UNDRR
UN Office for Disaster Risk Reduction

Earthquake Hazard and Risk Assessment of Bangladesh

AT UPAZILA LEVEL

GLOBAL EARTHQUAKE MODEL FOUNDATION

31 JANUARY 2024

working together
to assess risk

GEM
GLOBAL EARTHQUAKE MODEL

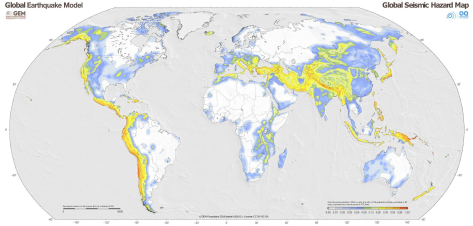
OQ
OPENQUAKE

Time	Speaker	Topic
11:00–11:05	Chair, MoDMR	Welcome and introduction of new members
11:05–11:25	Prof. Mehedi Ahmed Ansary, BUET	(i) Insights about earthquake vulnerability in Bangladesh following the Rana Plaza collapse, and (ii) Status of earthquake risk mitigation in Bangladesh
11:25–11:45	Asst. Prof. Uttama Barua, BUET; UNSW Sydney	Earthquake risk-sensitive land-use planning at the local level in Bangladesh
11:45–12:30	Anirudh Rao, GEM	Brief recap of sessions 1–3
	Catalina Yepes-Estrada, GEM	Results from the scenario risk assessment
	Anirudh Rao, GEM	Results from the probabilistic seismic risk assessment at upazila level
	Lana Todorović, GEM	Earthquake-induced liquefaction assessment: scenario and probabilistic analysis
12:30–12:45	All panel members	Open discussion, Q&A
12:45–12:55	UNDRR+GEM	Tentative dates and agenda for in-person workshop
12:55–13:00	Chair, MoDMR	Closing remarks

Our Methodology

We collect and process data worldwide, related to the main components of risk

Currently GEM has fully functional global model components to assess earthquake impact worldwide

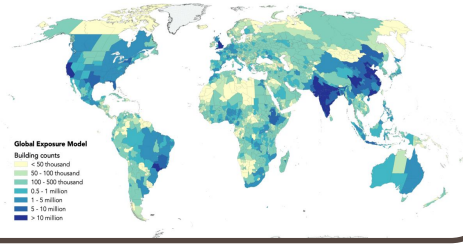


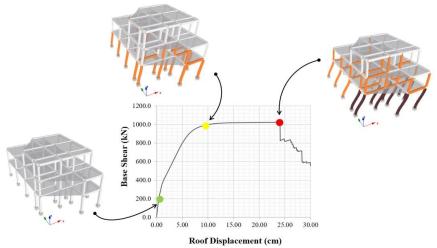
Hazard

The seismic potential at any location

Exposure

The built environment at risk





Vulnerability

The expected damage to an event

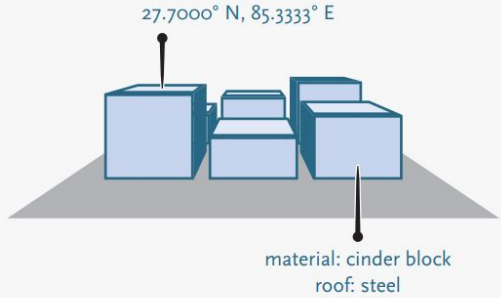
Seismic Risk

HAZARD

The likelihood, probability, or chance of a potentially destructive phenomenon.

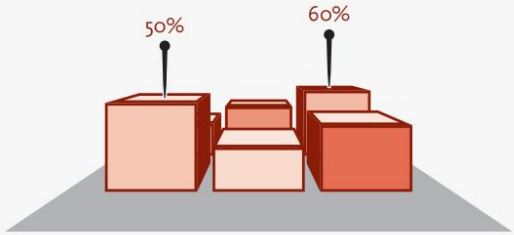
EXPOSURE

The location, attributes, and values of assets that are important to communities.



VULNERABILITY

The likelihood that assets will be damaged or destroyed when exposed to a hazard event.



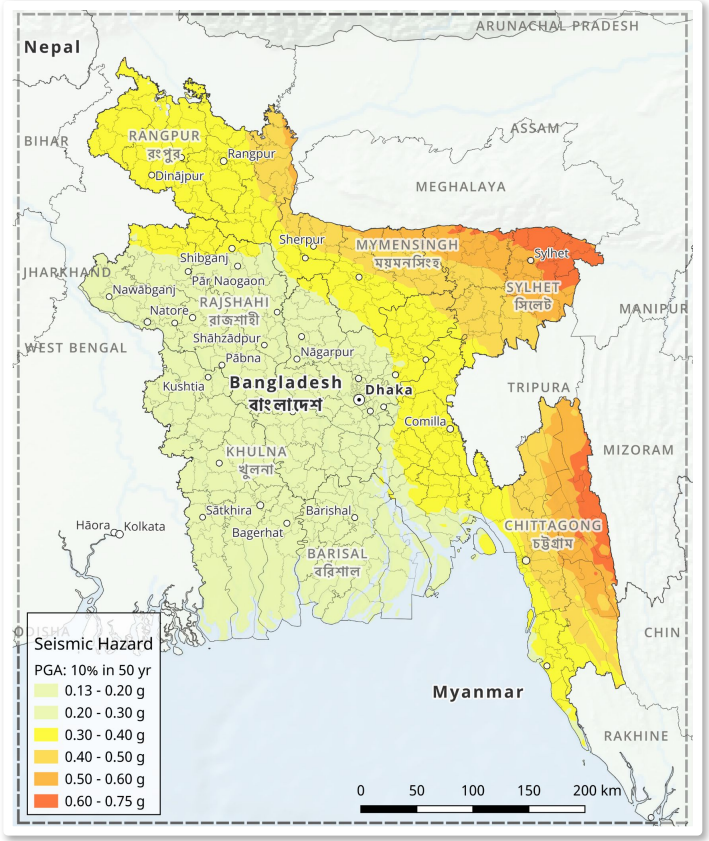
HAZARD **EXPOSURE** **VULNERABILITY**

Risk occurs when there is a spatial and temporal overlap of these three elements

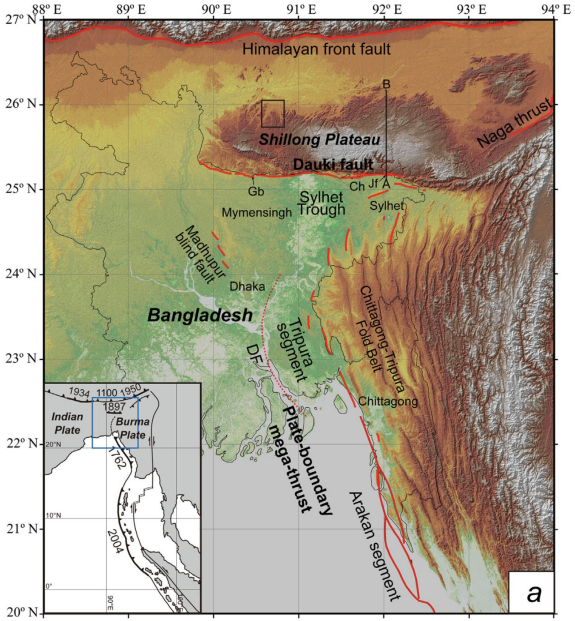
Source: gfdrr.org/sites/gfdrr/files/publication/opendri_fg_web_20140629b_0.pdf

Seismic Hazard

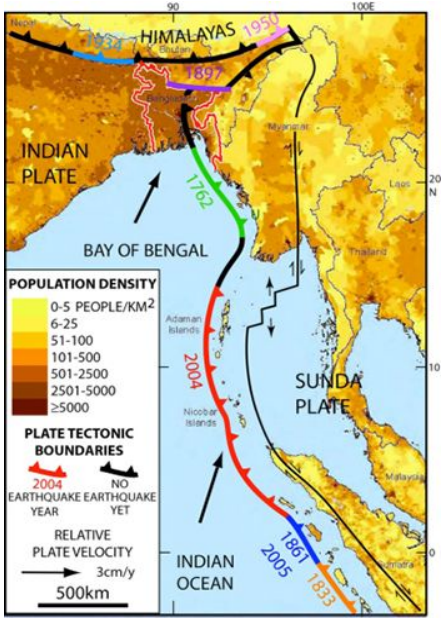
PSHA for the country



Seismic Hazard Assessment



Active fault map of Bangladesh



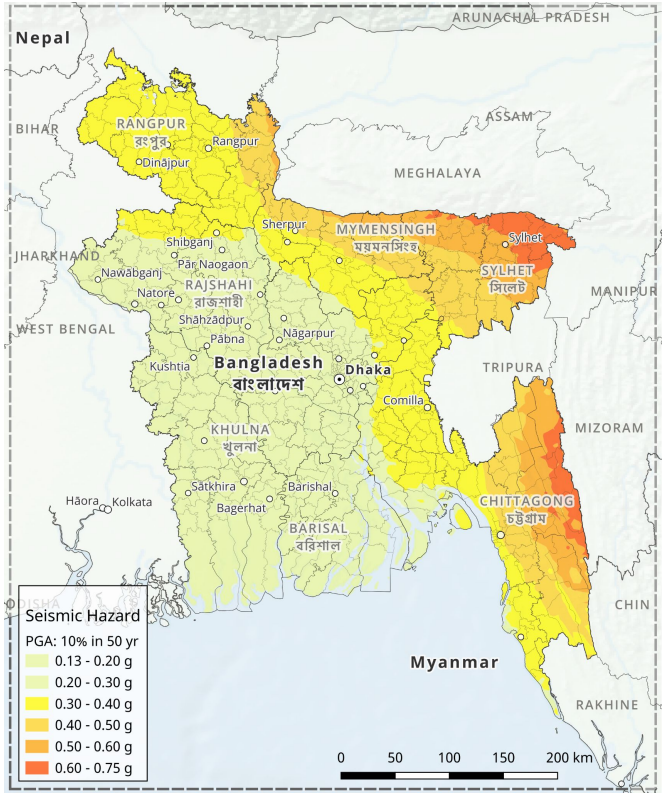
Subduction plate boundaries

Morino et al. (2014). A paleo-seismological study of the Dauki fault at Jaflong, Sylhet, Bangladesh: Historical seismic events and an attempted rupture segmentation model. Journal of Asian Earth Sciences, 91, 218–226.

Source: Michael Steckler / Lamont-Doherty Earth Observatory

- Identification of active faults
- Historical earthquakes
- Seismic source model
- Soil characterization using secondary data
- Ground motion model
- Probabilistic seismic hazard assessment

Seismic Hazard Assessment



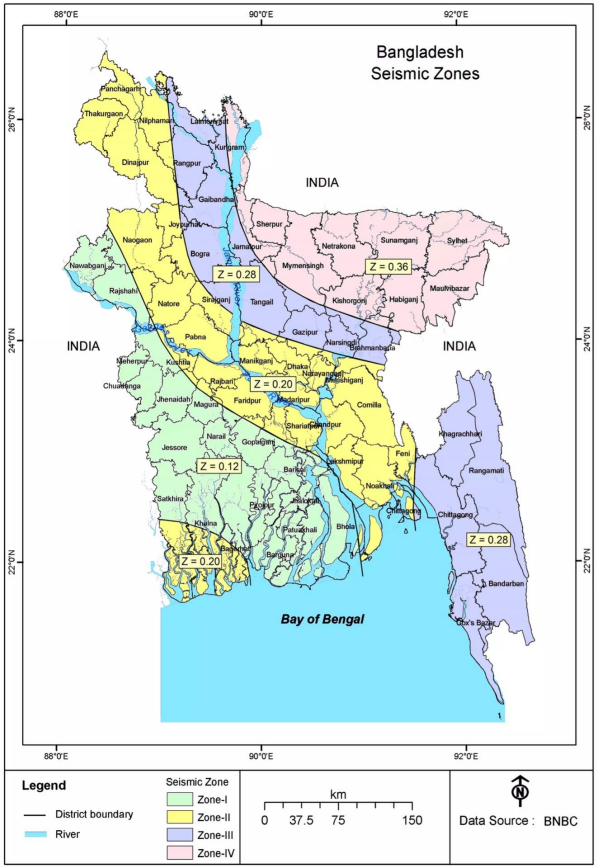
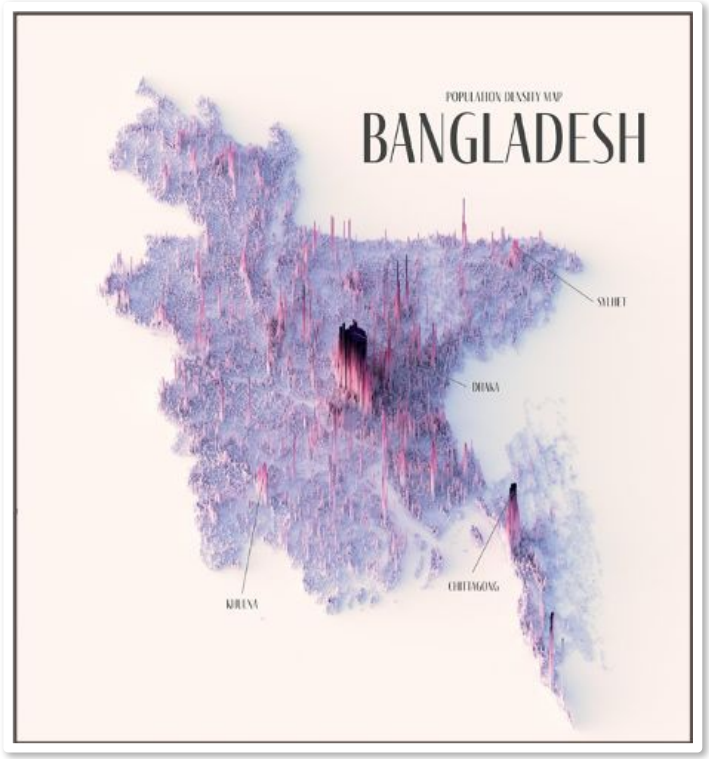


