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DELIVERABLE

D25.4. Updated GMPE logic tree and rock/soil parametrization for ESHM20 (preliminary version)

Work package	WP25 (ETH)
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Summary

This report present the activities performed to update the ground-motion model logic tree and parametrize rock/soil amplifications factors for ESHM20. The final report will be delivered at M23.

1 Validation of a pan-European Engineering Strong Motion (ESM) flatfile

A large amount of work has been done to validate and disseminate the pan-European Engineering Strong Motion (ESM) flatfile (close collaboration between INGV and GFZ). The new flatfile has been published in June 2018 (Lanzano et al., 2018a) and it is actually used to develop the next generation of European Ground Motion models in active regions. Two companion articles (Lanzano et al., 2018b; Bindi et al., 2018a) have been published to describe the flatfile: whereas the former discusses the applied compilation criteria and shows several data statistics, the latter presents the outcomes of consistency analysis performed to qualify the data from the ground motion variability point of view. In particular, the between-event residuals (δB_e) obtained by considering two different sources of moment magnitude (i.e., from the EMEC catalogue and the moment magnitudes included in the ESM data base) are presented. The results show that, at long periods, the between-event terms from the two regressions have a weak correlation and the overall between-event variability is dissimilar (Figure 1), highlighting the importance of magnitude source in the regression results.

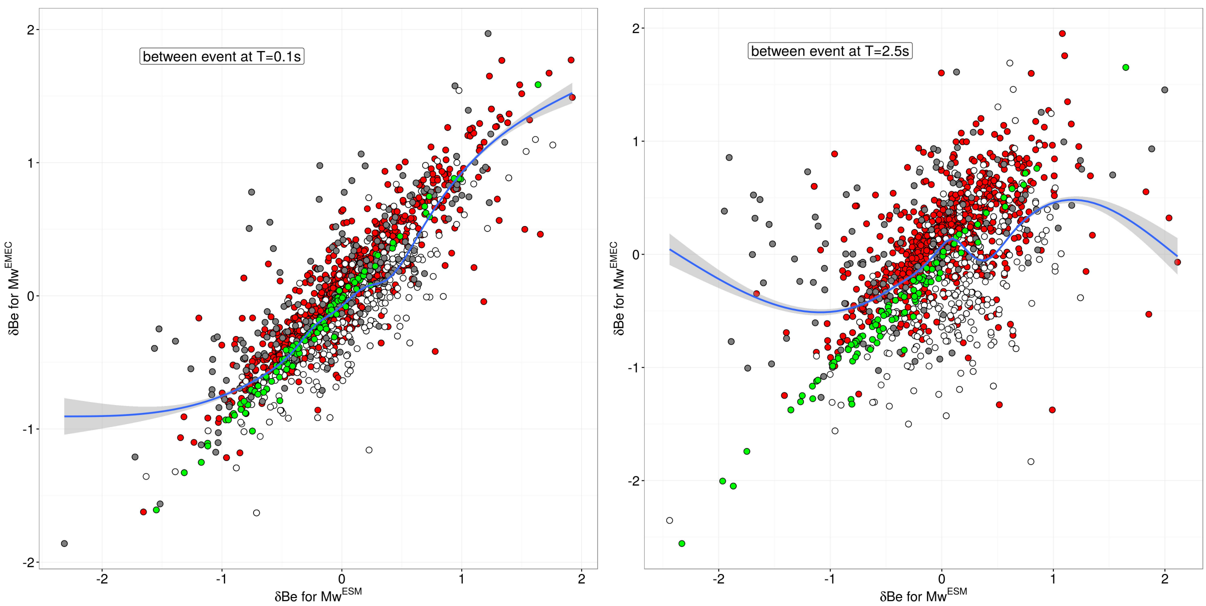

Figure 1. Between events residuals δB_e obtained considering M_w either from EMEC or ESM data bases, for T = 0.1s (left) and 2.5s (right). Red points represent recordings with both M_w^{EMEC} and M_w^{ESM} available, whereas the other colours imply conversions from M_l to M_w. In particular, the green dots represents earthquakes for which both M_w^{ESM} and M_w^{EMEC} are derived from the local magnitude (and therefore showing high correlation). The blue curves are the results of the trend analysis (LOESS) with high order polynomials, giving an idea about the degree of correlation between the two δB_e estimates. See Bindi et al. (2018a) for more details.

