DOCUMENTATION OF STATION/AGENCY MAGNITUDE PROCEDURES

(Modified from the SUMMARY OF IASPEI MAGNITUDE WORKING GROUP RECOMMENDATIONS ON DETERMINING EARTHQUAKE MAGNITUDES FROM DIGITAL DATA, updated version 2011; see http://www.iaspei.org/commissions/CSOI/Summary_WG-Recommendations_20110909.pdf)

This document is to outline the procedures adopted by seismological agencies to compute magnitudes of seismic events.

Agency Name: Swiss Seismological Service (SED)

Please list the magnitudes computed and corresponding phase type analyzed in the table below (example provided). Add as many rows as required.

Magnitude type (nomenclature used at the agency)	Full name	Wave type analyzed
MLh	SED Local Magnitude	P+S body-waves; surface waves
Mw	Moment Magnitude from regional Broad-Band Moment Tensor Inversion	P+S body-waves; surface waves
MWspec	Moment Magnitude from spectral fitting method	S body-waves

For each magnitude type computed at the agency, please specify:

1. The equations that are used for calculating each magnitude type and
a: specify if distance is measured as epicentral distance or hypocentral distance;
b: specify the distance range for which the equation is applied;
c: specify restrictions on hypocentral focal-depth, if any.

a) MLh (D: hypocentral distance; W-A: Wood-Anderson Amplitude):
For $D \leq 60$ km:
$MLh = LogA(W\text{-}A) + 0.0180 * D + 1.87$
For $60 \text{ km} < D < 700$ km:
$MLh = LogA(W\text{-}A) + 0.0038 * D + 2.72$

D is hypocentral distance. MLh is not calculated if focal depths > 80km.

If possible, only stations at epicentral distances ≥15 km are used for MLh (since original definition is based on distances ≥15 km). No strong motion stations are included du to possible site amplifications. No restriction on focal depth (maximum depth in Switzerland and surrounding regions are about 30 km).

b) Mw

Broadband time domain full waveform fitting. Green's functions derived from Swiss 1D model. Wavform duration / bandpass / maximum distance defined by MLh magnitude. From 20km up to 700km epicentral distance.

Depths only considered up to 40km.

c) MWspec

Fitting spectra with Brune (1970) ω^2 spectrum and attenuation according to the model of Anderson and Hough (1984). Geometrical attenuation of 1/R to 150km, thereafter $1/R^{0.5}$. Site amplification referenced to Swiss rock model (Poggi *et al.*, 2011).

a) Hypocentrel distance; b) 0 to 200 km; c) no depth restriction.

2. Is any signal-to-noise ratio criterion applied to the analyzed signal?

a) MLh

Selection based on manual review and visual quality control, no fixed value

b) Mw

Manual review. Typically waveforms that have low Variance Reduction compared to synthetic (<70%) are rejected.

c) MWspec

Automatic – continuous bandwidth with SNR > 3. Bandwidth must be at least a decade, with minimum at least 5Hz and maximum frequency greater than 10 Hz.

3. Specify the software used (such as SeisComp, Antelope, Seismic Handler, Seisan, SAC, in-house developed programs) to perform the analyses for magnitude computation.

a) MLh

SeisComP3 – MLh plugin module (developed in-house)

b) Mw

SeisComp3 – scmtv module, before in-house development

c) MWspec

in-house development

d) If the agency is computing magnitudes not based on some amplitude/period measurement (e.g., moment magnitude Mw) please summarize the details of the technique used. For example, is Mw obtained with a centroid moment tensor, W-phase and/or spectral fitting technique?

a) Mw

Based on the point-source time domain inversion scheme of Dreger (2003). Epicentral location fixed to network location, depth can vary.

b) MWspec

Spectral fitting technique based on the method of Edwards et al. (2010).

c) Other restrictions on the calculation of a specific magnitude. For example, is the magnitude measured only for earthquakes of a certain size, as defined by an independent measure of earthquake size? Also, are specific magnitudes computed only for seismic events occurring in specific areas?

All 3 magnitudes are calculated for all Swiss and neighbouring seismicity within the magnitude limits for each method.

a) MLh: No upper limit, though MLh will saturate ~M6.0. For events with MLh<1.8, additional high pass filters are systemically applied to suppress microseismic noise.

b) Mw: only calculated for bandpasses with high frequency corner >10s. Limited to events that generate long period energy above background noise / microseism, starts ~M3.5. Should not saturate, but point source approximation will break down in the near field for M>6.5

c) MWspec: MWspec is likely to fail for small events with MLh<1.0, as signal-to-noise is insufficient.

Detailed questions on the magnitudes based on amplitude/period measurements:

a) How the network (event) magnitude and corresponding uncertainty is obtained? For example, is the network magnitude an arithmetic/trimmed mean, median value of the single station magnitudes?

a) MLh
network magnitude is median of station magnitudes
uncertainty –standard deviation of station magnitudes

b) Mw

magnitude is determined during inversion which minimizes residual between synthetic and observed data for candidate waveforms
uncertainty – not determined

c) MWspec: standard error from inversion.

b) Units of the reported amplitudes. Specify if amplitudes are reported in units of trace-amplitude motion instead of ground motion.

a) MLh
Not clear what we send to ISC – Could be raw counts or WA displacement in micron – Clarify with Philipp Kaestli

b) Mw
N/A

c) MWspec
N/A

d) Time-window in which the amplitude measurement is made for the phase type analyzed. For example, for body wave magnitudes, is the time window a flexible time-interval between the P onset and the PP onset or a fixed time window after the first P onset (e.g. 5 s, 10 s or other)? Similarly, for the surface wave magnitudes, is the time window considered a time-interval spanned by waves having group-velocities between, e.g., 3.2 and 4.0 km/s or is always the maximum velocity amplitude, respectively (A/T)max in the whole surface-wave train in a wide range of periods be measured? If so, give the range of periods.

