PSHA input model documentation for Western Africa (WAF)

GEM Hazard Team

Version history

Table 1 summarises version history for the WAF input model, named according to the versioning system described here, and indicating which version was used in each of the global maps produced since 2018. Refer to the GEM Products Page for information on which model versions are available for various use cases. The changelog describes the changes between consecutive versions and are additive for all versions with the same model year.

Table 1 – Version history for the WAF input model.

Version	2018.1	2019.1	2022.1	2023.1	Changelog
v2018.0.0	X	X	X		First version of the model.
v2018.1.0				X	Mmin extended to M4 for crustal distributed seismicity. The gmmLT.xml file has been modified to include a third GMPE.

The following text describes v2018.1.0.

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1 Summary

The Western Africa model (WAF) was developed internally by GEM. The model encompasses the whole Atlantic side of the Africa continent. An ad-hoc homogenised earthquake catalogue was developed based on globally available information, which was used as primary base for seismic occurrence analysis and the subsequent development of the source zonation model. The analysis was particularly challenging in the region, due to the severe incompleteness of calibration data, and the virtually nonexistent neotectonic information.

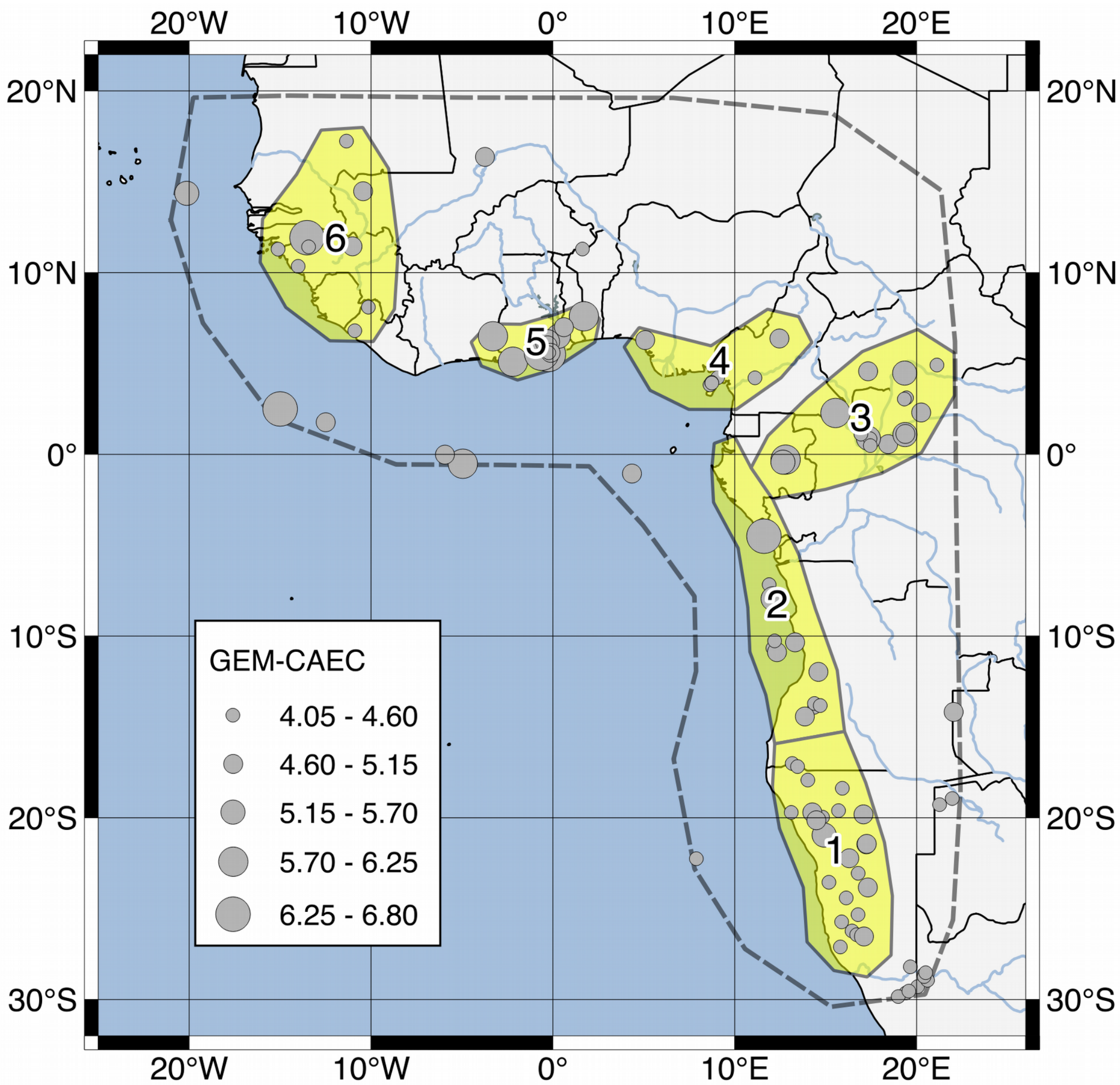
2 Tectonic overview

Western Africa has very little tectonic activity, with low rates and magnitudes of seismicity. A few old faults within the African craton may be episodically reactivated, such as in the Cameroon Volcanic Line, but these earthquakes are somewhat rare and poorly understood.

3 Basic Datasets

GEM has created a new Mw-homogenised earthquake catalogue by assembling globally (ISC review bulletin, GCMT, ISG-GEM, GHEC) and locally available sources (Ghana catalogue, Amponsah et al., 2012). The GEM implementation of the Earthquake Catalogue for Central Africa (hereinafter GEM-CAEC) consists of 114 events with $4 \geq M_w \geq 6.5$, covering a period from 1636 to 2013 (Figure 1).