Figure 6.2.24 Seismic zoning map of Bangladesh

Exposure

Buildings
Population
Infrastructure



Exposure Modelling

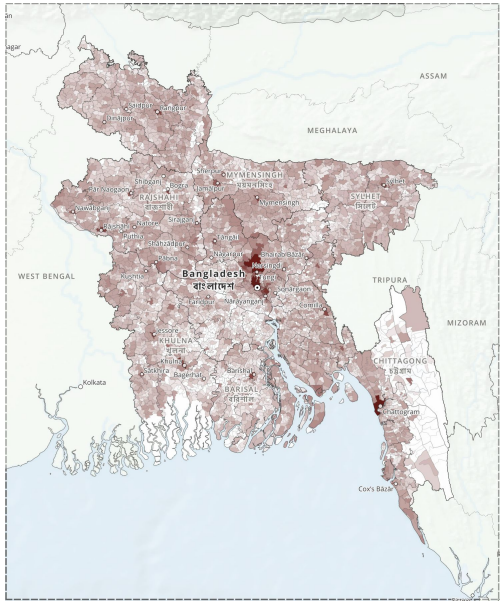
It is necessary to identify the physical characteristics of the built environment, to classify each exposed element according to its seismic fragility and vulnerability



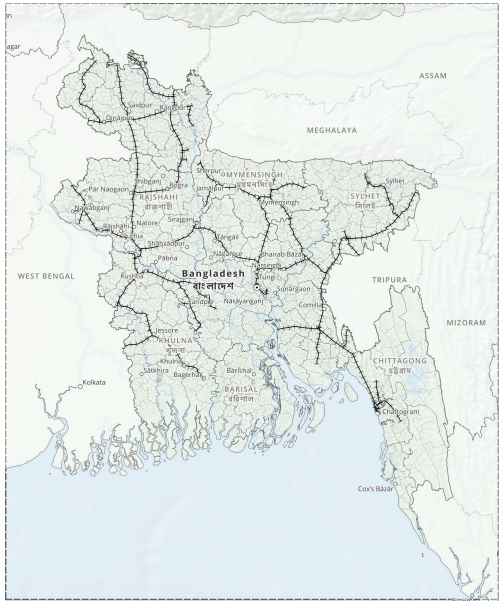

Some of the main attributes that need to be identified are:

location, construction material, structural system, height, and code compliance

Exposure Modelling



Residential Buildings



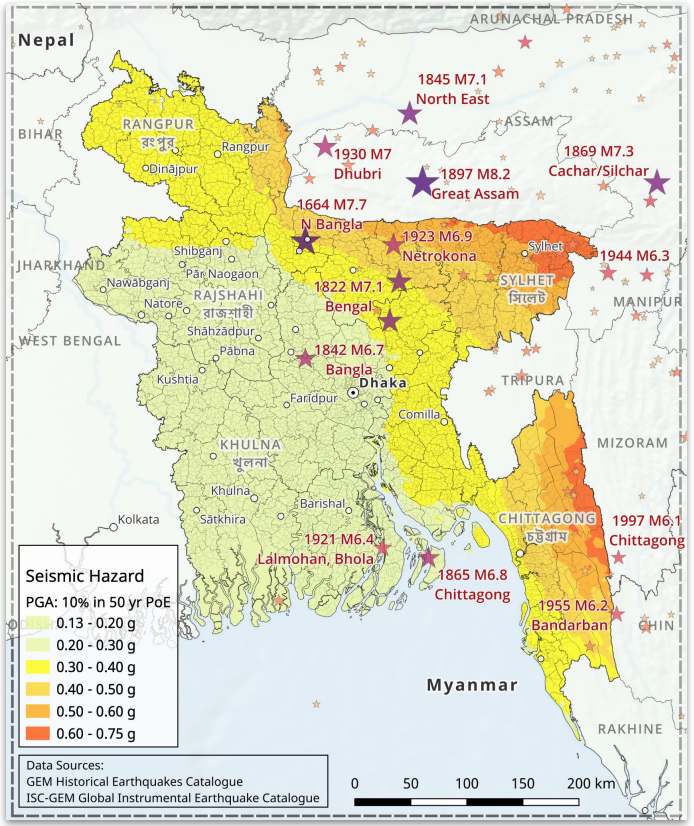
Railway Lines

- **Buildings**
  - Residential
  - Commercial
  - Industrial
  - Healthcare
  - Education
- **Infrastructure**
  - Roads
  - Railways
- **Population**

- **Attributes**
  - Location
  - Typology
  - Valuation
  - Age

Earthquake Scenarios

Historical and hypothetical events

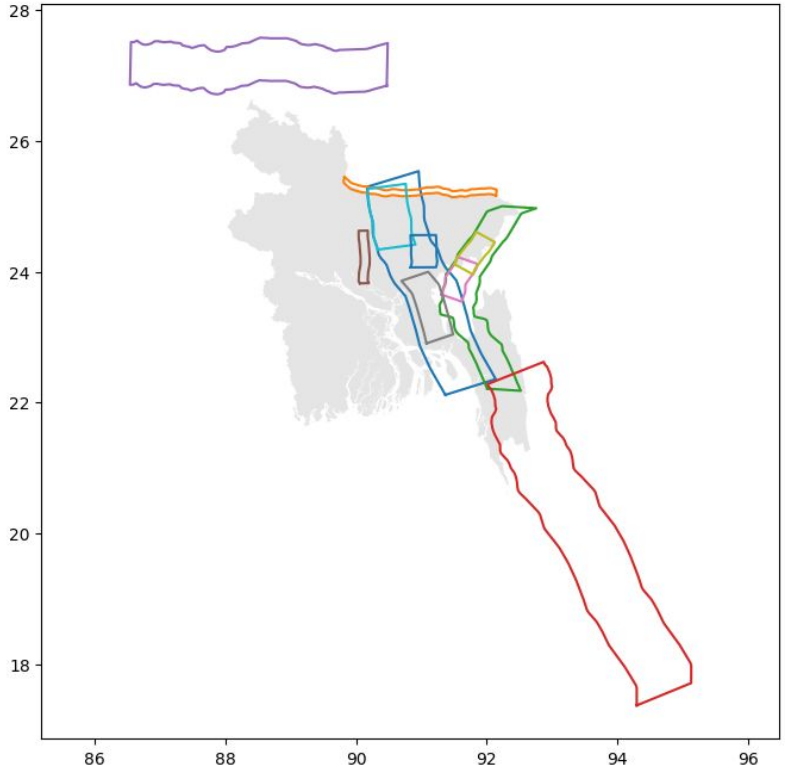


Scenario Ruptures

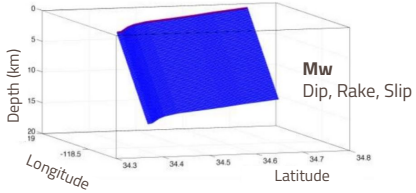
12 Scenario Ruptures

Based on historical and likely potential events

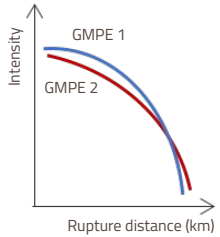
Faults from existing GEM research in region, or (for Madhupur, etc.) mapped for this project based on publications and topography



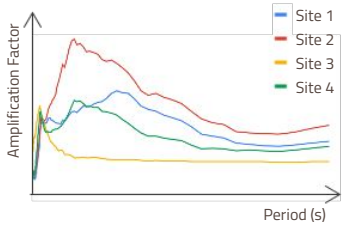
Scenario Calculator



Seismic rupture



GMPEs



Site effects

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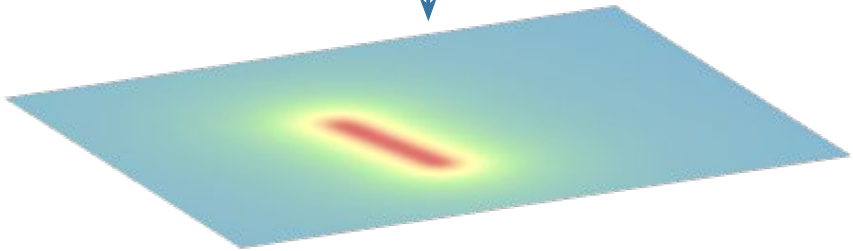
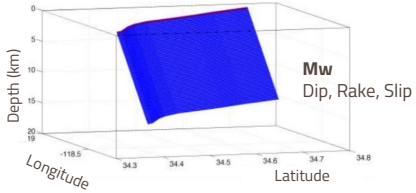
calculate share explore

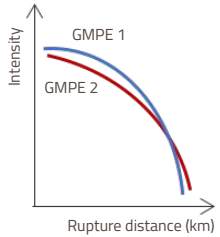


Ground motion fields

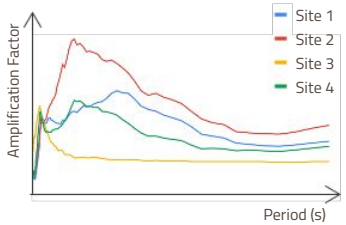
Scenario Calculator



Seismic rupture



GMPEs



Site effects

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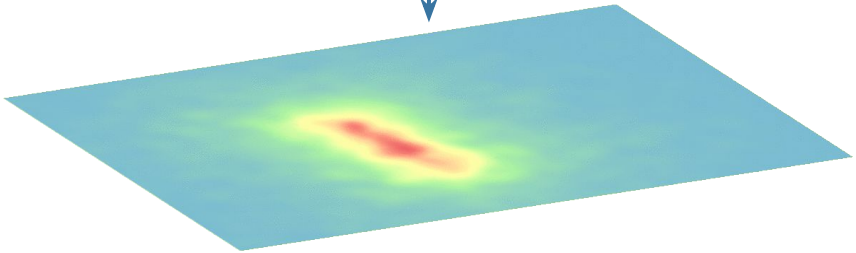
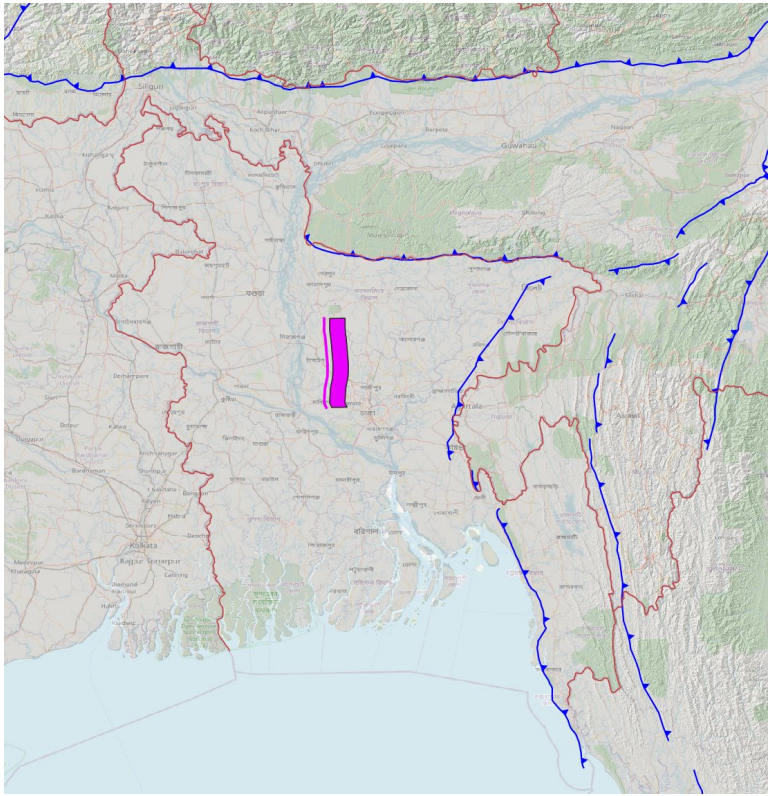