2 Implementation and testing of new GMPEs

New available models have been implemented in the Openquake library. ESHM13 GMPEs and their "updates" have been compared (see Figure 2). Several test have been performed to identify regional variations (see Figure 3)

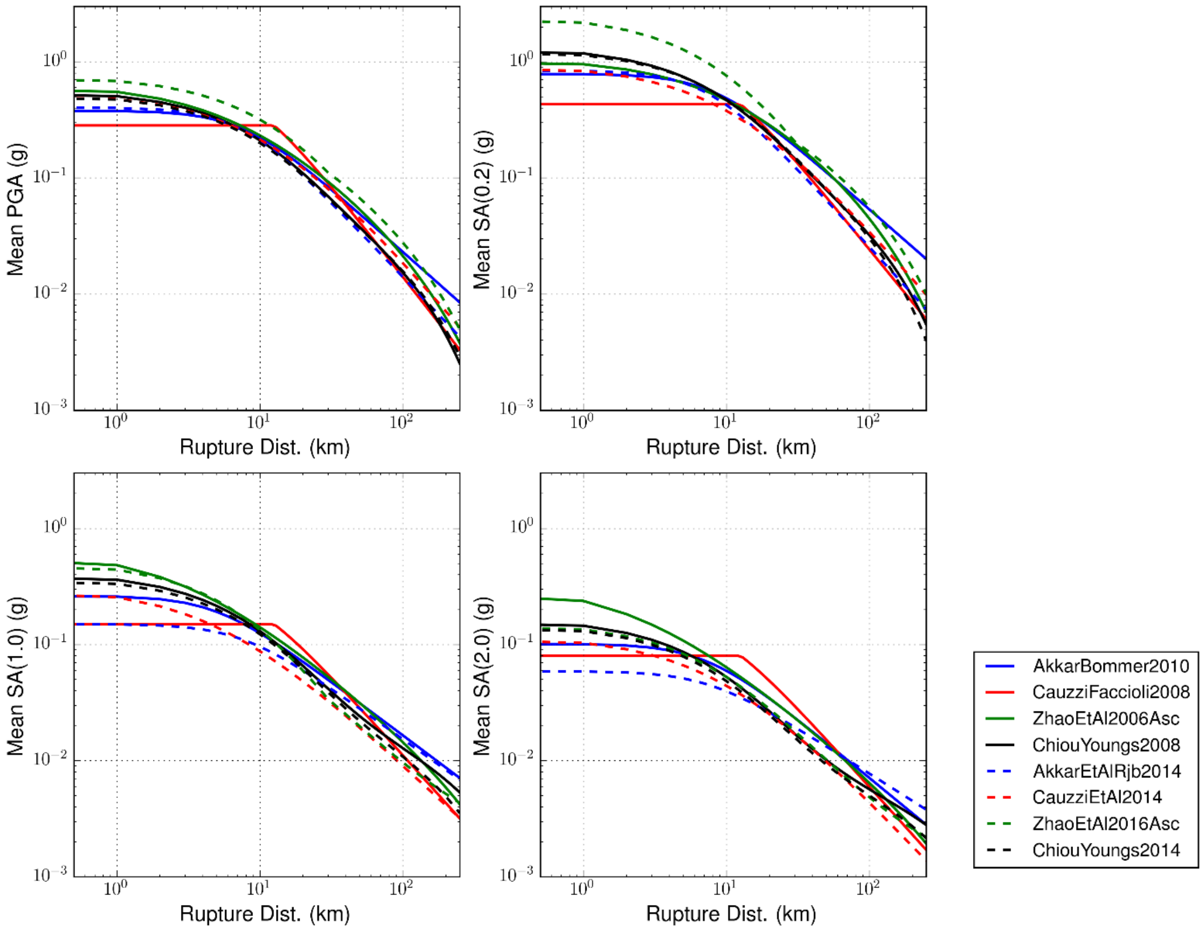

Figure 2. ESHM13 Active Shallow GMPEs (solid) and their "updates" (dashed). In many cases, we observe a shift toward higher short-period accelerations

