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A new dataset of Wood Anderson magnitude from the Trieste (Italy) seismic station

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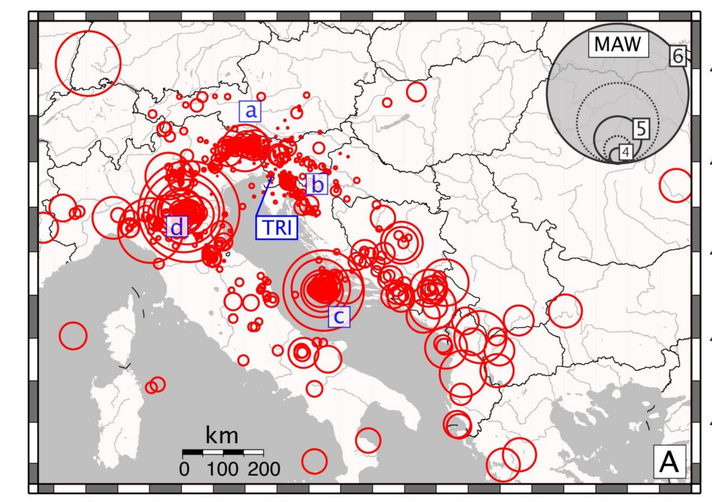
ABSTRACT

The standard torsion Wood Anderson (WA) seismograph owes its fame to the fact that historically it has been used for the definition of the magnitude of an earthquake (Richter, 1935). With the progress of the technology, digital broadband (BB) seismographs replaced it. However, for historical consistency and homogeneity with the old seismic catalogues, it is still important continuing to compute the so called Wood Anderson magnitude. In order to evaluate WA magnitude, the synthetic seismograms WA equivalent are simulated convolving the waveforms recorded by a BB instrument with a suitable transfer function. The value of static magnification that should be applied in order to simulate correctly the WA instrument is debated. The original WA instrument in Trieste operated from 1971 to 1992 and the WA magnitude (MAW) estimates were regularly reported in the seismic station bulletins. The calculation of the local magnitude was performed following the Richter's formula (Richter, 1935), using the table of corrections factor unmodified from those calibrated for California and without station correction applied (Finetti, 1972). However, the WA amplitudes were computed as vector sum rather than arithmetic average of the horizontal components, resulting in a systematic overestimation of approximately 0.25, depending on the azimuth. In this work, we have retrieved the E-W and N-S components of the original recordings and re-computed MAW according to the original Richter (1935) formula. In 1992, the WA recording were stopped, due to the long time required for the daily development of the photographic paper, the costs of the photographic paper and the progress of the technology. After a decade of interruption, the WA was recovered and modernized by replacing the recording on photographic paper with an electronic device and it continues presently to record earthquakes. The E-W and N-S components records were memorized, but not published till now. Since 2004, next to the WA (few decimeters apart), a Guralp 40-T BB seismometer was installed, with a proper period extended to 60 s.

Aim of the present work is twofold: from one side to recover the whole data set of MAW values recorded from 1971 until now, with the correct estimate of magnitude, and from the other side to verify the WA static magnification, comparing the real WA data with the ones simulated from broadband seismometer recordings.

CATALOGUE



Final catalogue: 1495 located event in two main cluster (a) local (b) Slovenia-Croatia (c) Adriatic (mainly sequence of march 2003 (d) Emilia (mainly sequence May 2012)

First period: 1971 – 1992

- the calculation of the local magnitude was performed following the Richter's formula (Richter, 1935), using the table of corrections factor unmodified from those calibrated for California and without station correction applied (Finetti, 1972). However the WA amplitudes were computed as vector sum rather than as arithmetic average of the horizontal components, resulting in a systematic overestimation.
- No more data are available on the two EW and NS components but only the magnitude has been recorded
- Crossing the TRI catalogue with the localized events by the OGS network, active from 1977, we retrieved a data set of 319 instrumentally located events with their MAW

Second period: 12/2002-5/2005 and 3/2010-today

- The WA was digital, the NE and SW amplitudes were available. However, only the data on amplitude magnitude and the epicentral distance has been catalogued.
- We have considered 10 earthquake catalogues to associate to each event their hypocentral coordinates. Mostly OGS, CSEM, ISIDe. We located 1175 events.
- When the location in other catalogues was not available we estimated the distance from S-P. At the end, MWA was available for 1231 events.
- Duration magnitudes of OGS and local magnitudes from ISIDe were compared with WA ones
- From October 22, 2004, the WA is placed side by side to a Guralp 40-T BB seismometer with a period extended to 60 s. The WA was simulated on this instrument in order to check the reliability of the simulation.

