

# Recalibration of the local magnitude scale of the Belgian seismic network: Improved models of geometrical spreading and path duration

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This electronic supplement contains seven figures and four tables.

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Figure S1

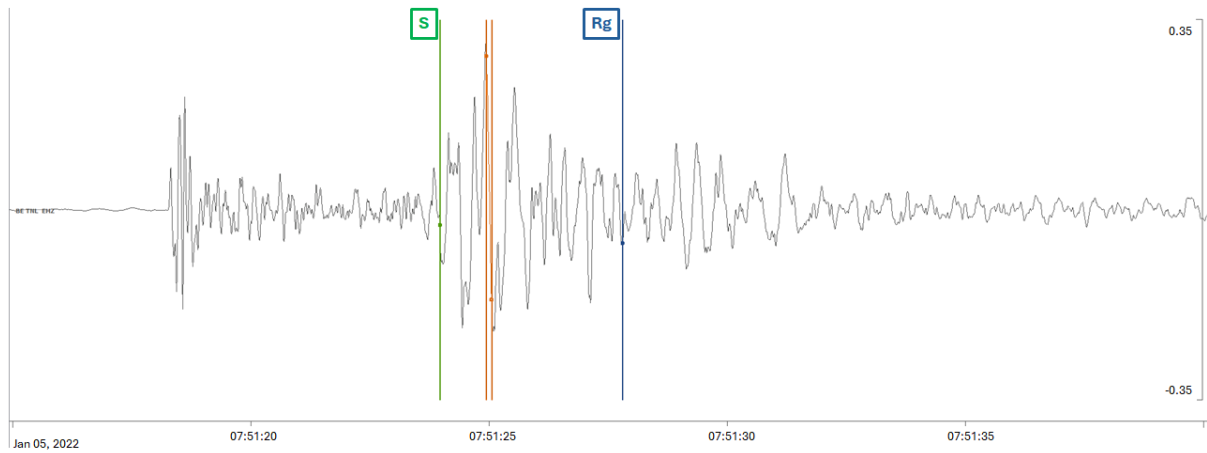
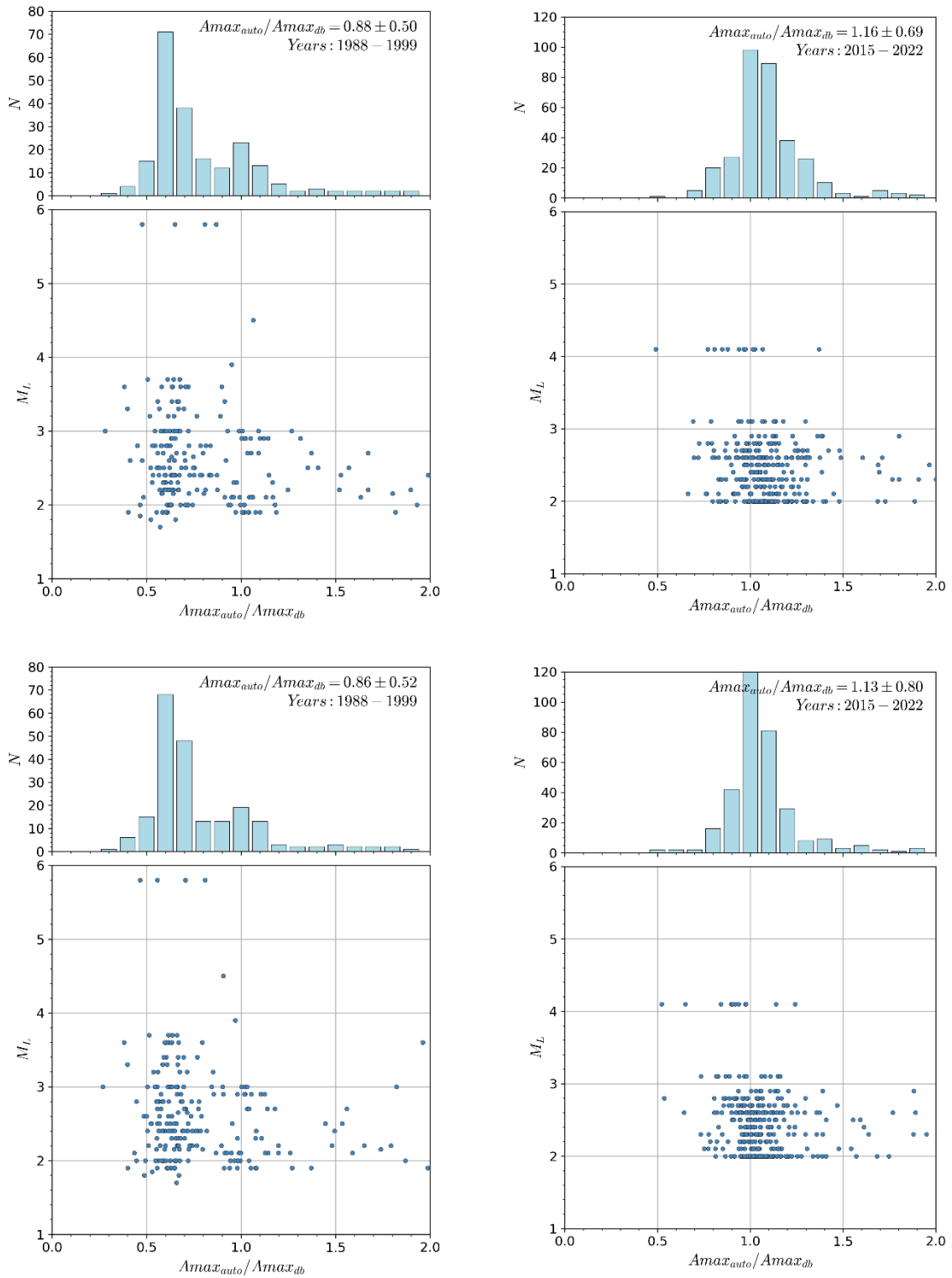