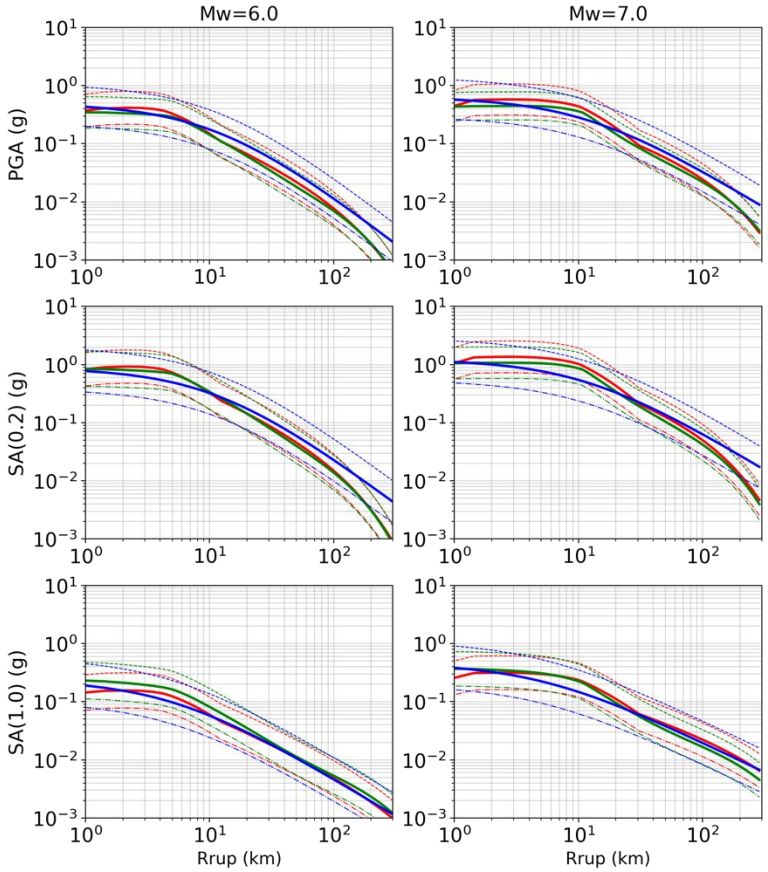
Ground motion fields

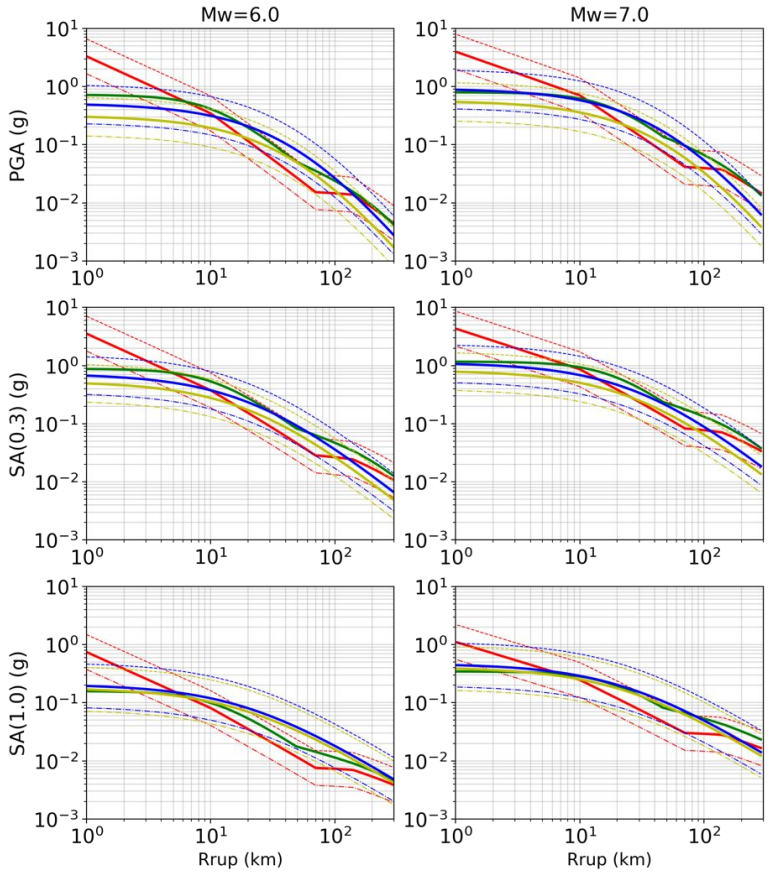
1885 Manikganj Mw7.2 earthquake



- Very damaging earthquake, widespread destruction in Dhaka
- Placed on the Madhupur fault
- Assigned Mw 7.2 based on area-magnitude scaling relationships
- Martin and Szeliga assigned M 7.1

Ground Motion Models: Active (left) vs. Stable (right) ?

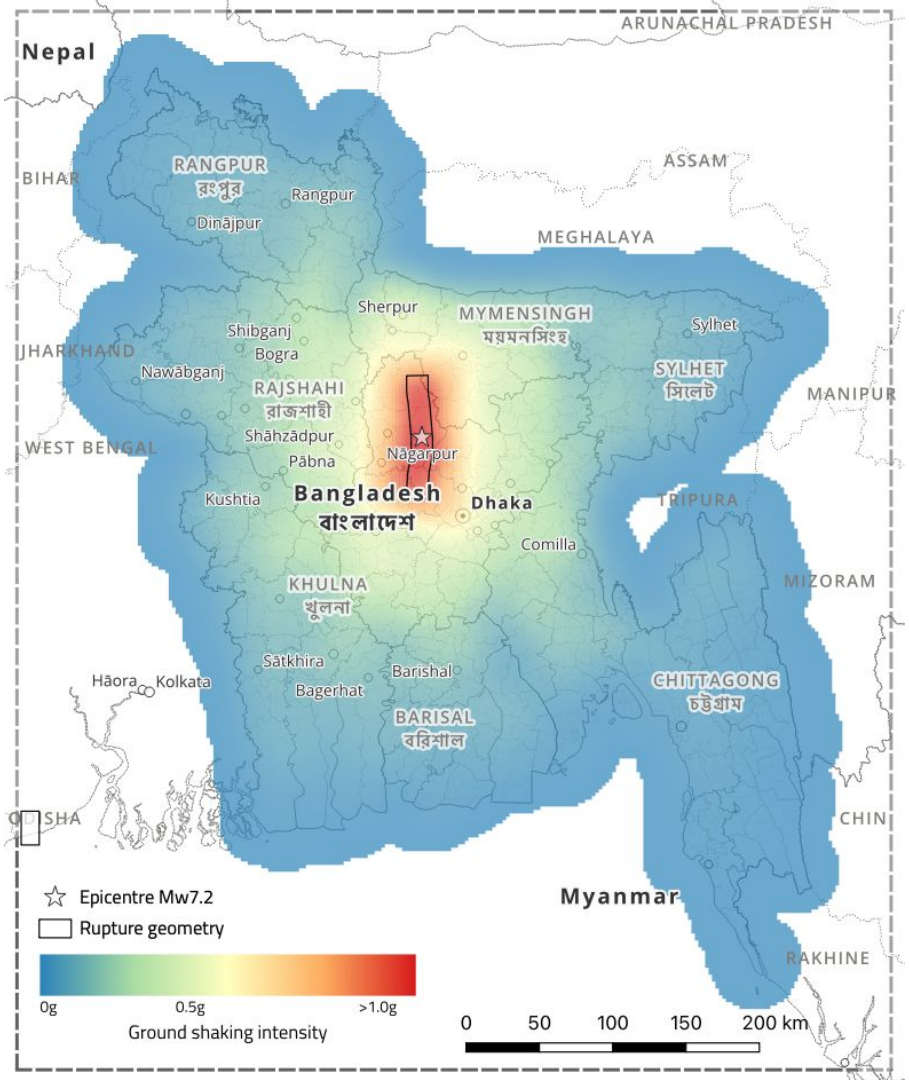




1885 Manikganj Mw7.2 earthquake

Active shallow crust
(*Stable continental crust?*)

- ChiouYoungs2014
- AbrahamsonEtAl2014
- Modifications for Al-Atik and Youngs (2014) epistemic uncertainty factors for reverse faulting



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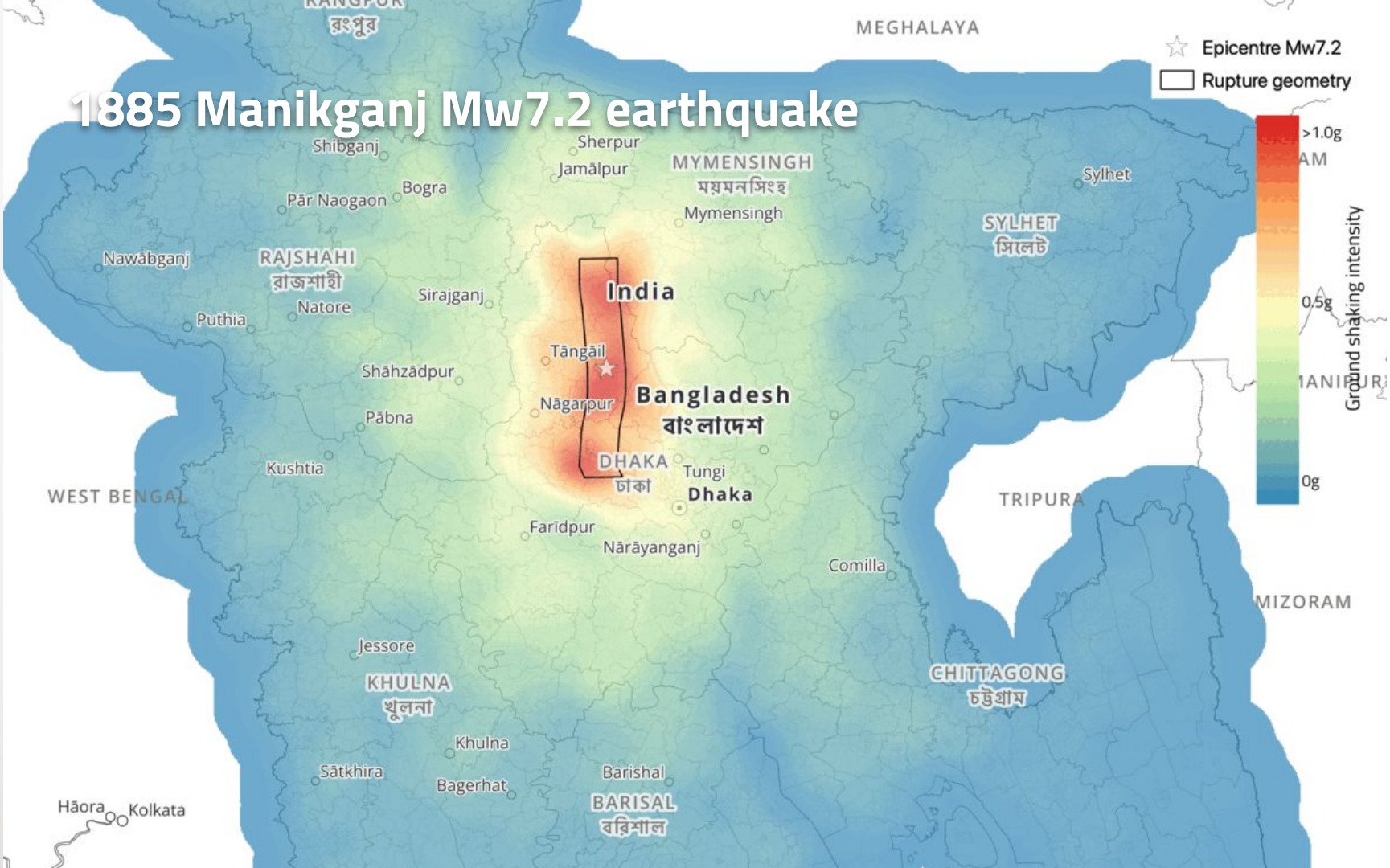
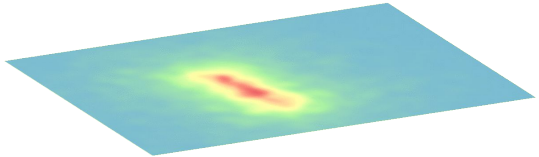
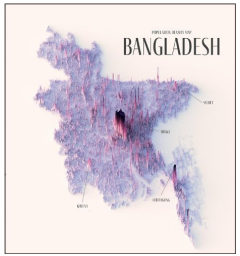


