

GEM

GLOBAL
EARTHQUAKE
MODEL

working
together to
assess
risk

OpenQuake-engine: general introduction

GEM Hazard Team

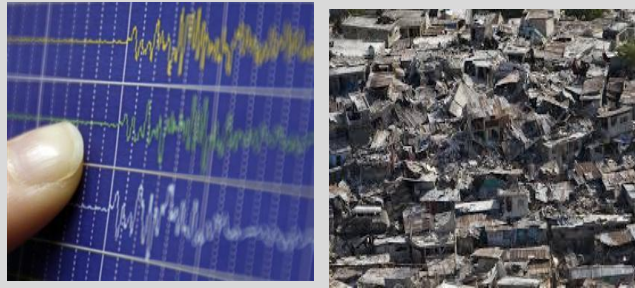
hazard@globalquakemodel.org



October 1st-5th, 2018 – GEM OpenQuake/Hazard Tools workshop

Main characteristics of OpenQuake

A **modular software** for computing earthquake hazard and risk



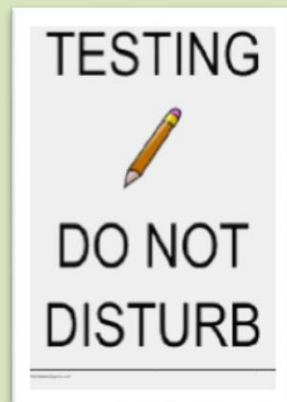
Open and Transparent software



Developed in Python

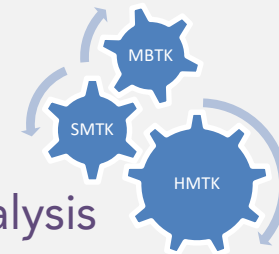


Extensively Tested



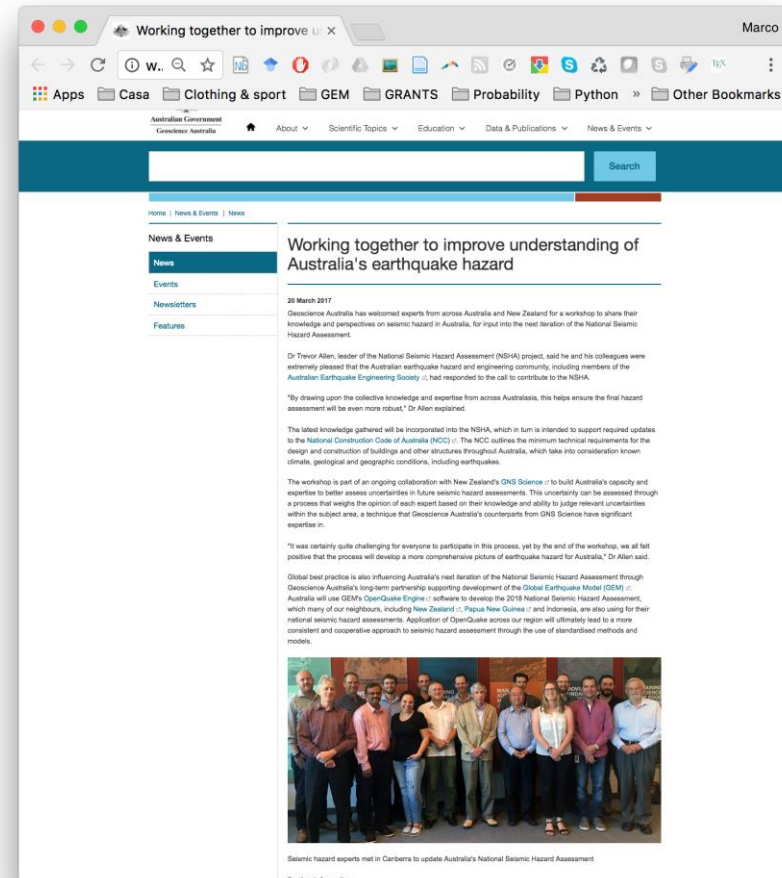
Toolkits

- Seismicity analysis
- Fault modelling
- Ground motion analysis



Use of the hazard component the OQ engine

- Regional seismic hazard analysis: SHARE, EMME, EMCA, CCARA, SARA, and SSAHARA, Southeast Asia
- National seismic hazard analysis:
 - Australia
 - Canada
 - Colombia
 - Ecuador
 - Italy
 - New Zealand
 - South Africa
 - Switzerland
 - Taiwan
 - Turkey
- Real time ground-shaking assessment: Components of OQ used in the 2.0 version of the USGS Shakemap system. EU Aristotle project.
- Site-specific studies: Nuclear earthquake hazard projects in Europe and Africa



2013 SHARE Hazard Map



European Seismic Hazard Map

edited by D. Giardini, J. Woessner, and L. Dancu, Swiss Seismological Service, ETH Zurich, August 2013



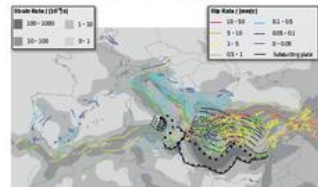
European Commission

The EU-FP7 SHARE Project

Europe has a long history of destructive earthquakes, and seismic risk can severely affect our modern society as recently shown by the 2009 L'Aquila (Italy) event. Seismic hazard defines the likelihood of ground shaking associated with the occurrence of future earthquakes, and a first step to evaluate seismic risk, the likelihood of damage and loss depending on vulnerability factors (e.g. the type and state of buildings and infrastructure, population density and land-use). High hazard does not necessarily imply high risk. Regional large earthquakes tend to high hazard but pose limited risk if they occur in remote areas, while even moderate earthquakes may impose elevated probabilities to high seismic risk.

The collaborative project "Seismic hazard assessment in Europe (SHARE)" was supported by the EU-FP7 to deliver the first state-of-the-art reference hazard maps for Europe, regarding major risks. The SHARE hazard contribution to the Global Earthquake Model (GEM) are services to risk-informed policies such as the design of earthquake resistant multi-story buildings and critical infrastructures such as bridges or dams.

Active Faults in Euro-Mediterranean Region



Active faults and fault zones in the Euro-Mediterranean region are identified by color from rapidly changing depths along dipping strands. Over 1,200 active faults have been mapped, covering more than 60,000 km of fault length. The background depicts the tectonic plate configuration of the region's crust derived from geologic and geodynamic data.

Map Content

The European Seismic Hazard Map displays the ground shaking (i.e. Peak Horizontal Ground Acceleration) to be expected or associated with a 10% probability in 50 years, corresponding to the average recurrence of such ground motion every 475 years, as prescribed by the relevant building codes in Europe for detailed building. Shaded regions show the regional ground shaking returning every 1,000-5,000 years, of importance for critical infrastructures such as dams or bridges. The ground shaking value depicted in the map reach over 0.5g in the operational accelerations. Low hazard areas (PGA < 0.1g) are colored in blue-green, moderate low and near in yellow-orange and high hazard areas (PGA > 0.5g) in red.

The SHARE seismic hazard is assessed with a time-independent, probabilistic approach. Indices of future ground shaking are based on the history of earthquakes of the past 1,000 years, on the knowledge of active faults mapped in the field, on the state-of-the-art of deformation of the Earth's crust from GPS measurements, and on the reconstruction knowledge of strong ground motions generated by past earthquakes.

The SHARE results do not replace the existing national design regulations and seismic provisions, which must be adapted for today's design and construction of buildings.

Acknowledgements

Supported by the EU FP7 Framework Program, the 4-year SHARE program brought together a core team of over 50 scientists from 16 research institutions and 22 countries, including Italy, France, Germany, and more than 200 additional European experts participating in workshops, providing their expertise and data.

SHARE was funded by the FP7 (2007-2013) under grant agreement no. 200807.

SHARE hazard maps computed using the EQM OpenQuake software. Maps were created using GMT software and Smith, 1992) and the poster was produced with Adobe Illustrator CS5.

Color map credits:
 G. Giardini, J. Woessner, L. Dancu, N. Crowley, J. Cobain, B. Grünthal, R. Fritzsche, G. Valeriani and the SHARE Consortium.
 SHARE European Seismic Hazard Map for the Euro-Mediterranean, 10% Exceedance Probability in 50 years, doi:10.22773/SHARE.10%_50_07-2013-08.

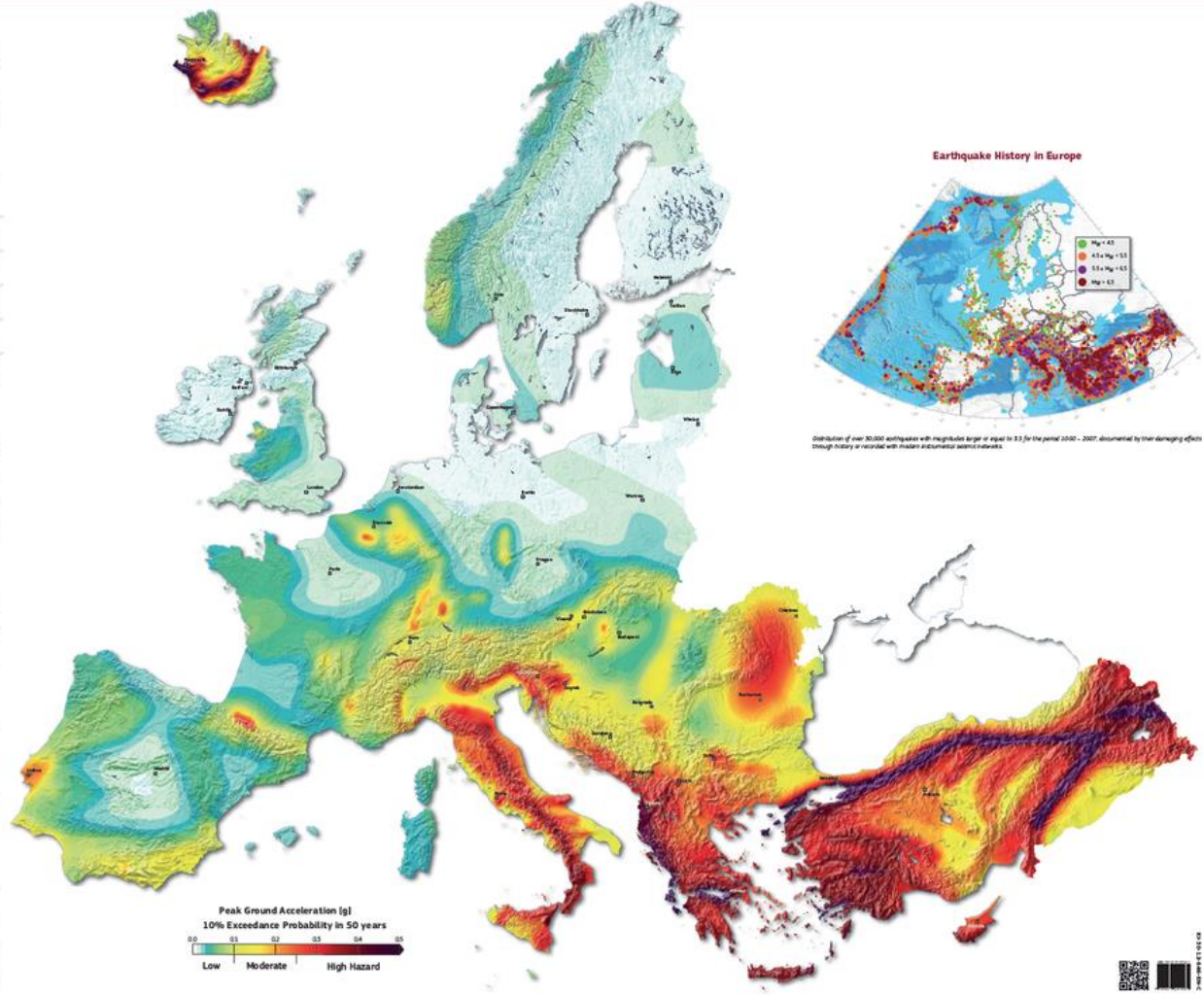
Online Access

All SHARE products, data and results are provided through the project website at www.share.eu.org and the European Facility for Earthquake Hazard and Risk at www.efeh.org.

Legal Notice

Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of the following information. The contents of this publication do not necessarily reflect the position or the opinion of the European Commission.

SHARE Partners



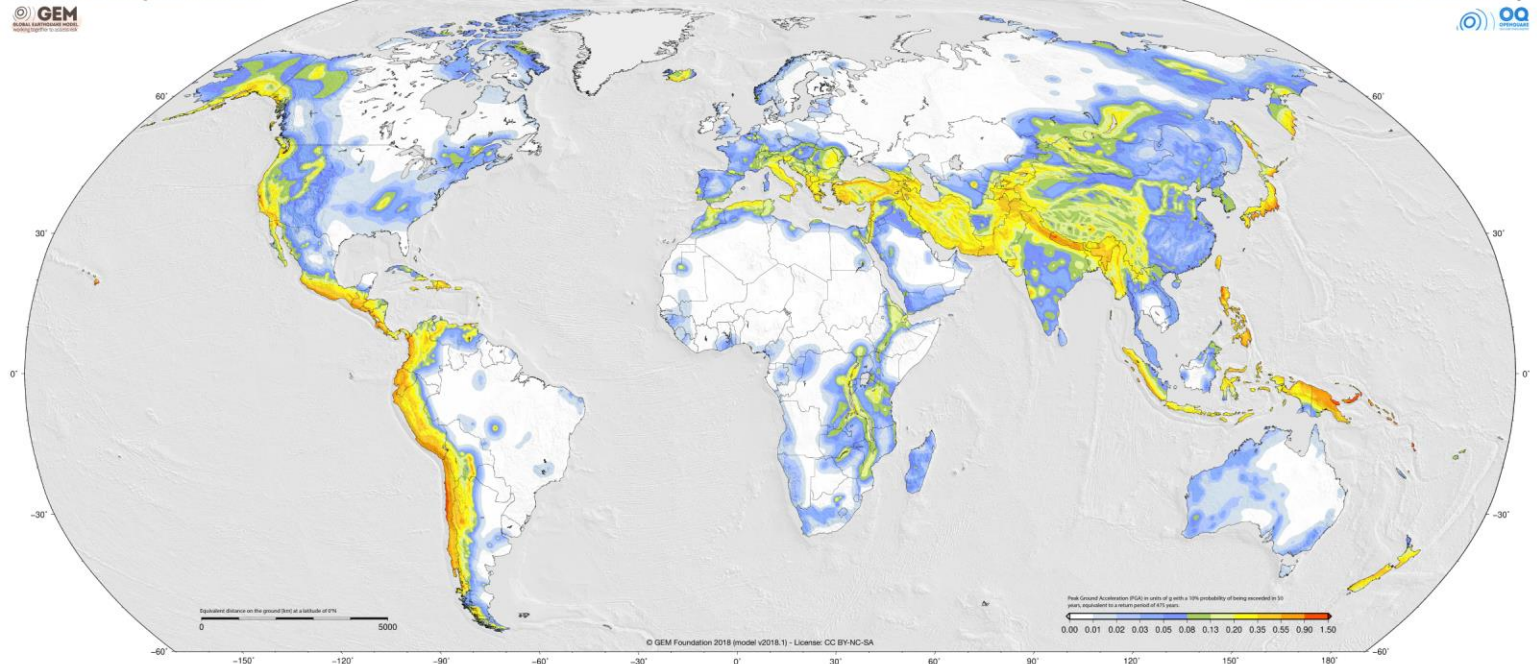
Distribution of over 30,000 earthquakes with magnitudes larger or equal to 3.0 for the period 2000 - 2007, documented by their damaging effects through history or recorded with modern instrumented seismic networks.



2018 GEM Global Hazard and Risk Maps

Global Earthquake Model

Global Seismic Hazard Map



Global Earthquake Model (GEM) Global Seismic Hazard Map

The Global Earthquake Model (GEM) Global Seismic Hazard Map version 2018 displays the probabilistic distribution of the Peak Ground Acceleration (PGA) over a 50-year period of time, averaged over 10 years, computed for reference site conditions (peak wave velocity V_{s0} of 750-850 m/s). The map was created by collating hazard maps computed using national and regional probabilistic hazard models developed by various national and regional projects, and the GEM Foundation scientists. The OpenQuake engine, an open-source seismic hazard and risk calculator software developed previously by the GEM Foundation, was used to calculate the hazard values, a weighting methodology was applied to homogenize hazard values along the model borders. The map is based on a database of hazard models developed using the OpenQuake engine data format (EQE). These models originally implemented in other software formats were converted into EQE, while translating these models, various checks were performed to test for consistency between the original results and the new results computed using the OpenQuake engine. Overall, the intercomparison between the original and translated model results are small, notwithstanding some diversity in modeling methodology (e.g., different hazard models). Due to possible model limitations, regions populated with low hazard may experience generally stronger earthquakes. The GEM Foundation plans to release future updates of this map on a regular basis as new information becomes available. Technical details on the compilation of the hazard map and the underlying models are available at <http://www.gem-foundation.org>.

How to use and cite this work

Please cite this work as: Pagan, J., Garcia-Prados, M., Diaz, F., Johnson, J., Pagan, R., Spagnoli, G., Stenhouse, M., Smerovska, D., Vignoli, L., Dierich, D., Moroni, D., 2018, Global Earthquake Model (GEM) Global Seismic Hazard Map (version 2018) - December 2018, DOI:10.1111/1365-3113.12616, GEM-SC-14-02-001-001-18-01-01. This work is licensed under the terms of the Creative Commons Attribution Non-Commercial-ShareAlike 4.0 International License (CC BY-NC-SA) <http://creativecommons.org/licenses/by-nc-sa/4.0/>.

Acknowledgments

This map is the result of a collaborative effort and extensive relies on the contribution and commitment of various organizations and groups to design and coordinate. The creation of this map would not have been possible without the support provided by many public and private organizations using 2017 seismic re-evaluation phase (2014-2018). Thereby, the contributors are gratefully acknowledged. Some of the vital help have been provided under the cooperative support of all GEM Secretariat staff. The map was collated using the Generic Mapping Tools software (Wessel et al., 2013).

Contributing models

- 1. Mexico (MEX) 2018**
- 2. Chile (CHL) 2018**
- 3. Colombia (COL) 2018**
- 4. Ecuador (ECU) 2018**
- 5. Peru (PER) 2018**
- 6. Argentina (ARG) 2018**
- 7. Brazil (BRA) 2018**
- 8. USA (USA) 2018**
- 9. Canada (CAN) 2018**
- 10. Europe (EUR) 2018**
- 11. Africa (AFR) 2018**
- 12. Asia (ASA) 2018**
- 13. Oceania (OCE) 2018**
- 14. Antarctica (ANT) 2018**

Legal statements

This map was created for dissemination purposes. The information included in this map must not be used for the design of earthquake-resistant structures or to support any important decision involving human life, capital and irreplaceable properties. The values of hazard based on this map are not intended as alternatives to the existing building codes defined in national building codes. Readers seeking this information should consult national building codes or other maps for the computation of hazard maps. The hazard map is not intended for use in any other way without the permission of the GEM Foundation. This work is licensed under the terms of the Creative Commons Attribution Non-Commercial-ShareAlike 4.0 International License (CC BY-NC-SA) <http://creativecommons.org/licenses/by-nc-sa/4.0/>.

