Spatio-Temporal Stochastic Analysis for Seismic Risk

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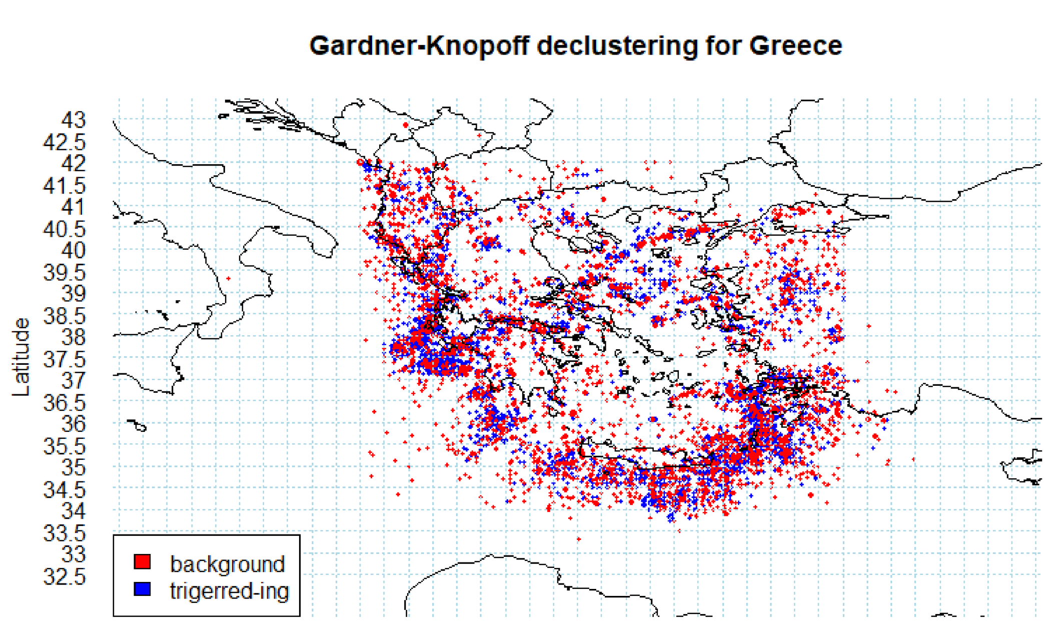
Objectives

- Statistical analysis of area and fault sources based on their magnitude properties and re-activation times.
- Vulnerability analysis using fragility curves and intensity measures of ground motion arrived to buildings
- Annual risk premium and Solvency Capital Requirement evaluation for a realistic portfolio of buildings.

Area sources

Earthquake declustering The Gardner Knopoff declustering method [1] is used to result to independent background events sufficiently modelled in terms of a Poisson process.



Gutenberg-Richter Law The GR-law [2] is a magnitude-frequency distribution applied to regions stating that:

$$\Lambda(m_1) = 10^{a-bm_1} \tag{1}$$

where $\Lambda(m_1)$ is the rate of events having magnitude greater than m_1.

Voronoi polygons and Akaike's information criterion The voronoi polygon associated with a particular center x_i, is defined as the region of space that is closer to x_i than to any other point in the pattern $\underline{x}$. These tiles form the Dirichlet tessellation.