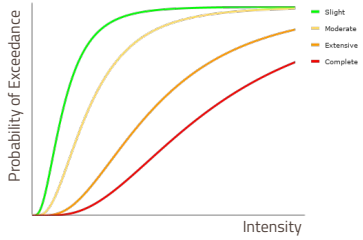
Scenario Damage Calculator



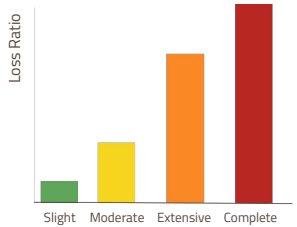
Ground motion fields



Exposure model



Fragility functions



Consequence model

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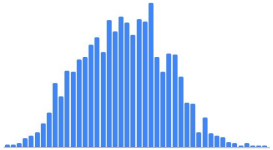
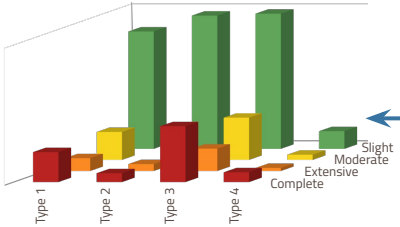
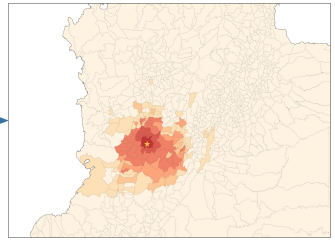
calculate share explore



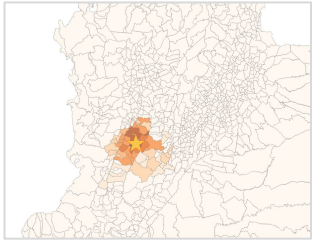
Loss statistics



Damage distribution



Loss maps



Damage maps

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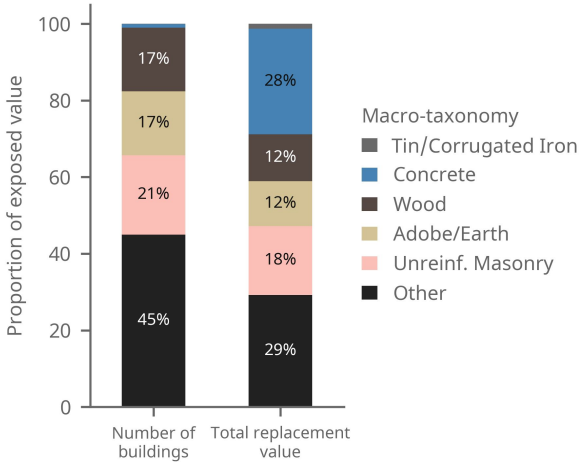
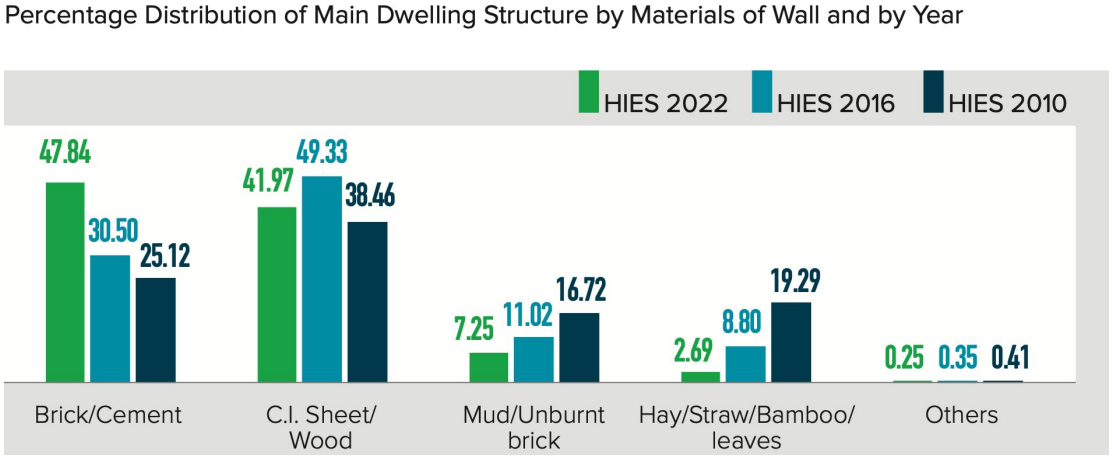
Seismic Vulnerability Analysis





EARTHQUAKE SCENARIO IMPACT

Earthquake scenario	Magnitude Mw	Collapsed buildings	Economic losses (USD Million)	Fatalities	Injured population	Displaced population
1869_cachar	7.3	3,919	516	2,440	10,087	368,829
sikkim_mht	8.5	11,797	1,082	5,119	20,384	722,949
chittagong_thrust_smaller	7.25	33,750	5,039	17,978	75,808	2,750,990
1822	7.1	38,237	3,803	16,620	69,471	2,469,500
1918_Srimangal	7.4	40,673	4,481	20,793	83,612	2,950,110
1762_arakan	8.5	44,942	5,295	25,277	94,867	3,149,590
1885_manikganj	7.2	68,568	13,009	36,725	159,097	5,732,280
1897_Dauki	8.7	112,151	9,570	50,112	193,221	6,668,340
1664_N_Bang	7.7	117,069	13,072	53,969	214,315	7,501,590
western_deformation_front_partial	7.7	118,547	18,874	64,118	274,348	9,526,090
chittagong_north	8.2	121,569	13,483	61,667	249,080	8,455,880
western_deformation_front	8.5	378,213	43,064	184,541	737,858	24,396,100

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1885 Manikganj Mw7.2 earthquake

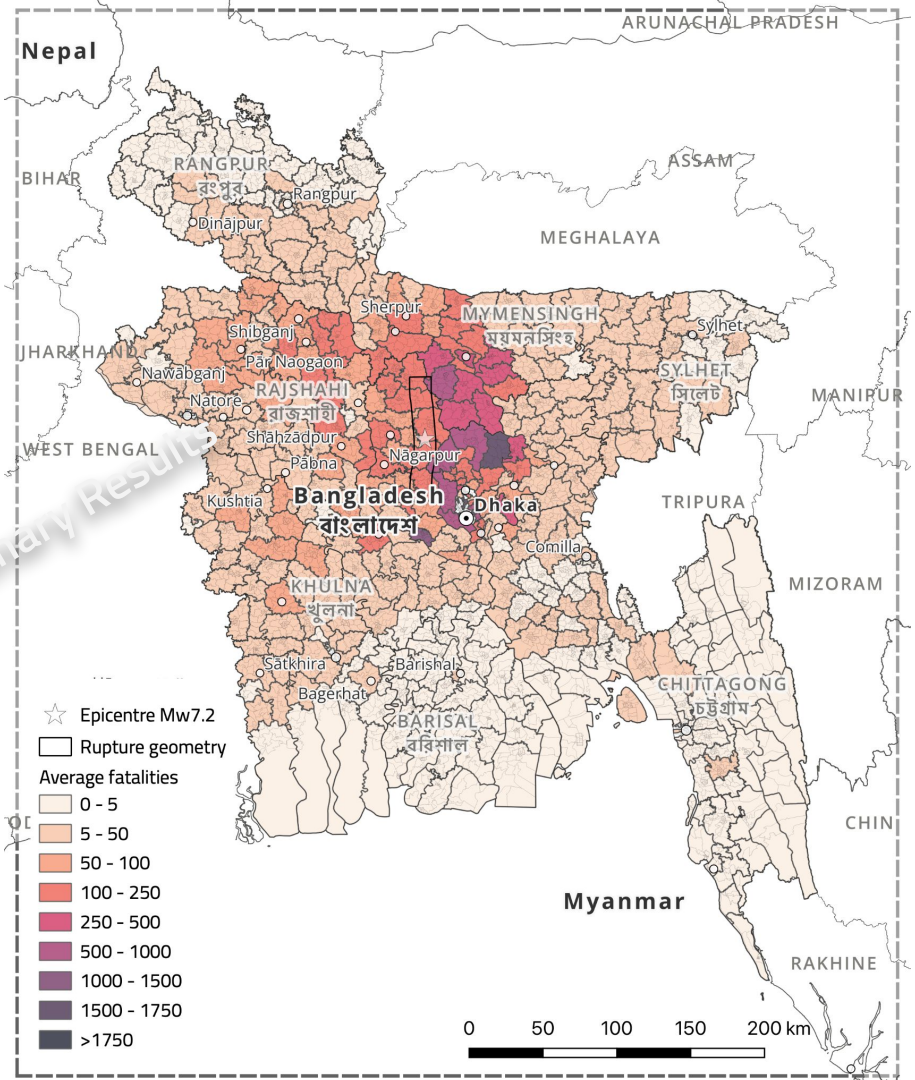
Mean Fatalities

Time of the event
- night
- day
- Transit

Fatalities at night:

