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Toward a new seismic hazard model for Guadeloupe: Model development and sensitivity analysis

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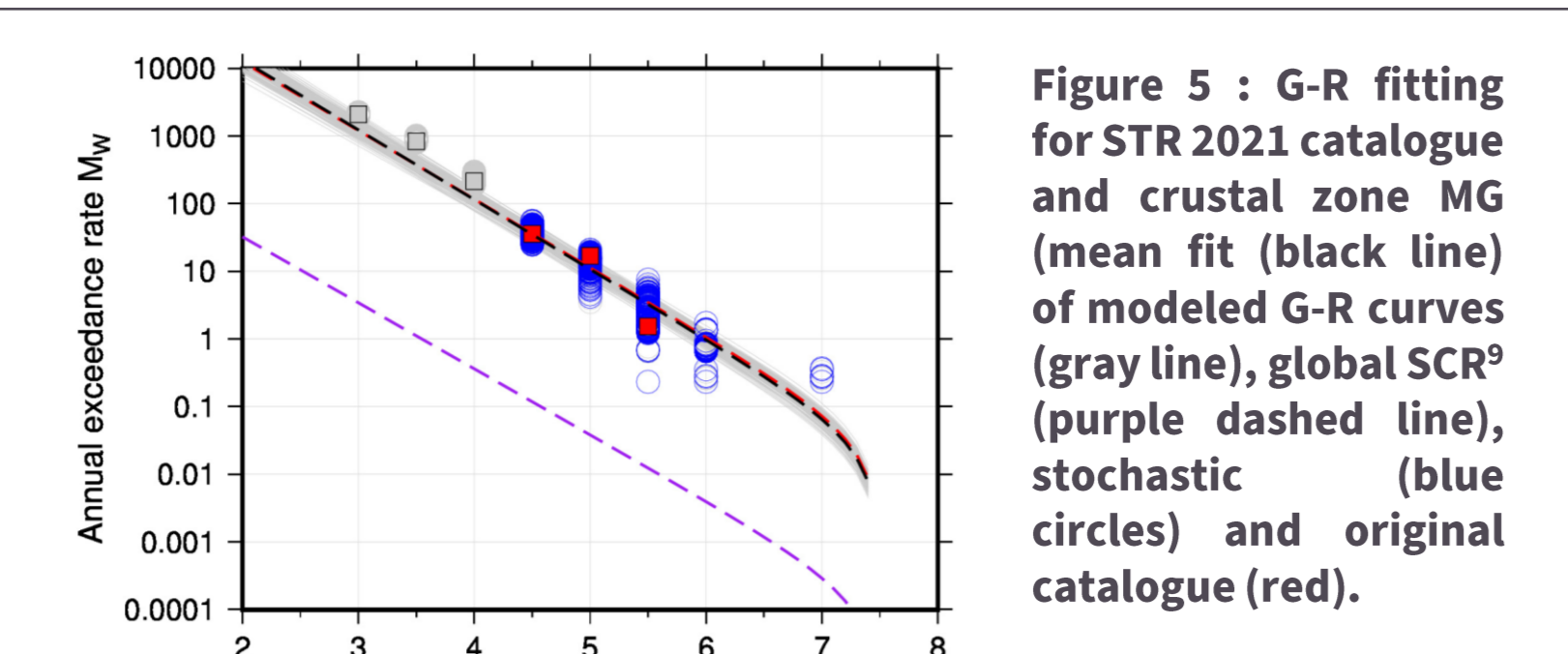
Abstract

The official probabilistic seismic hazard model made for the purpose of the EC8 enforcement in France was based on the state of knowledge at the beginning of 2000. Based on that model the French ministry established the French seismic zonation which classifies the territory in 5 zones where the highest level is assigned to the Antilles. Since then, relevant progresses have been made in the acquisition of new data and in the development of new models and methods to be used in probabilistic seismic hazard assessment (PSHA). Moreover, PSHA practice evolved significantly particularly in terms of treatment and consideration of uncertainties.

In this contribution we present the development of a new seismic hazard model for Guadeloupe. We focus on the development of a homogenized earthquake catalogue, the integration of recent studies to develop seismic source models for both subduction and crustal sources and the consideration of new ground motion models.

A sensitivity analysis shows the impact of alternative models on the resulting hazard. Preliminary results at 475 years return period are compared to the official French zonation & GEM hazard maps at selected location.

Magnitude-Frequency Distribution



The a & b values of the Gutenberg-Richter models are determined based on a maximum likelihood approach with a prior b-value. The correlation between a & b values is considered in the uncertainty propagation.

