

PAGER 2.0: Next Generation Forecasts to Inform Rapid Global Earthquake Response

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University of Zagreb, Croatia

GEM CONFERENCE
FROM FAULTS TO FUTURE SCENARIOS

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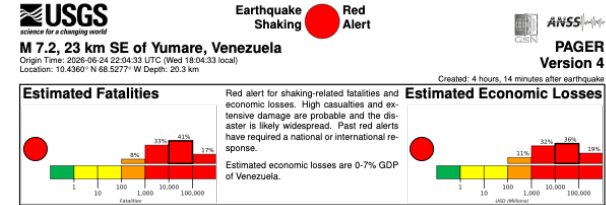
Part 1:

PAGER @ 15

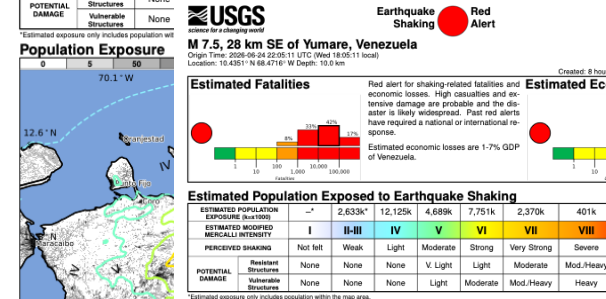
Prompt Assessment of Global Earthquakes for Response (PAGER)



- Issues global alerts within ~20 minutes
- NEIC detects ~20–30k earthquakes annually; ~650 PAGER alerts produced
- Alerts guide immediate operational response for the US State Dept, and provide critical inputs for national and international response agencies
- Supports preparedness via tabletop exercises (TTX), USAR deployments



ESTIMATED POPULATION EXPOSED TO EARTHQUAKE SHAKING	
ESTIMATED POPULATION EXPOSURE (x1000)	655k*
ESTIMATED MODIFIED MERCALLI INTENSITY	II-III
PERCEIVED SHAKING	Weak
POTENTIAL DAMAGE	Resistant Structures: None; Vulnerable Structures: None



ESTIMATED POPULATION EXPOSED TO EARTHQUAKE SHAKING	
ESTIMATED POPULATION EXPOSURE (x1000)	2,653k*
ESTIMATED MODIFIED MERCALLI INTENSITY	IV
PERCEIVED SHAKING	Light
POTENTIAL DAMAGE	Resistant Structures: None; Vulnerable Structures: None

ECONOMY

Trump pledges rapid U.S. response for Venezuela after historic earthquakes kill dozens

PUBLISHED THU, JUN 25 2026-1:25 AM EDT | UPDATED 5 MIN AGO



Anniek Bao
@IN/ANNIEK.BAO-460A48107/
@ANNIEKBYX

KEY POINTS

- Trump pledged Wednesday to deploy U.S. resources to Venezuela, saying that U.S. stands “ready, will
- The quakes are among the strongest to strike at least 32.
- The swift U.S. offer of assistance reflects a decision between the Trump administration and the int

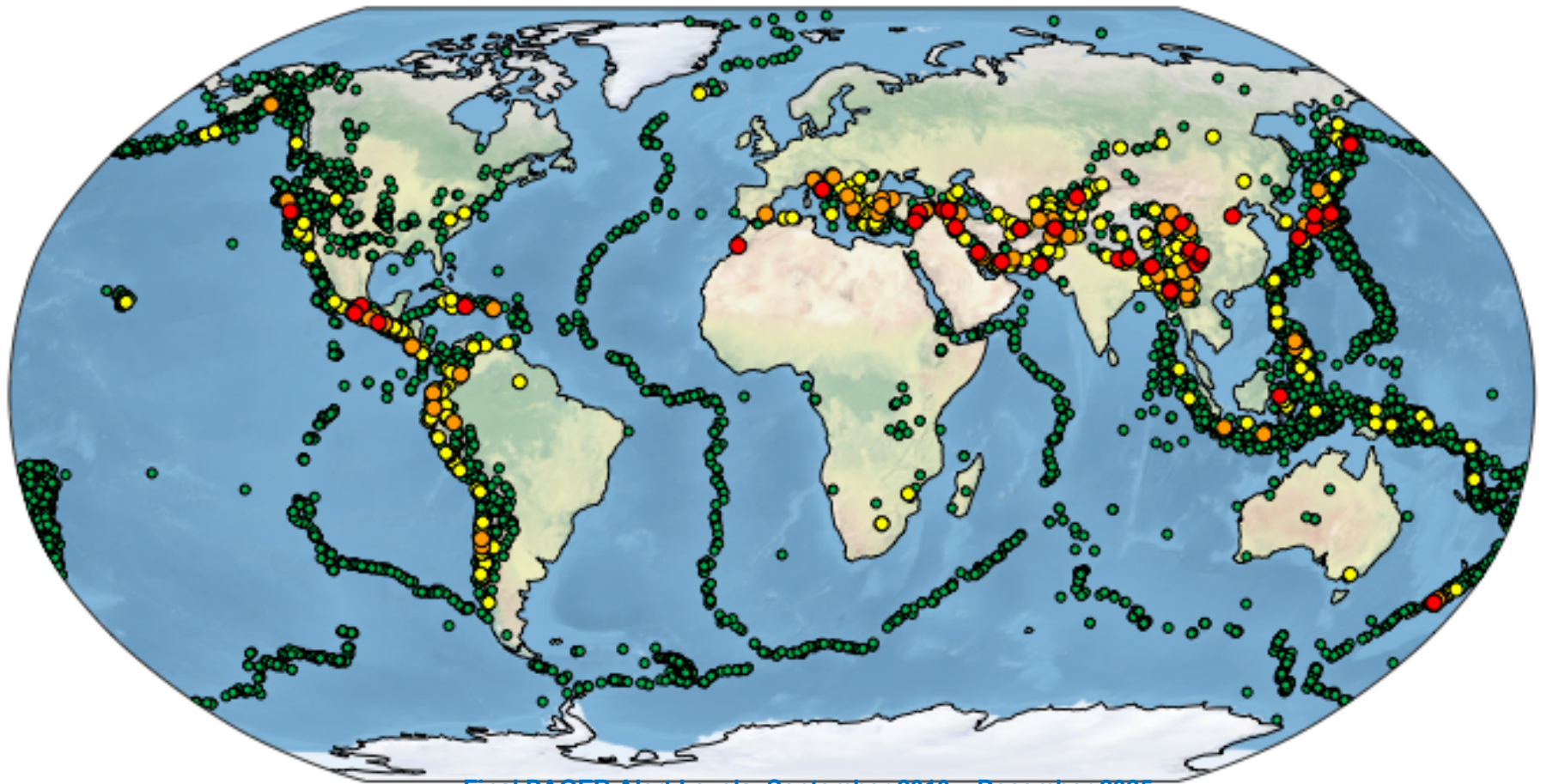


The State Department has already mobilized a [disaster assistance team and task force](#) to deliver and coordinate critical assistance to Venezuelans, including search and rescue teams, medical supplies, and humanitarian resources, according to senior State Department official Jeremy Lewin.

