

# UPDATE OF THE GLOBAL SEISMIC RISK MODEL

VITOR SILVA, ALEJANDRO CALDERON, MARTINA CARUSO, CATARINA COSTA, MARIA CAMILA HOYOS, LUIS MARTINS, NICOLE PAUL, ANIRUDH RAO, MICHELE SIMIONATO, CATALINA YEPES, LANA TODOROVIC, ZARRIN KARIMZADEH



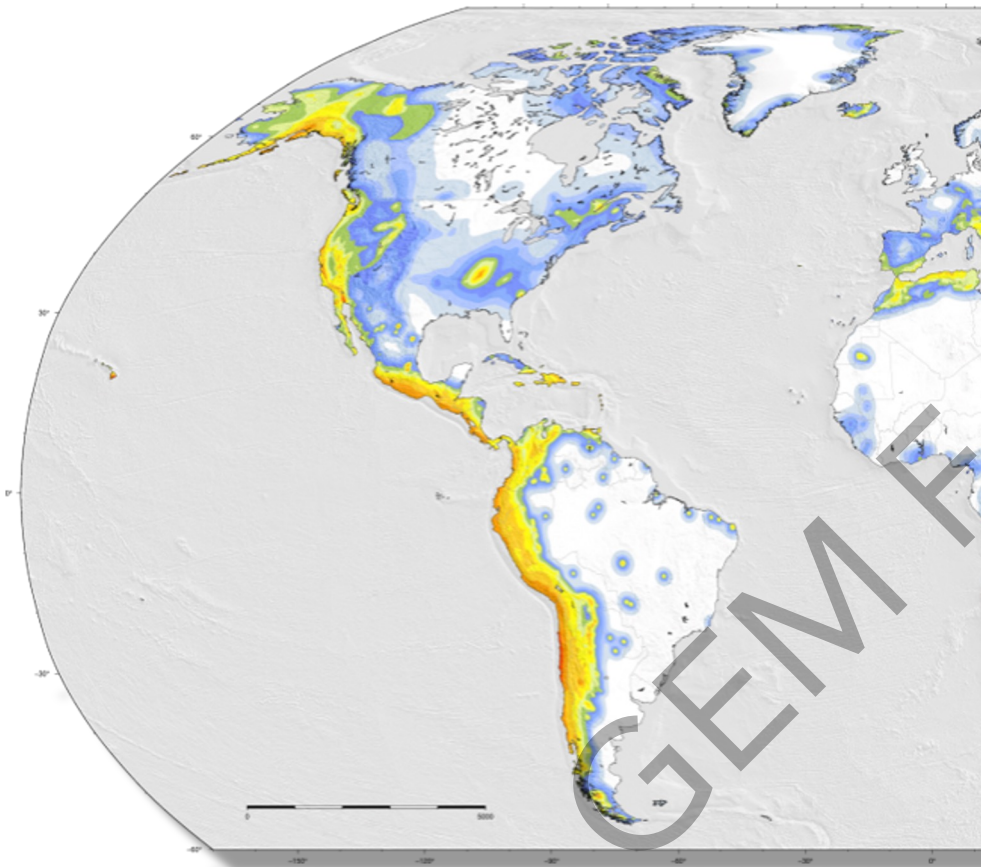
working together  
to assess risk

**GEM**  
GLOBAL EARTHQUAKE MODEL

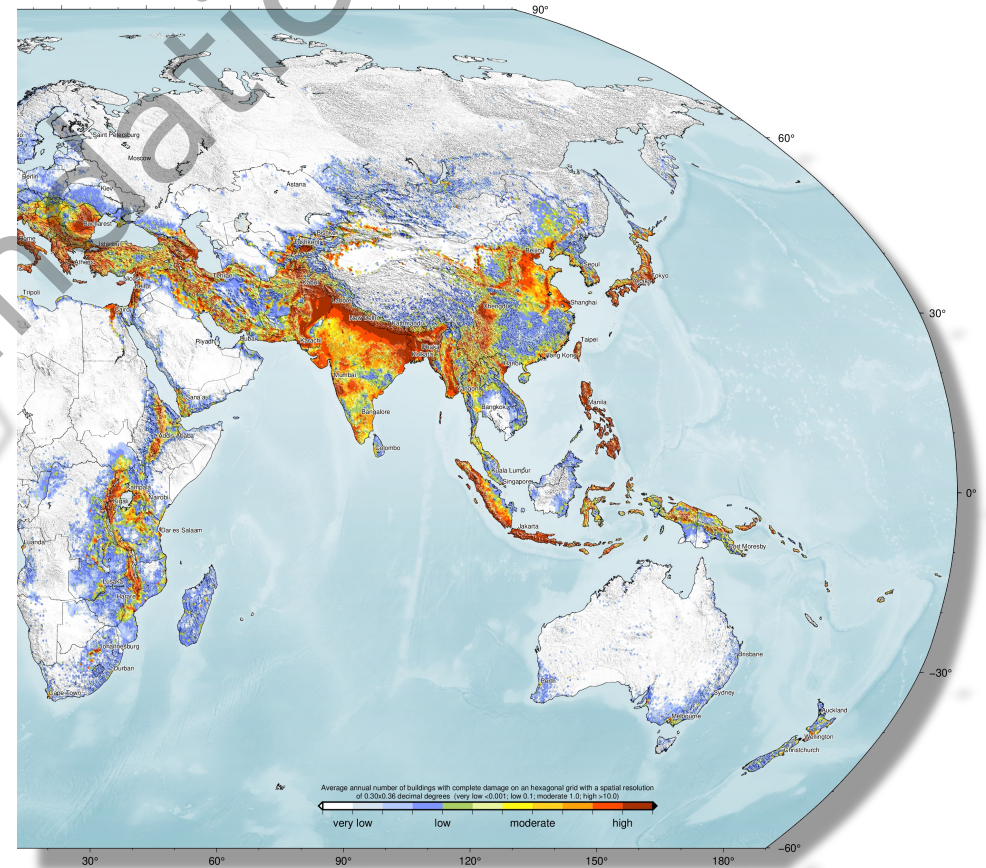
**OO**  
OPENQUAKE

# FROM SEISMIC HAZARD TO IMPACT

From hazard...

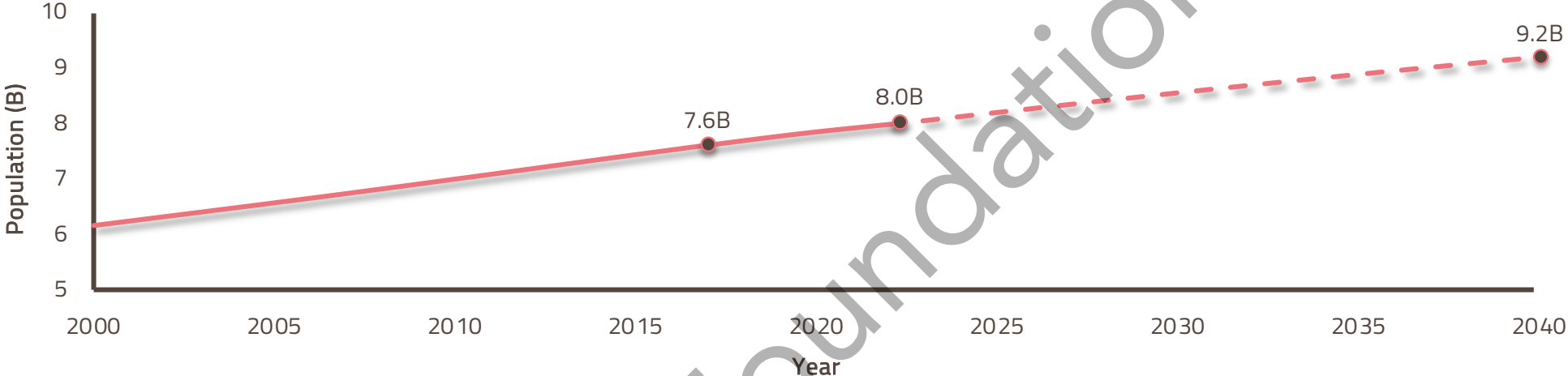


...to seismic risk!



GLOBAL EARTHQUAKE MODEL

# SINCE 2018, A LOT HAS HAPPENED



+ 375 million people



Equivalent to the population of United States + Canada

+ 98 million dwellings



Equivalent to all dwellings in Indonesia + South Korea

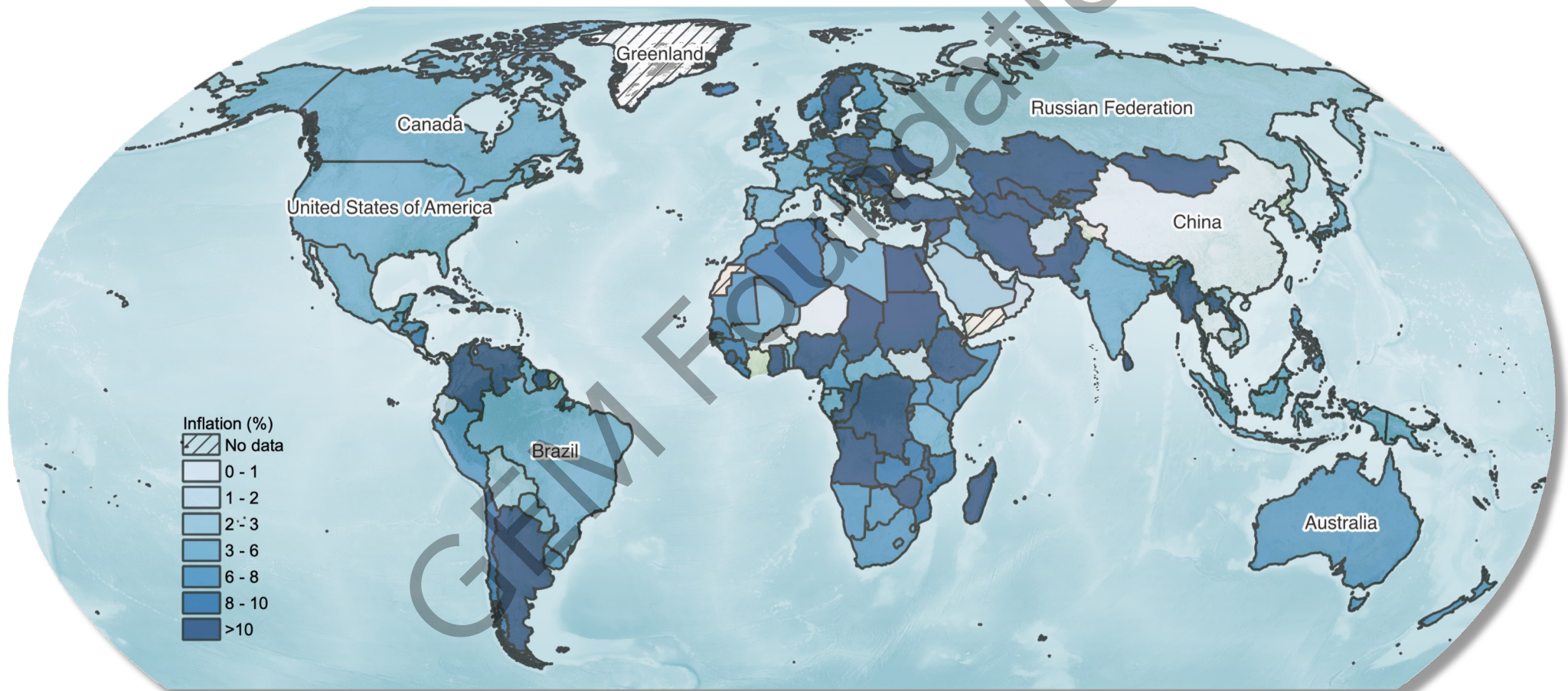
+ 73 million buildings



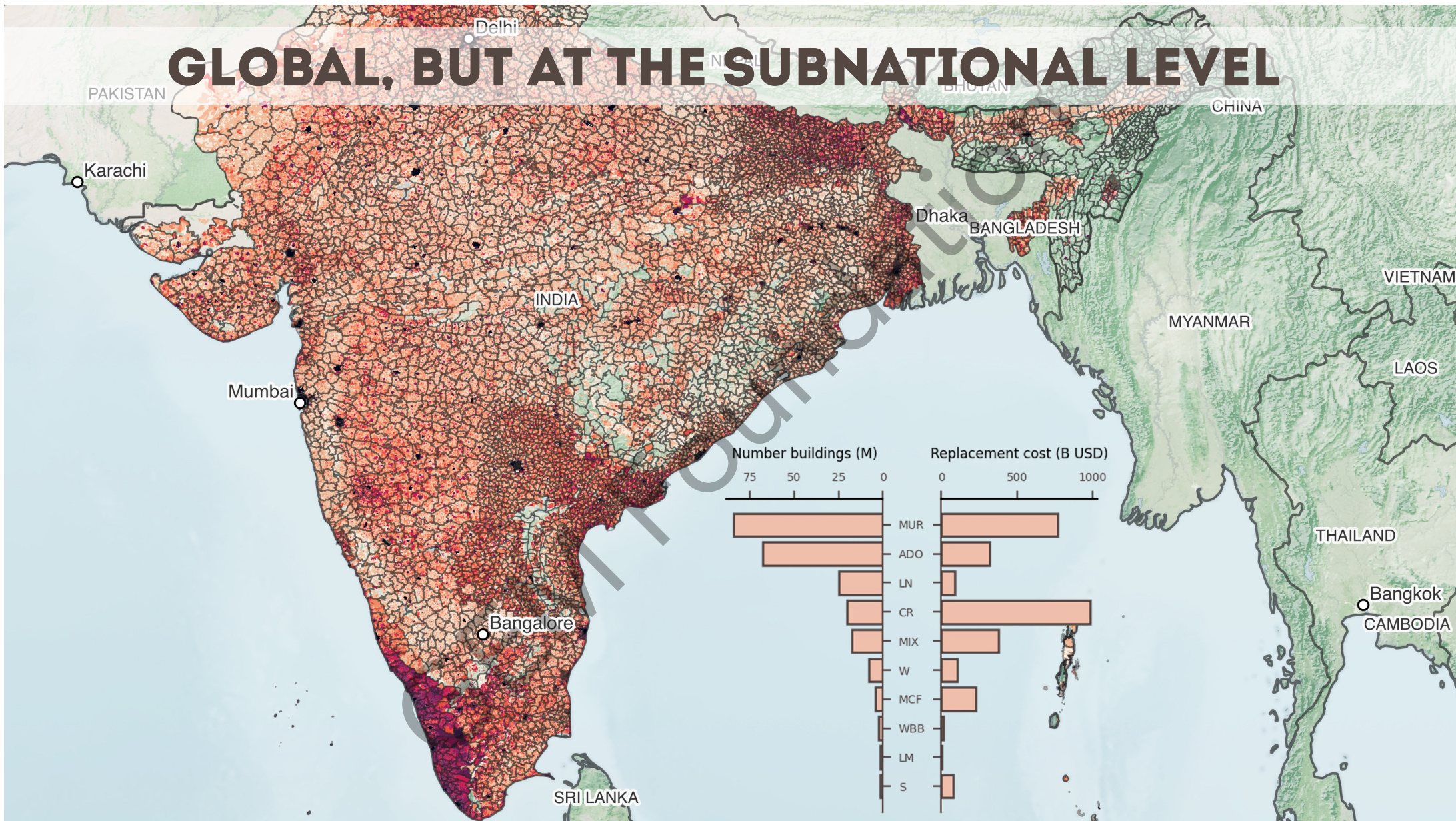
Equivalent to all buildings in Brazil + Argentina

