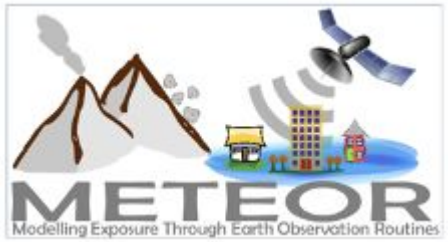

METEOR
Modelling Exposure Through Earth Observation Routines

# Disaster Risk Assessment for Earthquakes

*Produced as a part of a series of videos within the METEOR project*

# METEOR project




Modeling Exposure Through Earth Observation Routines

- Three-year project
- Funded by UK Space Agency
- Aims to develop innovative application of Earth Observation (EO) technologies to improve understanding of exposure
- Specific focus on pilot countries Nepal and Tanzania
- Consortium of eight organizations

funded by:

UK SPACE AGENCY

project consortium:

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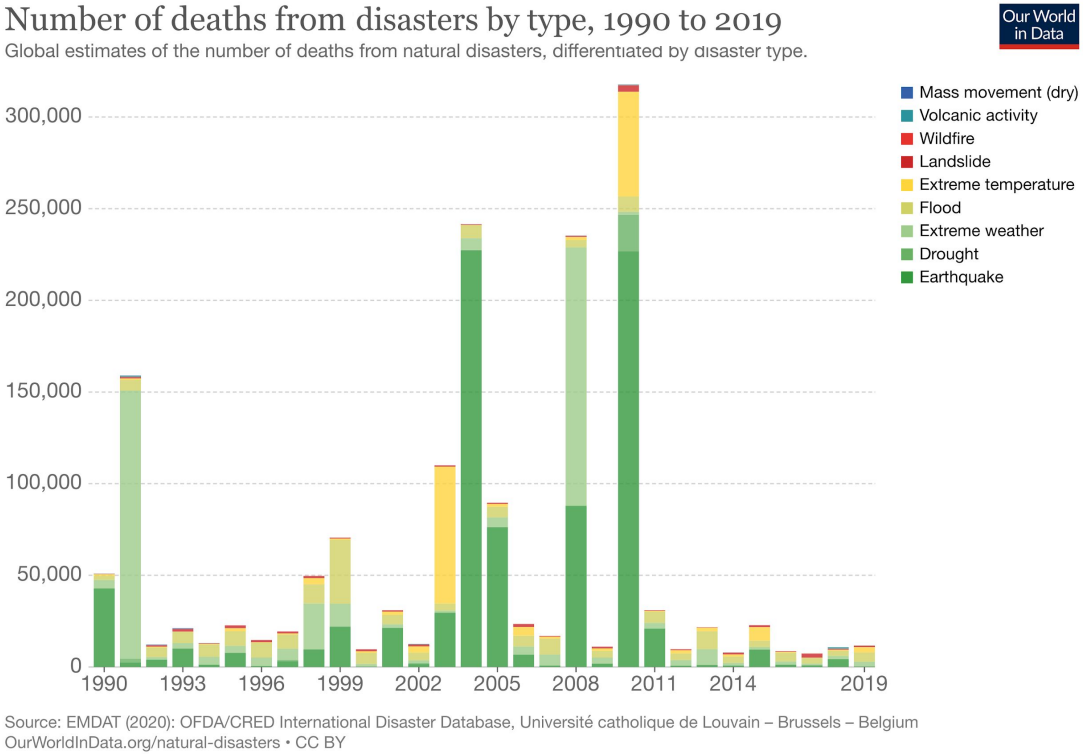
# Introduction

# Why disaster risk assessment?

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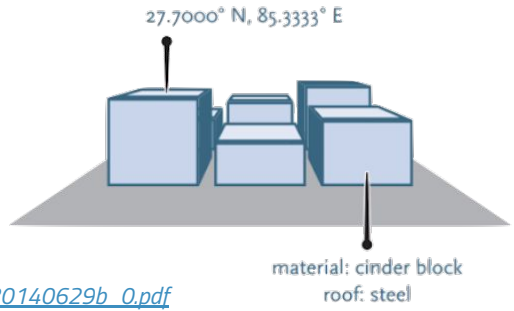
# Components of risk

## HAZARD

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

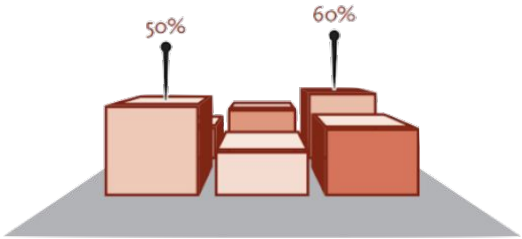
## EXPOSURE

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.




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

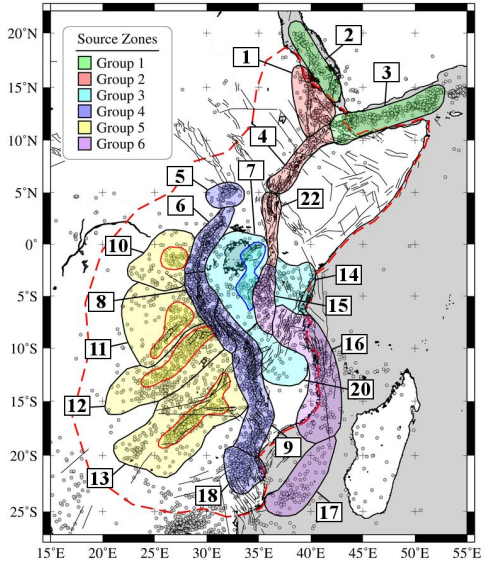
**HAZARD** **EXPOSURE** **VULNERABILITY**

The **RISK** occurs when there is a spatial and temporal overlap of these three elements

# Hazard

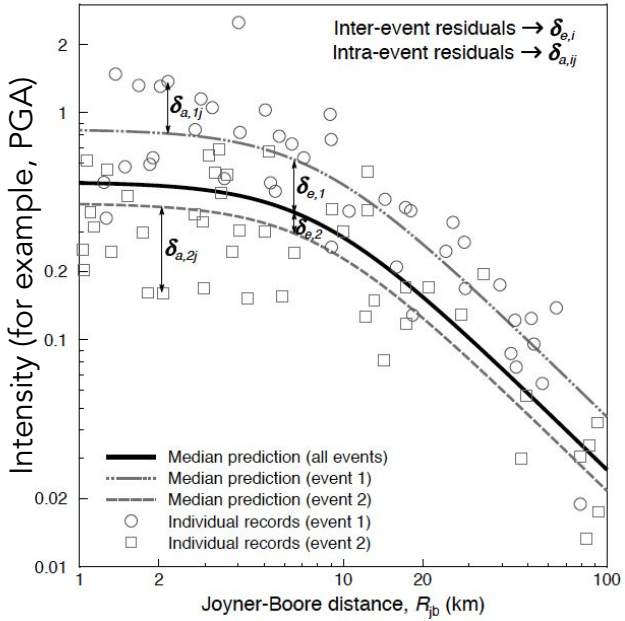
# Hazard | Components of a hazard model

## Seismic source characterization




Poggi, V., Durrheim, R., Mavonga Tuluka, G., Weatherill, G., Gee, R., Pagani, M., Nyblade, A., Delvaux, D., 2017. Assessing Seismic Hazard of the East African Rift: a pilot study from GEM and AfricaArray. *Bulletin of Earthquake Engineering.* Volume 15, Issue 11, 4499–4529, DOI: 10.1007/s10518-017-0152-4