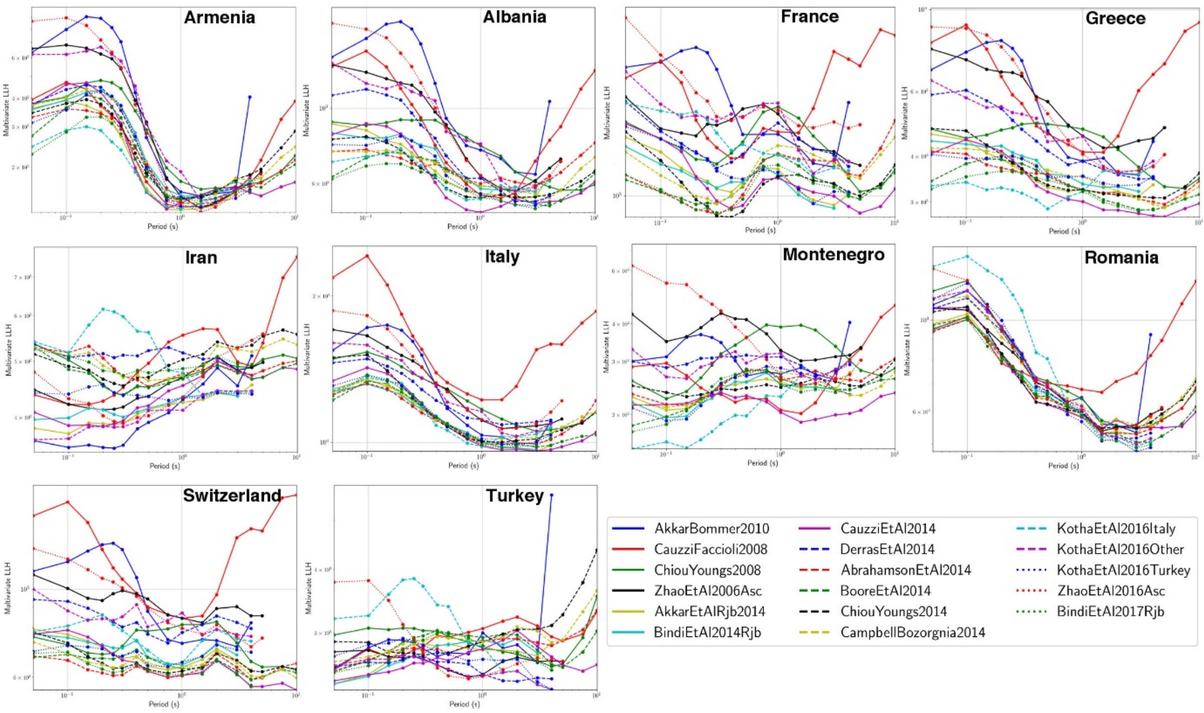

Figure 3. GMPEs testing to identify regional variations.

The significant increase in strong motion data provided by the ESM flatfile also allows for a more robust comparison of models to data for the non-active shallow earthquake sources in Europe, namely the Hellenic and Calabrian Arcs and the Vrancea deep-source seismic zone. Classification of the subduction records is undertaken using a novel fuzzy methodology, whilst records from the Vrancea deep seismic zone are extracted by hand. The magnitude and distance composition of these sub-sets are shown in Figure 4.