Contact:
GEM Global Earthquake Model Foundation
Via Ferrata, 1 - 27100, Pavia, Italy
info@gem-foundation.org

More information available at:
<http://www.gem-foundation.org>

Sponsors and major contributors

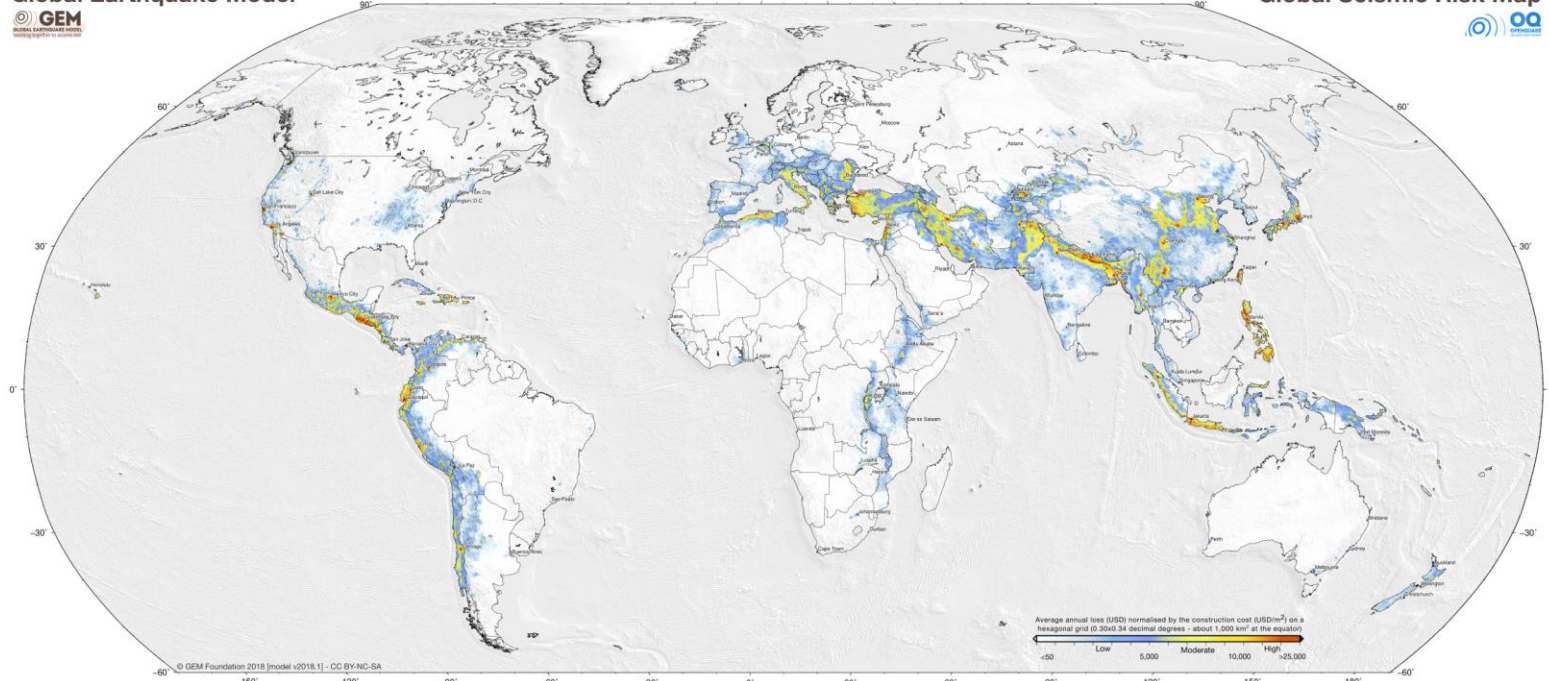


2018 GEM Global Hazard and Risk Maps

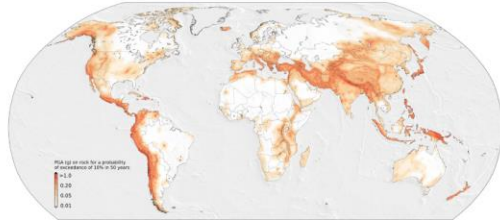
Global Earthquake Model



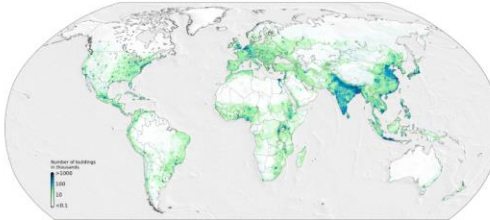
Global Seismic Risk Map



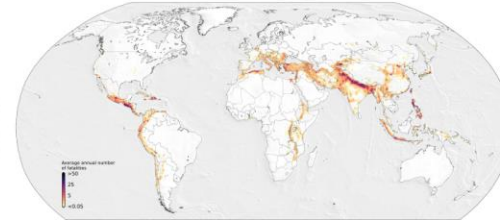
Global Seismic Hazard Map



Global Exposure Map



Global Seismic Fatalities Map



Global Earthquake Model (GEM) Global Seismic Risk Map

The Global Seismic Risk Map (2018) completes four global maps. The main map presents the geographic distribution of average annual loss (USD) normalised by the average construction costs of the respective country (USD/m²) due to ground shaking of the residential, commercial and industrial building stock, considering contents, structural and non-structural components. The normalised metric allows a direct comparison of the risk between countries with widely different construction costs. It does not consider the effects of business, transportation, societal and free-falling fatalities. The risk estimates are from direct physical damage to buildings due to shaking, and thus change to indirect or reduced losses due to business interruption are not included. The Global Seismic Hazard Map depicts the geographic distribution of the Peak Ground Acceleration (PGA) with a 10% probability of being exceeded in 50 years, computed for reference soil conditions (class B) with a return period of 700-800 years. The Global Exposure Map depicts the geographic distribution of residential, commercial and industrial buildings. The Global Seismic Fatalities Map depicts an estimate of average annual human losses due to earthquake-induced structural collapse of buildings. The results for

human losses do not consider indirect fatalities such as those from post-earthquake epidemics. The average annual losses and number of fatalities are presented on a hexagonal grid with a spacing of 0.30 x 0.34 decimal degree (approximately 1,300 km² at the equator). The average annual losses were computed using the event-based capabilities of the OpenQuake engine, an open-source software for seismic hazard and risk analysis developed by the GEM Foundation. The seismic hazard, exposure and vulnerability models employed in these calculations were provided by national institutions or developed within the scope of regional programs or bilateral collaborations. These global maps and the underlying databases are based on best available and publicly accessible datasets and models. Due to possible model limitations, regions characterised with low risk may still experience potentially damaging earthquakes. The GEM Risk Map is provided for an illustrative purpose, such that it may be updated when new datasets and models become available. Releases of updated versions of the seismic risk maps are anticipated on a regular basis. Additional hazard and risk metrics for each country can be explored at globalquakemodel.org.

The Global Earthquake Model (GEM) Foundation

The Earthquake Risk Map 2018 is a product of the GEM Foundation initiated by the Organisation for Economic Co-operation and Development (OECD) Global Science Forum in 2008. GEM was formed in 2016 as a not-profit foundation in Paris that, funded through a public-private sponsorship with the aim to create a world that is resilient to earthquakes. Participants represent national, research or disaster management institutions, the private sector and international organisations. GEM enables the assessment of seismic hazard at the global scale initiated by the Global Seismic Hazard Assessment Program (GSHAP) in support of the UN International Decade of Natural Disaster Reduction in 2009 in the consideration of direct economic, societal and public attention, datasets and models. Due to possible model limitations, regions characterised with low risk may still experience potentially damaging earthquakes. The GEM Risk Map is provided for an illustrative purpose, such that it may be updated when new datasets and models become available. Releases of updated versions of the seismic risk maps are anticipated on a regular basis. Additional hazard and risk metrics for each country can be explored at globalquakemodel.org.

GEM's OpenQuake platform (platform.openquake.org) provides access to all data, models, tools and software behind the maps. GEM's open-source OpenQuake engine enables probabilistic hazard and risk calculations worldwide and at all scales, from global down to regional, national, local, and also specific to a single software package. The Seismic Framework for Disaster Risk Reduction (SFRDR) calls for "decision-making on disaster risk reduction to be based on solid and openly accessible scientific work". GEM supports the SFRDR goals by contributing openly accessible products for hazard and risk assessment and capacity development in risk reduction projects. GEM also serves as a baseline or example for the development of a broader multi-hazard framework for risk assessment and capacity development in risk reduction projects. GEM's collaborative network comprises more than 70 public and private institutions organised under more than 25 regional, national and multi-lateral projects.

How to use and cite this work

Please refer the work as: D. Amis-Obono, A. Castanon, J. Dolanek, V. Dewasak, L. Martina, A. Pico, M. Scomastri, D. Vignati, C. Vojtek, E. Stokich, A. Acemovic, H. Chouvy, S. Harwood, K. Gohshi, M. Jaraman, M. Pithon, 2018. Global Earthquake Model (GEM) Seismic Risk Map (version 2018.1). DOI: 10.13111/GEM-GLOBAL_SEISMIC_RISK_MAP_2018. This work is licensed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License (CC BY-NC-SA). Acknowledgements: This map is the result of a collaboration effort and numerous sites in the earthquake and risk assessment and capacity development in risk reduction projects. The creation of this map would not have been possible without the support provided by various public and private organisations during GEM's second working programme (2014-2018). None of the model have been provided without the extensive support of all GEM participating staff. These key contributors are profoundly acknowledged. A complete list of the contributors can be found at globalquakemodel.org.

Legal statements

This map is an informational product created by the GEM Foundation for public dissemination purposes. The information included in this map must not be used for the design of earthquake-resistant structures or to support any required decisions involving human life, capital and movable and immovable properties. The values of seismic hazard and risk in this map do not constitute an alternative nor do constitute building actions defined in national building codes or earthquake risk estimates derived nationally. Residents seeking this information should contact the national authorities, based with seismic hazard and risk assessment. The seismic risk map results from an iterative process that is subject to the responsibility of the GEM Foundation.

Contacts:
GEM Global Earthquake Model Foundation
Via Farnesina, 1 - 27100, Parma, Italy
info@globalquakemodel.org



OpenQuake Calculation Workflows

Workflows 1 and 3: Classical PSHA and Disaggregation

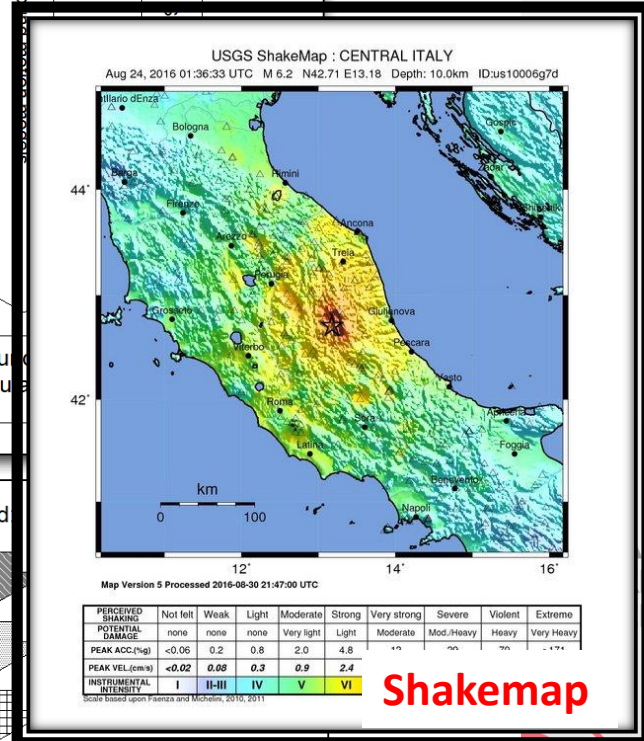
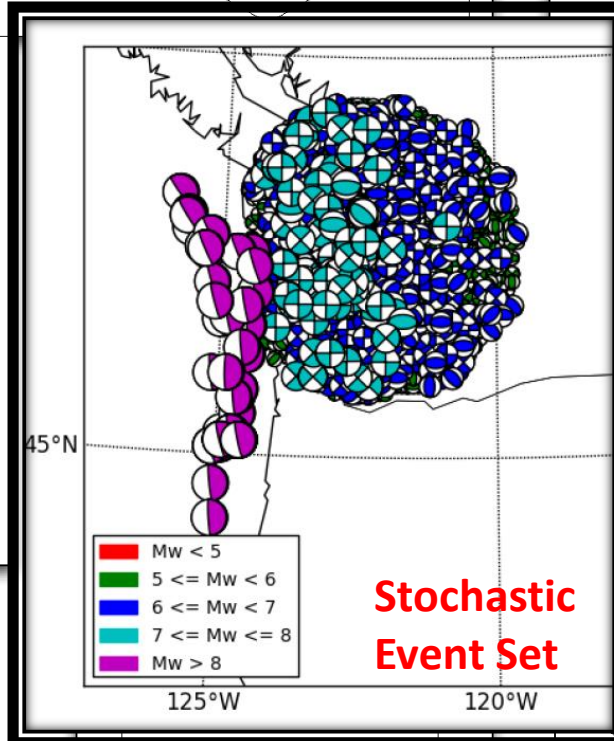
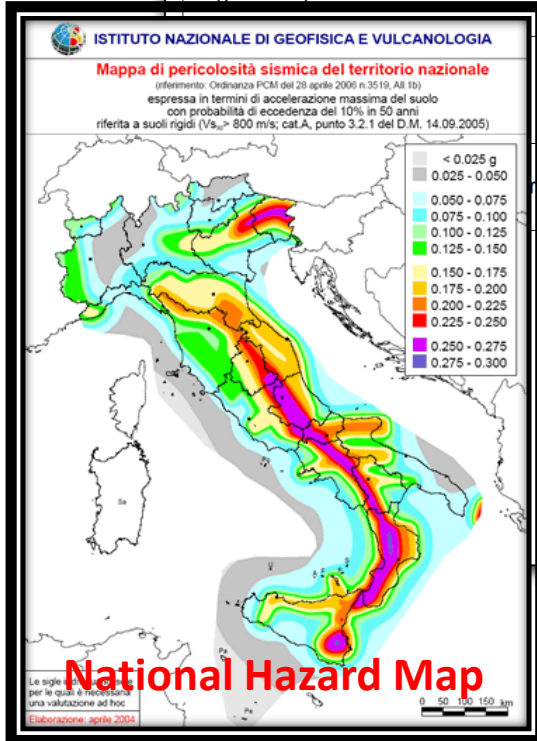
Workflow 2: Event-based PSHA

Workflow 4: scenario-based hazard

Seismic Hazard Analysis Input
 - Seismic sources logic tree
 - Ground motion logic tree

Logic Tree processor

Logic Trees Description

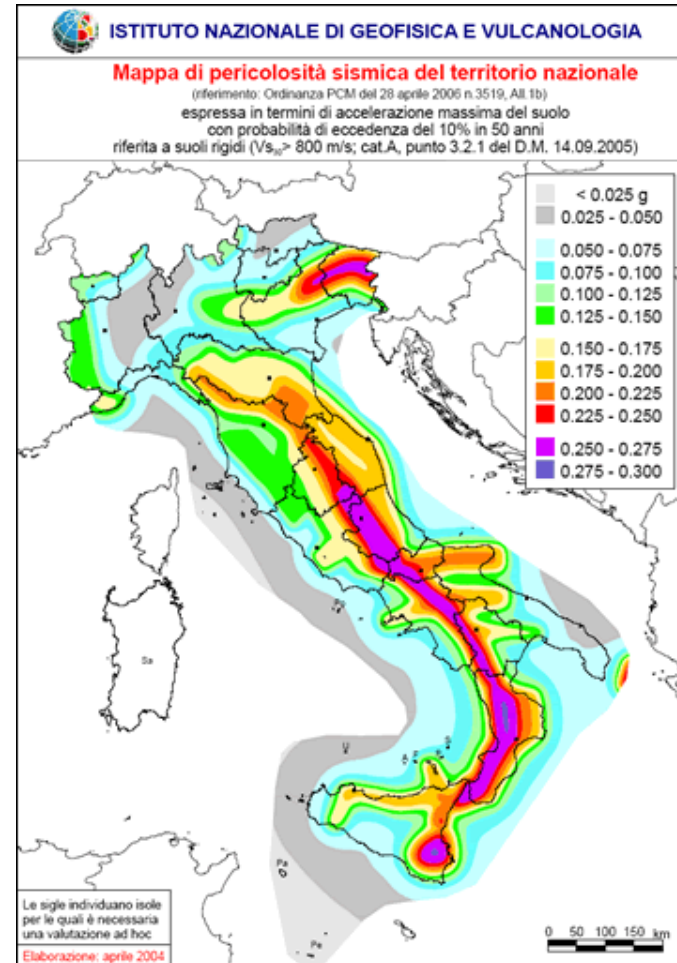


Seismic Hazard Calculator

Output information used by the OQ-engine risk calculators

Classical PSHA

- Probabilistic: All possible earthquake scenarios of engineering relevance for the investigated site are considered in the analysis
- Approach used for regional/national-scale hazard assessment, as well as in site-specific studies.

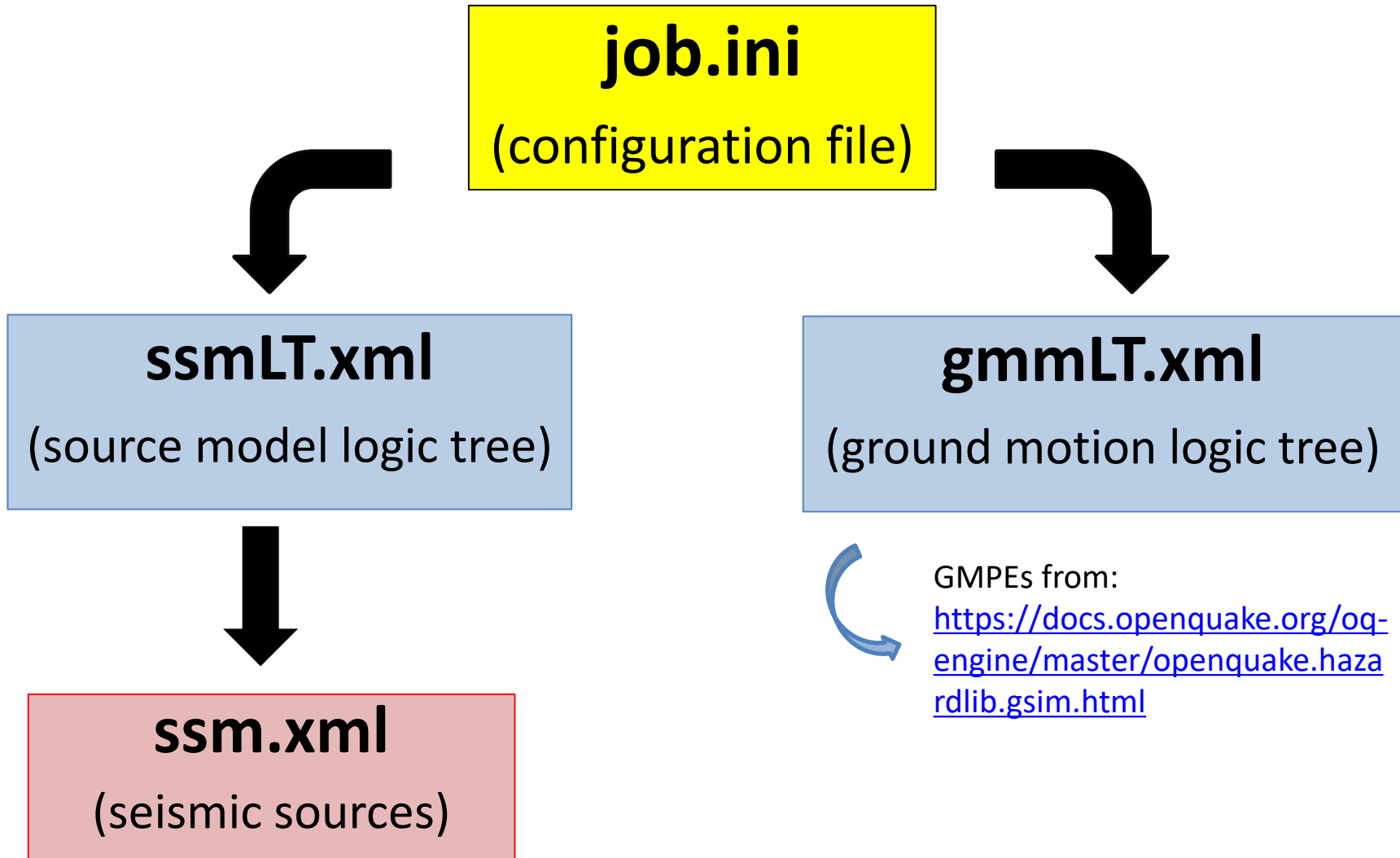


OpenQuake input file format

- Natural hazard's Risk Markup Language (NRML) format
- Files end in ".xml"
- A markup language is a set of markup tags
- The tags (**shown in green**) describe document content

```
<simpleFaultSource tectonicRegion="Active Shallow Crust" id="1234" name="ITCS044">
  <simpleFaultGeometry>
    ...
    <magScaleRel>WC1994</magScaleRel>
    <ruptAspectRatio>1.0</ruptAspectRatio>
    <truncGutenbergRichterMFD minMag="5.0" maxMag="6.5" bValue="1.31" aValue="4.28" />
    <rake>90.0</rake>
  </simpleFaultSource>
```

Hazard Calculation Input files



Note: files can use any name; these are the standard names (keeping extensions)



