Generation of a mixture model ground-motion prediction equation for Northern Chile

A. Händel, F. Scherbaum, N. Kühn, S. Specht — *Institute of Earth and Environmental Science, Potsdam University*
ahaendel@uni-potsdam.de, Frank.Scherbaum@geo.uni-potsdam.de, nico@geo.uni-potsdam.de, sspecht@uni-potsdam.de

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1. Motivation

Ground-motion prediction equations (GMPEs) are an essential component of any probabilistic seismic hazard analysis.
But:

- for Northern Chile no empirically derived GMPE exists
- the choice of appropriate GMPEs can lead to large uncertainties in hazard estimates

We propose a new method that combines GMPEs from other regions as weighted components of a mixture model.

2. Mixture Model

- is a probabilistic model that approximates an unknown distribution by a weighted sum of K probability distributions M_i:

$$M_{mix}(x) = \sum_{i}^{K} \Phi_i M_i(x)$$

- Φ_i denote mixture weights with $\sum_i^K \Phi_i = 1$
- Φ_i are learned from observed ground motion data x_j using the Expectation-Maximization (EM) algorithm

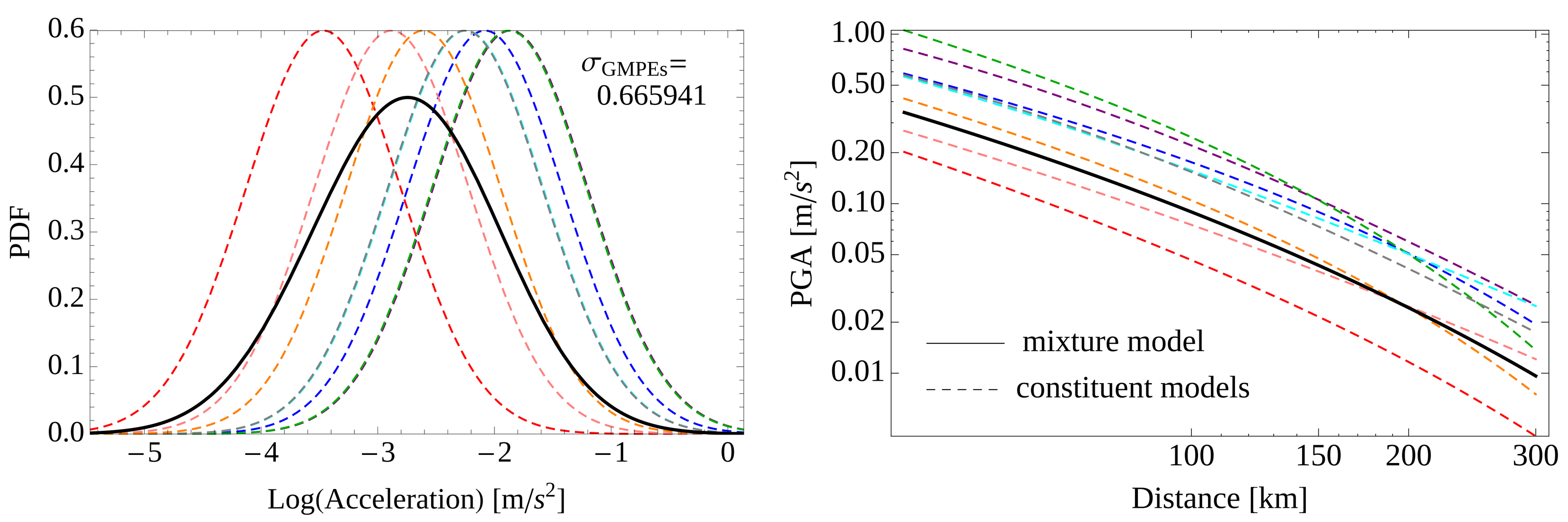

Fig. 1 GMPEs and mixture model for an Mw 6 interface event and PGA. Left: Probability distribution in 120 km distance. Right: PGA versus distance.

Advantages for ground-motion prediction:

- each GMPE is assumed to reflect the generation process of at least a fraction of the ground-motion in the region of interest
- the new model is able to predict ground motion that cannot be described by any of the constituent models alone

3. GMPEs and Data

Data: 371 interface and 713 intraslab strong-motion records from Northern and Central Chile coming from:

- Arango et al. (2012)
- IPOC network, year 2006 - 2012

GMPEs: 9 GMPEs developed for different subduction zones of the world

Model	Short
Youngs et al. (1997)	y97
Zhao et al. (2006)	z06
Kanno et al. (2006)	k06
Atkinson & Boore (2003)	ab03
Garcia et al. (2005)	g05
Lin & Lee (2008)	ll08
BC Hydro (2011)	bch11
McVerry et al. (2006)	mv06
Arroyo et al. (2010)	a10