Figure 1 *– Seismic zones of the Western Africa model (in yellow) and the GEM earthquake catalogue for Central Africa (GEM-CAEC). The limit of the catalogue selection area is marked by the dashed line.*



4 Hazard Model

4.1 Seismic Source Characterisation

Area Source Zonation The seismic source model of the WAF model consists of six area source zones (Figure 1). Seismicity in each area source is assumed to follow a double truncated Gutenberg-Richter magnitude occurrence relation (or magnitude- frequency distribution, MFD). Lower truncation is arbitrarily assigned to Mw 4.5. Due to the scarcity of calibration data, a unique Gutenberg-Richter b-value has been calculated from all events in the study region. Conversely, occurrence rates (a-values) have been calculated separately for each source zone by imposing the previously calibrated b-value. A different maximum magnitude (Mw-Max) estimate is derived independently for each source zone as the largest observed event plus an arbitrary - although quite conservative - increment of 0.5 magnitude units. Seismicity parameters are summarised in Table 2.

Source	a-Value	b-Value	Mw-Max
1	4.04	1.04	5.76
2	3.85	1.04	5.76
3	4.12	1.04	6.5
4	3.83	1.04	5.43
5	3.70	1.04	7.3
6	3.84	1.04	6.82

Table 2 *– Seismicity parameters used in the WAF model.*

Smoothed Seismicity To better represent the spatial variability of seismicity across the study area, the annual occurrence rates previously obtained for the homogeneous source zones were redistributed within each polygon using a procedure that accounts for the irregular spatial pattern of the observed events (Figure 2). The procedure shares some similarity with the popular smoothed seismicity approach (e.g. Frankel, 1995), but is more convenient in that a unique fit of the MFD is required for each zone, while the corresponding total earthquake occurrence is a-posteriori spatially reorganised as a function of the epicentral distance to all neighbouring events. Moreover, the combined use of zones gives the possibility to account for different modelling parameters (b-value, depth distribution, rupture mechanism) in separate regions.

