METEOR

Modelling Exposure Through Earth Observation Routines

Disaster Risk Assessment for Earthquakes: Demonstration

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

METEOR project

Modeling Exposure Through Earth Observation Routines

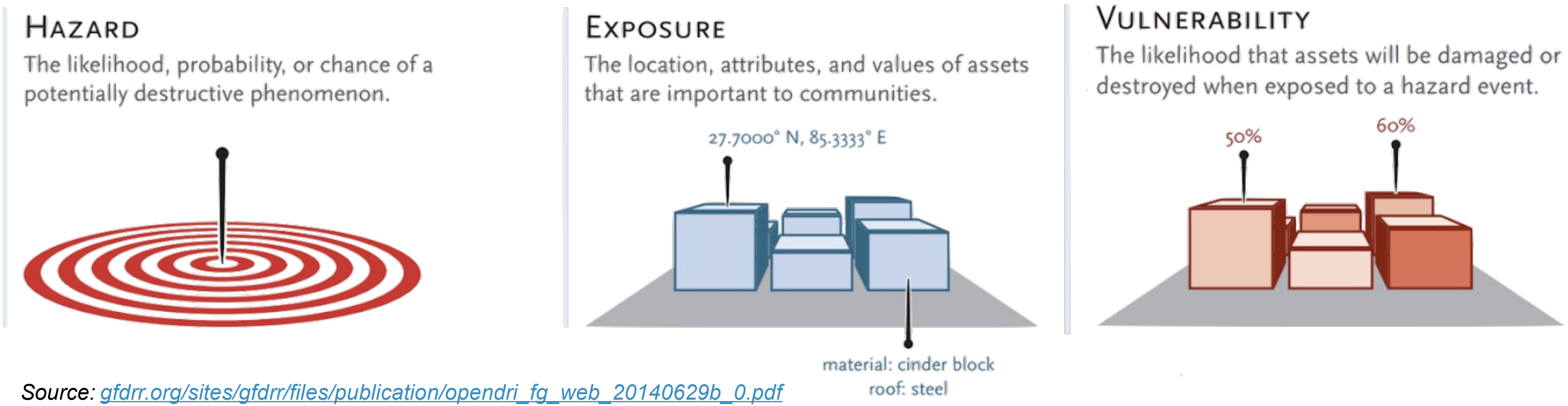
- Three-year project
- Funded by UK Space Agency
- Aims to develop innovative application of Earth Observation (EO) technologies to improve understanding of exposure
- Specific focus on pilot countries Nepal and Tanzania
- Consortium of eight organizations

funded by:

project consortium:

https://meteor-project.org

Components of risk



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

OpenQuake Engine

Combines seismic hazard and risk calculations

Probabilistic and deterministic calculations

Supports calculations at different scales

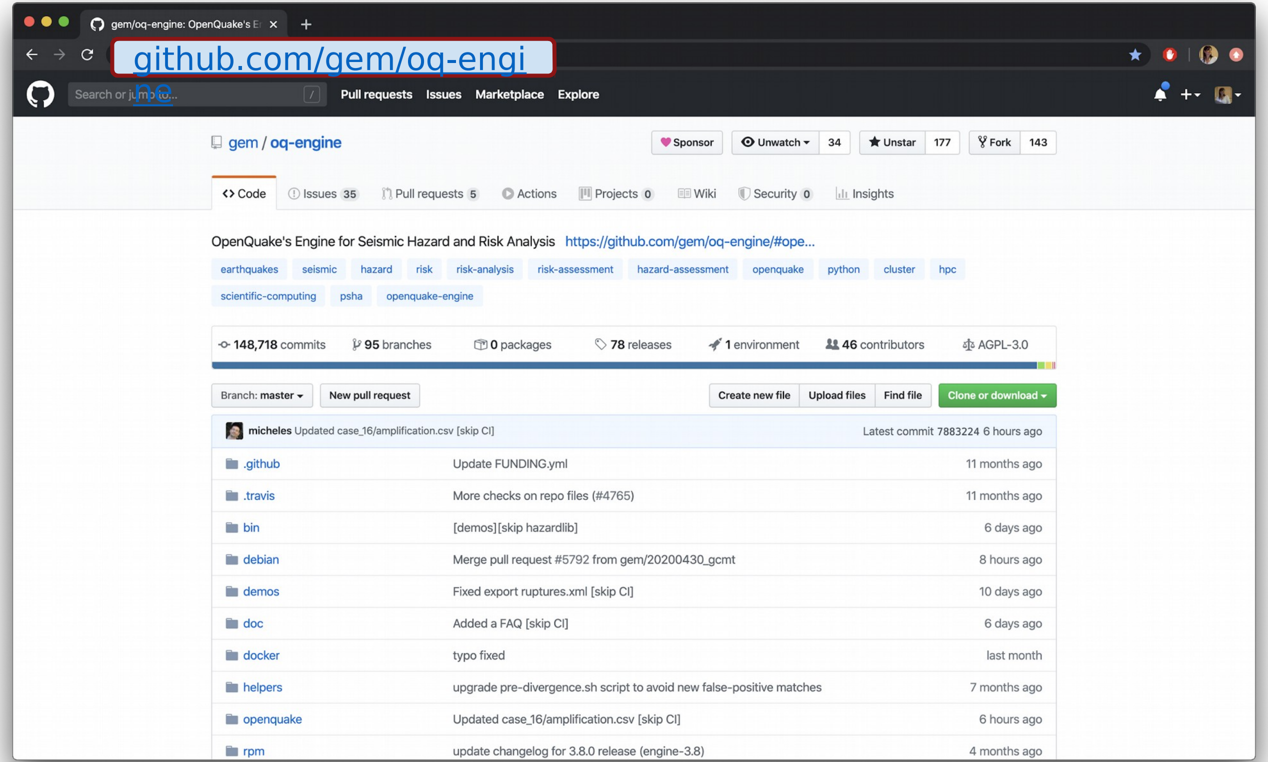
Incorporates a wide spectrum of uncertainties

Runs in single computers or clusters

Free, public and open source code

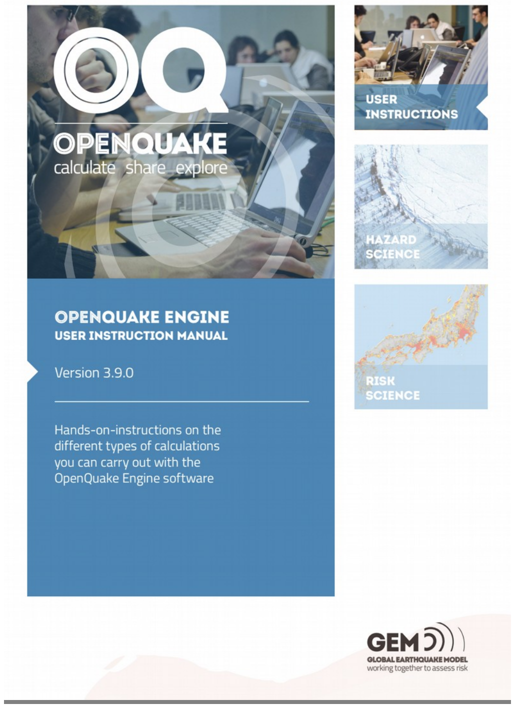
Installing OpenQuake Engine

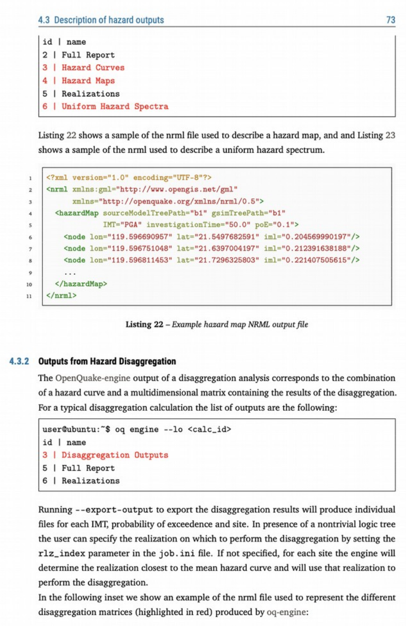
github.com/gem/oq-engine



OpenQuake Engine Manual

https://docs.openquake.org/manuals/






```
id | name
2 | Full Report
3 | Hazard Curves
4 | Hazard Maps
5 | Realizations
6 | Uniform Hazard Spectra
```

Listing 22 shows a sample of the nrml file used to describe a hazard map, and and Listing 23 shows a sample of the nrml used to describe a uniform hazard spectrum.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<nrml xmlns:gml="http://www.opengis.net/gml"
      xmlns="http://openquake.org/xmlns/nrml/0.5">
  <hazardMap sourceModelTreePath="b1" gsimTreePath="b1"
             IMT="PGA" investigationTime="50.0" poE="0.1">
    <node lon="119.596690957" lat="21.5497682591" iml="0.204569990197"/>
    <node lon="119.596751048" lat="21.6397004197" iml="0.212391638188"/>
    <node lon="119.596811453" lat="21.7296325803" iml="0.221407505615"/>
    ...
  </hazardMap>
</nrml>
```

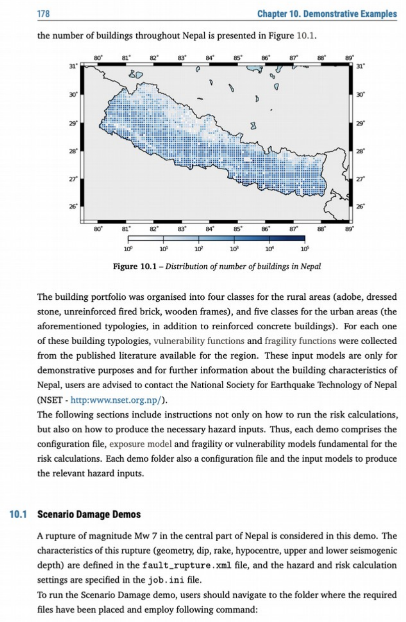
Listing 22 – *Example hazard map NRML output file*

4.3.2 Outputs from Hazard Disaggregation

The OpenQuake-engine output of a disaggregation analysis corresponds to the combination of a hazard curve and a multidimensional matrix containing the results of the disaggregation. For a typical disaggregation calculation the list of outputs are the following:

```
user@ubuntu:~$ oq engine --lo <calc_id>
id | name
3 | Disaggregation Outputs
5 | Full Report
6 | Realizations
```

Running `--export-output` to export the disaggregation results will produce individual files for each IMT, probability of exceedence and site. In presence of a nontrivial logic tree the user can specify the realization on which to perform the disaggregation by setting the `rlz_index` parameter in the `job.ini` file. If not specified, for each site the engine will determine the realization closest to the mean hazard curve and will use that realization to perform the disaggregation.
In the following inset we show an example of the nrml file used to represent the different disaggregation matrices (highlighted in red) produced by oq-engine:



the number of buildings throughout Nepal is presented in Figure 10.1.

Figure 10.1 – *Distribution of number of buildings in Nepal*

The building portfolio was organised into four classes for the rural areas (adobe, dressed stone, unreinforced fired brick, wooden frames), and five classes for the urban areas (the aforementioned typologies, in addition to reinforced concrete buildings). For each one of these building typologies, vulnerability functions and fragility functions were collected from the published literature available for the region. These input models are only for demonstrative purposes and for further information about the building characteristics of Nepal, users are advised to contact the National Society for Earthquake Technology of Nepal (NSET - http:www.nset.org.np/).
The following sections include instructions not only on how to run the risk calculations, but also on how to produce the necessary hazard inputs. Thus, each demo comprises the configuration file, exposure model and fragility or vulnerability models fundamental for the risk calculations. Each demo folder also a configuration file and the input models to produce the relevant hazard inputs.

10.1 Scenario Damage Demos

A rupture of magnitude Mw 7 in the central part of Nepal is considered in this demo. The characteristics of this rupture (geometry, dip, rake, hypocentre, upper and lower seismogenic depth) are defined in the `fault_rupture.xml` file, and the hazard and risk calculation settings are specified in the `job.ini` file.
To run the Scenario Damage demo, users should navigate to the folder where the required files have been placed and employ following command:

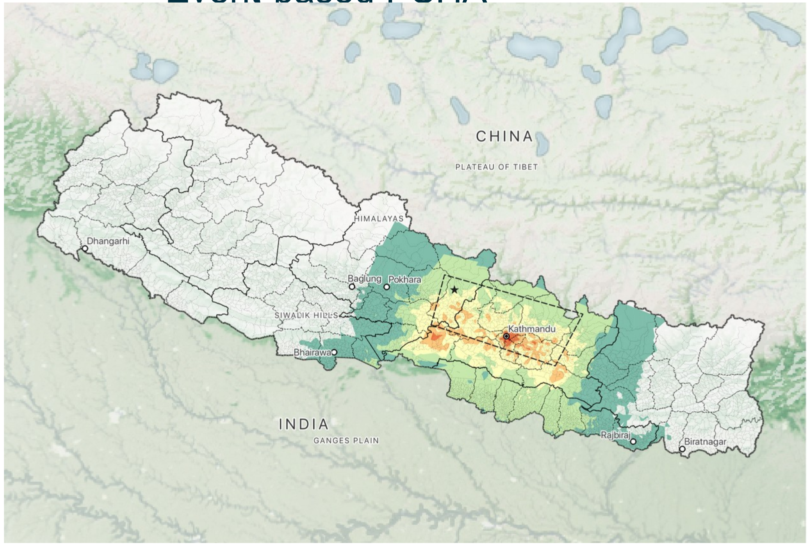
OpenQuake Engine Calculators

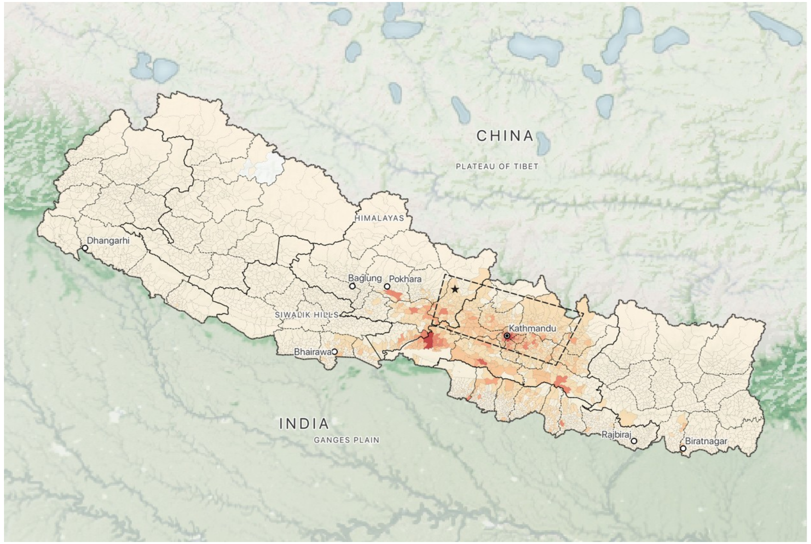
Hazard

- Scenario Hazard
- Classical PSHA
- Event-based PSHA

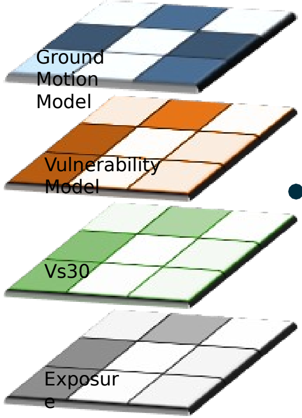
Risk

- Scenario Damage or Loss
- Classical Damage or Loss
- Event-based Damage or Loss





OpenQuake Engine Scenario Model



Input files

Files needed to run hazard or risk calculations (i.e. exposure model, vulnerability model, Vs30, GMPEs)

OpenQuake Engine

Specific calculators of the engine (e.g. scenario, scenario_damage, scenario_risk)

Output files

Results for the corresponding calculation (e.g. ground motion fields, damage maps, risk maps)

Useful links for OpenQuake

- Main OpenQuake site (versions, installers and development):
  https://github.com/gem/oq-engine
- OpenQuake Documentation: Hazard and risk manuals, QA testing
  https://docs.openquake.org/manuals/
- OpenQuake Input Preparation Toolkit (online version):
  https://platform.openquake.org/ipt
- OpenQuake Support Forum:
  https://groups.google.com/g/openquake-users

Running OpenQuake

Command Line

Command line

OpenQuake manual

Web Interface

Graphical web browser interface to run OQ calculations

Plugins:
- Input Preparation Toolkit - IPT
- QGIS

Command line basics

Running the model

> oq engine --run path/to/job.ini

Listing all results

> oq engine --lo <calc_id>

Exporting a specific result

> oq engine --eo <output_id> *path/to/output/folder*

Exporting all results

> oq engine --eos <calc_id> *path/to/output/folder*

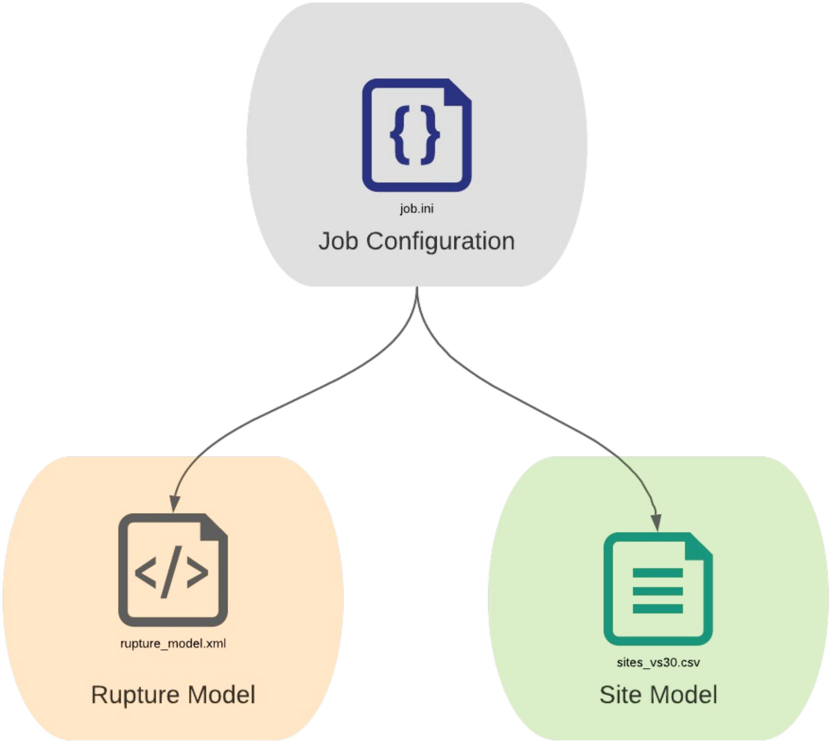
Starting the web interface

> oq webui start

Demo #1: Scenario Hazard

Scenario hazard | Input and output files

Scenario hazard | Input files



Scenario hazard | Job configuration file

```
[general]
description = 2015 Gorkha (Scenario Hazard)
calculation_mode = scenario
# example comment

[rupture]
rupture_model_file = rupture_model.xml
rupture_mesh_spacing = 2.0

[sites]
site_model_file = sites_vs30.csv

[hazard_calculation]
intensity_measure_types = PGA, SA(0.3)
gsim = CampbellBozorgnia2014
truncation_level = 3.0
maximum_distance = 500
number_of_ground_motion_fields = 100

[output]
export_dir = out
```

← description of your model
← desired OQ-engine calculator
← example of a comment or note (not used in analysis)

← rupture model path
← mesh size (in km) used to discretize the rupture in OQ

← site model path

← desired intensity measures
← desired ground motion prediction model (GMPE)
← desired truncation level for GMPE
← max distance from source to compute ground motion
← desired number of stochastic ground motion fields

← desired output directory

Scenario hazard | Rupture model file

```xml
<?xml version="1.0" encoding="utf-8"?>
<nrml xmlns:gml="http://www.opengis.net/gml" xmlns="
http://openquake.org/xmlns/nrml/0.4">

  <singlePlaneRupture>

    <magnitude>7.8</magnitude>
    <rake>100</rake>
    <hypocenter lon="84.731" lat="28.231"depth="8"/>

    <planarSurface strike="293" dip="7">
      <bottomLeft  lon="84.62" lat="28.40" depth="20"/>
      <bottomRight lon="86.17" lat="27.96" depth="20"/>
      <topLeft     lon="84.47" lat="27.84" depth="13"/>
      <topRight    lon="85.86" lat="27.38" depth="13"/>
    </planarSurface>