Figure S1 - Illustration of automated picking of maximum peak-to-peak amplitude in suitable time window, with optional manual adjustment in pyrocko (Heimann et al., 2017). Green vertical line: S-wave arrival; Purple vertical line: theoretical Rayleigh-wave arrival; Red vertical lines: interval corresponding to maximum peak-to-peak amplitude

Figure S2



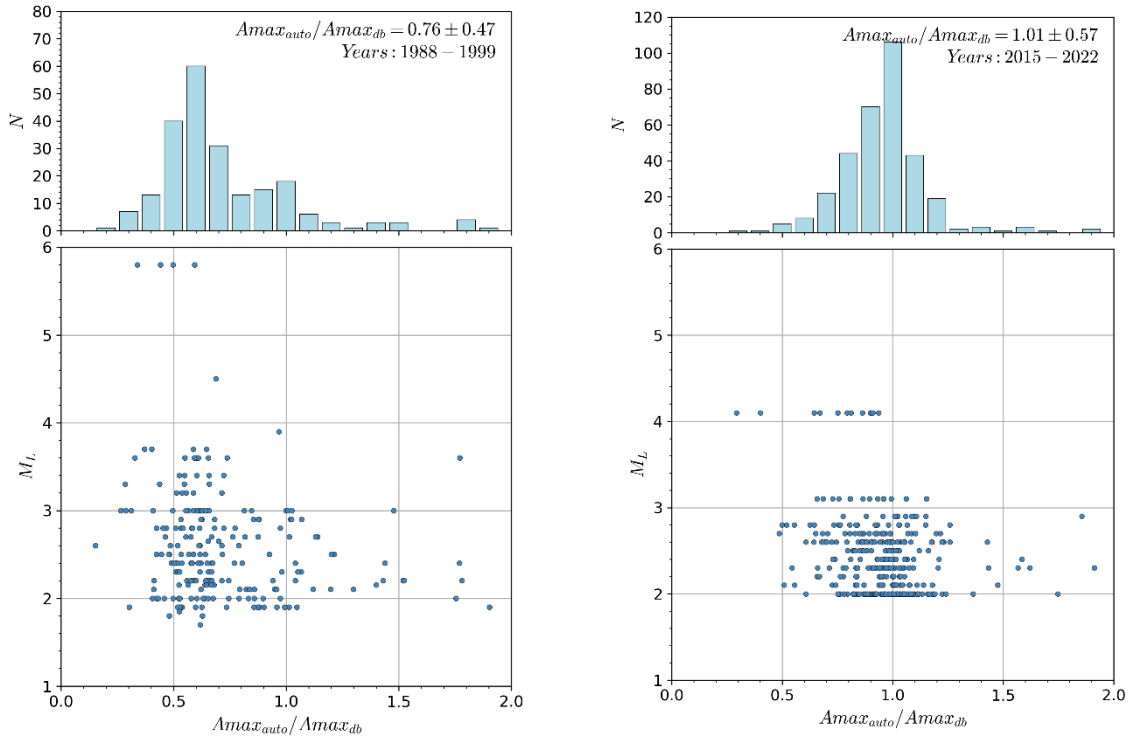


Figure S2 - Distribution of ratios between automatically determined amplitudes (labelled  $Amax_{auto}$ ) and amplitudes in the ROB catalog (labelled  $Amax_{db}$ ) for two different periods (left: 1988 – 1999; right: 2015 – 2022) and three different combinations of peak measurement and restitution method (top: restitution method 1, peak method 1; middle: restitution method 2, peak method 1; bottom: restitution method 2, peak method 2). Bottom plots show amplitude ratios versus  $M_L$ , top plots show corresponding histograms