# INFLATION AND CONSTRUCTION COSTS

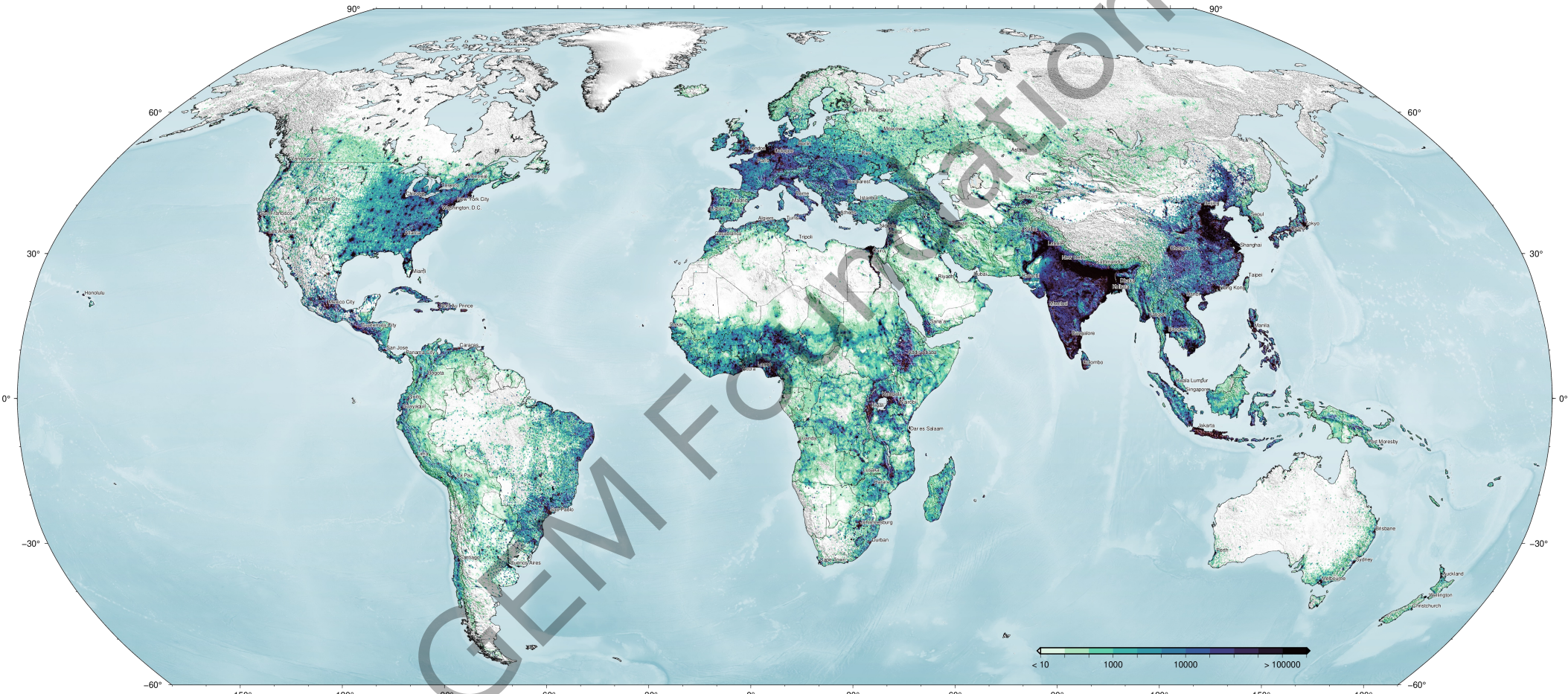
More than 54 countries currently have inflation above 10%, which tends to be 50% higher for the construction sector



# GLOBAL, BUT AT THE SUBNATIONAL LEVEL



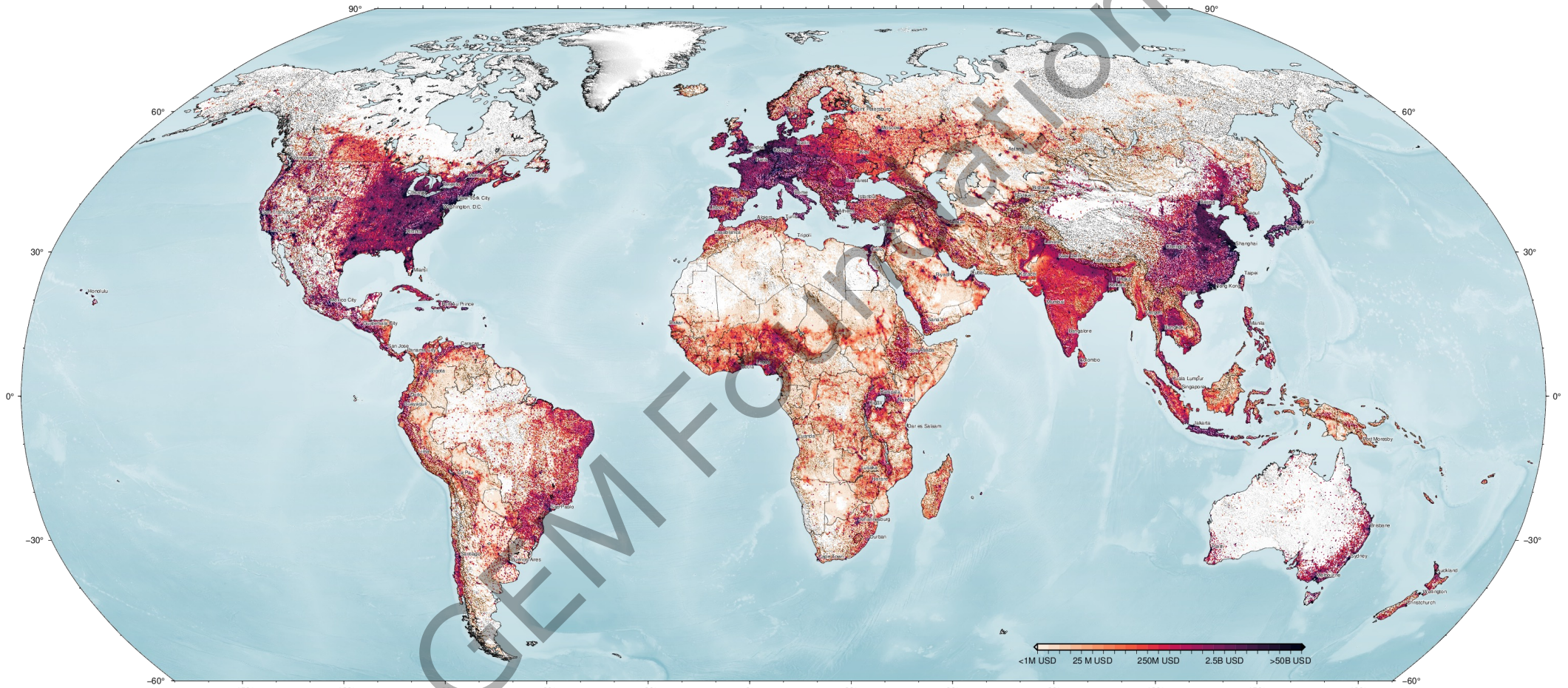
# THE 2023 GEM'S GLOBAL EXPOSURE MODEL



Number of residential, commercial and industrial buildings on an evenly spaced hexagon grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

GLOBAL EARTHQUAKE MODEL

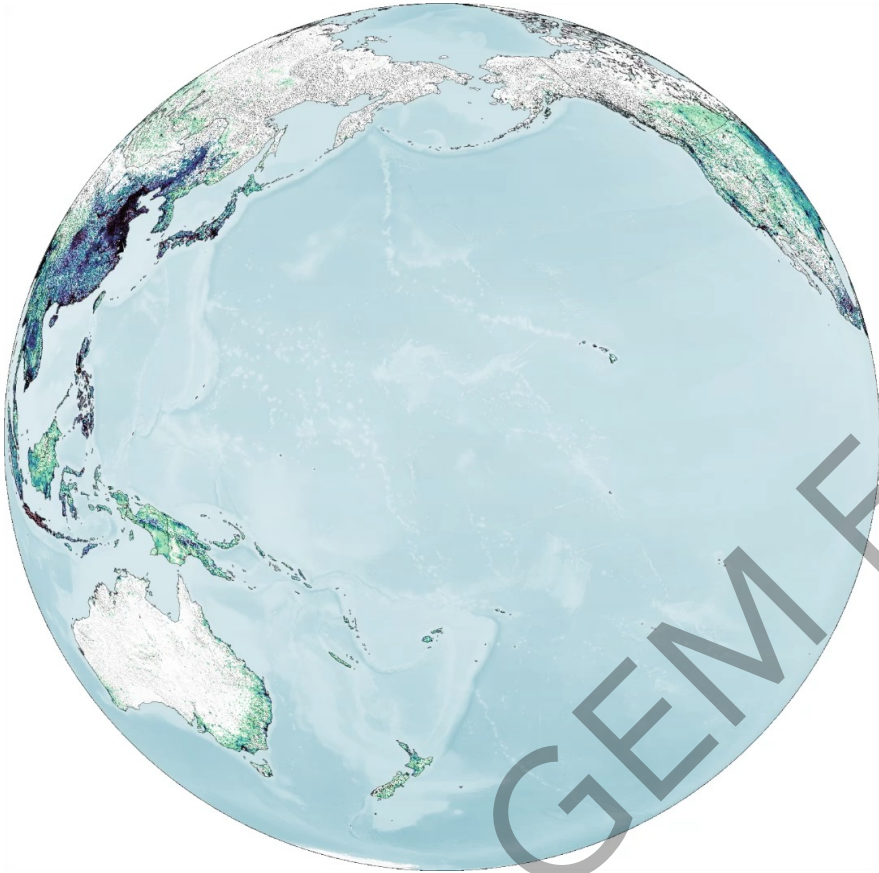
# THE 2023 GEM'S GLOBAL EXPOSURE MODEL







Economic value of the residential, commercial and industrial buildings stock on an evenly spaced hexagonal grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

GLOBAL EARTHQUAKE MODEL

# THE 2023 GEM'S GLOBAL EXPOSURE MODEL



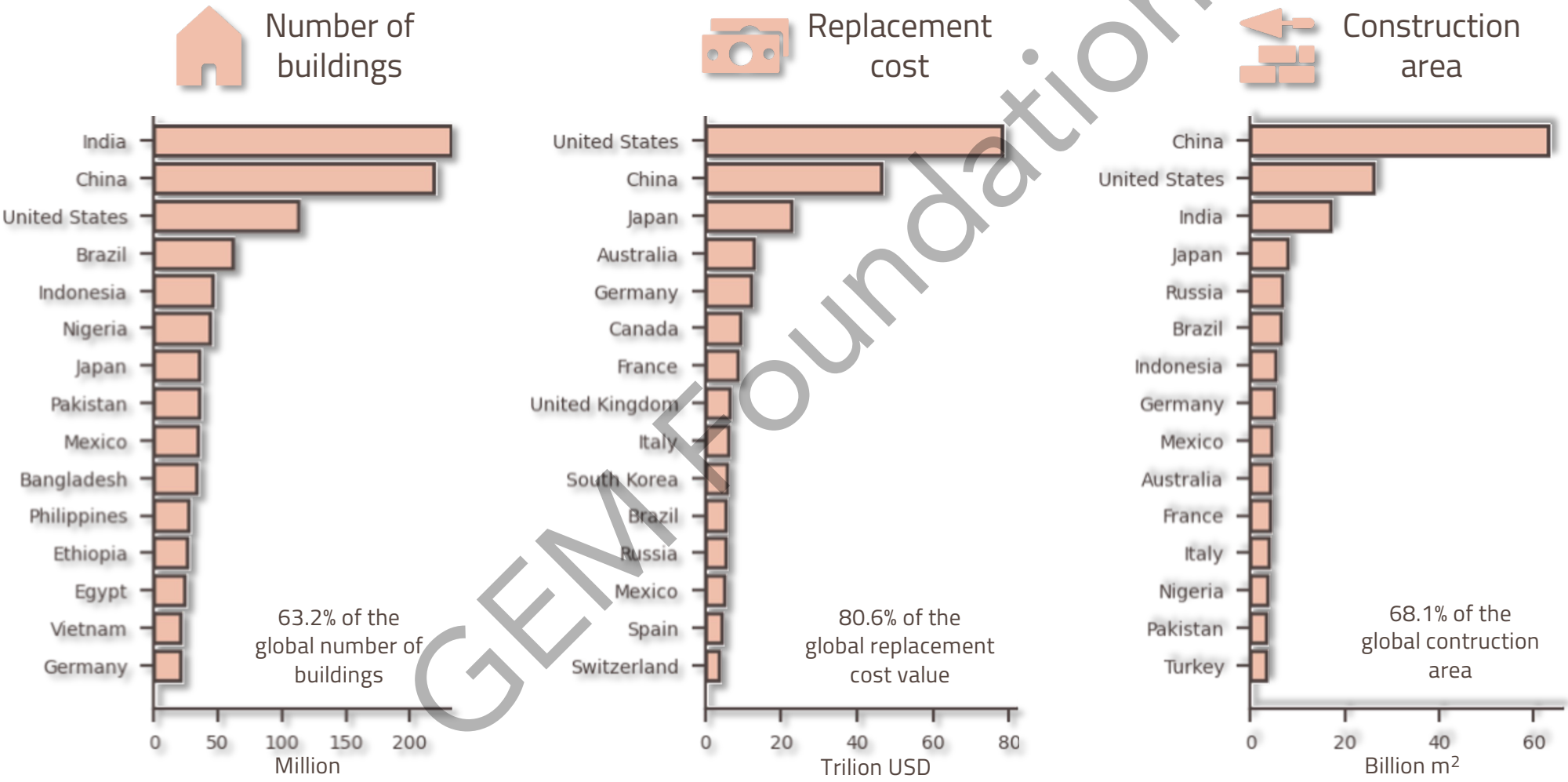
	Residential	Commercial	Industrial	Total
	7.87B	-	-	7.87B
	1.39B	0.10B	0.03B	1.52 B
 (m2)	193B	29B	20B	242B
 (USD)	202T	57T	28T	287T

components

components



# THE 2023 GEM'S GLOBAL EXPOSURE MODEL



# BUT WHERE IS IT?

gem / global\_exposure\_model

github.com/gem/global\_exposure\_model

gem / global\_exposure\_model

Code Issues 2 Pull requests Actions Projects Security Insights

global\_exposure\_model Public

Watch 4 Fork 2 Star 5

main 2 branches 4 tags

Go to file Add file Code

raoanirudh Merge pull request #24 from gem/spectra-doi 002ca08 last month 160 commits

Africa	Add exposure at Adm1 for Africa (see #20)	2 months ago
Caribbean_Central_America	Add exposure at Adm1 for CCA (see #20)	2 months ago
Central_Asia	Add exposure at Adm1 for Central_Asia (see #20)	2 months ago
East_Asia	Add exposure at Adm1 for East_Asia	2 months ago
Europe	Add exposure at Adm1 for Europe	2 months ago
Middle_East	Add exposure at Adm1 for Middle_East	2 months ago
North_America	Add exposure at Adm1 for North_America	2 months ago
North_Asia	Add exposure at Adm1 for North_Asia (see #20)	2 months ago
Oceania	Add exposure at Adm1 for Oceania	2 months ago
South_America	Add exposure at Adm1 for South_America (see #20)	2 months ago
South_Asia	Add exposure at Adm1 for South_Asia (see #20)	2 months ago
Southeast_Asia	Add exposure at Adm1 for SEA	2 months ago

About

This is the web repository of the GEM's Global Exposure Model

Readme View license Activity 5 stars 4 watching 2 forks Report repository

Releases 3

v2023.1.1 Latest on Aug 8 + 2 releases

Packages

GLOBAL EARTHQUAKE MODEL

# BUT WHERE IS IT?





GEM GLOBAL SEISMIC RISK MODEL UPDATE 2023

# EXPANDING THE VULNERABILITY DATABASE

GEM Foundation

GLOBAL EARTHQUAKE MODEL

# EXPANDING THE GLOBAL VULNERABILITY MODEL

We have expanded the vulnerability database from 544 functions to 1201 functions (times 3 occupancy types – for a total of 3603 functions)

