Updated determination of earthquake magnitudes at the Swiss Seismological Service

R Racine[1], C Cauzzi[1], J Clinton[1], D Fäh[1], B Edwards[2], T Diehl[1], S Heimers[1], N Deichmann[1], P Kästli[1], F Haslinger[1] & S Wiemer[1]

1- Swiss Seismological Service at ETH Zürich
2- School of Environmental Sciences, University of Liverpool

(1) Local magnitude equation in use in Switzerland: M_{Lh}.

The local magnitude relationship in use in Switzerland was originally calibrated by Kradolfer (1984) - K84 - and later amended to maintain consistency after the upgrade of the Swiss Seismic Network to 3-channel digital broadband instrumentation and the use of horizontal recordings. The current equation is:

$$M_{Lh} = \log_{10}A_0 + C_d + C_e \quad (1)$$

where

$$C_d = 0.0180\ R + 1.77;\ R <= 60\ km \quad (2)$$
$$C_d = 0.0038\ R + 2.62;\ R > 60\ km \quad (3)$$
$$C_e = 0.1 \quad (4)$$

R is the hypocentral distance in km and A_0 is the maximum mean-to-peak horizontal amplitude in mm on a simulated 2,800x Wood-Anderson seismometer.

There are two main problems with the current procedure:

1. Eq. (1) is poorly constrained at distances < 20 km; hence, station magnitudes, especially for small events (M_{Lh} < ~ 2), are strongly overestimated.

2. Station correction factors are not systematically used. This is not acceptable for the routine operations of the modern Swiss National Seismic Network, that includes more than 180 high-quality real-time strong-motion stations installed on soft sediments and in urban areas.

(2) Proposal to update the Swiss local magnitudes: M_{Lhc}.

Edwards (2015) proposed to:

a. extend the applicability of Eq. (1) to distances < 20 km introducing the additional geometric attenuation branch:

$$C_d = 0.0180\ R + 1.77 + 0.968\ \log(R/20);\ R < 20\ km \quad (5)$$

Eq. (5) is based on analyses of the residuals of station magnitudes w.r. to the overall local magnitude of Swiss earthquakes.

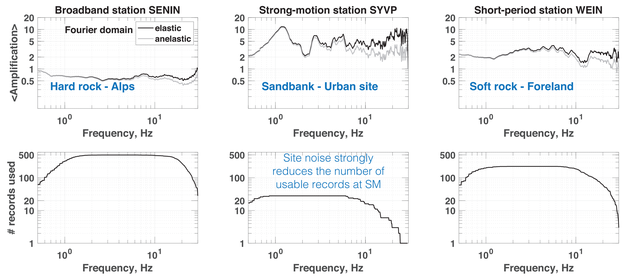
b. include station correction factors computed w.r. to the Swiss reference ground motion model of Edwards and Fäh (2013) - EF13 - following the strategy of Edwards et al. (2013). In this way, the amplification factors are physics-based rather than being simply determined as average station residuals.

This makes the routine computation of official local magnitudes in Switzerland fully consistent with the state-of-the-art of engineering seismology research at the SED. A similar approach was taken for Swiss ShakeMaps (Cauzzi et al. 2015).

(3) Calculating M_{Lhc} (and M_WSpec).

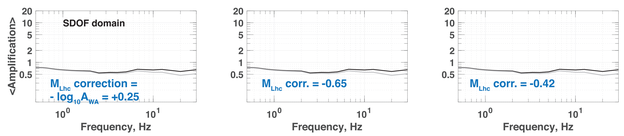
1. For each earthquake record with SNR(f) >= 3 (min. bandpass [5;10] Hz): *updated every second week based on recent earthquakes*

a. compute elastic amplification w.r. to EF13 in the Fourier domain;
b. estimate near-surface attenuation kappa;
c. compute anelastic amplification;
d. update average station / channel elastic & anelastic amplification;



2. For each station / channel with stable average amplification (> 20 obs. at 3 Hz): *updated every second week based on recent earthquakes*

a. compute elastic and anelastic amplification in the SDOF domain (using Inverse Random Vibration Theory), ζ = 5%;
b. simulate anelastic Wood-Anderson amplification (A_{WA}) in the SDOF domain, *f* = 1.25 Hz and ζ = 70%.

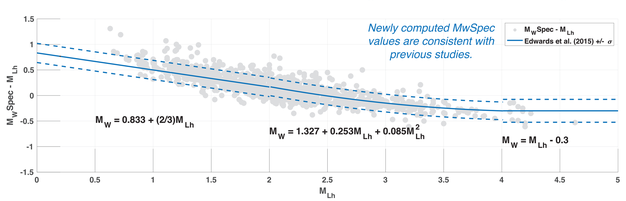


3. Compute station / stream M_{Lhc} amplification (Sect. 4) factors from Wood-Anderson amplification. *Updated every six months.*

4. Real-time use updated equation and M_{Lhc} correction factors in SeisComP3 module scmag.

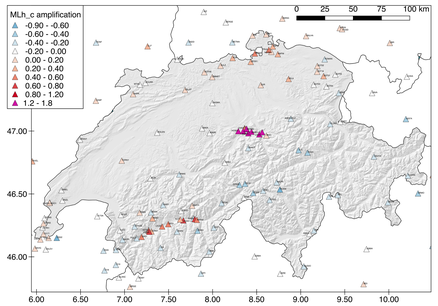
SED station information available at stations.seismo.ethz.ch & eida.ethz.ch/fdsnws/station/1

Real-time 1a allows parallel computation of M_w from spectral fitting (M_WSpec).