  </singlePlaneRupture>

</nrml>
```

The rupture model file defines the scenario:

- Magnitude
- Geometry
- Mechanism

In this example, we are using the parameters described by the USGS finite fault model for the 2015 Gorkha earthquake
https://earthquake.usgs.gov/earthquakes/eventpage/us20002926/finite-fault?source=us&code=us20002926

The Input Preparation Toolkit (IPT) can be used to create your own rupture model file:
https://platform.openquake.org/ipt/

Scenario hazard | Site model file

lon	lat	vs30	z1pt0	z2pt5	vs30measured
87.6574	27.3591	880.94	17.62	0.51	1
87.6963	27.3795	900.0	15.46	0.5	1
87.7225	27.4006	900.0	15.46	0.5	1
87.7322	27.448	900.0	15.46	0.5	1
87.6774	27.3319	900.0	15.46	0.5	1
87.9067	27.4038	900.0	15.46	0.5	1
87.8486	27.4308	900.0	15.46	0.5	1
87.8601	27.3874	636.16	98.8	0.74	1
87.8329	27.3749	900.0	15.46	0.5	1
88.0246	27.561	619.68	110.45	0.77	1
87.7069	27.3178	900.0	15.46	0.5	1
87.7482	27.3087	867.49	19.34	0.52	1
87.7773	27.4064	900.0	15.46	0.5	1
87.7485	27.3493	900.0	15.46	0.5	1
87.8318	27.3371	900.0	15.46	0.5	1

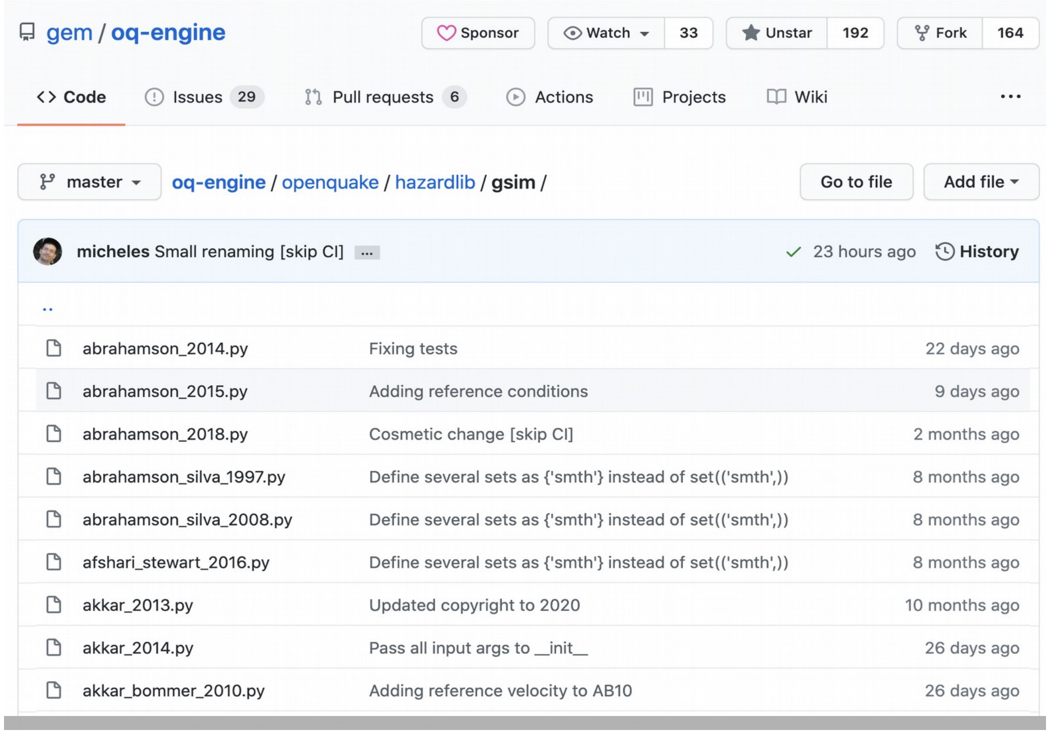
The site model provides inputs to the ground motion prediction equations, such as the shear wave velocity in the upper 30 m ($V_{S,30}$)

In this example, we are using values interpolated from the USGS Global $V_{S,30}$ Map, which is available for download here: https://earthquake.usgs.gov/data/vs30/

Scenario hazard | Ground motion models

100+ ground motion prediction equations (GMPEs) have been implemented in OQ for various tectonic regions

https://github.com/gem/oq-engine/tree/master/openquake/hazardlib/gsim



Scenario hazard | Running the analysis

Let’s run the model…

Scenario hazard | Outputs from calculation

sitemesh_<*id*>.csv

site_id	lon	lat
0	87.65740	27.35910
1	87.69630	27.37950
2	87.72250	27.40060
3	87.73220	27.44800
4	87.67740	27.33190
5	87.90670	27.40380
6	87.84860	27.43080
7	87.86010	27.38740
8	87.83290	27.37490
9	88.02460	27.56100
10	87.70690	27.31780

geolocation of each site id modeled

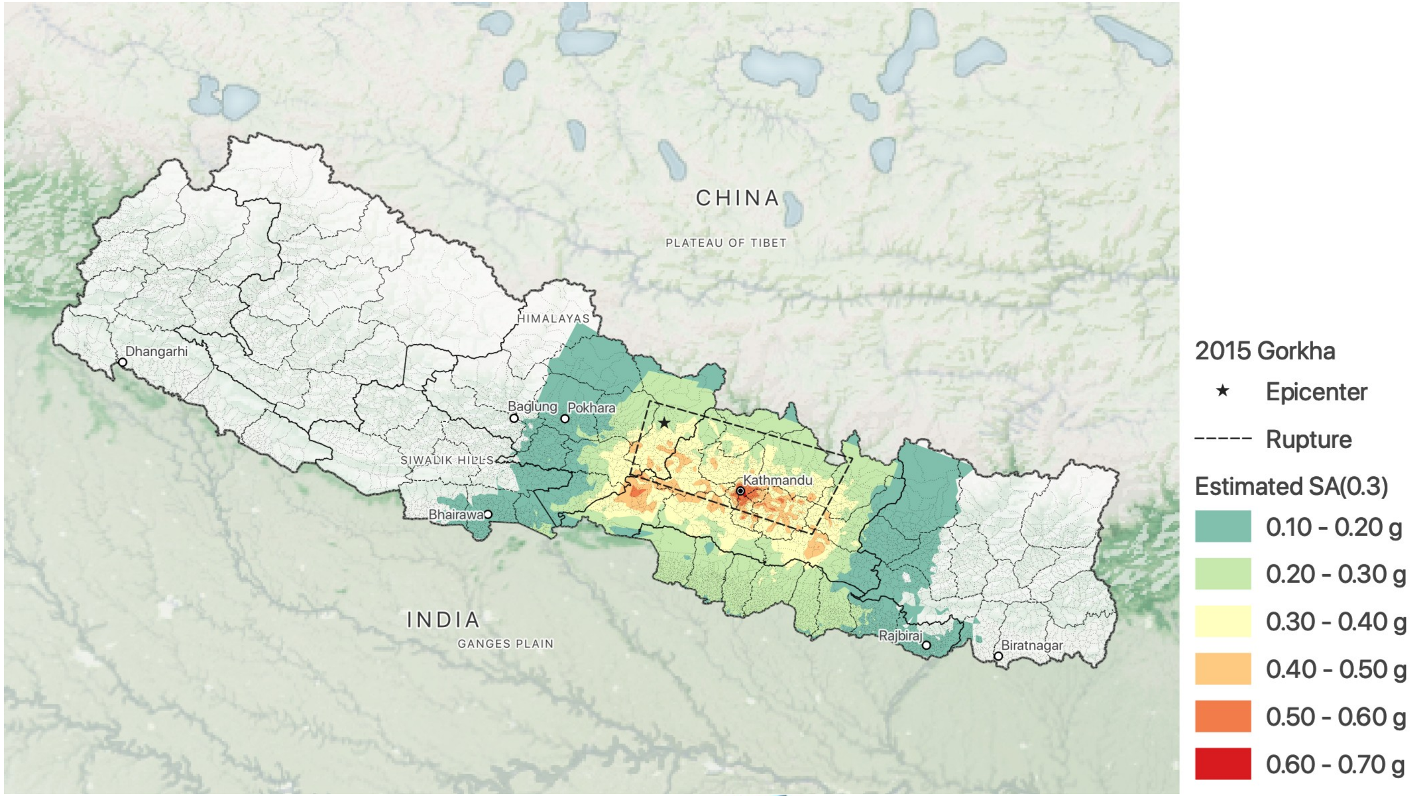
gmf-data_<*id*>.csv

site_id	event_id	gmv_PGA	gmv_SA(0.3)	gmv_SA(0.6)	gmv_SA(1.0)
0	0	2.781869E-02	4.838535E-02	1.201265E-02	3.626274E-02
1	0	7.036357E-02	1.851527E-02	2.214223E-02	4.367710E-02
2	0	4.183962E-02	1.828716E-02	2.682907E-02	3.176953E-02
3	0	3.525484E-02	4.715155E-02	7.344340E-03	1.356439E-02
4	0	1.909876E-02	6.542979E-02	1.604086E-02	1.217751E-02
5	0	1.581660E-02	1.132581E-02	6.596297E-03	1.740119E-02
6	0	1.284939E-02	2.349910E-02	1.887096E-02	2.407458E-02
7	0	5.114931E-02	2.537706E-02	6.280401E-02	1.070349E-01
8	0	3.120039E-02	4.750334E-02	7.753461E-02	8.244608E-03
9	0	3.544920E-02	1.369540E-02	3.451663E-02	8.229124E-03
10	0	1.123054E-02	1.744190E-02	1.231883E-02	2.400807E-02

ground motion values for each desired intensity measure type (e.g. PGA, SA(0.3)) and site id and event id

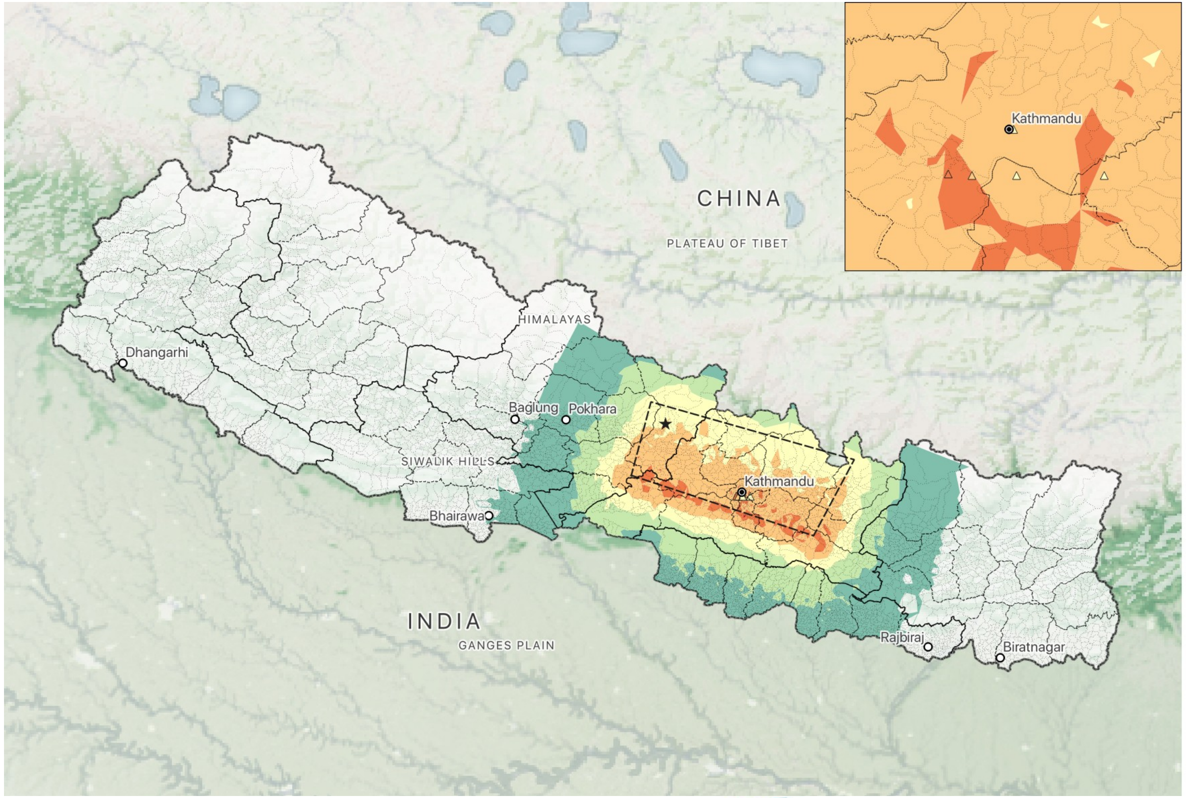
The number of rows will be equal to the number of sites multiplied by the number of ground motion fields requested

Scenario hazard | Hazard maps



https://meteor-project.org

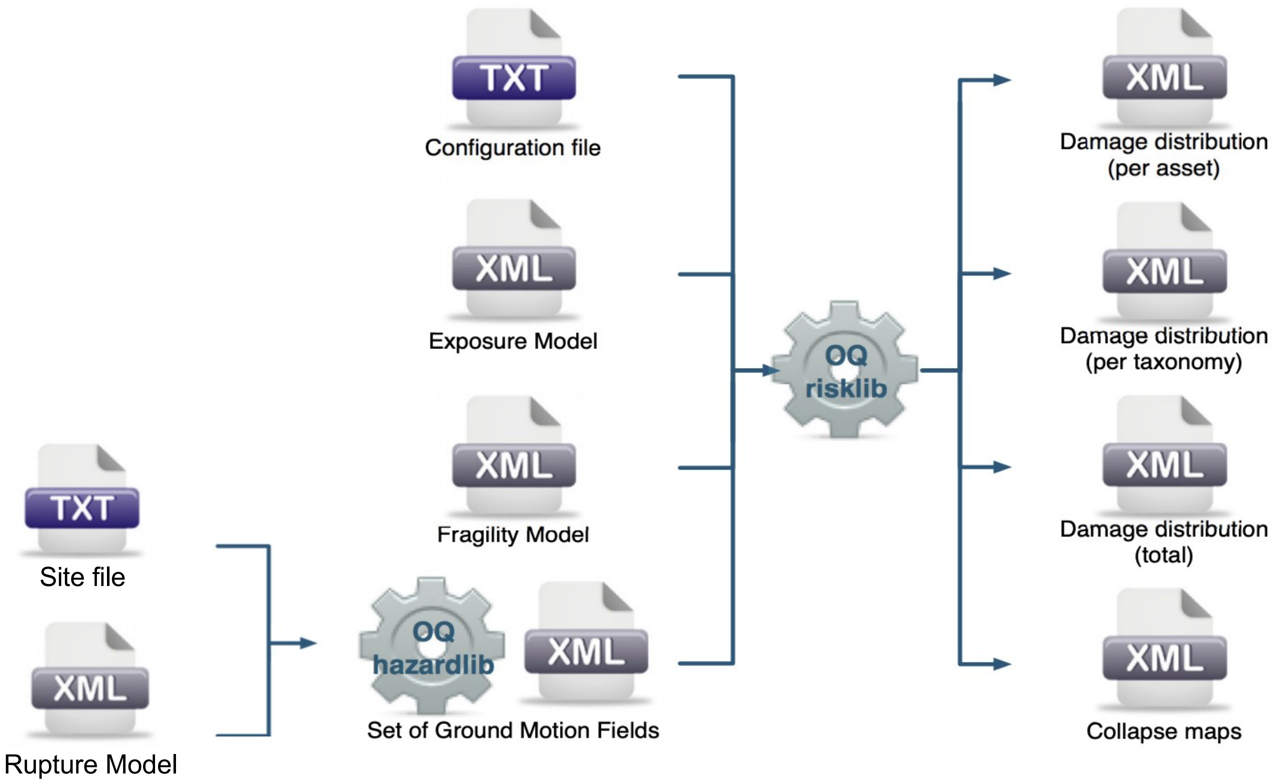
Scenario hazard | Hazard maps



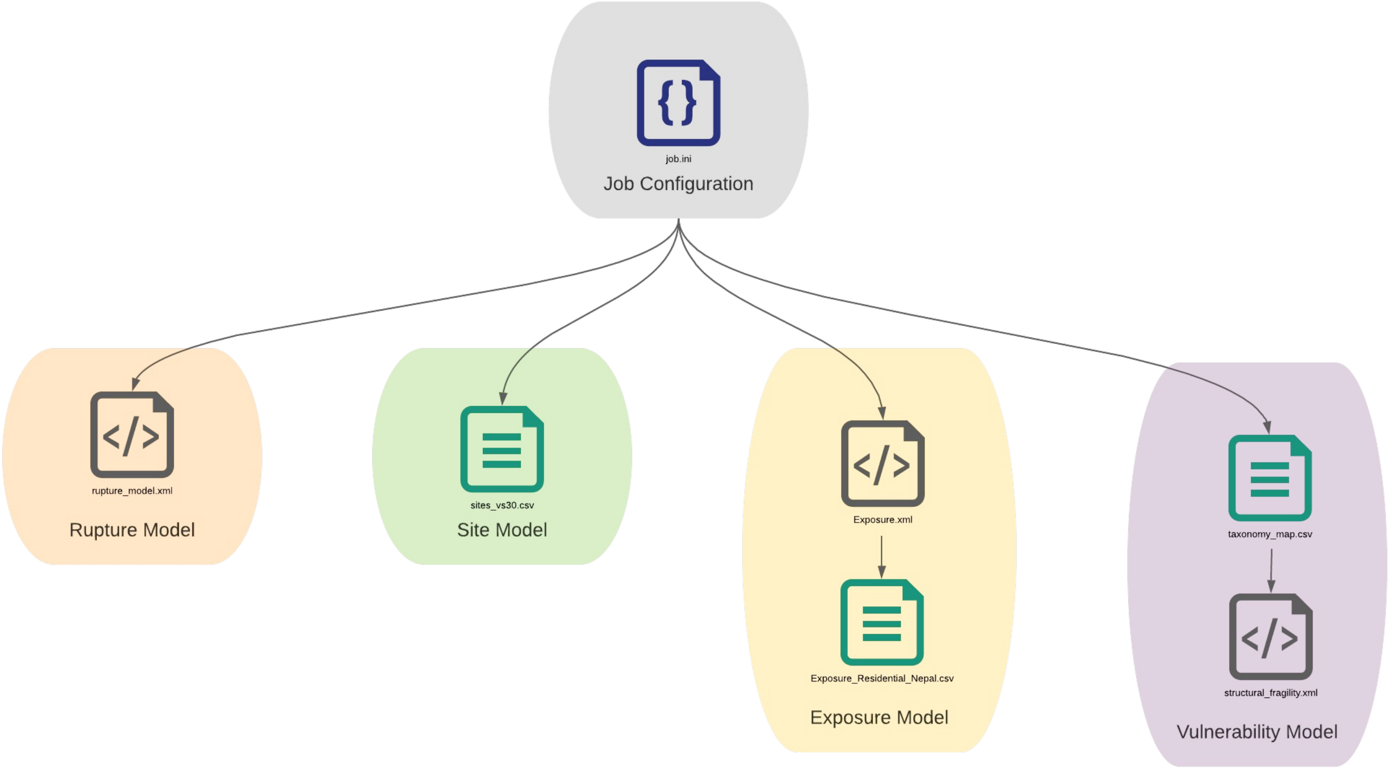
2015 Gorkha
★ Epicenter
----- Rupture
Recorded PGA
△ Station
Estimated PGA
0.05 - 0.10 g
0.10 - 0.15 g
0.15 - 0.20 g
0.20 - 0.25 g
0.25 - 0.30 g
0.30 - 0.35 g

Demo #1: Scenario Damage

Scenario damage | Input and output files



Scenario damage | Input files



Scenario damage | Job configuration file

