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Homogenization of the moment magnitude estimates available in the French datasets and implications on ground motion model variability

Aurore Laurendeau, Sreeram Reddy Kotha

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INTRODUCTION

Seismic hazard assessment (SHA) studies require earthquake events characterized in terms of the moment magnitude (M_w) scale both in the earthquake catalogs and in the ground-motion databases. These magnitudes are either estimated directly after an inversion or deduced from other magnitude scales using a scale conversion formula. However, for the same event, M_w estimates provided by different agencies may differ due to differences in computation methods, input data or seismic networks – especially among small-moderate sized events.

Various strategies have been adopted in the literature to define a unique, reference M_w for each event in earthquake catalogues. Some strategies follow a priority scheme to prefer an M_w source over another, e.g., the European-Mediterranean Earthquake Catalog [EMEC]. While others prefer to correct the M_w estimates of each source for their systematic deviation relative to an M_w reference source, and then average the available M_w estimates for each event, e.g., the Italian Catalogue [CPTI15]. A recent study, Laurendeau et al. (2022) collected a large number of M_w for the Euro-Mediterranean region with a focus on metropolitan France for the lowest M_w . They chose to define a unique and unified M_w by combining these two strategies (ranking and unification) in order to have a consistency of M_w down to lower M_w [$M_{w_unified}$].

Since in low-moderate seismicity regions of Europe, small-moderate sized events significantly contribute to hazard estimates, it becomes critical that their M_w estimates are homogenized prior to development of regional seismic source models and GMMs. In this study, we developed Fourier Spectrum GMMs using the pan-European Engineering Strong Motion [ESM] database using two possible choices for defining M_w : (1) the revised EMEC M_w data set already used in the regression of Kotha et al. (2022) [$M_{w_EMEC_revised}$] and (2) the $M_{w_unified}$ data set when an M_w value is available and $M_{w_EMEC_revised}$ otherwise. We then analyzed the impact of these two data sets on the GMMs, and especially on the inter-event variability.

THE M_w DATA SETS

In this study, the same database is used with 2 strategies to define M_w :

(1) Based only on $M_{w_EMEC_revised}$

These M_w were defined in a similar way than the M_w in the published EMEC catalog (Grünthal & Wahlström, 2012) adding some new sources in the priority scheme. These M_w were used to develop the new Fourier Spectrum GMM of Kotha et al. (2022).

The sources are ranked as following:

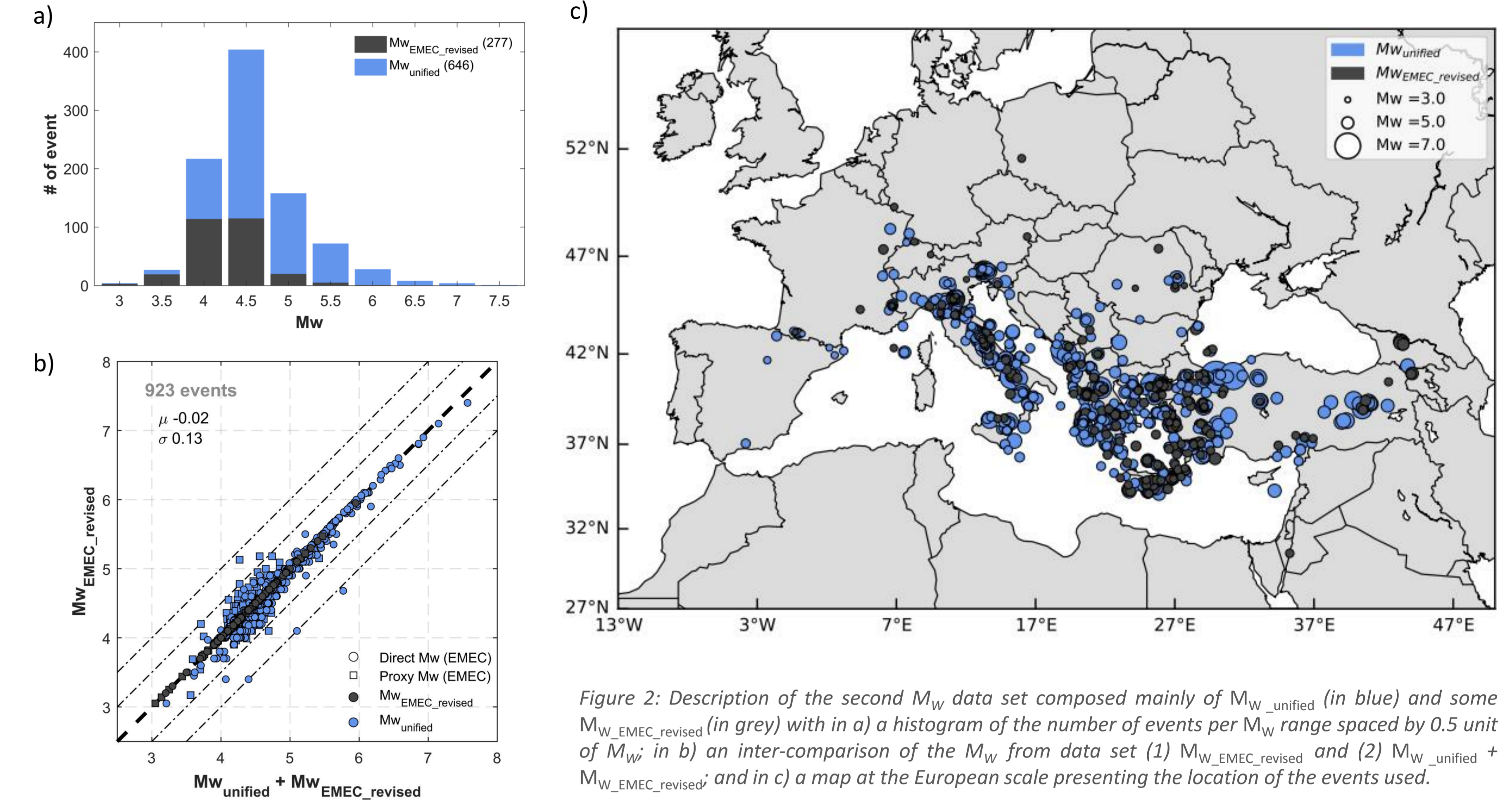
1. Specific studies
2. GEOFON
3. RCMT
4. GCMT
5. Regional catalogs (e.g., CPTI15, ECOS09)
6. M_w from Proxies (M_s ISC)