THE WOOD ANDERSON SEISMOGRAPH

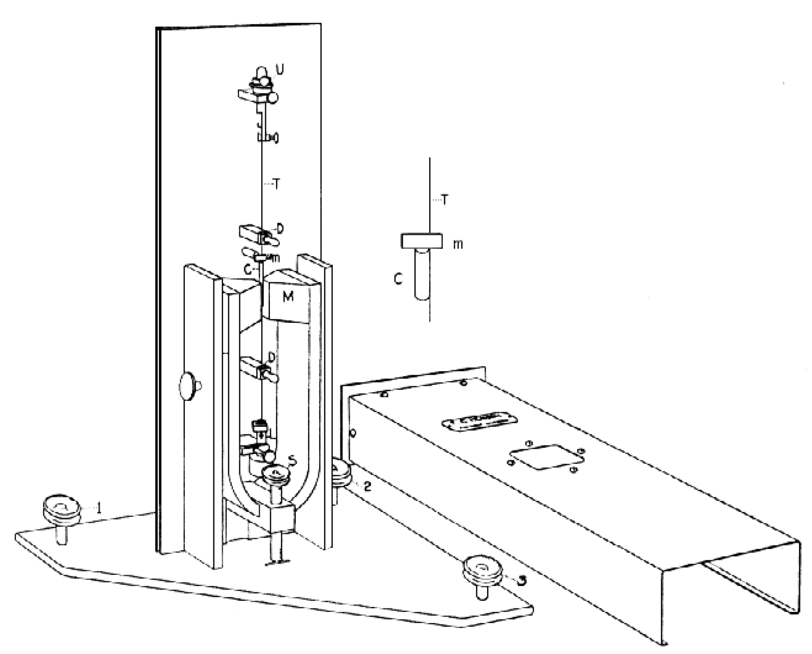
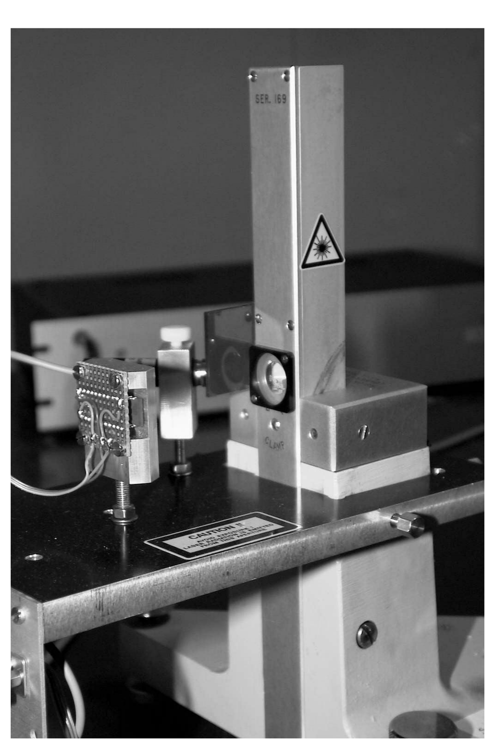


Fig. 2

- The motion generated when the WA was shaken by an earthquake caused the rotation of a small, copper, cylindrical inertial mass (C) affixed to a thin wire under high tension (T). Damping of the torsional motion was accomplished using magnets (M).
- A mirror (m) attached to the mass reflected incident light, generated by an external bulb lamp, on a fixed cylindrical mirror, fixed on the instrument frame (not shown).
- The mirror reflected back the light on m which reflected it on photosensitive paper (not shown).