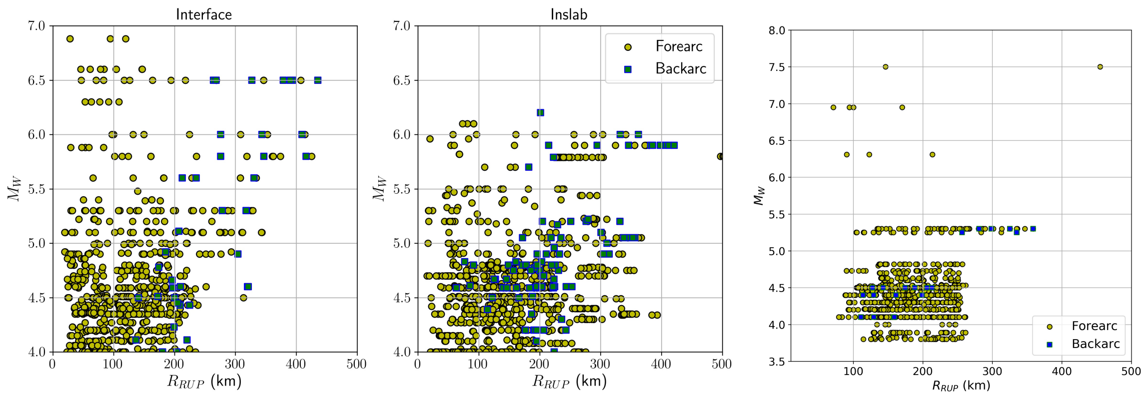

Figure 4. Magnitude and distance composition for non-shallow sources the ESM flatfile: subduction interface (left), subduction in-slab (middle) and Vrancea deep source (right).

Since the completion of the ESM2013, new GMPEs for subduction and other deep sources have been published, and a comparison of these results against data for Europe has been undertaken in Weatherill et al. (2018b). These results (Figure 5) demonstrate that recent models for subduction regions, such as those of Abrahamson et al. (2016) [BC Hydro], Montalva et al. (2017) and Vacareanu et al. (2015) show a general improvement in fit, by way of a lower multivariate loglikelihood (Mak et al.,