## Ground motion characterization

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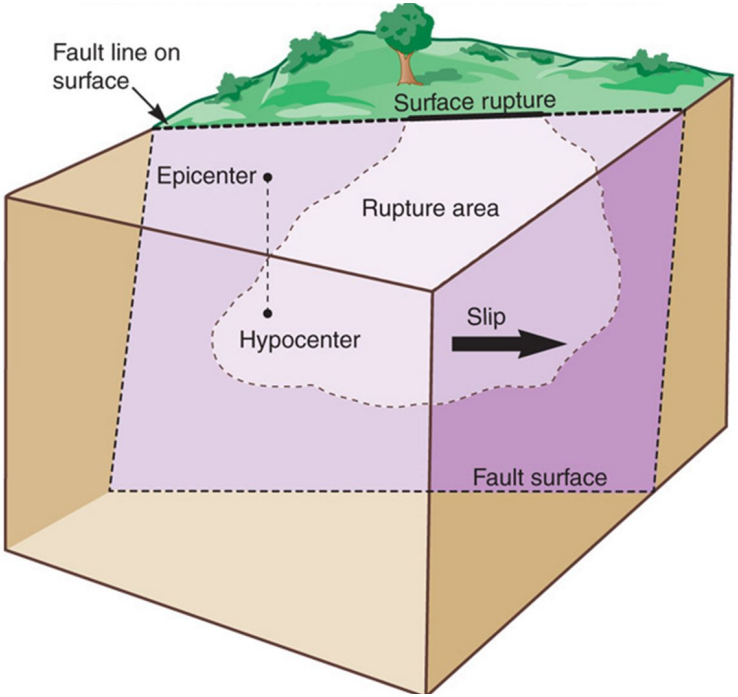
# Hazard | Faults and ruptures

**Fault**

plane of discontinuity in the earth's crust

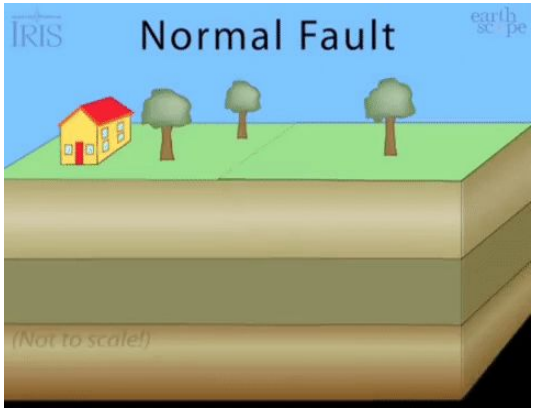
**Rupture**

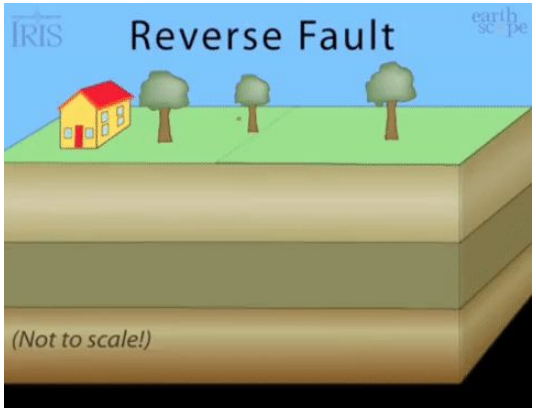
portion of the fault area that slips in a seismic event

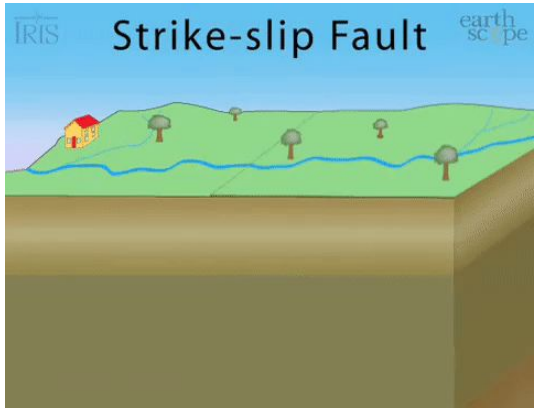



Source: J.Ziony, ed. “Earthquakes in the Los Angeles Region.” USGS

# Hazard | Fault mechanisms




## Normal Fault

The earth blocks move away from each other

## Reverse Fault

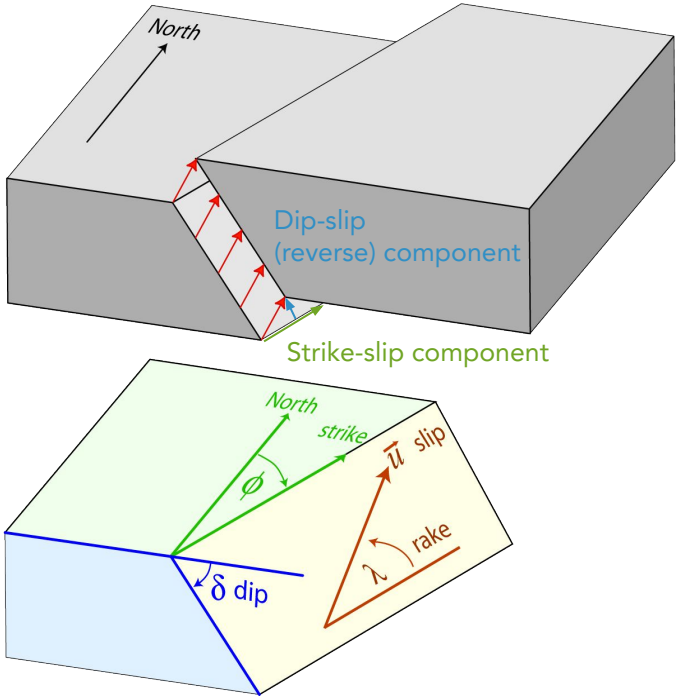
The earth blocks exert compression on each other