Figure S3

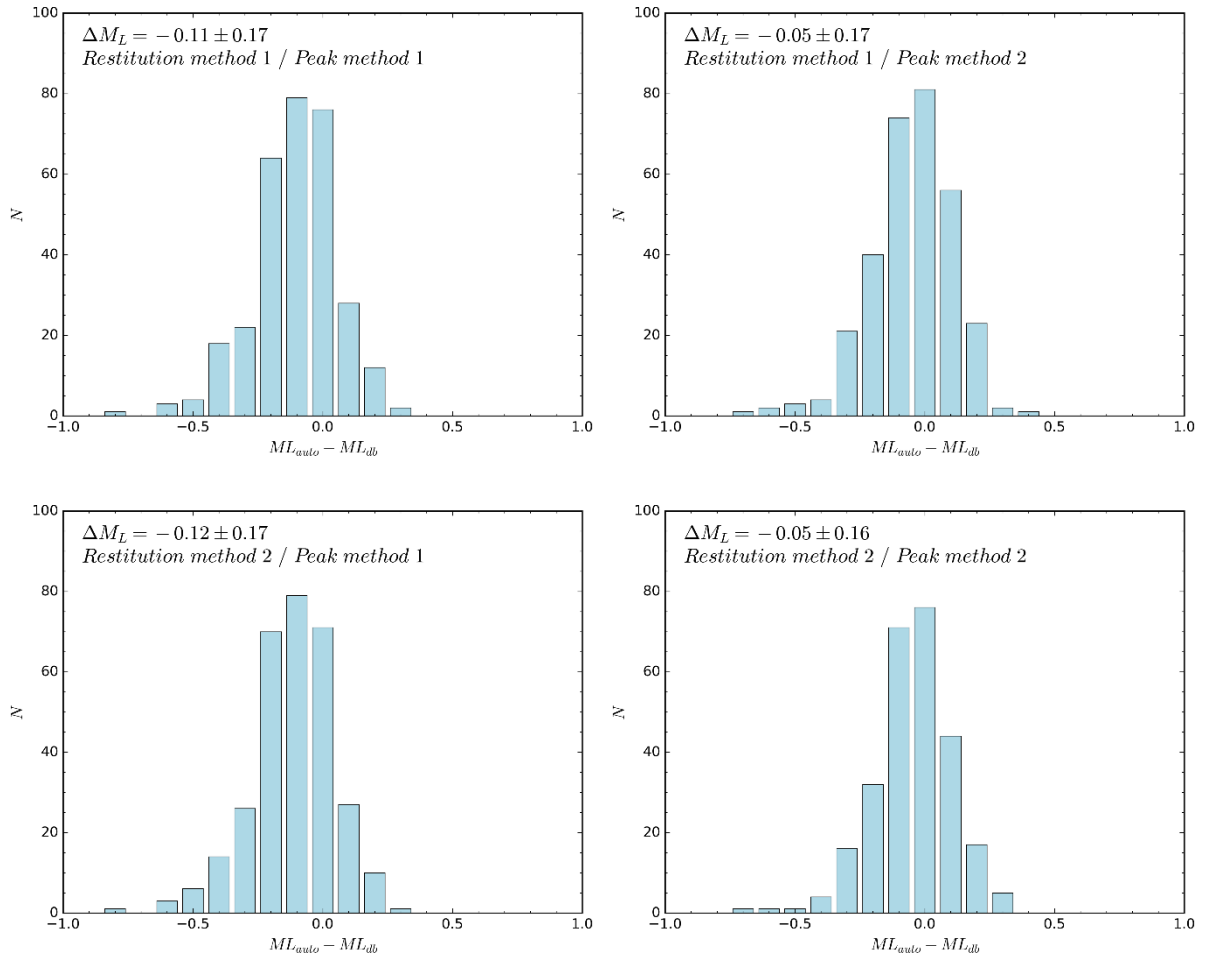


Figure S3 - Histograms of differences between  $M_L$  values recomputed from automatically determined amplitudes and  $M_L$  values in the ROB catalog. Panels correspond to amplitudes obtained with 4 different methods. Top row: restitution method 1; Bottom row: restitution method 2; Left column: peak measurement method 1; Right column: peak measurement method 2

Figure S4

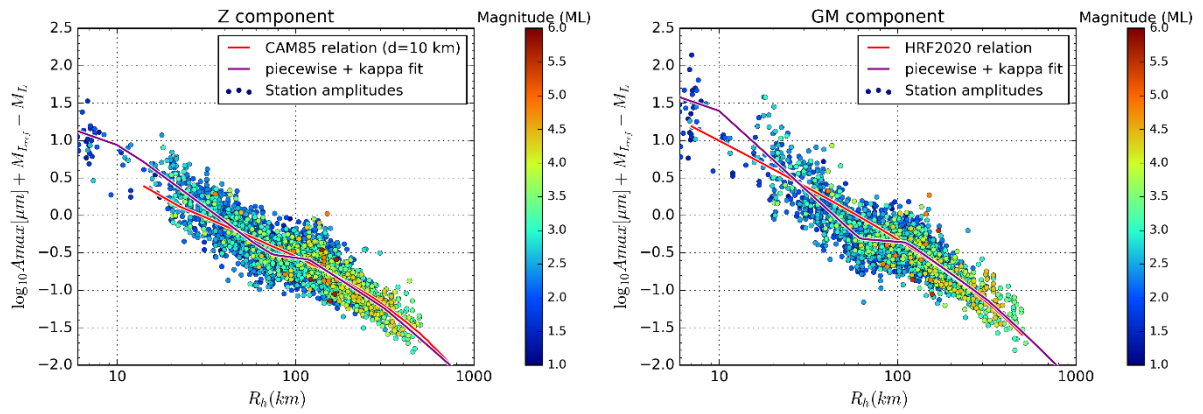


Figure S4 - Magnitude-corrected amplitudes, with station corrections applied, versus hypocentral distance, along with piecewise continuous powerlaw + kappa gradient fit. Left: Z component; Right: GM component