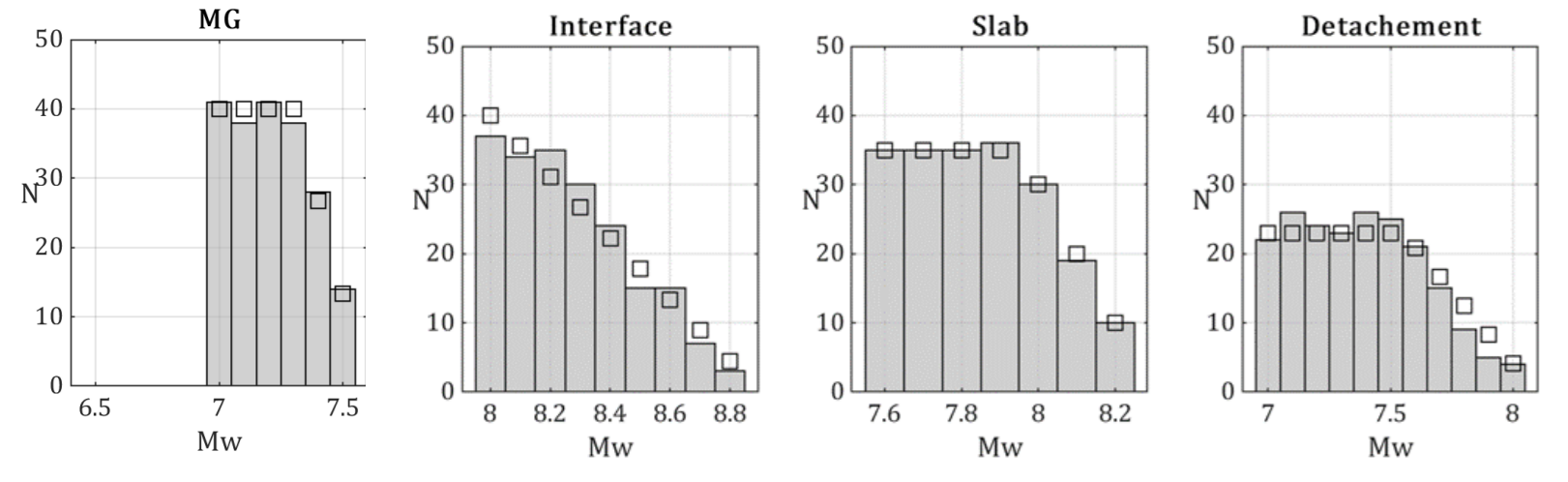


Figure 6 : Mmax distributions (left-most) of crustal zone MG, (right) for subduction zones propagated with 200 random Monte-Carlo samples.

