improved and original bathymetry.

- Maximum wave arrival times were close to the observed data: 9 minutes earlier at Kuraburi station and 28 minutes later at Taphao Noi station.

- Among other simulated epicenters along the Sumatra-Andaman subduction zone, Lam Kaen Subdistrict was the first location to be impacted.

- Simulated tsunami matches IMS T-wave observations, confirming correct event order despite local tide gauge validation, first T-wave ~32 min, tsunami arrival ~hour after earthquake (Tolstoy & Bohnenstiehl, 2006).

Chutimon Promsuk, Patinya Pornsopin

CONCLUSIONS

Future plans

- Integrate multiple bathymetry datasets for higher-resolution tsunami modeling.
- Refine forecast zones and points down to village level for precise impact prediction.
- Enhance validation with additional observations (tide gauges, field surveys, or IMS data) and develop rapid assessment tools for early warning.
- Develop a custom tsunami model to potentially replace EasyWave, making it more suitable for Thailand's coast.

THANK YOU

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