Figure S5

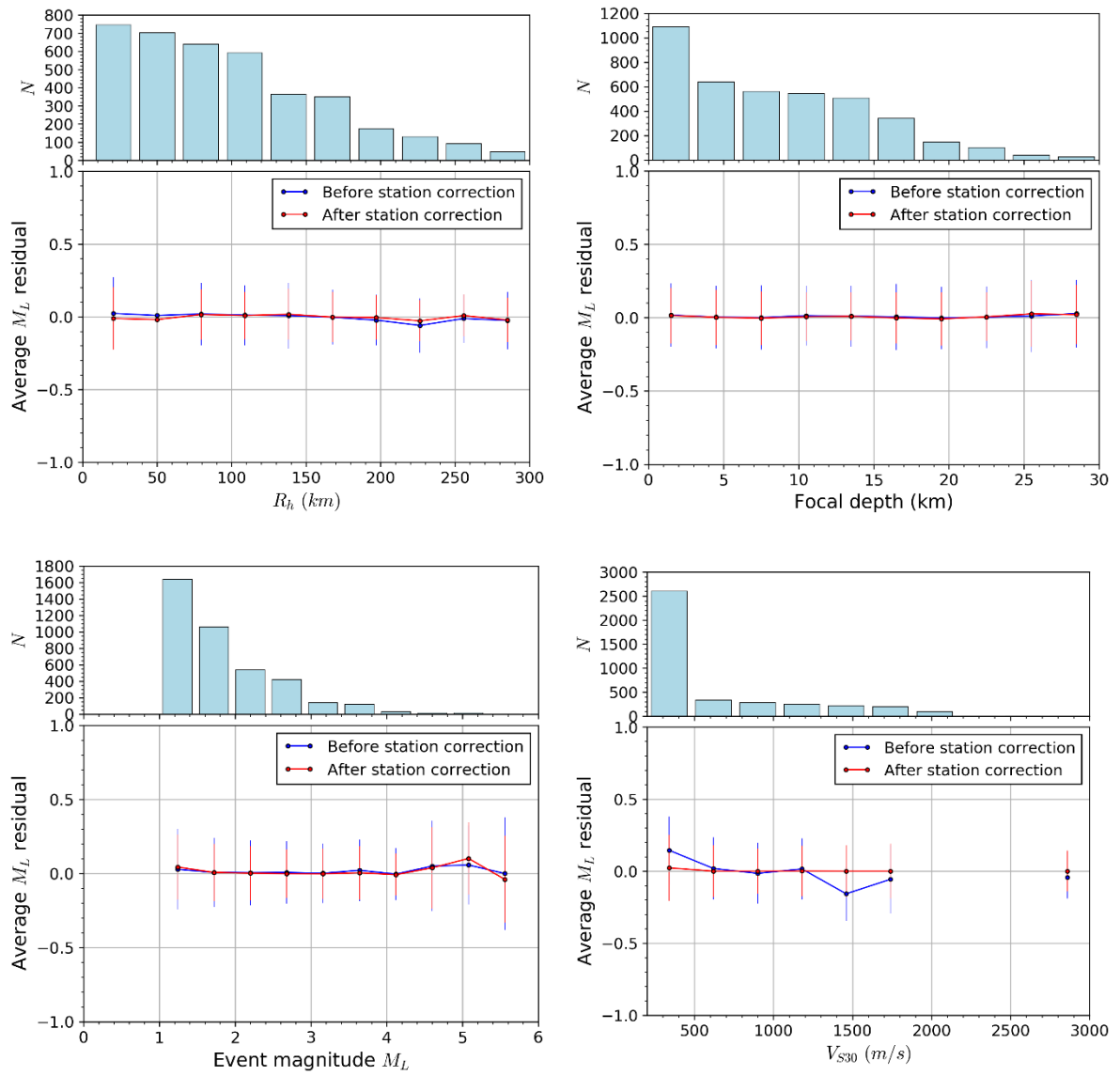


Figure S5 - Average  $M_L$  residuals (Z component), calculated using the recalibrated scale with and without applying station corrections, versus different parameters. Top left: hypocentral distance; Top right: focal depth; Bottom Left: event magnitude; Bottom right:  $V_{S30}$ . For each parameter, residuals are binned in 10 linearly spaced intervals. In each panel, the bottom plot shows the binned means (small circles) and standard deviations (vertical lines), plotted in the center of each bin, while the top plot shows the corresponding bin counts