The U.S. Geological Survey issued [two consecutive red alerts](#) through its PAGER system, and estimated a 41% probability that fatalities could exceed 10,000 and a 17% chance they could reach 100,000. The authority also projected that the devastating earthquake could dent Venezuela’s GDP by up to 7%.

Venezuela’s acting president Delcy Rodriguez declared a [state of emergency in a national address](#) on Wednesday night, and later said 32 people were killed and 700 were injured, according to Reuters.

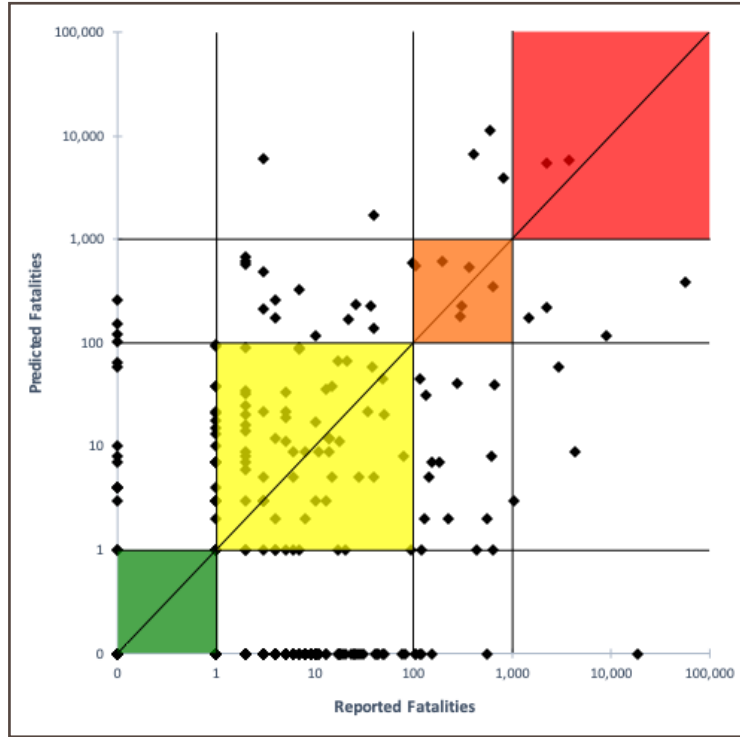
In a [video message](#) posted on X Thursday morning, Rodriguez thanked the Trump administration for providing “support and solidarity.” and the



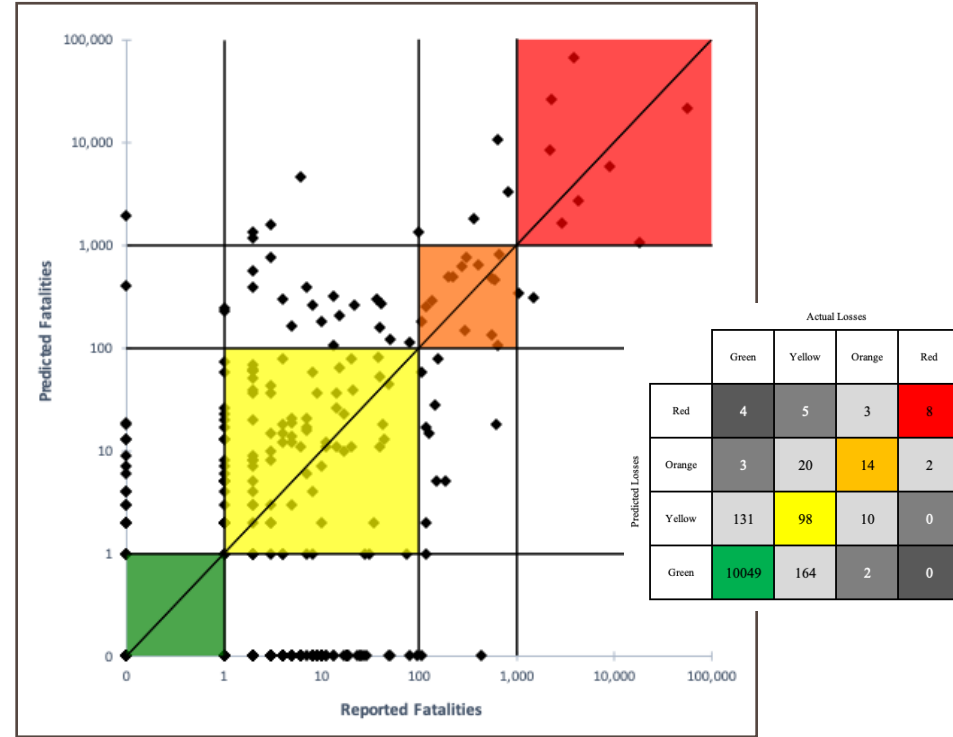
Final PAGER Alert Levels, September 2010 – December 2025

We have generated **10,513** alerts, of which 10,063 were green, 333 were yellow, 72 were orange, and 45 were red alerts.