Smoothed Seismicity

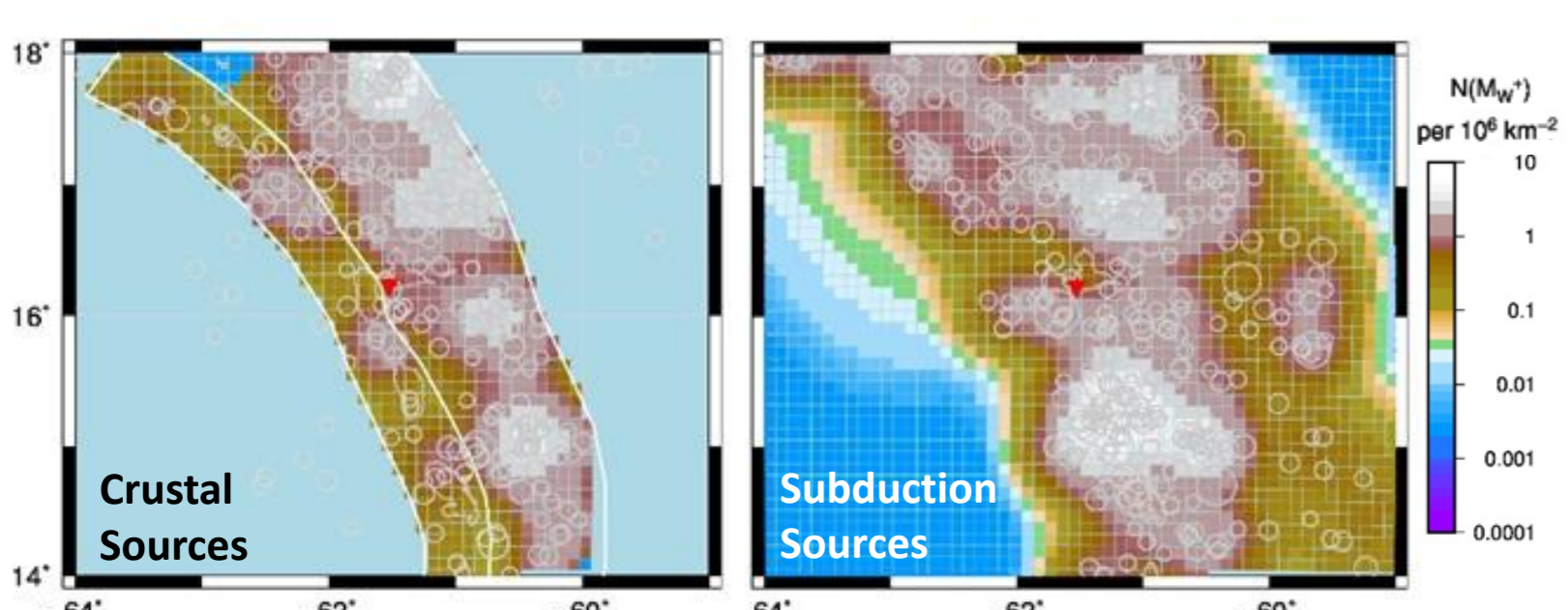


Figure 7 : Example of annual activity rates for Mw >= 4.5 using the adaptive kernels¹⁰ at the distance of the 2 nearest neighbors to determine the smoothing length (red triangle is city of Pointe-à-Pitre).

The smoothing approach is an alternative to the source zone seismotectonic model allowing to capture the local variability of seismic rates. A wide range of kernels was adopted to better account for the epistemic uncertainties in the activity rate estimates. The smoothing is based on macrozones, to limit the seismicity with a strict boundary between the active arc and the pre-arc for crustal zones (left). No spatial limits are used to compute the rates for deep seismicity (right).

Sensitivity Analysis

The sensitivity analysis was carried out in order to better characterize the center, body and range and to identify the components of the SSC models that affect the most the hazard estimate variability.

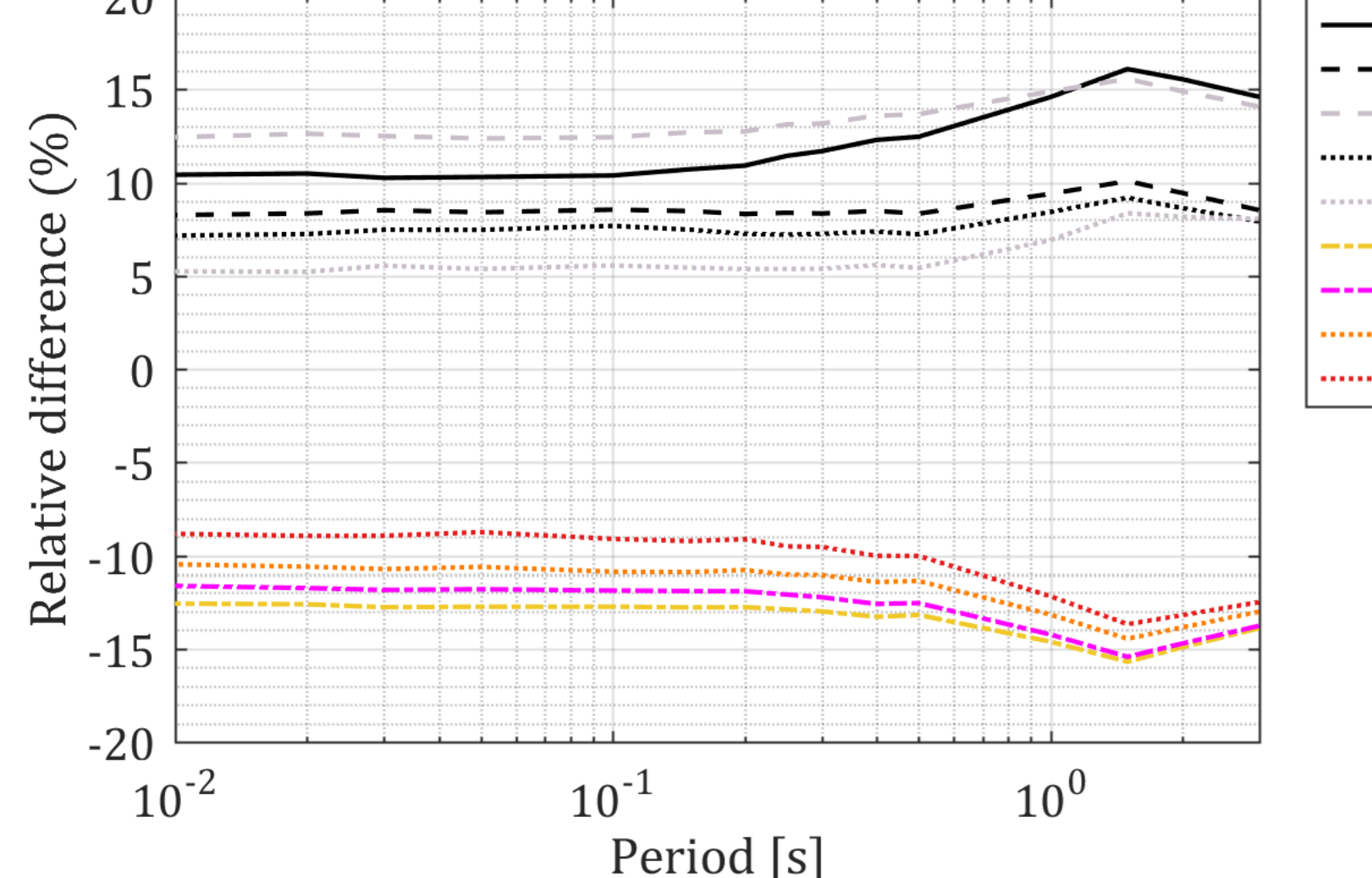


Figure 12 : Sensitivity tests on different SSCs, using STR 2021 catalogue for a return period of 475 years at the Pointe-à-Pitre site (n°1).