(2) Based mainly on $M_{w_unified}$

These M_w were defined in the Laurendeau et al. (2022) study. The sources were ranked in five different categories, from global to specific studies. The first category based on CMT services was chosen as reference (Level I). M_w of the next levels (II, III and IV) were then compared with its reference and corrected for their systematic discrepancies. The reference data set is thus evolving by including progressively lower M_w from one level to the next.

The sources are ranked in levels as following:

1. Level I: Reference based on CMT services (M_w of GCMT, RCMT, Italian CMT)
2. Level II: Other global services: GEOFON, NEIC (M_{ww} , M_{wb} , M_{wc})
3. Level III: Regional services: M_w of INGV-TDMT, IGN-TDMT, SED-TDMT, NEIC-TDMT, IAG, SismoAzur
4. Level IV: Regional specific studies: *SED regional studies*; Delouis et al. (2009); Chevrot et al. (2011);
5. $M_{w_EMEC_revised}$ is used if the event have no $M_{w_unified}$



THE FOURIER SPECTRUM GMM – KOTHA ET AL. (2022)

$$\ln(EAS) = e_1 + f_{R,g}(R_{JB}) + f_{R,a}(R_{JB}) + f_M(M_w) + N(0, \phi_{S2S}) + N(0, \tau_0) + N(0, \tau_{L2L}) + N(0, \tau_{c3}) + N(0, \phi)$$

- EAS : Effective Amplitude Spectrum with $f = 0.186\text{Hz} - 15.051\text{Hz}$
- e_1 : Offset term
- $f_{R,g}(R_{JB})$: M_w independent geometric spreading
- $f_{R,a}(R_{JB})$: M_w independent anelastic attenuation
- $f_M(M_w)$: M_w scaling
- $N(0, \phi_{S2S})$: Between-site variability
- $N(0, \tau_0)$: Region corrected between-event variability
- $N(0, \tau_{L2L})$: Regional variability of event characteristics
- $N(0, \tau_{c3})$: Regional variability of anelastic attenuation
- $N(0, \phi)$: Residual variability

The 923 events used in to develop the new GMMs represented in the Figure 1 are from the Fourier Spectrum ESM database. Each event is defined in an $M_{w_EMEC_revised}$ and has at least 3 recordings.