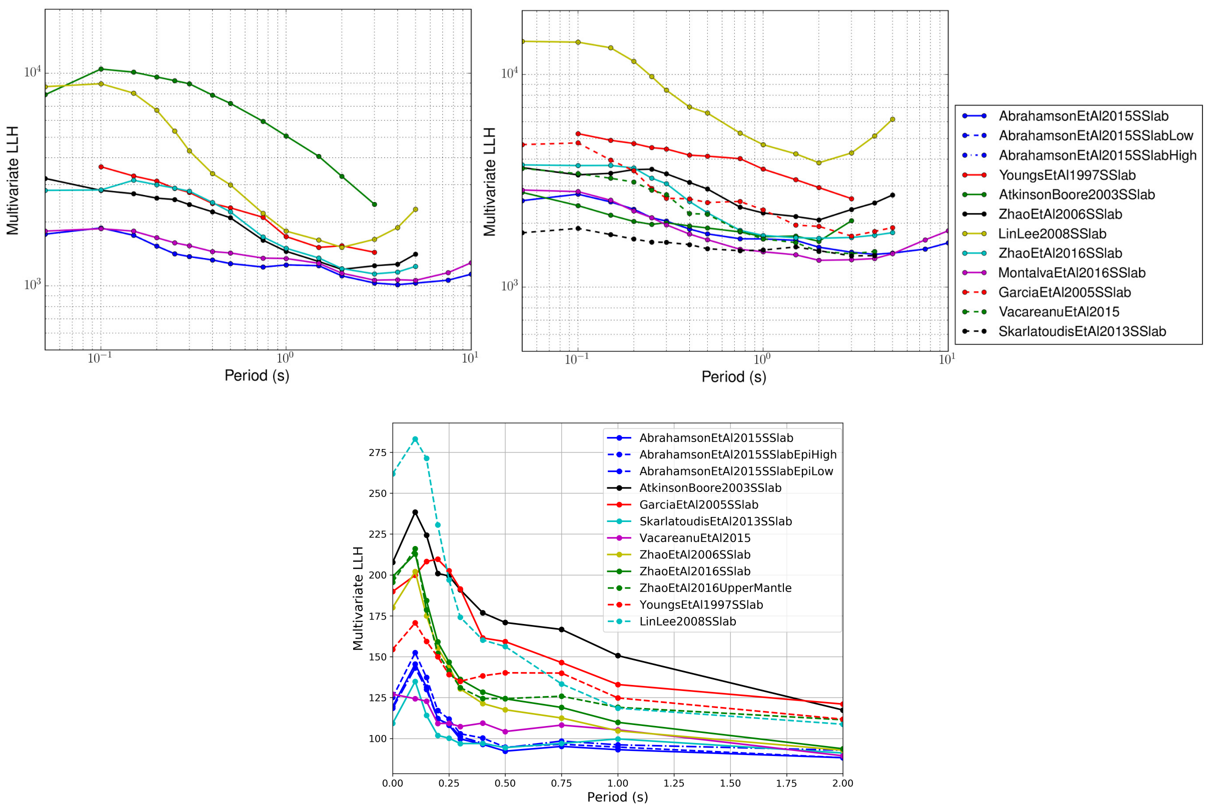

Figure 5. Multivariate loglikelihood fits of subduction ground motion models to ESM data for subduction interface (top left), subduction in-slab (top right) and Vrancea (bottom) events.

2017), to European data than the previous models selected within the SHARE project – a strong justification for the comprehensive update of the logic tree being undertaken in this task.

3 Definition of the new ESHM2020 GMPE logic tree

The strategy to develop the new ESHM2020 GMPE logic tree has been discussed in two meetings (Lisbon, November 2017) and Thessaloniki (June 2018). The chosen methodology and strategy has been presented at the EGU meeting (Vienna April 2018, Weatherill et al., 2018). The potential impact of the new GMPE development and choices have been presented and discussed with the ES8 SC8 committee (Ispra, March 2018).

Following these discussions, we are currently planning to adopt the logic tree structure proposed by John Douglas (2018 ECEE). In the active and stable regions we are building a new model from ESM, which we plan to use as the backbone, and are still in the process of calibrating the coefficients and, subsequently, the epistemic uncertainties.

For the subduction zones and Vrancea progress had been made are also working along the same lines, albeit recognising that ESM still only provides sufficient data to identify the most appropriate GMPEs and attempt some partial calibrations. In this case the Abrahamson et al. (2016) BC Hydro GMPE is the backbone (Figure 6), with magnitude scaling epistemic adjustment factors as proposed in the original paper, statistical uncertainties from the application of the Al Atik & Youngs (2014) approach made during the Hanford Site PSHA (Coppersmith et al., 2014), and anelastic attenuation adjustments calibrated to the ESM data. A publication detailing the developments of the subduction and deep earthquake logic tree, including details on classification of subduction records in the ESM, analysis of epistemic uncertainty and impact on seismic hazard is in currently preparation (Weatherill et al., 2019).

Given that with SERA this is still a work in progress, one alternative logic tree that could be considered is presented in Weatherill and Danciu (2018). In this paper a broadband GMPE logic tree (Sa 0.05 to 10 s) is developed to explore the calibration between design code long period coefficients and long