4.2 Ground Motion Characterisation

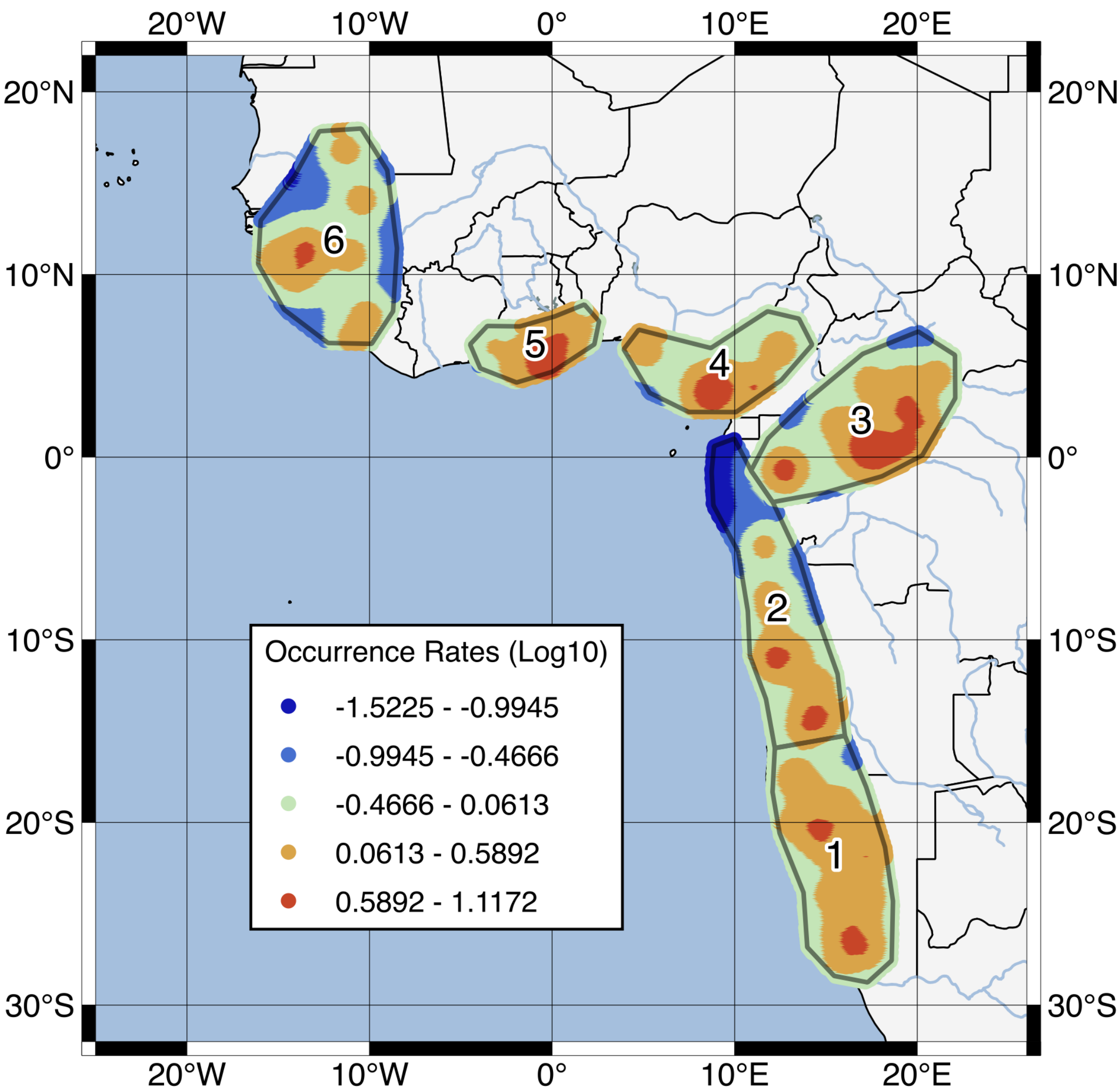
Table 2 shows the ground motion logic tree. The tectonic region type for WAF was assumed to be stable continental crust (*Tectonic_Type_A*).

Epistemic Uncertainties Given the lack of calibration data and a local ground motion prediction model, we used the GMPEs (Atkinson and Boore, 2006; Pezeshk et al., 2011) selected by Poggi et al. (2017) for the stable continental regions of the Sub-Saharan Africa model.

Tectonic_Type_A	Weight
YenierAtkinson2015BSSA	0.34
PezeshkEtAl2011NEHRPBC	0.33
AtkinsonBoore2006Modified2011	0.33

Table 3 *– GMPEs used in the WAF model.*

Figure 2 *– Spatial redistribution of the cumulative annual rates (M > 0) using a smoothing parameter (λ) of 100.*



5 Results

Hazard curves are shown for Accra in Figure 3.