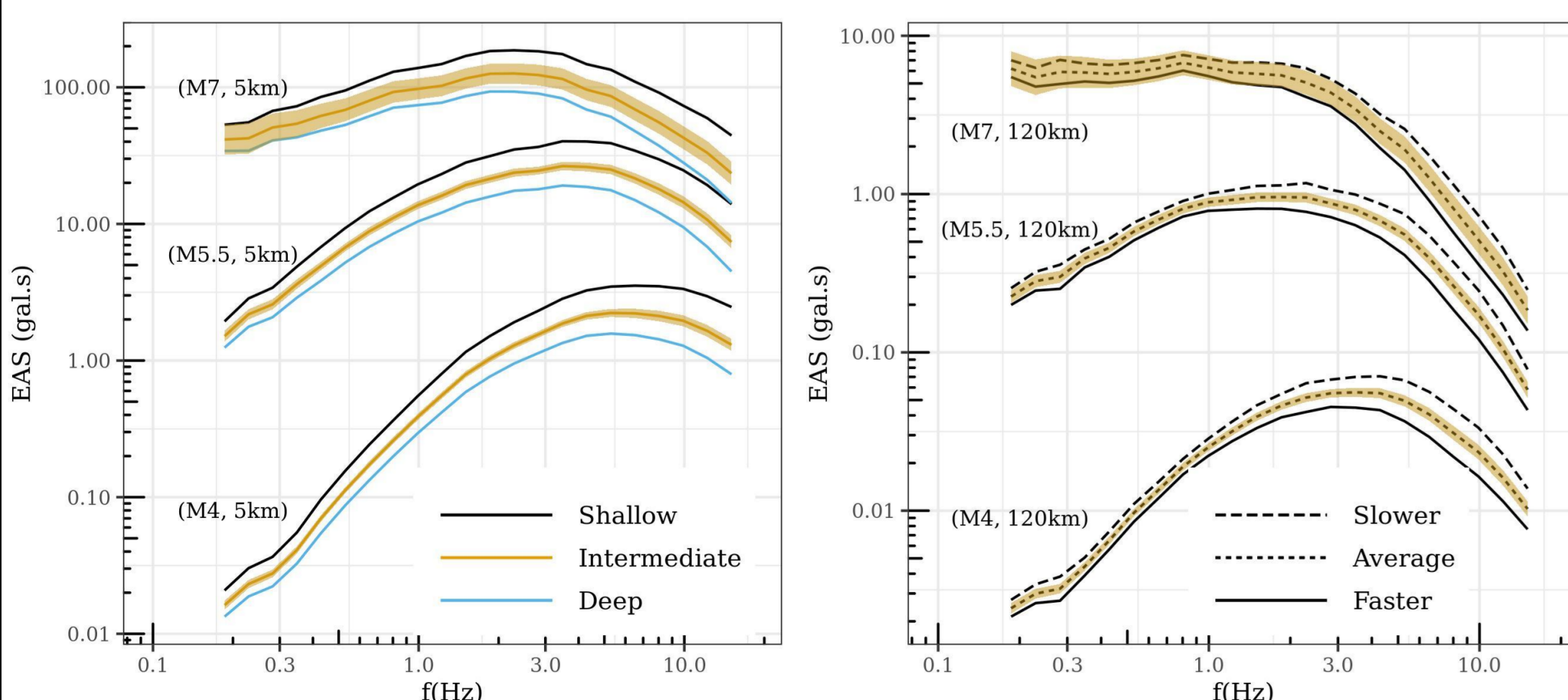