GEM

GLOBAL
EARTHQUAKE
MODEL

working
together to
assess
risk

OpenQuake-engine: seismic source definition and rupture calculation

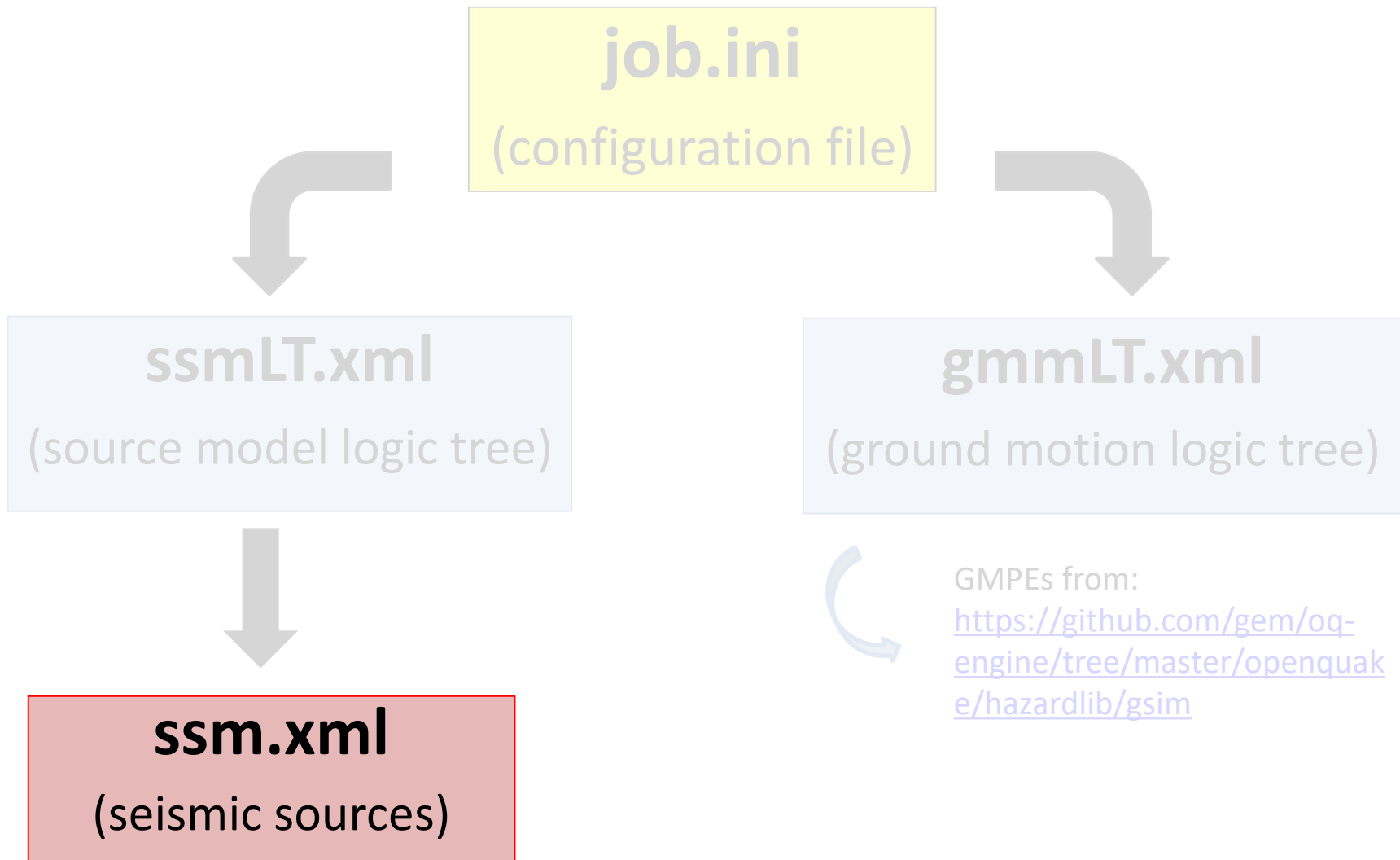
GEM Hazard Team

hazard@globalquakemodel.org



October 1st-5th, 2018 – GEM OpenQuake/Hazard Tools workshop

Hazard Calculation Input files

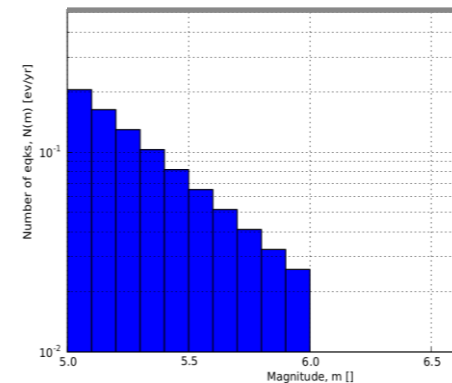
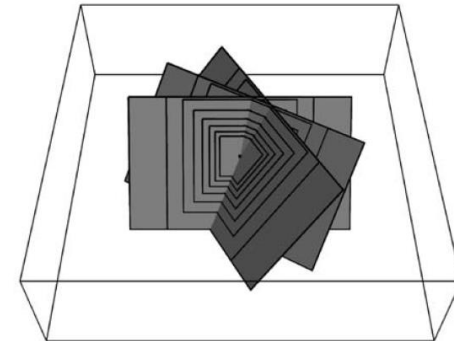
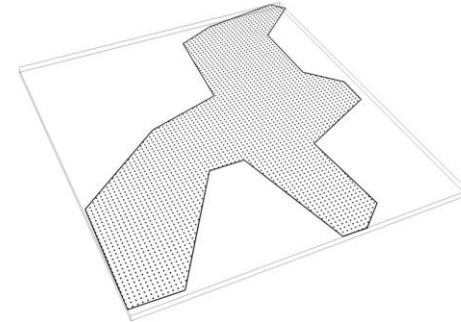


Note: files can use any name; these are the standard names (keeping extensions)



Seismic sources: essential parameters

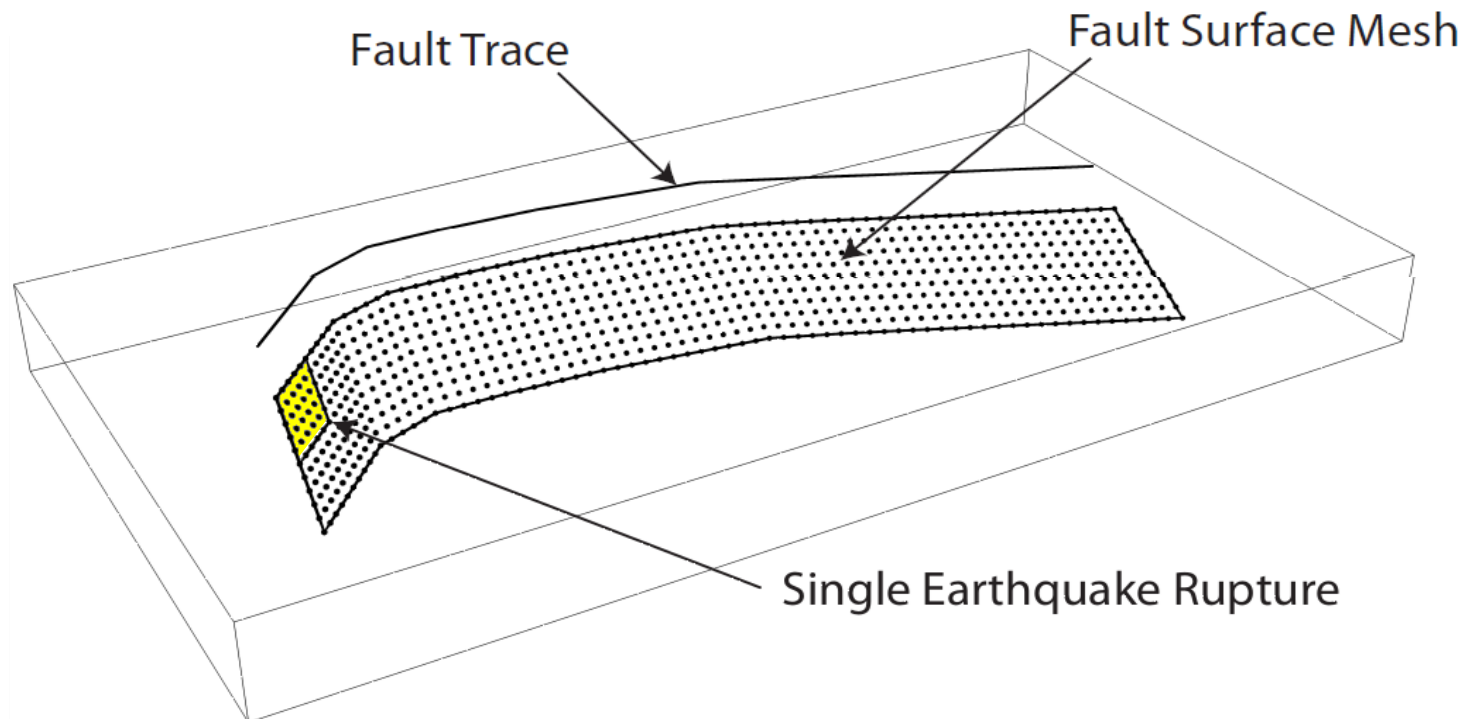
1. Source geometry
 - Typology, location
2. Magnitude-scaling relationship:
 - Required for finite (3D) rupture modelling
3. Magnitude-frequency distribution:
 - Frequency of occurrence of the earthquakes generated by a specific source



An important distinction

- Seismic "**source**" vs "**rupture**"
- A seismic source can host **many possible ruptures**

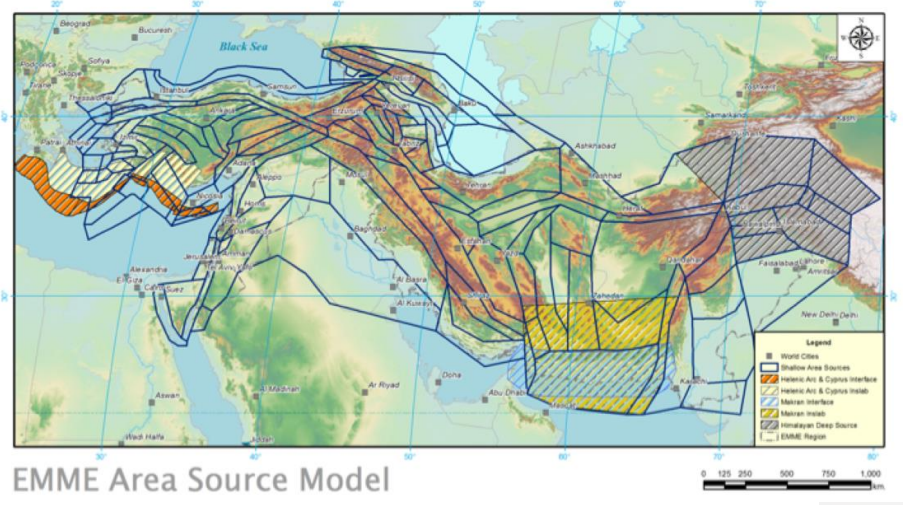
Seismic Source



Seismic sources: Source Typologies in OpenQuake

Modelling off-fault seismicity

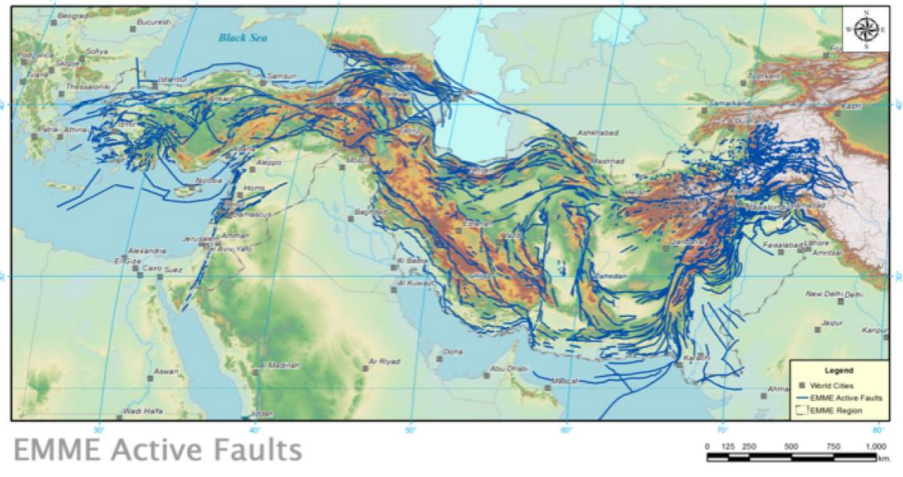
- Point Source
- Area Source



EMME Area Source Model

Modelling on-fault seismicity

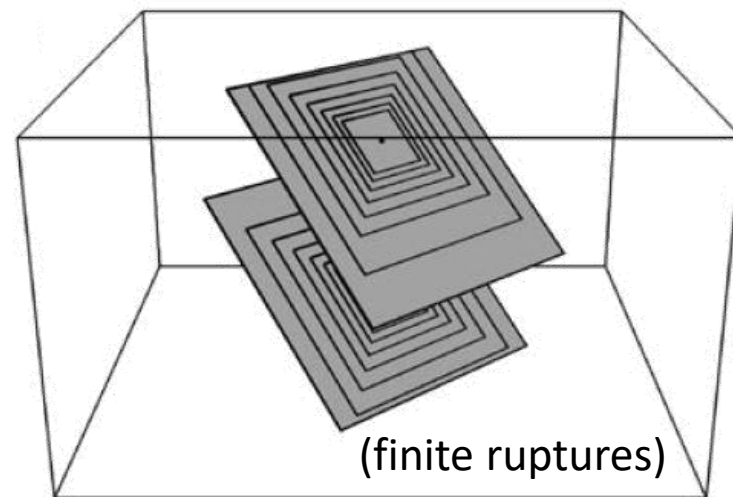
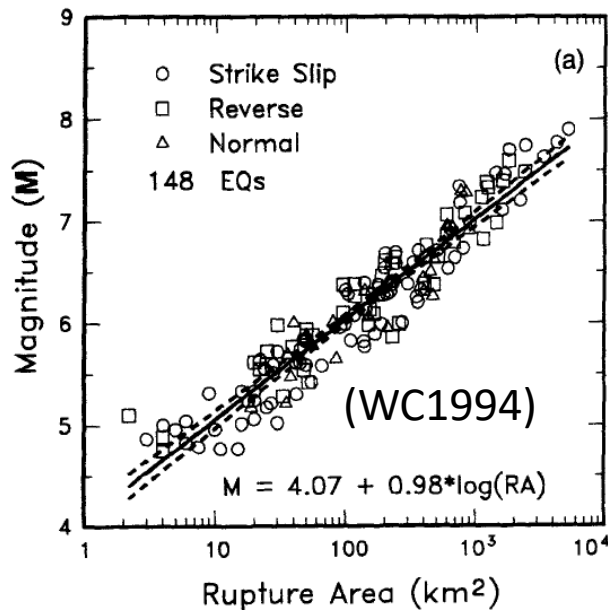
- Simple fault
- Complex fault



EMME Active Faults

Magnitude scaling relationships (MSR)

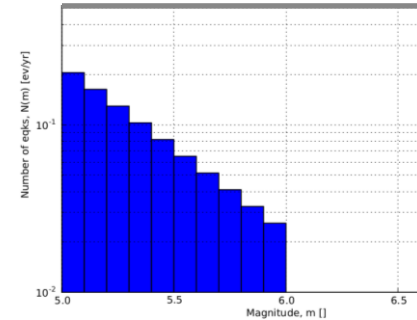
- All sources typologies in OQ generate “finite ruptures” (i.e. 3D rectangular planes)
- Rupture area is computed using a MSR, e.g. Wells and Coppersmith, 1994 (WC1994)



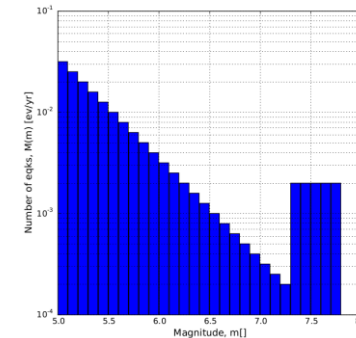
Magnitude-frequency distribution (MFD)

MFDs supported in OQ are:

- Double truncated Gutenberg-Richter
- Evenly Discretised MFD
- Youngs and Coppersmith (1985)



> All represented in discrete form



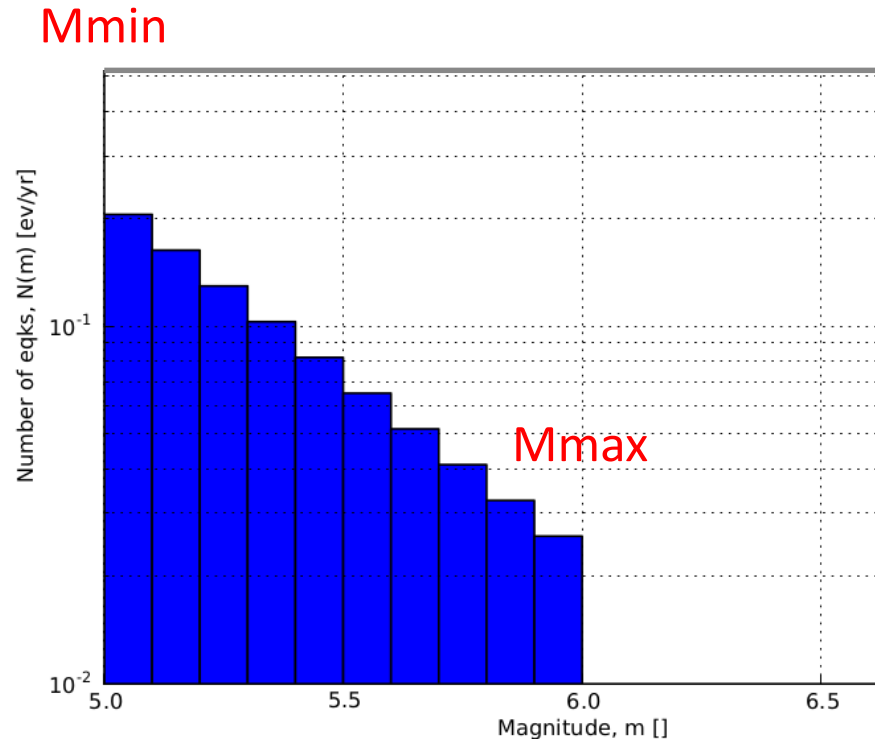
MFDs in OQ: <http://docs.openquake.org/oq-hazardlib/master/openquake.hazardlib.mfd.html>



Double truncated Gutenberg-Richter MFD

Parameters:

- **a-value**: log of the number of earthquakes with $M > 0$
- **b-value**
- Minimum magnitude (**Mmin**)
- Maximum magnitude (**Mmax**)
- *Note: bin width is specified in the job.ini*



The xml syntax (the order of xml parameters doesn't matter):

```
<truncGutenbergRichterMFD avalue="5.0" bValue="1.0" minMag="5.0" maxMag="6.5" />
```

```
<truncGutenbergRichterMFD minMag="5.0" maxMag="6.5" avalue="5.0" bValue="1.0" />
```

OpenQuake-engine: seismic source definition and rupture calculation

Source Typologies



Point Source



Point source

- The simplest source typology in OQ
- Used to model distributed seismicity, e.g. through an **area source**
- As with all sources in OQ, ruptures are extended (despite being called "point" source)