## Strike-slip Fault

The earth blocks slide without compression or tension

Source: https://www.iris.edu/hq/inclass/animation/

# Hazard | Rupture parameters




Source: OpenQuake Manual

**Strike** Angle between the intersection of the fault plane with a horizontal surface (relative to the North)

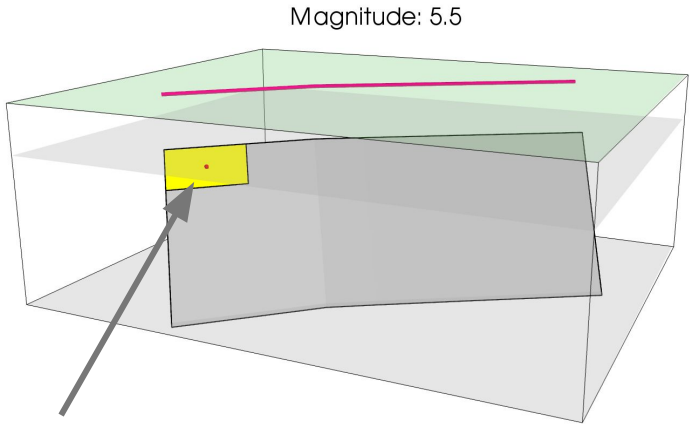
**Dip** Angle between the fault and a horizontal plane

**Rake** Direction in which the hanging wall moves during rupture

# Hazard | Defining a seismic rupture

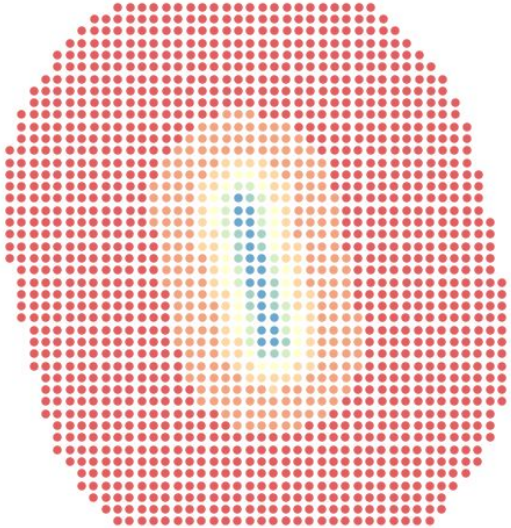
**Fault Source**

- Geometry
- Magnitude
- Mechanism




**Seismic Rupture**

**Ground Motion Field from 1 Rupture**



Acceleration - PGA

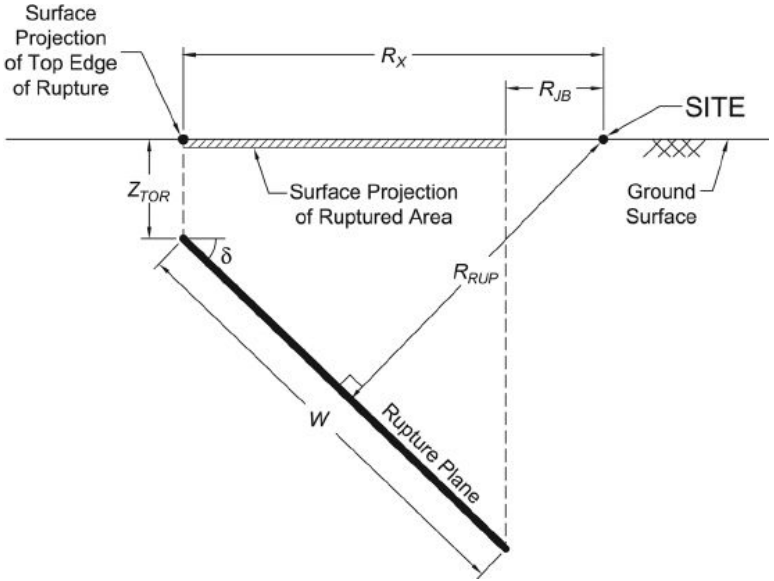
# Hazard | Ground motion prediction equations

$$\underbrace{\ln y}_{1} \underbrace{= c_1 + c_2 m + c_3 m^{c_4}}_{2} \underbrace{+ c_5 \ln r}_{3} \underbrace{+ f(F) + f(HW) + f(S)}_{4}$$

**y:** Expected ground motion intensity (PGA, SA)
**m:** Magnitude
**r:** Distance
**F:** Fault mechanism
**HW:** Site location, with respect to the fault plane
**S:** Local site conditions

# Hazard | Ground motion distance metrics

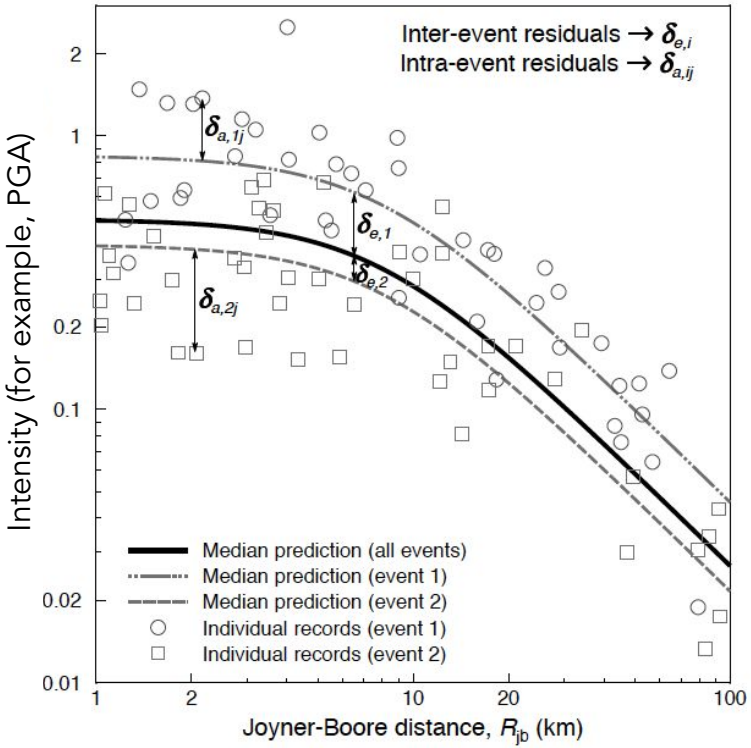
Kaklamanos et al. (2011) DOI: 10.1193/1.3650372




$R_{JB}$ Joyner-Boore Distance

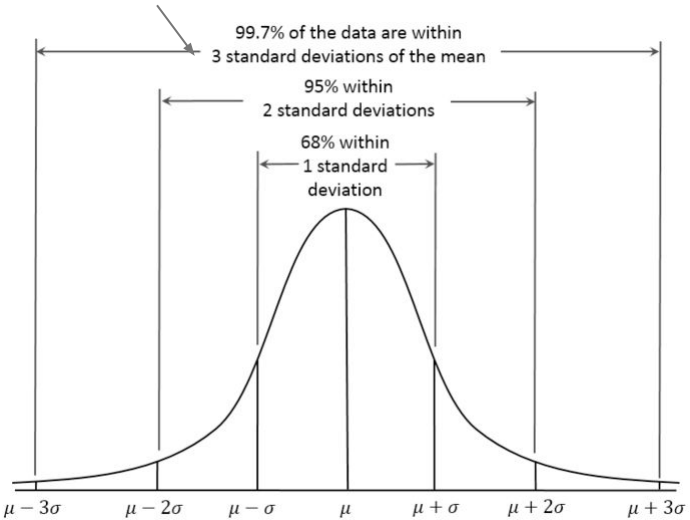
$R_{RUP}$ Distance between the site and the hypocenter