Bamboo houses



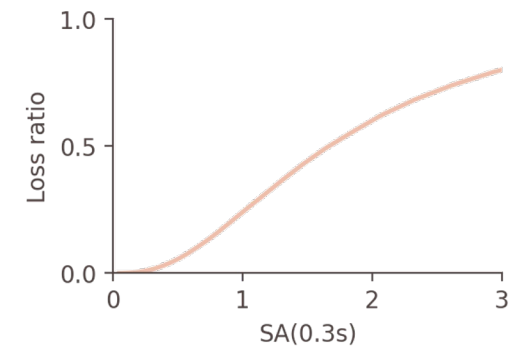
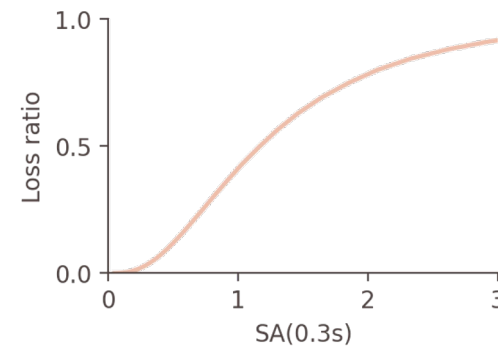
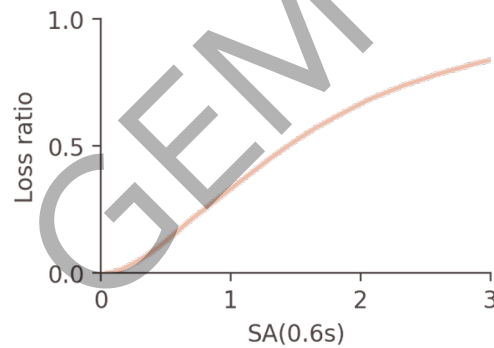
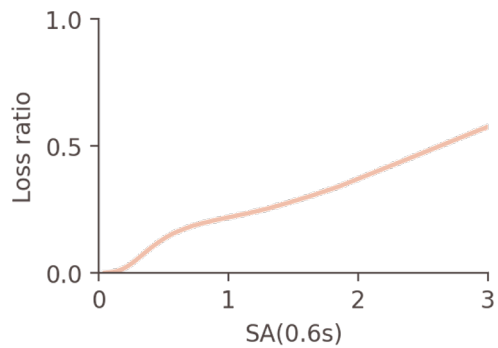
Large panel buildings



Rubble stone masonry



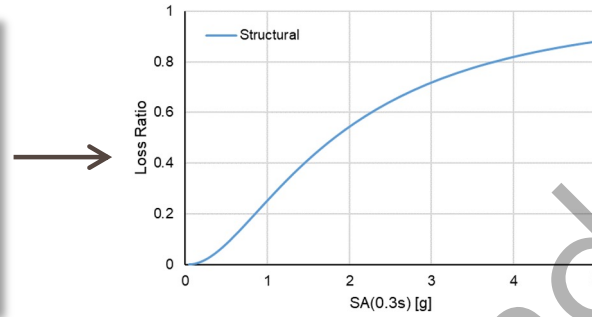
Concrete bricks masonry



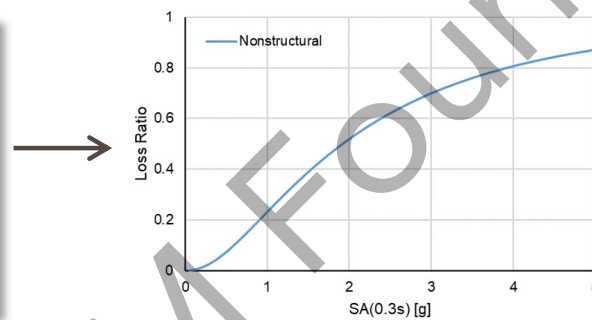
GLOBAL EARTHQUAKE MODEL

# EXPANDING THE GLOBAL VULNERABILITY MODEL

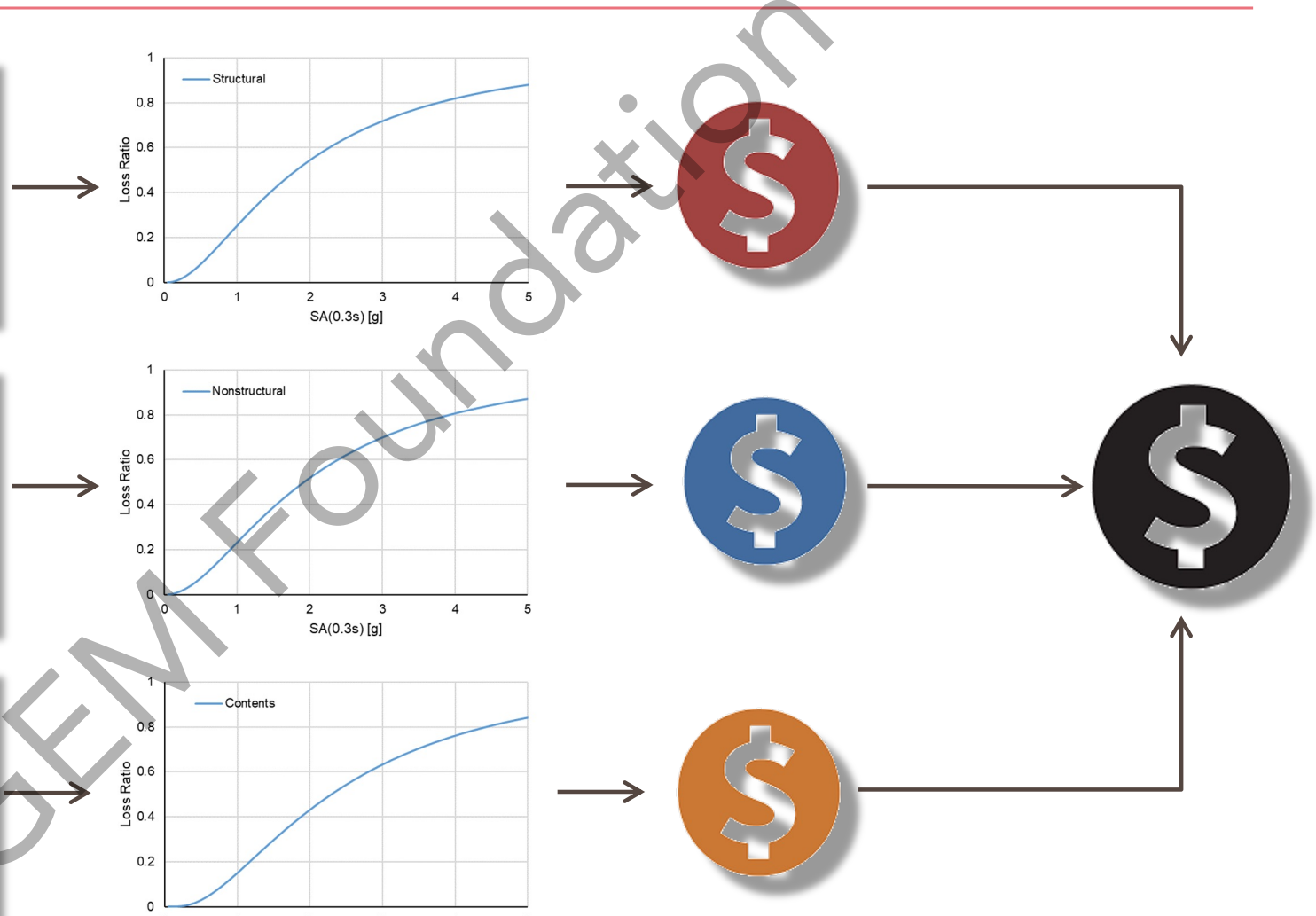
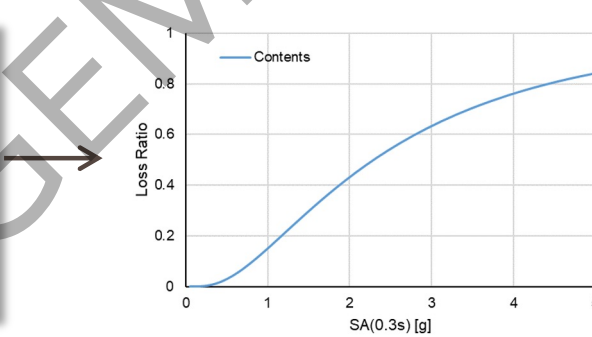
Structural