25k - 52k people

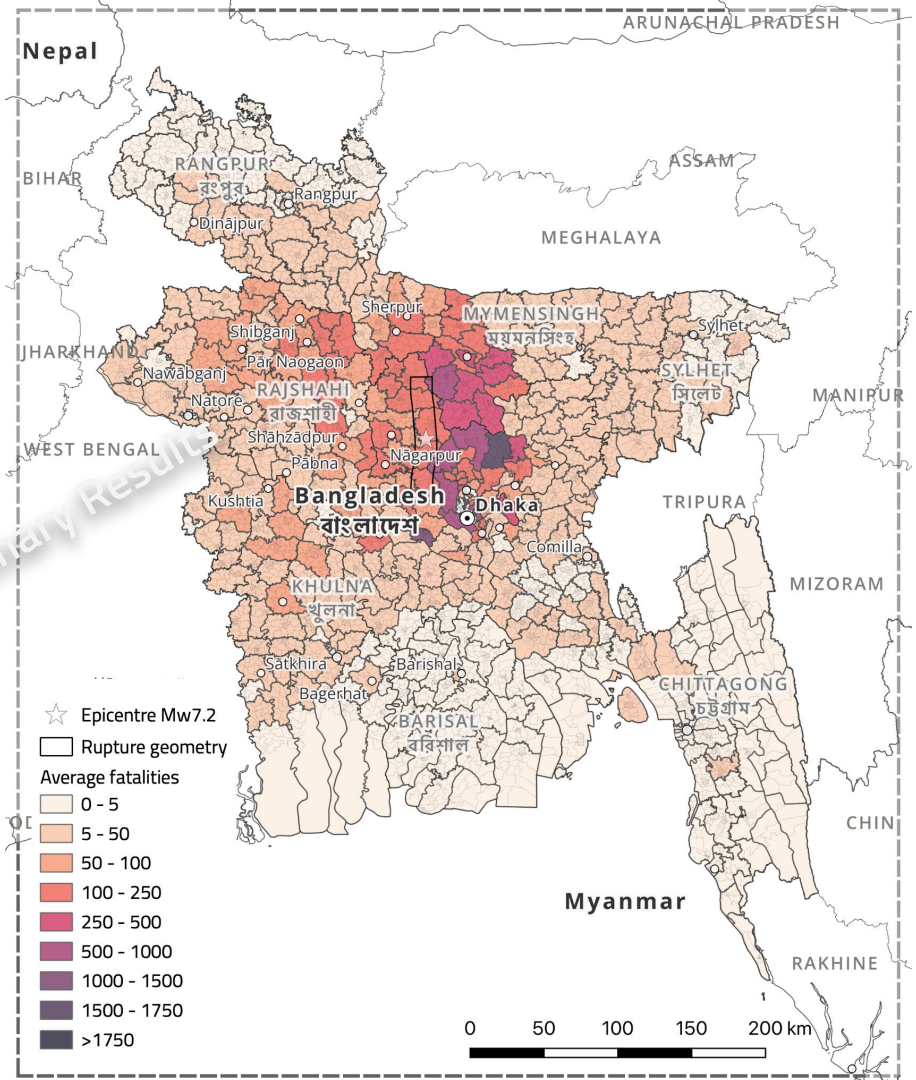
~ 37k people



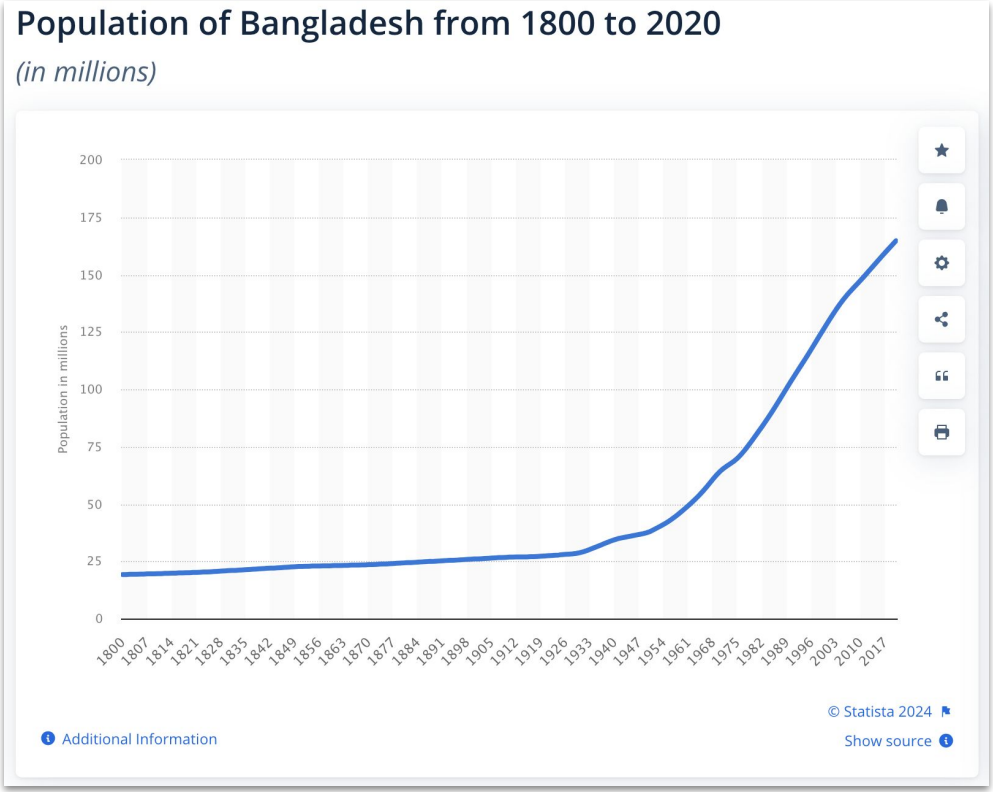
1885 Manikganj Mw7.2 earthquake

1885 Manikganj (Bengal) Mw 7.2 earthquake	
Upazila	**Fatalities**
Darussalam	2,144
Shahbag	1,836
Kapasia	1,747
Sabujbag	1,661
Cantonment	1,587
Dohar	1,485
Rupnagar	1,354
Keraniganj	995
Sreepur	857
Badda	845
Fulbaria	812
Demra	802
Savar	686
Shyampur	656
Hazaribag	643

Fatalities at night:
25k - 52k people
~ 37k people



1885 Manikganj Mw7.2 earthquake



https://www.statista.com/statistics/1066829/population-bangladesh-historical/

Supplementary notes

Data from UN used for period between 1950-2020. Data from Gapminder used for period between 1800-1949.

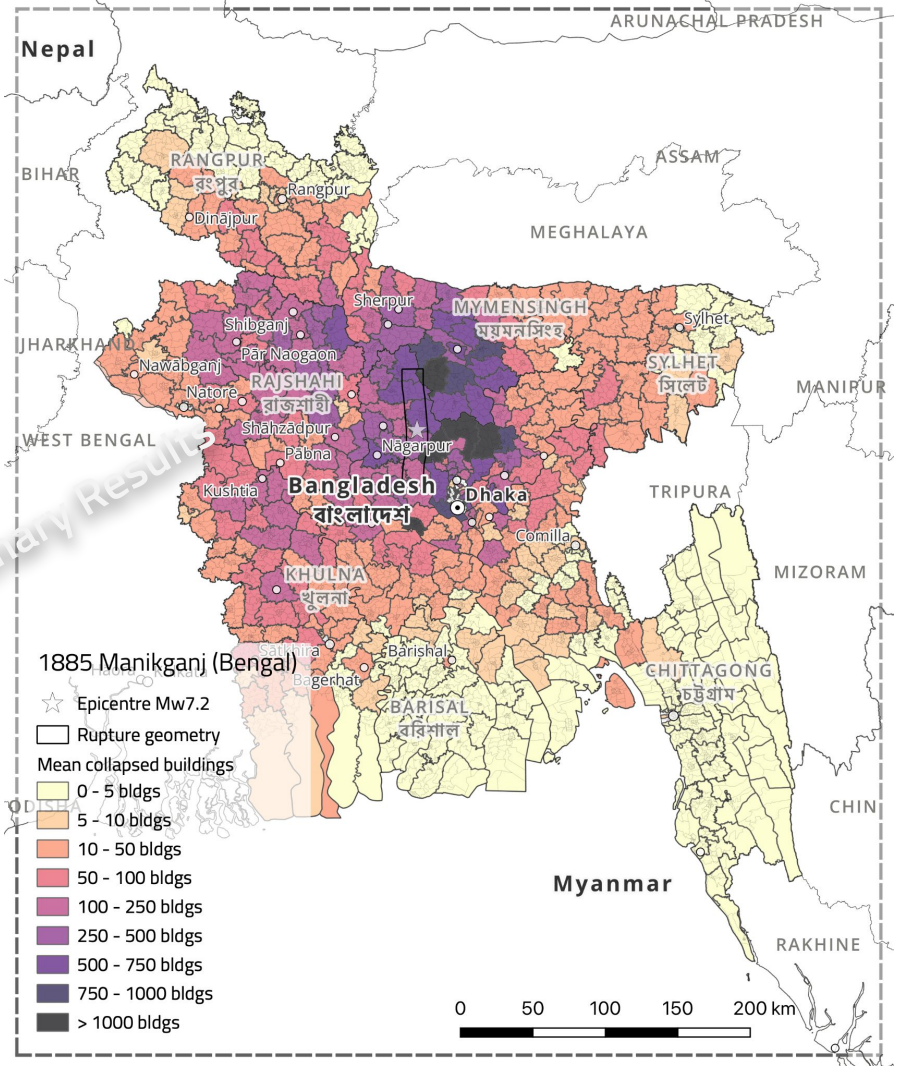
The sources do not give their methodology, but appear to use estimates from extended periods of time to calculate gradual annual figures, therefore the impact of major events (such as the Bengal Famine or Liberation War) may appear smaller when represented on the graph.

1885 Manikganj Mw7.2 earthquake

Mean Collapsed Buildings:

43k - 101k units

~ 69k units



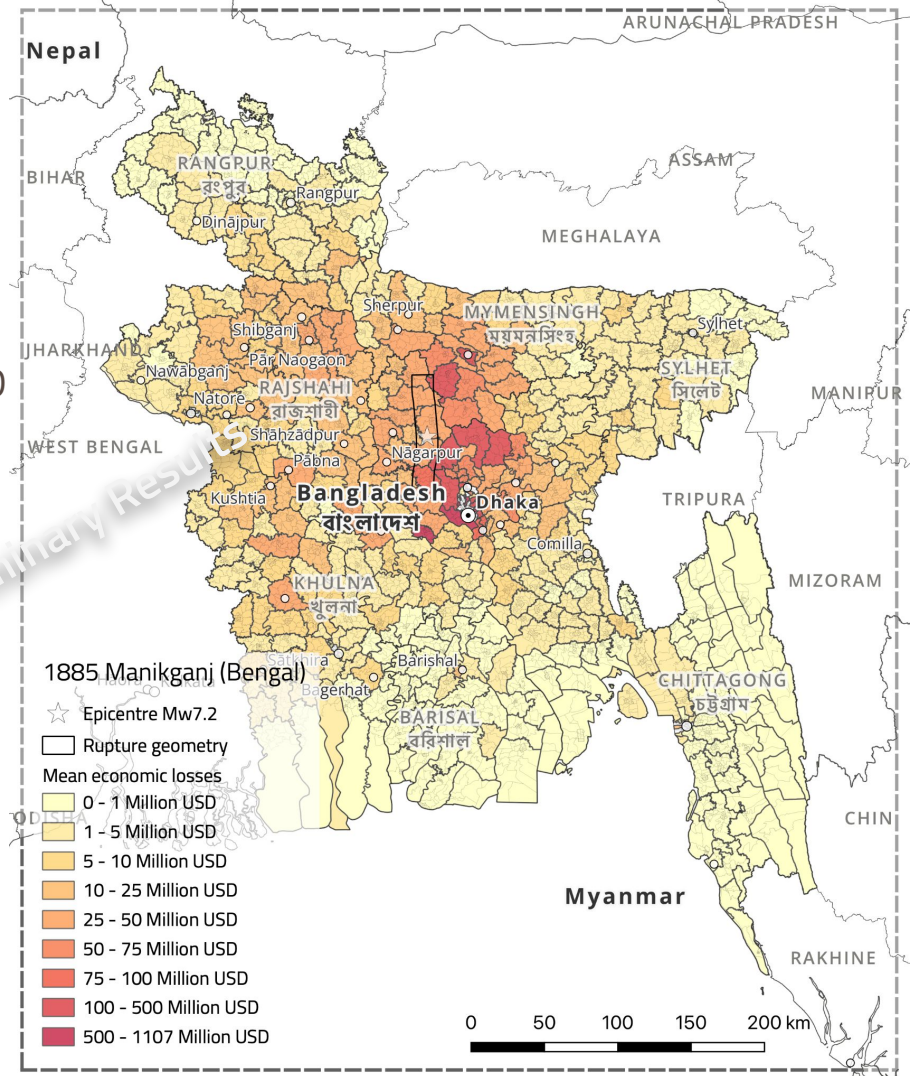
1885 Manikganj Mw7.2 earthquake

Mean Economic losses

1885 Manikganj (Bengal) Mw 7.2 earthquake	
Upazila	**Economic losses (USD Million)**
Darussalam	1,107,360,748
Shahbag	1,023,889,355
Sabujbag	966,311,281
Cantonment	871,900,055
Rupnagar	659,250,899
Keraniganj	554,794,262
Dohar	550,718,471
Demra	477,073,991
Badda	463,702,866
Shyampur	382,684,207
Savar	323,123,384
Hazaribag	313,021,438
Kapasia	268,332,416
Tongi Pashchim	187,756,761
Narayanganj Sadar	169,709,673