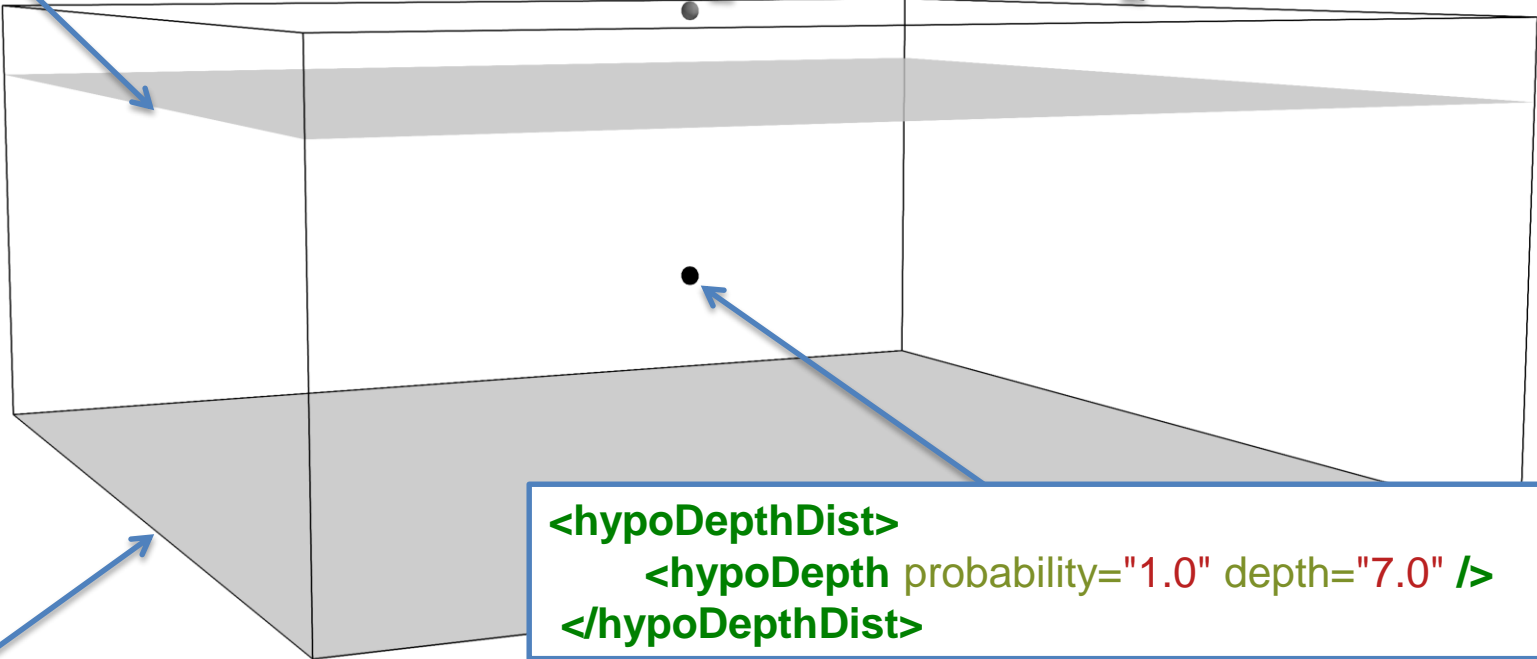


```
<gml:Point>
  <gml:pos>0.0 0.0</gml:pos>
</gml:Point>
```

```
<upperSeismoDepth>2.0</upperSeismoDepth>
```

Earth surface

Seismogenic layer



```
<hypoDepthDist>
  <hypoDepth probability="1.0" depth="7.0" />
</hypoDepthDist>
```

```
<lowerSeismoDepth>12.0</lowerSeismoDepth>
```

Source geometry definition

Depths in km
Coordinates in lon,lat

Point Source – Example of input file

```
<pointSource id="1234" name="Point Source"  
  tectonicRegion="Active Shallow Crust">  
  <pointGeometry>  
    <gml:Point>  
      <gml:pos>0.0 0.0</gml:pos>  
    </gml:Point>  
    <upperSeismoDepth>2.0</upperSeismoDepth>  
    <lowerSeismoDepth>12.0</lowerSeismoDepth>  
  </pointGeometry>  
  <magScaleRel>WC1994</magScaleRel>  
  <ruptAspectRatio>1.</ruptAspectRatio>  
  <truncGutenbergRichterMFD  
    aValue="0.1" bValue="1.0" minMag="5.0" maxMag="6.5" />  
  <nodalPlaneDist>  
    <nodalPlane probability="1." strike="0.0" dip="90.0" rake="0.0"/>  
  </nodalPlaneDist>  
  <hypoDepthDist>  
    <hypoDepth probability="1." depth="7." />  
  </hypoDepthDist>  
</pointSource>
```

Source geometry



Point Source – Example of input file

```
<pointSource id="1234" name="Point Source"  
  tectonicRegion="Active Shallow Crust">  
  <pointGeometry>  
    <gml:Point>  
      <gml:pos>0.0 0.0</gml:pos>  
    </gml:Point>  
    <upperSeismoDepth>2.0</upperSeismoDepth>  
    <lowerSeismoDepth>12.0</lowerSeismoDepth>  
  </pointGeometry>  
  <magScaleRel>WC1994</magScaleRel>  
  <ruptAspectRatio>1.</ruptAspectRatio>  
  <truncGutenbergRichterMFD  
    aValue="0.1" bValue="1.0" minMag="5.0" maxMag="6.5" />  
  <nodalPlaneDist>  
    <nodalPlane probability="1." strike="0.0" dip="90.0" rake="0.0"/>  
  </nodalPlaneDist>  
  <hypoDepthDist>  
    <hypoDepth probability="1." depth="7." />  
  </hypoDepthDist>  
</pointSource>
```

Seismicity occurrence (rupture generation)



<truncGutenbergRichterMFD

aValue="0.1" bValue="1.0"
minMag="5.0" maxMag="6.5"

/>



<magScaleRel>WC1994</magScaleRel>

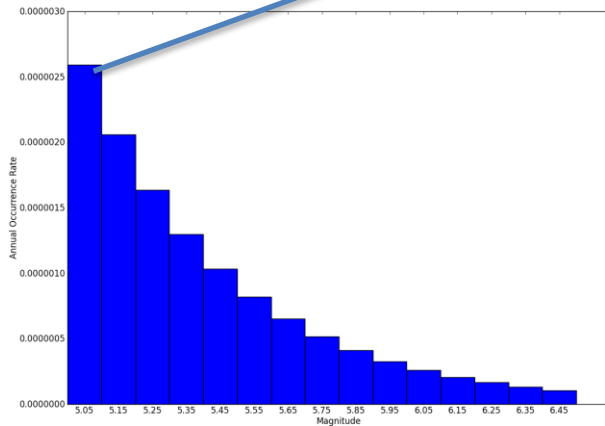
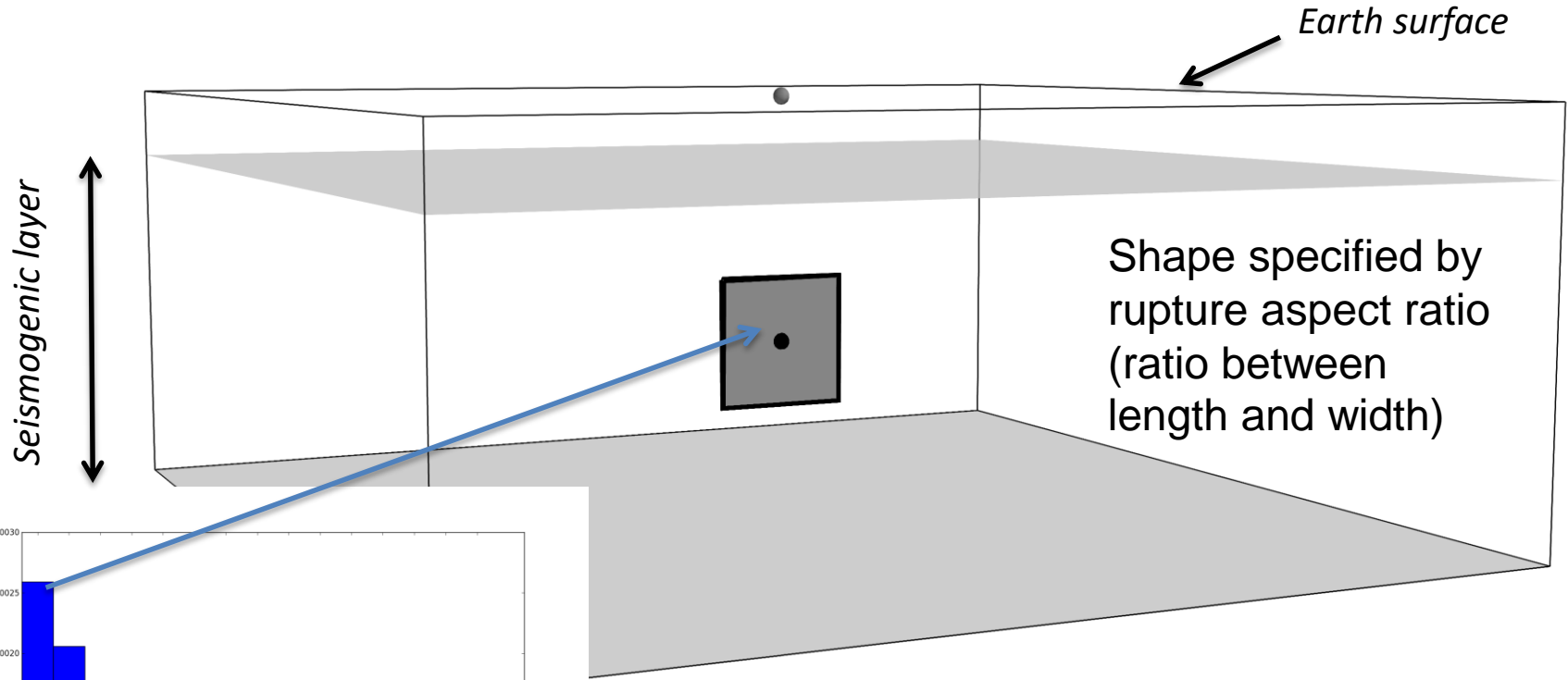
<ruptAspectRatio>1.0</ruptAspectRatio>

<nodalPlaneDist>

<nodalPlane probability="1.0"

strike="0.0" dip="90.0" rake="0.0" />

</nodalPlaneDist>

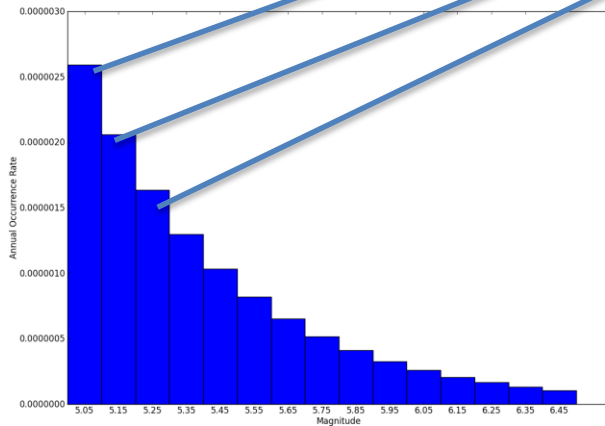
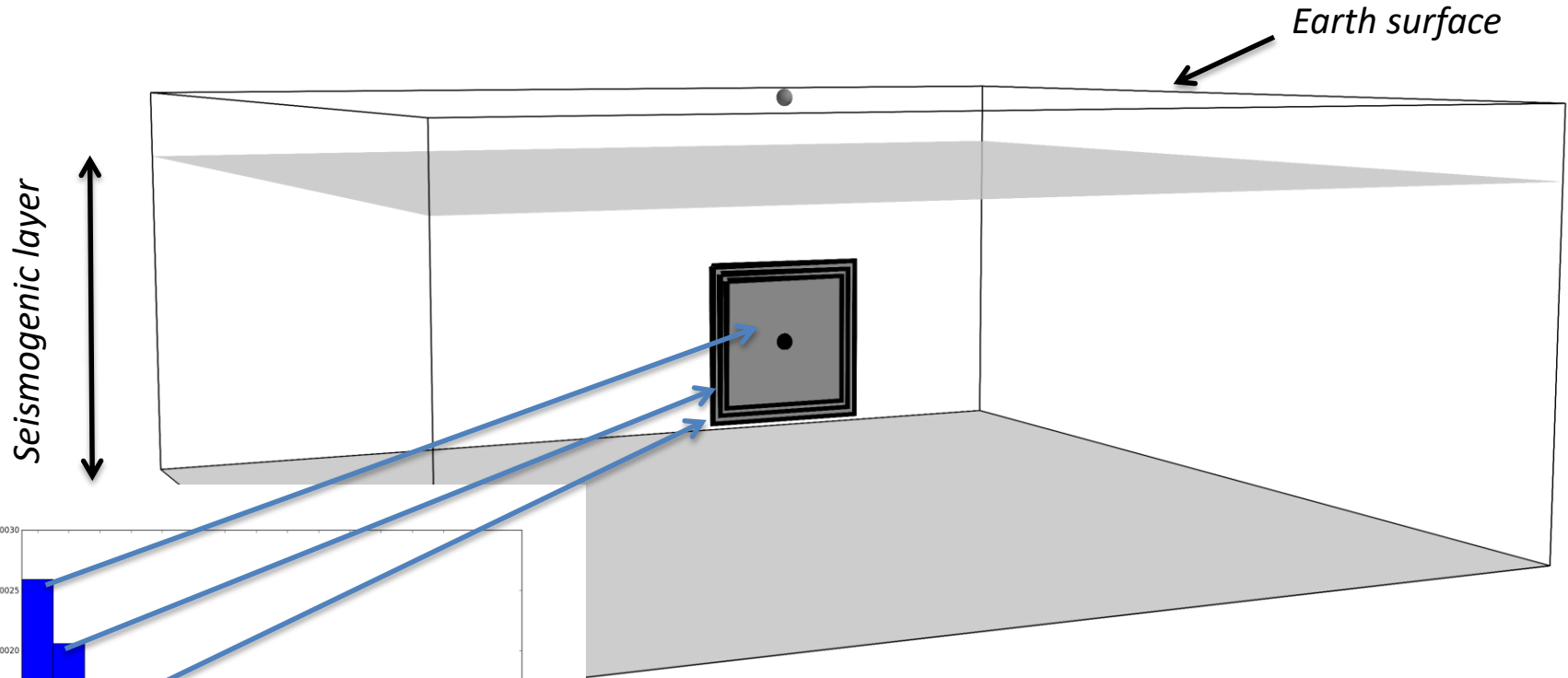


<truncGutenbergRichterMFD

aValue="0.1" bValue="1.0"
minMag="5.0" maxMag="6.5"

/>

<magScaleRel>WC1994</magScaleRel>
<ruptAspectRatio>1.0</ruptAspectRatio>
<nodalPlaneDist>
 <nodalPlane probability="1.0"
 strike="0.0" dip="90.0" rake="0.0" />
</nodalPlaneDist>



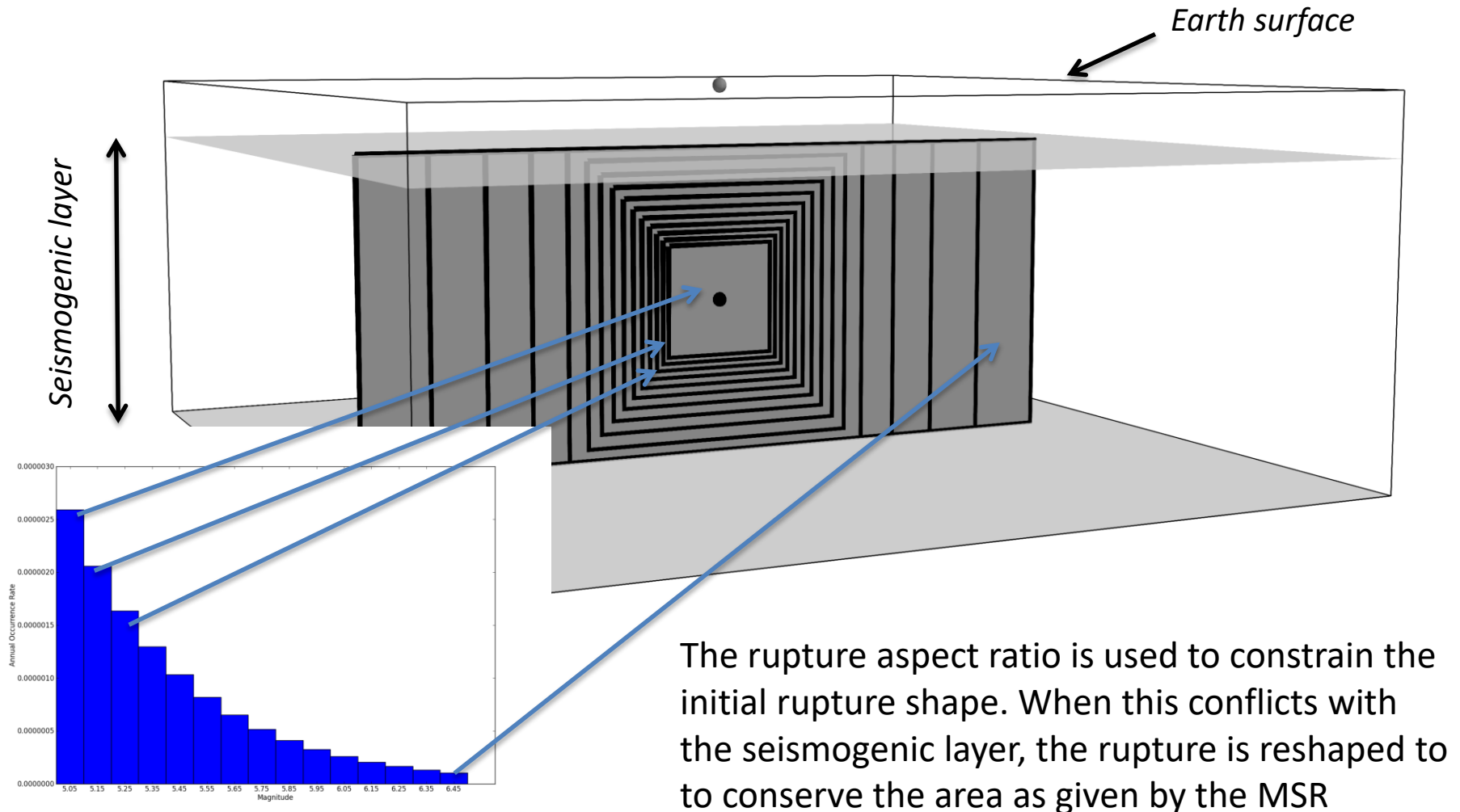
<truncGutenbergRichterMFD

aValue="0.1" bValue="1.0"
minMag="5.0" maxMag="6.5"

</>



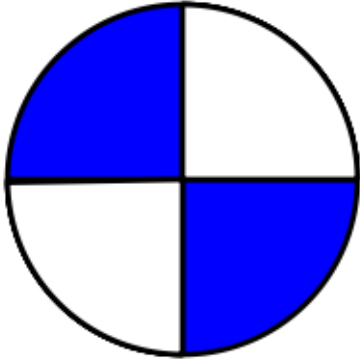
```
<magScaleRel>WC1994</magScaleRel>  
<ruptAspectRatio>1.0</ruptAspectRatio>  
<nodalPlaneDist>  
  <nodalPlane probability="1.0"  
    strike="0.0" dip="90.0" rake="0.0" />  
</nodalPlaneDist>
```



The rupture aspect ratio is used to constrain the initial rupture shape. When this conflicts with the seismogenic layer, the rupture is reshaped to conserve the area as given by the MSR

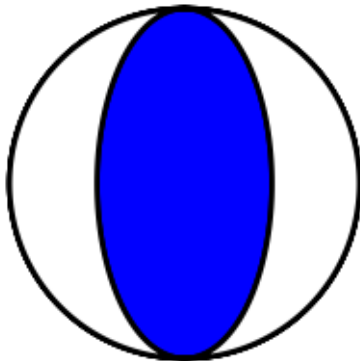
Defining rupture planes

Strike slip



```
<nodalPlaneDist>  
  <nodalPlane probability="1.0" strike="0.0"  
    dip="90.0" rake="180" />  
</nodalPlaneDist>
```

Reverse

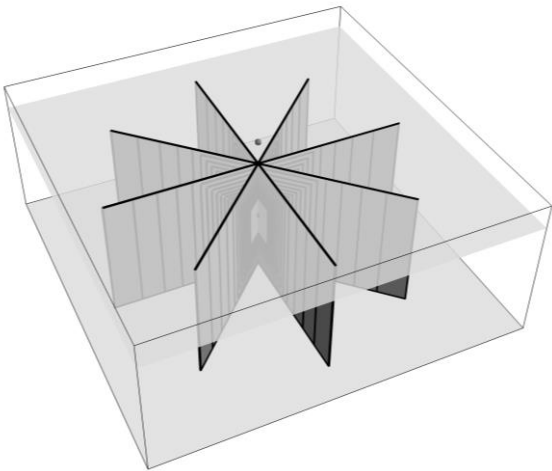


```
<nodalPlaneDist>  
  <nodalPlane probability="1.0" strike="0.0"  
    dip="45.0" rake="90" />  
</nodalPlaneDist>
```



Defining multiple rupture planes

- Multiple nodal planes are sometimes called “spinning ruptures”
- Used to consider (aleatory) uncertainty of rupture planes, if there isn’t a predominant rupture orientation

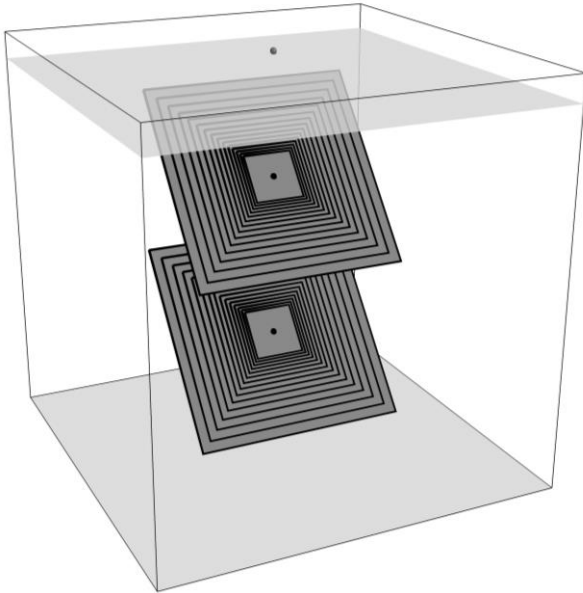


```
<nodalPlaneDist>  
  <nodalPlane probability="0.25" strike="0.0"  
    dip="90.0" rake="0.0" />  
  <nodalPlane probability="0.25" strike="45.0"  
    dip="90.0" rake="0.0" />  
  <nodalPlane probability="0.25" strike="90.0"  
    dip="90.0" rake="0.0" />  
  <nodalPlane probability="0.25" strike="135.0"  
    dip="90.0" rake="0.0" />  
</nodalPlaneDist>
```



Defining multiple hypocentral depths

- Used to consider (aleatory) uncertainty of hypocentral depth



```
<hypoDepthDist>  
  <hypoDepth probability="0.5" depth="10.0" />  
  <hypoDepth probability="0.5" depth="15.0" />  
</hypoDepthDist>
```



Point source – summary of parameters

- The **coordinates of the point** (longitude and latitude) [degrees]
- The **upper and lower seismogenic depths** [km]
- A **magnitude-frequency distribution** (e.g. Gutenberg-Richter)
- A **magnitude-scaling relationship** (e.g. Wells and Coppersmith, 1994)
- A **rupture aspect ratio** (e.g. 1)
- A *distribution* of **nodal planes** i.e. one (or several) instances of the following set of parameters. All probabilities must sum to 1
 - strike [degrees]
 - dip [degrees]
 - rake [degrees]
- A *distribution* of **hypocentral depths** [km] i.e. one (or several) instances. All probabilities must sum to 1



Area Source



Area source

- Area sources rely almost entirely on **point source** implementation.
- In the OQ-engine an area source is a set of equally spaced **point sources**
- Typically used to model seismicity occurring over wide areas where identification/characterization of single fault structures is difficult.