Non-structural



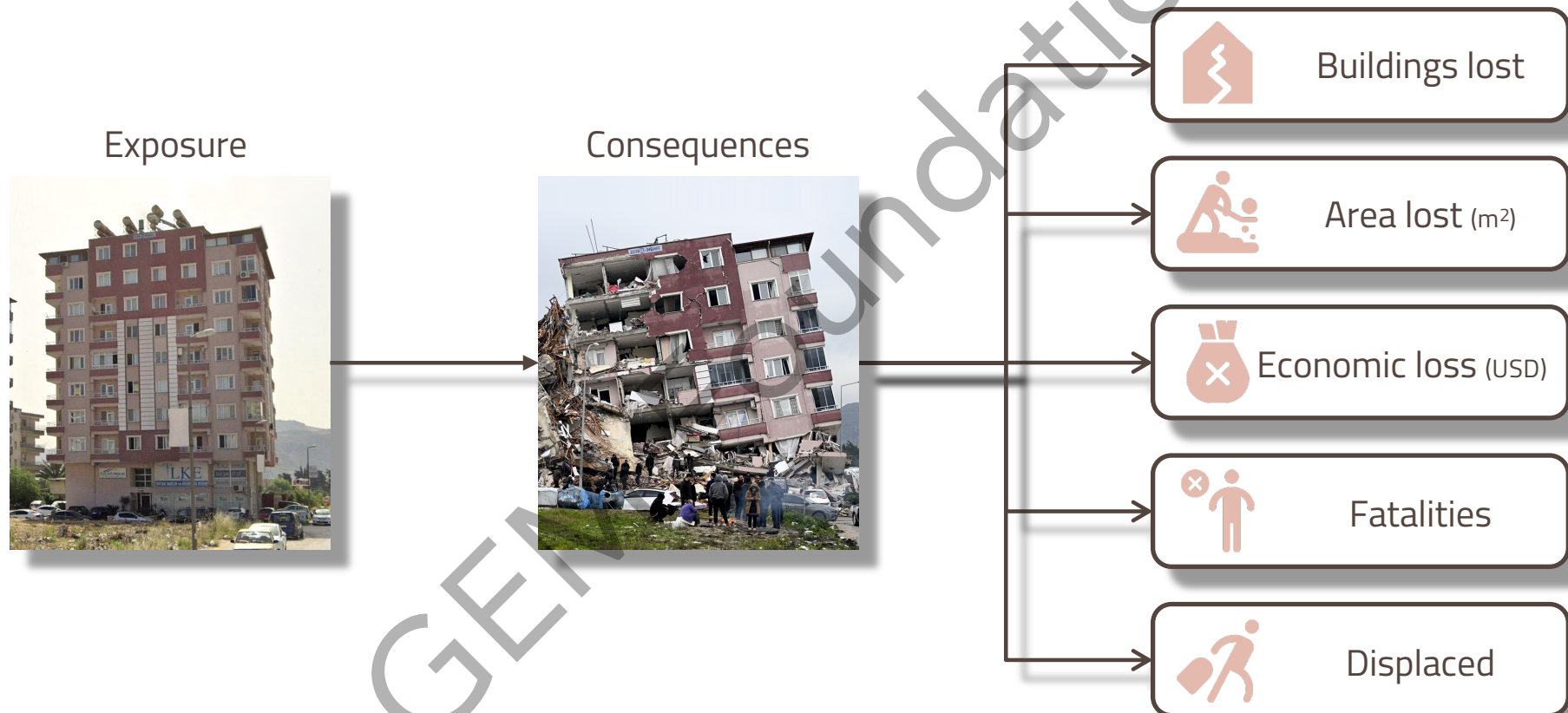
Contents



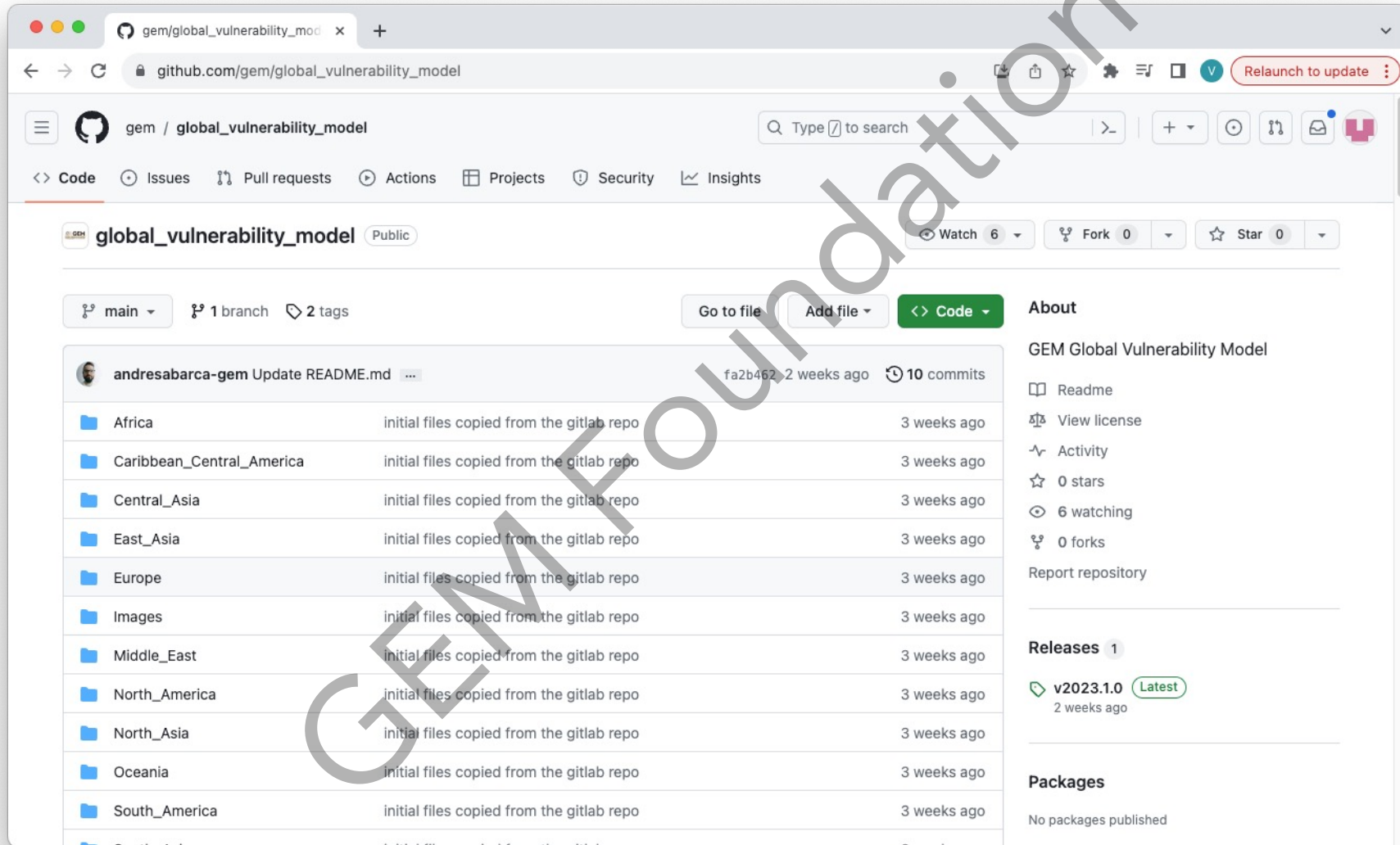
GLOBAL EARTHQUAKE MODEL

# EXPANDING THE GLOBAL VULNERABILITY MODEL

The vulnerability model currently covers five main risk metrics



# BUT WHERE IS IT?



GLOBAL EARTHQUAKE MODEL





GEM GLOBAL SEISMIC RISK MODEL UPDATE 2023

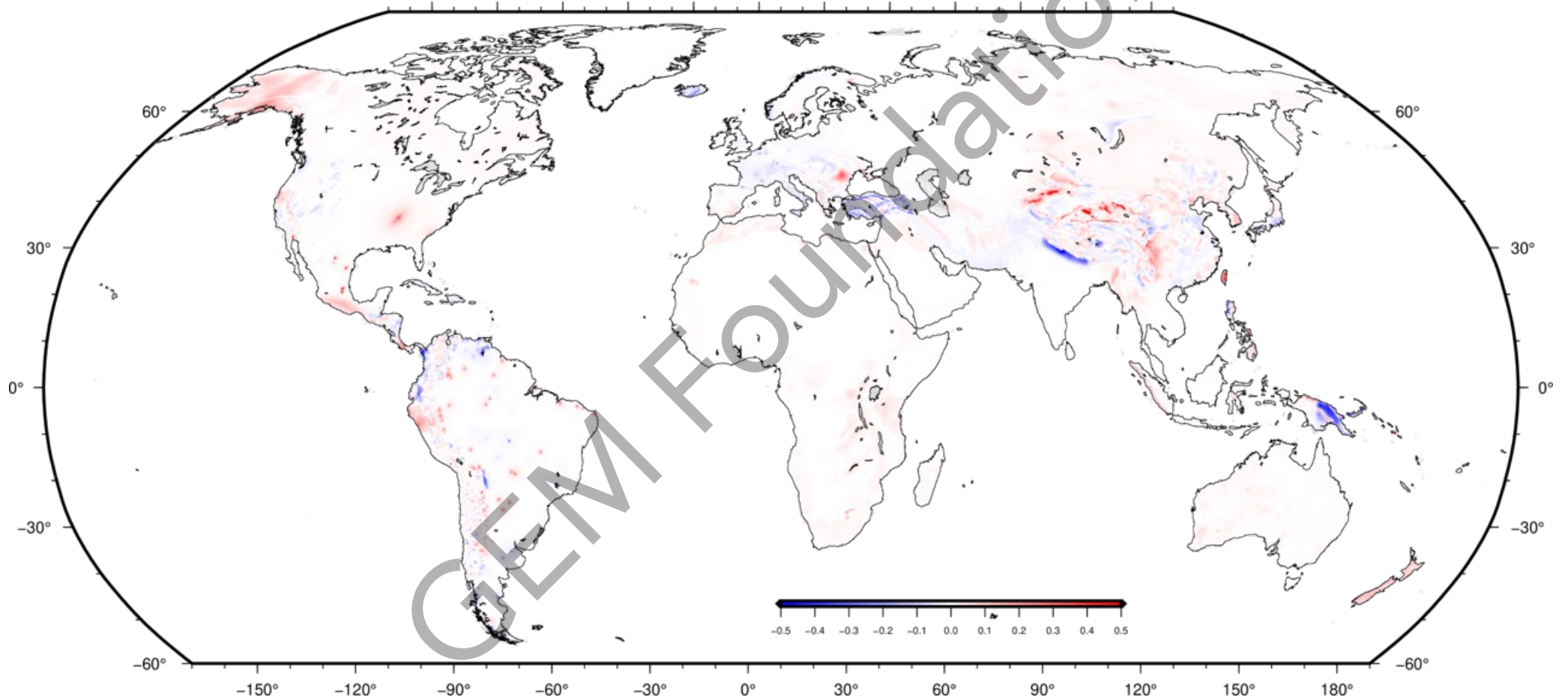
# IMPACT OF THE SEISMIC HAZARD

GEM Foundation

GLOBAL EARTHQUAKE MODEL

# DIFFERENCES ON THE SEISMIC HAZARD

Differences in the seismic hazard between 2018 and 2023 (PGA for the 475year RP on rock).



(courtesy of the hazard team)

GLOBAL EARTHQUAKE MODEL



GEM GLOBAL SEISMIC RISK MODEL UPDATE 2023

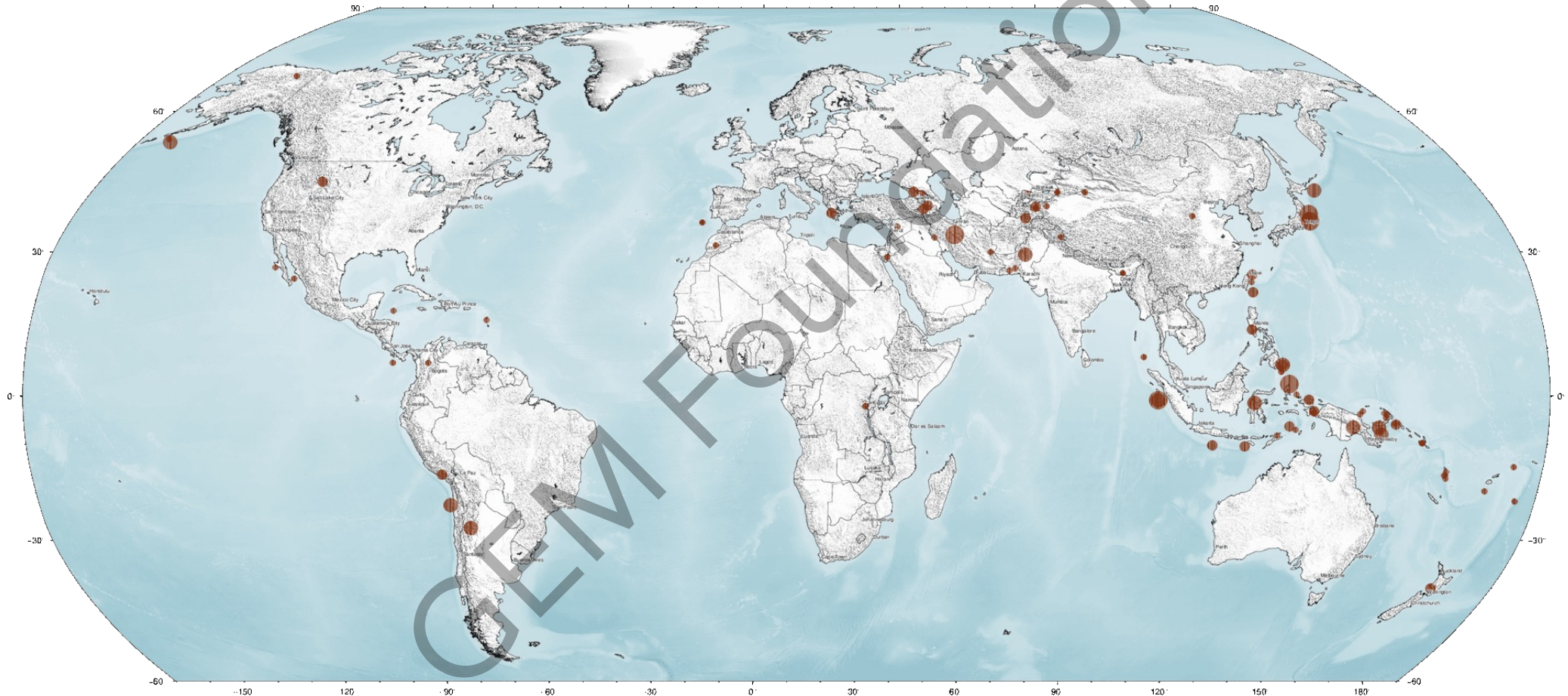
# GLOBAL SEISMIC RISK ASSESSMENT

GEM Foundation

GLOBAL EARTHQUAKE MODEL

# GLOBAL SEISMIC RISK ASSESSMENT

Stochastic generation of million of seismic events using the seismic hazard mosaic

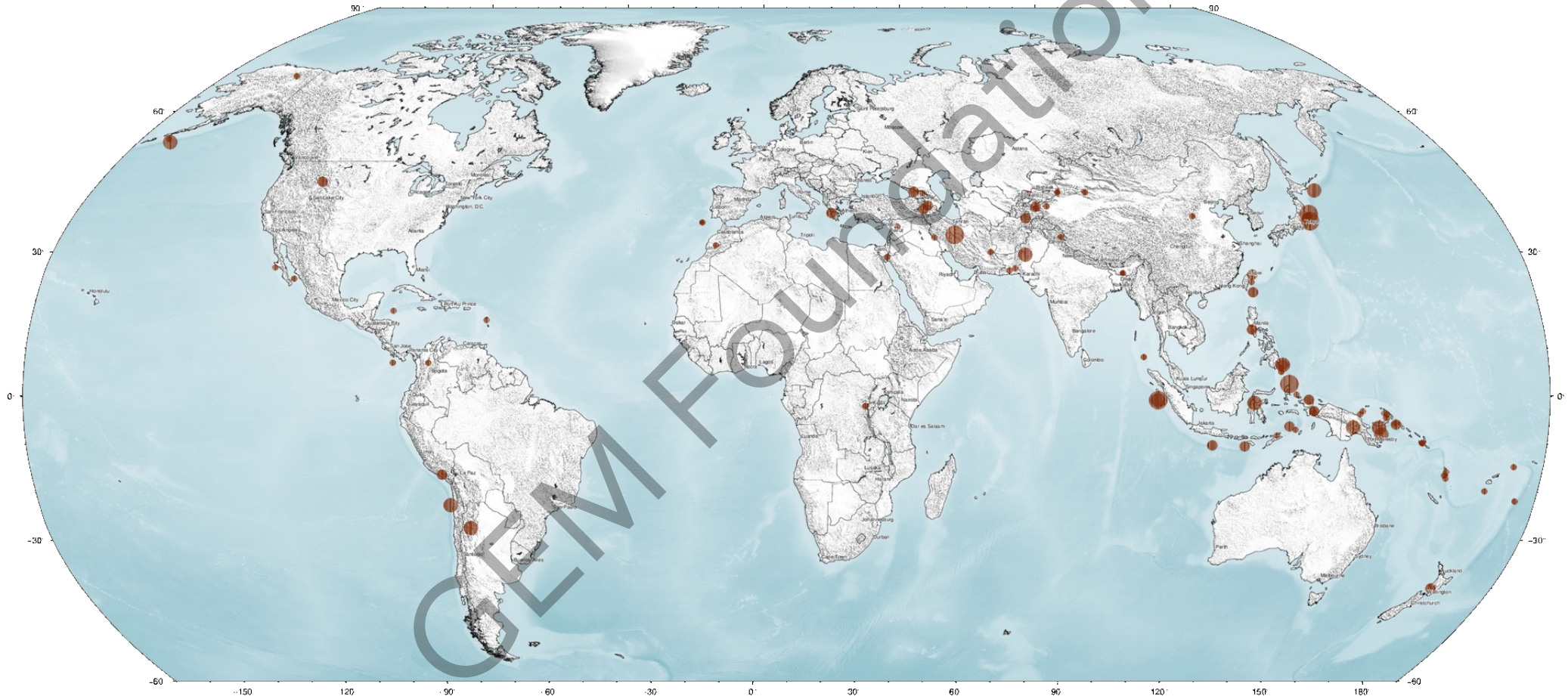


Each frame represents 1 year of seismicity

GLOBAL EARTHQUAKE MODEL

# GLOBAL SEISMIC RISK ASSESSMENT

Generation of ground motion fields for each stochastically generated seismic event



Each frame represents 1 year of seismicity

GLOBAL EARTHQUAKE MODEL

# GLOBAL SEISMIC RISK ASSESSMENT

Seismic Risk

=

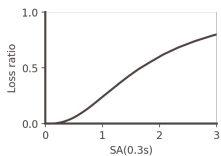
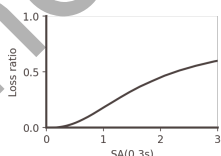
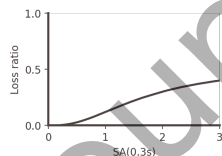
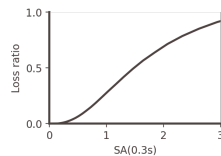
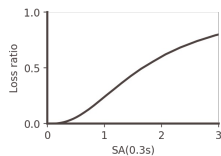
Vulnerability

⊗

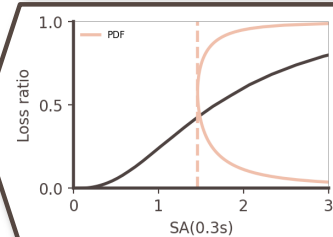
Exposure

⊗

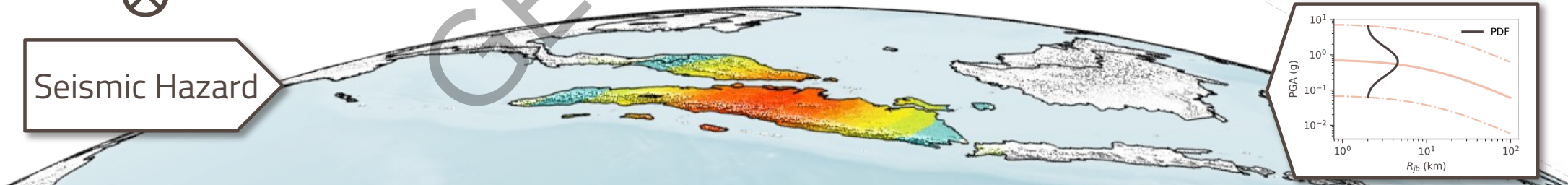
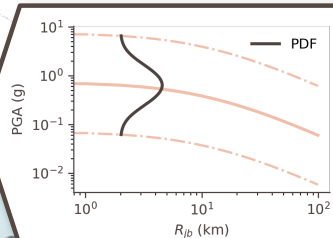
Seismic Hazard



- Buildings lost
- Area lost
- Economic losses
- Fatalities
- Homeless

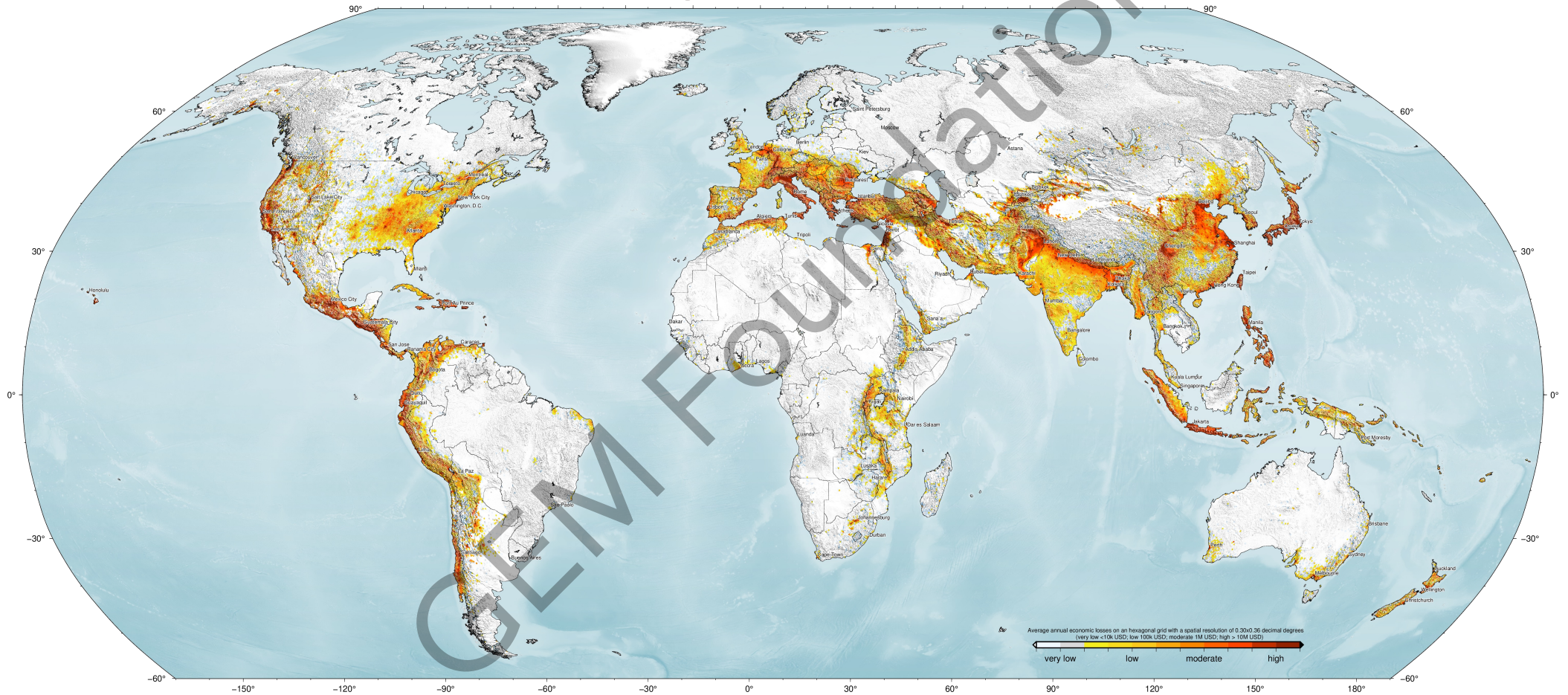


- Number of buildings
- Number of dwellings
- Built up area
- Replacement cost
- Number of occupants