# Hazard | Ground motion variability




The ground motion intensity has an associated variability, observed in the same event and in different events, although it is the same type of rupture, magnitude and distance

*A truncation level of 3 considers 99.7% of the variability*

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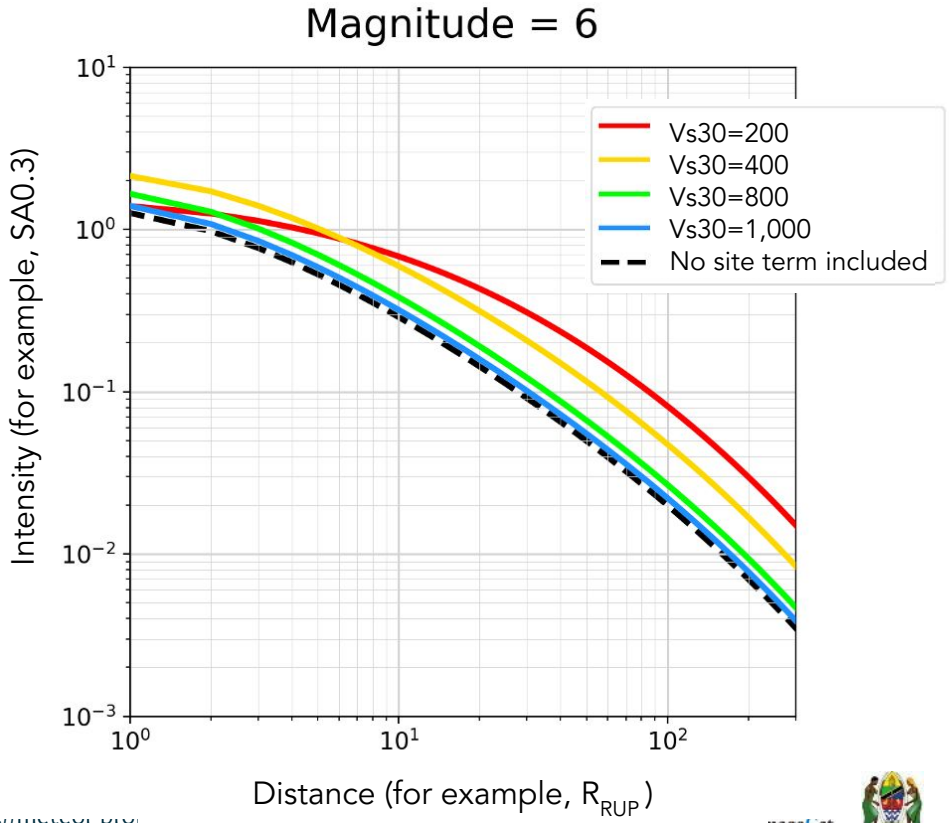
# Hazard | Site effects



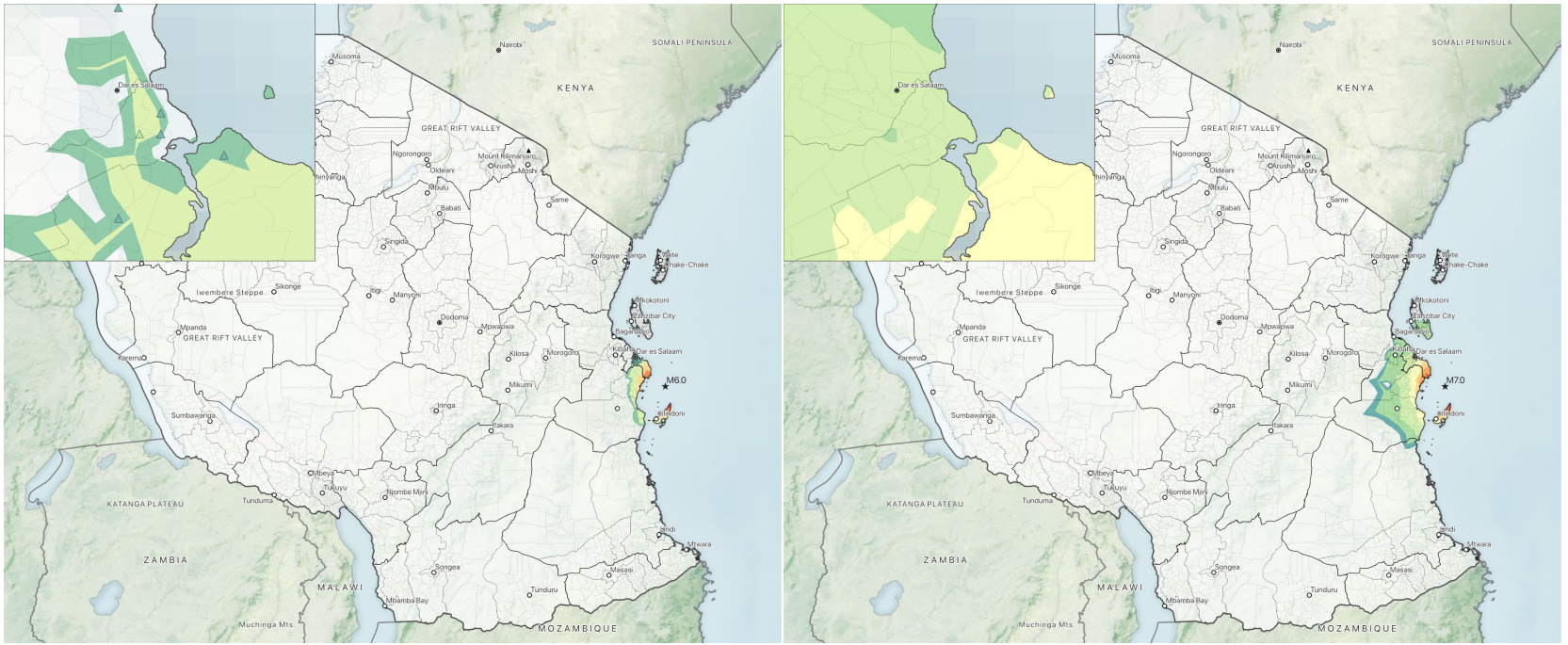

Softer soils can amplify ground shaking, often referred to as a “site effect”