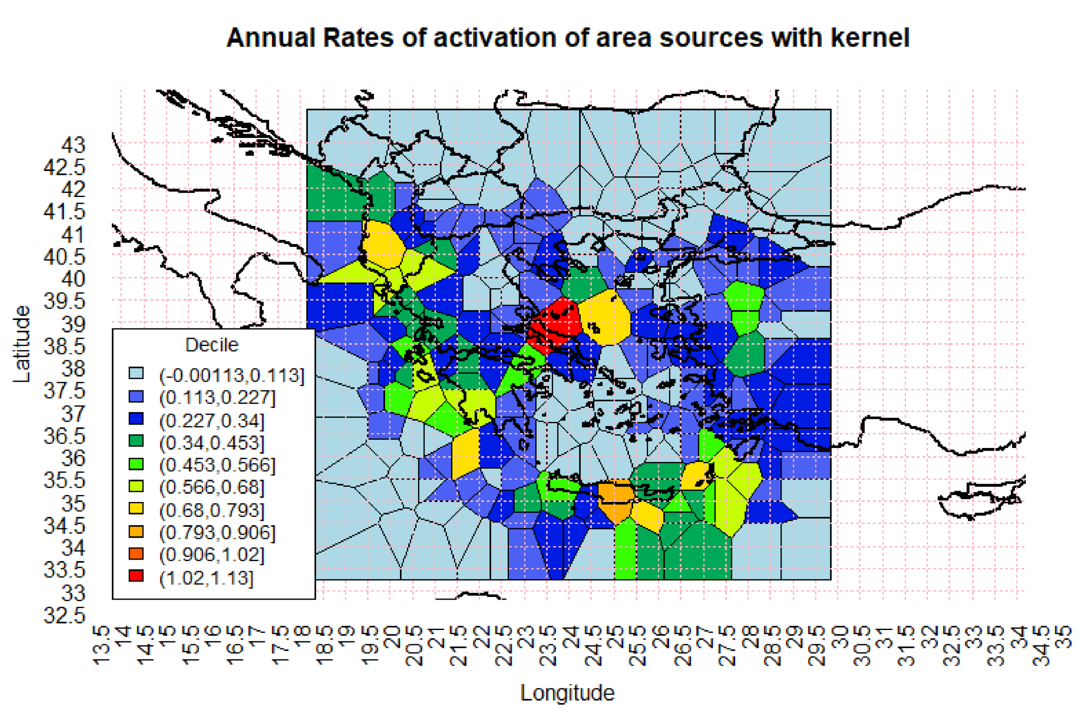


Fig. 2: Voronoi diagram for the region of Greece

Fault Sources

Geometrical properties of fault sources for potential magnitude and mean re-activation times estimation

$$E(T) = \frac{10^{9.1+1.5M_{max}}}{\mu \times SR \times L \times W} \tag{2}$$

where the shear modulus $\mu = 3 \times 10^{10}$ Pa, SR is the slip rate of the fault, L the strike length and W the down-dip width, while M_{max} is the maximum expected moment magnitude of the fault estimated via the MB tool of the FiSH (version 1.02) Package in Matlab [4].

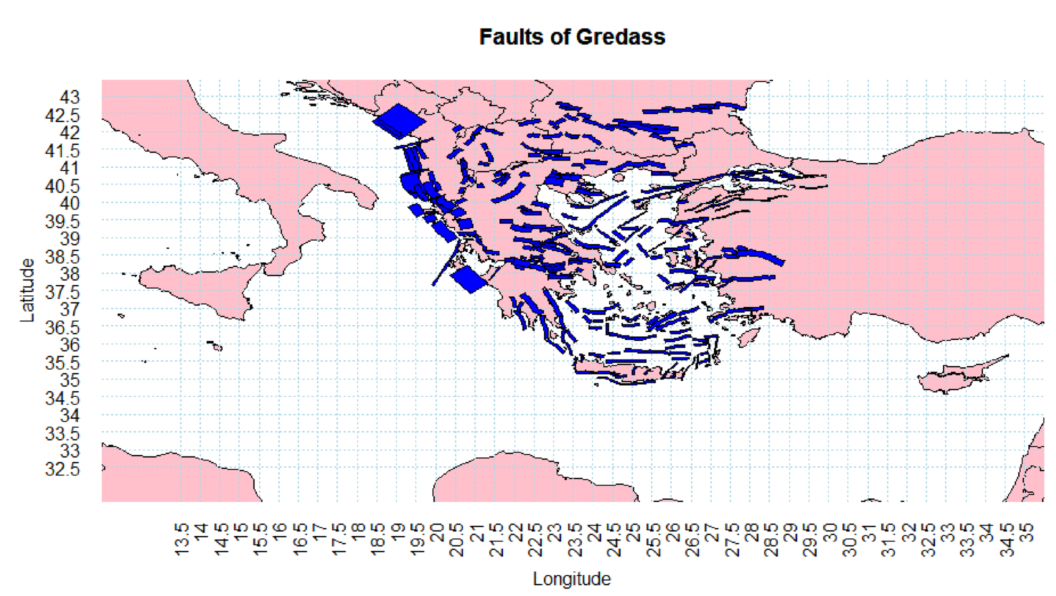


Fig. 3: Faults of Gredass

Fragility curves

Fragility curves are continuous functions expressing the probability of exceeding a given damage state, given a continuous earthquake intensity measure [3] (figure 4). We consider the Peak Ground Acceleration as the intensity measure using the ground motion prediction equation of Rinaldis et al. 1998 of the following general form:

$$\overline{ln(PGA)} = f(M, R, \underline{\theta}) \tag{3}$$

where M is the magnitude and R is the distance from the building of interest to the epicentre of the earthquake.

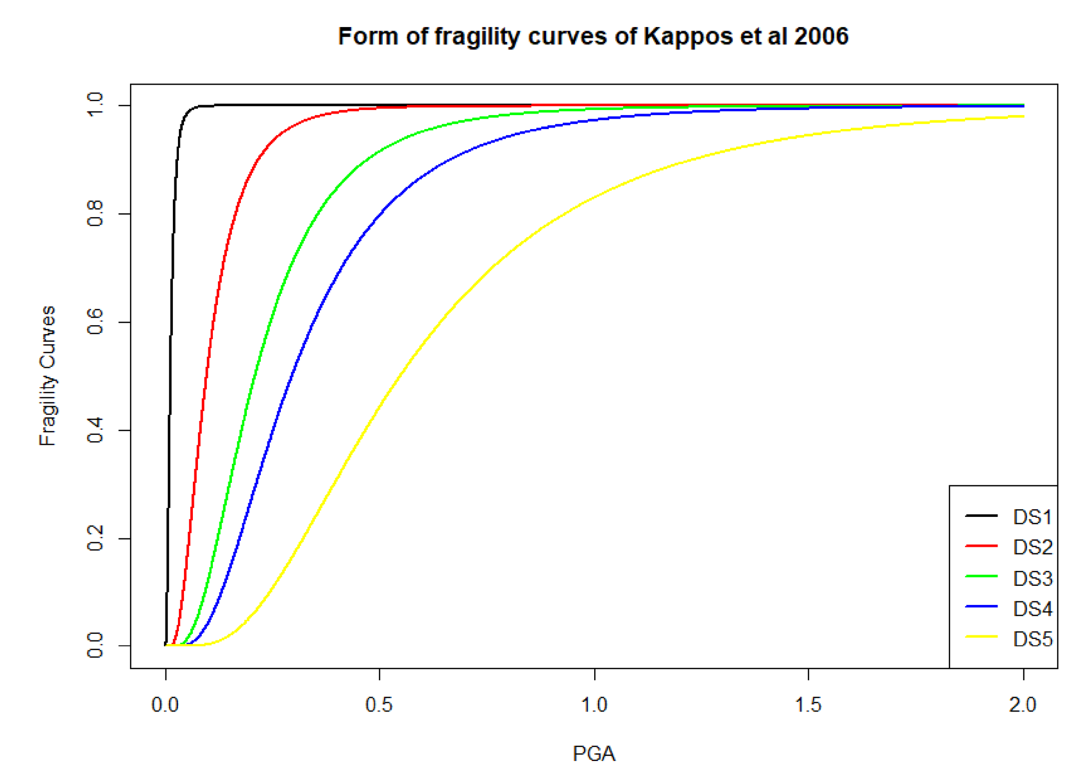


Fig. 4: Fragility curves form

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Insurance pricing and SCR

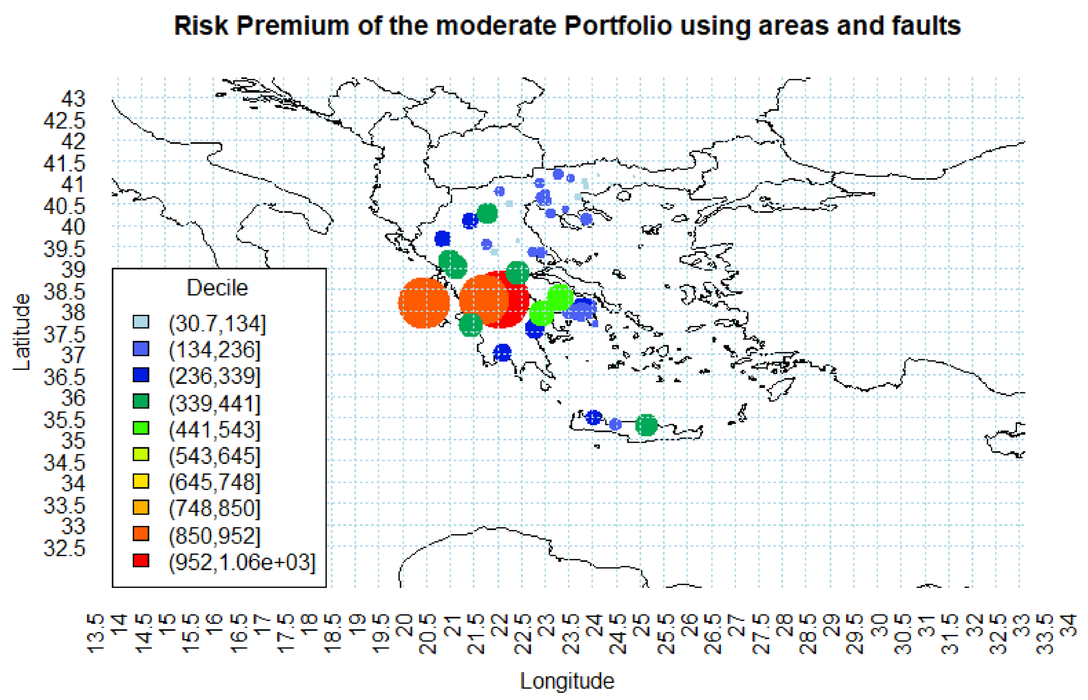
Insurance pricing The portfolio of the 100 considered buildings is constructed based on the building census that was carried by the Hellenic Statistical Authority (ELSTAT) in 2011.

Our algorithm produces many annual simulations of the whole problem, i.e.

- where and when earthquakes become
- their carrying magnitude
- the intensity measure accepted by all buildings by all sources
- the damage state reached inducing the Loss

The maximum damage of each building over a year is the random variable of interest. The produced risk premium rates for moderate buildings each valued 200.000 euros are presented in figure 5.

Fig. 5: Portfolio risk premium



SCR evaluation The solvency capital requirement is the unexpected loss, i.e. $SCR(Loss) = \rho(Loss) - E(Loss)$ where ρ is a risk measure. The random variable of interest now is the summation of the annual maximum damages of each building.