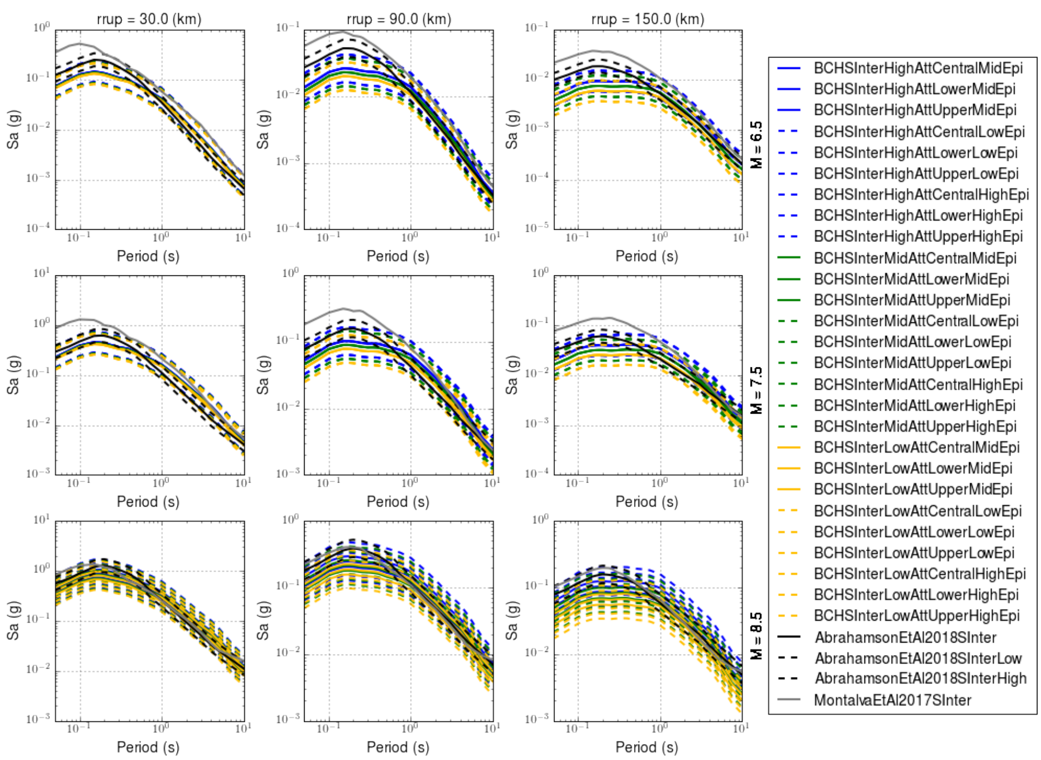

Figure 6. Trellis plots of variation in response spectra for various magnitudes (by row) and distances (by column) for a proposed subduction logic tree including epistemic adjustments for the Abrahamson et al. (2016) model (blue, green and yellow lines respectively)

period displacement UHS. For this the SHARE logic tree has been updated with mostly new models, but adding the condition that the selected GMPEs cover the 10 s period range, a requirement also made within Deliverable 25.1 (Crowley et al., 2018). For active shallow regions this replaces the SHARE selection with Chiou & Youngs (2014), Boore & Atkinson (2014) and Cauzzi et al. (2015) - adding on additional epistemic uncertainty using the results of Al Atik & Youngs (2014). For stable GMPEs this replaces Toro (2002) and Campbell (2003) with Pezeshk et al. (2011) and some of the Edwards & Fäh (2013) models (trying to capture stress parameter uncertainty), whist for subduction and Vrancea it ends up with the 2016 BC Hydro model as a backbone plus additional magnitude and statistical uncertainties (based on the aforementioned analysis). Given the additional broadband constraint Zhao et al. (2016), Akkar et al. (2014), Derras et al (2014) or Bindi et al. (2014), nor the Vacareanu et al. (2015) model for Vrancea could not be used. To a certain extent this addresses the question of what happens if the SHARE GMPEs are replaced with their updates, specifically focusing on the change with respect to the epistemic uncertainty range. Results for selected cities in Europe are shown in Figure 7.