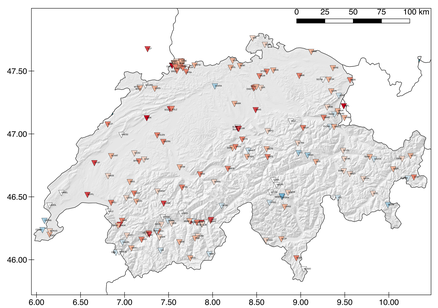


(4) M_{Lhc} amplification values (geometric mean of horizontal components).

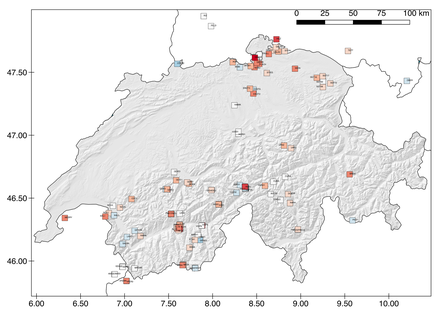
Broadband stations, incl. lake bottom seismometers.



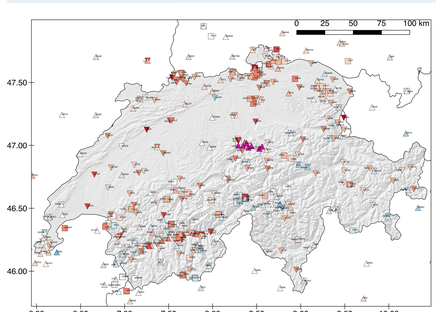
Strong-motion stations.



Short-period stations.

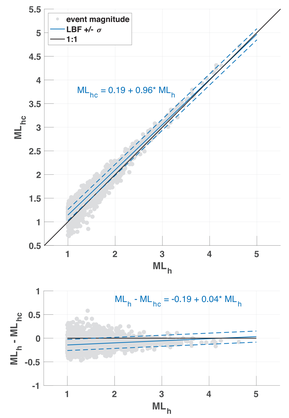


All stations.

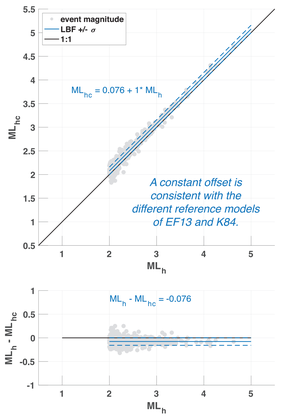


(5) Playback *scmag* analyses: 3411 earthquakes with M_{Lh} >= 1 and OT >= 01.2008 in the ECOS region (data from arclink.ethz.ch/fdsnws/event/1).

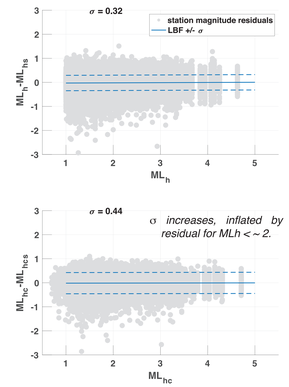
M_{Lh} >= 1: linear M_{Lh}:M_{Lhc} relationship; slope close to 1.



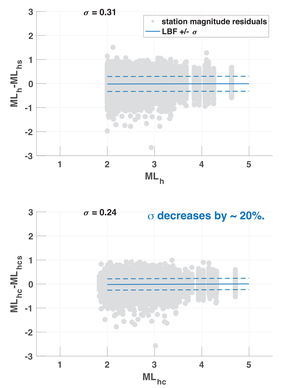
MLh >= 2: linear M_{Lh}:M_{Lhc}; slope = 1.



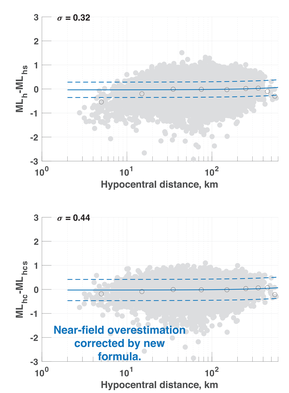
M_{Lh} >= 1: residuals as a function of M_L show neither offset nor trend.



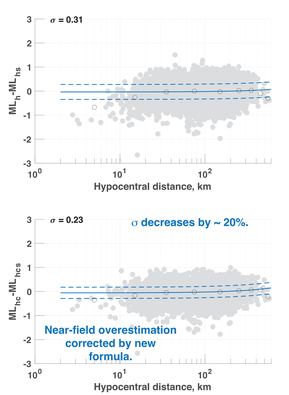
M_{Lh} >= 2: residuals as a function of M_L show neither offset nor trend.



M_{Lh} >= 1: residuals (all) as a function of R show neither offset nor trend.



M_{Lh} >= 2: residuals (all) as a function of R show neither offset nor trend.



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