# GLOBAL SEISMIC RISK ASSESSMENT

## Global Average Annual Economic Losses



Average Annual Economic Losses (in USD) on an evenly spaced hexagon grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

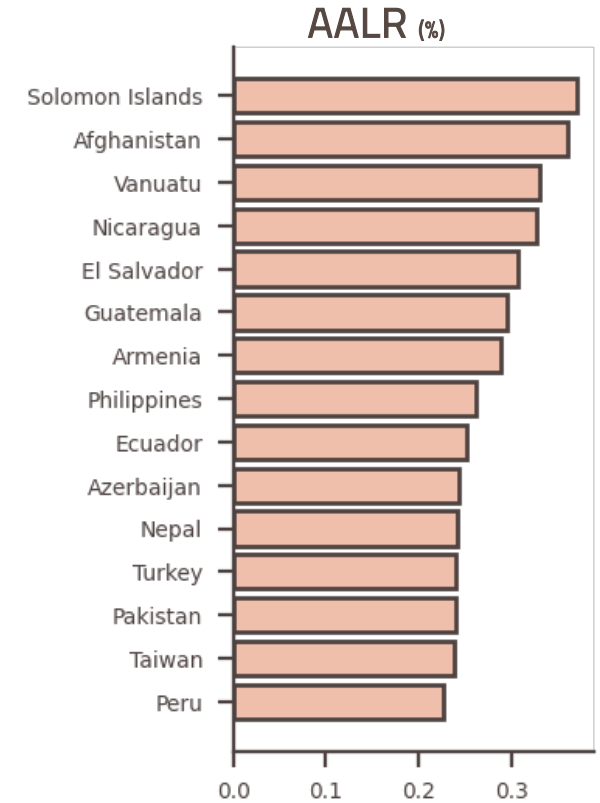
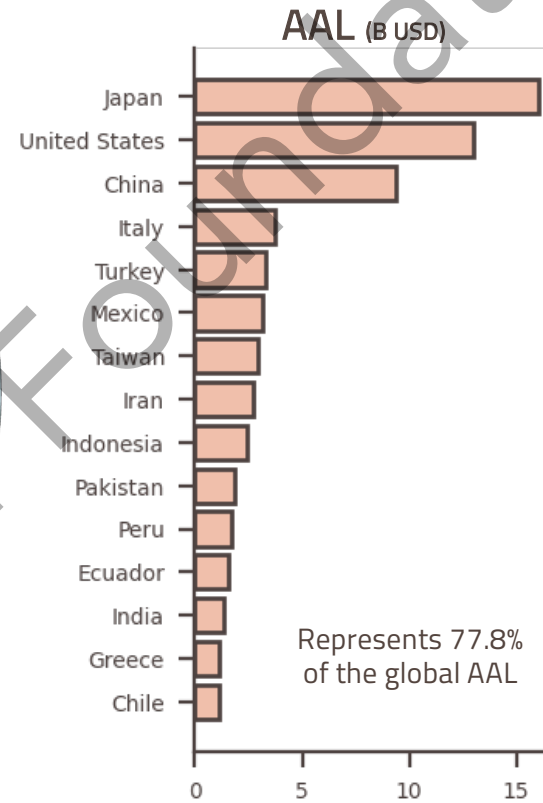
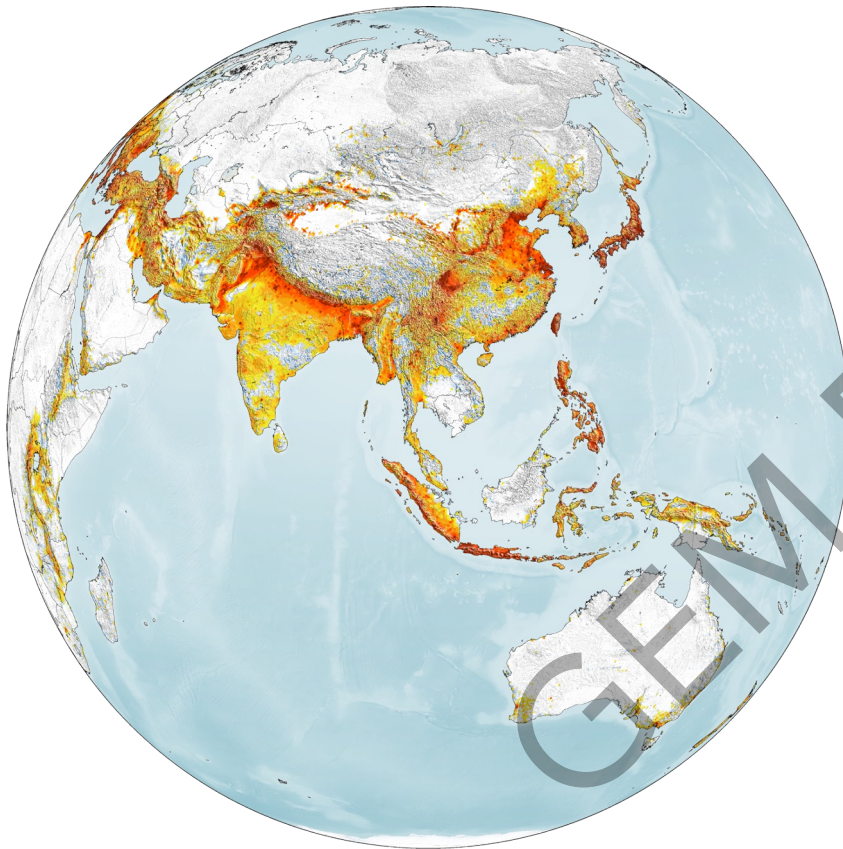
GLOBAL EARTHQUAKE MODEL

# GLOBAL SEISMIC RISK ASSESSMENT

Southeast Asia represent  
44.1% of the Global AAL



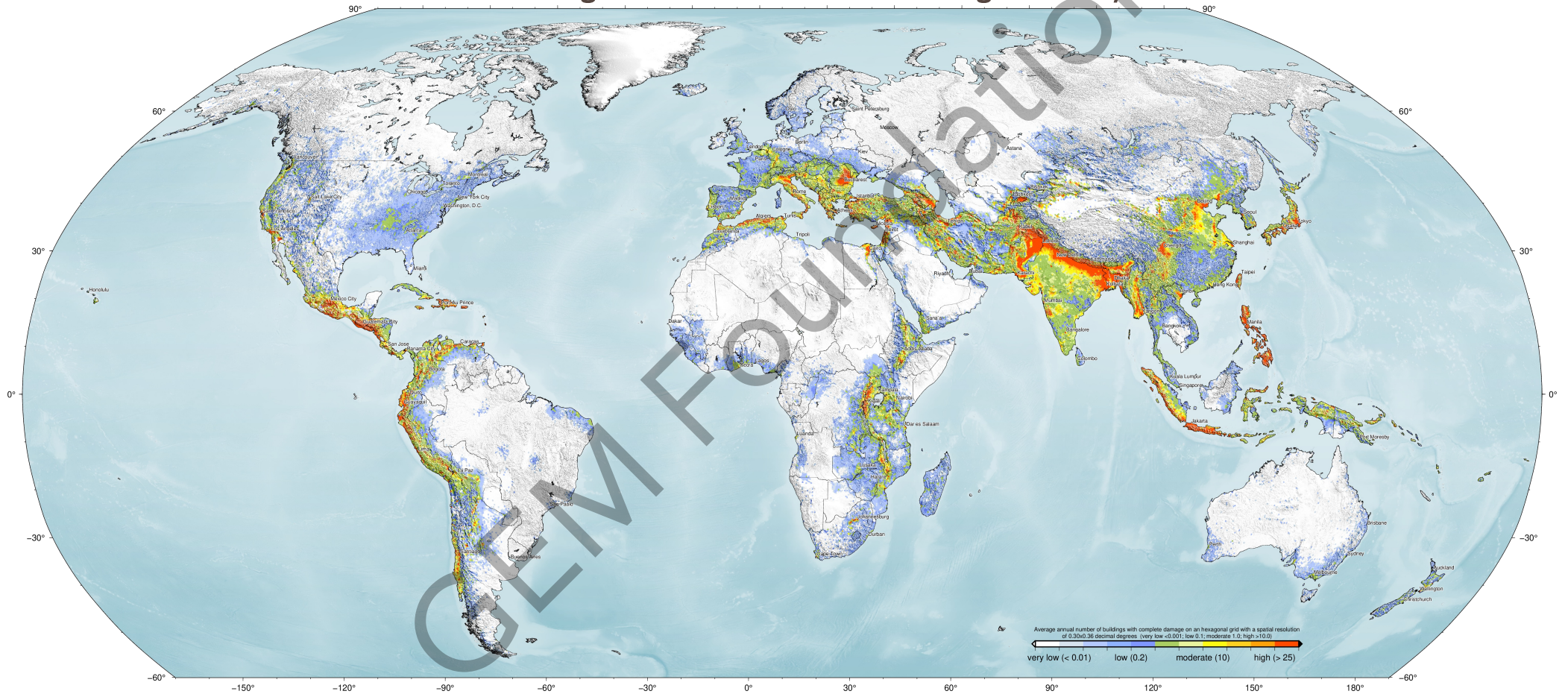
**84.1B USD / 0.029%**





# GLOBAL SEISMIC RISK ASSESSMENT

## Global Average Annual Number of Buildings Destroyed



Average Annual Number of Buildings Destroyed on an evenly spaced hexagonal grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

**GLOBAL EARTHQUAKE MODEL**

# GLOBAL SEISMIC RISK ASSESSMENT

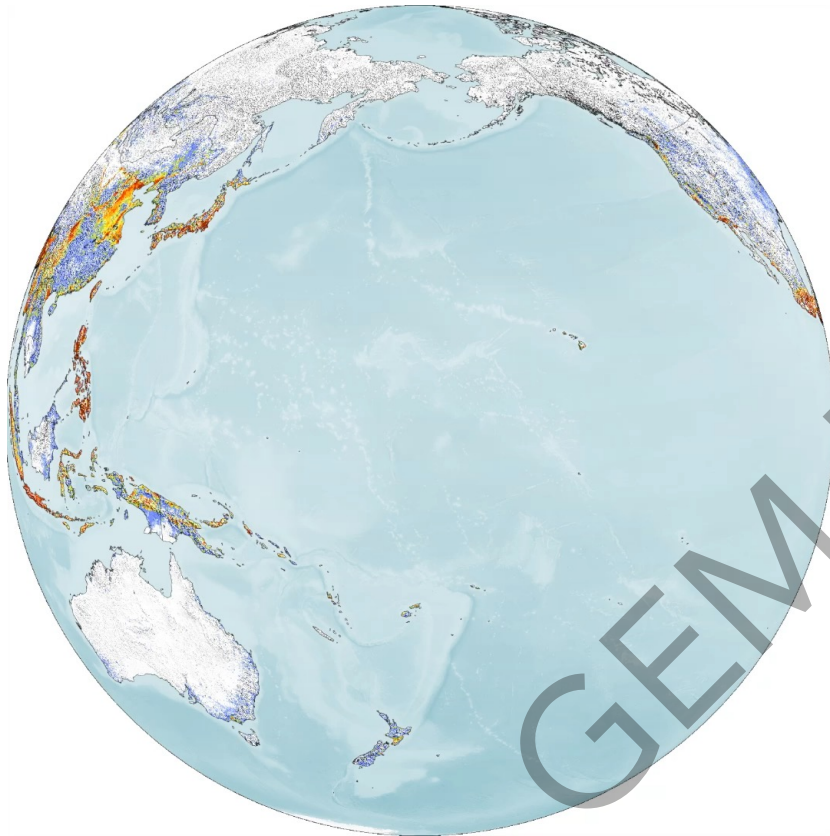
Average Annual Number of Buildings Destroyed



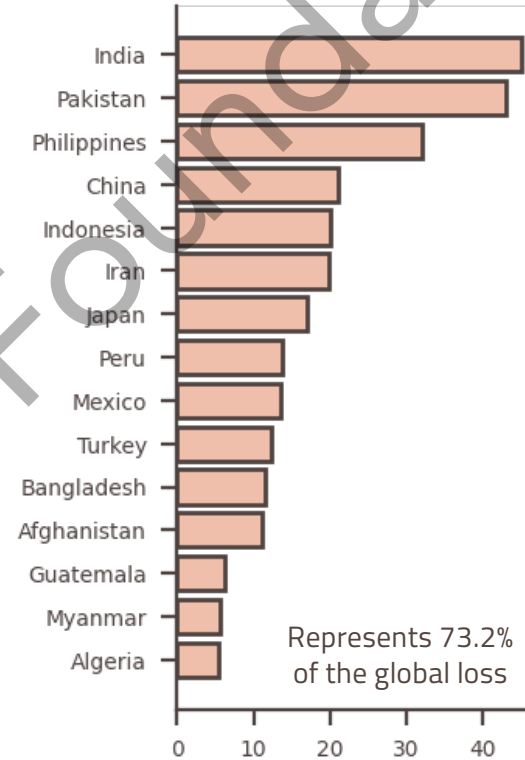
**379K**



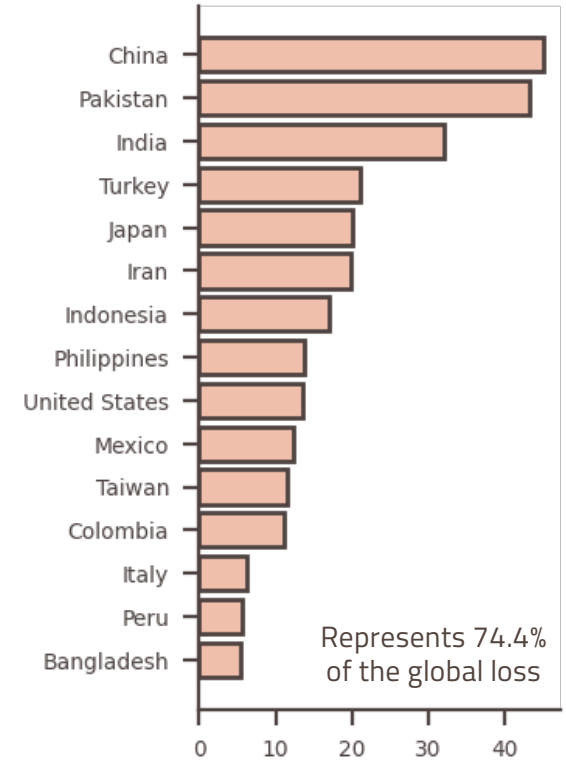
**109M M<sup>2</sup>**



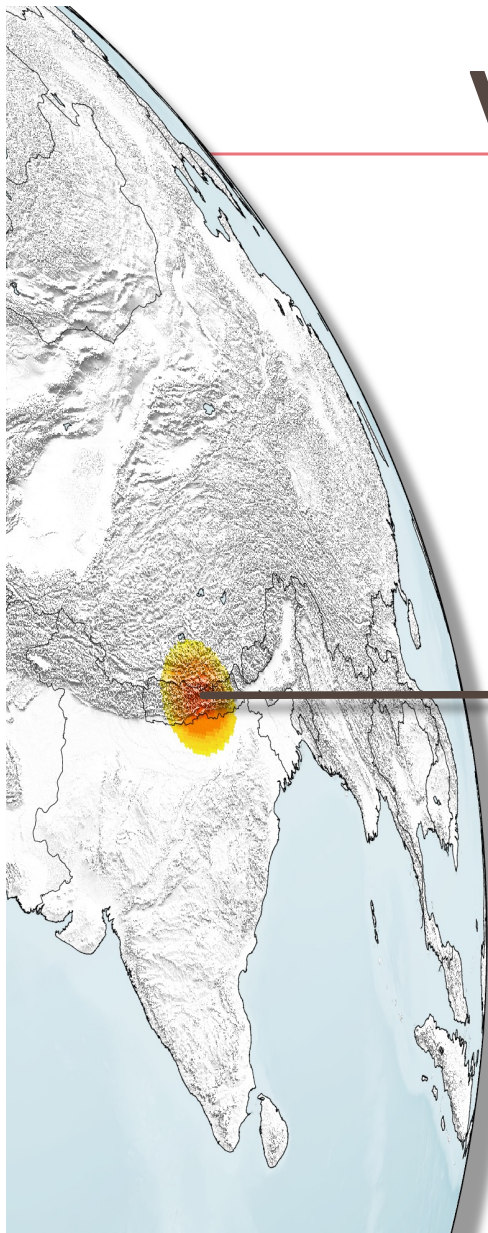
AA buildings lost (K)