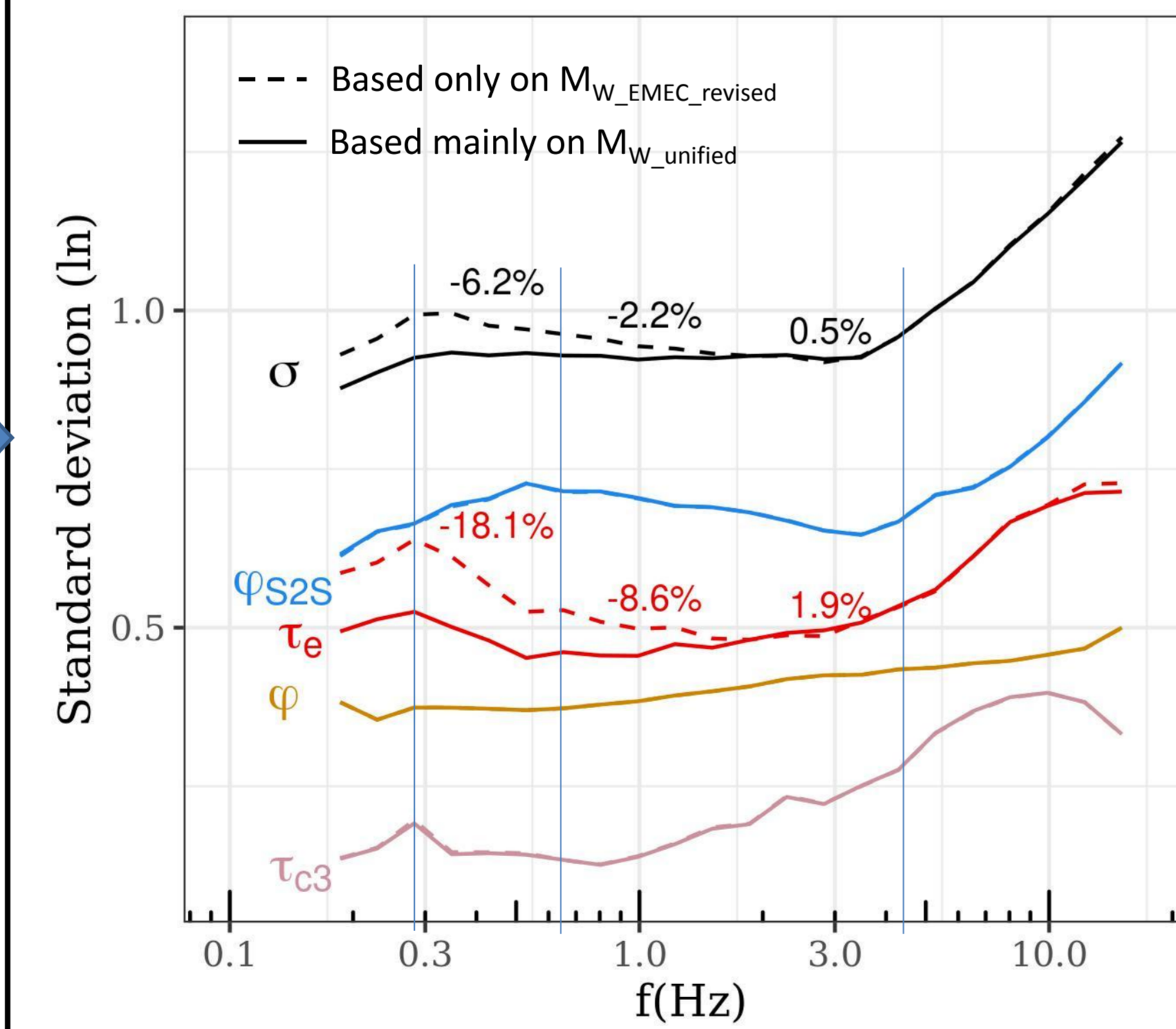