```
[general]
description = 2015 Gorkha (Scenario Damage)
calculation_mode = scenario_damage

...

[exposure]
exposure_file = Exposure.xml


[vulnerability]
taxonomy_mapping_csv = taxonomy_map.csv
structural_fragility_file = structural_fragility.xml

[risk]
minimum_intensity = {“PGA”:0.05, “SA(0.3)”:0.05,
                     “SA(0.6)”:0.05, “SA(1.0)”:0.05}

[output]
export_dir = out
```

← description of your model
← desired OQ-engine calculator

← exposure model path

← taxonomy mapping csv path
← fragility model path

← minimum intensity values considered for
damage analysis

← desired output directory

Scenario damage | Exposure model file

```xml
<?xml version="1.0" encoding="UTF-8"?>
<nrml xmlns:gml="http://www.opengis.net/gml" xmlns="
http://openquake.org/xmlns/nrml/0.4">

  <exposureModel category="buildings" id="exposure" taxonomySource="GEM
taxonomy">

    <description>Exposure Model</description>

    <conversions>
      <costTypes>
        <costType name="structural" type="aggregated" unit="USD"/>
      </costTypes>
    </conversions>

    <tagNames>ID_4</tagNames>

    <assets>Exposure_Residential_Nepal.csv</assets>

  </exposureModel>

</nrml>
```

← Description of model

← Loss types and units of currency

← Additional tags or attributes of interest

← Location(s) of exposure CSV files

Scenario damage | Exposure model file

id	lon	lat	taxonomy	number	structural	tot_size_m	zone	dist_name	ID_4	NAME_4
0	87.65735309	27.35906047	C99/LFINF+DNO/HBET:1,3	317	16568228.77	56818.34284	Mechi	Taplejung	524 1 01 01 5 001	Phungling
1	87.65735309	27.35906047	MUR+CL99+MOC	338	19373503.43	90873.501	Mechi	Taplejung	524 1 01 01 5 001	Phungling
2	87.65735309	27.35906047	MUR+CL99+MOM	335	7904714.341	59895.08957	Mechi	Taplejung	524 1 01 01 5 001	Phungling
3	87.65735309	27.35906047	MUR+STRUB+MOL	424	4243355.874	37998.38701	Mechi	Taplejung	524 1 01 01 5 001	Phungling
4	87.65735309	27.35906047	MUR+STRUB+MOM	1992	18093813.84	178229.0567	Mechi	Taplejung	524 1 01 01 5 001	Phungling
5	87.65735309	27.35906047	W+WWD	437	3374669.866	39058.679	Mechi	Taplejung	524 1 01 01 5 001	Phungling
6	87.69630437	27.3794796	C99/LFINF+DNO/HBET:1,3	117	4872391.885	16709.16284	Mechi	Taplejung	524 1 01 01 5 002	Hangdewa
7	87.69630437	27.3794796	MUR+CL99+MOC	1	57318.05747	268.8565118	Mechi	Taplejung	524 1 01 01 5 002	Hangdewa
8	87.69630437	27.3794796	MUR+CL99+MOM	113	2120455.469	16066.97785	Mechi	Taplejung	524 1 01 01 5 002	Hangdewa
9	87.69630437	27.3794796	MUR+STRUB+MOL	119	952988.6461	8533.819096	Mechi	Taplejung	524 1 01 01 5 002	Hangdewa
10	87.69630437	27.3794796	MUR+STRUB+MOM	729	5279562.401	52005.14579	Mechi	Taplejung	524 1 01 01 5 002	Hangdewa
11	87.69630437	27.3794796	W+WWD	114	703451.4498	8141.799187	Mechi	Taplejung	524 1 01 01 5 002	Hangdewa
12	87.72248825	27.40058186	C99/LFINF+DNO/HBET:1,3	2	82729.73276	283.709646	Mechi	Taplejung	524 1 01 01 5 003	Phuurumbu
13	87.72248825	27.40058186	MUR+ADO/HBET:1,3	2	13788.28879	141.854823	Mechi	Taplejung	524 1 01 01 5 003	Phuurumbu
14	87.72248825	27.40058186	MUR+CL99+MOM	91	1703650.323	12908.78889	Mechi	Taplejung	524 1 01 01 5 003	Phuurumbu
15	87.72248825	27.40058186	MUR+STRUB+MOL	102	807901.8014	7234.595972	Mechi	Taplejung	524 1 01 01 5 003	Phuurumbu
16	87.72248825	27.40058186	MUR+STRUB+MOM	346	2491390.582	24540.88438	Mechi	Taplejung	524 1 01 01 5 003	Phuurumbu
17	87.72248825	27.40058186	W+WWD	93	569915.9368	6596.249269	Mechi	Taplejung	524 1 01 01 5 003	Phuurumbu
18	87.73216883	27.44802489	MUR+ADO/HBET:1,3	58	399860.375	4113.789866	Mechi	Taplejung	524 1 01 01 5 004	Limkhim
19	87.73216883	27.44802489	MUR+CL99+MOM	1	18721.43212	141.854823	Mechi	Taplejung	524 1 01 01 5 004	Limkhim
20	87.73216883	27.44802489	MUR+STRUB+MOL	69	546521.8068	4893.991393	Mechi	Taplejung	524 1 01 01 5 004	Limkhim
21	87.73216883	27.44802489	MUR+STRUB+MOM	366	2635401.598	25959.43261	Mechi	Taplejung	524 1 01 01 5 004	Limkhim
22	87.73216883	27.44802489	W+WWD	55	337047.0594	3901.007632	Mechi	Taplejung	524 1 01 01 5 004	Limkhim
23	87.67735059	27.33193359	C99/LFINF+DNO/HBET:1,3	130	4807437.243	16486.4103	Mechi	Taplejung	524 1 01 01 5 005	Dokhu

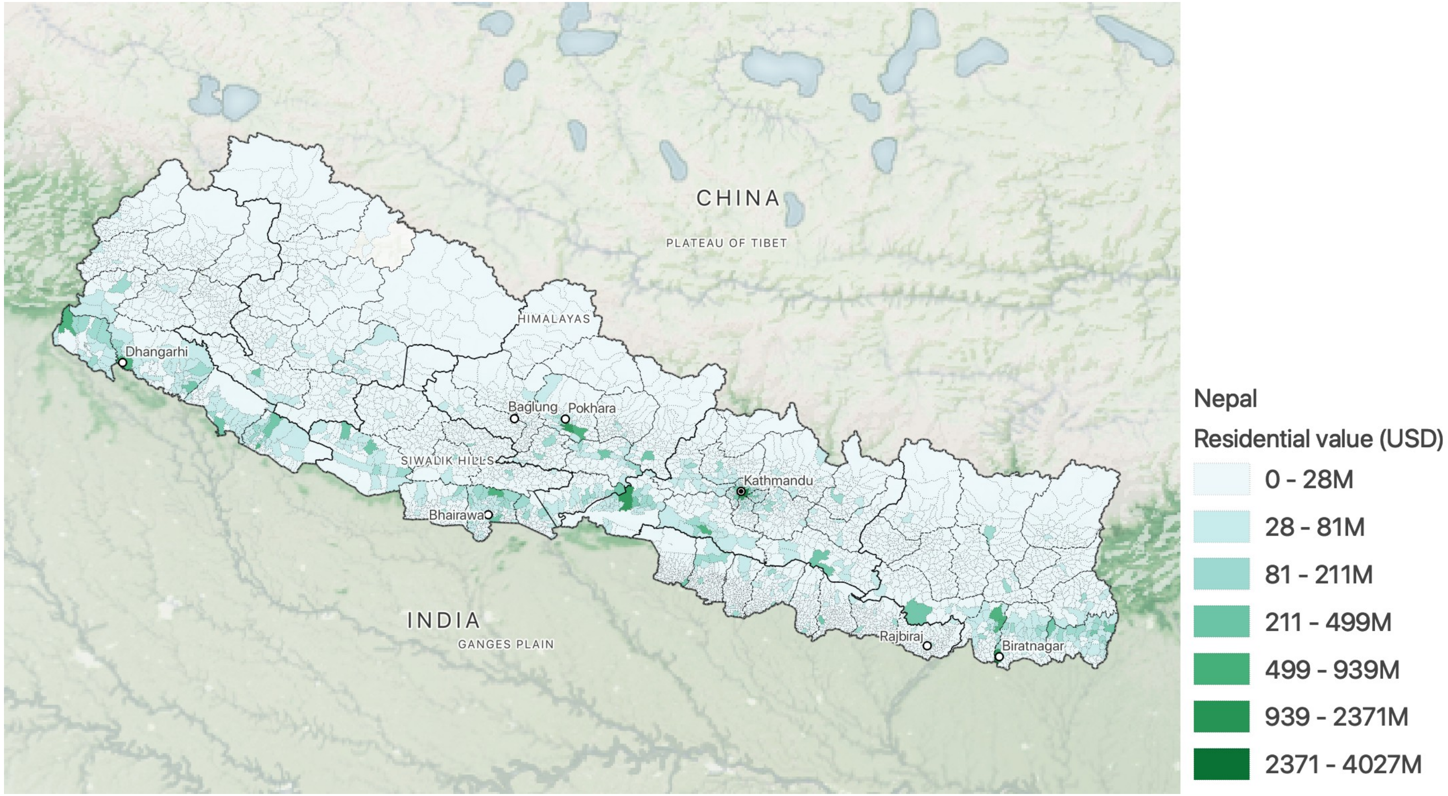
Required attributes

- ID
- Geolocation (lon, lat)
- Taxonomy
- Number
- Value (e.g., structural)

Optional attributes

Any information that would be useful for you, such as a field to aggregate by

Scenario damage | Visualization of exposure data



British Geological Survey

Oxford Policy Management

METEOR

Scenario damage | Taxonomy map file

taxonomy	conversion	weight
C99/LFINF+DNO/HBET:1,3	C99/LFINF+DNO/HBET:1,3	1
MUR+CL99+MOC	MUR+CL99+MOC	1
MUR+CL99+MOM	MUR+CL99+MOM	1
MUR+STRUB+MOL	MUR+STRUB+MOL	1
MUR+STRUB+MOM	MUR+STRUB+MOM	1
W+WWD	W+WWD	1
MUR+ADO/HBET:1,3	MUR+ADO/HBET:1,3	1
C99/LFINF+DNO/HBET:4,7	C99/LFINF+DNO/HBET:4,7	1
C99/LFINF+DNO/HBET:8,20	C99/LFINF+DNO/HBET:8,20	1
MATO/LN	MATO/LN	1
MUR+CL99/HBET:1,3	MUR+CL99/HBET:1,3	1
MUR+CL99/HBET:4,7	MUR+CL99/HBET:4,7	1
S	S	1
S/LFINF	S/LFINF	1
W	W	1

The exposure building class (**taxonomy**) and the vulnerability building class (**conversion**) can differ

An example is shown here, where there is a direct 1:1 mapping

If uncertainty in the mapping is to be considered, multiple **conversion** classes can be referenced for each **taxonomy** class along with each associated **weight**

Scenario damage | Fragility model file