10 - 17 Billion USD

~ 13 Billion USD

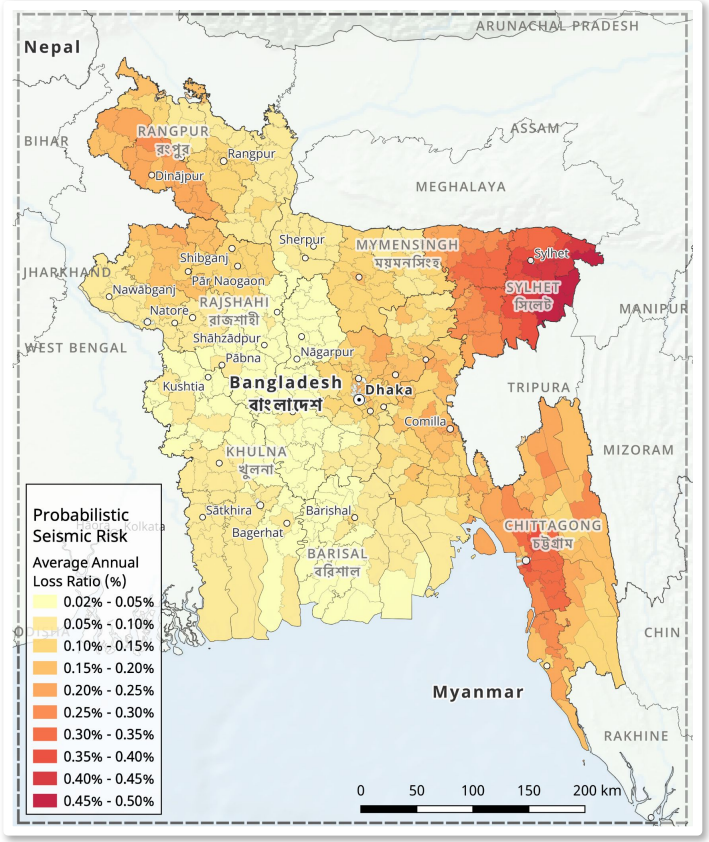


1885 Manikganj (Bengal) Mw 7.2 earthquake					
Upazila	Collapsed buildings	Economic losses (USD Million)	Fatalities	Injured population	Displaced population
Darussalam	1,937	1,107,360,748	2,144	9,480	340,444
Shahbag	1,602	1,023,889,355	1,836	8,155	301,341
Kapasia	4,949	268,332,416	1,747	6,814	250,910
Sabujbag	1,532	966,311,281	1,661	7,512	280,633
Cantonment	1,227	871,900,055	1,587	6,882	257,915
Dohar	5,979	550,713,471	1,485	8,860	328,284
Rupnagar	1,294	659,250,899	1,354	6,117	221,731
Keraniganj	862	554,794,262	995	4,510	173,095
Sreepur	2,385	151,729,440	857	3,386	122,846
Badda	703	463,702,866	845	3,765	143,824
Fulbaria	2,129	101,299,282	812	2,802	95,841
Demra	659	477,073,991	802	3,601	140,721
Savar	566	323,123,384	686	2,997	108,449
Shyampur	567	382,684,207	656	2,984	115,659
Hazaribag	598	313,021,438	643	2,927	108,143

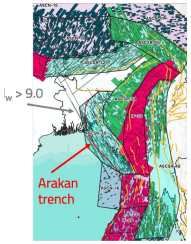
1885 Manikganj (Bengal) Mw 7.2 earthquake					
Zila	Collapsed buildings	Economic losses (USD Million)	Fatalities	Injured population	Displaced population
Dhaka	18,296	8,154,090,350	15,606	71,857	2,672,033
Gazipur	27% 11,361	1,[illegible]367,756 63%	43% 4,539	45% 18,828	47% 664,443
Mymensingh	9,905	673,807,792	3,975	15,137	524,123
Tangail	4,965	311,607,763	1,815	7,043	223,081
Bogura	3,463	286,152,308	1,500	5,674	204,411
Narsingdi	1,748	160,079,1[illegible]	688	2,898	106,137
Sirajganj	1,444	11[illegible]0,350	581	2,304	79,434
Narayanganj	1,412	343,261,531	723	3,822	137,894
Manikganj	1,148	103,347,268	477	2,097	61,024
Naogaon	1,101	106,325,585	588	2,204	79,944
Jamalpur	1,068	69,566,585	387	1,640	53,683
Sherpur	954	52,660,196	329	1,252	42,960
Natore	747	62,725,401	300	1,235	45,691
Pabna	667	77,493,311	252	1,159	42,016
Jhenaidah	643	65,083,643	232	1,046	39,928

Probabilistic Risk

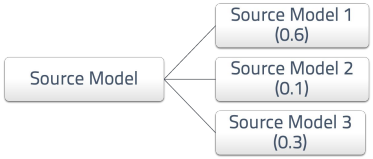
Event-based risk assessment



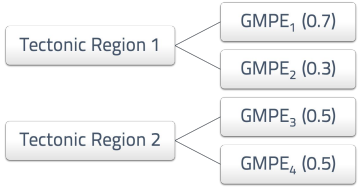
Event-Based PSHA Calculator



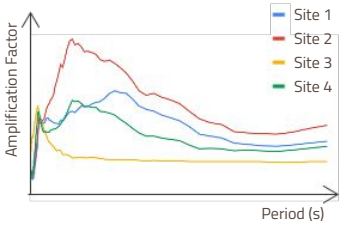
Source model



Source model logic tree

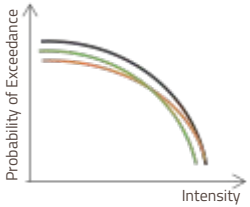


GMPE logic tree

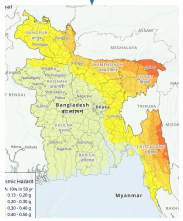


Site effects

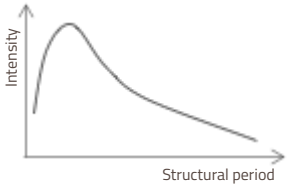
OPENQUAKE
calculate share explore



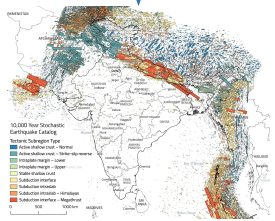
Hazard curves



Hazard maps

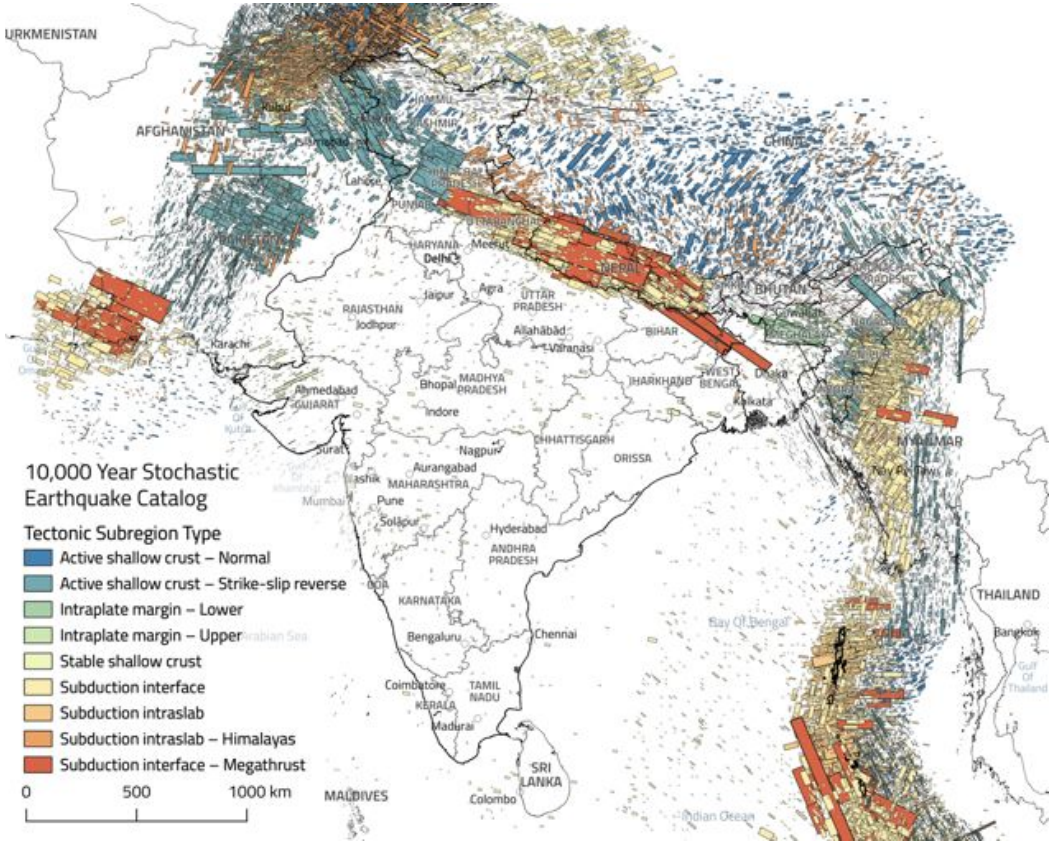


Uniform Hazard Spectra

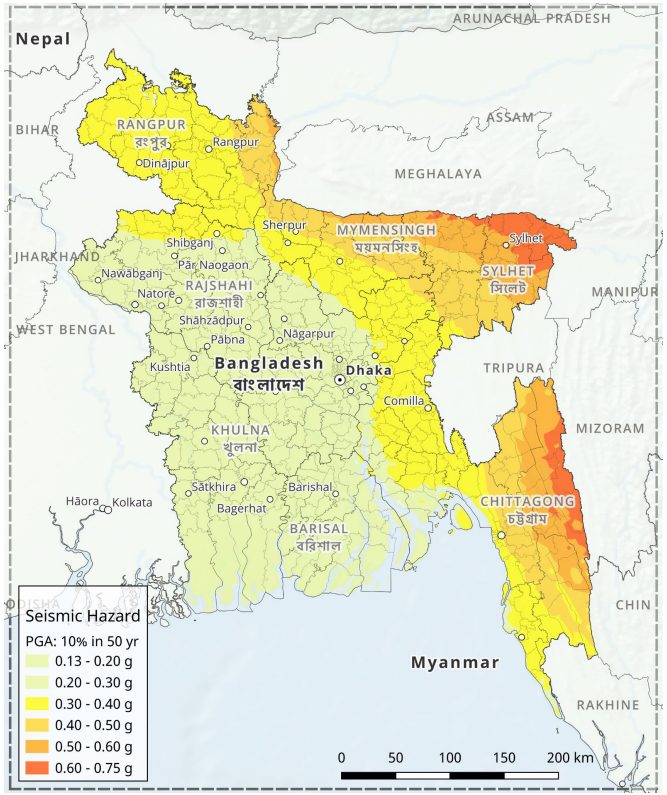


Earthquake Ruptures

Event-based PSHA Calculator

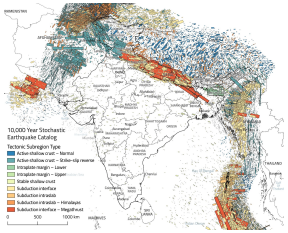


Stochastic earthquake catalog for the Indian subcontinent (10,000 years)

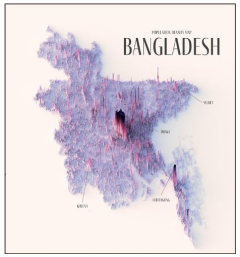


Probabilistic Seismic Hazard Map for Bangladesh

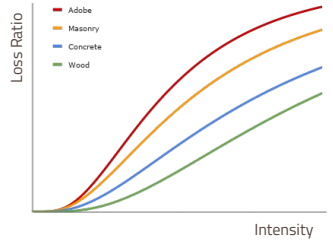
Probabilistic Event-Based Risk Calculator



Stochastic event sets
Ground motion fields

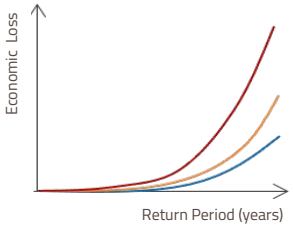


Exposure model

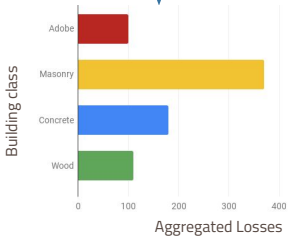


Vulnerability functions

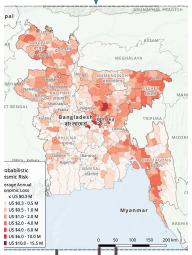
OPENQUAKE
calculate share explore



Loss curves (portfolio)