Area Source – Example of input file

```

<areaSource id="1234" name="Zone20" tectonicRegion="Cratonic">
  <areaGeometry>
    <gml:Polygon>
      <gml:exterior>
        <gml:LinearRing>
          <gml:posList>
            133.5 -22.5 133.5 -23.0 130.75 -23.75 130.75 -24.5 133.5 -26.0
            133.5 -27.0 130.75 -27.0 128.977 -25.065 128.425 -23.436
            126.082 -23.233 125.669 -22.351 125.4 -20.5 125.75 -20.25 126.7
            -21.25 128.5 -21.25 129.25 -20.6 130.0 -20.6 130.9 -22.25 133.0
            -22.0 133.5 -22.5
          </gml:posList>
        </gml:LinearRing>
      </gml:exterior>
    </gml:Polygon>
    <upperSeismoDepth>0.0</upperSeismoDepth>
    <lowerSeismoDepth>15.0</lowerSeismoDepth>
  </areaGeometry>
  <magScaleRel>WC1994</magScaleRel>
  <ruptAspectRatio>1.0</ruptAspectRatio>
  <truncGutenbergRichterMFD aValue="2.6218375188" bValue="0.763" maxMag="6.5" minMag="5.0"/>
  <nodalPlaneDist>
    <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="0.0"/>
    <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="45.0"/>
    <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="90.0"/>
    <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="135.0"/>
  </nodalPlaneDist>
  <hypoDepthDist>
    <hypoDepth depth="7.5" probability="1.0"/>
  </hypoDepthDist>
</areaSource>

```

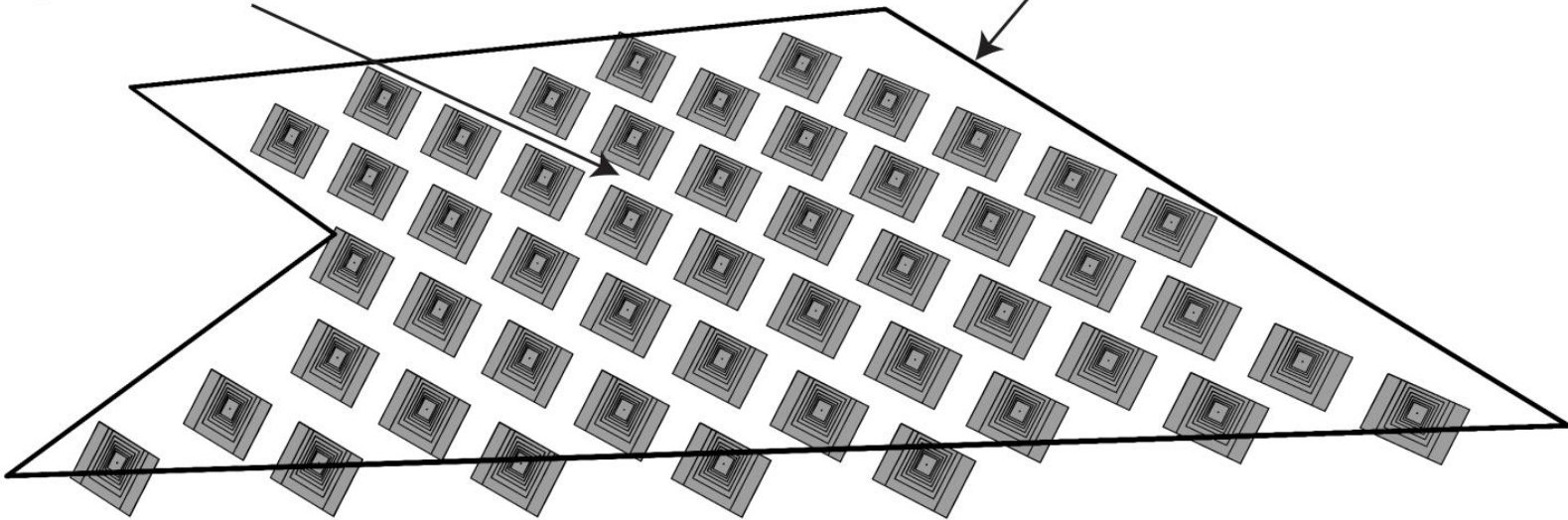
Source geometry



Area source boundary

```
<gml:Polygon>  
  <gml:exterior>  
    <gml:LinearRing>  
      <gml:posList>  
        ...  
      </gml:posList>  
    </gml:LinearRing>  
  </gml:exterior>  
</gml:Polygon>
```

Rupture Grid



Area Source – Example of NRML definition

```

<areaSource id="1234" name="Zone20" tectonicRegion="Cratonic">
  <areaGeometry>
    <gml:Polygon>
      <gml:exterior>
        <gml:LinearRing>
          <gml:posList>
            133.5 -22.5 133.5 -23.0 130.75 -23.75 130.75 -24.5 133.5 -26.0
            133.5 -27.0 130.75 -27.0 128.977 -25.065 128.425 -23.436
            126.082 -23.233 125.669 -22.351 125.4 -20.5 125.75 -20.25 126.7
            -21.25 128.5 -21.25 129.25 -20.6 130.0 -20.6 130.9 -22.25 133.0
            -22.0 133.5 -22.5
          </gml:posList>
        </gml:LinearRing>
      </gml:exterior>
    </gml:Polygon>
    <upperSeismoDepth>0.0</upperSeismoDepth>
    <lowerSeismoDepth>15.0</lowerSeismoDepth>
  </areaGeometry>

```

Seismicity occurrence
(rupture generation)

```

<magScaleRel>WC1994</magScaleRel>
<ruptAspectRatio>1.0</ruptAspectRatio>
<truncGutenbergRichterMFD aValue="2.6218375188" bValue="0.763" maxMag="6.5" minMag="5.0"/>
<nodalPlaneDist>
  <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="0.0"/>
  <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="45.0"/>
  <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="90.0"/>
  <nodalPlane dip="90.0" probability="0.25" rake="0.0" strike="135.0"/>
</nodalPlaneDist>
<hypoDepthDist>
  <hypoDepth depth="7.5" probability="1.0"/>
</hypoDepthDist>
</areaSource>

```

Same as for point source



Area source – summary of parameters

- A **polygon** defining the external border of the area (i.e. a list of Longitude-Latitude [degrees] coordinates)
- The **upper and lower seismogenic depths** [km]
- One **magnitude-frequency distribution** (e.g. Gutenberg-Richter)
- One **magnitude-scaling relationship** (e.g. Wells and Coppersmith, 1994)
- One **rupture aspect ratio** (e.g. 1)
- A *distribution* of **nodal planes** i.e. one (or several) instances of the following set of parameters. All probabilities must sum to 1
 - strike [degrees]
 - dip [degrees]
 - rake [degrees]
- A *distribution* of **hypocentral depths** [km] i.e. one (or several) instances. All probabilities must sum to 1

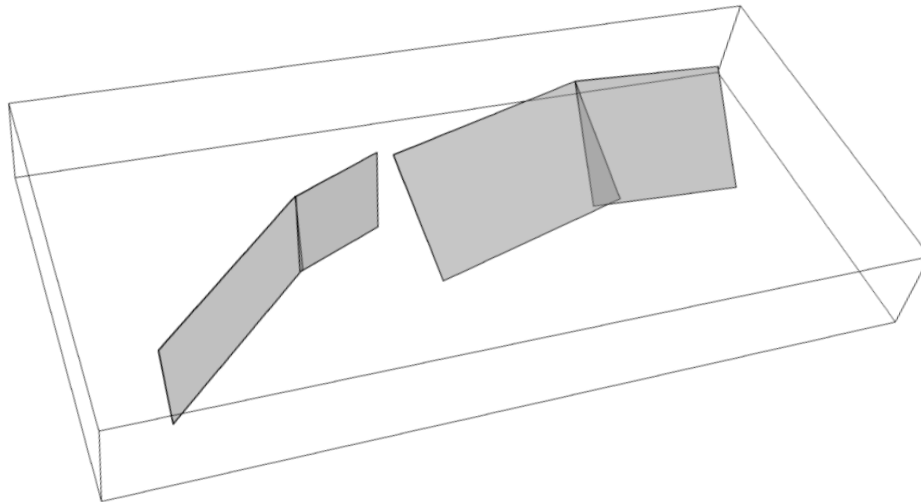


Simple fault source



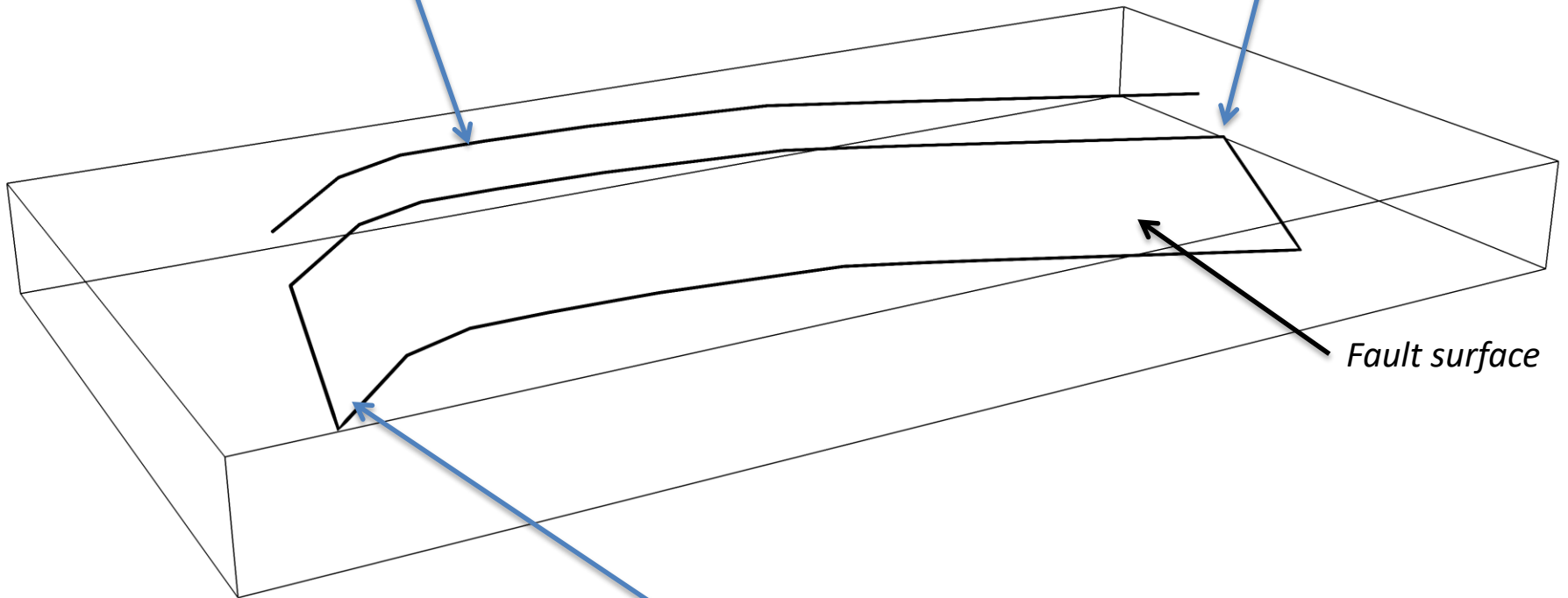
Simple Fault Source

- The most common source type used to model **shallow faults**
- “simple” is related to the geometry of the source which is obtained by projecting the fault trace (i.e. a line) along a dip direction, forming **planar** surfaces



```
<gml:LineString>  
  <gml:posList>  
    9.21602706445 45.1555287905  
    9.25645636929 45.1877167851 ...  
  </gml:posList>  
</gml:LineString>
```

```
<upperSeismoDepth>2.0</upperSeismoDepth>
```



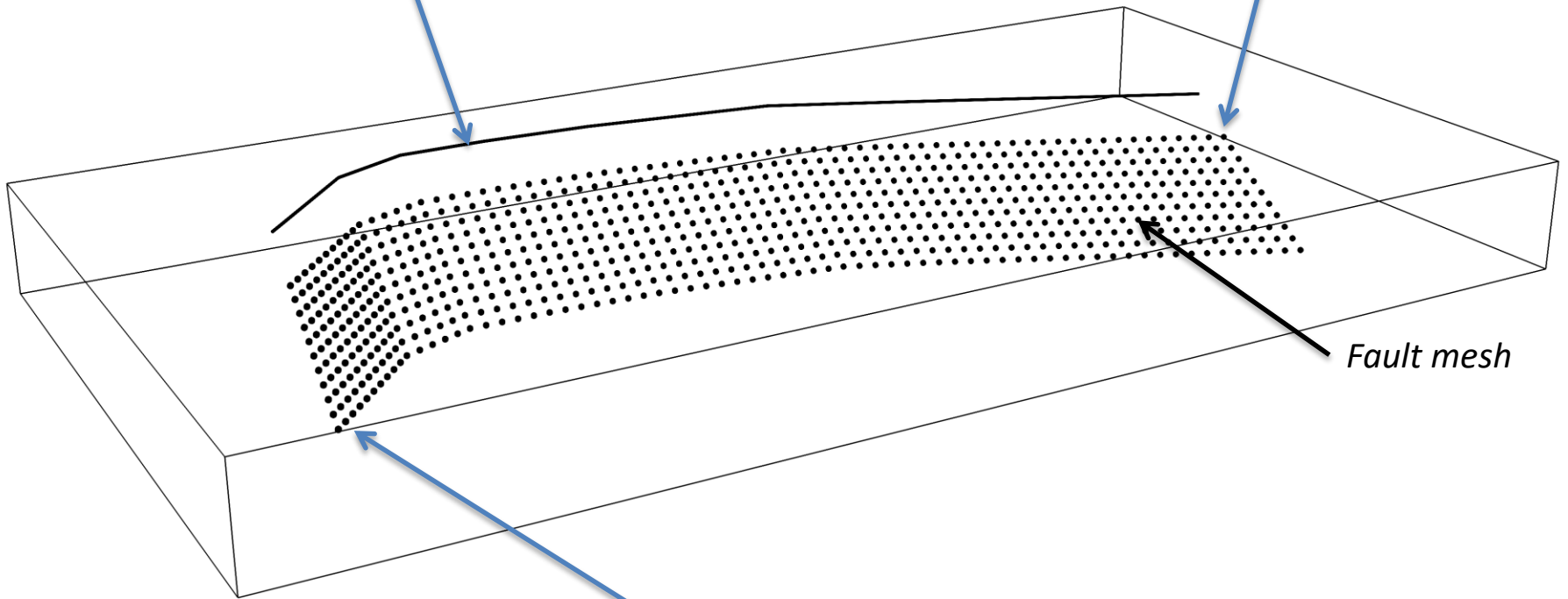
Fault surface

```
<lowerSeismoDepth>7.0</lowerSeismoDepth>
```



```
<gml:LineString>  
  <gml:posList>  
    9.21602706445 45.1555287905  
    9.25645636929 45.1877167851 ...  
  </gml:posList>  
</gml:LineString>
```

```
<upperSeismoDepth>2.0</upperSeismoDepth>
```



Fault mesh

```
<lowerSeismoDepth>7.0</lowerSeismoDepth>
```

Simple Fault Source – Example of input file

```

<simpleFaultSource tectonicRegion="Active Shallow Crust"
  id="1234" name="ITCS044">
  <simpleFaultGeometry>
    <gml:LineString>
      <gml:posList>
        9.21602706445 45.1555287905
        9.25645636929 45.1877167851 ...
      </gml:posList>
    </gml:LineString>
    <dip>30.0</dip>
    <upperSeismoDepth>2.0</upperSeismoDepth>
    <lowerSeismoDepth>7.0</lowerSeismoDepth>
  </simpleFaultGeometry>
  <magScaleRel>WC1994</magScaleRel>
  <ruptAspectRatio>1.0</ruptAspectRatio>
  <truncGutenbergRichterMFD maxMag="6.5" bValue="1.317"
    aValue="4.28448" minMag="5.0"/>
  <rake>90.0</rake>
</simpleFaultSource>

```

Source geometry



Simple Fault Source – Example of input file

```

<simpleFaultSource tectonicRegion="Active Shallow Crust"
  id="1234" name="ITCS044">
  <simpleFaultGeometry>
    <gml:LineString>
      <gml:posList>
        9.21602706445 45.1555287905
        9.25645636929 45.1877167851 ...
      </gml:posList>
    </gml:LineString>
    <dip>30.0</dip>
    <upperSeismoDepth>2.0</upperSeismoDepth>
    <lowerSeismoDepth>7.0</lowerSeismoDepth>
  </simpleFaultGeometry>
  <magScaleRel>WC1994</magScaleRel>
  <ruptAspectRatio>1.0</ruptAspectRatio>
  <truncGutenbergRichterMFD maxMag="6.5" bValue="1.317"
    aValue="4.28448" minMag="5.0"/>
  <rake>90.0</rake>
</simpleFaultSource>

```

Seismicity occurrence
(rupture generation)