Updated Seismic Catalogue

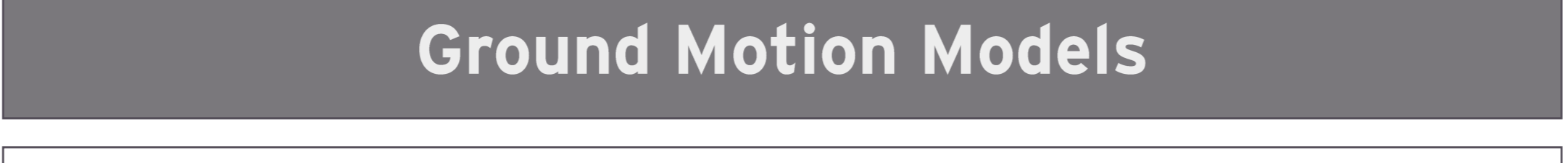
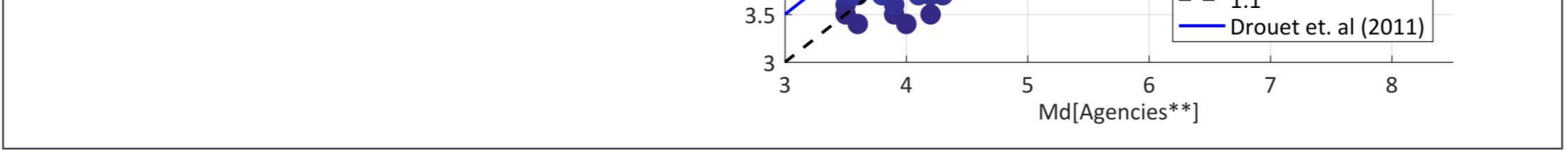
A new catalogue of earthquakes (STR 2021) covering the historical and instrumental periods is compiled up to end of 2020 to be able to work with a robust seismic sample to establish the correlations between the different magnitude scales and the moment magnitude Mw. When possible, the hypocentral location estimates from the local seismic networks like CDSA, IPGP were given priority over the location from global seismic database.

The project EQ catalogue is composed of crustal events (typically shallower than 33 km) and events related to the subduction process (interplate events typically shallower than 50 km or intraplate events with depth ranging from a few km down to more than 250 km).

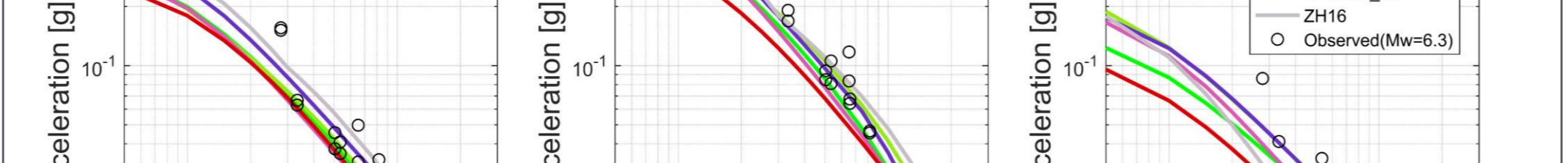
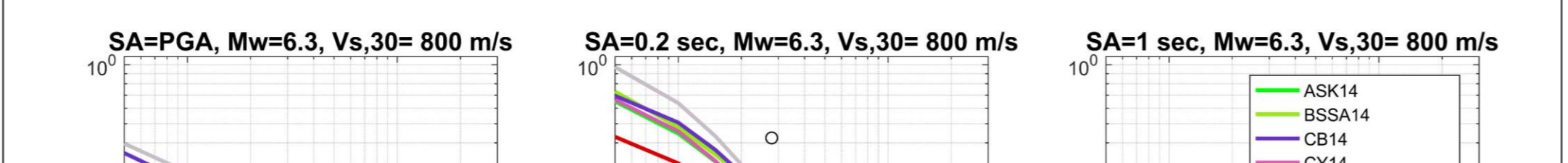
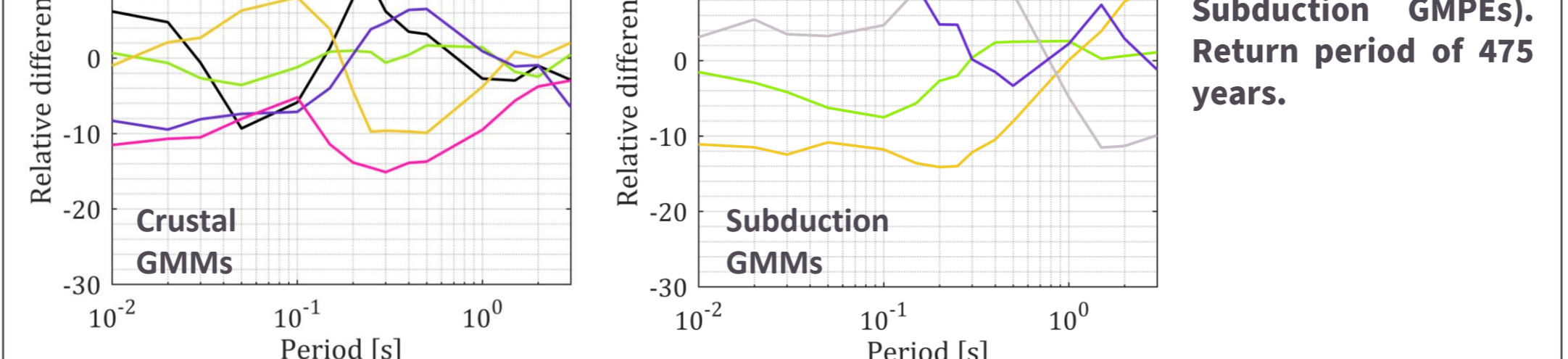
In the project catalogue ~30% events were converted from Md to Mw. Given the large uncertainties affecting the determination of Md-Mw, relationship proposed by Drouet et al. (2011)¹ conversion was replaced by a bilinear regression more consistent with the dataset.