PAGER Version 1 Estimated Fatalities vs Reported Total Deaths

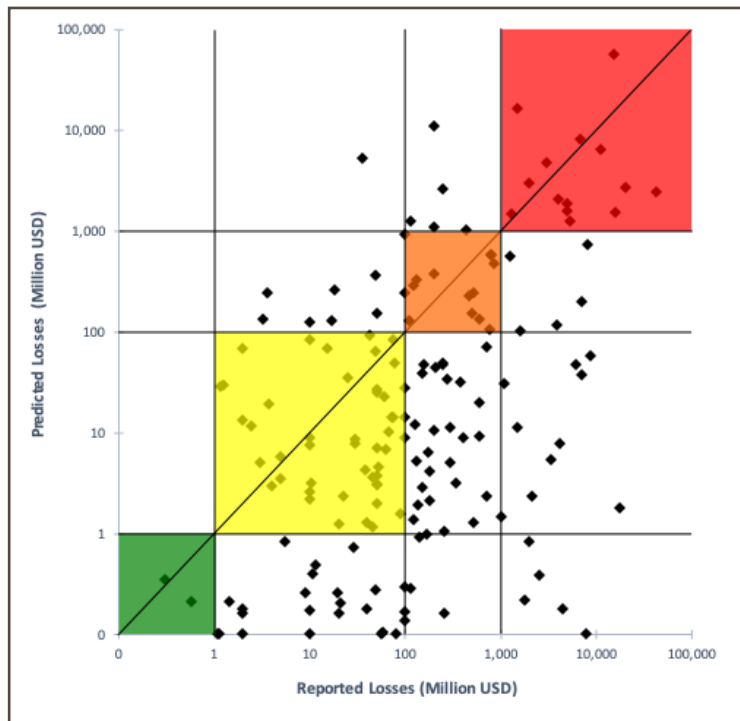


PAGER Final Version Estimated Fatalities vs Reported Total Deaths

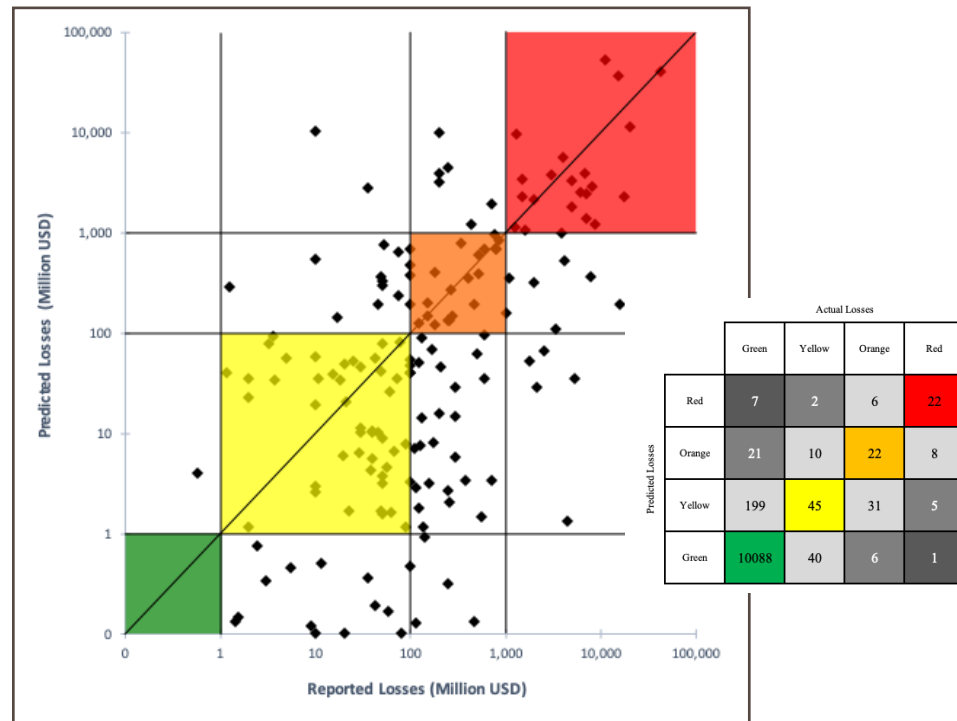


PAGER is exceedingly effective at separating the signal from the noise – PAGER has a **95% accuracy rate**, primarily in detecting and identifying events with little or no impact (green alert) from the consequential ones!

PAGER Version 1 Estimated Economic Losses vs Reported Total Losses



PAGER Final Version Estimated Economic Losses vs Reported Total Losses



The economic losses appear to be an underestimate compared to the initial versions of the ShakeMap, and in general, there is greater uncertainty in estimating economic losses (Note: authoritative estimates of economic losses are quite limited, and sometimes they appear to be biased!)

Part 2:

Post-Earthquake Response Needs

NEW ZEALAND GOVERNMENT'S RESPONSE TO M 6.4 FEBRUARY 22, 2011 EARTHQUAKE AT 12:51 PM



Courtesy: <https://www.nzdf.mil.nz/>



Credit: Geoff Sloan, New Zealand Herald

Rapid Emergency Protocol Activation

The National Crisis Management Centre (NCCM) issued first statement **~90 minutes**

National Emergency Declaration

Authorities declared a national level emergency **~120 minutes** enabling extraordinary powers for evacuation, asset deployment, building cordons, and utility restoration.

Damage and Casualty Assessments

Approx. 1,800 Defense Force personnel (Army, Navy, Air Force) deployed, including cordon security, medical teams, ground logistics, aerial damage recon via the Orion aircraft, evacuation flights with Hercules and 757s. Police, paramedics, hospitals documented injuries, fatalities, building failures—driving emergency deployment strategies.

~24-48 hours

Coordinated Search and Rescue/Resource Mobilization

The **Christchurch Response Centre (CRC)** was established to coordinate search and rescue and humanitarian aid effectively (McLean et al 2012). 185 people died and over 6,600 injured. Rapid assessments indicated approximately 10,000 homes required rebuilding and 3,500 were destroyed, and nearly 140,000 houses were the subject of claims to EQC for damage. Liquefaction and rockfall hazard contributed a major damage. **~3-10 days**

TURKISH GOVERNMENT'S RESPONSE TO M7.8 FEBRUARY 6, 2023 EARTHQUAKE AT 4.17 AM



Rapid Emergency Protocol Activation

The Turkish government AFAD issued first statement **~13 minutes**

Level-4 Disaster Alert Declaration

Authorities declared a Level-4 disaster alert **~86 minutes** to mobilize national and international assistance.