The shear wave velocity in the top 30 meters, VS,30, is used as a proxy for modeling site effects

# Hazard | Scenario hazard modeling

Actual magnitude, M6.0

Modified magnitude, M7.0

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Estimated shaking, PGA

- 0.025 - 0.050g
- 0.050 - 0.075g
- 0.075 - 0.100g
- 0.100 - 0.125g
- 0.125 - 0.150g
- 0.150 - 0.175g
- 0.175 - 0.200g
- > 0.200 g

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# Exposure

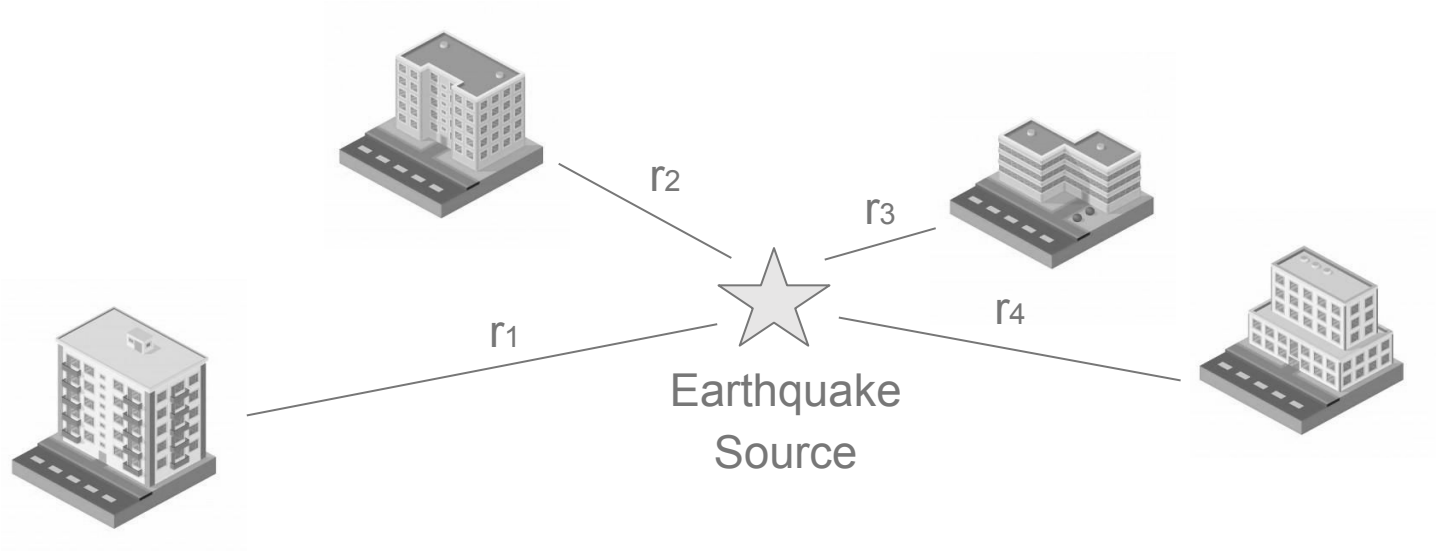
# Exposure | Components of an exposure model

The exposure refers to the built environment and its contents and occupants, which are exposed to a seismic hazard source.

Necessary parameters include the geographic location and replacement value for all loss types to be considered (e.g. financial loss due to building damage, casualties).

# Exposure | Geographic attribute of assets

It is necessary to identify the geographical location of the exposed elements with respect to the source(s) of seismicity, since the ground motion intensity is a function of the distance to the source.



# Exposure | Value attribute of assets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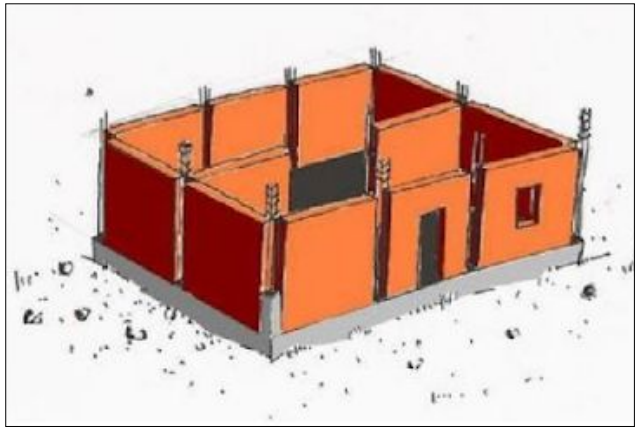
# Exposure | Structural attributes of assets

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





Some of the main attributes that can be identified are:

construction material, structural system, height and construction code compliance