```xml
<?xml version="1.0" encoding="UTF-8"?>
<nrml xmlns="http://openquake.org/xmlns/nrml/0.5">
<fragilityModel id="fragility_model" assetCategory="buildings" lossCategory="structural">
<description>Fragility model for Nepal</description>

<limitStates> slight moderate extensive complete </limitStates>
<fragilityFunction id="C99/LFINF+DNO/HBET:1,3" format="discrete">
<imls imt="SA(0.3)" noDamageLimit="0.050000"> 0 0.018144 0.019294 0.020518 0.02182 0.023204 0.024676 0.026241 0.027906 0.029676 0.031559
0.033561 0.03569 0.037953 0.040361 0.042921 0.045644 0.048539 0.051619 0.054893 0.058375 0.062078 0.066016 0.070204 0.074657 0.079393
0.084429 0.089785 0.09548 0.101537 0.107978 0.114828 0.122112 0.129858 0.138095 0.146855 0.156171 0.166077 0.176612 0.187816 0.19973
0.2124 0.225873 0.240201 0.255438 0.271642 0.288873 0.307198 0.326685 0.347408 0.369446 0.392882 0.417804 0.444307 0.472491 0.502464
0.534337 0.568233 0.604278 0.642611 0.683374 0.726724 0.772823 0.821847 0.873981 0.929421 0.988379 1.05108 1.11775 1.18866 1.26406
1.34424 1.42951 1.52019 1.61663 1.71918 1.82823 1.9442 2.06753 2.19869 2.33816 2.48648 2.64421 2.81194 2.99032 3.18001 3.38173 3.59625
3.82438 4.06697 4.32496 4.59931 4.89107 5.20133 5.53127 5.88215 6.25528 6.65208 7.07406 7.5228 8 </imls>
<poes ls="slight"> 0 0 1e-06 1e-06 2e-06 3e-06 5e-06 7e-06 1.1e-05 1.7e-05 2.7e-05 4.1e-05 6.2e-05 9.2e-05 0.000137 0.000201 0.000291
0.00042 0.000599 0.000846 0.001185 0.001644 0.002259 0.003076 0.004151 0.005549 0.007352 0.009652 0.012558 0.016192 0.020692 0.026209
0.032906 0.040955 0.050531 0.061811 0.074967 0.090158 0.107524 0.127181 0.149208 0.173646 0.20049 0.229684 0.261117 0.294625 0.32999
0.366944 0.405174 0.444332 0.484042 0.52391 0.563541 0.602543 0.640546 0.677206 0.71222 0.74533 0.776327 0.805059 0.831425 0.855381
0.87693 0.896122 0.913044 0.927817 0.940585 0.951512 0.960768 0.968533 0.974981 0.980283 0.984598 0.988076 0.990852 0.993044 0.994759
0.996087 0.997105 0.997878 0.998459 0.998891 0.99921 0.999442 0.999609 0.999729 0.999814 0.999874 0.999915 0.999943 0.999962 0.999975
0.999984 0.99999 0.999993 0.999996 0.999997 0.999998 0.999999 0.999999 1 </poes>
<poes ls="moderate"> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1e-06 1e-06 2e-06 3e-06 5e-06 9e-06 1.3e-05 2.1e-05 3.2e-05 4.8e-05
7.2e-05 0.000108 0.000159 0.000232 0.000336 0.000482 0.000685 0.000965 0.001347 0.001861 0.002549 0.003459 0.00465 0.006195 0.008179
0.0107 0.013873 0.017825 0.022701 0.028656 0.035856 0.044475 0.054691 0.066679 0.080605 0.096624 0.114867 0.135434 0.158394 0.183768
0.211532 0.24161 0.273869 0.308126 0.344141 0.381629 0.420263 0.45968 0.499499 0.539322 0.578754 0.617412 0.654933 0.690989 0.725293
0.757605 0.78774 0.815563 0.840998 0.864018 0.884645 0.902945 0.919018 0.932996 0.94503 0.955288 0.963945 0.971179 0.977163 0.982064
0.986038 0.989229 0.991765 0.993761 0.995315 0.996515 0.997431 0.998124 0.998642 </poes>
<poes ls="extensive"> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1e-06 1e-06 2e-06 3e-06 4e-06 7e-06 1e-05 1.6e-05 2.5e-
05 3.8e-05 5.8e-05 8.7e-05 0.000129 0.000189 0.000275 0.000397 0.000567 0.000802 0.001125 0.001562 0.002151 0.002933 0.003963 0.005306
0.007039 0.009254 0.012057 0.015569 0.019923 0.025271 0.031772 0.039597 0.048921 0.059923 0.072774 0.087636 0.104653 0.123945 0.145596
0.169656 0.196125 0.224956 0.256048 0.289243 0.324334 0.361058 0.399111 0.438148 0.477797 0.517667 0.557361 0.596486 0.634669 0.671561
0.706852 0.740275 0.771615 0.800709 0.827451 0.851786 0.87371 0.893266 0.910537 0.925638 0.93871 0.949914 0.95942 0.967407 0.97405
0.979521 0.983981 0.987581 </poes>
<poes ls="complete"> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1e-06 1e-06 2e-06 3e-06 5e-06 7e-06 1.2e-05
1.8e-05 2.8e-05 4.2e-05 6.4e-05 9.5e-05 0.000141 0.000207 0.0003 0.000432 0.000616 0.00087 0.001217 0.001687 0.002316 0.003152 0.004249
0.005677 0.007516 0.00986 0.012819 0.016517 0.021093 0.026698 0.033497 0.04166 0.051366 0.06279 0.076102 0.091462 0.109008 0.128851
0.151069 0.1757 0.202735 0.232111 0.263717 0.297382 0.332884 0.369952 0.40827 0.447486 0.487223 0.527087 0.566681 0.605617 0.643525
0.680064 0.714935 0.747883 0.778705 0.80725 0.833426 0.857189 0.878547 0.897554 0.9143 0.928908 0.941523 0.952309 0.96144 </poes>
</fragilityFunction>
```


The fragility model specifies a set of fragility curves for each limit state for each building class