Damage and Casualty Assessments

1,651 deaths and 11,119 injured initially. Preliminary assessments reported building collapses, infrastructure disruption, and rising casualties. President Erdoğan announced a **three-month state of emergency** in ten worst-hit provinces. **~24 hours**

Coordinated Search and Rescue/Resource Mobilization

Government activated frameworks to coordinate search and rescue and humanitarian aid effectively. At least 9.1 million people have been directly impacted, over 430,000 people internally displaced. Aid: 386,874 tents received, cooked meals served to 227,679. **~3-10 days** [OCHA Report 2, Feb 19]

JAPAN GOVERNMENT'S RESPONSE TO M7.5 JANUARY 1, 2024 NOTO EARTHQUAKE AT 4.10 PM



Credit: Jiji Press via AFP



Credit: Japan News

Rapid Emergency Protocol Activation

Within the first hour, the Prime Minister's Office (PMO) began **central coordination**, and the Cabinet Office dispatched a **disaster-management investigation team** by SDF aircraft to Kanazawa **-60 minutes**

Applied the Disaster Relief Act across 35 cities

PM-led Emergency HQ ordered **push-type support by air/sea** (food, water, blankets, **kerosene/gasoline/light oil**) and doubled the SDF personnel **~2000**. Deployed **wide-area police units**, and **emergency fire rescue teams** as **route conditions allowed**. No request for international assistance **~24 hours**

Damage and Casualty Assessments

Landslide counts (~440 occurrences) and **area isolation (33 areas, max 3,345 people by Jan 5)**, **power/water outage metrics** (e.g., **~44,160 power, ~136,440 water outages**), and **house damage certificates. ~3-5 days**

Coordinated Search and Rescue/Resource Mobilization

Day 9: death toll climbed to 161 (70 were in Wajima, 70 in Suzu and 11 in Anamizu). About 28,800 people packed into government shelters. 565 people were injured, and 1,390 homes were destroyed or seriously damaged. Road obstructions and snow hindered relief efforts **10 days** [<https://www.aljazeera.com>]

USGS
United States Geological Survey

Earthquake Shaking ● **Red Alert**

USAID
FROM THE AMERICAN PEOPLE

M 7.8, Pazarcik earthquake, Kahramanmaraş earthquake sequence #1557161 **PAGER Version 17**

Origin Time: 2023-02-06 01:17:34 UTC (Max 0.4, 1.734 local)
Location: 37.2256° N 37.0143° E Depth: 10.0 km

Created: 9 weeks, 4 days after earthquake

Estimated Fatalities

Red alert for shaking-related fatalities and economic losses. High casualties and extensive damage are probable and the disaster is likely widespread. Past red alerts have required a national or international response.

Estimated Economic Losses

Estimated economic losses are 1-20% GDP of Turkey.

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (x=1000)	ESTIMATED MODIFIED MERCALLI INTENSITY	PERCEIVED SHAKING	POTENTIAL DAMAGE
10,852k*	I	Not felt	Resistant Structures: None, Vulnerable Structures: None
239,202k*	II-III	Weak	Resistant Structures: None, Vulnerable Structures: None
22,835k*	IV	Moderate	Resistant Structures: None, Vulnerable Structures: None
13,482k*	V	Strong	Resistant Structures: None, Vulnerable Structures: Light
6,354k*	VI	Very Strong	Resistant Structures: None, Vulnerable Structures: Moderate
1,928k*	VII	Severe	Resistant Structures: None, Vulnerable Structures: Mod./Heavy
746k*	VIII	Violent	Resistant Structures: None, Vulnerable Structures: Heavy
0	IX	Extreme	Resistant Structures: None, Vulnerable Structures: V. Heavy
0	X+	Extreme	Resistant Structures: None, Vulnerable Structures: V. Heavy

Population Exposure

Estimated exposure only includes population within the map area.

Structures

Overall, the population in this region resides in structures that are extremely vulnerable to earthquake shaking, though some resistant structures exist. The predominant vulnerable building types are unreinforced brick masonry and low-rise nonductile concrete frame with infill construction.

Historical Earthquakes

Date (UTC)	Dist. (km)	Mag.	Max MMI(9)	Shaking Deaths
2001-06-25	71	5.4	VIII(1k)	0
1992-03-13	358	6.6	IX(151k)	498
1975-09-06	358	6.7	VIII(1k)	2k

Recent earthquakes in this area have caused secondary hazards such as landslides that might have contributed to losses.

Selected City Exposure

MMI	City	Population
IX	Akagi	1k
IX	Alanya	10k
IX	Alanya	~1k
IX	Nar	~1k
IX	Alasehir	~1k
IX	Golbasi	20k
IV	Cairo	7,735k
IV	Baghdad	7,216k
IV	Alexandria	5,812k
IV	Istanbul	11,174k
III	Ankara	3,517k

bold cities appear on map. (n = x1000) Event ID: us000012

Post-Earthquake Impact Summary

Shaking

Ground Shaking & Hazards

- ▶ Strong Ground Shaking
- ▶ Landslides, Fires, Utility Disruption

Damage

Collapsed Structures & Infrastructure

- ▶ Building Collapse
- ▶ Infrastructure Damage

Injuries

Earthquake-Related Injuries

- ▶ Falling Debris & Glass
- ▶ Burns & Trauma

Fatalities

Lives Lost in Collapse

- ▶ Trapped Victims
- ▶ Search & Rescue

Displaced Population

Displaced & Homeless

- ▶ Emergency Shelters
- ▶ Basic Needs Aid

Response Priorities

▶ Rescue & Medical Aid

▶ Damage Assessment

▶ Shelter & Supplies

▶ Safety & Coordination

PAGER 2.0

GEOSPATIAL EXTENT OF PHYSICAL DAMAGE AND IMPACT

FEATURES

- ESTIMATED BUILDING DAMAGE
- FATALITIES ESTIMATE
- LIFELINE IMPACTS

40,000-95,000

12,000-80,000

23,000-75,000

40,000-50,000

12,000-3,000

≥23,000

23,000-75,000

Petropavlovsk-Kamchatsky

Eurasian Plate

WEAK LIGHT MID EXTREME

- POPULATION DISPLACED
- CRITICAL FACILITIES AFFECTED
- GROUND FACILITIES AFFECTED
- GROUND FAILURE HAZARD

Part 3:

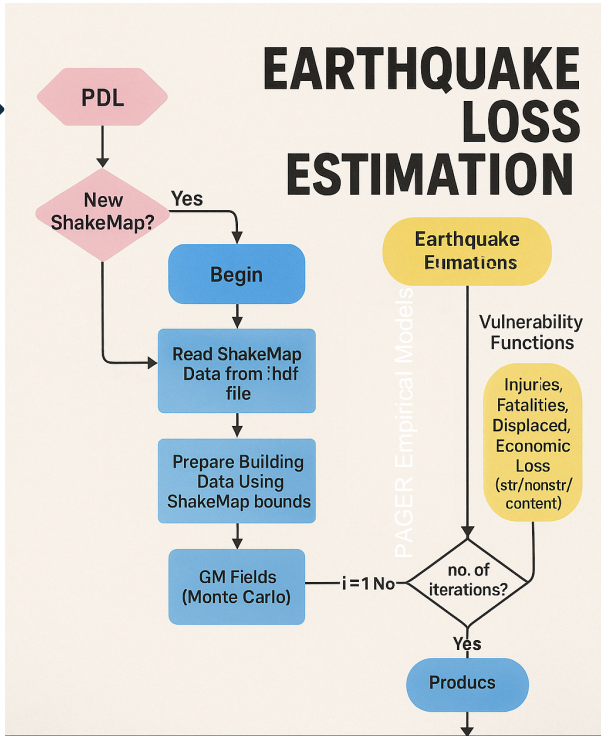
PAGER 2.0 Development Process




- Growing need for rapid, reliable global earthquake impact estimates
- Traditional PAGER provides valuable early alerts, but lacks full disaster scope
- PAGER 2.0 aims to deliver scalable, actionable, geographically detailed impact assessment



Detects






Earthquake Shaking ● **Red Alert**

M 7.5, 28 km SE of Yumare, Venezuela

Origin Time: 2025-04-24 22:05:11 UTC (Wed 18:05:11 local)
Location: 10.4351° N 68.4716° W Depth: 10.0 km



PAGER Version 6

Created: 8 hours, 3 minutes after earthquake

Estimated Fatalities

Red alert for shaking-related fatalities and economic losses. High casualties and extensive damage are probable and the disaster is likely widespread. Past red alerts have required a national or international response.

Estimated economic losses are 1-7% GDP of Venezuela.

Estimated Economic Losses

ESTIMATED POPULATION EXPOSURE (x=1000)	2,633k*	12,125k	4,689k	7,751k	2,370k	401k	29k	0	
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	None	None	None	V. Light	Light	Moderate	Mod./Heavy	Heavy
	Vulnerable Structures	None	None	None	Light	Moderate	Mod./Heavy	Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

Structures

Overall, the population in this region resides in structures that are vulnerable to earthquake shaking, though resistant structures exist. The predominant vulnerable building types are unreinforced brick masonry.

Historical Earthquakes

Date (UTC)	Dist. (km)	Mag.	Max MMI(9)	Shaking Deaths
1965-07-18	109	5.4	VIII(V)	0
1975-04-05	137	6.3	VIII(50k)	3
1967-07-30	127	6.6	VIII(952k)	240

Recent earthquakes in this area have caused secondary hazards such as tsunamis that might have contributed to losses.

Selected City Exposure

MMI City	Population
VIII Puerto Cabello	269k
VIII Catia La Mar	662k
VIII Occumare de la Costa	7k
VII Maiquetia	88k
VII San Felipe	221k
VII Caracas	2,246k
VII La Guaira	204k
VI Los Teques	251k
VI Petare	365k
VI Valencia	1,484k
VI Baruta	241k

bold cities appear on map

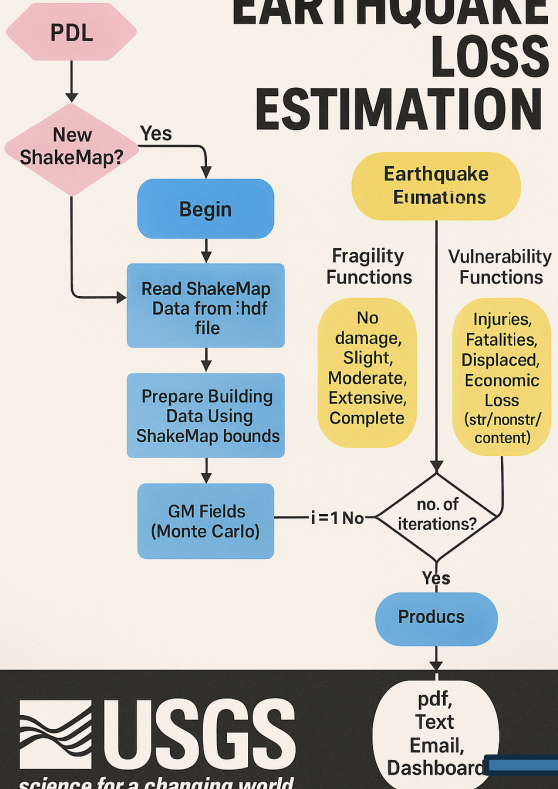
PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.

<https://earthquake.usgs.gov/earthquakes/eventpage/us600017z#pager>

Event ID: us600017z



Detects



M 7.1, 28 km NW of Montalbán, Venezuela
 Origin Time: 2026-06-24 22:04:32 UTC (Wed 18:04:32 local)
 Location: 10.4070°N -68.4932°E Depth: 13.2 km

PAGER+ Version 1
 Created: 0 weeks, 0 days after earthquake

DISTRIBUTION OF DAMAGED BUILDINGS

IMPACT SUMMARY

Physical Damage: Hundreds of structures are likely damaged; many beyond repair and likely uninhabitable. Damaged structures may require engineering interventions before resuming full occupancy.

Search and Rescue: Search and rescue demands are widespread. They may exhaust local capacity requiring federal interventions.

Humanitarian: Thousands needing shelter and the humanitarian crisis is highly likely and may affect multiple local jurisdictions.

BUILDING DAMAGE BY DISTRICT

Carabobo	0
Yaracuy	0
Lara	0
Cojedes	0
Aragua	0
Falcón	0
Táchira	0
Anzoátegui	0
Barinas	0

HUMANITARIAN IMPACT

Search and Rescue: 0 - 63,000

Debris and Civil Work (ton): 2,000 - 2,170,000

Population: 1,000 - 695,000

Shelter Requirements: 0 - 348,000

Affected Population

2,000 - 695,000

Affected Number of Structures

2,000 - 423,000

The extent of shaking and ground-failure estimates suggest additional impacts on linear infrastructure including the potential for road closures and loss of functionality of certain critical infrastructure system.