**GEM Taxonomy:** https://platform.openquake.org/taxtweb/

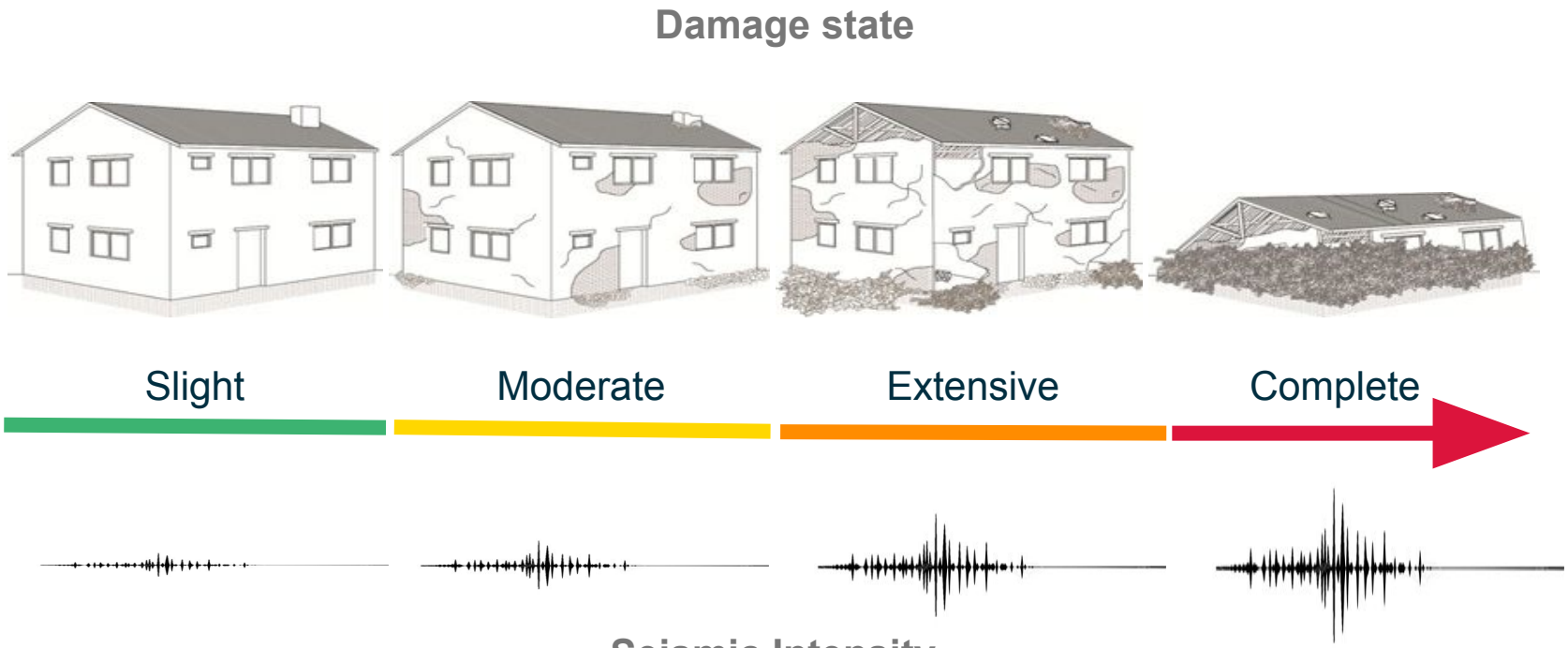
# Vulnerability

# Vulnerability | Fragility and vulnerability models

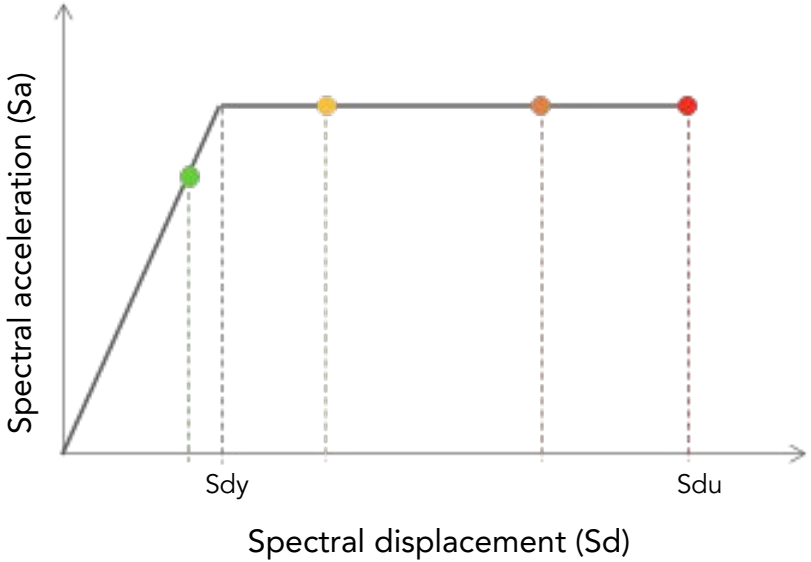
Seismic fragility and vulnerability refers to the likelihood that the built environment, its contents and occupants have, to suffer damage and losses due to earthquake ground shaking.

Fragilities require an additional consequence model (damage-to-loss) if losses are desired.

# Vulnerability | Defining seismic fragilities



# Vulnerability | Defining damage states



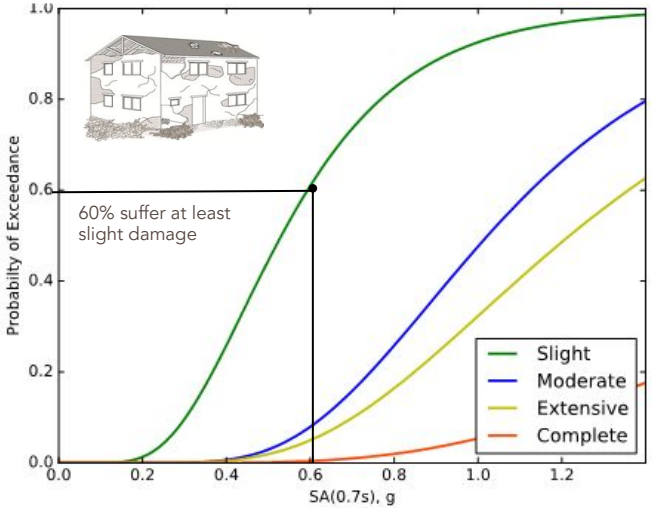

Example damage criteria

| | |
|---|---|
| Slight | = 0.7*Sdy |
| Moderate | = 0.7*Sdy + 0.25*Sdu |
| Extensive | = 0.5*(Sdy + Sdu) |
| Complete | = Sdu |

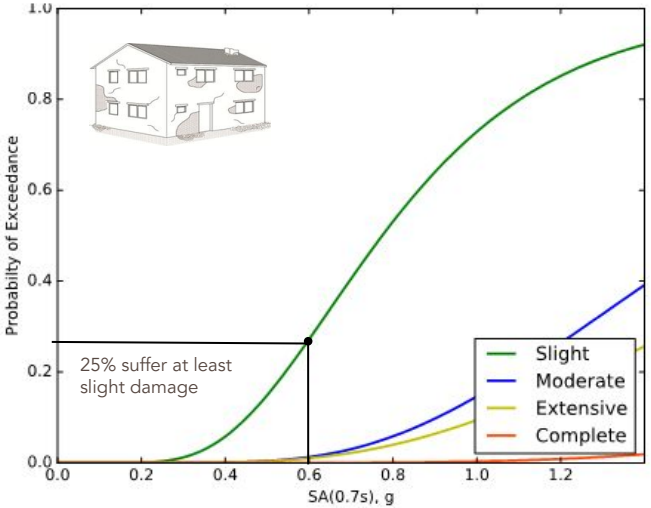
Damage states establish the level of damage that an exposed asset will experience under certain engineering demand parameters (EDPs) are met. Example EDPs include: spectral displacement, spectral acceleration, interstory drift, and peak floor acceleration.

