GEM's community tools for probabilistic seismic hazard modelling and calculation

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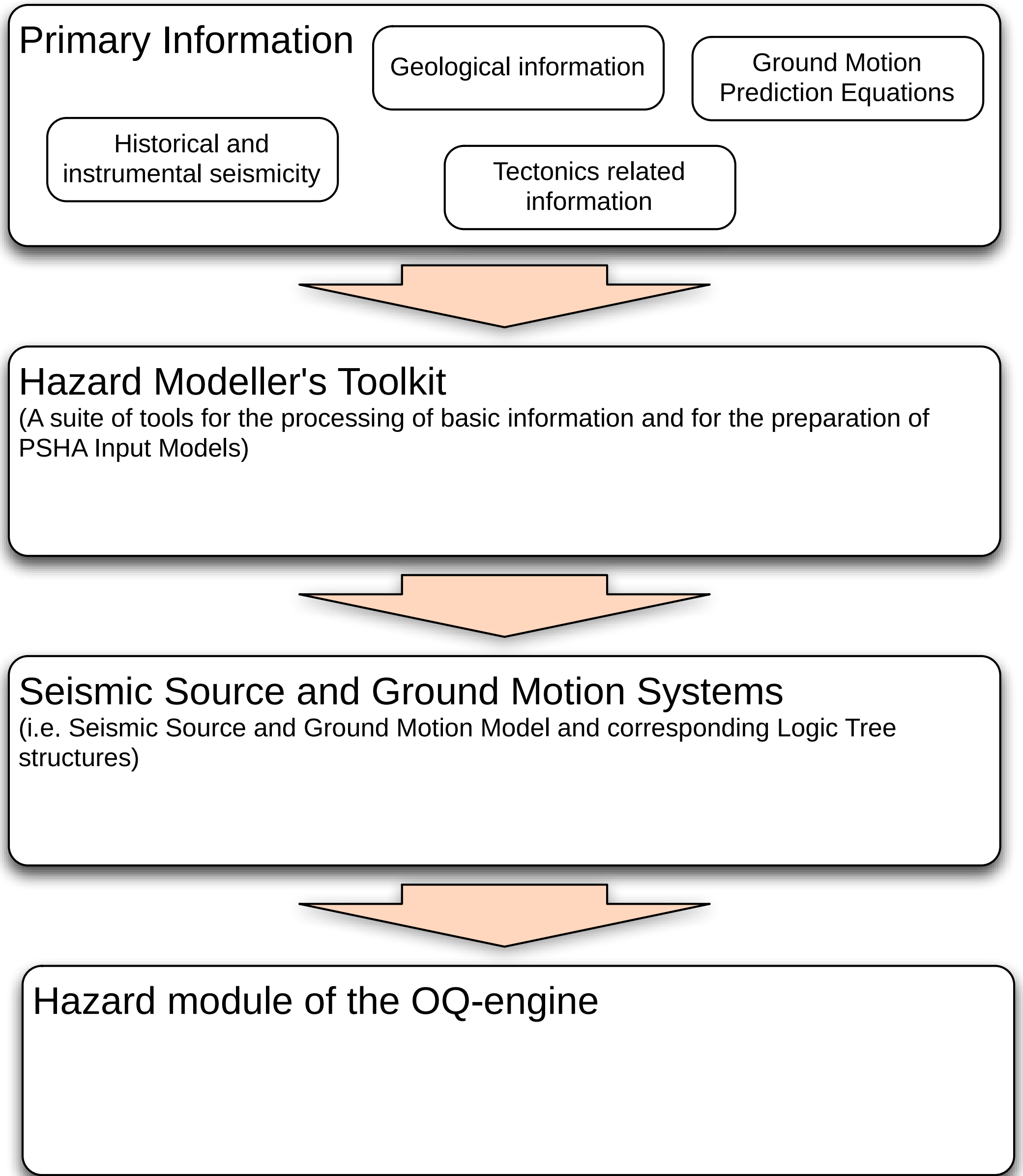
working together to assess risk