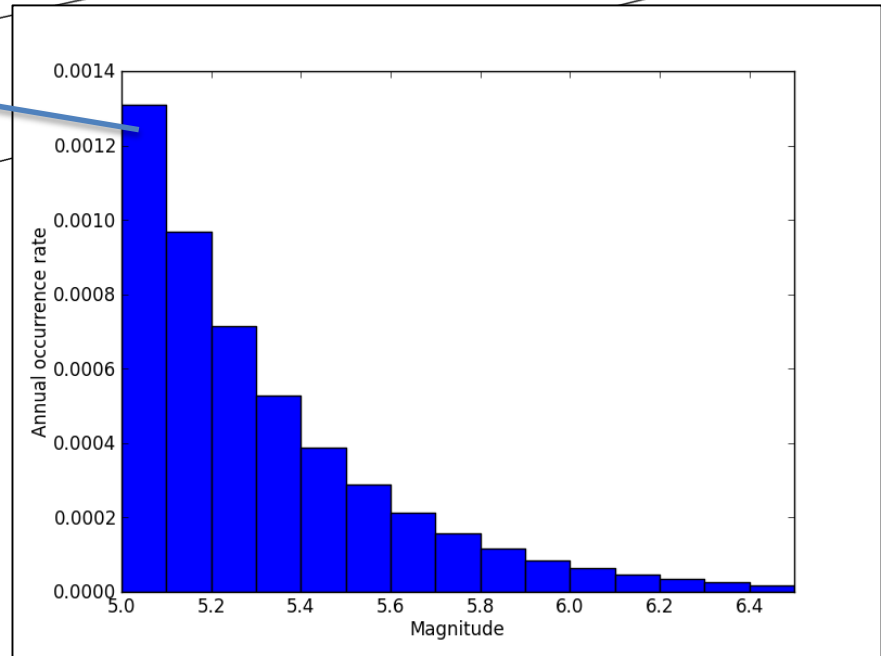
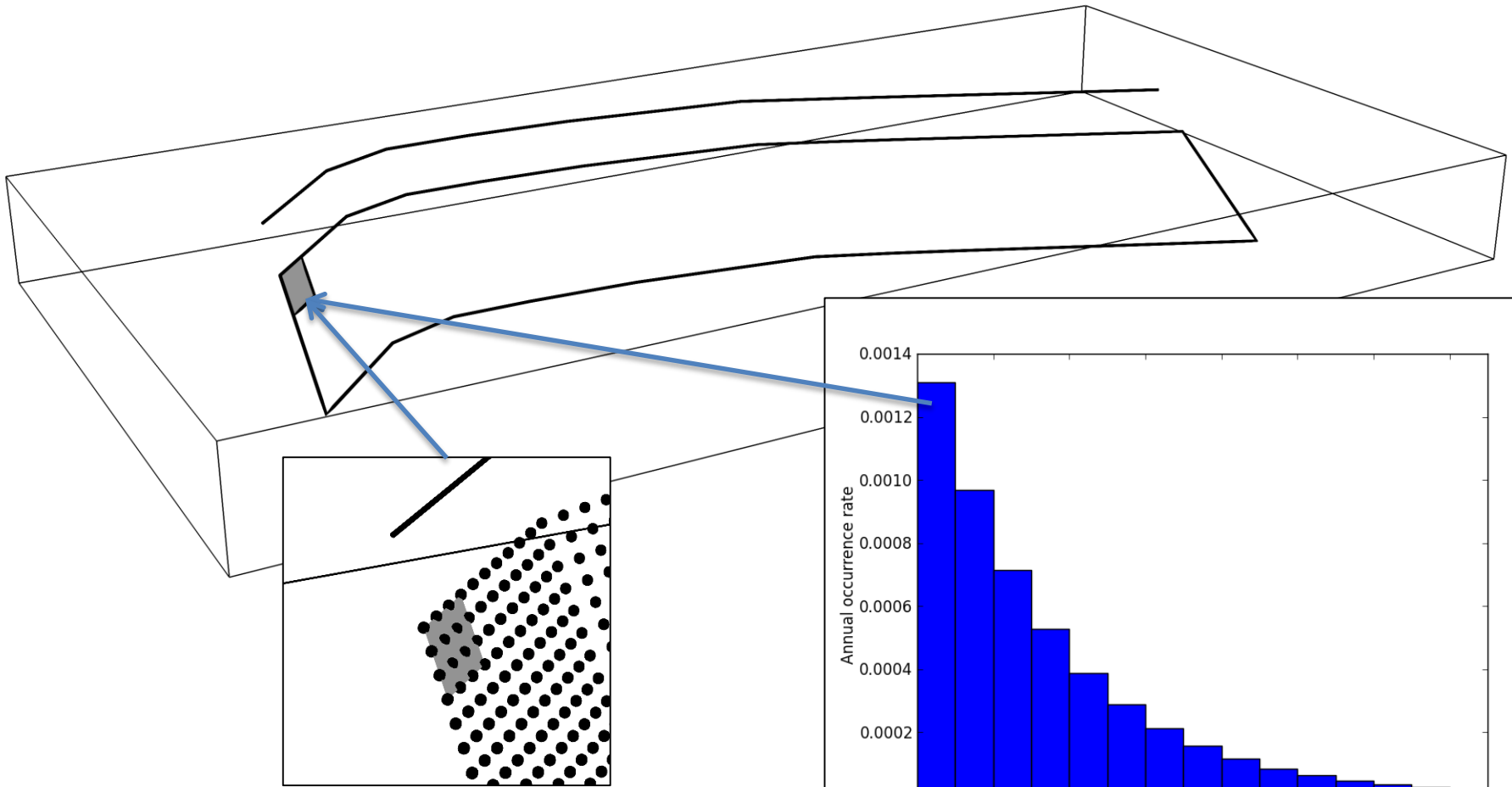


<truncGutenbergRichterMFD

maxMag="6.5" bValue="1.317"
aValue="4.28448" minMag="5.0"/>



**<magScaleRel>WC1994</magScaleRel>
<ruptAspectRatio>1.</ruptAspectRatio>**



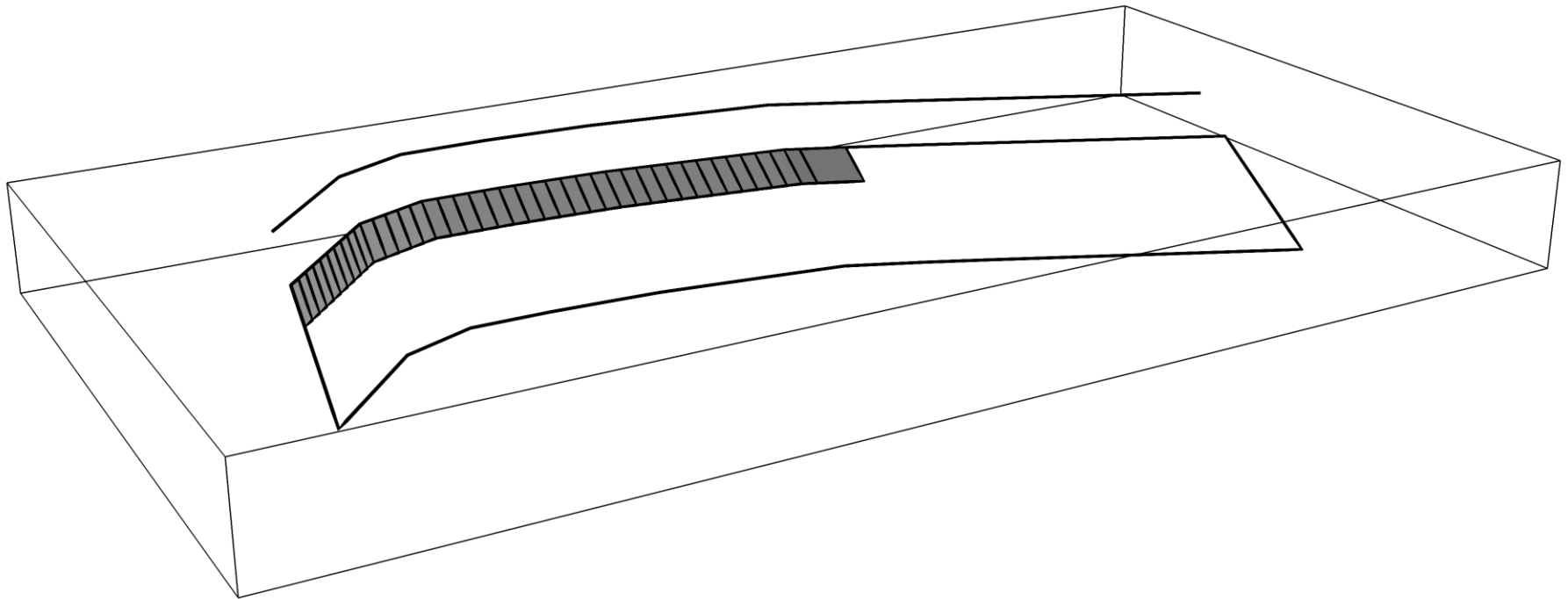
```
<truncGutenbergRichterMFD
```

```
maxMag="6.5" bValue="1.317"  
aValue="4.28448" minMag="5.0"/>
```



```
<magScaleRel>WC1994</magScaleRel>
```

```
<ruptAspectRatio>1.</ruptAspectRatio>
```



```
<truncGutenbergRichterMFD
```

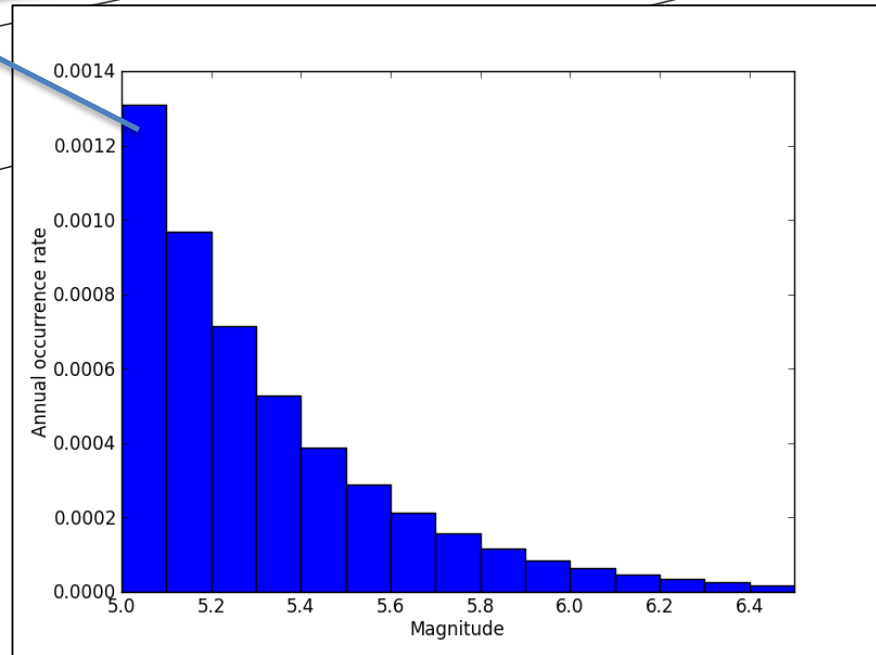
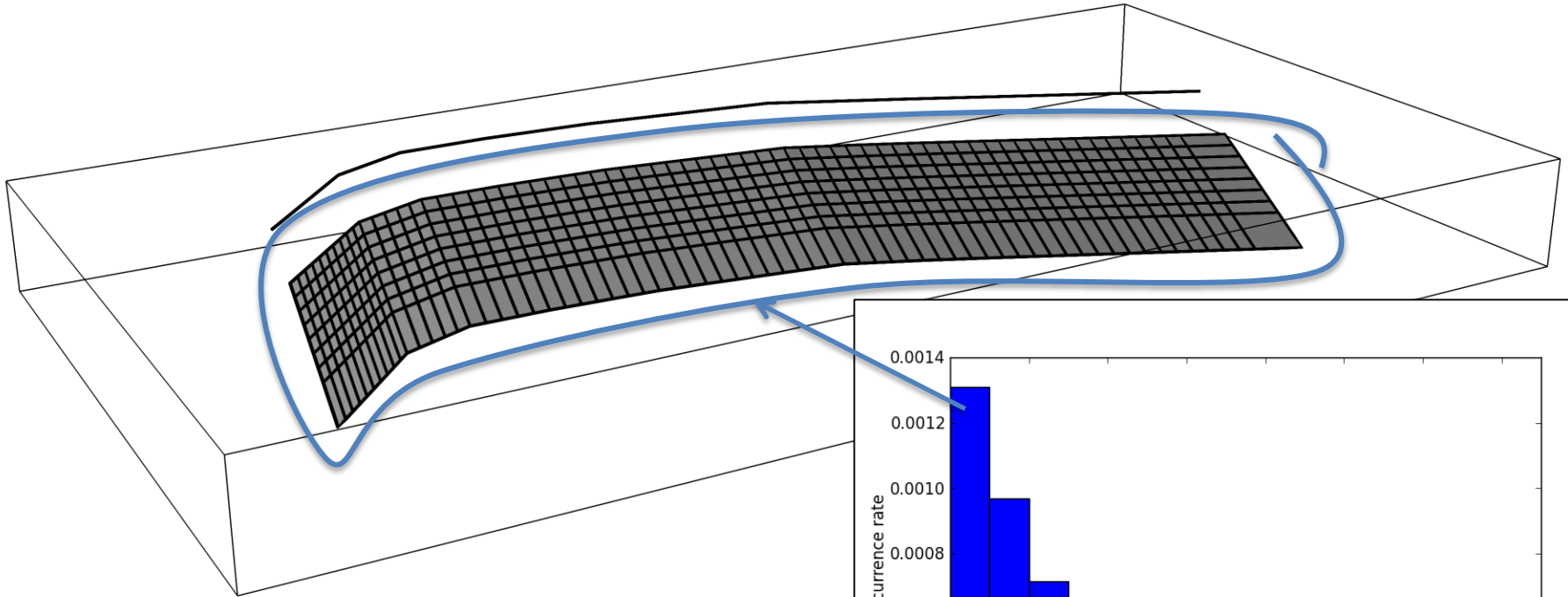
```
maxMag="6.5" bValue="1.317"
```

```
aValue="4.28448" minMag="5.0"/>
```



```
<magScaleRel>WC1994</magScaleRel>
```

```
<ruptAspectRatio>1.</ruptAspectRatio>
```



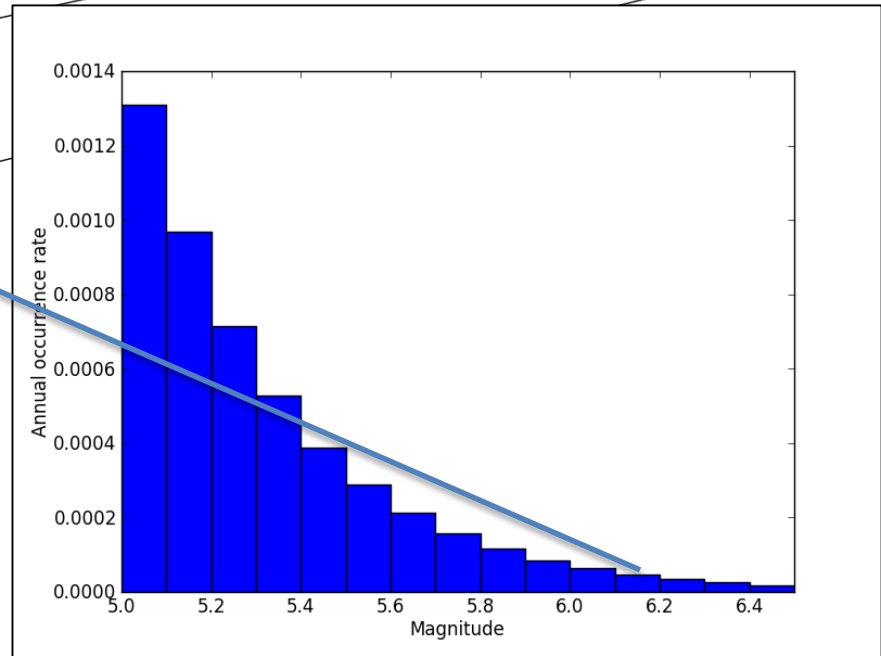
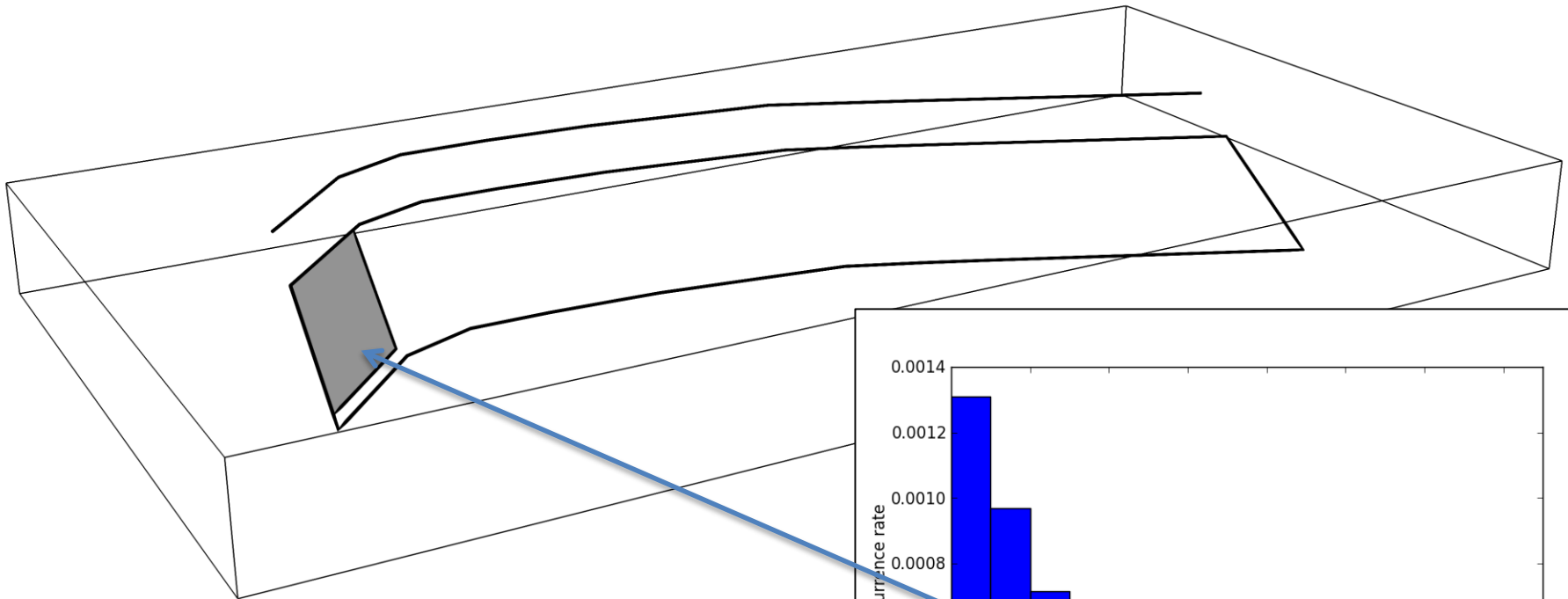
```
<truncGutenbergRichterMFD
```

```
maxMag="6.5" bValue="1.317"  
aValue="4.28448" minMag="5.0"/>
```



```
<magScaleRel>WC1994</magScaleRel>
```

```
<ruptAspectRatio>1.</ruptAspectRatio>
```