Figure S6

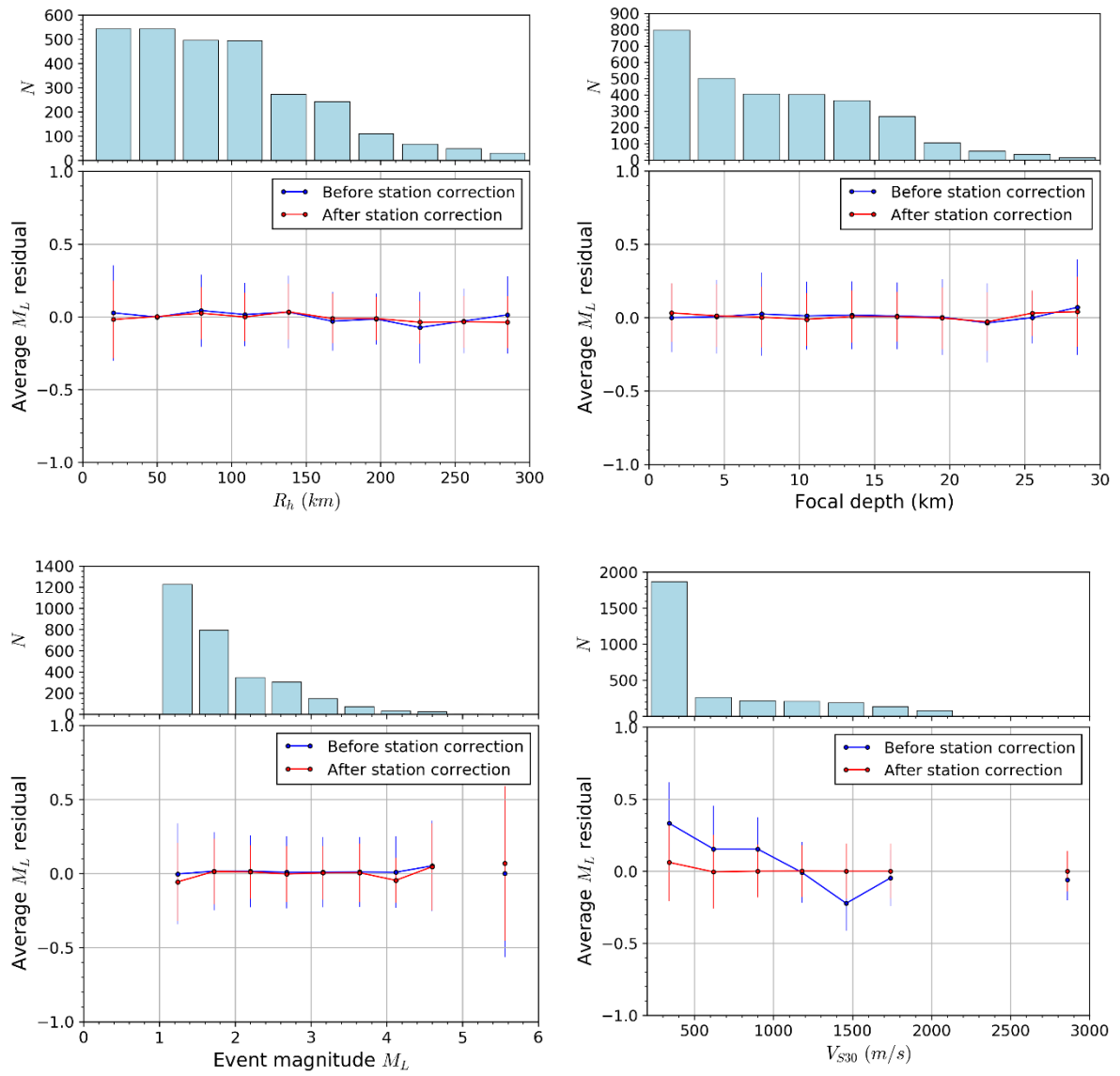


Figure S6 - Same as Figure S5 for  $M_L$  residuals based on the GM component

Figure S7

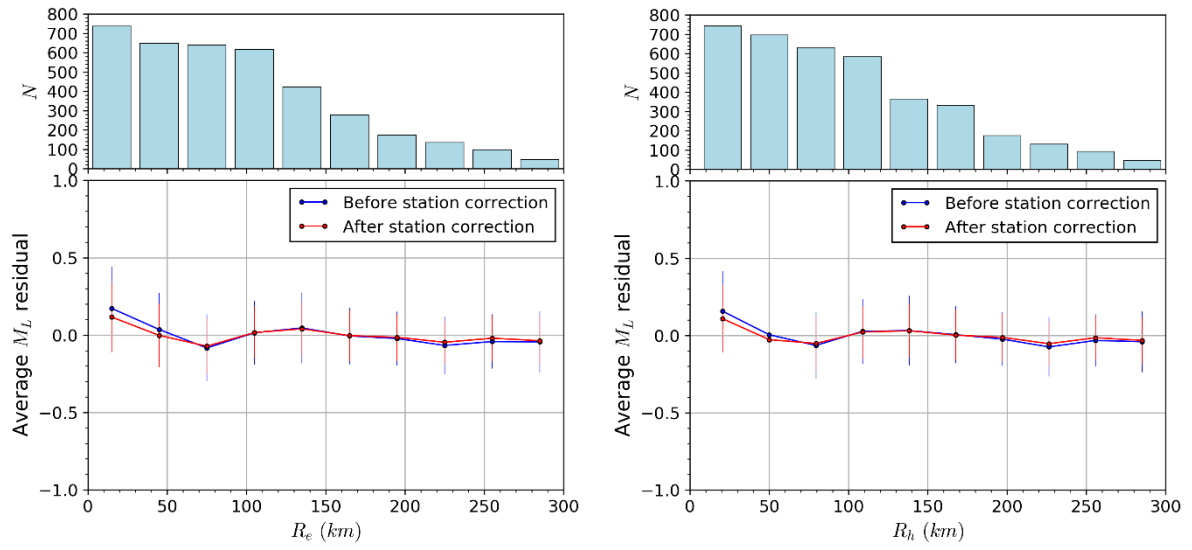


Figure S7 –  $M_L$  residuals (Z component) based on the original scale versus distance. Left: epicentral distance; Right: hypocentral distance. Legend as in Figure S5