GEM

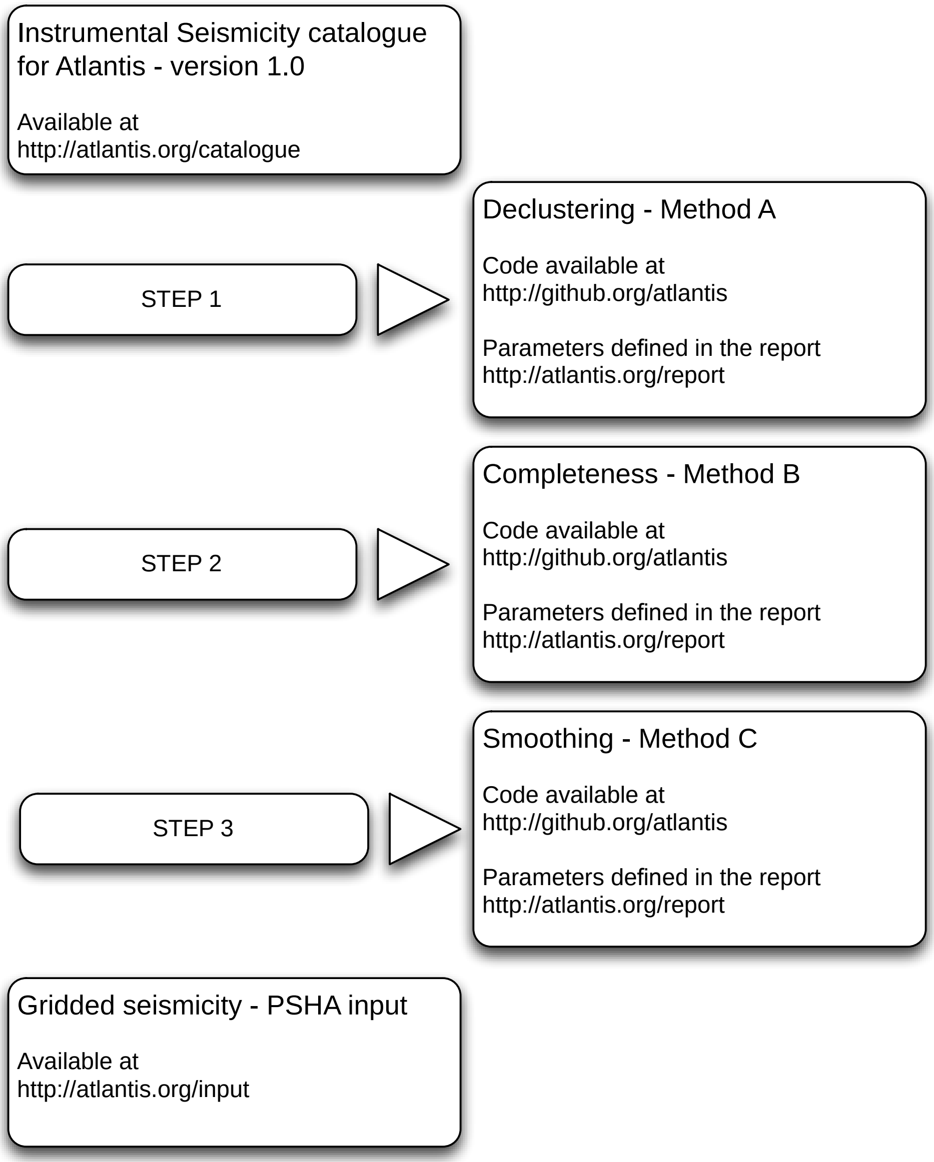
GLOBAL EARTHQUAKE MODEL

Tools for hazard modelling and calculation



Main goals of GEM's hazard component

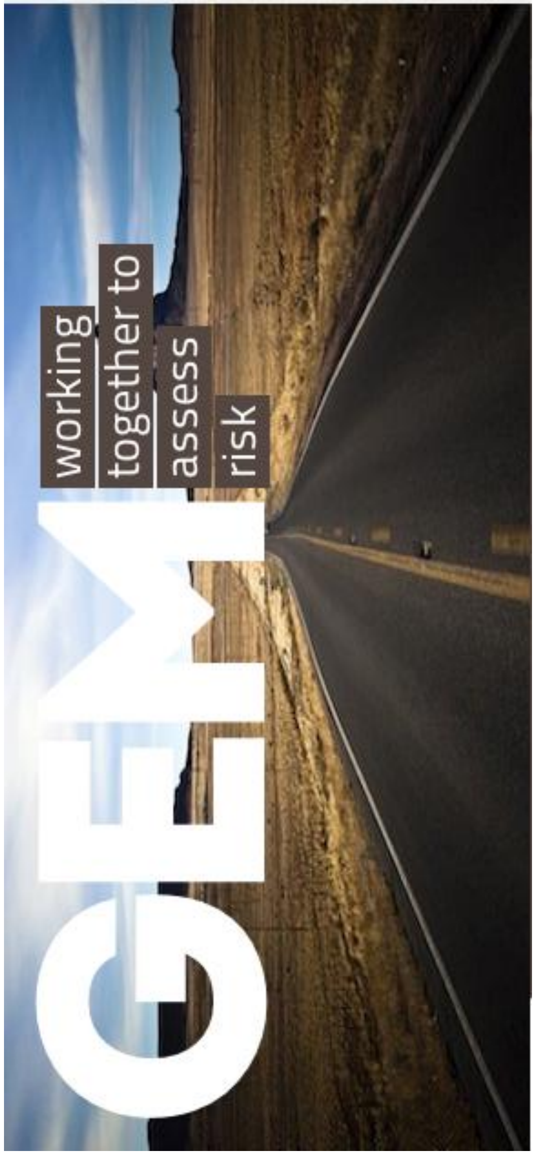
The overall goal of the tools GEM is to make the PSHA input model creation and calculation process fully reproducible and transparent.



Main goals of GEM's hazard component

Promote the creation of transparent, reproducible, open and testable hazard models

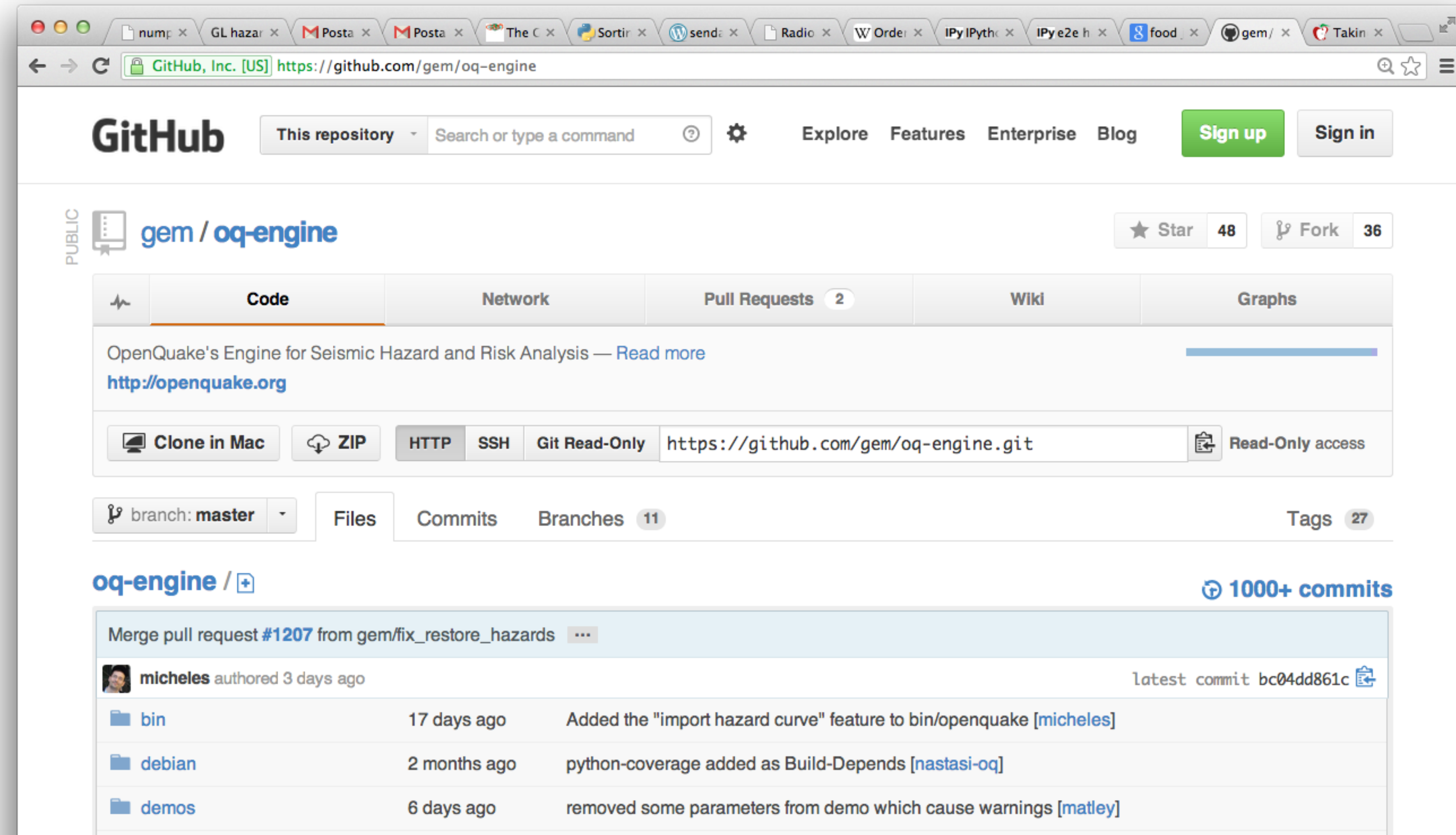
- By creating an open repository with PSHA models coming from different parts of the world
- By working with the local communities on the completion of new hazard projects
- By involving in the activities above the international scientific and engineering community
- *By offering tools for the preparation of PSHA input models and for the calculation of hazard*



Main features of tools developed

- Open source projects
  - OQ-engine code is available at the following repository http://github.com/gem
  - HMTK code is available at the following repository https://github.com/GEMScienceTools/hmtk
- Coded in python
- Developed using a unittest approach
- Everybody can contribute to development under certain rules

Online repository



Hazard Modeller's Toolkit

The hazard modeller's toolkit

The Hazard Modeler's Toolkit

- It's a python library of tools for processing basic information and creating PSHA input models
- Three main sections:
  - Seismicity
  - Geology
  - Tectonics

https://github.com/GEMScienceTools/hmtk

Example: smoothed seismicity

Tool (Algorithm)	Configurable Settings
Smoothed Seismicity First implementation based on Frankel (1995) approach: • Generalised implementation • Extended to 3D smoothing • Completeness correction factors now configurable (can be switched on or off) • Addition of new Kernels simpler in future	• Kernel choice • Bandwidth • B-Value • "Incremental" or "Cumulative" rates • Grid settings • Completeness correction factor • 3D smoothing

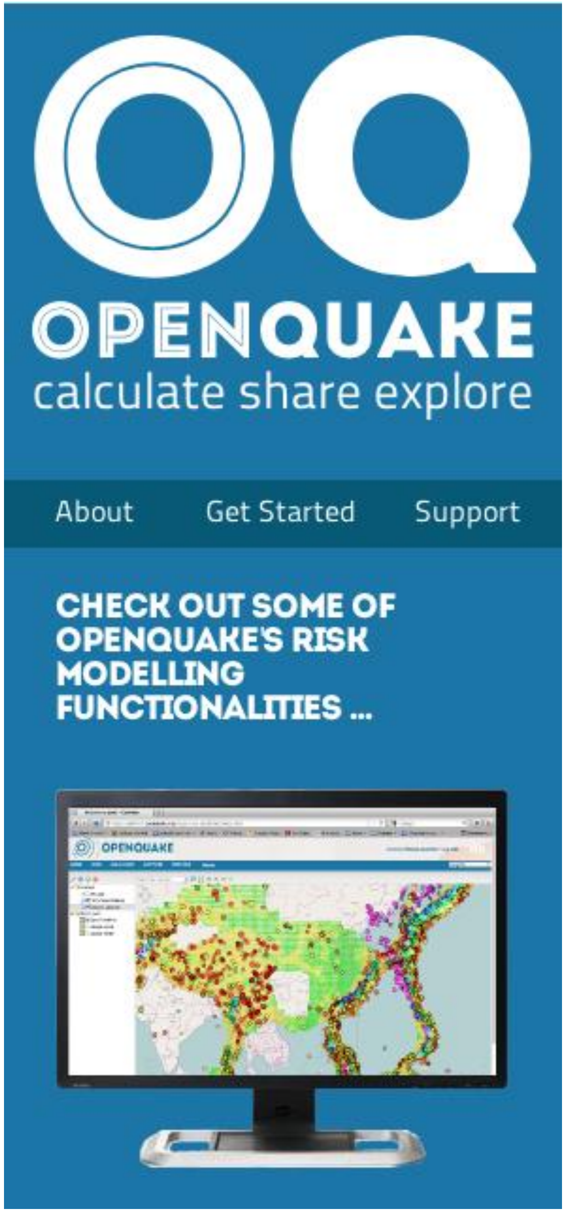
- Coded but still testing: Isotropic Gaussian (Zechar, 2010),
  Adaptive Spherical Fisher Kernel (Kagan & Jackson, 2012)