Agencies* : GCMT, USGS, NEIC, NEIS, IPGP, ISC-EHB and ISC-GEM.

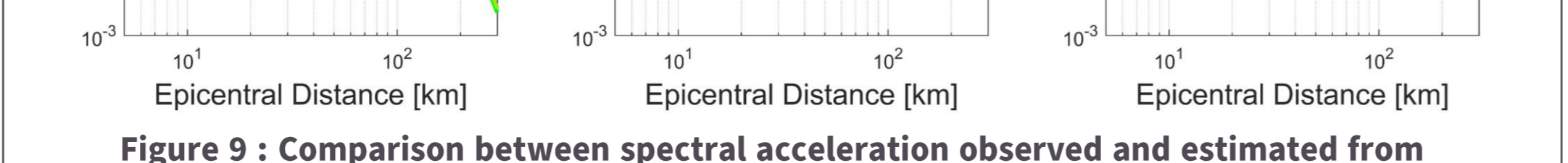
Agencies** : FDF, INET, OSPL, RSPR, EIDC, IASPEI, SDD, SFS and USGS.



Ground Motion Models



A weighting scheme based on the distribution of sum of different branches of the LT for each return period for given GMPE will be adopted to further refine the GMPE logic-tree. The corresponding value on a normal pdf allows to unambiguously weight the GMPE.



The SSM logic tree is composed of a branch considering homogeneous volume sources and a branch considering smoothed seismicity. A fault model is also considered and coupled with the crustal background volume zonation. Each crustal branch is coupled with the subduction source model. For the fault model, two alternatives are considered for the determination of activity parameters using a characteristic and a Poissonian (G-R) approach. The logic tree is also composed of two catalogues (this study and GEM¹¹).

Conceptual Model	Seismicity Model	Crustal Tectonic Seismicity Model	Subduction Tectonic Seismicity Model	Earthquake Catalogue	Volume Activity Parameters (MFD)	Active Fault Segmentation	Faults Activity Parameters (MFD)	Style Of Faulting	Mmax Max Approach
Crustal sources combined with subduction sources	1.00	0.50	1.00	Catalogue 2021	GR for each zone	0.60	1.00	Defined for each zone	RA, RL to Mw & Expert opinion
				Catalogue GEM	GR for each zone	0.40	1.00	Defined for each zone	RA, RL to Mw & Expert opinion
Crustal Model + Faults SM1+F	0.40	1.00	1.00	Catalogue 2021	GR for each zone	0.60	1.00	FM1 Single segment rupture	Char. Event
				Catalogue GEM	GR for each zone	0.40	1.00	FM2 Multi segment rupture	Char. Event
Smoothed seismicity	0.50	1.00	1.00	Catalogue 2021	Kernel SA2	0.25	1.00	Kernel SA2	0.25
				Catalogue GEM	Kernel SA2	0.25	1.00	Kernel SA2	0.25

Discussion & Conclusions

The PSHA calculations were carried out following the final logic tree at 15 points corresponding to the main cities of the Guadeloupe archipelago. At return period of 475 years, a gradual increase of the hazard from SSW to NNE is observed which can be attributed to a larger contribution of the subduction interface events.