# Table S1

|            | R1        | R2        | R3        | p0        | p1        | p2        | p3        | offset    | kappa_grad |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| R1         | 1.70E+01  | -5.50E-01 | 1.14E-01  | 2.57E+00  | 2.98E-02  | 3.88E-03  | 1.04E-02  | 2.15E+00  | -1.30E-05  |
| R2         | -5.50E-01 | 4.84E+00  | -3.11E+00 | 1.93E-04  | -3.45E-02 | -2.02E-01 | 6.21E-03  | 8.87E-05  | -7.77E-06  |
| R3         | 1.14E-01  | -3.11E+00 | 1.47E+01  | 3.23E-03  | 1.63E-02  | 3.74E-01  | 1.50E-01  | 1.48E-03  | -1.30E-04  |
| p0         | 2.57E+00  | 1.93E-04  | 3.23E-03  | 4.49E-01  | 4.64E-05  | 1.10E-04  | 2.96E-04  | 3.84E-01  | -3.70E-07  |
| p1         | 2.98E-02  | -3.45E-02 | 1.63E-02  | 4.64E-05  | 1.65E-03  | 5.55E-04  | 1.49E-03  | 2.13E-05  | -1.86E-06  |
| p2         | 3.88E-03  | -2.02E-01 | 3.74E-01  | 1.10E-04  | 5.55E-04  | 1.65E-02  | 3.54E-03  | 5.07E-05  | -4.42E-06  |
| p3         | 1.04E-02  | 6.21E-03  | 1.50E-01  | 2.96E-04  | 1.49E-03  | 3.54E-03  | 1.07E-02  | 1.36E-04  | -1.19E-05  |
| offset     | 2.15E+00  | 8.87E-05  | 1.48E-03  | 3.84E-01  | 2.13E-05  | 5.07E-05  | 1.36E-04  | 3.31E-01  | -1.70E-07  |
| kappa_grad | -1.30E-05 | -7.77E-06 | -1.30E-04 | -3.70E-07 | -1.86E-06 | -4.42E-06 | -1.19E-05 | -1.70E-07 | 1.48E-08   |

Table S1 – Covariance matrix for parameters of piecewise continuous powerlaw + kappa gradient fit for the vertical component

## Table S2

|            | R1        | R2        | R3        | p0        | p1        | p2        | p3        | offset    | kappa_grad |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| R1         | 6.61E+00  | -4.57E-01 | 6.64E-02  | 2.65E+00  | 4.05E-02  | 2.11E-03  | 6.55E-03  | 2.21E+00  | -8.07E-06  |
| R2         | -4.57E-01 | 2.86E+00  | -1.71E+00 | 1.30E-04  | -5.72E-02 | -1.31E-01 | 4.65E-03  | 5.47E-05  | -5.73E-06  |
| R3         | 6.64E-02  | -1.71E+00 | 1.36E+01  | 4.09E-03  | 1.95E-02  | 3.35E-01  | 2.10E-01  | 1.73E-03  | -1.80E-04  |
| p0         | 2.65E+00  | 1.30E-04  | 4.09E-03  | 1.24E+00  | 5.38E-05  | 1.30E-04  | 4.04E-04  | 1.05E+00  | -4.97E-07  |
| p1         | 4.05E-02  | -5.72E-02 | 1.95E-02  | 5.38E-05  | 4.31E-03  | 6.20E-04  | 1.92E-03  | 2.27E-05  | -2.37E-06  |
| p2         | 2.11E-03  | -1.31E-01 | 3.35E-01  | 1.30E-04  | 6.20E-04  | 1.56E-02  | 4.65E-03  | 5.50E-05  | -5.73E-06  |
| p3         | 6.55E-03  | 4.65E-03  | 2.10E-01  | 4.04E-04  | 1.92E-03  | 4.65E-03  | 1.63E-02  | 1.71E-04  | -1.78E-05  |
| offset     | 2.21E+00  | 5.47E-05  | 1.73E-03  | 1.05E+00  | 2.27E-05  | 5.50E-05  | 1.71E-04  | 8.88E-01  | -2.10E-07  |
| kappa_grad | -8.07E-06 | -5.73E-06 | -1.80E-04 | -4.97E-07 | -2.37E-06 | -5.73E-06 | -1.78E-05 | -2.10E-07 | 2.19E-08   |

*Table S2 – Covariance matrix for parameters of piecewise continuous powerlaw + kappa gradient fit for the horizontal geometric mean component*