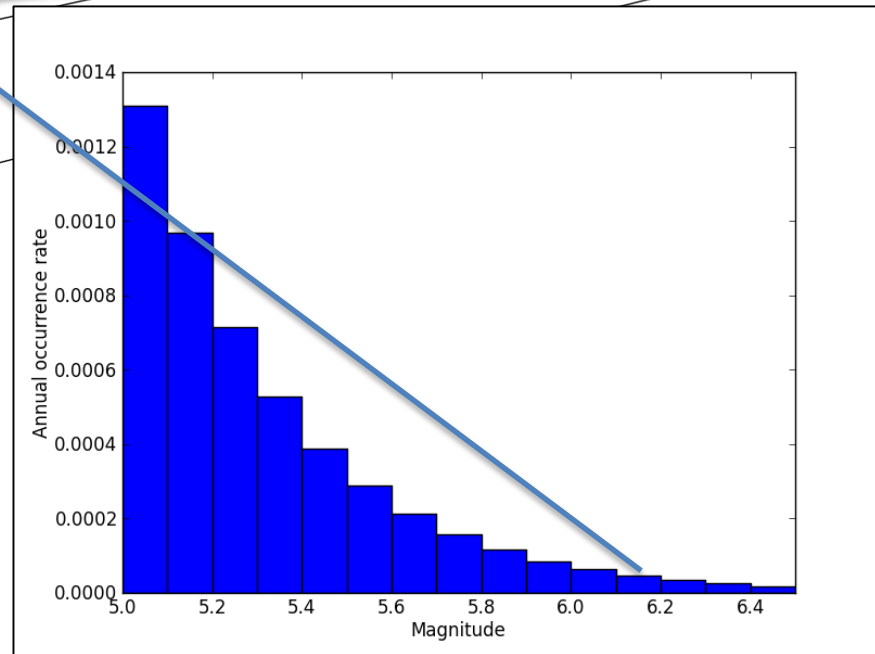
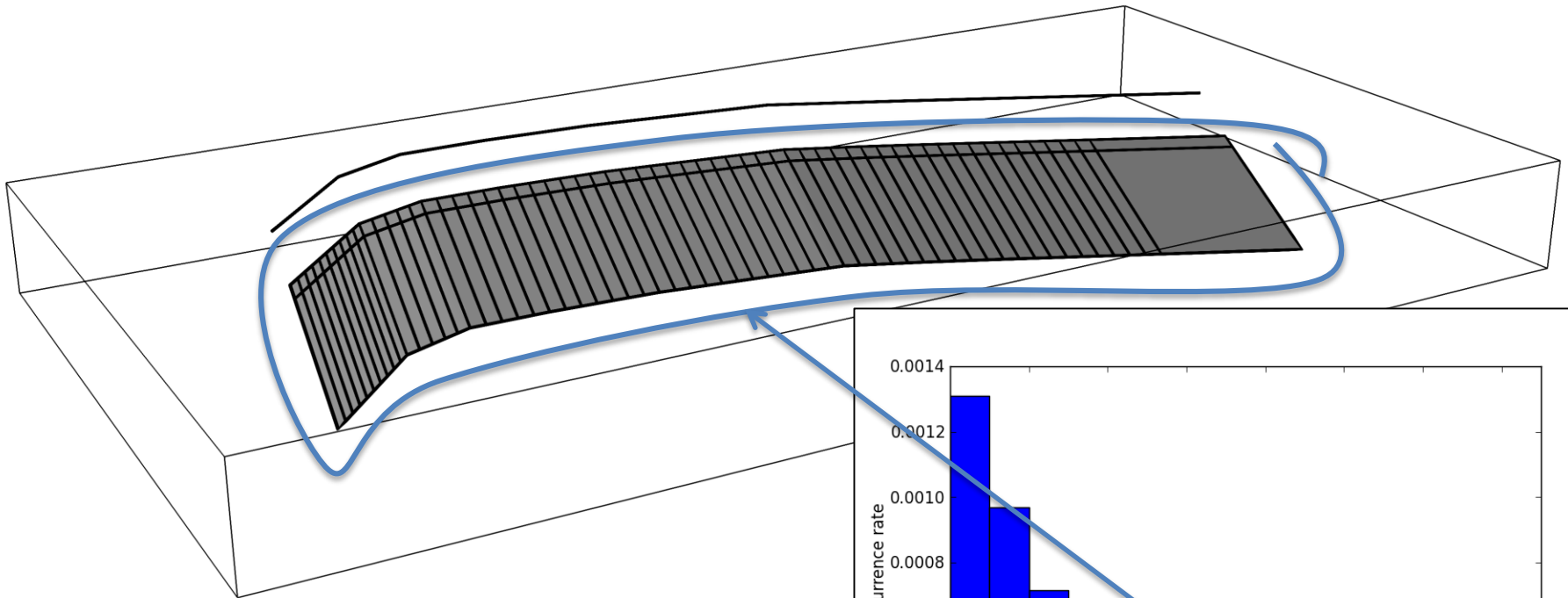
```
<truncGutenbergRichterMFD
```

```
maxMag="6.5" bValue="1.317"  
aValue="4.28448" minMag="5.0"/>
```



```
<magScaleRel>WC1994</magScaleRel>
```

```
<ruptAspectRatio>1.</ruptAspectRatio>
```



Simple Fault Source— summary of parameters

- A horizontal **fault trace** (polyline). It is a list of longitude-latitude tuples [degrees]
- Dip angle (specified following the *Aki-Richards convention; see Aki and Richards, (2002)) [degrees]
- The **upper and lower seismogenic depths** [km]
- One **magnitude-frequency distribution** (e.g. Gutenberg-Richter)
- One **magnitude-scaling relationship** (e.g. Wells and Coppersmith, 1994)
- One **rupture aspect ratio** (e.g. 1)
- **Rake angle** [degrees]

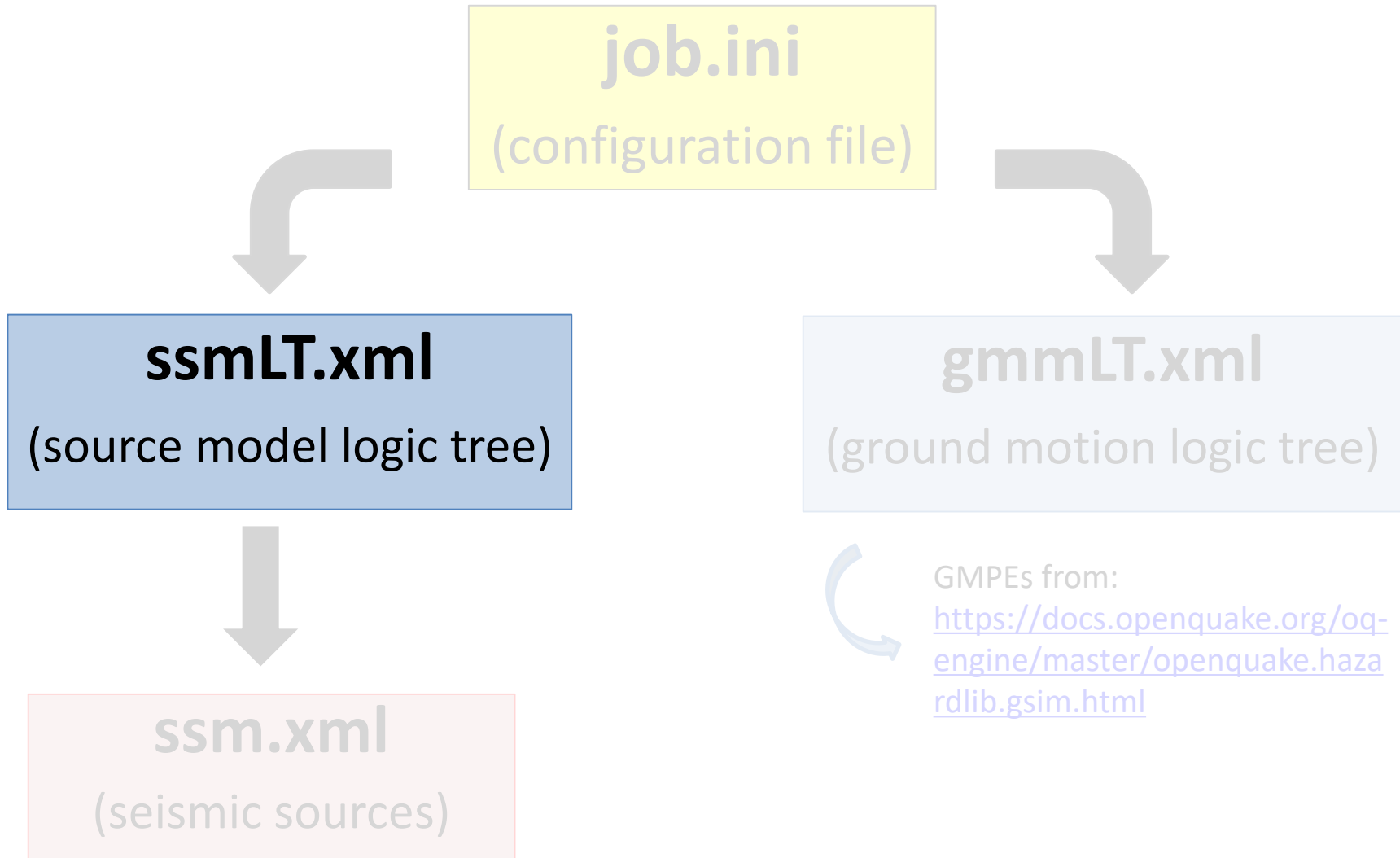
* The *Aki & Richards convention* requires that the order of the coordinates of the fault trace should be such that if we were to walk a path along the coordinates the fault should be dipping to the right.



Source Model Logic Tree



Hazard Calculation Input files



Note: files can use any name; these are the standard names (keeping extensions)




Source model logic tree

- The source model logic tree file points to the seismic source model(s)
- Used to formally specify the **epistemic uncertainties** in the source model
- Every logic tree branch represents one complete source model
- Every branch is assigned **weights** expressing the degree of belief in that model.



Source model logic tree

Example 1: One source model

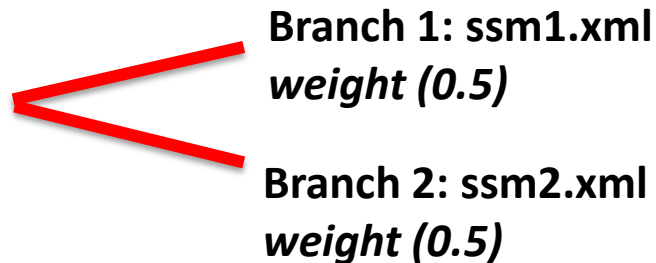
 Branch 1: ssm.xml
(*weight = 1.0*)

Only 1 source model file
means epistemic uncertainty
is not considered

```
<logicTree logicTreeID="lt1">
  <logicTreeBranchingLevel branchingLevelID="bl1">
    <logicTreeBranchSet uncertaintyType="sourceModel" branchSetID="bs1">
      <logicTreeBranch branchID="b1">
        <uncertaintyModel>ssm.xml</uncertaintyModel>
        <uncertaintyWeight>1.0</uncertaintyWeight>
      </logicTreeBranch>
    </logicTreeBranchSet>
  </logicTreeBranchingLevel>
</logicTree>
```

Source model logic tree

Example 2: Two alternative source models



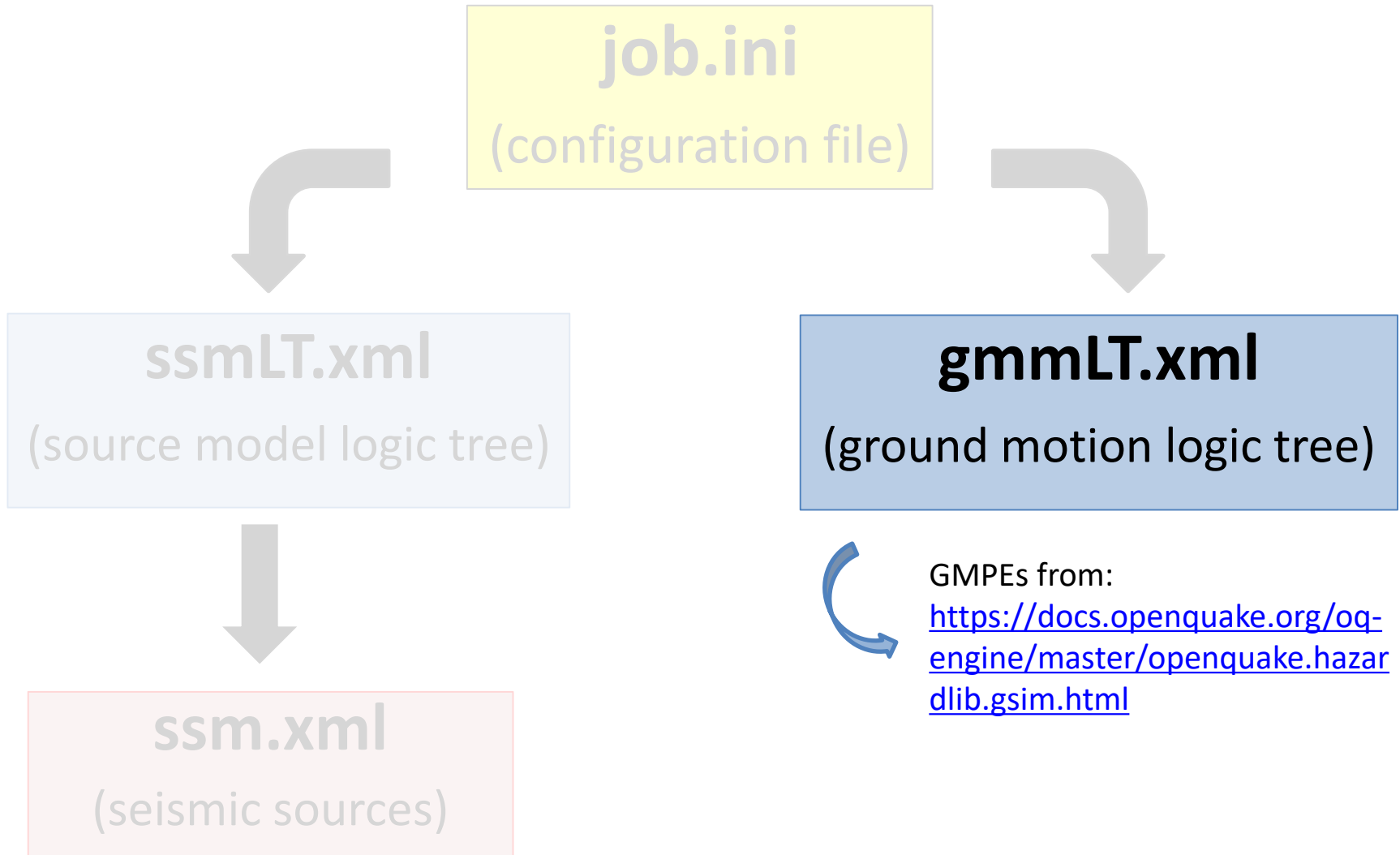
> 1 source model file
means epistemic
uncertainty is considered

```
<logicTree logicTreeID="lt1">
  <logicTreeBranchingLevel branchingLevelID="bl1">
    <logicTreeBranchSet uncertaintyType="sourceModel" branchSetID="bs1">
      <logicTreeBranch branchID="b1">
        <uncertaintyModel>ssm1.xml</uncertaintyModel>
        <uncertaintyWeight>0.5</uncertaintyWeight>
      </logicTreeBranch>
      <logicTreeBranch branchID="b2">
        <uncertaintyModel>ssm2.xml</uncertaintyModel>
        <uncertaintyWeight>0.5</uncertaintyWeight>
      </logicTreeBranch>
    </logicTreeBranchSet>
  </logicTreeBranchingLevel>
</logicTree>
```

Ground Motion Logic Tree



Hazard Calculation Input files



Note: files can use any name; these are the standard names (keeping extensions)




Ground motion logic tree

- The ground motion logic tree file points to the GMPE(s)
- Used to formally specify the **epistemic uncertainties** in the ground motion
- Every logic tree branch represents one GMPE
- Every branch is assigned **weights** expressing the degree of belief in that GMPE



Ground motion logic tree

Example 1: One source GMPE

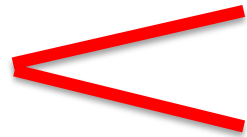
 Branch 1: BooreAtkinson2008
(*weight = 1.0*)

Only 1 GMPE means
epistemic uncertainty
is not considered

```
.....<logicTree logicTreeID='lt1'>
.....  <logicTreeBranchingLevel branchingLevelID="bl1">
.....    <logicTreeBranchSet uncertaintyType="gmpeModel" branchSetID="bs1">
.....      applyToTectonicRegionType="Active Shallow Crust">
.....        <logicTreeBranch branchID="b1">
.....          <uncertaintyModel>BooreAtkinson2008</uncertaintyModel>
.....          <uncertaintyWeight>1.0</uncertaintyWeight>
.....        </logicTreeBranch>
.....      </logicTreeBranchSet>
.....    </logicTreeBranchingLevel>
.....  </logicTree>
```

Ground motion logic tree

Example 2: Two alternative GMPEs



Branch 1: BooreAtkinson2008
weight (0.5)

Branch 2: ChiouYoungs2008
weight (0.5)

> 1 GMPE means
epistemic uncertainty
is considered

```
<logicTree logicTreeID='lt1'>
  <logicTreeBranchingLevel branchingLevelID="b11">
    <logicTreeBranchSet uncertaintyType="gmpeModel" branchSetID="bs1"
      applyToTectonicRegionType="Active Shallow Crust">
      <logicTreeBranch branchID="b11">
        <uncertaintyModel>BooreAtkinson2008</uncertaintyModel>
        <uncertaintyWeight>0.5</uncertaintyWeight>
      </logicTreeBranch>
      <logicTreeBranch branchID="b12">
        <uncertaintyModel>ChiouYoungs2008</uncertaintyModel>
        <uncertaintyWeight>0.5</uncertaintyWeight>
      </logicTreeBranch>
    </logicTreeBranchSet>
  </logicTreeBranchingLevel>
</logicTree>
```



GMPEs in OpenQuake

OpenQuake includes one of the most comprehensive libraries of GMPEs (“GSIMs”) for the most common tectonic regions considered in SHA e.g. active shallow crust, stable continental region, subduction interface, subduction inslab, with 100+ GMPEs

openquake 3.5.0 documentation » openquake.hazardlib package » [previous](#) | [next](#) | [m](#)

Table of Contents

- openquake.hazardlib.gsim package
 - Ground-shaking intensity models
 - abrahamson_2014
 - abrahamson_2015
 - abrahamson_silva_1997
 - abrahamson_silva_2008
 - afshari_stewart_2016
 - akkar_2013
 - akkar_2014
 - akkar_bommer_2010
 - akkar_bommer_2010_swiss_coeffs
 - akkar_cagnan_2010
 - allen_2012
 - allen_2012_ipe
 - armenia_2016
 - atkinson_2015
 - atkinson_boore_1995
 - atkinson_boore_2003
 - atkinson_boore_2006
 - atkinson_macias_2009
 - base
 - berge_thierry_2003
 - bindi_2011
 - bindi_2014
 - bindi_2017
 - bommer_2009
 - boore_1993
 - boore_1997
 - boore_2014
 - boore_atkinson_2008
 - boore_atkinson_2011
 - bradley_2013
 - bradley_2013b
 - campbell_1997

openquake.hazardlib.gsim package

Ground-shaking intensity models

abrahamson_2014

Module exports `AbrahamsonEtAl2014`

`AbrahamsonEtAl2014RegCHN AbrahamsonEtAl2014RegJPN AbrahamsonEtAl2014RegTWN`

```
class openquake.hazardlib.gsim.abrahamson_2014.AbrahamsonEtAl2014(**kwargs)
    Bases: openquake.hazardlib.gsim.base.GMPE
```

Implements GMPE by Abrahamson, Silva and Kamai developed within the the PE Project. This GMPE is described in a paper published in 2014 on Earthquake Volume 30, Number 3 and titled 'Summary of the ASK14 Ground Motion Relation Crustal Regions'.

```
COEFFS = <openquake.hazardlib.gsim.base.CoeffsTable object>
    Coefficient tables as per annex B of Abrahamson et al. (2014)
```

```
CONSTS = {'h1': 0.25, 'h2': 1.5, 'h3': -0.75, 'm2': 5.0, 'n': 1.5}
    equation constants (that are IMT independent)
```

```
DEFINED_FOR_INTENSITY_MEASURE_COMPONENT = 'Average Horizontal (RotD50)
    Supported intensity measure component is orientation-independent average RotD50, see page 1025.
```

```
DEFINED_FOR_INTENSITY_MEASURE_TYPES = frozenset(
    'openquake.hazardlib.imt.PGV', <class 'openquake.hazardlib.imt.PGA'>,
    'openquake.hazardlib.imt.SA'>})
```

To access the GMPE Library go to: <https://docs.openquake.org/oq-engine/master/openquake.hazardlib.gsim.html>

Example: Bindi et al., 2011

Name



bindi_2011

Module exports `BindiEtAl2011`.

Description



`class` `openquake.hazardlib.gsim.bindi_2011.BindiEtAl2011` (**kwargs) [\[source\]](#)

Bases: `openquake.hazardlib.gsim.base.GMPE`

Implements GMPE developed by D.Bindi, F.Pacor, L.Luzi, R.Puglia, M.Massa, G. Ameri, R. Paolucci and published as "Ground motion prediction equations derived from the Italian strong motion data", Bull Earthquake Eng, DOI 10.1007/s10518-011-9313-z. SA are given up to 2 s. The regressions are developed considering the geometrical mean of the as-recorded horizontal components

`COEFFS` = `<openquake.hazardlib.gsim.base.CoeffsTable object>`

`DEFINED_FOR_INTENSITY_MEASURE_COMPONENT` = `'Average horizontal'`

Supported intensity measure component is the geometric mean of two horizontal components

`DEFINED_FOR_INTENSITY_MEASURE_TYPES` = `frozenset({<class 'openquake.hazardlib.imt.PGA'>, <class 'openquake.hazardlib.imt.SA'>, <class 'openquake.hazardlib.imt.PGV'>})`

Set of `intensity measure types` this GSIM can calculate. A set should contain classes from module `openquake.hazardlib.imt`.

`DEFINED_FOR_STANDARD_DEVIATION_TYPES` = `frozenset({'Inter event', 'Intra event', 'Total'})`

Supported standard deviation types are inter-event, intra-event and total, page 1904

`DEFINED_FOR_TECTONIC_REGION_TYPE` = `'Active Shallow Crust'`

Supported tectonic region type is 'active shallow crust' because the equations have been derived from data from Italian database ITACA, as explained in the 'Introduction'.

`REQUIRES_DISTANCES` = `frozenset({'rjb'})`

Required distance measure is RRup (eq. 1).

`REQUIRES_RUPTURE_PARAMETERS` = `frozenset({'mag', 'rake'})`

Required rupture parameters are magnitude and rake (eq. 1).