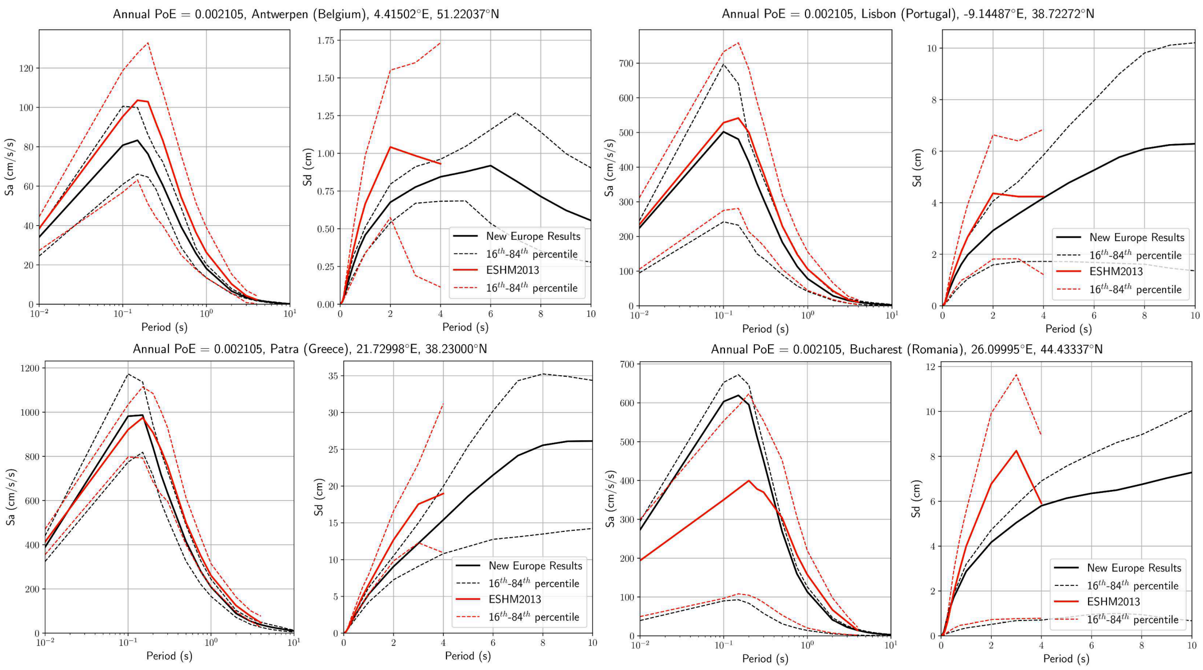

Figure 7. (From Weatherill & Danciu, 2018) Comparison of uniform hazard spectra between the proposed broadband European logic tree (black lines) and the 2013 European Seismic Hazard Model (red lines) for the mean and 16th and 84th percentiles, for Antwerpen (top left), Lisbon (top right), Patras (bottom left) and Bucharest (bottom right)

4 Toward physics based models: analysis of stress-drops and ground-shaking variabilities

A quantification of the between-event variability, as well as to highlight magnitude and stress-drops dependencies, is a key issue of modern ground-motion physics based modelling. We analysed the ground-motion variability in the Fourier and response spectra domains to investigate both the impact of the choice for which magnitude scale adopt and the role played by the stress drop variability in central Italy (Bindi et al., 2018b). In particular, we detected ground-shaking time-dependencies that can be related to stress-drop temporal changes (Bindi et al., 2018c). As shown in Figure 8, we also observed a good first order agreement with relative velocity temporal changes as observed by previous studies performed in the same area.