The SCR estimated with the standard formula of Solvency II overpasses the SCR obtained by our model and ignores many parameters of the problem.

Results

Premium Rating for high code buildings Our model produces risk premium rates with a coordinate precision. However, based on risk spread, the mean and median is presented below in the cases of using only areas and then adding fault sources.

Premium	Areas	+Faults	Increase
Mean	110	154	+40%
Median	88	134	+52%

SCR evaluation using Value at Risk

SCR	Low Code	Moderate Code
Areas	474,901	169,830
+Faults	800,035	295,497

References

References

[1] J. Gardner and L. Knopoff. Is the sequence of earthquakes in southern california, with aftershocks removed, poissonian? *Bulletin of the Seismological Society of America*, 64(5):1363–1367, 1974.

[2] B. Gutenberg and C. F. Richter. Frequency of earthquakes in california. *Bulletin of the Seismological Society of America*, 34(4):185–188, 1944.

[3] A. J. Kappos, G. Panagopoulos, C. Panagiotopoulos, and G. Penelis. A hybrid method for the vulnerability assessment of r/c and urm buildings. *Bulletin of Earthquake Engineering*, 4 (4):391–413, 2006.

[4] B. Pace, F. Visini, and L. Peruzza. Fish: Matlab tools to turn fault data into seismic-hazard models. *Seismological Research Letters*, 87(2A):374–386, 2016.