Aggregated losses

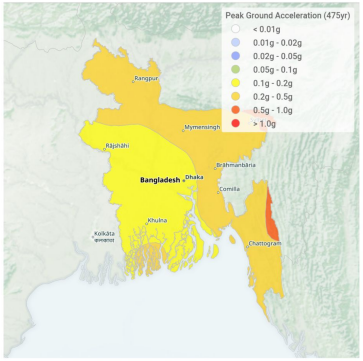


Aggregated loss maps

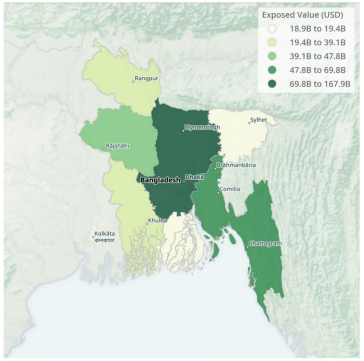
GLOBAL QUAKE MODEL .ORG

Division Level Seismic Risk Maps

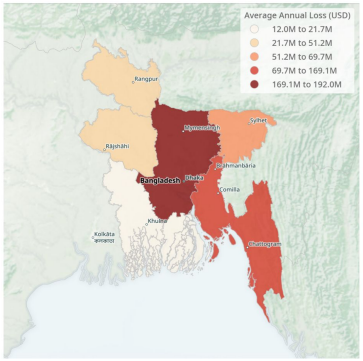
EARTHQUAKE HAZARD



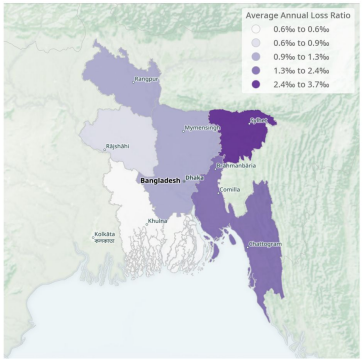
EXPOSED VALUE



AVERAGE ANNUAL LOSSES



AVERAGE ANNUAL LOSS RATIOS



BANGLADESH

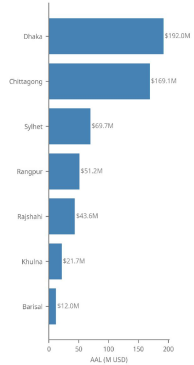
SOCIAL INDICATORS

- Population **164.7M**
- Population Growth **1.05%/year**
- GDP **250.0B USD**
- GDP per Capita **1,517 USD**
- GINI Index **32.1**
- Human Development Index **0.800**

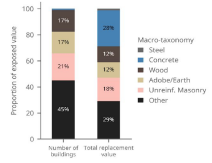
RISK INDICATORS

	Replacement cost (Billion USD)	Avg. annual loss (Thousand USD)	Avg. annual loss ratio (‰)
Residential	358.0	516,815	1.444
Commercial	27.5	36,888	1.340
Industrial	15.9	5,522	0.348

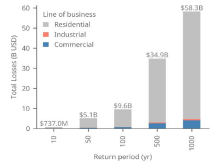
LOSS BY REGION



BUILDING CLASSES

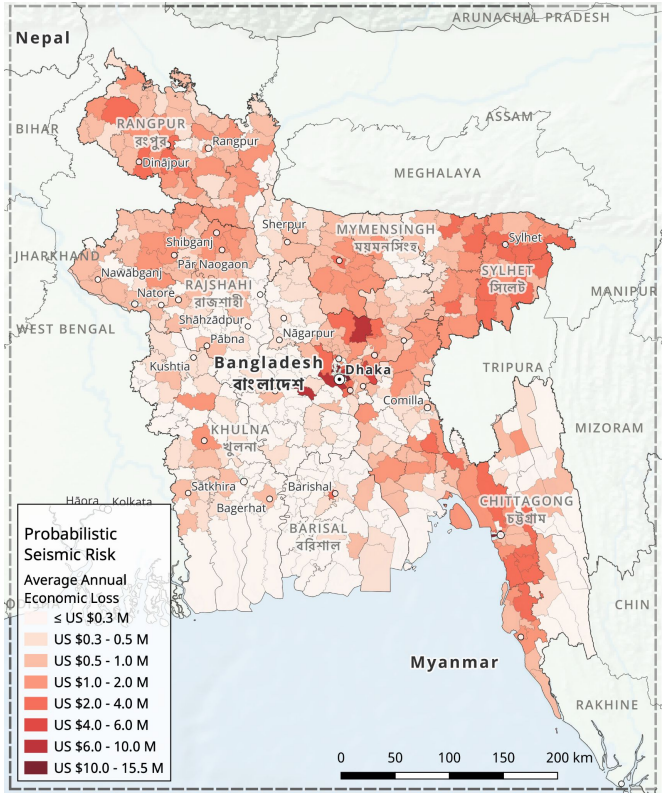


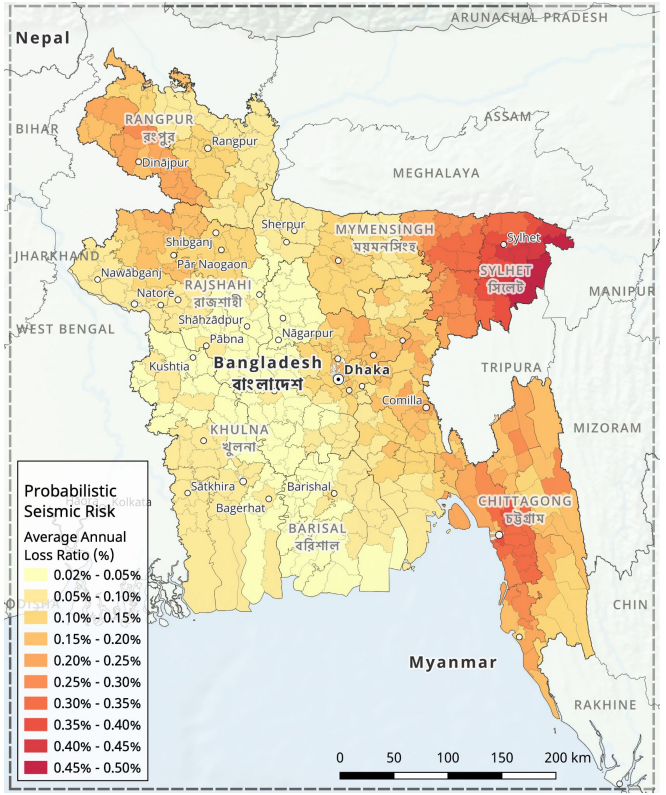
LOSS CURVES



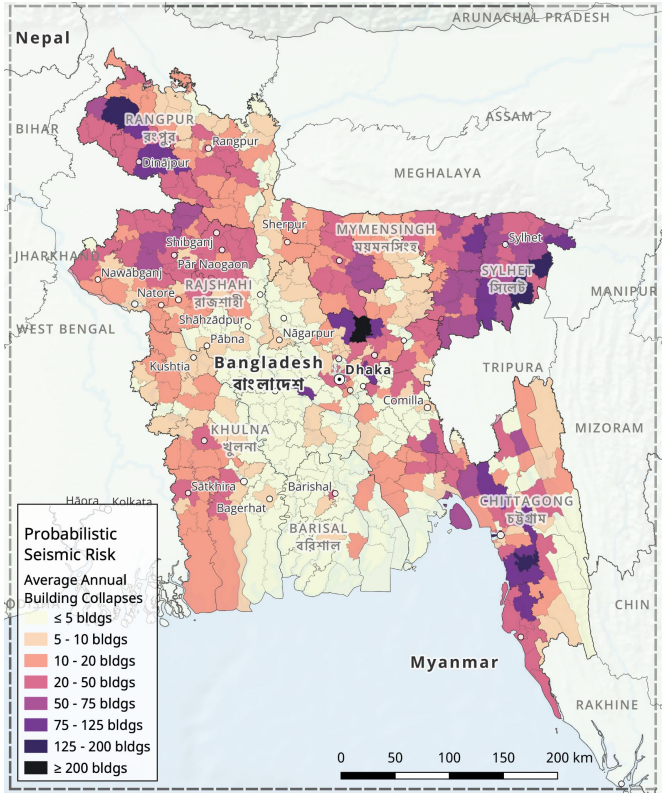
- GEM has published division-level maps of seismic hazard, exposure, and risk for Bangladesh
- The spatial resolution has been improved to upazila level in this project

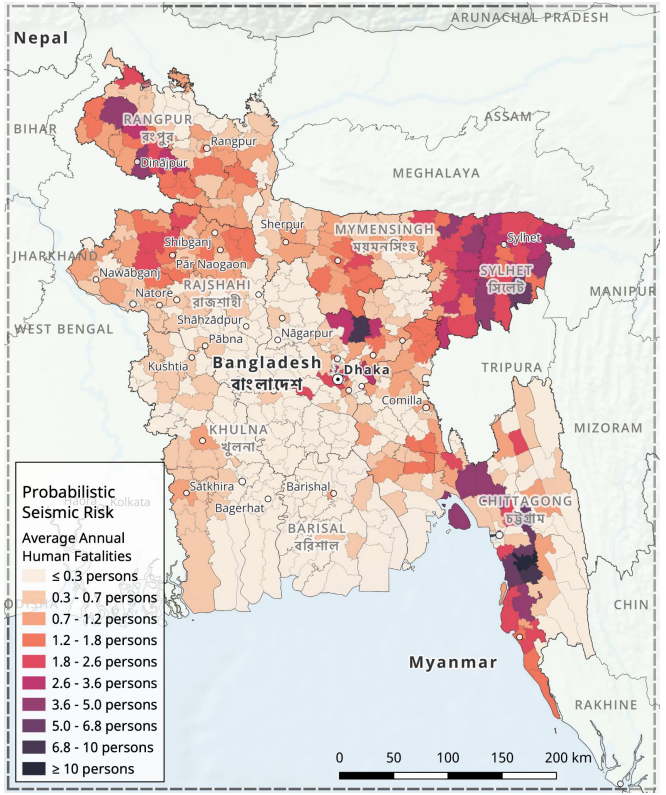
Average Annual Economic Losses at Upazila Level



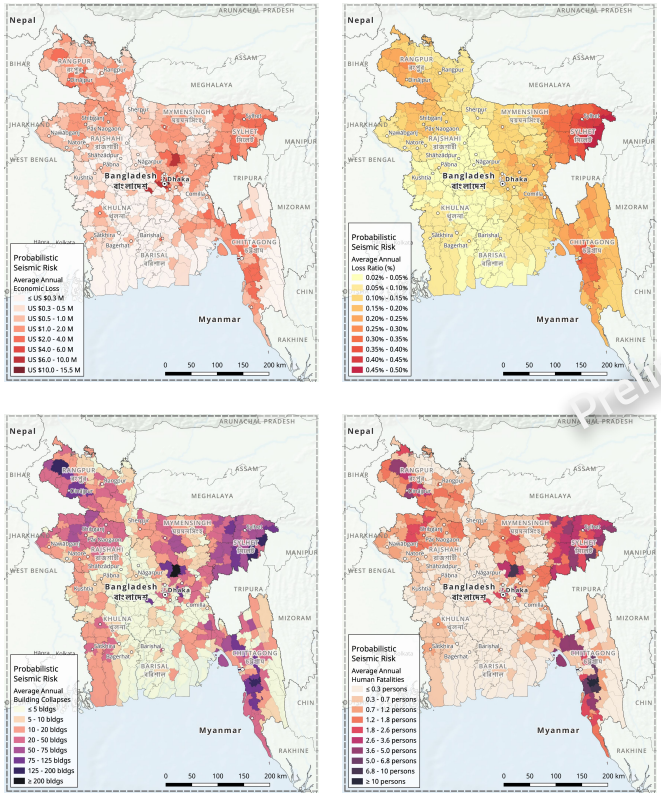


Average Annual Building Collapses and Fatalities



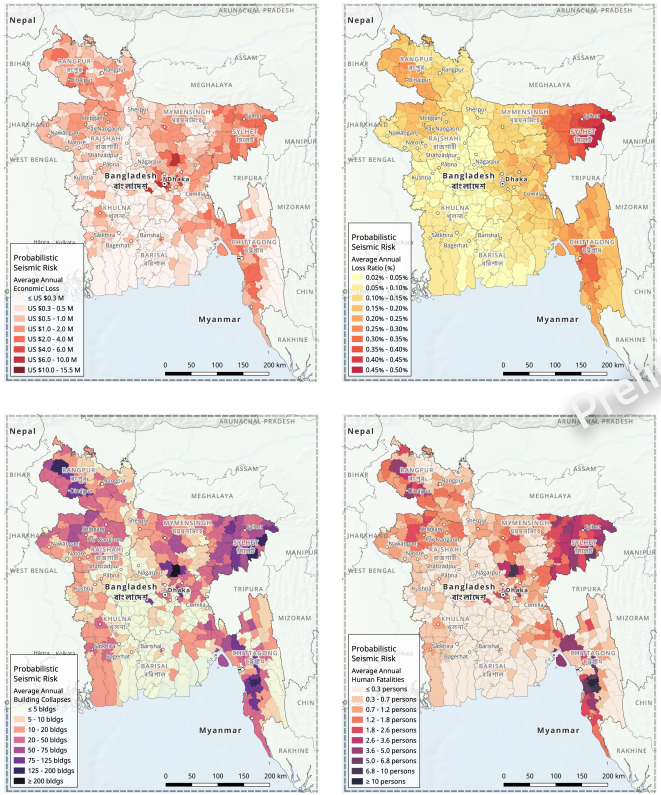


Probabilistic Risk Metrics at Upazila Level



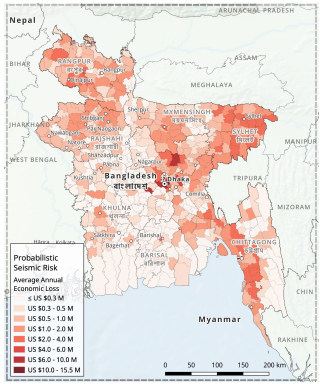
Probabilistic Upazila Level Seismic Risk	Average Annual Building Collapses	Average Annual Economic Losses	Average Annual Persons Displaced	Average Annual Lives Lost
Sabujbag, Dhaka	53	$ 15,472,279	1,180	4.0
Shahbag, Dhaka	53	$ 15,214,659	1,194	3.9
Cantonment, Dhaka	45	$ 14,859,005	1,162	3.6
Halishahar, Chattogram	197	$ 13,639,906	1,784	9.0
Darussalam, Dhaka	45	$ 12,458,379	994	3.2
Demra, Dhaka	35	$ 10,315,012	864	2.6
Panchlaish, Chattogram	99	$ 9,771,652	211	2.2
Keraniganj, Dhaka	32	$ 8,998,072	775	2.3
Badda, Dhaka	26	$ 7,707,311	643	1.9
Kapasia, Gazipur	358	$ 7,238,105	2,600	9.5
Shyampur, Dhaka	22	$ 6,382,309	530	1.6
Rupnagar, Dhaka	25	$ 6,319,348	554	1.7
Dohar, Dhaka	113	$ 6,295,368	905	2.0