In general, these values are in same order of magnitude and hence consistent with the GEM hazard maps¹² (mean PGA of 0.20 to 0.35 g). However, this study shows a higher resolution hazard range across the Guadeloupe archipelago.

Moreover, it is noted that, the mean hazard level at 475 years for standard rock condition (Vs,30=800 m/s) has increased compared to the results from Martin et al. (2002)⁸. This increase can be attributed to various components namely updated seismotectonic models, use of new and updated GMPEs, more robust observed seismicity, evolution of PSHA methodology, etc.

Hence, further research and studies should focus on harmonization of seismicity data in the Lesser Antilles region, development of the fault model and specific GMPEs applicable in Guadeloupe archipelago. The significant improvement of the regional accelerometric database authorizes the migration of the GMPEs model toward a non-ergodic model. Such efforts would be relevant to confirm these preliminary results and to further improve the hazard model.

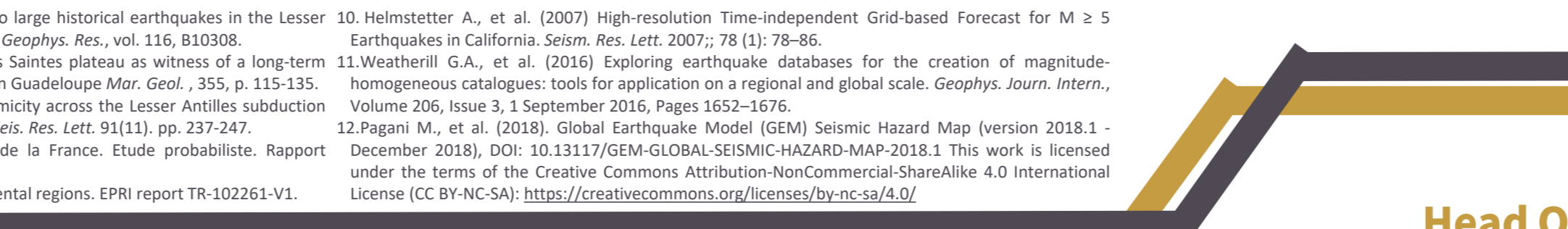


Figure 13 : Seismic hazard map of the Guadeloupe archipelago (Lesser Antilles), PGA for return period of 475 years (Vs,30=800 m/s).