Table S3

| station   | depth (m) | soil class | $V_{S30}$ | $V_{S30}$ | Z     |       |     | GM    |       |     |
|-----------|-----------|------------|-----------|-----------|-------|-------|-----|-------|-------|-----|
|           |           |            | (m/s)     | method    | mean  | sigma | n   | mean  | sigma | n   |
| BE.AUL    | 5         | A          | 1100      | Inferred  | -0.30 | 0.164 | 72  |       |       |     |
| BE.BEBN   | 46.7      | A          | 1100      | Measured  | 0.24  | 0.211 | 215 | 0.08  | 0.204 | 177 |
| BE.BOST   | 302       | A          | 1450      | Measured  | -0.27 | 0.185 | 18  | -0.32 | 0.205 | 18  |
| BE.BOU    | 8         | A          | 1100      | Inferred  | -0.05 | 0.188 | 160 |       |       |     |
| BE.BRE.01 | 0         | C          | 270       | Inferred  | -0.11 | 0.160 | 10  | 0.18  | 0.106 | 10  |
| BE.BRQ.00 | 0         | A          | 1100      | Inferred  | 0.17  | 0.157 | 45  |       |       |     |
| BE.BRQ.01 | 30        | A          | 1100      | Inferred  | 0.01  | 0.168 | 45  |       |       |     |
| BE.CLA    | 0         | A          | 2900      | Measured  | -0.07 | 0.134 | 185 | -0.08 | 0.153 | 179 |
| BE.CSE    | 0         | C          | 294.865   | Measured  | 0.58  | 0.183 | 21  | 0.68  | 0.155 | 21  |
| BE.CTH.01 | 37        | A          | 1100      | Inferred  | -0.11 | 0.106 | 33  | -0.08 | 0.092 | 33  |
| BE.CTH    | 0         | A          | 1100      | Inferred  | 0.00  | 0.199 | 50  | 0.15  | 0.157 | 23  |
| BE.DOU    | 0         | A          | 1100      | Inferred  | -0.02 | 0.198 | 259 | -0.03 | 0.190 | 253 |
| BE.DSLB   | 600       | A          | 1800      | Measured  | -0.24 | 0.181 | 32  | -0.11 | 0.208 | 30  |
| BE.DSLS   | 0         | C          | 300       | Measured  | 0.17  | 0.216 | 15  | 0.61  | 0.230 | 15  |
| BE.GES    | 0         | A          | 982       | Measured  | -0.07 | 0.147 | 142 | 0.09  | 0.190 | 142 |
| BE.GRZ    | 0         | B          | 570       | Measured  | 0.34  | 0.257 | 11  | 0.52  | 0.140 | 11  |
| BE.HEY    | 0         | A          | 1100      | Inferred  | 0.01  | 0.161 | 30  | -0.06 | 0.151 | 30  |
| BE.HLN    | 0         | C          | 233       | Measured  | 0.41  | 0.258 | 13  | 0.61  | 0.142 | 11  |
| BE.HOU    | 0         | A          | 947       | Measured  | 0.22  | 0.156 | 53  | 0.32  | 0.162 | 53  |
| BE.HRK    | 0         | C          | 270       | Inferred  | 0.08  | 0.194 | 86  | 0.19  | 0.201 | 86  |
| BE.HU1    | 0         | A          | 1100      | Inferred  | 0.01  | 0.217 | 10  | -0.09 | 0.216 | 10  |
| BE.HUM    | 0         | A          | 1100      | Inferred  | 0.02  | 0.177 | 121 | -0.02 | 0.176 | 113 |
| BE.KIN    | 0         | C          | 270       | Inferred  | 0.18  | 0.139 | 10  |       |       |     |
| BE.KLB    | 0         | A          | 1100      | Inferred  | -0.01 | 0.172 | 175 | -0.08 | 0.158 | 172 |
| BE.LCH    | 0         | A          | 1100      | Inferred  | -0.06 | 0.174 | 108 | -0.08 | 0.202 | 108 |
| BE.LES    | 0         | A          | 1100      | Inferred  | -0.01 | 0.192 | 101 | -0.14 | 0.202 | 91  |
| BE.MAS    | 0         | C          | 270       | Inferred  | 0.05  | 0.156 | 14  | 0.08  | 0.231 | 12  |
| BE.MEMA   | 0         | A          | 1100      | Inferred  | 0.34  | 0.203 | 15  | 0.19  | 0.190 | 15  |
| BE.MEMB   | 5.7       | A          | 1100      | Inferred  | 0.01  | 0.184 | 88  | -0.05 | 0.176 | 88  |
| BE.MEMH   | 5.7       | A          | 1100      | Inferred  | 0.00  | 0.174 | 102 | -0.11 | 0.195 | 102 |
| BE.MEMS   | 5.5       | A          | 1100      | Inferred  | -0.04 | 0.196 | 282 | -0.14 | 0.195 | 265 |
| BE.MEU    | 0         | B          | 585       | Measured  | 0.07  | 0.195 | 58  | 0.20  | 0.231 | 56  |
| BE.MOL1   | 120.9     | B          | 510       | Measured  | -0.15 | 0.156 | 21  | -0.24 | 0.345 | 21  |
| BE.MOL2   | 223.65    | B          | 640       | Measured  | -0.15 | 0.132 | 21  | -0.17 | 0.319 | 21  |
| BE.MOL3   | 221.4     | B          | 640       | Measured  | -0.20 | 0.126 | 20  | -0.18 | 0.315 | 20  |
| BE.MOL4   | 223.4     | B          | 640       | Measured  | -0.16 | 0.158 | 21  | -0.17 | 0.320 | 21  |