OQ-engine: introduction

Main features

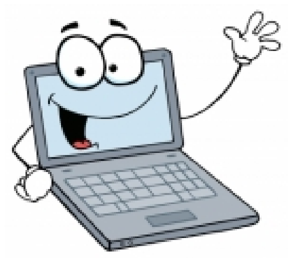
OQ-engine

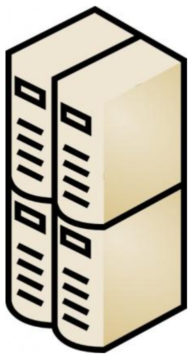
- A hazard and risk calculation engine
- Organised into a number of libraries (in case, they can be used separately as more flexible tools for prototyping and research)
  - oq-hazardlib
  - oq-risklib
  - oq-nrmllib



Supported architectures and OSs

On your laptop





On your cluster

On clouds accessible through the OpenQuake portal

- The OQ-engine can run on a single machine as well as on a cluster of computers
- The Operative System currently supported is Ubuntu Linux (support for additional Operative Systems might be also available in the future)
- OQ works from the command line i.e. no GUI is available

A single software for multiple use cases

- Classical PSHA – used for regional/national scale hazard assessment as well as in site-specific studies
- Event-based PSHA– used for the calculation of losses of a distributed set of assets
- Scenario hazard – used for urban scale loss analysis
- Disaggregation (currently only for Classical PSHA) – used for the definition of the controlling event/s e.g. for the calculation of the conditional mean spectrum (Baker, 2011)

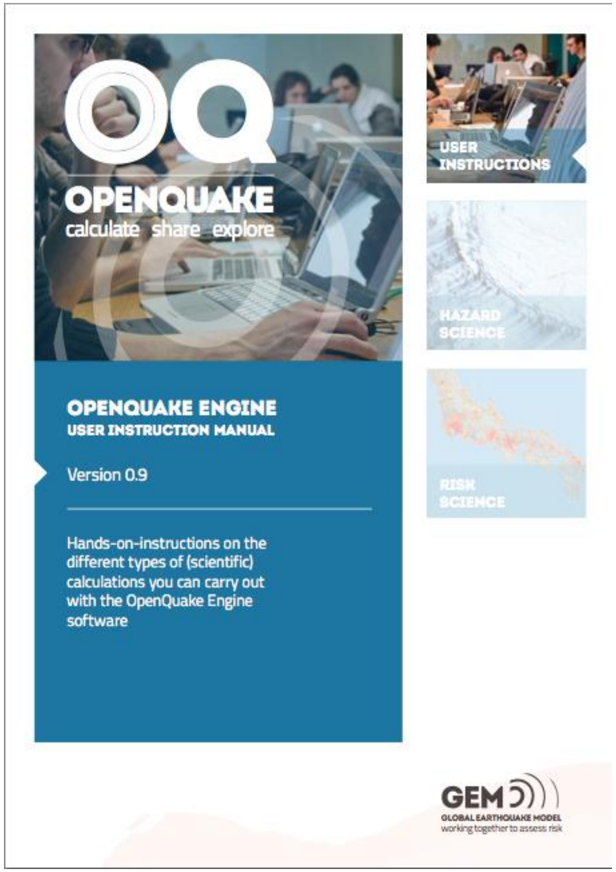
Hazard module

- A summary of the main OQ-engine features:
  - Based on a standardized and flexible input data format
  - Earthquake Rupture Forecast creation for different tectonic regimes (e.g. active shallow crust, stable continental regions, subduction)
  - Calculate hazard considering spatially variable site conditions
  - Stochastic Event Set generation
  - Ground Motion fields calculation (eventually accounting for spatial correlation of ground motion within-event residuals)
  - Supports logic trees
  - Disaggregation

Documentation

- OQ-engine manual and OQ-engine risk book are available

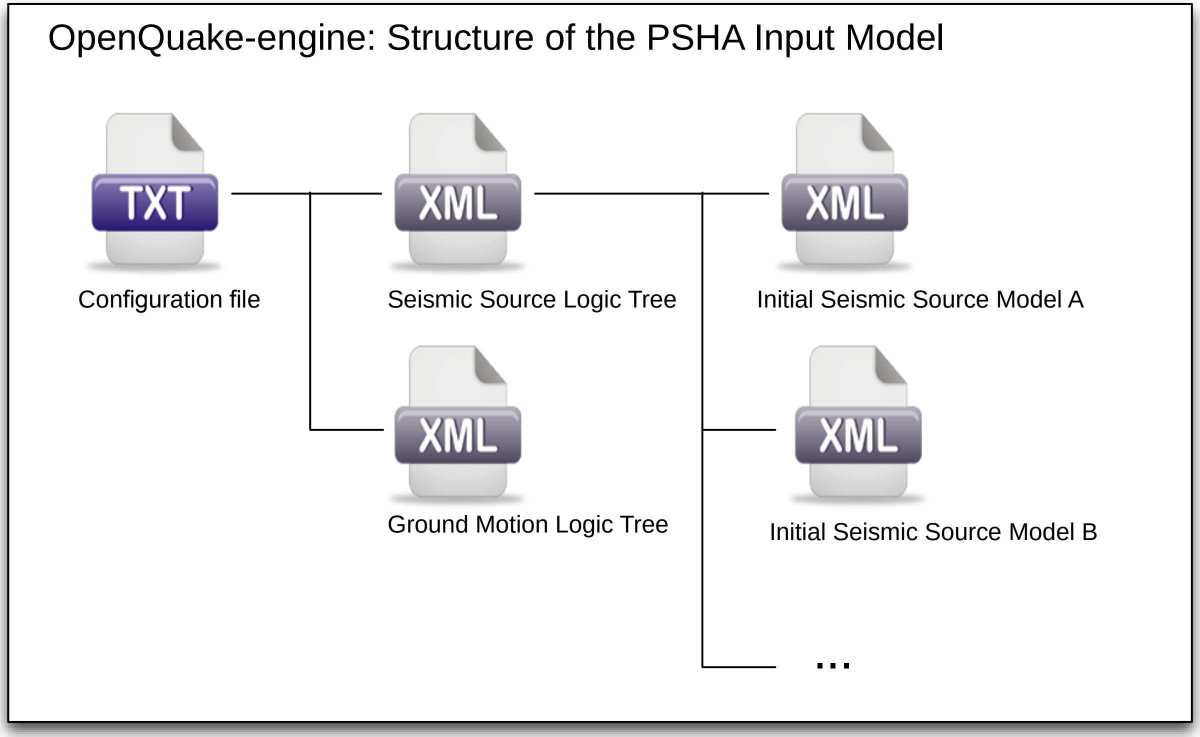
http://www.globalquakemodel.org/openquake/support/documentation/



OQ-engine: input data model

Input model

- An OQ-engine PSHA input model is always described by means of a logic tree structure
- The OQ-engine offers a framework, based on the NRML format (XML), to programmatically define logic trees describing epistemic uncertainties in the source and ground motion models.