Seismic Source Models

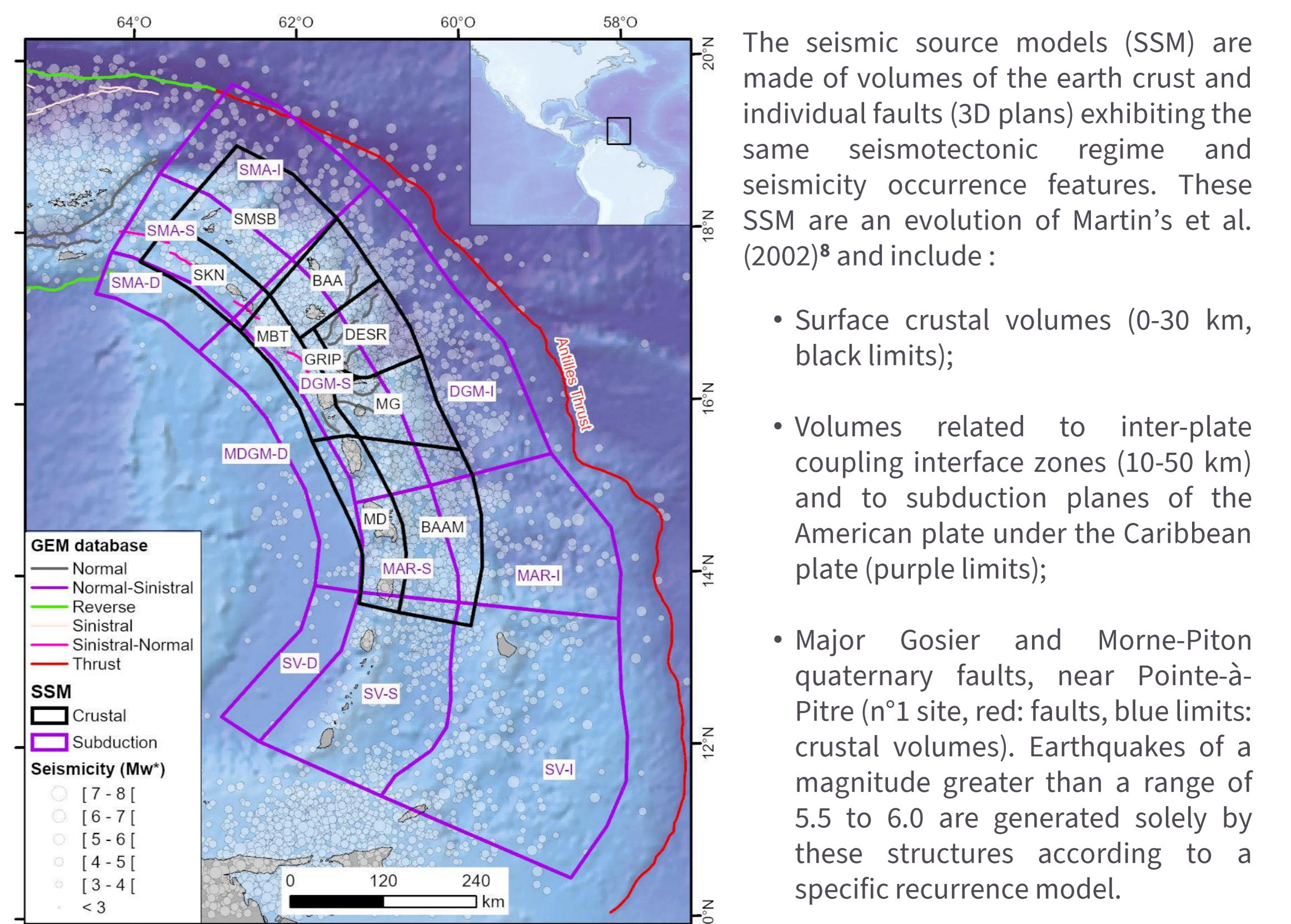


Figure 3 : Earthquake catalogue (1690-2020) and crustal and subduction SSM of the Lesser Antilles developed in this study based on the GEM active fault database², local studies about faults^{3,4,5,6}, and seismicity and subduction geometry⁷.

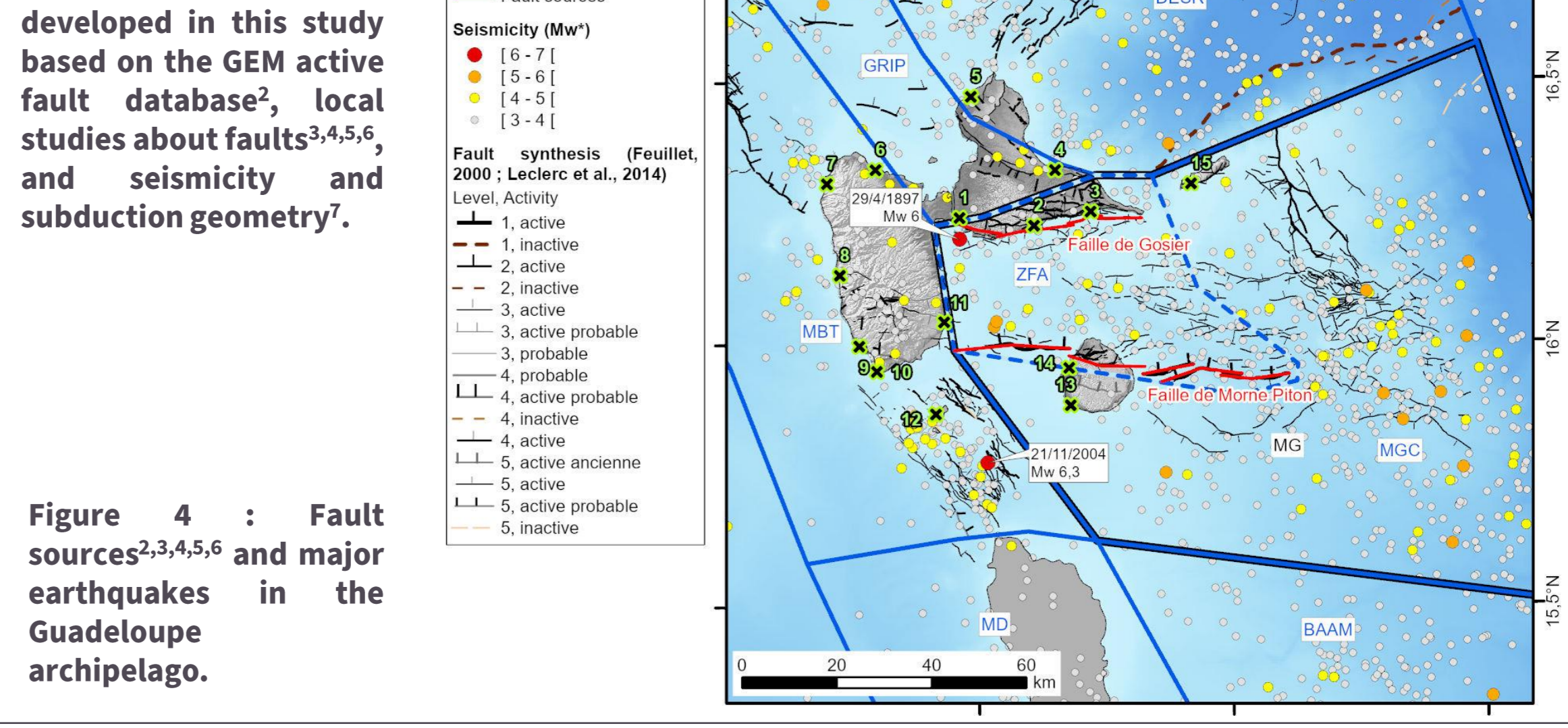


Figure 4 : Fault sources^{3,4,5,6} and major earthquakes in the Guadeloupe archipelago.