# Vulnerability | Fragility models

## Pre-code Building



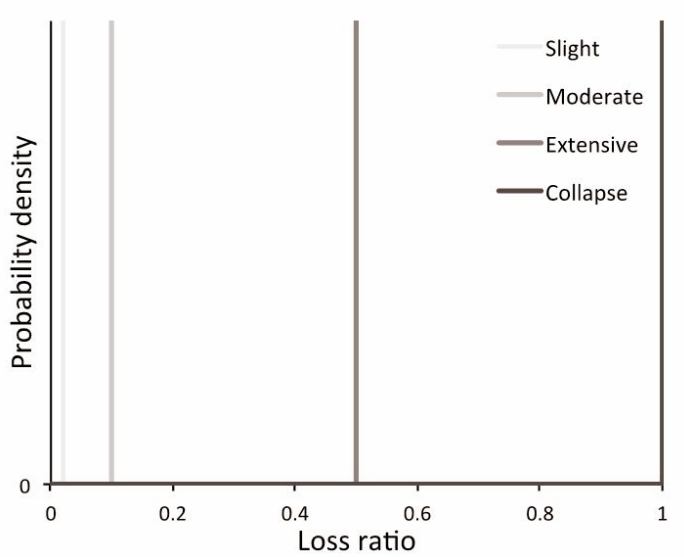

## Code Compliant Building



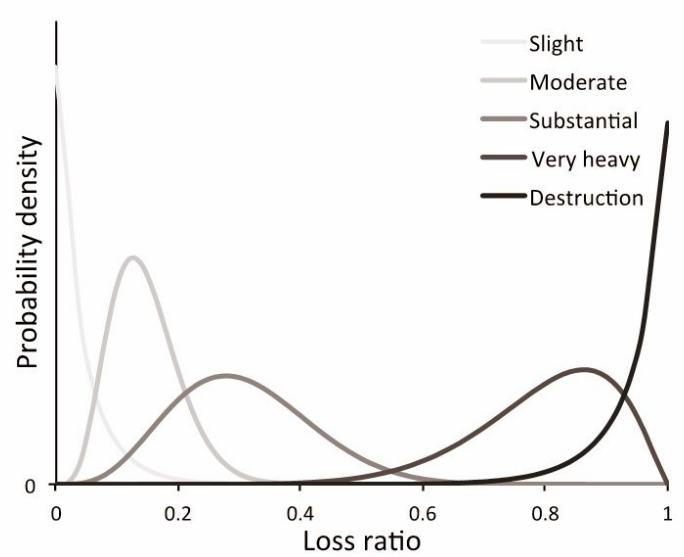

The structural attributes of a building (e.g. construction material, construction system, height, design regulations) directly influence its fragility, making it more or less vulnerable to ground agitation.

# Vulnerability | Consequence models

## Deterministic

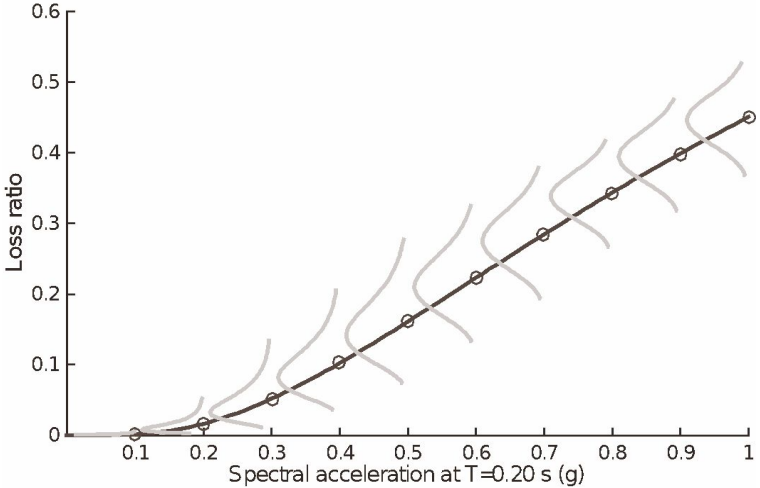



## Probabilistic

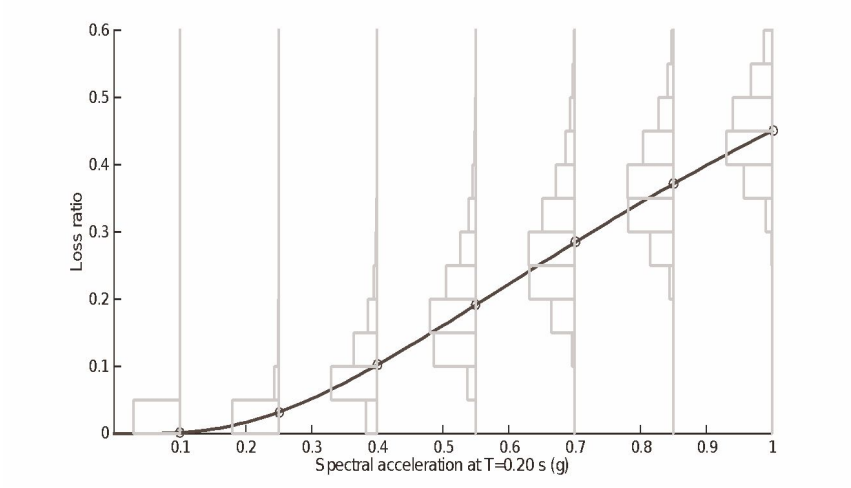



A consequence model (also known as damage-to-loss model) establishes the relation between a physical damage state and the corresponding loss-ratio.

# Vulnerability | Vulnerability models




**Continuous distribution of loss ratio**
**Lognormal distribution**



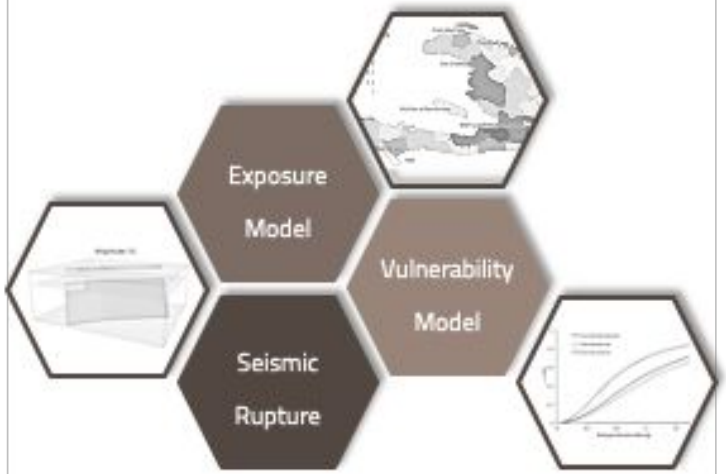

**Discrete distribution of loss ratio**
**with probability mass functions**

A vulnerability model establishes the probability of a given loss ratio for a set of intensity measure levels