MLh: Needs to be checked in SeisComP3, not sure if relevant for MLh something like epidist/3.3 + offset

Mw: Broadband inversion, should include body and surface waves. Fixed window start time at Origin Time. End window time is dependent on 1) event size, ranging from 80s- 180s and 2) extended dependent on epicentral distance

MWspec: Flexible time window based on cumulative velocity – aims to window S body-phases.

e) Orientation of seismograph (horizontal or vertical) from which the measurement is made. For example, is Ms computed using both horizontal and vertical components? Specify also if, as for example might be the case for ML, data from each of the two horizontal components at a single station are used, are data from each component treated as a separate observation in the network magnitude computation, or are the two components first averaged into a station magnitude, which is then treated as a single observation in the network magnitude computation?

MLh: The maximum amplitude of the two (filtered) horizontal traces (N or E component) is used

Mw: use all 3 components, ZRT. Can deselect any single component if too noisy.

MWspec: both horizontal. Each fit separately and treated as individual observations.

f) Describe the amplitude-response, filter characteristics, or transfer-function of the seismograph or simulated seismograph through which the amplitude measurement is made. For example, is the IASPEI recommended standard Wood-Anderson seismometer simulation filter with the parameters according to Uhrhammer and Collins (1990) used to compute ML?

MLh: the broad-band signals are filtered with a recursive, time domain, impulse invariant Wood-Anderson filter. The trace corresponding to ground displacement is converted to the equivalent signal on a Wood-Anderson seismograph assuming an amplification of 2800.

Mw: broadband inversion. Instrument response removed prior to processing. Strong motion and broadband data can be used. Bandpass filters are magnitude dependent, and applied equally to observed and synthetic data.

MWspec: complete removal of instrument response.

g) Details of measuring amplitude:

a: For example, does the amplitude correspond to 0.5*(peak-to-trough amplitude), where “peak-to-trough amplitude” corresponds to difference between a maximum positive excursion and a maximum negative excursion of the trace, or is the amplitude instead measured as the

maximum absolute excursion from the “zero” position of the seismograph trace?

MLh: we measure the maximum absolute excursion from the “zero” position of the seismograph trace

Mw: N/A

MWspec: N/A

b: for example, if the amplitude corresponds to 0.5*(peak-to-trough amplitude), are the “peak” and “trough” respectively the absolute maximum and absolute minimum values of the entire wave-group, or are they the adjacent peak and trough corresponding to the maximum trace excursion that is associated with a single zero-crossing?

doesn't apply since we report the zero-to-absolute-maximum instead of 0.5*peak-to-trough value

c: for example, are displacement amplitude(A) and period(T) measured at the time of maximum A or at the time of the maximum of the quotient (A/T)?
MLh, Mw, MWspec: No period measured

h) Details of measuring period. For example, is it the time between the neighboring peaks, respectively troughs or twice the time span measured between the largest peak and adjacent trough at which the double amplitude has been measured?
MLh, Mw, MWspec: No period measured

i) To what part of a phase the amplitude-measurement time refers. For example, is the amplitude-measurement time the time of the zero-crossing associated with a peak-to-adjacent trough measurement or is it the time of an absolute maximum or absolute minimum?
MLh: the time of the absolute maximum

Mw, MWspec: N/A

Finally, please add publications as well as internal reports or web links that can be quoted to describe the magnitude procedures adopted at the agency and/or

any other relevant information which may not have been included in the questions above.

-SeisComP3 links:

http://www.seiscomp3.org/doc/jakarta/current/apps/global_mlh.html

- Any Annual Earthquake Report, e.g.:
  Diehl, T., Deichmann, N., Clinton, J., Husen, S., Kraft, T., Plenkers, K., et al. (2013). Earthquakes in Switzerland and surrounding egions during 2012. Swiss Journal of Geosciences, 106, 543–558. doi:10.1007/s00015-013-0154-4.
- Kradolfer, U. and Mayer-Rosa, D. (1988). Attenuation of seismic waves in Switzerland. In: Recent Seismological Investigations in Europe. In: Proceedings of the XIX General Assembly of the European Seismological Commission, Moscow, October 1–6, 1984, 481–488.
- Edwards, B., Allmann, B., Fa¨h, D., & Clinton, J. (2010). Automatic computation of moment magnitudes for small earthquakes and the scaling of local to moment magnitude. Geophysical Journal International, 183(1), 407–420. doi:10.1111/j.1365-246X.2010. 04743.x.
- Dreger, D. S. (2003). TDMT INV: Time domain seismic moment tensor INVersion. In Lee, W. H. K., Kanamori, H., Jennings, P. C., and Kisslinger, C. (Eds.), International Handbook of Earthquake and Engineering Seismology (Part B). London: Academic Press, pp. 1627.

- Additional References related to MWspec calculations:

Anderson, J. G. and S. E. Hough (1984). A Model for the Shape of the Fourier Amplitude Spectrum of Acceleration at High-Frequencies, *Bulletin of the Seismological Society of America* **74**, 1969-1993.

Brune, J. N. (1970). Tectonic Stress and Spectra of Seismic Shear Waves from Earthquakes, *Journal of Geophysical Research* **75**, 4997-5009.

Poggi, V., B. Edwards and D. Fäh (2011). Derivation of a Reference Shear-Wave Velocity Model from Empirical Site Amplification, *Bulletin of the Seismological Society of America* **101**, 258-274.