PHYSICAL DAMAGE

Estimated Injuries: 0-14,000

Estimated Fatalities: 0-4,000

ECONOMIC IMPACT

Complete Damage: 0-190,000

Estimated Direct Loss: 95-10,600 millions USD

Potential economic losses in the following countries: Venezuela, Colombia, Aruba

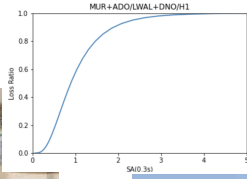
<https://earthquake.usgs.gov/earthquakes/everpage/us600072c>
 Event ID: us600072c

For PAGER:
 Orange or higher

~3 hours



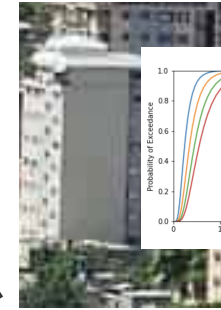
Adobe



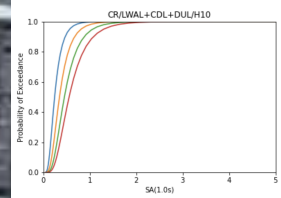
MUR+ADO/LWAL+CDN/H.
1/RES
Or H:2/RES



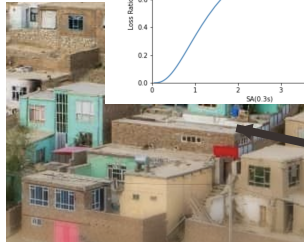
Photo Credit: <https://www.rjtravelagency.com/geography-of-afghanistan/>



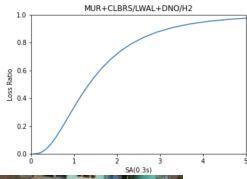
Reinforced conc. shear wall



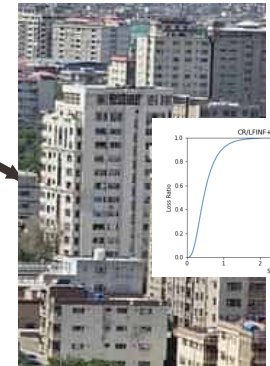
CR/LWAL+CDL+DUL/H:10/RES



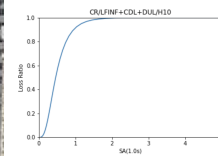
Unreinforced brick/block masonry



MUR+CB/LWAL+CDN/
H:1/RES
Or H:2/RES

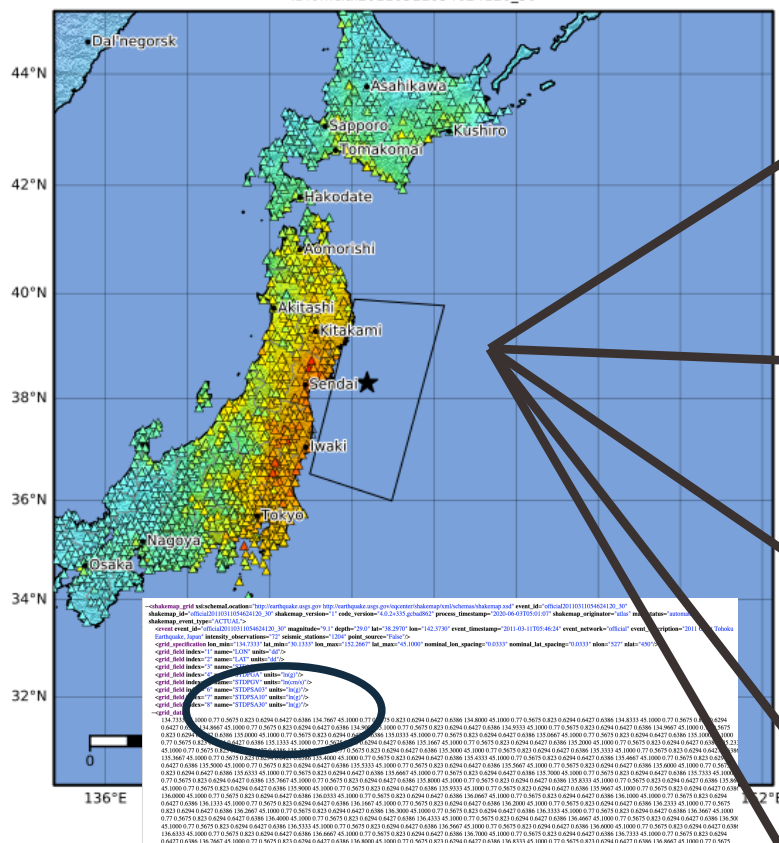


Reinforced conc. frames



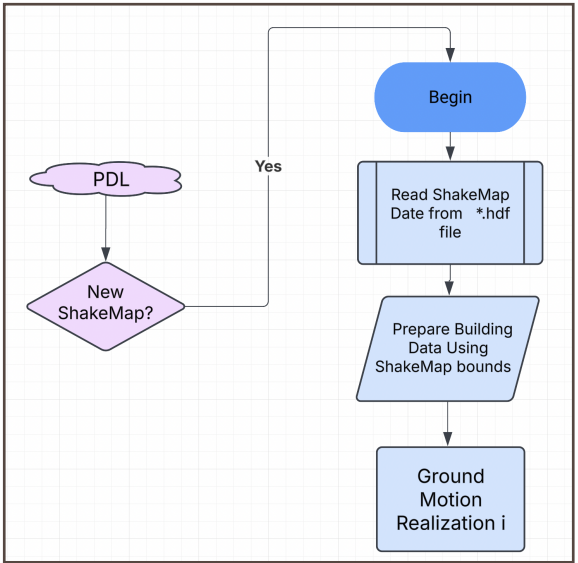
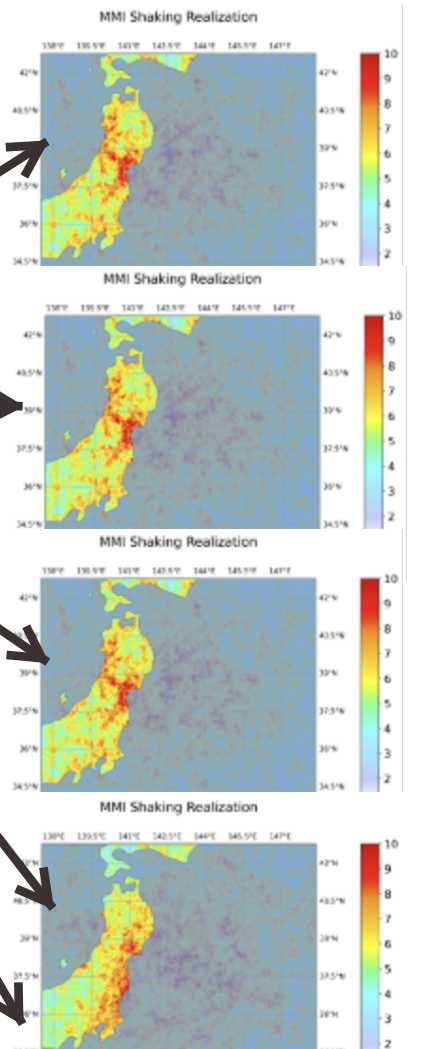
CR/LFINF+CDM/H:7/RES