Modeling Earthquake Sources

Five source typologies:

- Point Source
- Area Source

Can be used for modeling distributed seismicity

With floating ruptures

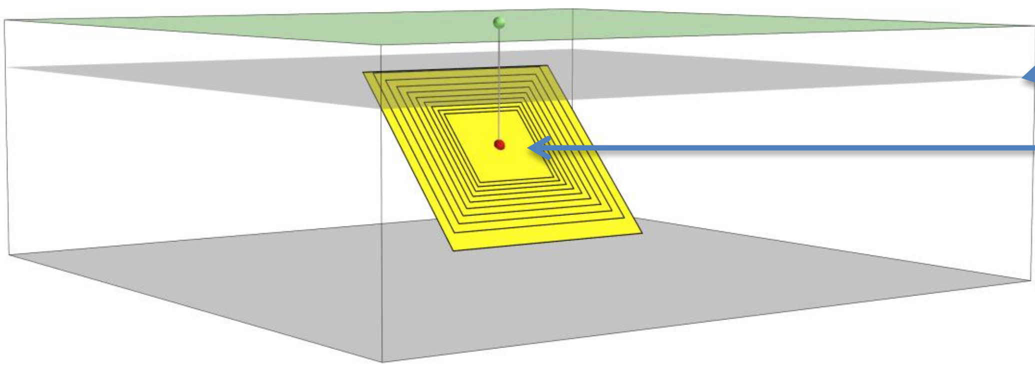
- Simple Fault Source
- Complex Fault Source
- Characteristic fault Source

Can be used for modeling shallow crustal faults, subduction faults

Without floating ruptures

The Point Source

Mmin = 5.0, Mmax = 6.0



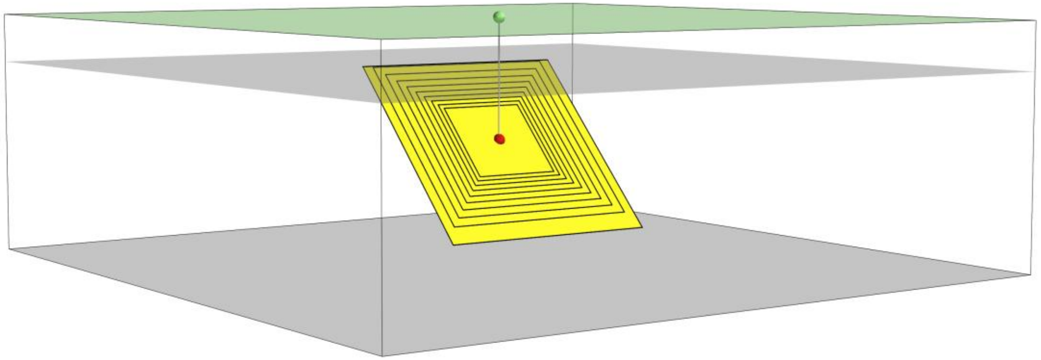
- Upper Seismogenic depth
- Hypocenter position (lon,lat)
- Lower Seismogenic depth

- Nodal Plane (strike, dip, rake) distribution (allowing distribution rates over multiple rupture orientations/styles)
- Hypocenter Depth distribution (allowing distribution ruptures over depth)

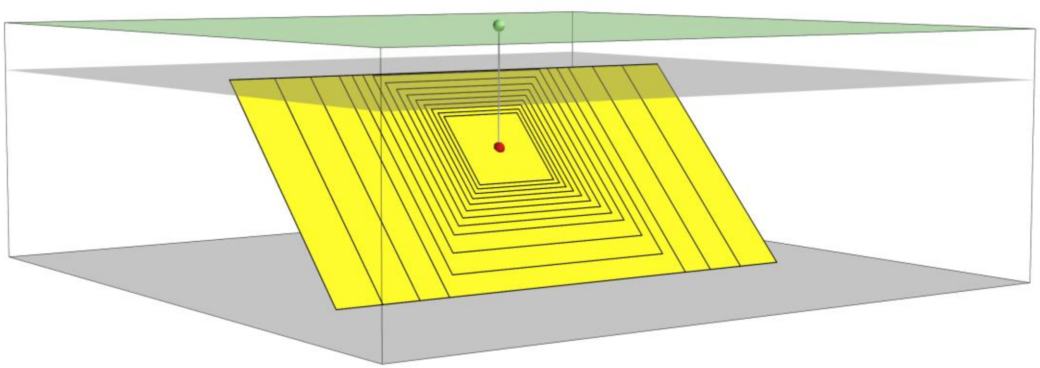
- Magnitude Frequency Distribution
- Magnitude Scaling relationship
- Rupture Aspect Ratio

The Point Source

Mmin = 5.0,
Mmax = 6.0



Mmin = 5.0,
Mmax = 6.5



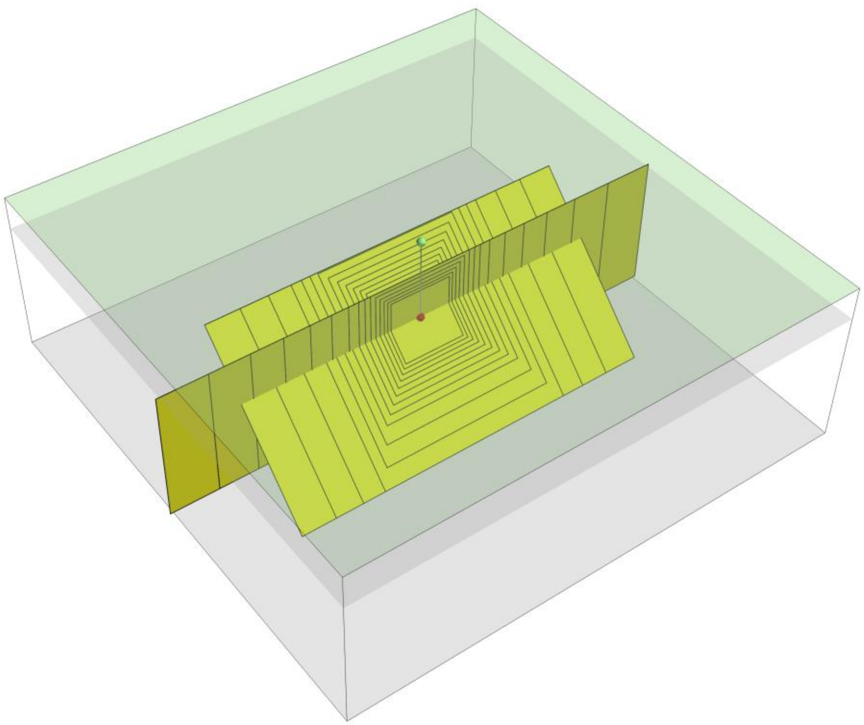
Ruptures are reshaped as soon as their width exceed the maximum rupture width (constrained by dip angle and upper and lower seismogenic depths)

- Rupture area is preserved

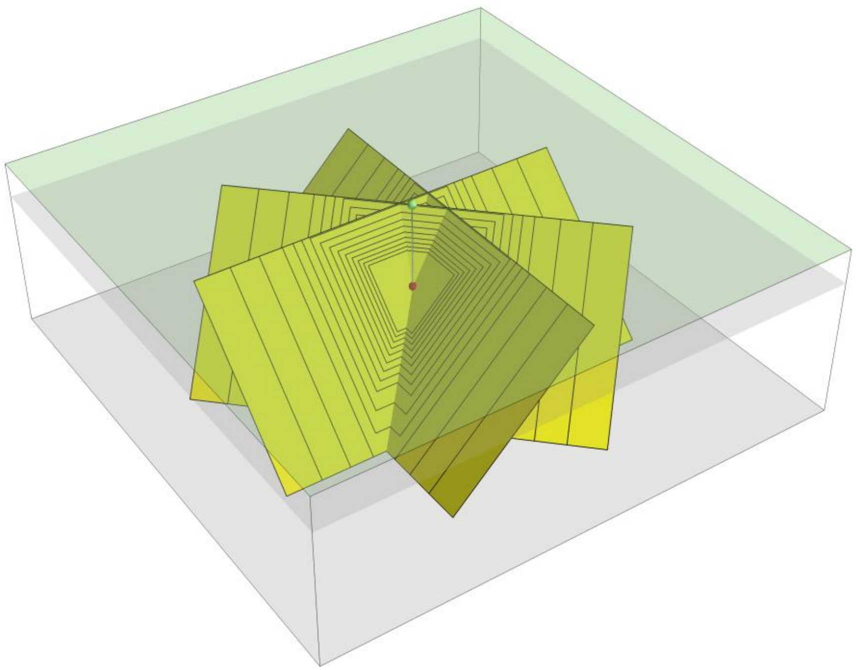
The Point Source

Examples of rupture sets that can be generated using different nodal plane distributions