Figure 1: Predicted Effective Fourier Acceleration Spectra [EAS] in gal.s with respect to the frequency (Hz) for different scenarios: left) Shallow, Intermediate, Deep correspond to hypocentral depths. Right) Slower, Average, Faster correspond to regions with different anelastic attenuation rates.

IMPACT ON THE VARIABILITY



$$\sigma = \sqrt{\tau_e^2 + \phi_{S2S}^2 + \phi^2} : \text{Total variability}$$

$$\tau_e = \sqrt{\tau_0^2 + \tau_{L2L}^2} : \text{Between-event variability}$$

- No change are observed in median predictions, τ_{c3} , ϕ_{S2S} , ϕ .
- Only τ_e and thus σ are affected by the choice of the M_w data set.
- τ_e is notably reduced at low frequencies (<3 Hz) and especially around 0.3 Hz when the data set (2) based on $M_{w_unified}$ is used instead of the data set (1) based only on $M_{w_EMEC_revised}$.
- This reduction could be due to a better fit to the source corner frequency of the events using this new M_w data set (2).

Figure 3: Values of the different components of the variability associated to the GMMs as a function of frequency obtained with the two data sets used in this study.

CONCLUSIONS

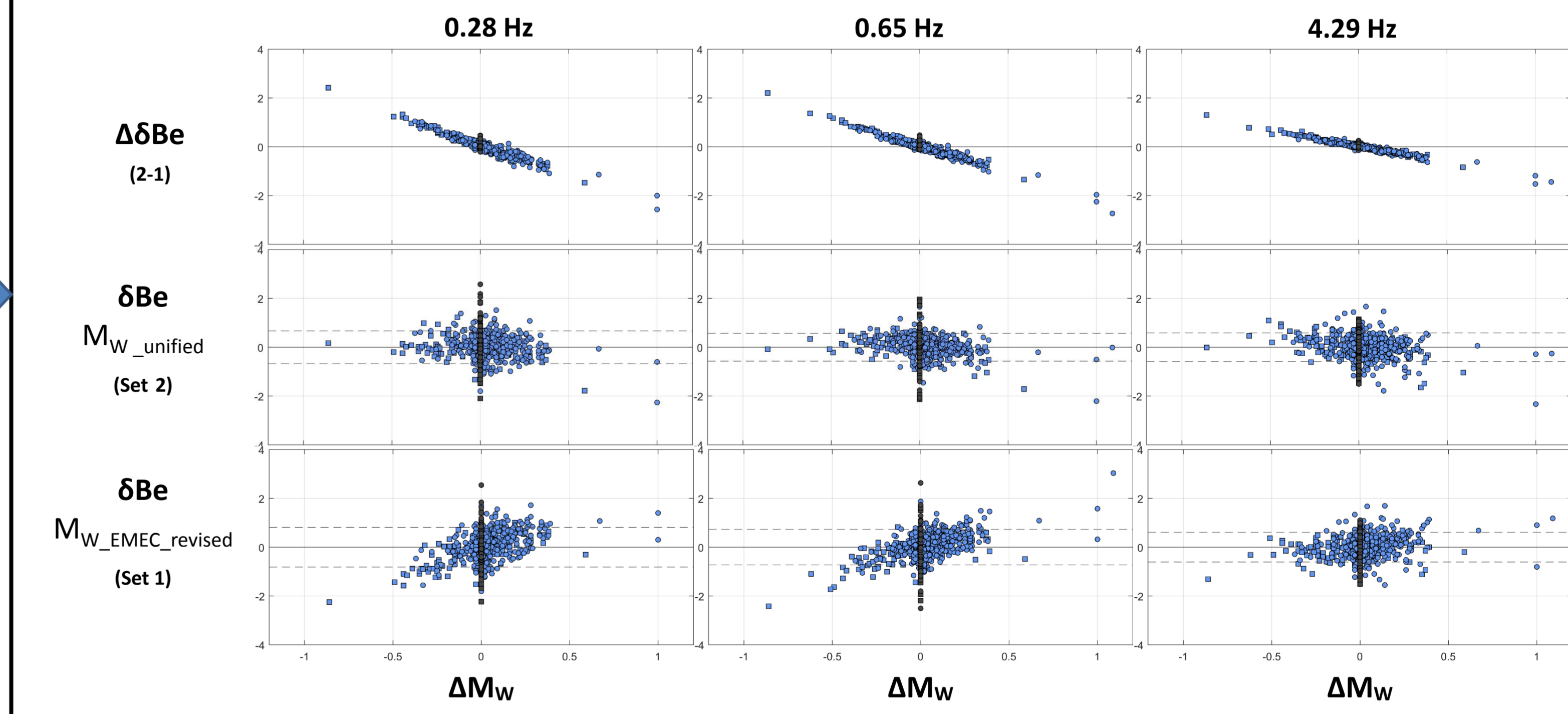
- The strategy used to define M_w can have a significant impact on the GMM aleatory variability: replacing the M_w values from the $M_{w_EMEC_revised}$ data set with the $M_{w_unified}$ data set led to a noticeable decrease of the inter-event variability, up to 18% around 0.3 Hz.

PERSPECTIVES

- Analyze in more detail the differences in behavior between the two data sets especially for $M_w < 5.0$ earthquakes. In particular, look at the outliers, the correlation with the source parameters (stress drop, ...), and the contribution of the unification step in the $M_{w_unified}$ data set.
- Repeat this study in term of response spectrum GMMs.
- Extend this study to the French data set by replacing the M_w in the Résif flatfile with the ones in the $M_{w_unified}$ data set.
- Extend the unification of the M_w data set at the European scale, especially adding the regional M_w estimates (Greece, Turkey).

ANALYSIS OF δBe

Figure 4: Inter-event residuals δBe or differences of inter-event residuals $\Delta \delta Be$ with respect to differences between M_w values of the 2 data sets ($\Delta M_w = M_{w_set2} - M_{w_set1}$) for three different frequencies: 0.28 Hz, 0.65 Hz, 4.49 Hz. The markers and colors are like figure 2.



- A clear trend is observed between $\Delta \delta Be$ and δBe using the $M_{w_EMEC_revised}$ data set and ΔM_w , especially at low frequencies. Such tendencies are not observed when the $M_{w_unified}$ data set was employed.
- The largest δBe are generally observed when M_w were defined using proxies (M_L , M_s) in the $M_{w_EMEC_revised}$ data set (square), especially for negative ΔM_w ($M_w(1) > M_w(2)$). The use of $M_{w_unified}$ data set clearly improves the δBe in this case.
- We observe also large δBe for the events without M_w from the $M_{w_unified}$ data set (in grey with ΔM_w of 0).

MAIN REFERENCES

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