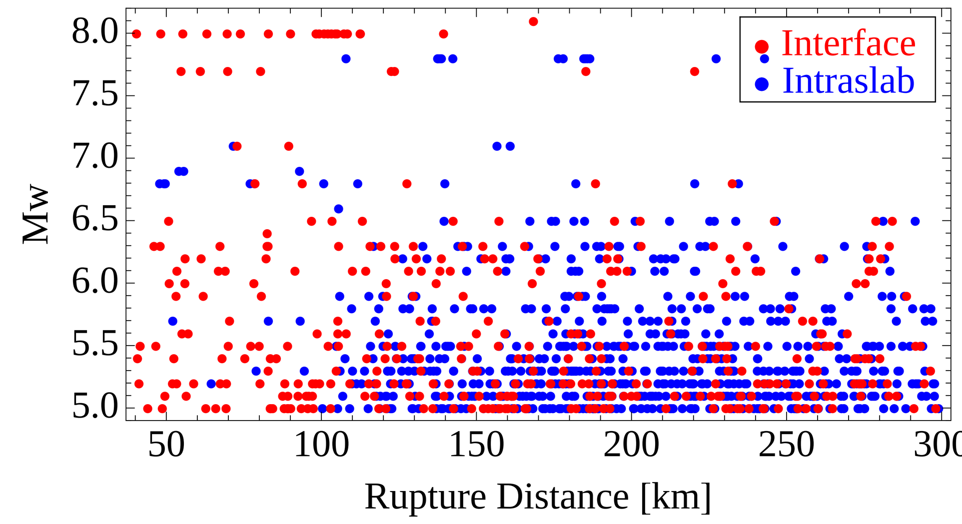

Fig. 2 Magnitude-distance distribution of the Chilean recordings.

4. Example

Performance measures:

- average residuals: $res = \mu(log_2(Y_{obs}) - log_2(Y_{pre}))$
- average negative log-likelihood (Scherbaum et al., 2009): $LLH(M_i, \boldsymbol{x}) := -\frac{1}{N}\sum_{j=1}^{N} log_2(M_i(x_j))$