Multiple dip angles



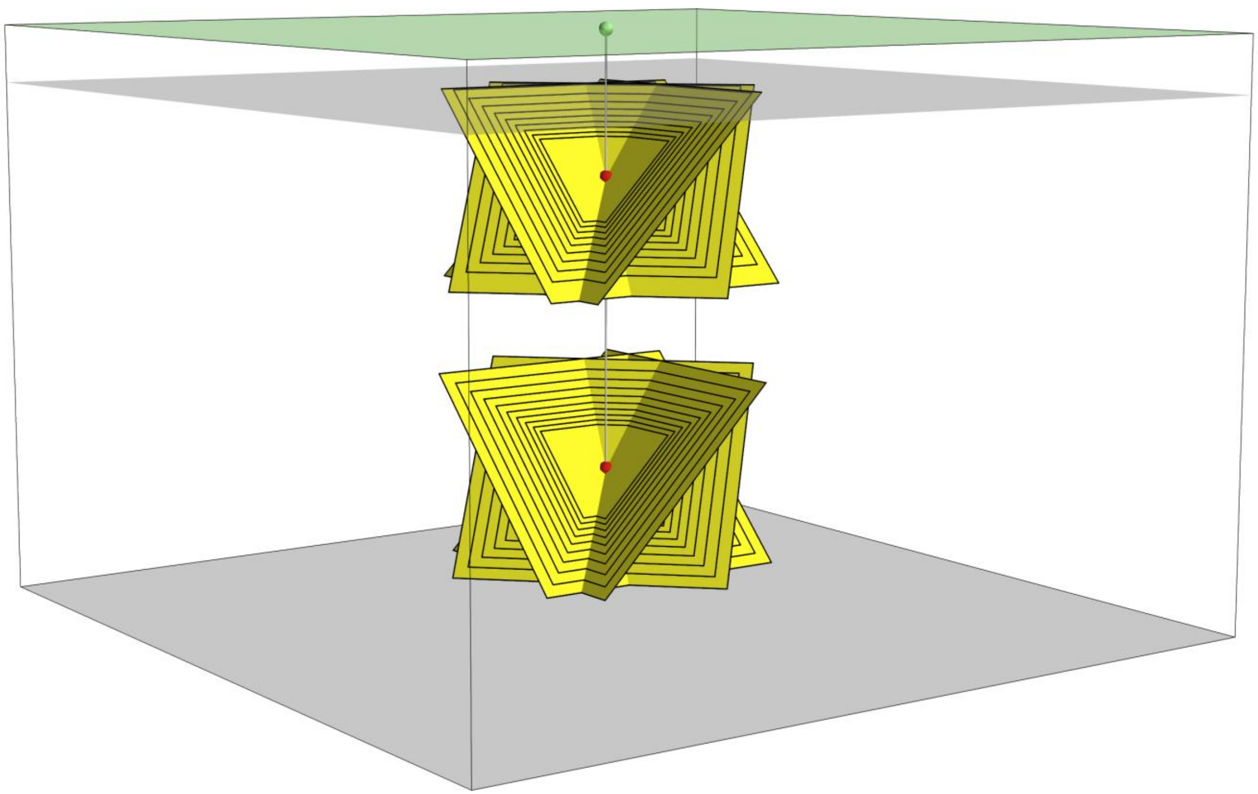
Multiple strike angles



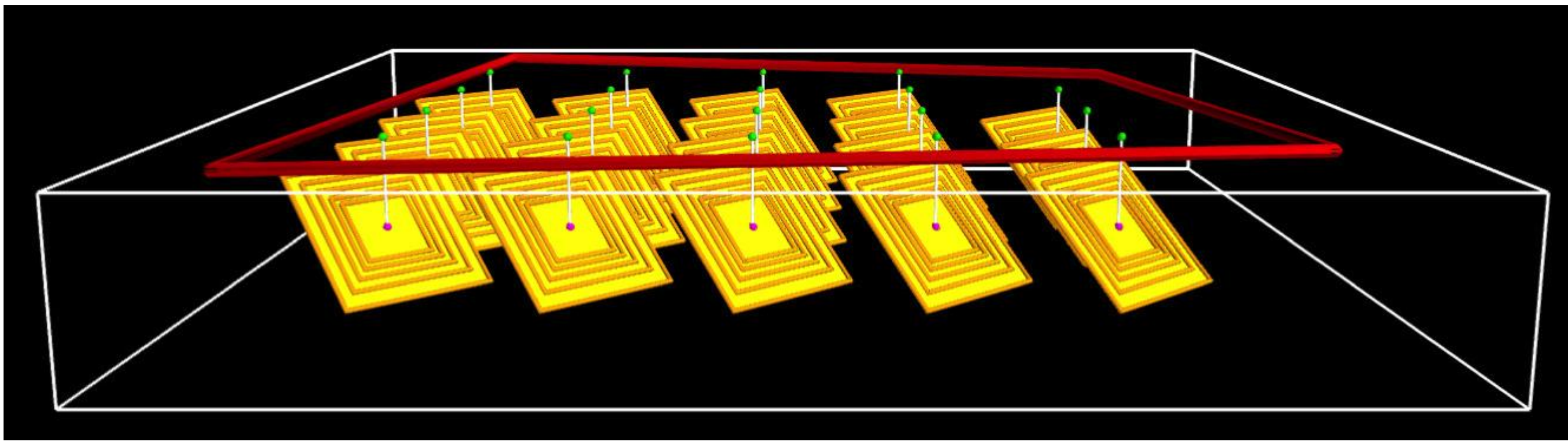
The Point Source

Examples of rupture sets that can be generated using different nodal plane and hypocentral depth distributions

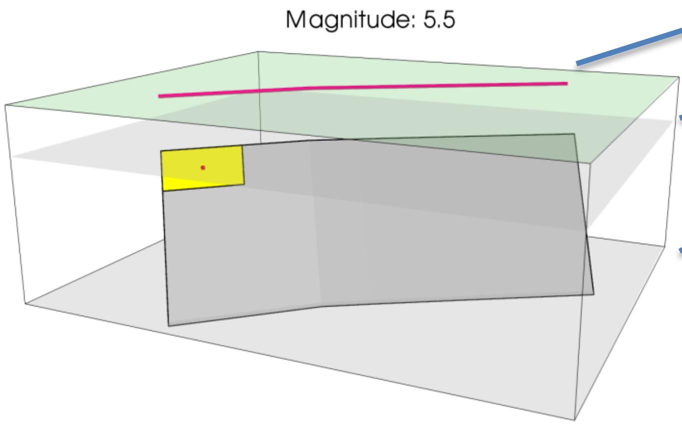
Multiple strike angles and hypocentral depths



