GLOBAL EARTHQUAKE MODEL
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# PSHA input model documentation for South Africa (ZAF)

GEM Hazard Team

## Version history

Table 1 summarises version history for the ZAF 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 ZAF input model.*

| Version | 2018.1 | 2019.1 | 2022.1 | 2023.1 | Changelog |
|---|---|---|---|---|---|
| v2018.0.0 | X | | | | First version of the model. |
| v2018.0.1 | | X | | | Updated version following the model described in Midzi et al., 2020. Two fault sources were removed as suggested by the authors, and two area sources were added to the logic tree that were previously missing; small changes in hazard. |
| v2018.0.2 | | | X | | Updated source model logic tree so that it no longer contains duplicated branch ids. This is needed to run the model with engine 3.13+. The hazard results are not affected. |
| v2018.1.0 | | | | X | Mmin extended to M4 for crustal distributed seismicity. gmmLT.xml updated with more recent GMPEs. |

The following text describes v2018.1.0.

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## 1 Summary

The seismic hazard model for South Africa (ZAF) was developed by scientists from the Council for Geoscience, South Africa and the Indian Institute of Technology, Jammu, India. The model is described by Midzi et al. (2019). The seismic source model was developed using a newly updated catalogue and consists of zones of distributed seismicity, while the ground motion logic tree consists of two existing ground motion prediction equations (GMPEs) derived for active shallow crust. The model was originally created for the OpenQuake (OQ) engine.

## 2 Tectonic overview

South Africa sits at the southern passive margin of the African continent, where it transitions into oceanic crust. It is bounded to the northeast by the East African Rift System. The basement geology of the region is dominated by Archean cratons and mobile belts. No plate boundaries are present in the region and deformation is slow. Nonetheless, several moderate to large earthquakes have occurred in the country with the largest recorded being the 1969 *M*W 6.2 Ceres earthquake. The Cape Fold Belt is a dominant structural domain along the coast of South Africa and displays some paleoseismic evidence for Holocene faulting (e.g., Goedhart and Booth, 2016).

## 3 Basic Datasets

The seismic source model was developed using a newly updated earthquake catalogue in conjunction with a seismotectonic model for Southern Africa. The catalogue incorporates data predominantly from the South African National Seismograph Network (SANSN) and also includes events generated by gold mining activity around the Witwatersrand Basin. The seismotectonic model was derived through analysis of available structural, neotectonic, and seismological data. A full description of the datasets used for developing the hazard model can be found in Midzi et al. (2019).

# 4 Hazard Model

## 4.1 Seismic Source Characterisation

The seismic source characterisation (SSC) consists entirely of zones of distributed seismicity. Specifically, 22 seismic source zones are used to model areas assumed to be uniform in terms of their seismicity characteristics. The seismicity of each of these zones is assumed to follow a truncated exponential (Gutenberg-Richter) distribution. The specific seismicity parameters for each zone can be found in Midzi et al. (2019). Although major faults in Southern Africa have been identified, uncertainty associated with characterising the faults were deemed too large to confidently use them as unique sources in this study.

The OQ implementation uses the **Area Source** typology to model these zones.

**Epistemic Uncertainties** The PSHA for ZAF thoroughly accounts for epistemic uncertainties associated with the seismicity parameters. Uncertainties are large in the region because seismic and fault data is limited. Alternative seismicity parameters are considered through the use of a logic tree, which considers alternative values of earthquake recurrence (*a*- and *b*-values), maximum magnitude (*M*max), and depth.

## 4.2 Ground Motion Characterisation

South Africa is generally considered a stable continental region (Johnston et al., 1994) due to its position relative to plate boundaries, low level of earthquake activity and slow rates of crustal deformation. However, the current tectonic regime of South Africa also shows evidence of extensional tectonic stresses with dominant normal faulting. For this reason, two GMPEs are used for modelling ground motion attenuation in active crustal regions: Boore and Atkinson (2008) and Akkar et al. (2014), the latter having the ability to consider style of faulting.

**Epistemic Uncertainties** Using both GMPEs results in two alternative and complete hazard models, which are combined together through the use of a logic tree. The table below shows the logic tree with the GMPEs and their associated weights. Note that although the tectonic setting in South Africa is modelled as active shallow, the sources are labelled in the OpenQuake input as *Stable Continental Crust*, which is generally considered to be the predominant tectonic setting of South Africa.

| Stable Continental Crust | Weight |
|---|---|
| AbrahamsonEtAl2014 | 0.33 |
| AkkarCagnan2010 | 0.33 |
| ChiouYoungs2014 | 0.34 |

***Table 2*** *– GMPEs used in the ZAF model.*

## 5 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: Maseru, Mbabane and Pretoria. 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.

## 6 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

Goedhart ML, Booth PWK (2016) A palaeoseismic trench investigation of early Holocene neotectonic faulting along the Kango Fault, southern Cape Fold Belt, South Africa–Part II: earthquake parameters. South African Journal of Geology 119: 569-582

Midzi, V., Manzunzu, B., Mulabisana, T., Zulu, B.S., Pule, T., and Myendeki, S. (2019) Probabilistic seismic hazard maps for South Africa. Journal of African Earth Sciences, Volume 162, February 2020

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