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: (HT, Department of Geophysics, Aristotle University of Thessaloniki)

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**
M_L (Manual)	Local Magnitude	S-waves on synthetic WA recordings from Broad-band horizontal components
M_L (Automatic)		Automatic M_L from Vertical components (MLv)
M_w	Moment magnitude	Body waves (mainly S waves) recorded from broad-band horizontal and vertical components

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.

ML (Manual)

We use the relation of Bacun and Joyner (1984):

$$M_L = log A + n.log(R/100) + K(R-100) + c_i$$

with the coefficients n=1.11, K=0.00189, as they are proposed by Hutton and Boore (1987), where, A is the average maximum 0-peak amplitude (in μm) of the two horizontal components of the synthetic Wood-Anderson (SWA) recordings, R the hypocentral distance (in km) and c_i a standard station correction.
This relation is valid for shallow (h<60km), local (D<~800km) earthquakes. However, in some rare cases, we use it for intermediate-depth earthquakes.

M_L (Automatic)
In SeisComP3 a modified local magnitude Mlv is determined by simulation of a Wood-Anderson instrument and then measuring the amplitude in a 150 s time window on the vertical component of each station for epicentral distances smaller than 8°.
MLv: Local magnitude calculated on the vertical component using a correction term to fit with the standard M_L
MLh: Local magnitude calculated on the horizontal components to SED specifications.

Mw
Directly estimated from Mo using the well-known Hanks and Kanamori (1979) relation

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

For M_L (Manual) and M_w, SNR is empirically determined from the user and data with low SNR are simply disregarded (e.g. after the application of the WA filter). For M_L (Automatic), no SNR is applied

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

For the M_L (Automatic) we adopt the automatically produced solutions of the SeisComP software. For the off-line analysis (M_L-Manual and M_w) we use the previously described procedures through ATLAS (earthquake analysis software provided by Nanometrics) and in-house developed software which utilizes SAC and other tools.

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

We employ the Time Domain Seismic Moment Tensor Inversion (Dreger, 2003) for M_w estimation. Additional information can be found here:

http://geophysics.geo.auth.gr/the_seisnet/WEBSITE_2005/MT_method2.htm

5. 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?

We usually estimate M_L magnitude, which means we follow the restrictions of this magnitude scale (epicentral distances up to ~800km). We do not apply any filter connected with the size of the earthquake, that is, we perform magnitude estimations for all regional earthquakes with $M_L \geq 2.0$ (and many smaller events), given that they are sufficiently recorded by the network. For M_w, we usually compute moment-magnitudes for all events in the same region (broader Aegean region) with $M_w \geq 4.0$ (approximately).

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

6. 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?

As M_L magnitude we consider the arithmetic mean of the participating magnitude values (corresponding to the stations that recorded the event). We also provide its standard deviation. Special care is taken in order to remove participating magnitudes with values out of the range $M_{mean} \pm 1.645*sd$ (90% confidence limits). For M_w a single M_o value (with uncertainty) is provided for each event, leading to a single M_w value (with the corresponding uncertainty).

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

We provide bulletins in GSE2.0 format, where is reported the mean value of the maximum 0-peak amplitudes (in μm) of the two horizontal (NS-EW) components of SWA records for M_L. No such info is applicable (hence provided) for M_w.

8. 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.

As previously described for M_L magnitudes the amplitudes used are the max trace amplitudes that correspond to the S-waves of the two horizontal (NS-EW) components of the Synthetic WA recordings. For M_w we employ a full-waveform modeling.

9. 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?

The M_L magnitude value of each horizontal component is participating as individual (separate) value in the event's mean magnitude estimation. For M_w a single M_o value is used for all stations, hence leading to a single M_w value.

10. 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?

Yes, we use: static magnification V_0=2080, natural period T=0.8sec, critical damping 0.7, zeroes (0.0, 0.0) (0.0, 0.0), poles (-5.49779, -5.60886) (-5.49779, 5.60886).

11. 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?

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?

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)?

The amplitude used for M_L corresponds to the half peak-to-trough amplitude. The max peak and min peak are adjacent, i.e. corresponding to the maximum trace excursion that is associated with a single zero-crossing (though some tolerance is applied for minimal waveform jerks from the user).

12. 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?

The period is twice the time span between the largest peak and the adjacent trough at which the peak-to-trough amplitude is measured

13. 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?

It is the time of the zero-crossing associated with a peak-to-adjacent trough measurement

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.

For ML estimation, please check:

Scordilis, E.M., D.A. Kementzetzidou and B.C. Papazachos (2013). Local magnitude estimation in Greece based on readings of the Hellenic Unified Seismic Network (HUSN), *"Bull. Geol. Soc. Greece"*, XLVII, No 3, 1241-1250, 2013 (see attached file).

A new version of the above paper, based on more data and performing some more tests, is submitted for publication in "Journal of Seismology" (current status: under review).

For Mw estimation, please check:

http://geophysics.geo.auth.gr/the_seisnet/WEBSITE_2005/new-fps.html

Roumelioti, Z., Benetatos, C., Kiratzi, A. and D. Dreger (2007). Rapid estimation of seismic parameters in Greece using broad band waveforms of the Hellenic Unified Seismic Network, 3rd Hellenic Conference of Earthquake

Engineering and Engineering Seismology, Athens, 5 -7 November, 2008 (Abstract No 1789).