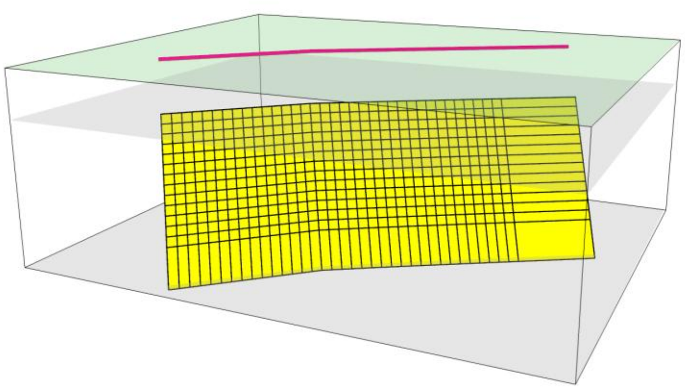
The Area Source

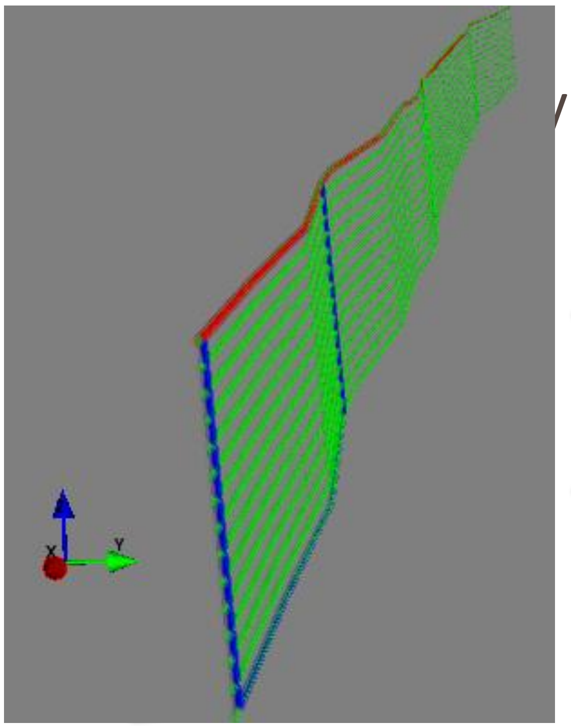


The Simple Fault Source



- Fault trace
- Upper seismogenic depth
- Lower seismogenic depth
- Dip angle

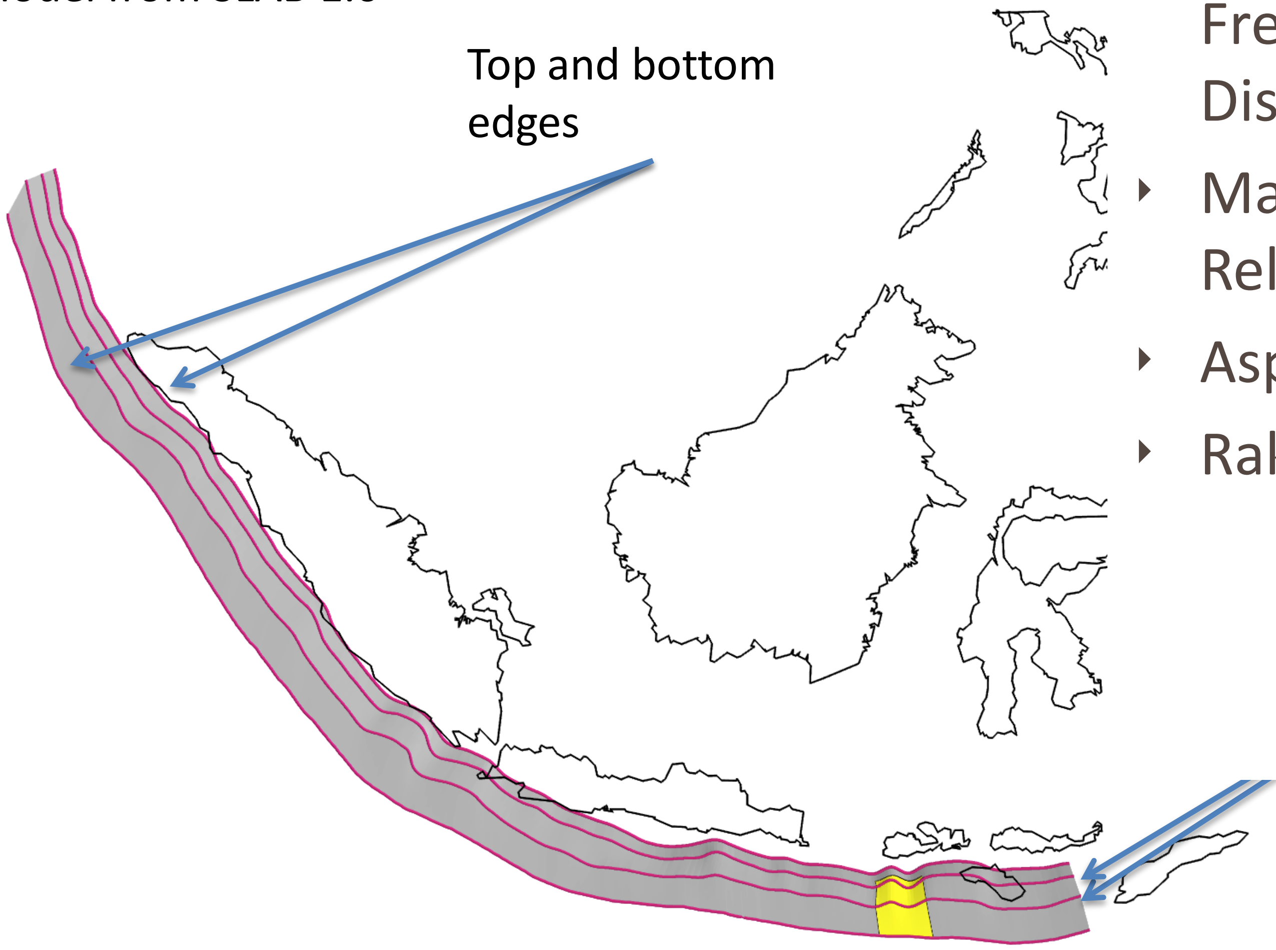




Rupture size and shape

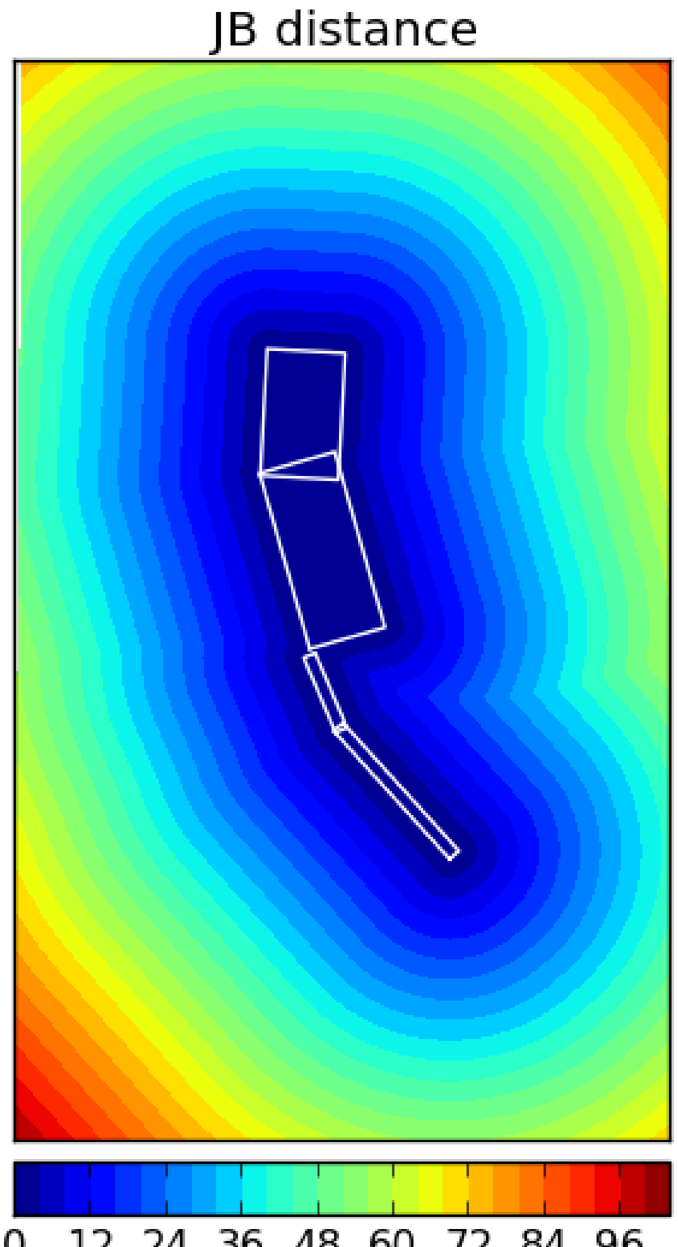
The Complex Fault Source

Sumatra Subduction Model from SLAB 1.0



- Magnitude Frequency Distribution
- Magnitude Scaling Relationship
- Aspect ratio
- Rake