| station | depth (m) | soil class | $V_{S30}$<br>(m/s) | $V_{S30}$<br>method | Z     |       |     | GM    |       |     |
|---------|-----------|------------|--------------------|---------------------|-------|-------|-----|-------|-------|-----|
|         |           |            |                    |                     | mean  | sigma | n   | mean  | sigma | n   |
| BE.MOL5 | 223.15    | B          | 640                | Measured            | -0.17 | 0.138 | 20  | -0.16 | 0.305 | 20  |
| BE.MOLS | 0         | C          | 300                | Measured            | 0.18  | 0.218 | 27  | 0.44  | 0.225 | 27  |
| BE.MOLT | 222.9     | B          | 640                | Measured            | -0.17 | 0.151 | 73  | 0.03  | 0.215 | 73  |
| BE.MRD  | 0         | A          | 2900               | Measured            | -0.01 | 0.164 | 116 | -0.08 | 0.158 | 116 |
| BE.MRG  | 0         | A          | 1100               | Inferred            | -0.12 | 0.168 | 45  | 0.09  | 0.140 | 45  |
| BE.OPTB | 379       | A          | 846                | Measured            | -0.21 | 0.201 | 21  | -0.08 | 0.215 | 21  |
| BE.OPT  | 0         | B          | 362                | Measured            | 0.15  | 0.190 | 49  | 0.24  | 0.198 | 49  |
| BE.OSP  | 0         | C          | 270                | Inferred            | 0.11  | 0.220 | 13  | 0.53  | 0.198 | 13  |
| BE.OT2  | 0         | B          | 366                | Measured            | 0.37  | 0.131 | 10  | 0.12  | 0.179 | 10  |
| BE.OT3  | 0         | C          | 308                | Measured            | 0.50  | 0.174 | 15  | 0.38  | 0.297 | 15  |
| BE.OT5  | 0         | B          | 750                | Measured            | 0.24  | 0.152 | 13  | 0.18  | 0.171 | 13  |
| BE.OTT  | 0         | A          | 1188               | Measured            | 0.10  | 0.192 | 17  | 0.12  | 0.140 | 17  |
| BE.RCHB | 45        | A          | 1100               | Inferred            | 0.05  | 0.169 | 83  | -0.05 | 0.190 | 80  |
| BE.ROB  | 0         | A          | 1400               | Measured            | -0.20 | 0.191 | 78  | -0.27 | 0.196 | 72  |
| BE.RQR  | 18        | A          | 1200               | Measured            | -0.16 | 0.166 | 131 |       |       |     |
| BE.SKQ  | 0         | A          | 1492               | Measured            | -0.12 | 0.184 | 155 | -0.21 | 0.192 | 155 |
| BE.SNF  | 14        | A          | 1200               | Measured            | -0.10 | 0.153 | 161 |       |       |     |
| BE.STI  | 17        | A          | 760                | Measured            | 0.02  | 0.176 | 214 |       |       |     |
| BE.TGA  | 0         | A          | 1188               | Measured            | 0.30  | 0.152 | 12  | 0.27  | 0.140 | 12  |
| BE.THN  | 0         | C          | 251                | Measured            | 0.00  | 0.205 | 10  |       |       |     |
| BE.TMM1 | 0         | A          | 1100               | Inferred            | 0.26  | 0.190 | 20  | 0.25  | 0.170 | 20  |
| BE.TMM2 | 1         | A          | 1100               | Inferred            | 0.25  | 0.154 | 21  | 0.10  | 0.120 | 21  |
| BE.TMM3 | 2.5       | A          | 1100               | Inferred            | 0.18  | 0.161 | 20  | 0.02  | 0.133 | 20  |
| BE.TMM4 | 4         | A          | 1100               | Inferred            | 0.05  | 0.166 | 20  | -0.08 | 0.155 | 20  |
| BE.TNL  | 0         | A          | 1100               | Inferred            | -0.12 | 0.151 | 45  | -0.05 | 0.178 | 45  |
| BE.UCCB | 95        | A          | 1800               | Measured            | 0.02  | 0.198 | 66  | -0.04 | 0.158 | 66  |
| BE.UCCS | 5         | C          | 280                | Measured            | 0.54  | 0.265 | 84  | 0.44  | 0.188 | 61  |
| BE.VIA  | 0         | A          | 1100               | Inferred            | 0.17  | 0.163 | 145 | 0.24  | 0.156 | 142 |
| BE.WIB  | 0         | A          | 1100               | Inferred            | -0.04 | 0.187 | 22  | -0.12 | 0.209 | 17  |
| BE.WLF  | 0         | A          | 1100               | Inferred            | 0.06  | 0.177 | 205 | -0.04 | 0.210 | 205 |
| BE.WOR  | 169       | A          | 1100               | Inferred            | -0.13 | 0.249 | 13  | -0.13 | 0.161 | 13  |
| BE.ZEV  | 0         | C          | 270                | Inferred            | 0.34  | 0.319 | 19  | 0.60  | 0.269 | 16  |

Table S3 – Mean and standard deviation of station  $M_L$  residuals obtained for the Z component and the geometric mean (GM), for stations with at least 10 amplitude records

Table S4

|    | a2       | a1       | a0       |
|----|----------|----------|----------|
| a2 | 0.000551 | -0.00323 | 0.004455 |
| a1 | -0.00323 | 0.019403 | -0.02737 |
| a0 | 0.004455 | -0.02737 | 0.03941  |

Table S4 – Covariance matrix for coefficients of quadratic fit between  $M_L$  and  $M_W$  based on the BELSHAKE database

## References

Heimann, S., M. Kriegerowski, M. Isken, S. Cesca, S. Daout, F. Grigoli, C. Juretzek, T. Megies, N. Nooshiri, A. Steinberg, *et al.*, 2017, Pyrocko - An open-source seismology toolbox and library, GFZ Data Services.