`REQUIRES_SITES_PARAMETERS` = `frozenset({'vs30'})`

Required site parameter is only Vs30

Tectonic
region



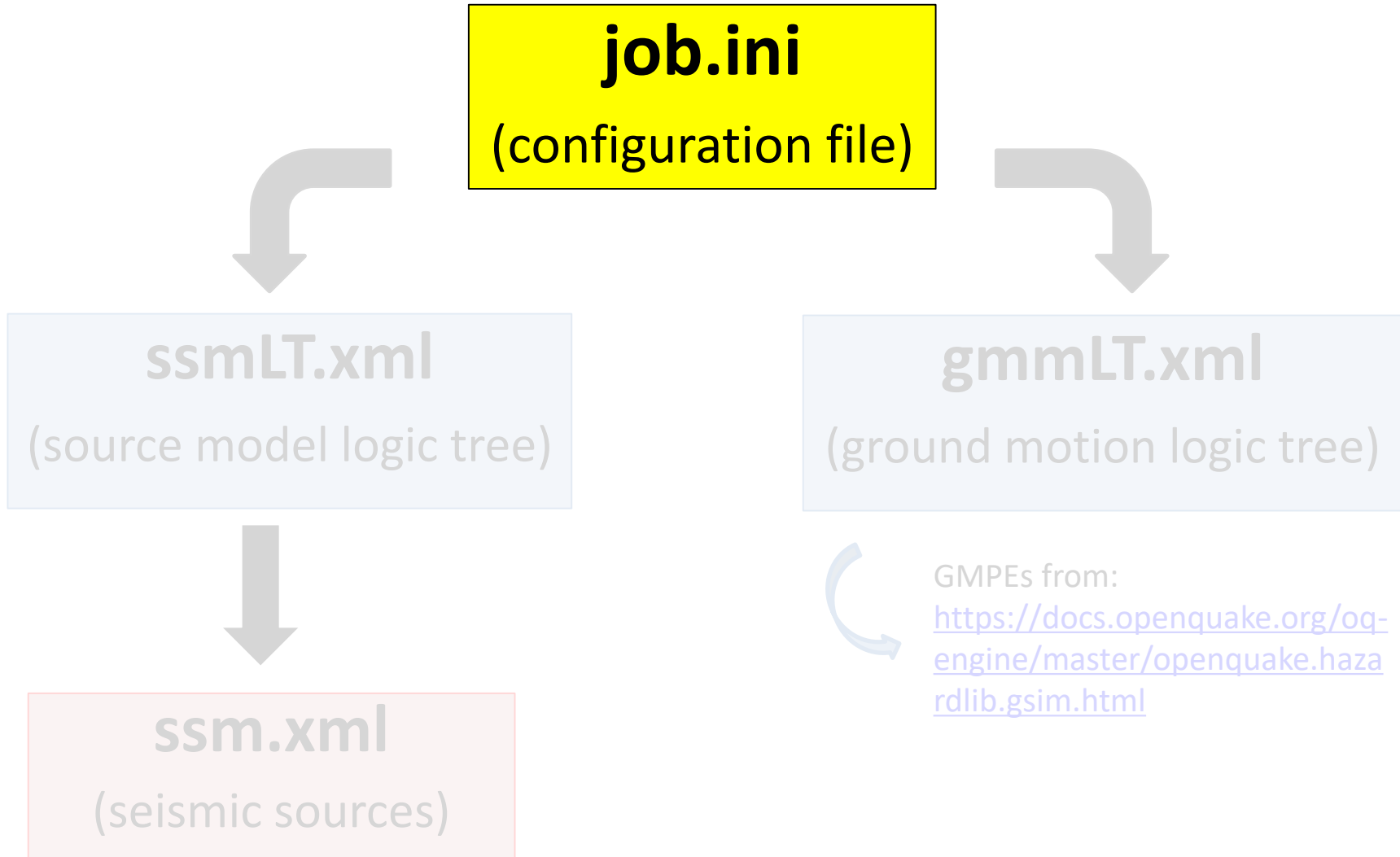
GMPEs in OpenQuake

- The name(s) after “module exports” is the name that should be specified in the ground motion logic tree
- Examples:

GMPE	name to be used
bindi_2011	BindiEtAl2011
boore_atkinson_2008	BooreAtkinson2008
chiou_youngs_2014	ChiouYoungs2014
akkar_2014	AkkarEtAIRjb2014 AkkarEtAIRepi2014 AkkarEtAIRhypo2014



Hazard Calculation Input files



Note: files can use any name; these are the standard names (keeping extensions)



Job.ini

```
[general]
description = Seismic hazard analysis for Italy - simplified model
calculation_mode = classical

[geometry]
region = 5.7 47, 5.7 35, 18 35, 18 47
region_grid_spacing = 20

[calculation]
source_model_logic_tree_file = ssmLT.xml
gsim_logic_tree_file = gmmLT.xml
investigation_time = 50.0
intensity_measure_types_and_levels = {
  "PGA": [0.005, 0.0098, 0.0192, 0.0376, 0.0738, 0.145, 0.284, 0.556, 1.09, 2.13],
  "SA(0.1)": [0.005, 0.0098, 0.0192, 0.0376, 0.0738, 0.145, 0.284, 0.556, 1.09, 2.13]}
truncation_level = 3
maximum_distance = 200

[erf]
rupture_mesh_spacing = 2
width_of_mfd_bin = 0.2
area_source_discretization = 10.0

[site_params]
reference_vs30_value = 800.0
reference_vs30_type = measured
reference_depth_to_2pt5km_per_sec = 5.0
reference_depth_to_1pt0km_per_sec = 100.0

[output]
poes = 0.1
mean_hazard_curves = true
quantile_hazard_curves = 0.15 0.5 0.85
hazard_maps = true
uniform_hazard_spectra = true
export_dir = .
```




```
[general]
description = Seismic hazard analysis for Italy - simplified model
calculation_mode = classical
```

- Calculation description
- Calculation type (in this course we perform classical PSHA)

```
[geometry]
region = 5.7 47, 5.7 35, 18 35, 18 47
region_grid_spacing = 20
```

- Geometry of calculation sites defined by a polygon (longitude-latitude) and a distance (in km) to be used to discretize the polygon area into individual sites



```
[calculation]
source_model_logic_tree_file = ssmLT.xml
gsim_logic_tree_file = gmmLT.xml
```

- Points to the seismic source and ground motion logic tree files

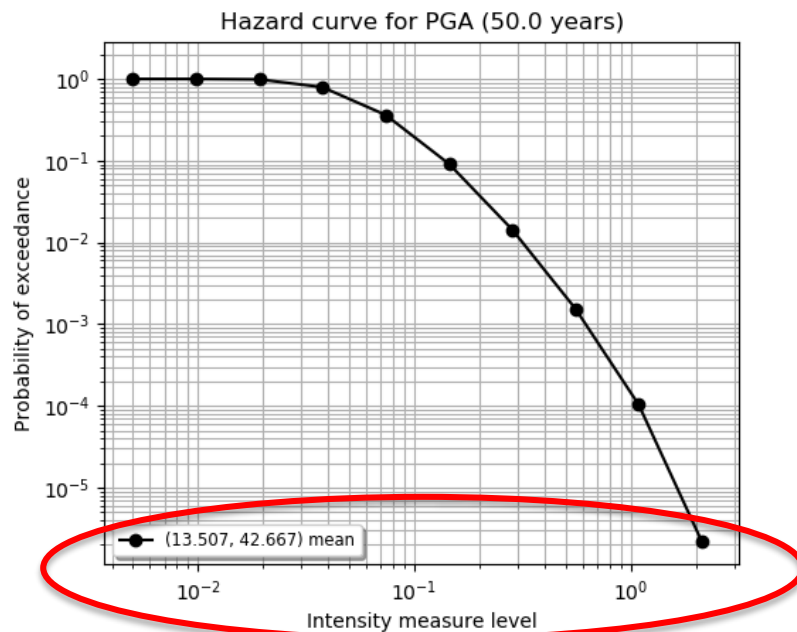
```
investigation_time = 50.0
```

- Investigation time of the calculation (in years)



```
intensity_measure_types_and_levels = {  
  "PGA": [0.005, 0.0098, 0.0192, 0.0376, 0.0738, 0.145, 0.284, 0.556, 1.09, 2.13],  
  "SA(0.1)": [0.005, 0.0098, 0.0192, 0.0376, 0.0738, 0.145, 0.284, 0.556, 1.09, 2.13]}
```

- Ground motion intensity measure types and levels (usually in g) for which the probability of exceedence will be computed
- The independent variable (x-axis)
- Values must be consistent with GMPE(s) being used



IMLS

```
truncation_level = 3
```

- Level of truncation of the Gaussian distribution of the logarithm of ground motion used in the calculation of hazard (typically 3)

```
maximum_distance = 200
```

- The largest distance (in km) between a rupture and the target calculation sites in order for the rupture to be considered in the PSHA calculation.
- (i.e. the distance within which sources will contribute to the computation of the hazard).



```
[erf]
rupture_mesh_spacing = 2
width_of_mfd_bin = 0.2
area_source_discretization = 10.0
```

- Parameters related to the ruptures (ERF = earthquake rupture forecast)
- Here we specify the level of discretization of the:
 - mesh representing faults (km)
 - magnitude-frequency distribution bins
 - grid used to delineate the area sources (km)



```
[site_params]
reference_vs30_value = 800.0
reference_vs30_type = measured
reference_depth_to_2pt5km_per_sec = 5.0
reference_depth_to_1pt0km_per_sec = 100.0
```

- Specification of local soil conditions for computation sites
- Parameter required by the majority of GMPEs:
 - Vs30 (m/s)
- Parameters only used by a few GMPEs (ignored if not needed)
 - If Vs30 was “measured” or “inferred”
 - Depth (km) to Vs=2500m/s
 - Depth (m) to Vs=1000m/s



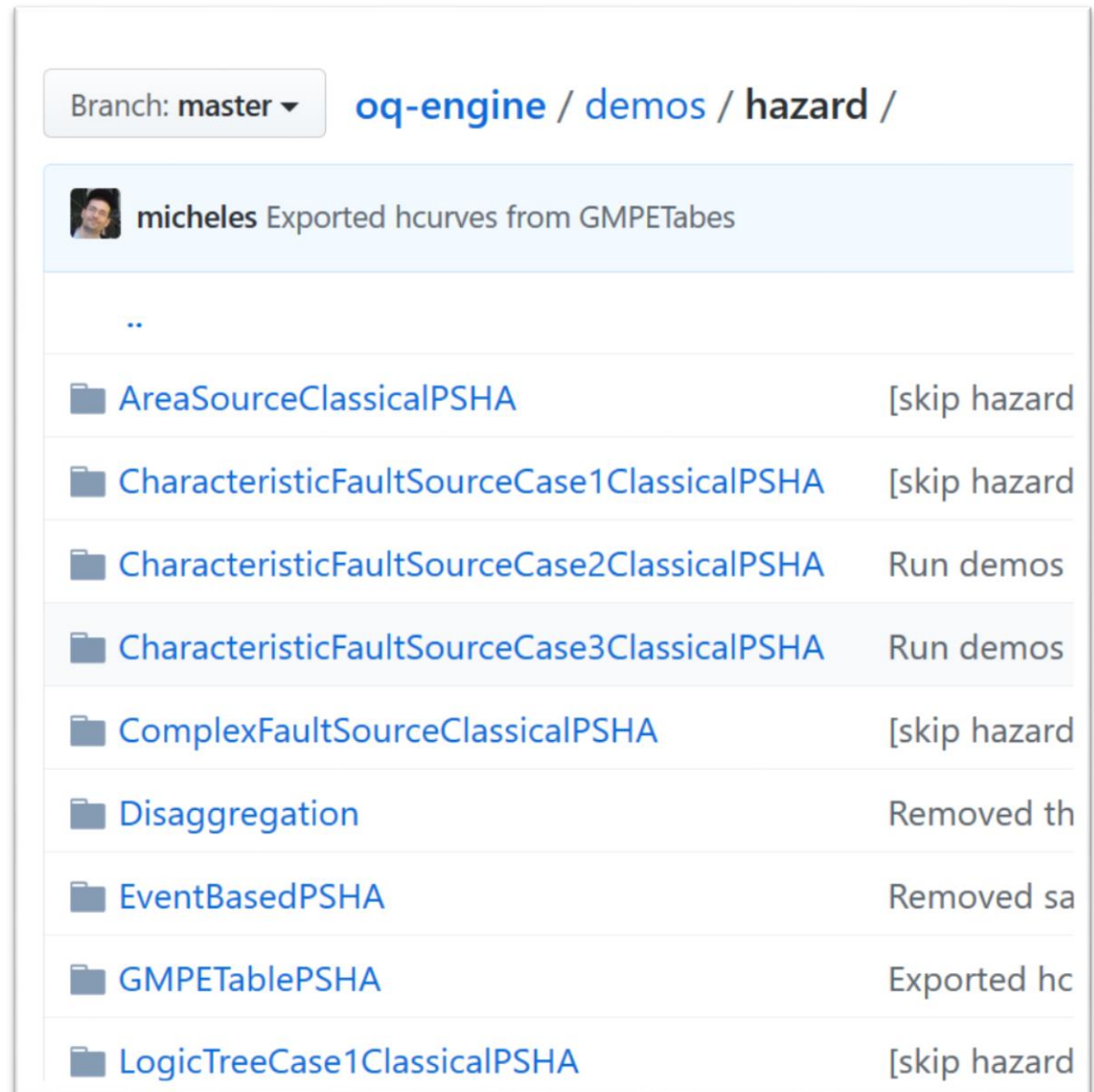
```
[output]
poes = 0.1
mean_hazard_curves = true
quantile_hazard_curves = 0.15 0.5 0.85
hazard_maps = true
uniform_hazard_spectra = true
export_dir = .
```

- Specifying poes (probability of exceedance) will output hazard maps
- Setting mean_hazard_curves to true will result in a specific output containing the mean curves of the logic tree
- quantile_hazard_curves will produce separate files containing the quantile hazard curves at the quantiles listed
- Setting uniform_hazard_spectra to true will output the uniform hazard spectra at the poes specified
- Providing an export directory will tell OpenQuake where to place the output files if the --exports flag is used in the command line (e.g. oq engine -run job.ini -exports=csv)




Want to see more calculation examples?










- OpenQuake Demos:
<https://github.com/gem/oq-engine/tree/master/demos/hazard>
- Examples of hazard calculations using different source typologies, logic trees, etc..



Branch: master ▾ oq-engine / demos / hazard /

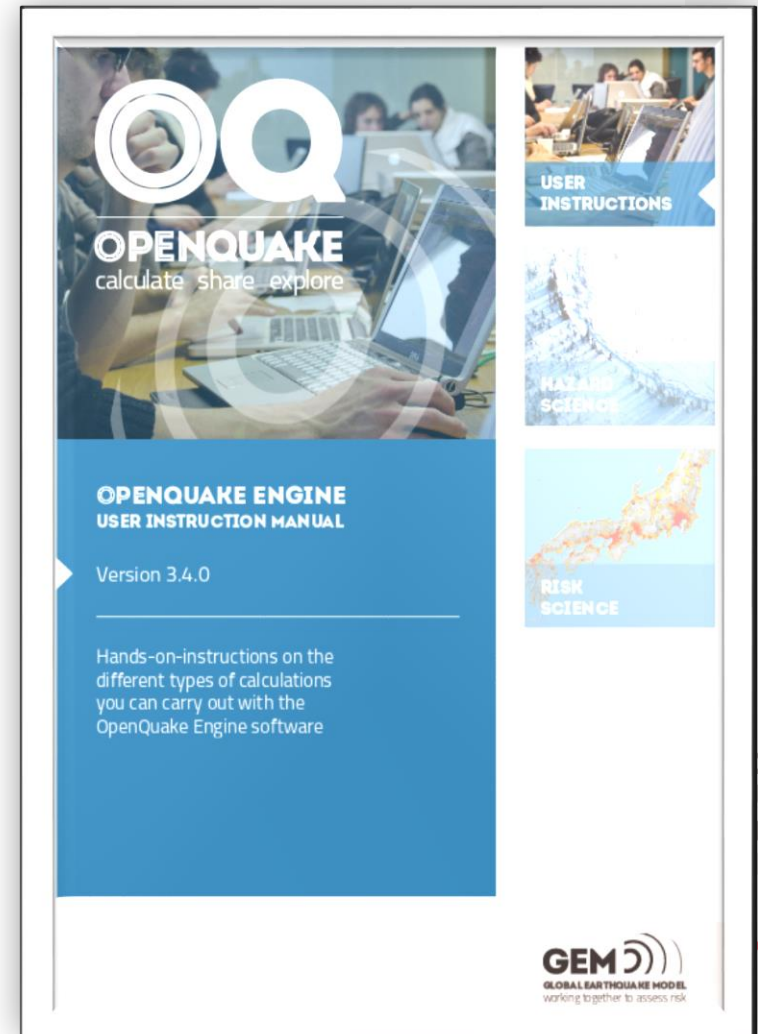
 micheles Exported hcurves from GMPETabes

..

 AreaSourceClassicalPSHA	[skip hazard]
 CharacteristicFaultSourceCase1ClassicalPSHA	[skip hazard]
 CharacteristicFaultSourceCase2ClassicalPSHA	Run demos
 CharacteristicFaultSourceCase3ClassicalPSHA	Run demos
 ComplexFaultSourceClassicalPSHA	[skip hazard]
 Disaggregation	Removed th
 EventBasedPSHA	Removed sa
 GMPETablePSHA	Exported hc
 LogicTreeCase1ClassicalPSHA	[skip hazard]

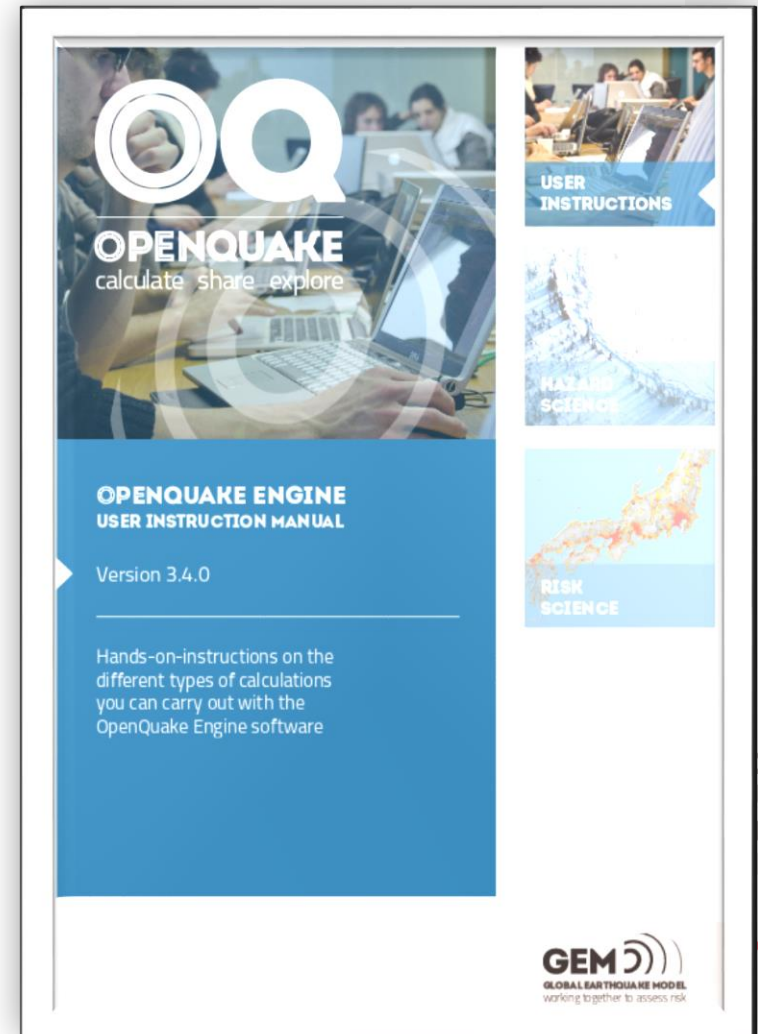
Your OQ reference for this course

- The OQ manual explains all the input parameters required to run hazard (and risk) calculations, including examples.
- The manual can be found here:
<https://docs.openquake.org/manuals/OpenQuake%20Manual%20%28latest%29.pdf>



Your OQ reference for this course

- Mistakes? Anything unclear?
- Add your comments to this [Google Document](#), and we'll include your suggestion in future versions of the manual.



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



Except where otherwise noted, this work is licensed under

<https://creativecommons.org/licenses/by-nc-nd/3.0/>