# Risk

# Risk | Conducting a risk analysis

Inputs

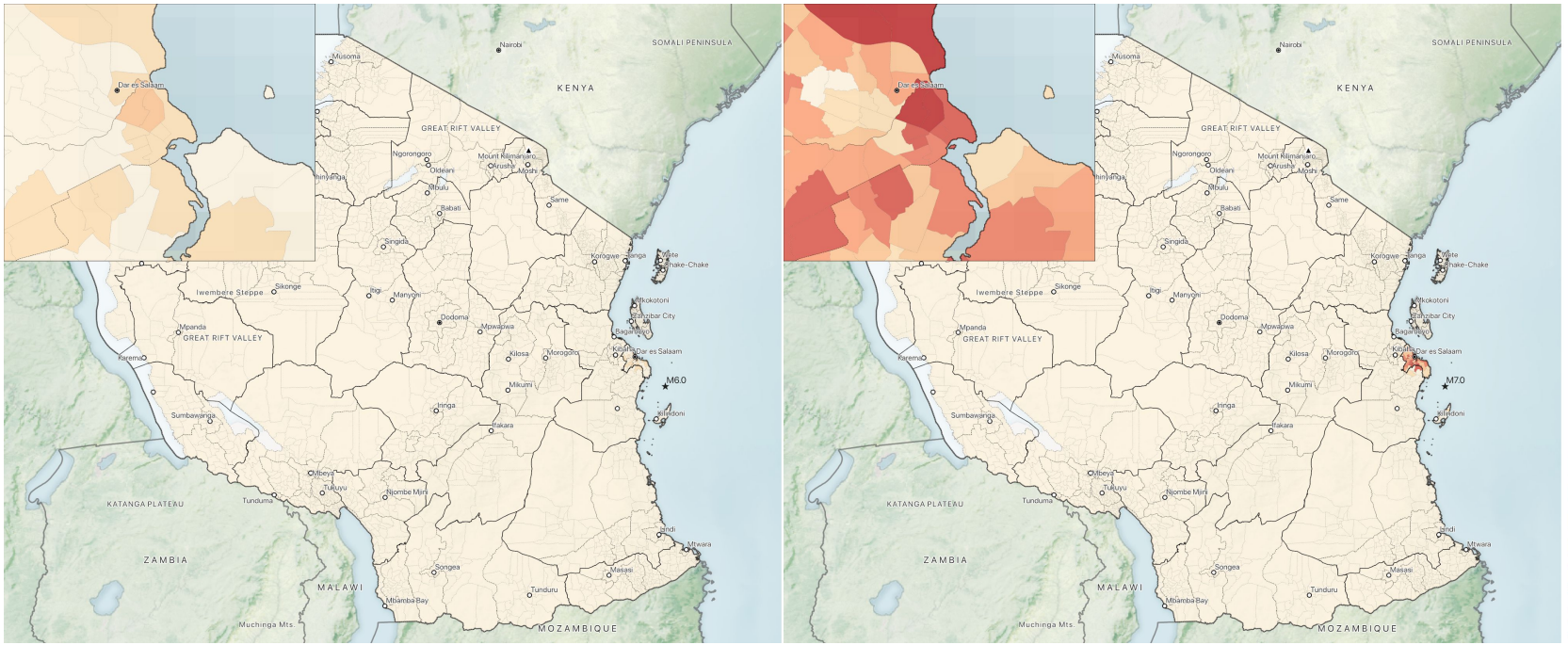



Outputs

# Risk | Scenario loss map

Actual magnitude, M6.0

Modified magnitude, M7.0

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Estimated losses

Residential (USD)

- $0M - $1M
- $1M - $3M
- $3M - $5M
- $5M - $7M
- $7M - $10M
- $10M - $18M
- $18M - $31M

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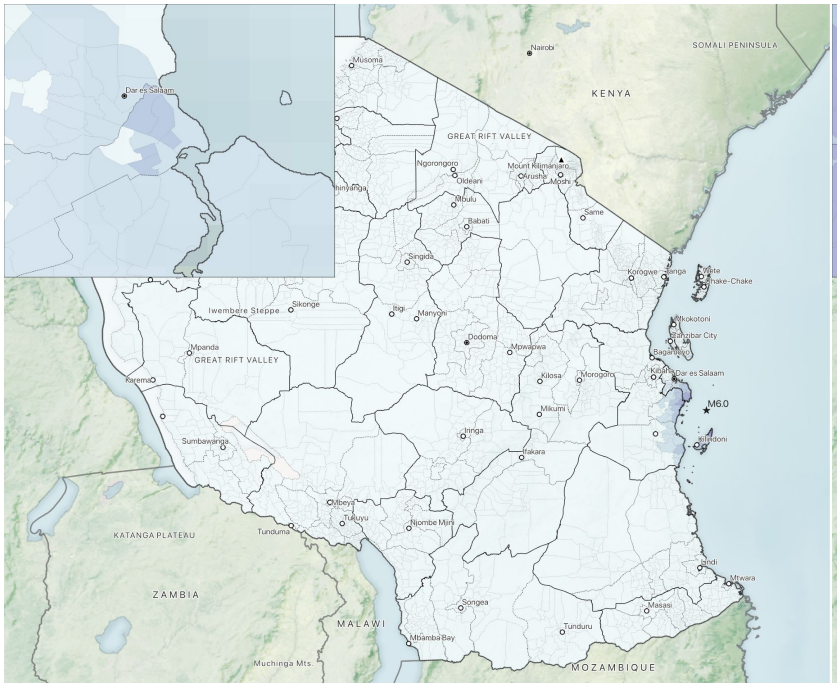
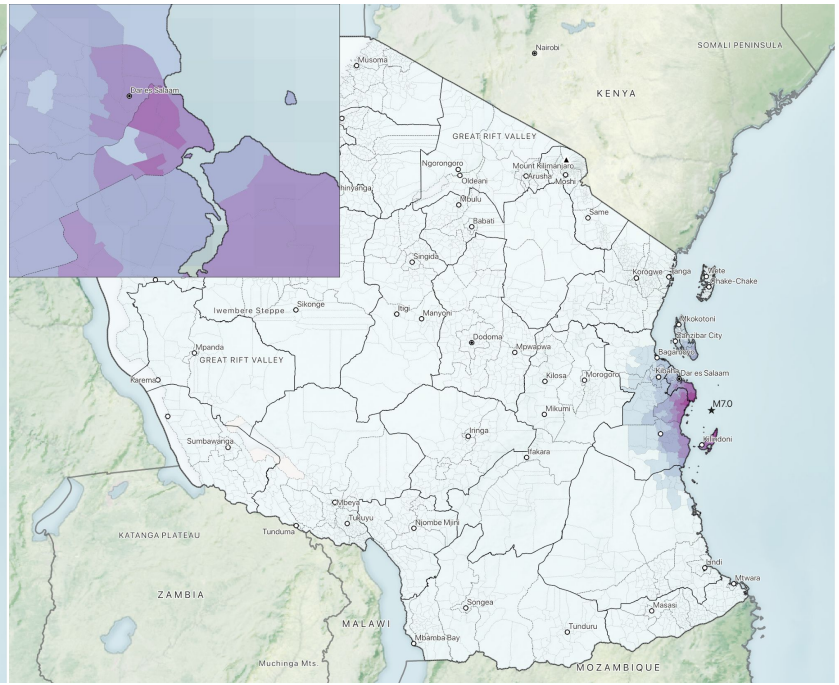
# Risk | Scenario loss ratio map

Actual magnitude, M6.0

Modified magnitude, M7.0

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Estimated losses

Residential

- 0% - 0.2%
- 0.2% - 0.7%
- 0.7% - 1.5%
- 1.5% - 2.7%
- 2.7% - 4.2%
- 4.2% - 6.8%
- 6.8% - 12%

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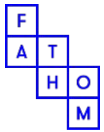





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