Martins and Silva (2021) Development of a fragility and vulnerability model for global seismic risk analyses



SHAKING	Not	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
DAMAGE	None	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.046	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139	
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178	
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+	

Scale based on Worden et al. (2014) Version 1: Processed 2020-06-03T04:57:14Z
 △ Seismic Instrument ○ Report srt Intensity ★ Epicenter □ Rupture



Mw 7.7 - 2025/03/28 00:20:52 - 2025 Mandalay, Burma (Myanmar) Earthquake

PAGER ESTIMATED IMPACTS

Slight Damage
🏠 183k - 412k
Buildings

Moderate Damage
🏠 57k - 128k
Buildings

Extensive Damage
🏠 29k - 66k
Buildings

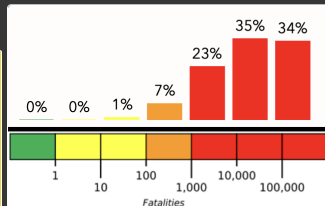
Complete Damage
🏠 61k - 138k
Buildings

Estimated Injuries
👤 101k - 228k
People

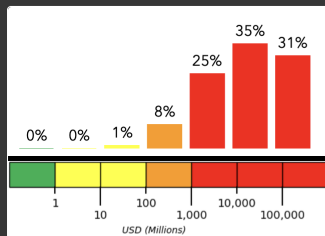
Estimated Fatalities
☠️ 1363 - 13630
People

Estimated Economic Loss
💰 \$3917 - \$8814
million USD

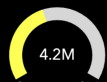
ESTIMATED FATALITIES DISTRIBUTION



ESTIMATED ECONOMIC LOSSES DISTRIBUTION



Population at MMI VI



Population at MMI VII



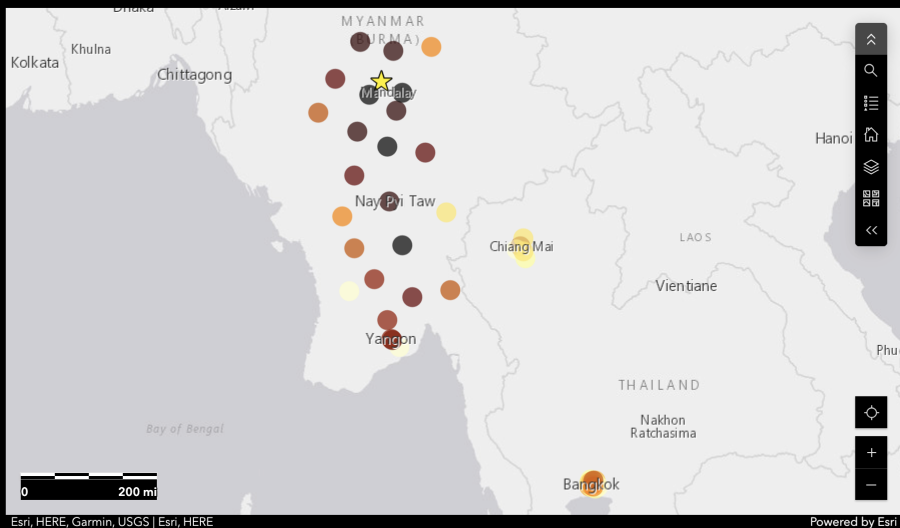
Buildings at MMI VII



Buildings at MMI VI



DISTRIBUTION OF COMPLETE DAMAGED BUILDINGS



IMPACT BY GEOGRAPHIC REGION

Total Building Damage by District

Mandalay	239,580
Meiktila	93,833
Sagaing	79,258
Yamethin	77,476
Kyaukse	49,376
Taungoo	48,599
Shwebo	48,594
Pyin-Oo-Lwin	32,626
Myingyan	24,860
Monywa	22,370
Muang Chiang Mai	16,907
Taunggye	15,271
Naypyitaw	9,926

ShakeMap (MMI)

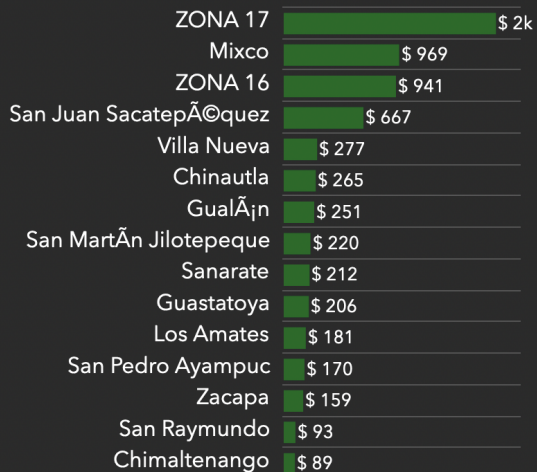
Damage

Hospital Locations

Impacts by Geographic/Admin Region

IMPACT BY GEOGRAPHIC REGION

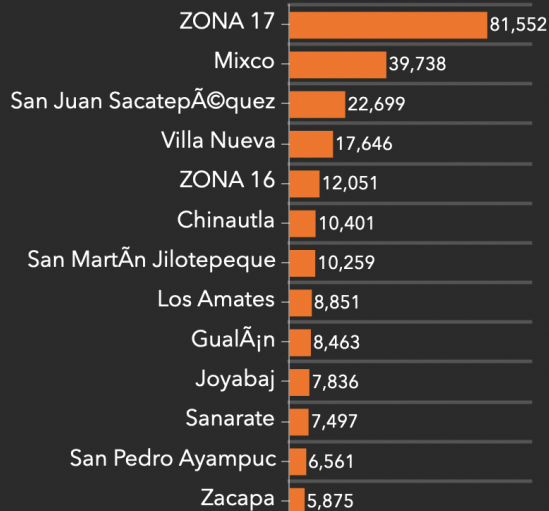
Economic Loss (in million USD) by District