In this example, we consider four limit states (slight, moderate, extensive, complete)

The **imls** tag provides values at the x-axis

The **poes** tag provides values at the y-axis

Scenario damage | Running the analysis

Let's run the model…

Scenario damage | Outputs from calculation

dmg_by_event_<*id*>.csv

event_id	rlz_id	structural~no_damage	structural~slight	structural~moderate	structural~extensive	structural~complete
0	0	4.67976e+06	877361	134552	41122	34223
1	0	4.47972e+06	981171	184973	62486	58666
2	0	4.44227e+06	964019	192178	75939	92605
3	0	4.7151e+06	777894	144859	55187	73976
4	0	4.50138e+06	936466	178998	67982	82183
5	0	4.62461e+06	894664	155584	49831	42327
6	0	4.20146e+06	1.11481e+06	247259	94998	108481
7	0	4.69063e+06	768673	149858	61119	96736
8	0	3.91718e+06	1.23642e+06	317819	131826	163770
9	0	4.33652e+06	1.00548e+06	222654	89524	112832
10	0	4.38959e+06	1.0309e+06	205751	72353	68422

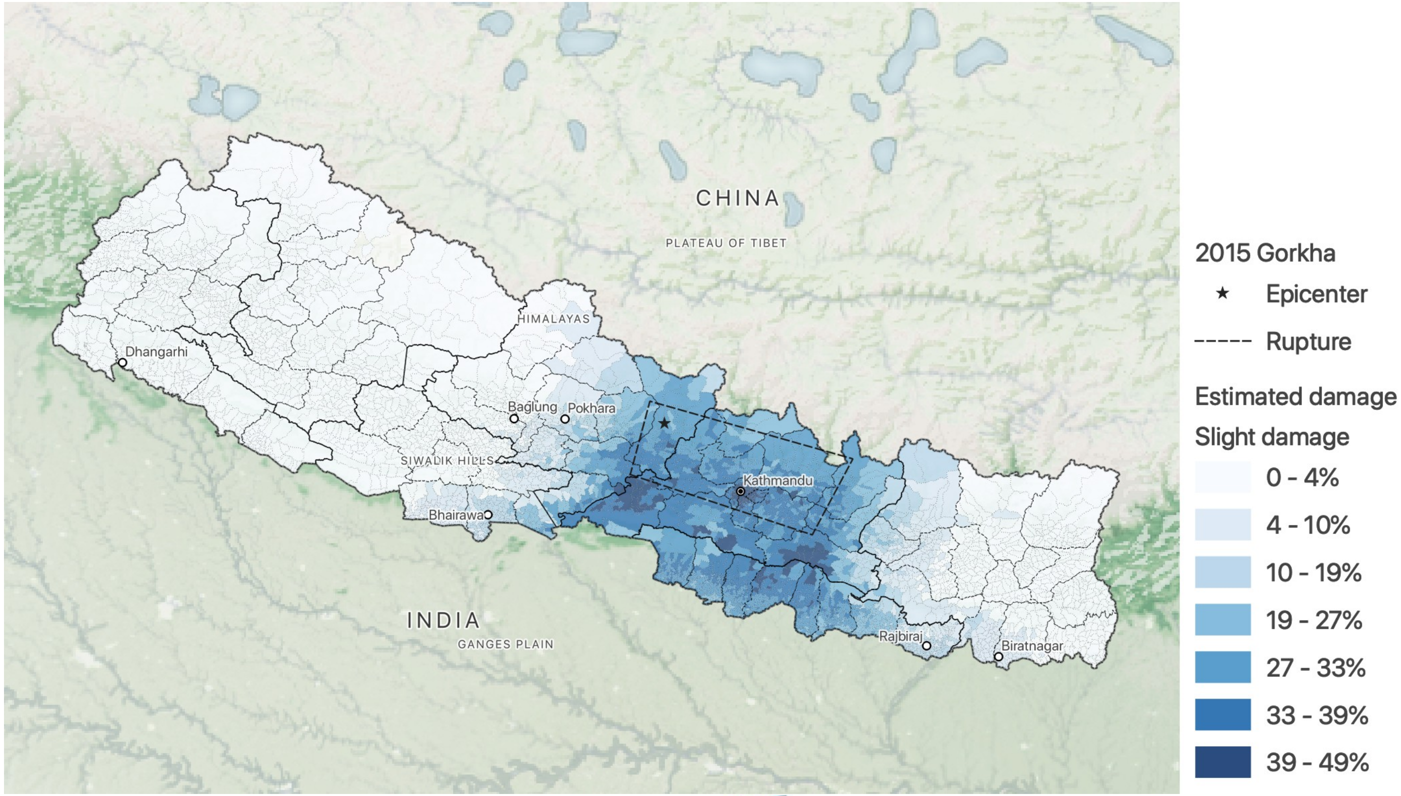
aggregated counts in each damage state for each event

damages-<*rlz*>_<*id*>.csv

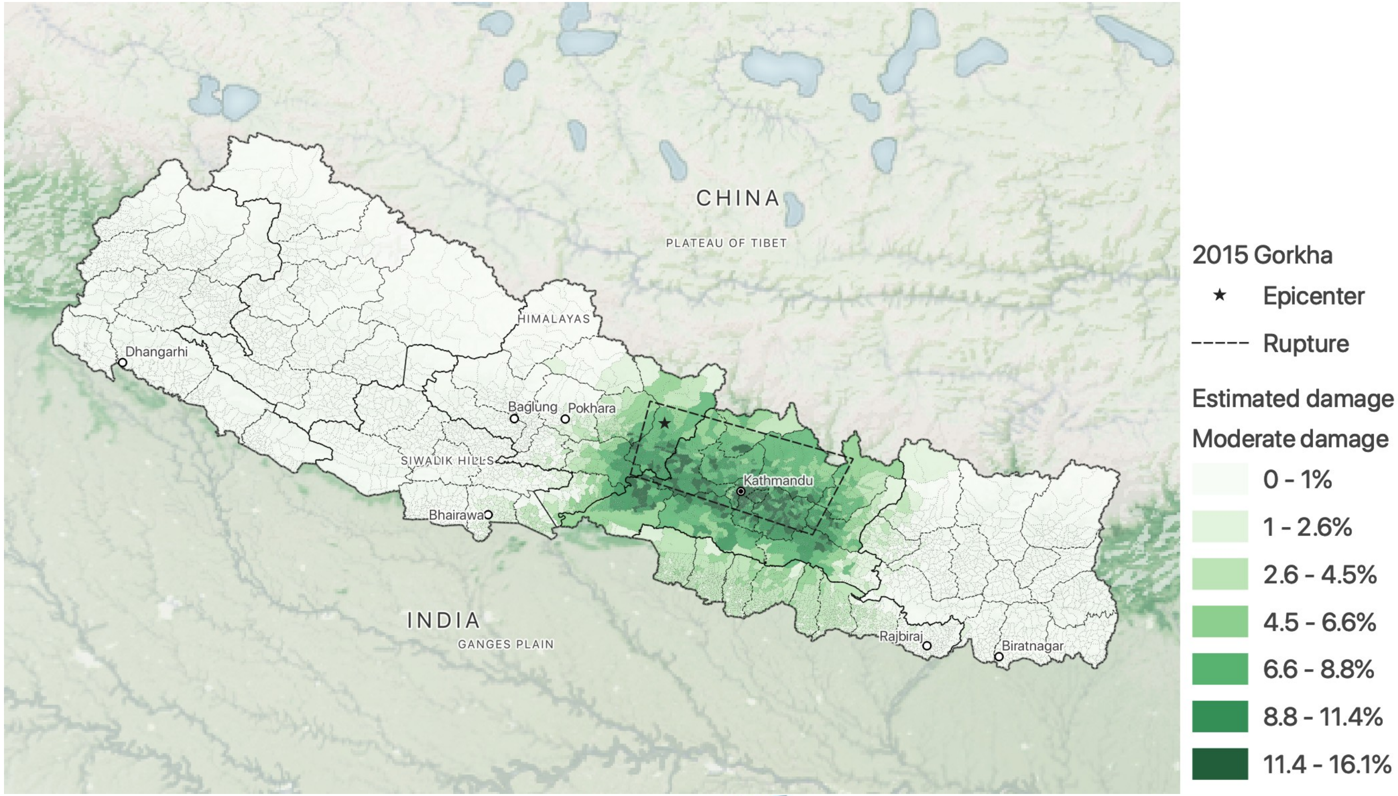
asset_id	ID_4	taxonomy	lon	lat	structural~no_damage	structural~slight	structural~moderate	structural~extensive	structural~complet
0	524 1 01 01 5 001	C99/LFINF+DNO/HBET:1,3	87.65735	27.35906	3.157200E+02	1.270000E+00	1.000000E-02	0.000000E+00	0.000000E+00
1	524 1 01 01 5 001	MUR+CL99+MOC	87.65735	27.35906	3.364300E+02	1.490000E+00	7.000000E-02	1.000000E-02	0.000000E+00
2	524 1 01 01 5 001	MUR+CL99+MOM	87.65735	27.35906	3.334300E+02	1.470000E+00	1.000000E-01	0.000000E+00	0.000000E+00
3	524 1 01 01 5 001	MUR+STRUB+MOL	87.65735	27.35906	4.222300E+02	1.690000E+00	8.000000E-02	0.000000E+00	0.000000E+00
4	524 1 01 01 5 001	MUR+STRUB+MOM	87.65735	27.35906	1.983330E+03	8.020000E+00	5.800000E-01	4.000000E-02	3.000000E-02
5	524 1 01 01 5 001	W+WWD	87.65735	27.35906	4.333000E+02	3.650000E+00	5.000000E-02	0.000000E+00	0.000000E+00
6	524 1 01 01 5 002	C99/LFINF+DNO/HBET:1,3	87.69630	27.37948	1.163100E+02	6.500000E-01	4.000000E-02	0.000000E+00	0.000000E+00
7	524 1 01 01 5 002	MUR+CL99+MOC	87.69630	27.37948	1.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
8	524 1 01 01 5 002	MUR+CL99+MOM	87.69630	27.37948	1.122400E+02	6.900000E-01	6.000000E-02	1.000000E-02	0.000000E+00
9	524 1 01 01 5 002	MUR+STRUB+MOL	87.69630	27.37948	1.183400E+02	5.500000E-01	8.000000E-02	3.000000E-02	0.000000E+00
10	524 1 01 01 5 002	MUR+STRUB+MOM	87.69630	27.37948	7.247000E+02	3.840000E+00	3.100000E-01	9.000000E-02	6.000000E-02
11	524 1 01 01 5 002	W+WWD	87.69630	27.37948	1.128600E+02	1.120000E+00	2.000000E-02	0.000000E+00	0.000000E+00
12	524 1 01 01 5 003	C99/LFINF+DNO/HBET:1,3	87.72249	27.40058	1.990000E+00	1.000000E-02	0.000000E+00	0.000000E+00	0.000000E+00
13	524 1 01 01 5 003	MUR+ADO/HBET:1,3	87.72249	27.40058	1.980000E+00	2.000000E-02	0.000000E+00	0.000000E+00	0.000000E+00
14	524 1 01 01 5 003	MUR+CL99+MOM	87.72249	27.40058	9.086000E+01	1.400000E-01	0.000000E+00	0.000000E+00	0.000000E+00
15	524 1 01 01 5 003	MUR+STRUB+MOL	87.72249	27.40058	1.018300E+02	1.700000E-01	0.000000E+00	0.000000E+00	0.000000E+00
16	524 1 01 01 5 003	MUR+STRUB+MOM	87.72249	27.40058	3.454400E+02	5.600000E-01	0.000000E+00	0.000000E+00	0.000000E+00
17	524 1 01 01 5 003	W+WWD	87.72249	27.40058	9.261000E+01	3.900000E-01	0.000000E+00	0.000000E+00	0.000000E+00
18	524 1 01 01 5 004	MUR+ADO/HBET:1,3	87.73217	27.44802	5.769000E+01	3.100000E-01	0.000000E+00	0.000000E+00	0.000000E+00
19	524 1 01 01 5 004	MUR+CL99+MOM	87.73217	27.44802	9.900000E-01	1.000000E-02	0.000000E+00	0.000000E+00	0.000000E+00
20	524 1 01 01 5 004	MUR+STRUB+MOL	87.73217	27.44802	6.885000E+01	1.500000E-01	0.000000E+00	0.000000E+00	0.000000E+00
21	524 1 01 01 5 004	MUR+STRUB+MOM	87.73217	27.44802	3.653700E+02	6.300000E-01	0.000000E+00	0.000000E+00	0.000000E+00

count in each damage state on a site-per-site basis, along with additional tags retained (e.g., ID_4)

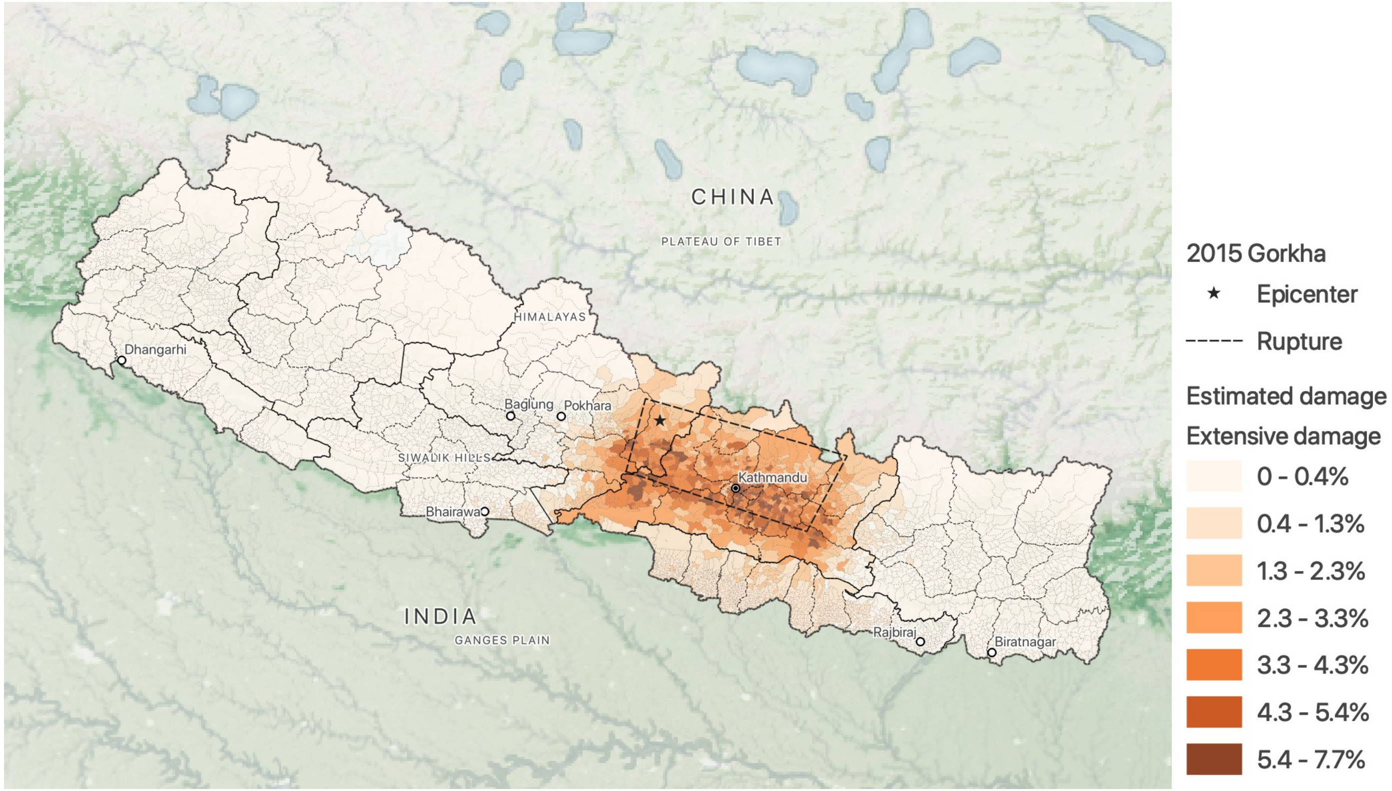
Scenario damage | Scenario damage maps



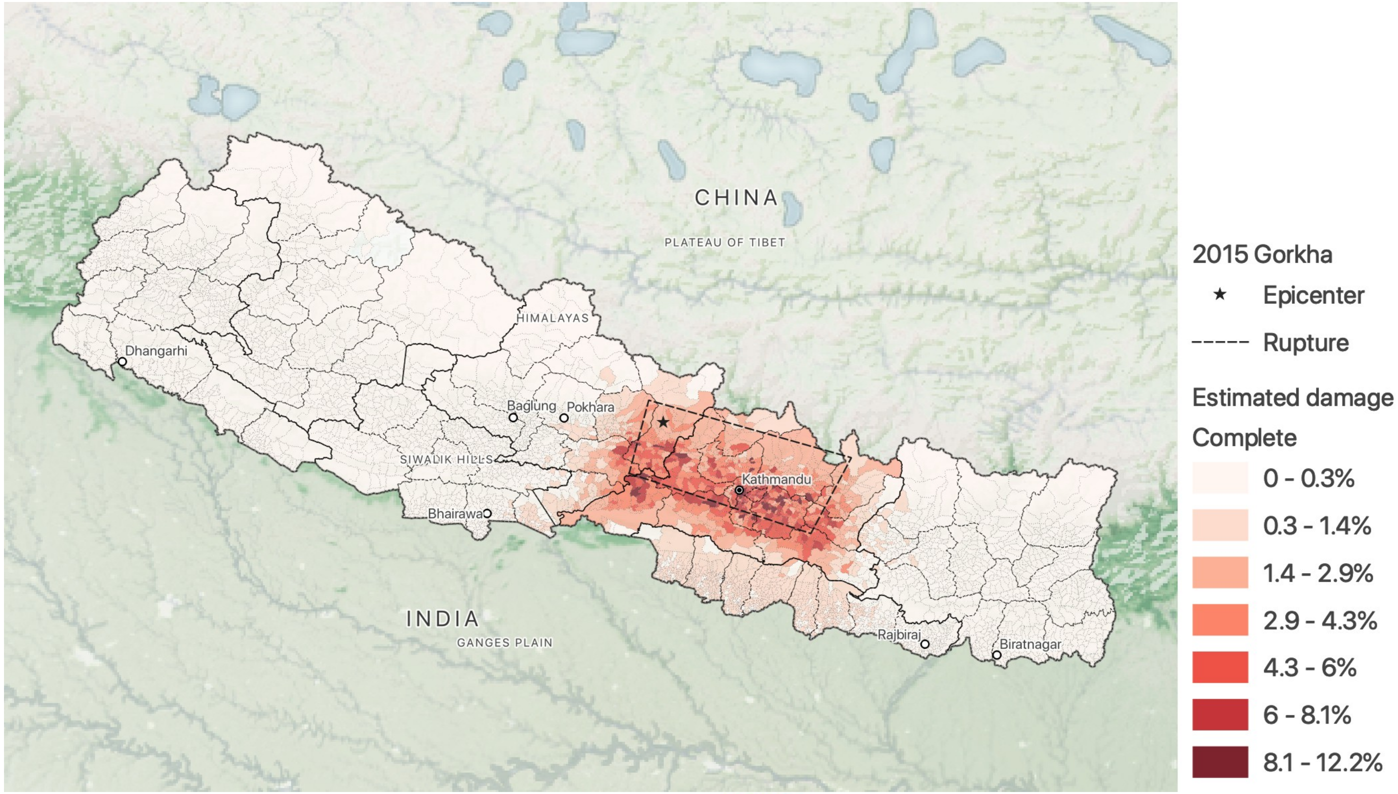
Scenario damage | Scenario damage maps



Scenario damage | Scenario damage maps



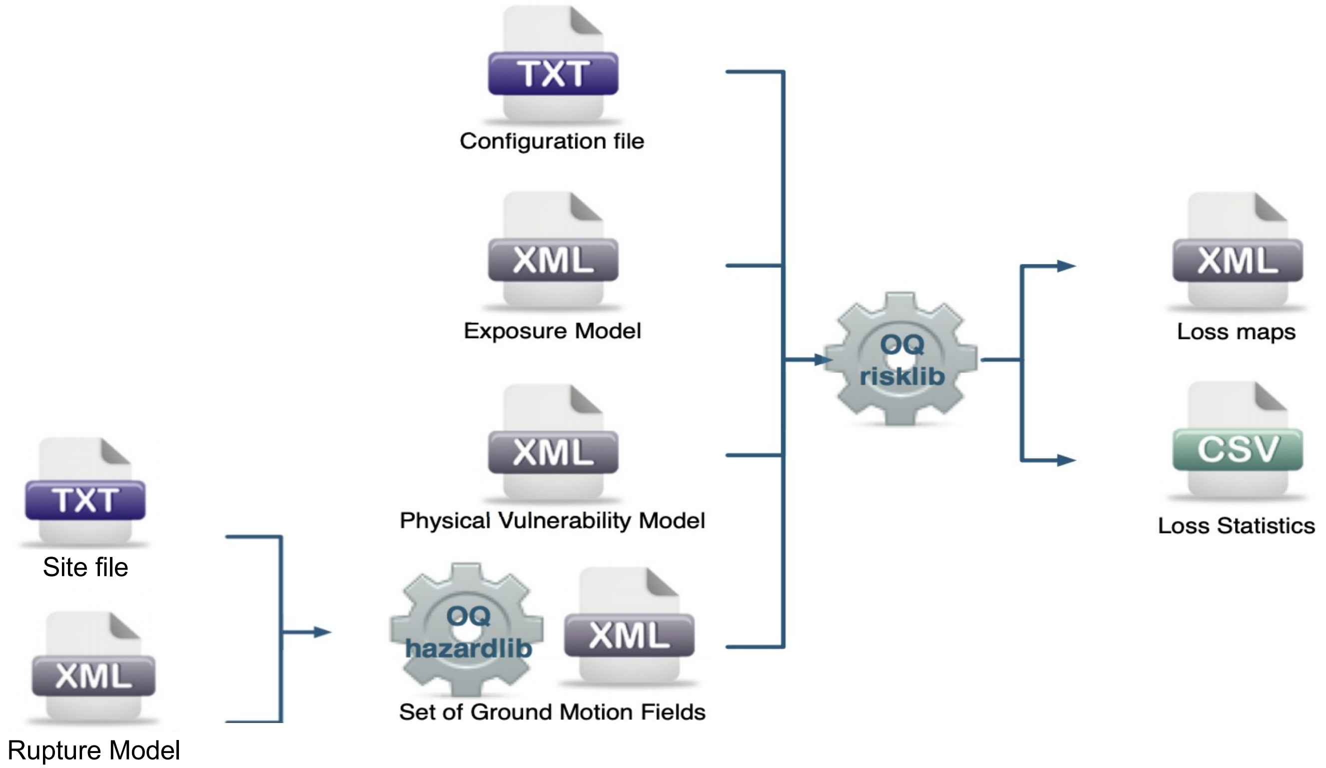
Scenario damage | Scenario damage maps



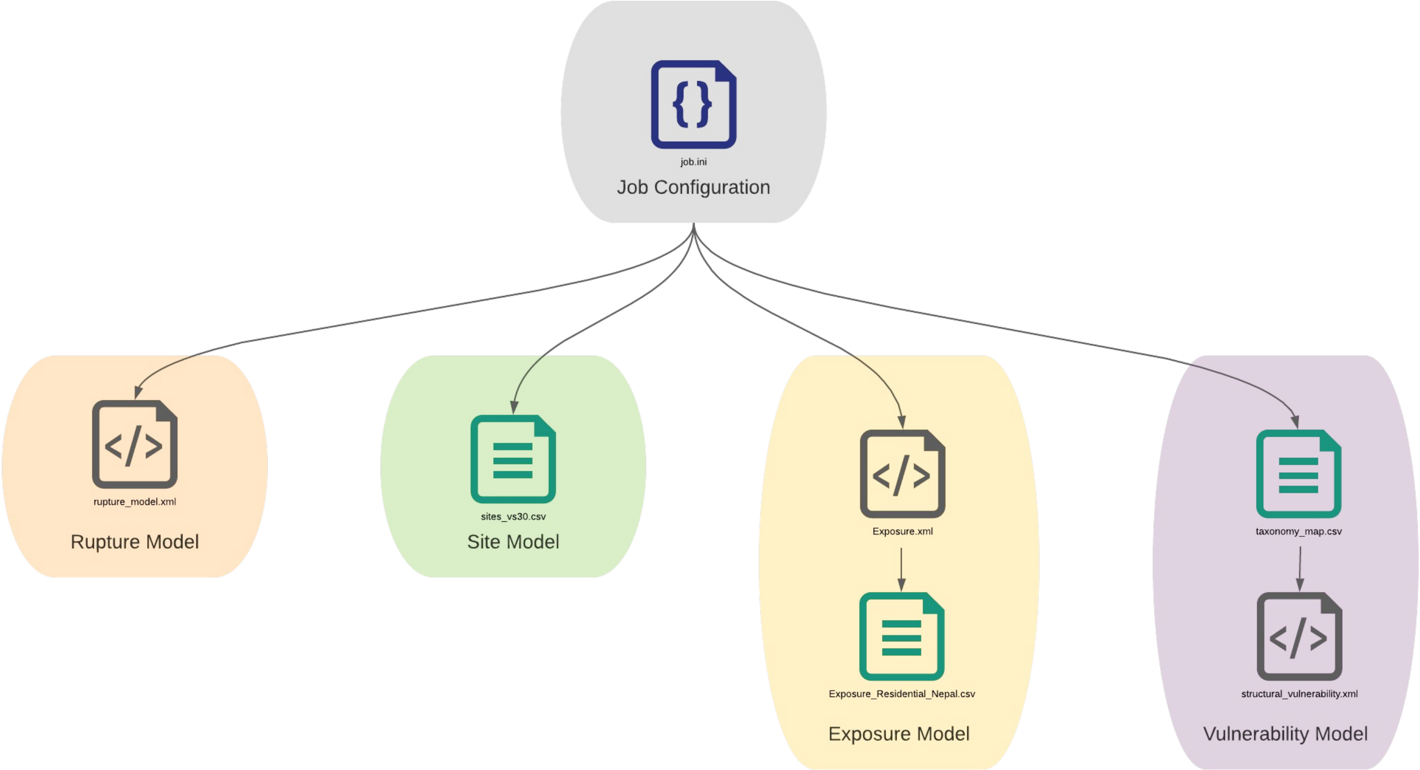
https://meteor-project.org

Demo #1: Scenario Risk

Scenario risk | Input and output files



Scenario risk | Input files



Scenario risk | Job configuration file