AA area lost (M m<sup>2</sup>)



# WHAT ABOUT HUMAN IMPACT?



High fatality rates  
(Concrete)



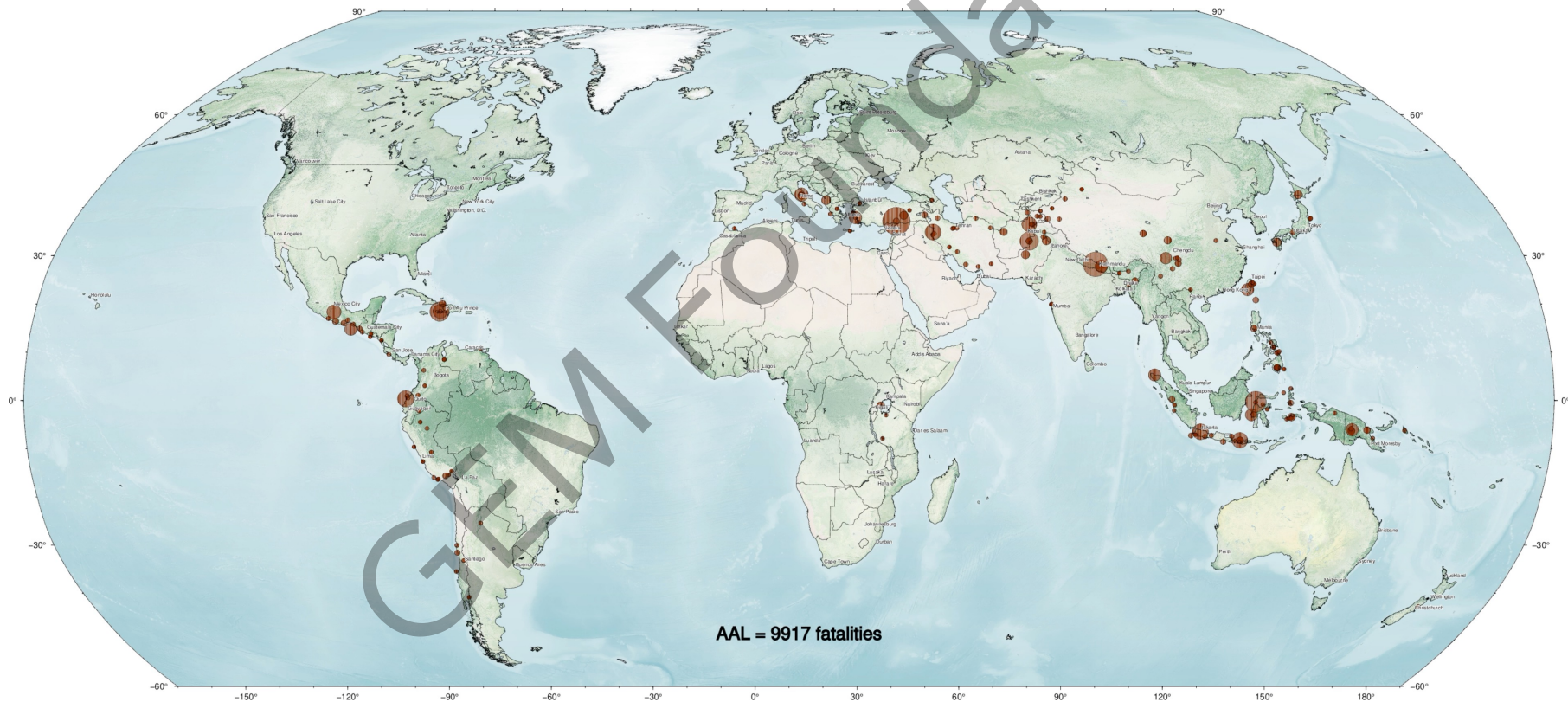
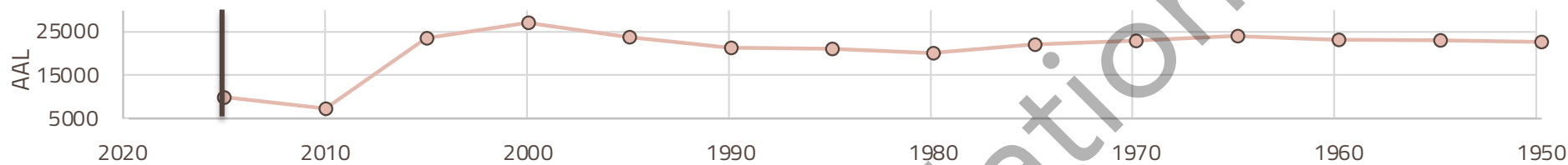
Moderate fatality  
rates (Masonry)



Low fatality rates  
(Wood)

GLOBAL EARTHQUAKE MODEL

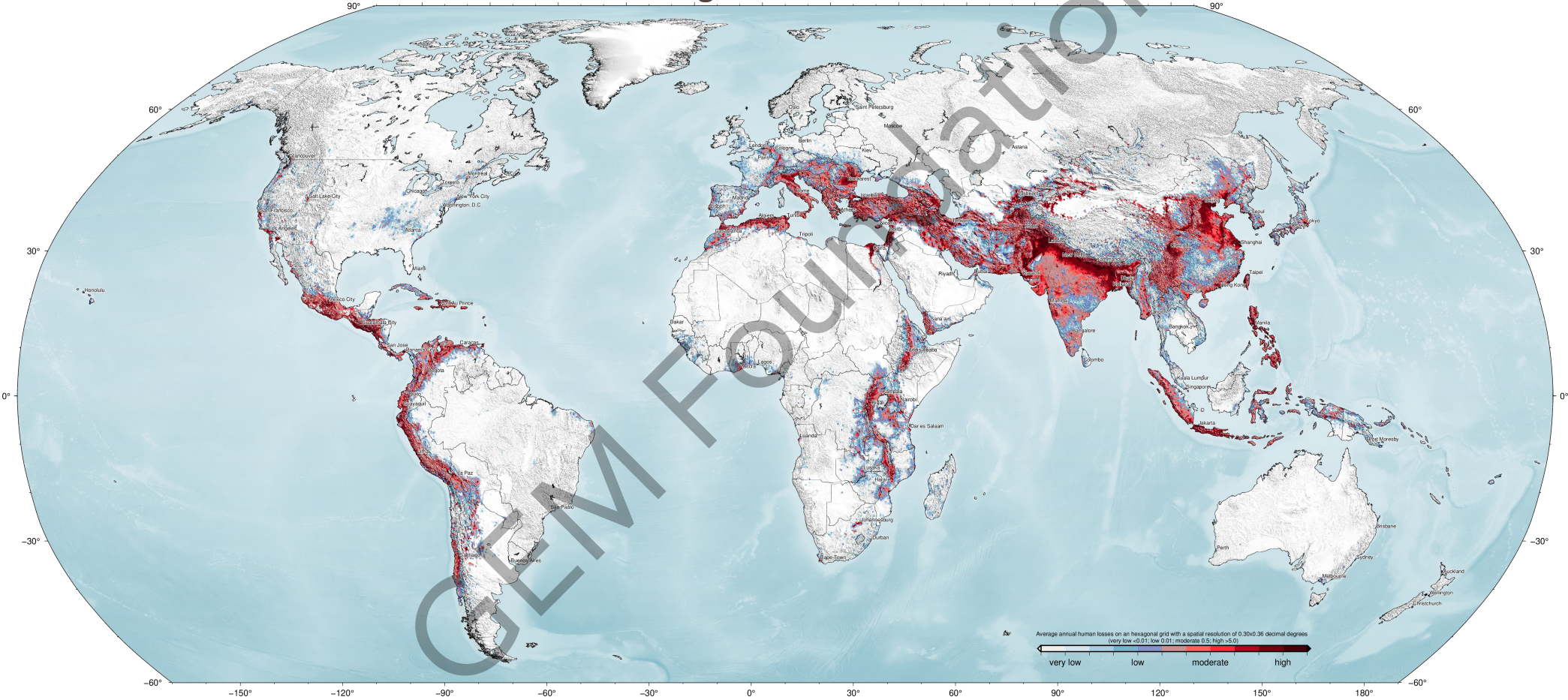
# EMPIRICAL AVERAGE ANNUAL FATALITIES



GLOBAL EARTHQUAKE MODEL

# GLOBAL EARTHQUAKE FATALITY MODEL

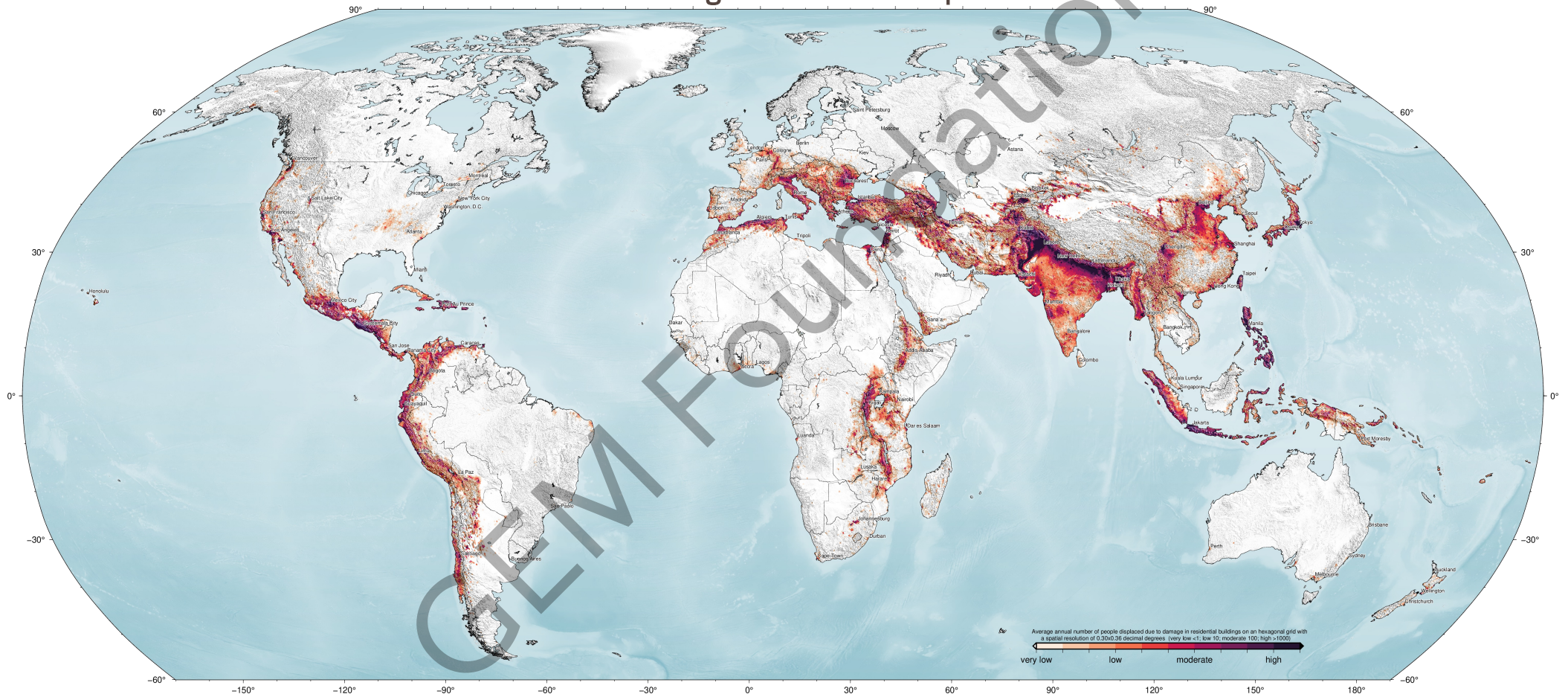
Global Average Annual Human Losses



Average number of human losses on an evenly spaced hexagon grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

# GLOBAL EARTHQUAKE DISPLACED MODEL

Global Average Number of Displaced








Average number of people displaced due to damage in the residential building stock on an evenly spaced hexagon grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

**GLOBAL EARTHQUAKE MODEL**

# TOP 10 COUNTRIES PER RISK METRIC

 Buildings lost	 Area lost	 Economic loss	 Fatalities	 Displaced
India	China	Japan	China	Pakistan
Pakistan	Pakistan	United States	Pakistan	India
Philippines	India	China	Turkey	China
China	Turkey	Italy	India	Indonesia
Indonesia	Japan	Turkey	Iran	Philippines
Iran	Iran	Mexico	Afghanistan	Turkey
Japan	Indonesia	Taiwan	Indonesia	Iran
Peru	Philippines	Iran	Algeria	Afghanistan
Mexico	United States	Indonesia	Nepal	Bangladesh
Turkey	Mexico	Pakistan	Peru	Japan

# TOP 10 COUNTRIES PER RISK METRIC

 Buildings lost	 Area lost	 Economic loss	 Fatalities	 Displaced
India	China	Japan	China	Pakistan
Pakistan	Pakistan	United States	Pakistan	India
Philippines	India	China	Turkey	China
China	Turkey	Italy	India	Indonesia
Indonesia	Japan	Turkey	Iran	Philippines
Iran	Iran	Mexico	Afghanistan	Turkey
Japan	Indonesia	Taiwan	Indonesia	Iran
Peru	Philippines	Iran	Algeria	Afghanistan
Mexico	United States	Indonesia	Nepal	Bangladesh
Turkey	Mexico	Pakistan	Peru	Japan



# DEVELOPMENT OF COUNTRY PROFILES

## GEORGIA

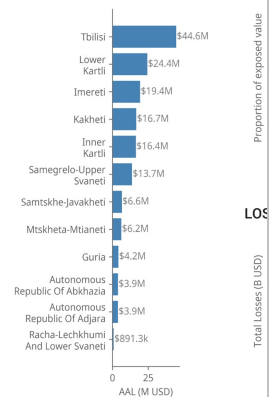
### SOCIAL INDICATORS

Population 4.0M  
 GDP 18.6B USD  
 Gini Index 34.5

### RISK INDICATORS

Residential Replacement cost (Billion USD) 56.1  
 Commercial 19.4  
 Industrial 9.0  
 Total 84.5

### LOSS BY REGION



## MAJOR EARTHQUAKES

1991 M 7.0 - Racha - 270 fatalities

## GUATEMALA

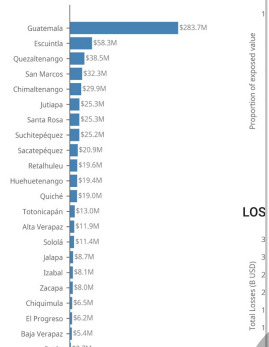
### SOCIAL INDICATORS

Population 18.2M  
 GDP 86.0B USD  
 GINI Index -

### RISK INDICATORS

Residential Replacement cost (Billion USD) 187.4  
 Commercial 585  
 Industrial 18.6

### LOSS BY REGION



## INDIA

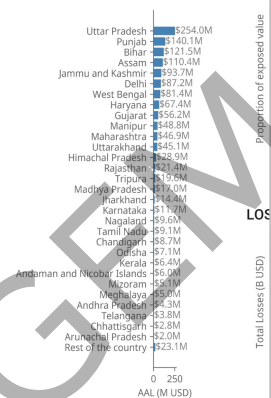
### SOCIAL INDICATORS

Population 1,393.4M  
 GDP 3,180.0B USD  
 Gini Index -

### RISK INDICATORS

Residential Replacement cost (Billion USD) 2,218.2  
 Commercial 548.2  
 Industrial 212.3  
 Total 2,978.8

### LOSS BY REGION



## MAJOR EARTHQUAKES

1976 M 7.5 - Chimaltenango - 23,000 fatalities

## PERU

### SOCIAL INDICATORS

Population 32.2M  
 GDP 211.0B USD  
 GINI Index 45.3

### RISK INDICATORS

Residential Replacement cost (Billion USD) 631.9  
 Commercial 86.9  
 Industrial 44.4