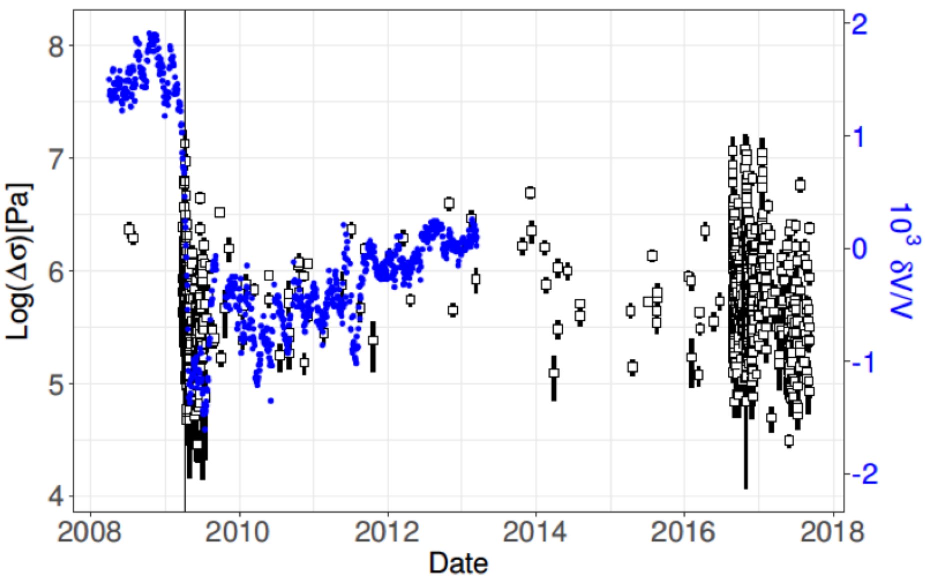

Figure 8. Comparison between the relative shear-wave velocity variation computed by Soldati et al. (2015) (blue) and the Δσ (black) time variability.

5 A European Site Response Model For Risk – Exploring New Approaches

In collaboration with JRA4, work is also underway to explore possible approaches for the characterisation of site response at a European scale. Whilst other partners have been given the task of developing a reference average 30-m shearwave velocity (V_{s30}) model for Europe based on topography, work is also ongoing to explore the potential for direct characterisation of site amplification (with respect to a reference ground motion model) by exploring correlation between the mean site-specific residual (δ_{S2S}) from sets of well recorded sites and potential proxies that can be retrieved on a spatial scale needed for risk analysis. Such proxies include the geological unit, elevation derived parameters, global soil thickness datasets, gravity etc. This approach divergences from conventional site amplification methods by relating observed amplifications to the mapped proxies directly, albeit tolerating higher but well-quantified uncertainty in the amplification factors in the process.

Compilation of both the mapped proxies and the geological data for Europe is underway, led by BRGM, as too is δ_{S2S} in the ongoing logic tree construction. As a proof-of-concept, however, geological data and other information from Japan is being compared against measured δ_{S2S} from KikNet sites (Kotha et al., 2018) to explore potential correlations; approaches that may be transferred to Europe as soon as the data is available. Examples of the trends in amplification factors with respect to geological period are shown in Figure 9. Further work to explore the trends more deeply is still underway, with the eventual deliverable being a set of calibrated amplification functions or tables for application across Europe.

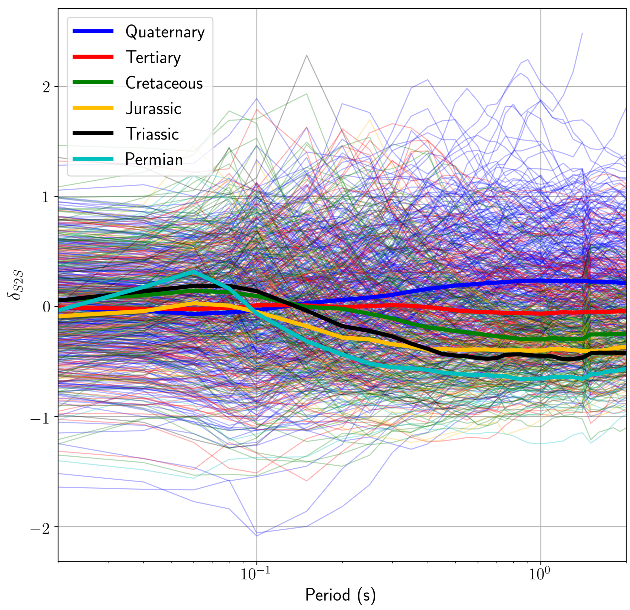

Figure 9. Observed δ_{S2S} organised by geological period for KikNet recording stations, with means from each geological class indicated by thicker lines.

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