```
[general]
description = 2015 Gorkha (Scenario Risk)
calculation_mode = scenario_risk

...

[exposure]
exposure_file = Exposure.xml


[vulnerability]
taxonomy_mapping_csv = taxonomy_map.csv
structural_vulnerability_file = structural_vulnerability.xml

[risk]
minimum_intensity = {“PGA”:0.05, “SA(0.3)”:0.05,
                     “SA(0.6)”:0.05, “SA(1.0)”:0.05}

[output]
export_dir = out
```

← description of your model
← desired OQ-engine calculator

← exposure model path

← taxonomy mapping csv path
← vulnerability model path

← minimum intensity values considered for damage analysis

← desired output directory

Scenario risk | Vulnerability model file

```xml
<?xml version="1.0" encoding="UTF-8"?>
<nrml xmlns="http://openquake.org/xmlns/nrml/0.5">
<vulnerabilityModel id="vm-global" assetCategory="buildings" lossCategory="structural">
<description>Vulnerability model for Nepal</description>

<vulnerabilityFunction id="C99/LFINF+DNO/HBET:1,3" dist="LN">
<imls imt="SA(0.3)"> 0.018144 0.019294 0.020518 0.02182 0.023204 0.024676 0.026241 0.027906 0.029676 0.031559 0.033561 0.03569 0.037953
0.040361 0.042921 0.045644 0.048539 0.051619 0.054893 0.058375 0.062078 0.066016 0.070204 0.074657 0.079393 0.084429 0.089785 0.09548
0.101537 0.107978 0.114828 0.122112 0.129858 0.138095 0.146855 0.156171 0.166077 0.176612 0.187816 0.19973 0.2124 0.225873 0.240201
0.255438 0.271642 0.288873 0.307198 0.326685 0.347408 0.369446 0.392882 0.417804 0.444307 0.472491 0.502464 0.534337 0.568233 0.604278
0.642611 0.683374 0.726724 0.772823 0.821847 0.873981 0.929421 0.988379 1.05108 1.11775 1.18866 1.26406 1.34424 1.42951 1.52019 1.61663
1.71918 1.82823 1.9442 2.06753 2.19869 2.33816 2.48648 2.64421 2.81194 2.99032 3.18001 3.38173 3.59625 3.82438 4.06697 4.32496 4.59931
4.89107 5.20133 5.53127 5.88215 6.25528 6.65208 7.07406 7.5228 8 </imls>
<meanLRs> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3e-05 4.2e-05 5.9e-05 8.2e-05 0.000113 0.000154 0.000208 0.000278 0.000368 0.000484 0.00063
0.000813 0.00104 0.001318 0.001657 0.002066 0.002553 0.00313 0.003806 0.004591 0.005496 0.00653 0.007702 0.00902 0.010494 0.01213
0.013938 0.015925 0.018104 0.020485 0.023085 0.025923 0.029027 0.032427 0.036164 0.040289 0.044859 0.049946 0.055629 0.062 0.069161
0.077221 0.086297 0.09651 0.107983 0.120836 0.135186 0.151135 0.168775 0.188174 0.209381 0.232413 0.257259 0.283872 0.312168 0.342029
0.3733 0.405789 0.439278 0.473517 0.508236 0.543153 0.577975 0.612409 0.646171 0.678989 0.710616 0.740829 0.769439 0.796293 0.821276
0.844311 0.865361 0.884423 0.90153 0.916743 0.930149 0.941854 0.95198 0.96066 0.968032 0.974234 0.979405 </meanLRs>
<covLRs> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 </covLRs>
</vulnerabilityFunction>