SSM Logic Tree

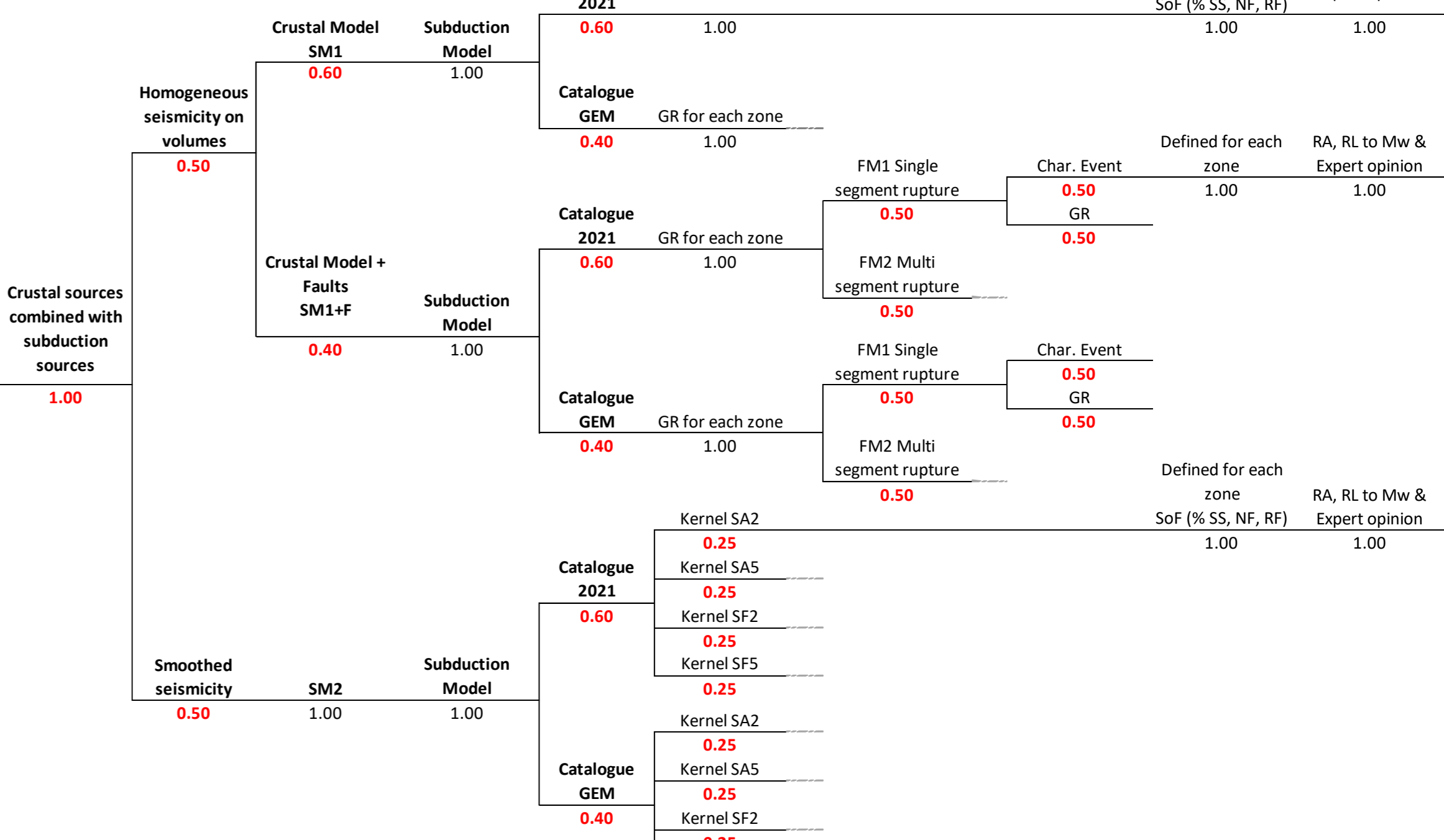


Figure 11 : Final SSM logic tree. The SSM logic tree is composed of a branch considering homogeneous volume sources and a branch considering smoothed seismicity. A fault model is also considered and coupled with the crustal background volume zonation. Each crustal branch is coupled with the subduction source model. For the fault model, two alternatives are considered for the determination of activity parameters using a characteristic and a Poissonian (G-R) approach. The logic tree is also composed of two catalogues (this study and GEM¹¹).

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