The Characteristic Fault Source



The only fault source type supported in the OQ-engine without floating ruptures

Parameters:

- A group of rectangular fault surfaces OR one simple fault surface OR one complex fault surface
- Magnitude Frequency Distribution
- Rake

Software testing

Software testing

- OpenQuake-hazardlib is developed using ‘unit testing’ procedures i.e. each function in the software is tested by a corresponding code implementing a number of use cases and aiming at checking correctness

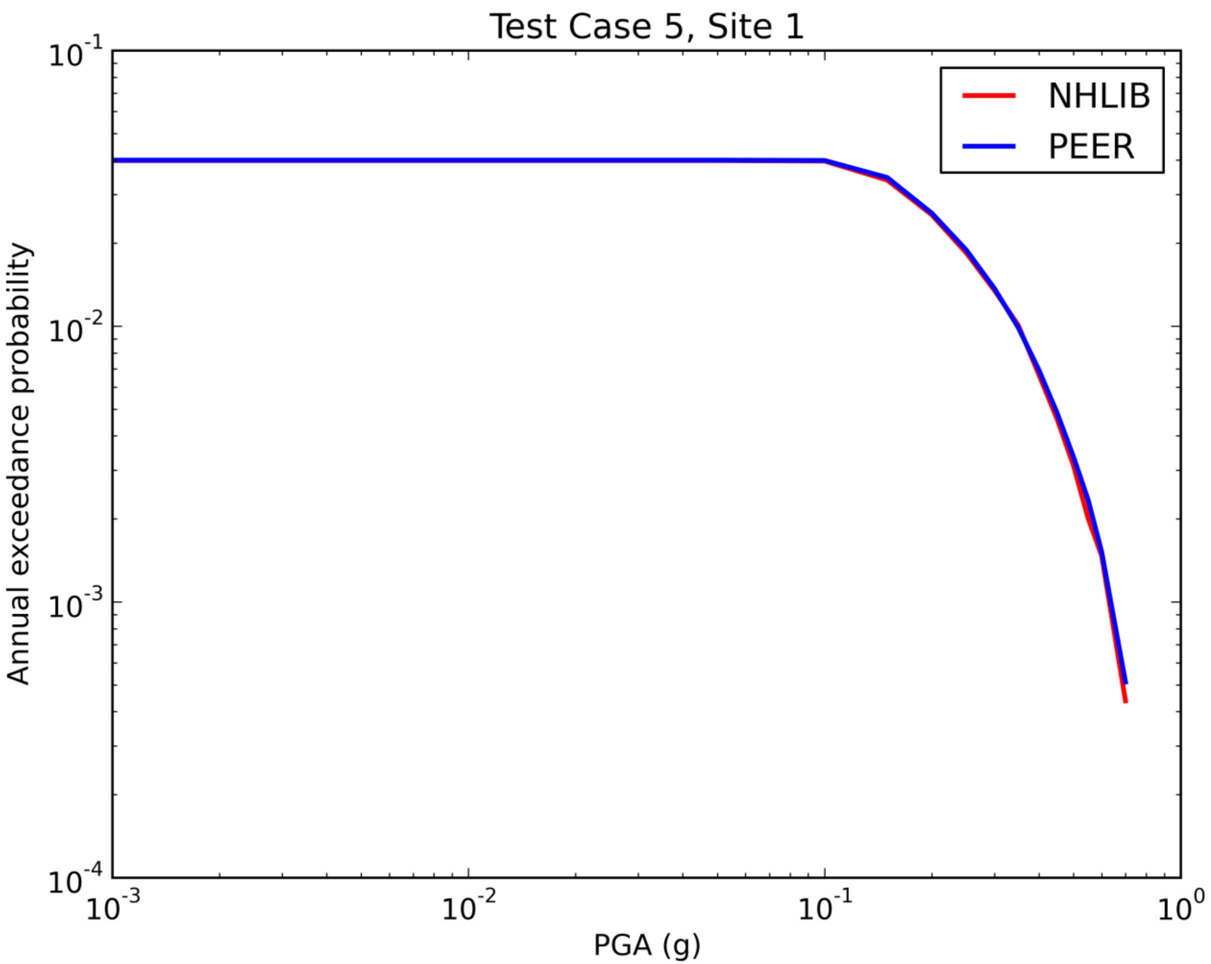
```
tests/source/complex_fault_test                        92      0   100%
tests/source/point_test                               280      1    99%   58
tests/source/rupture_test                              46      0   100%
tests/source/simple_fault_test                        117      0   100%
tests/speedups_test                                    38      1    97%   59
tests/tom_test                                         32      0   100%
-------------------------------------------------------------------------------
TOTAL                                                8942    388    96%
----------------------------------------------------------------------
```

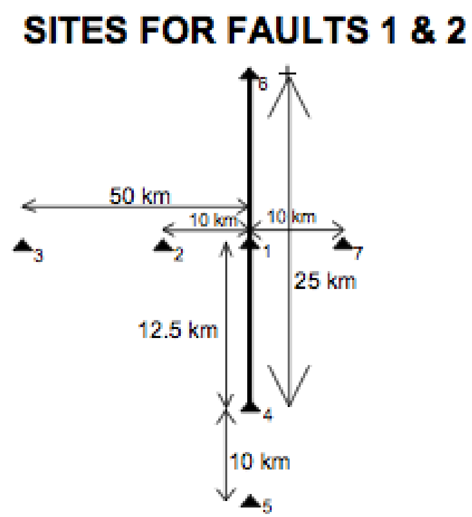
- OpenQuake-hazardlib uses the PEER Tests as ‘Quality Assurance Tests’

  Thomas et al. (2010). Verification of Probabilistic Seismic Hazard Analysis Computer Programs. Peer report 2010/106.

Software testing: PEER Tests

Vertical Strike-Slip fault with Truncated Gutenberg Richter MFD



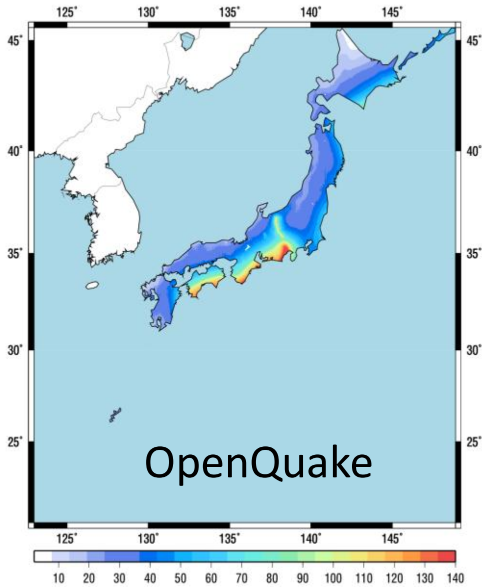


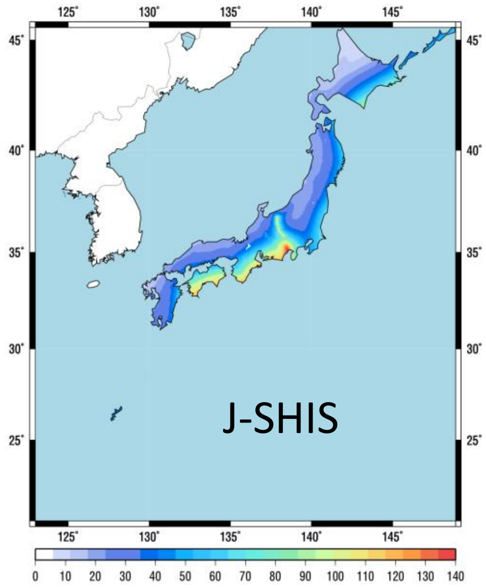
Site 1: On fault, at midpoint along strike
Site 2: 10 km west of fault, at midpoint along strike
Site 3: 50 km west of fault, at midpoint along strike
Site 4: On fault, at southern end
Site 5: 10 km south of fault along strike
Site 6: On fault, northern end
Site 7: 10 km east of fault, at midpoint along strike