<vulnerabilityFunction id="MUR+CL99+MOC" dist="LN">
<imls imt="SA(0.3)"> 0.018144 0.019294 0.020518 0.02182 0.023204 0.024676 0.026241 0.027906 0.029676 0.031559 0.033561 0.03569 0.037953
0.040361 0.042921 0.045644 0.048539 0.051619 0.054893 0.058375 0.062078 0.066016 0.070204 0.074657 0.079393 0.084429 0.089785 0.09548
0.101537 0.107978 0.114828 0.122112 0.129858 0.138095 0.146855 0.156171 0.166077 0.176612 0.187816 0.19973 0.2124 0.225873 0.240201
0.255438 0.271642 0.288873 0.307198 0.326685 0.347408 0.369446 0.392882 0.417804 0.444307 0.472491 0.502464 0.534337 0.568233 0.604278
0.642611 0.683374 0.726724 0.772823 0.821847 0.873981 0.929421 0.988379 1.05108 1.11775 1.18866 1.26406 1.34424 1.42951 1.52019 1.61663
1.71918 1.82823 1.9442 2.06753 2.19869 2.33816 2.48648 2.64421 2.81194 2.99032 3.18001 3.38173 3.59625 3.82438 4.06697 4.32496 4.59931
4.89107 5.20133 5.53127 5.88215 6.25528 6.65208 7.07406 7.5228 8 </imls>
<meanLRs> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1.8e-05 2.7e-05 3.9e-05 5.7e-05 8.2e-05 0.000116 0.000163 0.000227 0.000311 0.000423
0.000569 0.000757 0.000997 0.001301 0.001681 0.002152 0.002728 0.003429 0.004273 0.005279 0.006472 0.007875 0.009513 0.011418 0.013621
0.016159 0.019074 0.022415 0.026239 0.030611 0.035607 0.041315 0.047832 0.055272 0.063755 0.073414 0.084389 0.096825 0.110864 0.126646
0.144298 0.16393 0.185627 0.209444 0.235395 0.263454 0.293546 0.325548 0.359283 0.394528 0.431012 0.468425 0.506425 0.544648 0.582718
0.620259 0.656905 0.692316 0.726182 0.758236 0.78826 0.816086 0.841605 0.864758 0.885541 0.903996 0.920207 0.934293 0.946398 0.956687
0.965338 0.97253 0.978443 0.983251 0.987117 0.990191 0.992607 0.994485 0.995929 0.997026 0.99785 0.998462 0.998912 </meanLRs>
<covLRs> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 </covLRs>
</vulnerabilityFunction>
```

The vulnerability model specifies a vulnerability curve for each building class

The **imls** tag provides values at the x-axis

The **meanLRs** tag provides values at the y-axis

The **covLRs** tag allows for a distribution to be considered around the y-axis values

Scenario risk | Running the analysis

Let’s run the model…

Scenario risk | Outputs from calculation

agglosses_<*id*>.csv

rlz_id	loss_type	unit	mean	stddev
0	structural	USD	3.814281E+09	1.749267E+09

statistics for aggregated losses across all sites

avg_losses-mean_<*id*>.csv

asset_id	ID_4	taxonomy	lon	lat	structural
0	524 1 01 01 5 001	C99/LFINF+DNO/HBET:1,3	87.65735	27.35906	8.00220E+03
1	524 1 01 01 5 001	MUR+CL99+MOC	87.65735	27.35906	1.14407E+04
2	524 1 01 01 5 001	MUR+CL99+MOM	87.65735	27.35906	4.66799E+03
3	524 1 01 01 5 001	MUR+STRUB+MOL	87.65735	27.35906	2.40589E+03
4	524 1 01 01 5 001	MUR+STRUB+MOM	87.65735	27.35906	1.02588E+04
5	524 1 01 01 5 001	W+WWD	87.65735	27.35906	3.08002E+03
6	524 1 01 01 5 002	C99/LFINF+DNO/HBET:1,3	87.69630	27.37948	2.88702E+03
7	524 1 01 01 5 002	MUR+CL99+MOC	87.69630	27.37948	4.61448E+01
8	524 1 01 01 5 002	MUR+CL99+MOM	87.69630	27.37948	1.70711E+03
9	524 1 01 01 5 002	MUR+STRUB+MOL	87.69630	27.37948	7.75534E+02
10	524 1 01 01 5 002	MUR+STRUB+MOM	87.69630	27.37948	4.29646E+03

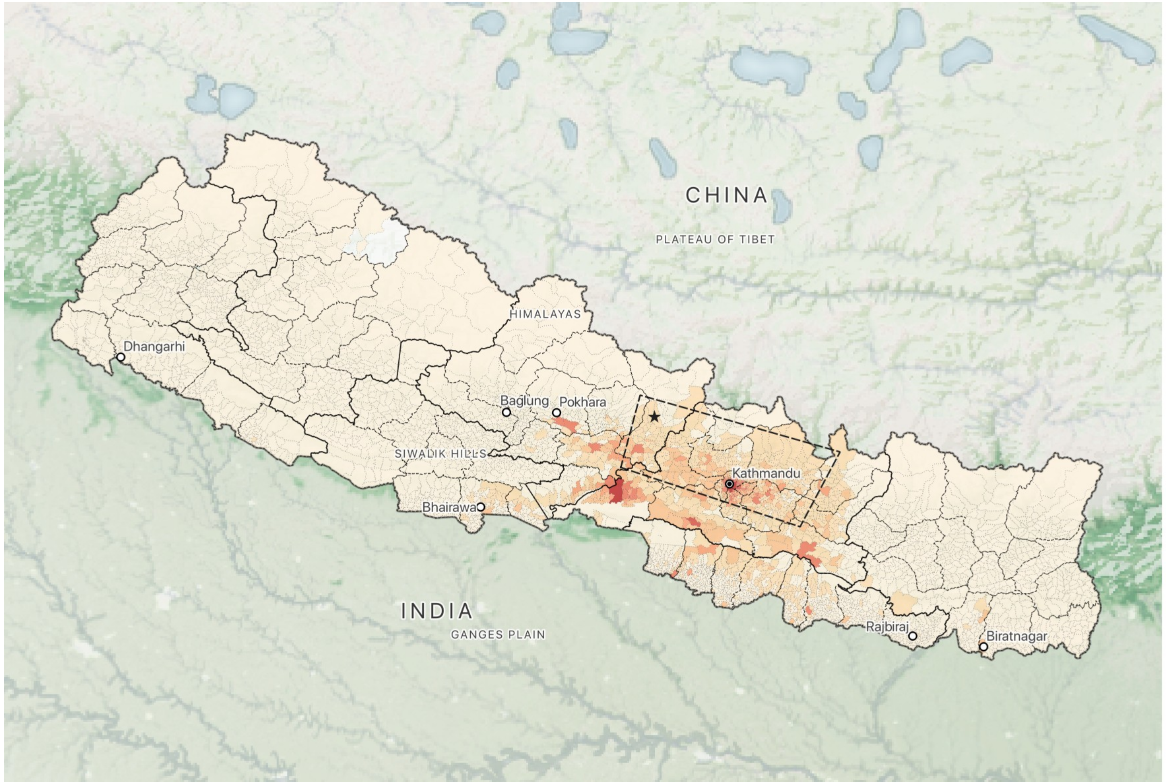
mean losses for each site *(across all realizations)*

avg_losses-rlz_<*rlz*>_<*id*>.csv

asset_id	ID_4	taxonomy	lon	lat	structural
0	524 1 01 01 5 001	C99/LFINF+DNO/HBET:1,3	87.65735	27.35906	8.00220E+03
1	524 1 01 01 5 001	MUR+CL99+MOC	87.65735	27.35906	1.14407E+04
2	524 1 01 01 5 001	MUR+CL99+MOM	87.65735	27.35906	4.66799E+03
3	524 1 01 01 5 001	MUR+STRUB+MOL	87.65735	27.35906	2.40589E+03
4	524 1 01 01 5 001	MUR+STRUB+MOM	87.65735	27.35906	1.02588E+04
5	524 1 01 01 5 001	W+WWD	87.65735	27.35906	3.08002E+03
6	524 1 01 01 5 002	C99/LFINF+DNO/HBET:1,3	87.69630	27.37948	2.88702E+03
7	524 1 01 01 5 002	MUR+CL99+MOC	87.69630	27.37948	4.61448E+01
8	524 1 01 01 5 002	MUR+CL99+MOM	87.69630	27.37948	1.70711E+03
9	524 1 01 01 5 002	MUR+STRUB+MOL	87.69630	27.37948	7.75534E+02
10	524 1 01 01 5 002	MUR+STRUB+MOM	87.69630	27.37948	4.29646E+03

realized losses for each site *(per realization)*

Scenario risk | Scenario loss map

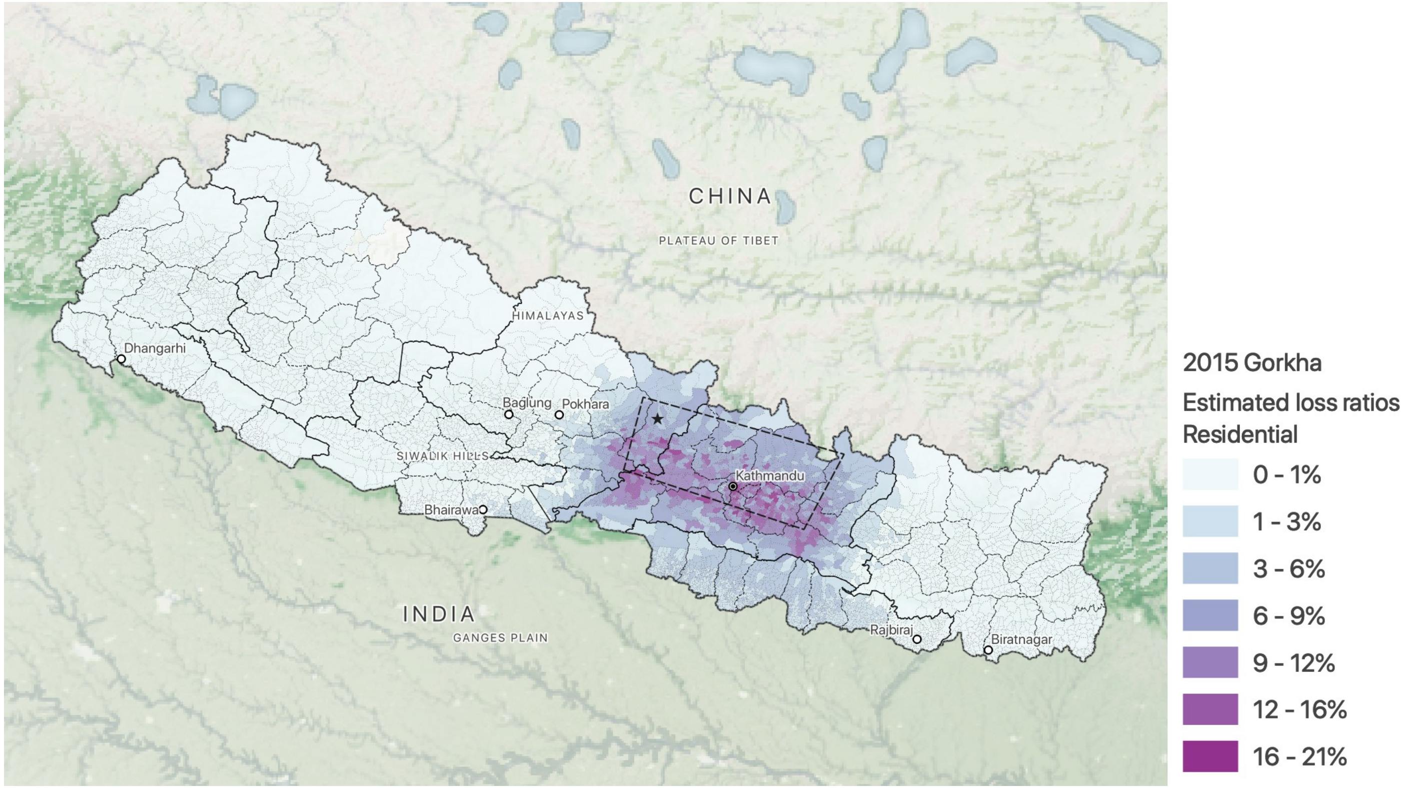


2015 Gorkha

Estimated losses Residential (USD)

- < 0.6M
- 0.6M - 2M
- 2M - 6M
- 6M - 13M
- 13M - 45M
- 45M - 70M
- 70M - 747M

Scenario risk | Scenario loss ratio map



Thank you for your interest

For further information please see
http://meteor-project.org