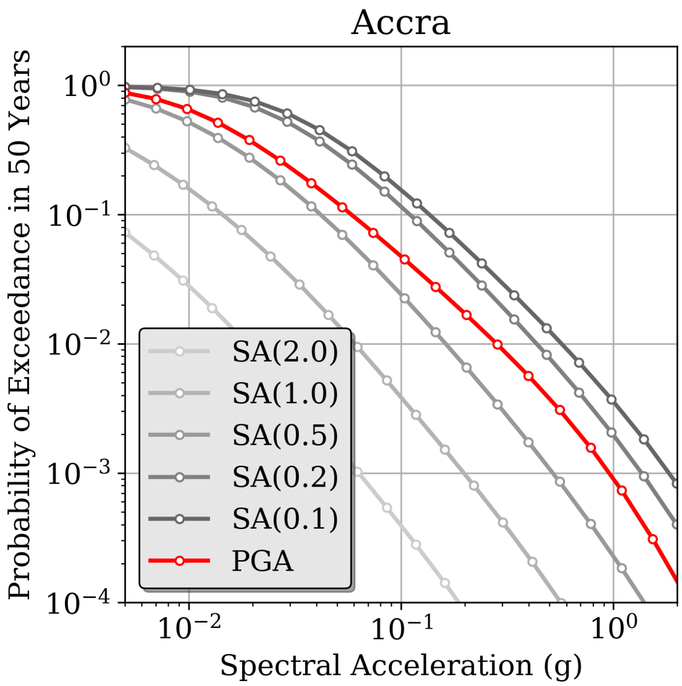


Figure 3 *– Hazard curves calculated at different spectral periods for the city of Accra, capital of Ghana.*

6 Results

Hazard curves were computed with the OQ engine for the following:

- Intensity measure types (IMTs): peak ground acceleration (PGA) and spectral acceleration (SA) at 0.2s, 0.3s, 0.6s, 1.0s, and 2s
- reference site conditions with shear wave velocity in the upper 30 meters (Vs30) of 760-800 m/s, as well as for Vs30 derived from a topography proxy (Allen and Wald, 2009)

Hazard maps were generated for each reference site condition-IMT pair for 10% and 2% probabilities of exceedance (POEs) in 50 yrs. Additionally, disaggregation by magnitude, distance, and epsilon was computed for the following cities: Libreville, Porto Novo, Lome, Bamako, Windhoek, Freetown, Bangui, Dakar, Bissau, Kinshasa, Accra, Luanda, Sao Tome, Brazzaville, Conakry, Yaounde, Yamoussoukro, Malabo, Monrovia and Banjul. The results were produced as csv files and bar plots for each of the following combinations:

- hazard levels for 10% and 2% POE in 50 yrs
- PGA and SA at 0.2s, 0.3s, 0.6s, and 1.0s

- Vs30=800 m/s

All calculations used a ground motion sigma truncation of 5. Results were computed for sites with 6 km spacing

Visit the GEM Interactive Viewer to explore the Global Seismic Hazard Map values (PGA for Vs30=800 m/s, 10% poe in 50 years). For a comprehensive set of hazard and risk results, see the GEM Products Page.

7 References

Allen, T. I., and Wald, D. J., 2009, On the use of high-resolution topographic data as a proxy for seismic site conditions $Vs30$, Bulletin of the Seismological Society of America, 99, no. 2A, 935-943

Amponsah, P., Leydecker, G. & Muff, R., 2012. Earthquake catalogue of Ghana for the time period 1615–2003 with special reference to the tectono-structural evolution of south-east Ghana. Journal of African Earth Sciences, Vol. 75, pp. 1-13

Poggi, V., Durrheim, R., Mavonga Tuluka, G., Weatherill, G., Gee, R., Pagani, M., Nyblade, A., Delvaux, D., 2017. Assessing Seismic Hazard of the East African Rift: a pilot study from GEM and AfricaArray. Bulletin of Earthquake Engineering. doi:10.1007/s10518-017-0152-4.

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