Avg. annual loss (Thousand USD) 1,433,926  
 Avg. annual loss ratio (%) 2.269

Population Growth 1.23%/year  
 GDP per Capita 6,572 USD  
 Human Development Index 0.750

### LOSS BY REGION



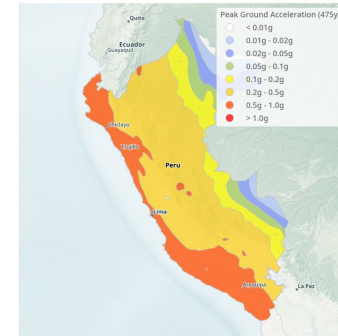
## MAJOR EARTHQUAKES

2001 M 7.6 - Bhuji - 20,023 fatalities

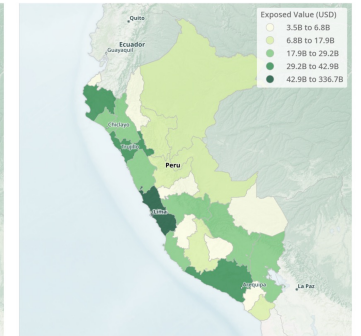
## MAJOR EARTHQUAKES

2007 M 8.0 - Ica - 514 fatalities  
 1970 M 7.9 - Pisco - 66,794 fatalities  
 1946 M 7.3 - Jocaibamba - 800 fatalities

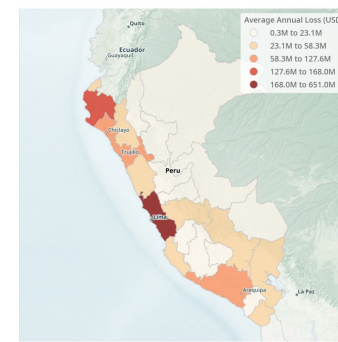
### EARTHQUAKE HAZARD



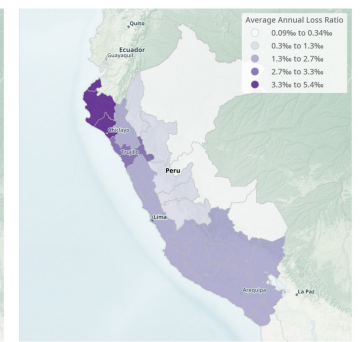
### EXPOSED VALUE



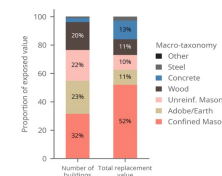
### AVERAGE ANNUAL LOSSES



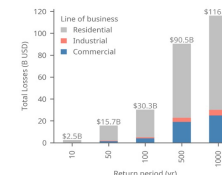
### AVERAGE ANNUAL LOSS RATIOS



### BUILDING CLASSES



### LOSS CURVES

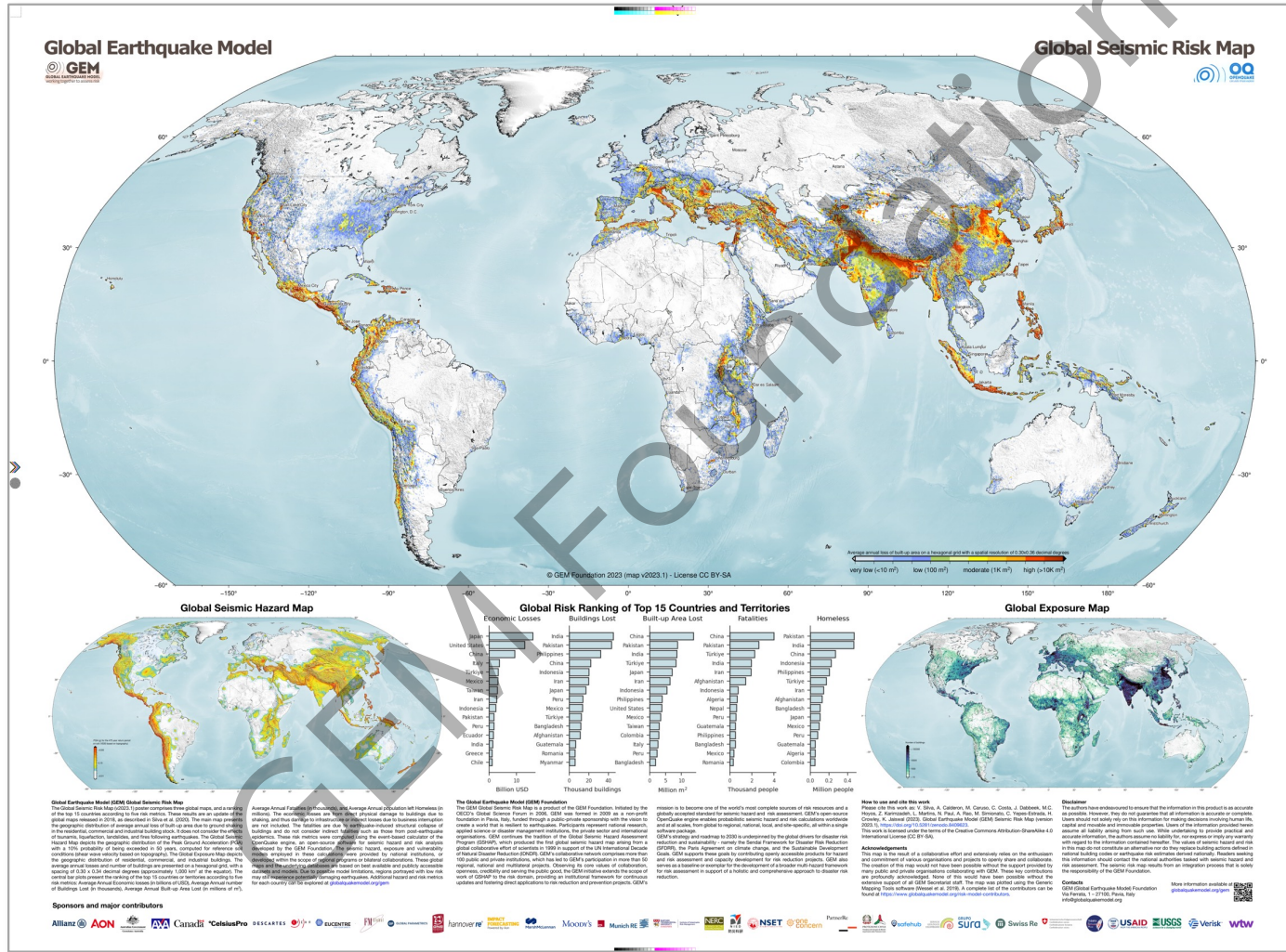


# BUT WHERE IS IT?

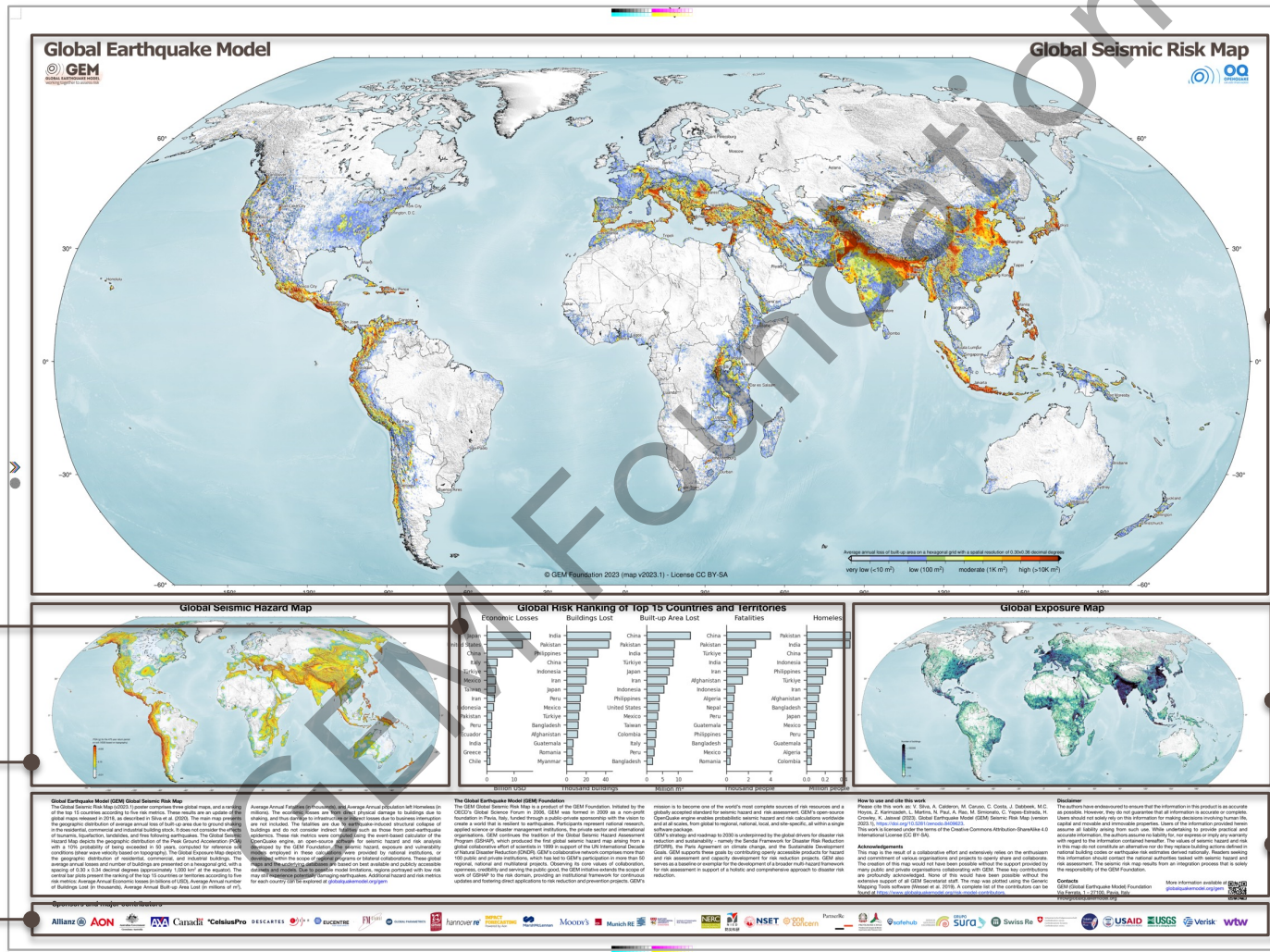
The screenshot shows the GitHub repository page for 'gem/risk-profiles'. The repository is public and has 1 star, 0 forks, and 9 watchers. The main content area displays a list of files and folders, all of which were added 2 days ago. The files are organized by region: Africa, Caribbean\_Central\_America, Central\_Asia, East\_Asia, Europe, Middle\_East, North\_America, North\_Asia, Oceania, South\_America, and South\_Asia. Each file is named 'add license files to each country/territory'. The repository also has a README file and a release named 'v2023.0.0' (Latest) published yesterday. The repository is described as 'This is the web repository of the GEM's Risk Profiles'.

File/Folder	Description	Time
Africa	add license files to each country/territory	2 days ago
Caribbean_Central_America	add license files to each country/territory	2 days ago
Central_Asia	add license files to each country/territory	2 days ago
East_Asia	add license files to each country/territory	2 days ago
Europe	add license files to each country/territory	2 days ago
Middle_East	add license files to each country/territory	2 days ago
North_America	add license files to each country/territory	2 days ago
North_Asia	add license files to each country/territory	2 days ago
Oceania	add license files to each country/territory	2 days ago
South_America	add license files to each country/territory	2 days ago
South_Asia	add license files to each country/territory	2 days ago

# ANATOMY OF A GLOBAL SEISMIC RISK MAP



# ANATOMY OF A GLOBAL SEISMIC RISK MAP



Top 15 countries and territories according to specific risk metrics

Global seismic hazard map (PGA for the 475-year RP on soil)

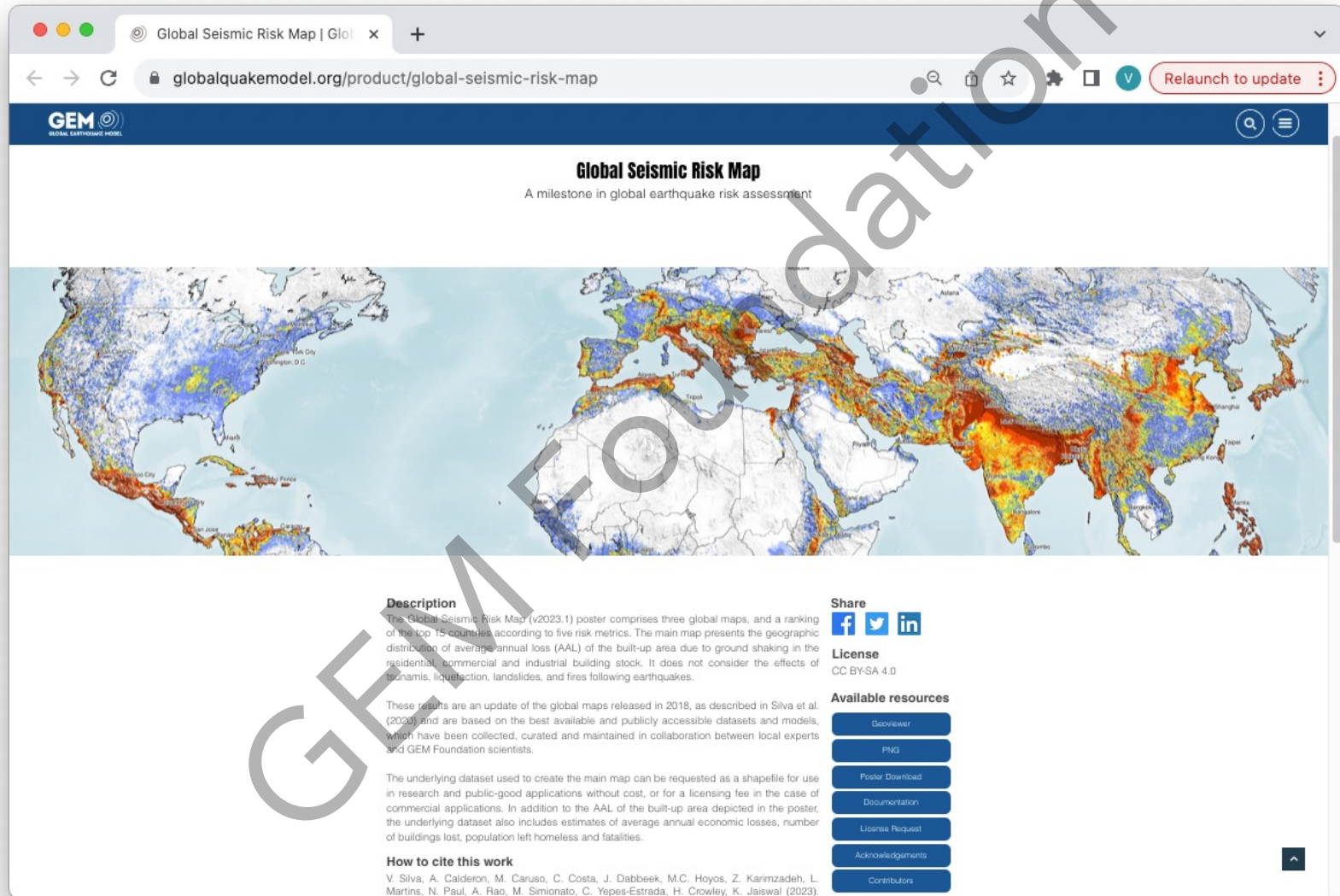
Sponsors and main partners

Global map of average annual loss of built area

Global map of the number of residential, commercial and industrial buildings

Description of GEM, the current global seismic risk products and terms of use

# BUT WHERE IS IT?



The screenshot shows a web browser displaying the 'Global Seismic Risk Map' website. The browser's address bar shows the URL 'globalquakemodel.org/product/global-seismic-risk-map'. The website header includes the GEM logo and navigation icons. The main content area features a world map with color-coded seismic risk levels, ranging from blue (low risk) to red (high risk). High-risk areas are concentrated in the Mediterranean-Himalayan region, the western Pacific, and parts of the western United States. Below the map, there is a 'Description' section, a 'Share' section with social media icons, a 'License' section (CC BY-SA 4.0), and an 'Available resources' section with buttons for Geoviewer, PNG, Poster Download, Documentation, License Request, Acknowledgements, and Contributors. A 'How to cite this work' section provides the citation: V. Silva, A. Calderon, M. Caruso, C. Costa, J. Dabbeek, M.C. Hoyos, Z. Karimzadeh, L. Martins, N. Paul, A. Rao, M. Simonato, C. Yepes-Estrada, H. Crowley, K. Jaiswal (2023).