Preliminary models implemented

Examples of hazard models implemented

- United States 2008 (USGS)
- Canada (Canada Geological Survey)
- Alaska 2007 (USGS)
- Japan 2012 (J-SHIS – NIED)
- SHARE (EU funded project)
- Australia (Geoscience Australia)
- South America 2010 (USGS)
- Mexico (UNAM)
- Taiwan (Cheng et al., 2007)





OQ-engine hazard

Use examples

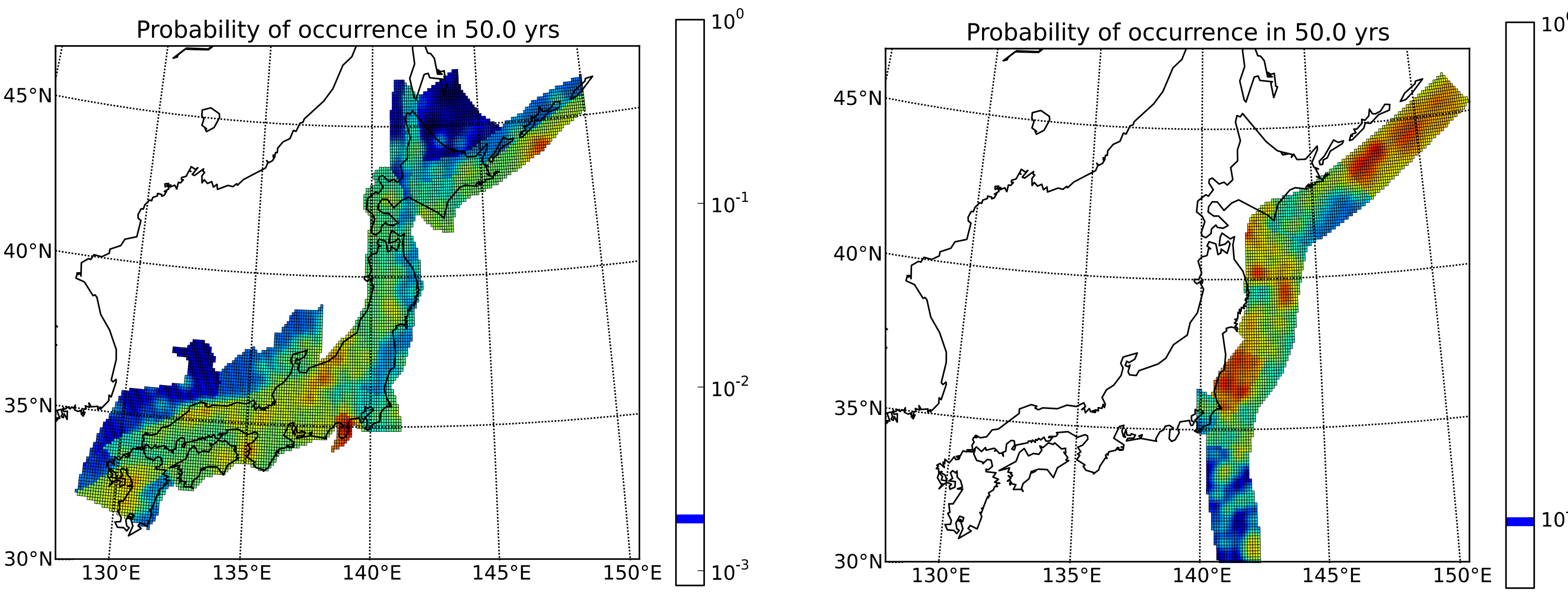
- [fall 2012] verification calculations of the SSHAC level 3 project sponsored by Eskom (a South African electricity public utility)
- [winter 2012/2013] calculation of the new generation of hazard maps in Europe (SHARE project)
- [spring-summer 2012/2013] calculation of the new generation of hazard maps in the Middle East (EMME project)
- [fall 2013] calculation of the new generation of hazard maps in Central Asia (EMCA project)

Stochastic event set and ground motion fields

Total number of sources: 10756

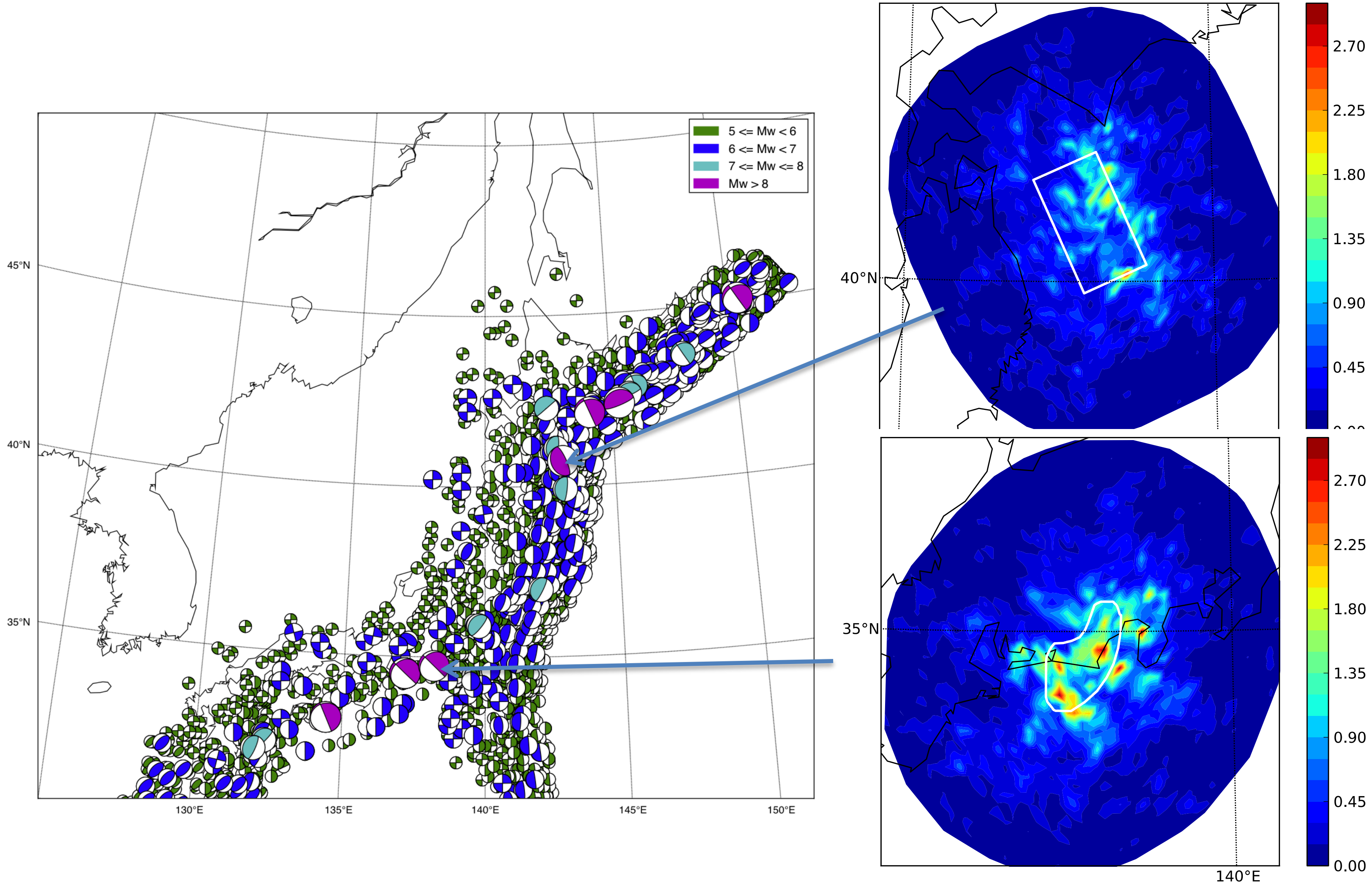
Total number of ruptures: 120832

Gridded Seismicity



2012- Version 2

Stochastic event set and ground motion fields



Thank you

http://globalquakemodel.org