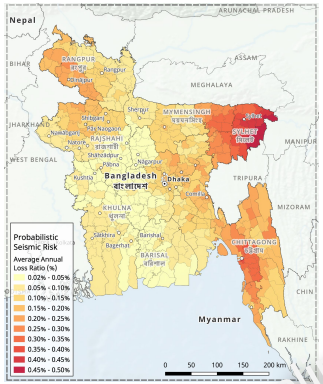
Probabilistic Risk Metrics at Zila Level

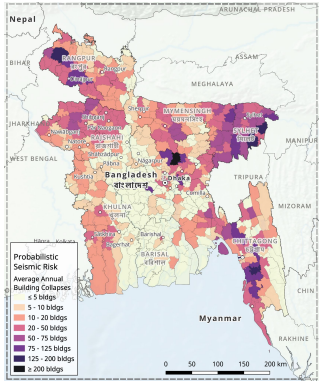


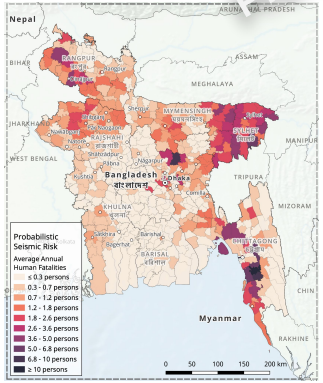
Probabilistic Zila Level Seismic Risk	Average Annual Building Collapses	Economic Losses	Persons Displaced	Lives Lost
Dhaka, Dhaka	494	$ 117,149,897	9,931	29.9
Chattogram, Chattogram	1,340	$ 65,919,225	16,440	71.3
Sylhet, Sylhet	811	$ 26,968,074	9,772	39.2
Gazipur, Dhaka	573	$ 18,677,629	4,401	16.5
Moulvibazar, Sylhet	699	$ 16,060,810	6,299	25.3
Mymensingh, Mymensingh	505	$ 15,976,302	4,005	16.8
Cumilla, Chattogram	321	$ 15,184,825	2,994	12.4
Dinajpur, Rangpur	665	$ 14,688,452	5,474	24.3
Narayanganj, Dhaka	154	$ 12,676,179	1,776	5.7
Sunamganj, Sylhet	481	$ 12,188,687	5,413	25.6
Bogura, Rajshahi	354	$ 11,371,980	3,012	12.5
Habiganj, Sylhet	409	$ 11,084,929	4,067	17.8
Naogaon, Rajshahi	416	$ 9,992,321	3,577	15.4

Probabilistic Risk Metrics at Division Level



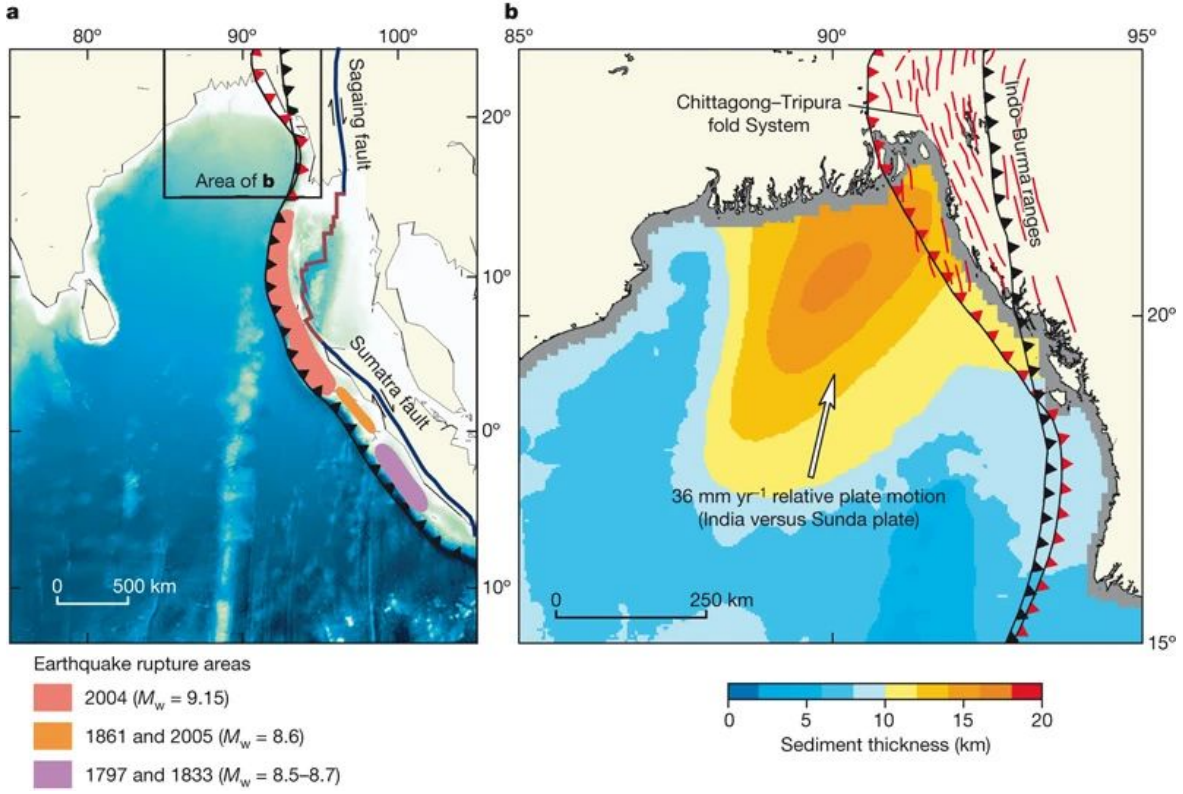






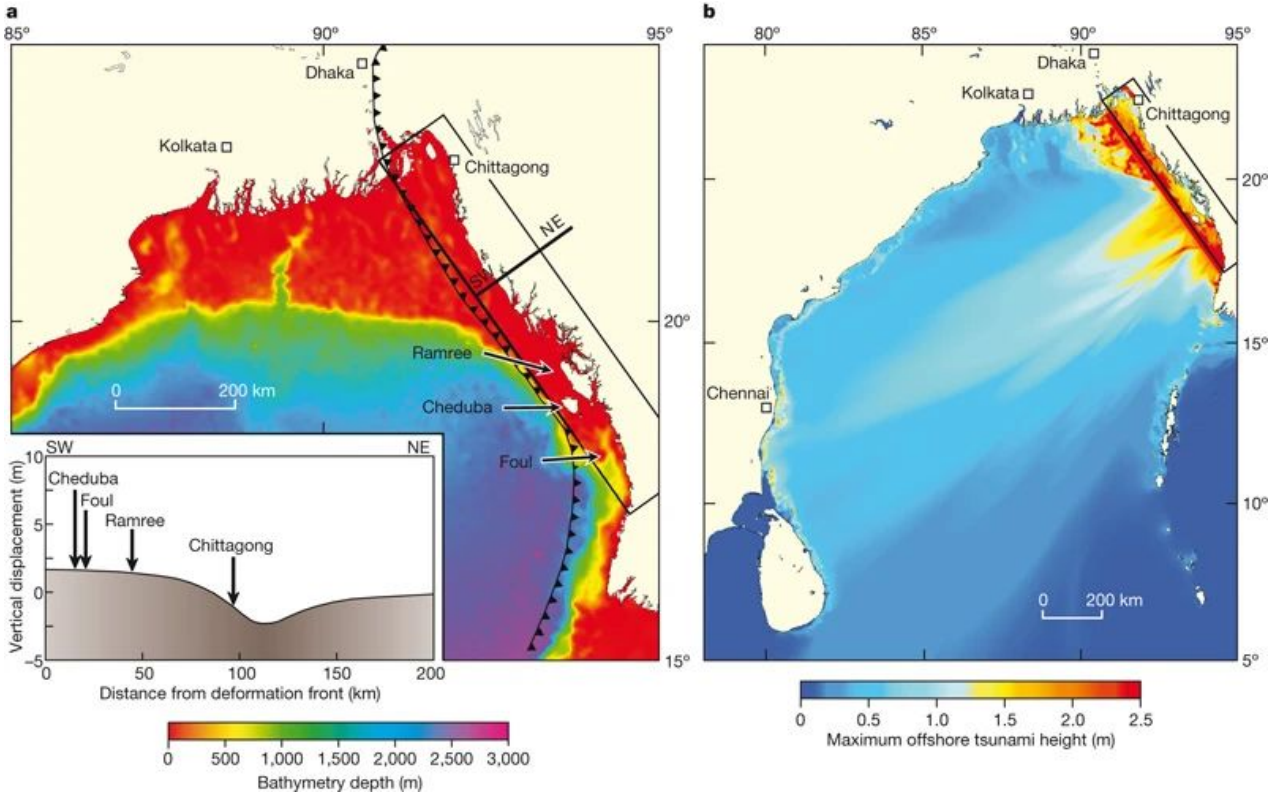
Probabilistic Division Level Seismic Risk	Average Annual Building Collapses	Economic Losses	Persons Displaced	Lives Lost
Dhaka	1,724	$ 176,126,852	20,317	71.5
Chattogram	2,771	$ 125,885,321	30,310	131.0
Sylhet	2,400	$ 66,302,500	25,550	107.9
Rangpur	1,613	$ 50,271,803	12,964	59.6
Rajshahi	1,376	$ 42,640,948	11,775	48.8
Mymensingh	727	$ 25,888,796	5,657	25.8
Khulna	569	$ 20,199,942	4,603	16.7
Barishal	126	$ 10,233,051	1,158	5.7
Bangladesh	***11,306***	***$ 517,549,212***	***112,334***	***467.1***

Tectonic setting of the Bay of Bengal



Cummins, P. The potential for giant tsunamigenic earthquakes in the northern Bay of Bengal. Nature 449, 75–78 (2007). https://doi.org/10.1038/nature06088

Models for the 1762 Arakan earthquake and tsunami



Cummins, P. The potential for giant tsunamigenic earthquakes in the northern Bay of Bengal. Nature 449, 75–78 (2007). https://doi.org/10.1038/nature06088

Tentative agenda for in-person workshops in Dhaka

Tentative dates: 3rd March – 7th March, 2024

Day 1: MoDMR, technical panel, and selected members from other key ministries
Goals: Presentation of the project goals, components, and key findings to the government

Day 2: Broader stakeholder audience
Goals: Presentation of the project components, datasets, methodologies, models, and results; interwoven by presentations by key technical panel members

Day 3: Primarily academic audience – Dhaka University & BUET faculty and graduate students
Goals: Hands-on working session with the datasets, models, and OpenQuake software

Day 4: UN Humanitarian Advisory Group, UN Cluster Coordination Group, and UN Humanitarian Coordination Task Team
Goals: High-level presentation of the project and key findings, discussions focussed on risk reduction, preparedness, and response

Day 5: Bilateral meetings and spillover discussions

Thank you!

Please attribute to the GEM Foundation with a link to:
https://www.globalquakemodel.org