## Global Seismic Risk Map

A milestone in global earthquake risk assessment

**Description**

The Global Seismic Risk Map (v2023.1) poster comprises three global maps, and a ranking of the top 15 countries according to five risk metrics. The main map presents the geographic distribution of average annual loss (AAL) of the built-up area due to ground shaking in the residential, commercial and industrial building stock. It does not consider the effects of tsunamis, liquefaction, landslides, and fires following earthquakes.

These results are an update of the global maps released in 2018, as described in Silva et al. (2020) and are based on the best available and publicly accessible datasets and models, which have been collected, curated and maintained in collaboration between local experts and GEM Foundation scientists.

The underlying dataset used to create the main map can be requested as a shapefile for use in research and public-good applications without cost, or for a licensing fee in the case of commercial applications. In addition to the AAL of the built-up area depicted in the poster, the underlying dataset also includes estimates of average annual economic losses, number of buildings lost, population left homeless and fatalities.

**How to cite this work**

V. Silva, A. Calderon, M. Caruso, C. Costa, J. Dabbeek, M.C. Hoyos, Z. Karimzadeh, L. Martins, N. Paul, A. Rao, M. Simonato, C. Yepes-Estrada, H. Crowley, K. Jaiswal (2023).

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**Available resources**

- Geoviewer
- PNG
- Poster Download
- Documentation
- License Request
- Acknowledgements
- Contributors



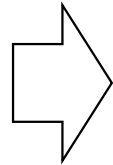
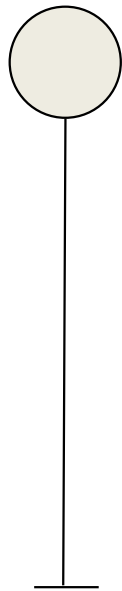
GEM GLOBAL SEISMIC RISK PRODUCTS

# FUTURE DEVELOPMENTS

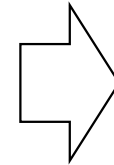
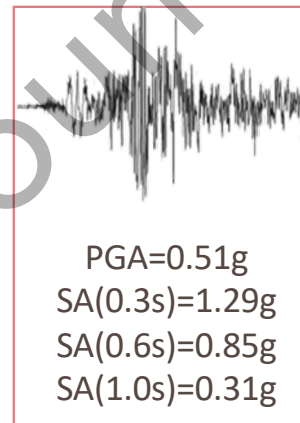
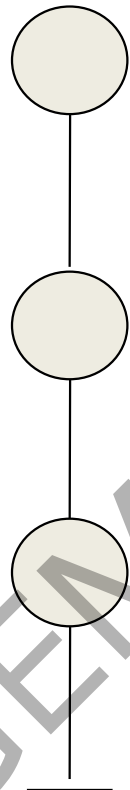
GEM Foundation

# NEW VULNERABILITY MODELLING APPROACH

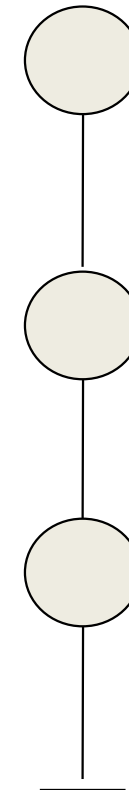
Eq. SDOF oscillator



Stick and mass MDOF model



Structural response



$\max\{\ddot{u}(t)\}=1.02g$ ;  
 $\max\{u(t)\}=3.30cm$

$\max\{\ddot{u}(t)\}=0.74g$   
 $\max\{u(t)\}=2.05cm$

$\max\{\ddot{u}(t)\}=0.74g$   
 $\max\{u(t)\}=2.03cm$

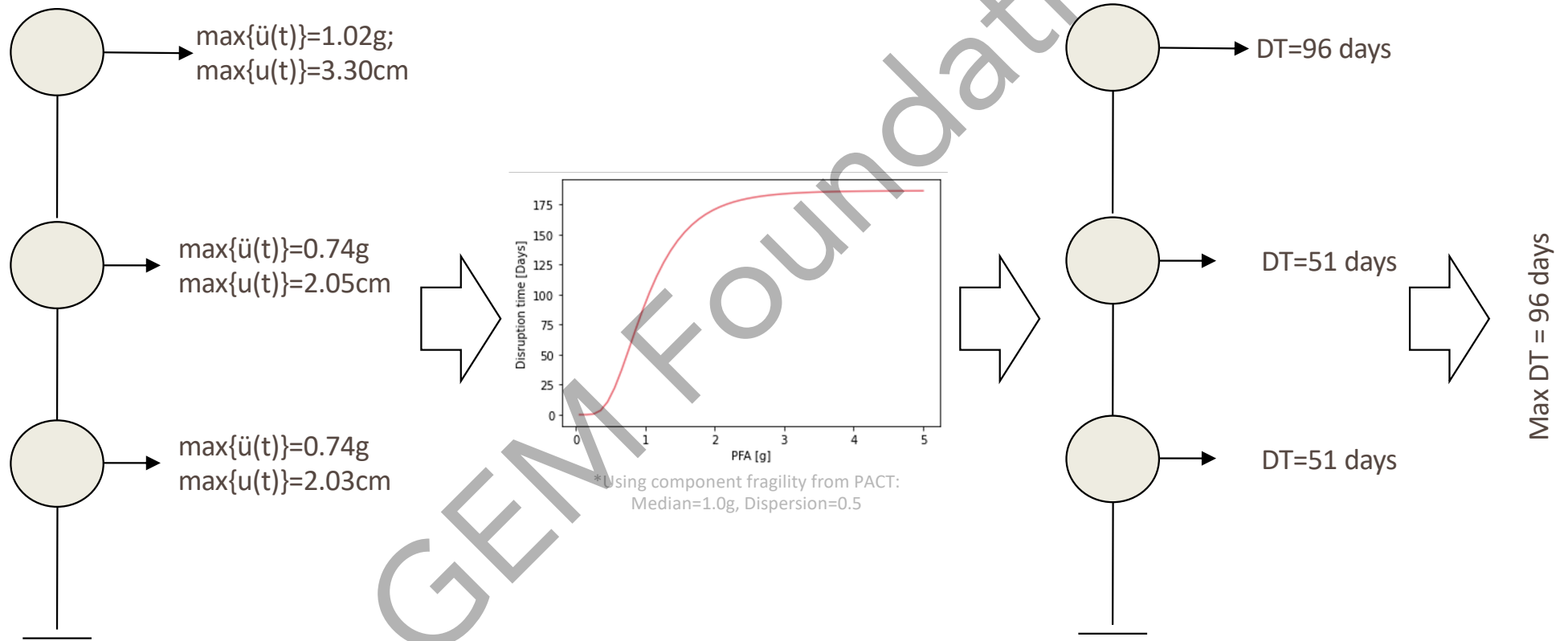
Supported by:



GLOBAL EARTHQUAKE MODEL

# NEW VULNERABILITY MODELLING APPROACH

Example of business interruption estimation based on one content (computer equipment)

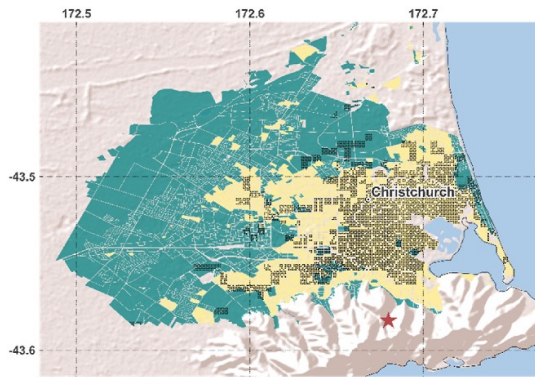




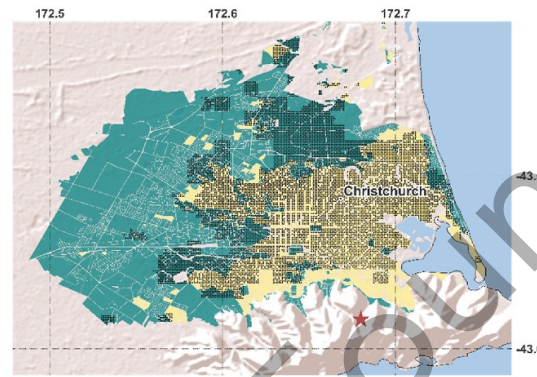
# STILL MUCH TO BE DONE

It is fundamental to go beyond the impact of ground shaking, and explore current or new methodologies to account for secondary hazards

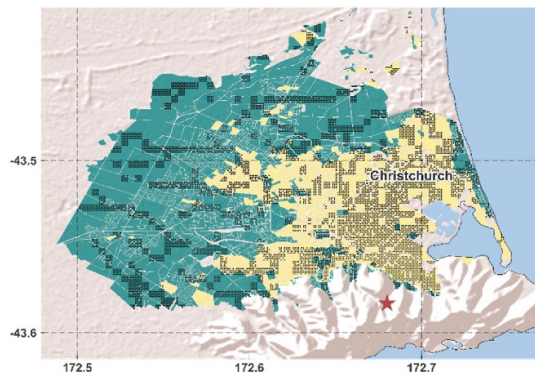
Zhu et al. 2015



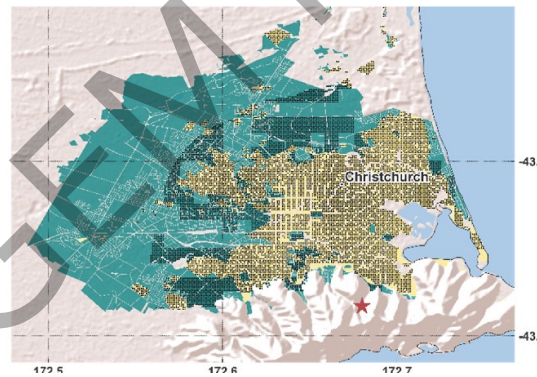
Zhu et al. 2017



Bozzoni et al. 2020



Todorovic and Silva 2022



★ Epicentre    ■ Liquefaction    ■ Nonliquefaction    ● Predicted occurrence

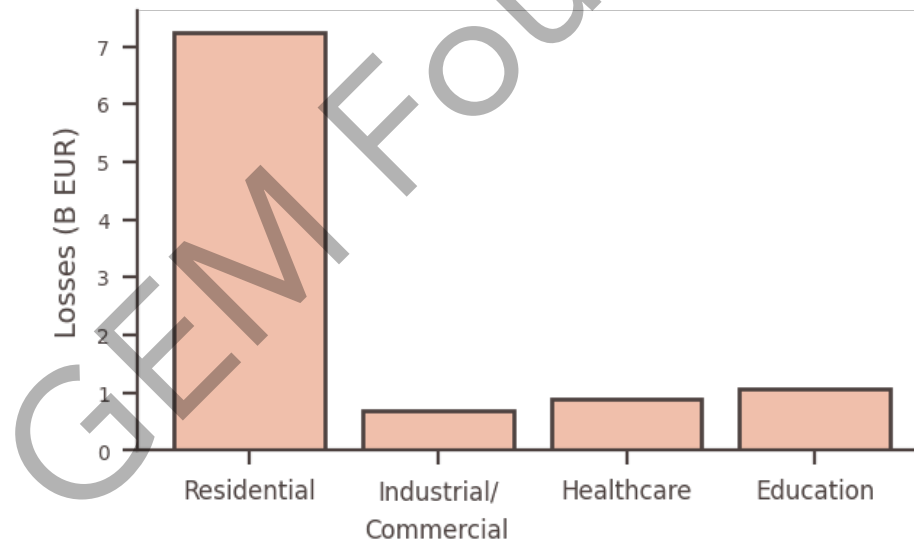
Some existing models already predict with a reasonable level of accuracy liquefaction occurrence, but the estimation of ground deformation is still challenging.

Todorovic L, Silva V (2022). A Liquefaction Occurrence Model for Regional Analysis. Soil Dynamics and Earthquake Engineering, 161:107430.

# STILL MUCH TO BE DONE

- It is fundamental to go beyond the impact of ground shaking, and explore current or new methodologies to account for **secondary hazards**.
- The current Global Seismic Risk Model covers the impact on residential, commercial and industrial building stock, but **governmental, healthcare and educational** facilities can also contribute significantly to the impact.

Direct economic losses due to the 2020 M5.5 Zagreb earthquake



# STILL MUCH TO BE DONE

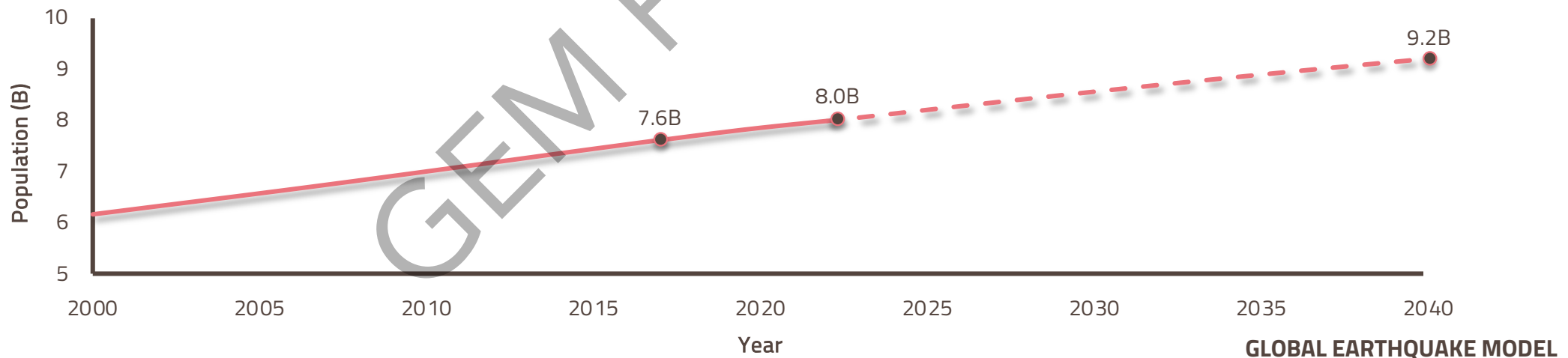
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- It is fundamental to go beyond the impact of ground shaking, and explore current or new methodologies to account for **secondary hazards**.
- The current Global Seismic Risk Model covers the impact on residential, commercial and industrial building stock, but **governmental, healthcare and educational** facilities can also contribute significantly to the impact.
- The current Global Seismic Risk Model covers direct losses, and neglects **indirect losses**. Moreover, it also does not cover damage in the infrastructure, nor the impact due to the disruption in these systems.

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# STILL MUCH TO BE DONE

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- The current Global Seismic Risk Model covers direct losses, and neglects **indirect losses**. Moreover, it also does not cover damage in the infrastructure, nor the impact due to the disruption in these systems.
- The Global Seismic Risk Model reflects current risk, which becomes rapidly obsolete. It is fundamental to incorporate **future exposure and vulnerability** in the global model.
- Some of the new risk metrics bring the current model to a more equitable risk assessment, but we are still far from having **equity in the risk** assessment process.

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# THANK YOU

VITOR.SILVA@GLOBALQUAKEMODEL.ORG

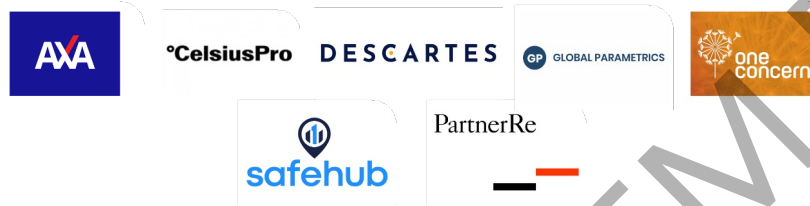
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<https://www.globalquakemodel.org>



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