Economic Loss

IMPACT BY GEOGRAPHIC REGION

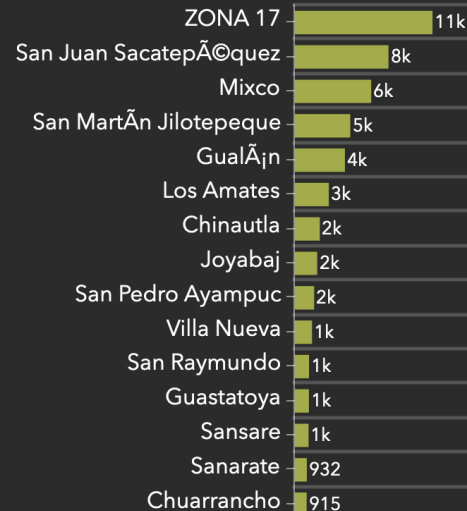
Total Building Damage by District



Damage

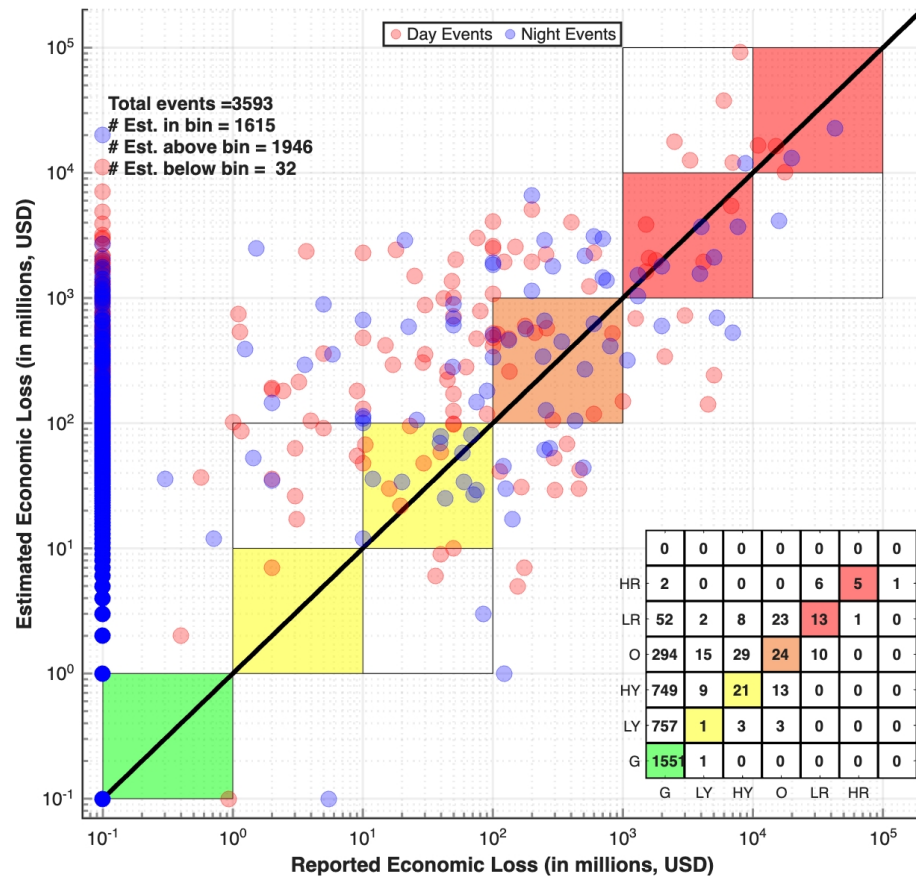
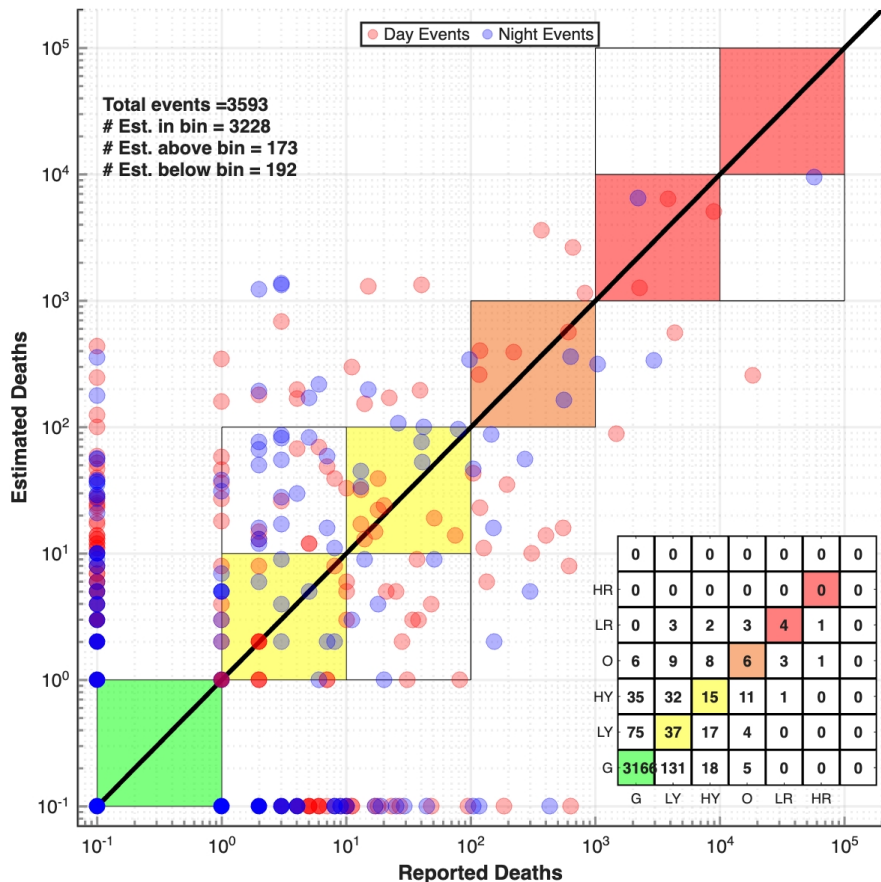
IMPACT BY GEOGRAPHIC REGION

Estimated Injuries by District



Casualties

PAGER 2.0 Model Testing & Performance





THANK YOU!

June 23 - 25, 2026

University of Zagreb, Croatia

GEM CONFERENCE

FROM FAULTS TO FUTURE SCENARIOS



kjaiswal@usgs.gov