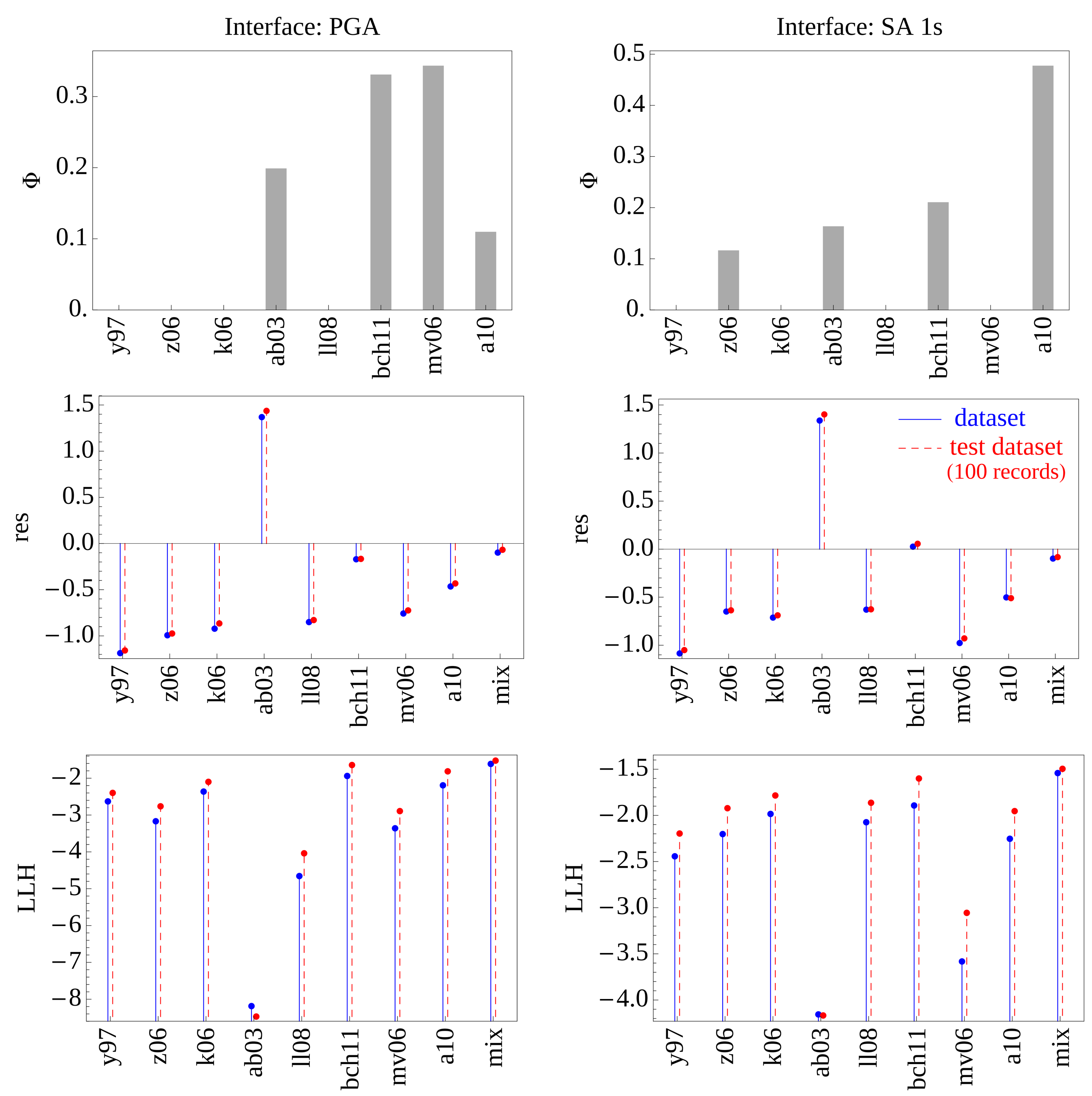

Fig. 3 Mixture weights for two oscillator periods (top). Comparison of the resulting average residuals (middle) and LLH values (bottom) for the dataset and a test dataset. A smaller negative LLH value corresponds to a higher ranking.

5. Results

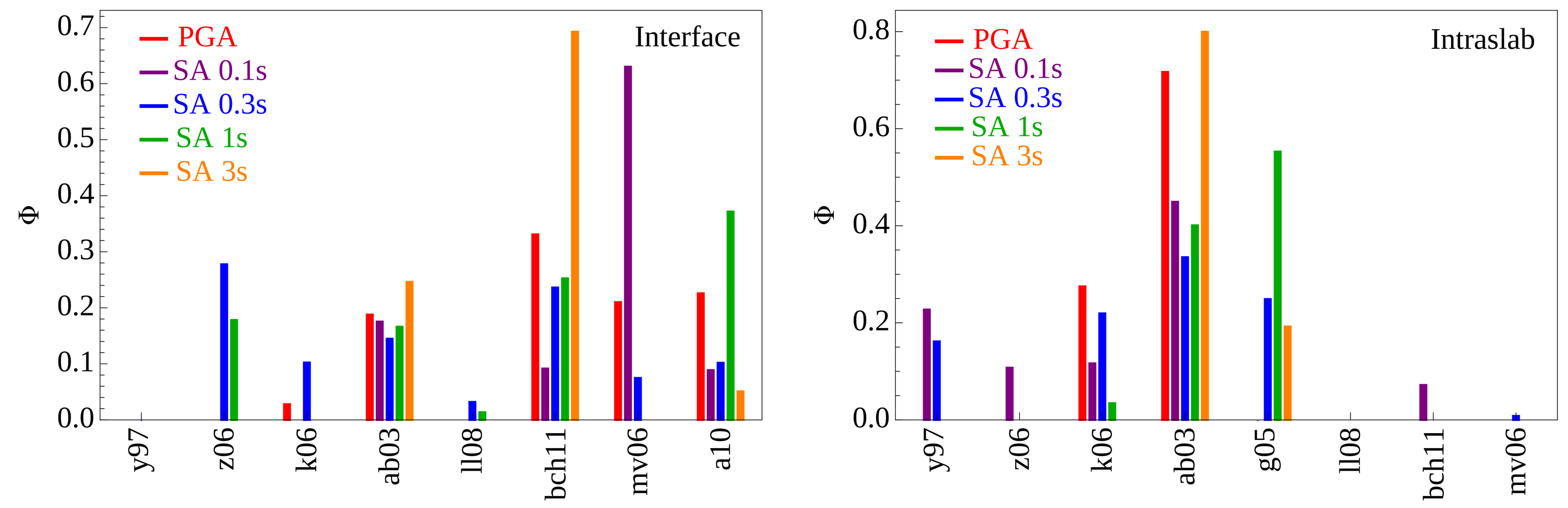

Fig. 4 Comparison of mixture weights obtained for different oscilator periods. Calculated for magnitudes Mw 5-8.1 and rupture distances from 40 to 300 km.

Overall performance of the mixture distributions in comparison to their constituent models:

- average residuals: always smallest or at least second smallest
- average negative log-likelihood measure: always ranked best

A new model for Northern Chile was generated by:

- combining diffent GMPEs into a mixture model
- using mixture weigths that have been derived in a purely data driven way

References and Acknowledgements

Arango, M.C., Strasser, F.O., Bommer, J.J., Boroschek, R., Comte, D., & Tavera, H., 2011. A strong-motion database from the Peru-Chile subduction zone, *Journal of Seismology*, **15**(1), 19-41.
Scherbaum, F., Delavaud, E., & Riggelsen, C., 2009. Model selection in seismic hazard analysis: An information-theoretic perspective, *Bulletin of the Seismological Society of America*, **99**(6), 3234-3247.
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