H. O. Wood and J. A. Anderson
1925. BSSA, 15, 1-72.

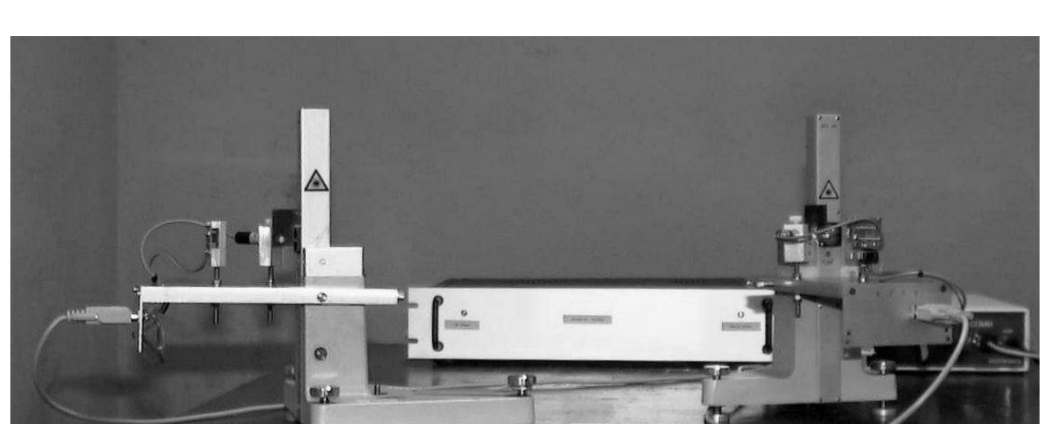
THE DIGITAL WOOD ANDERSON SEISMOGRAPH

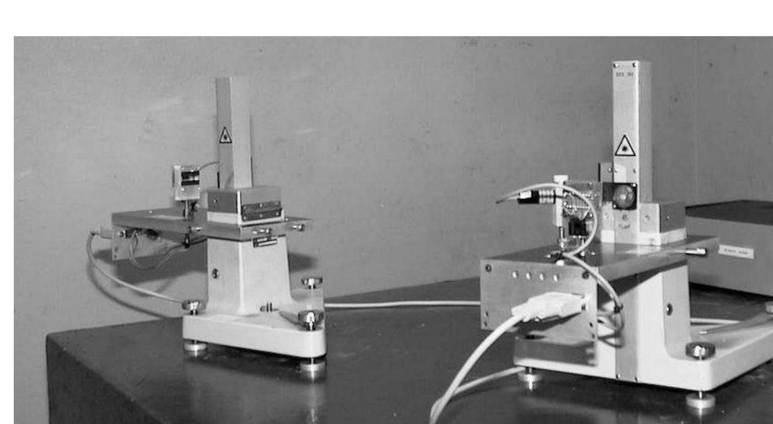


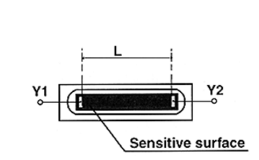
The WA was modernized by:

- Removing the bulb lamp and the fixed cylindrical mirror with its support and creating a small side window;
- Adding a laser (Flexpoint model FP-65/5 AE-AW-SD5-GL47, 650 nm wavelength, Power 5 mW). Through the new window the red laser visible beam hits the moving mirror m;
- Adding a Sitek 1L20 position-sensing detector (PSD), a few centimetres far from the instrument on which the laser beam is reflected.

By removing the cylindrical mirror the ray undergoes a single reflection changing the optical leverage from 4 to 2 times. The PSD is a 1D semiconductor device sensitive to visible radiation. The sensor has two anodes (Y1 and Y2) and a cathode (bias) and provides an analogue output directly proportional to the position of the spotlight on its surface (20x3 mm of active area). It offers high resolution and linearity: it is enough to stay inside the 80% of his surface to preserve a 0.1% of linearity.

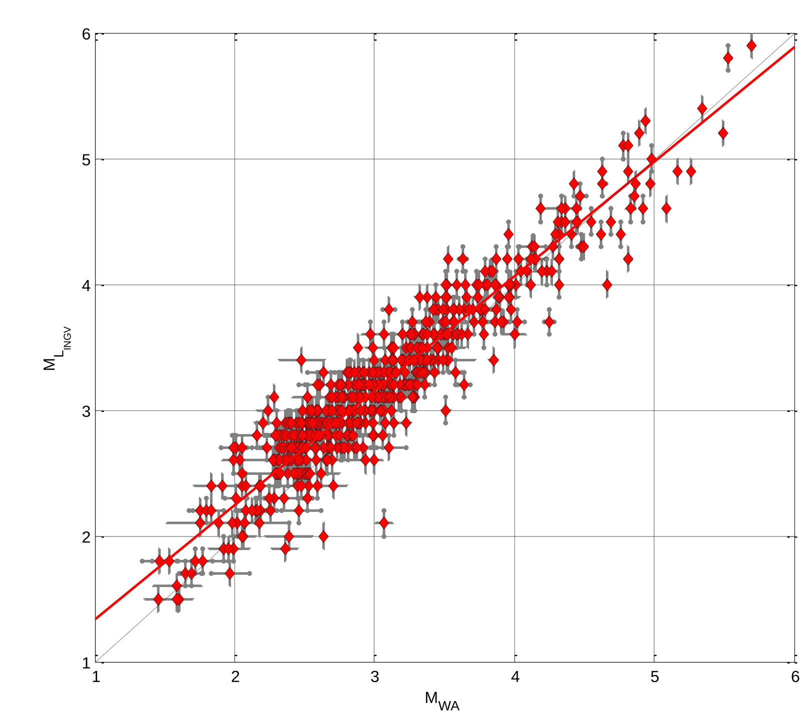






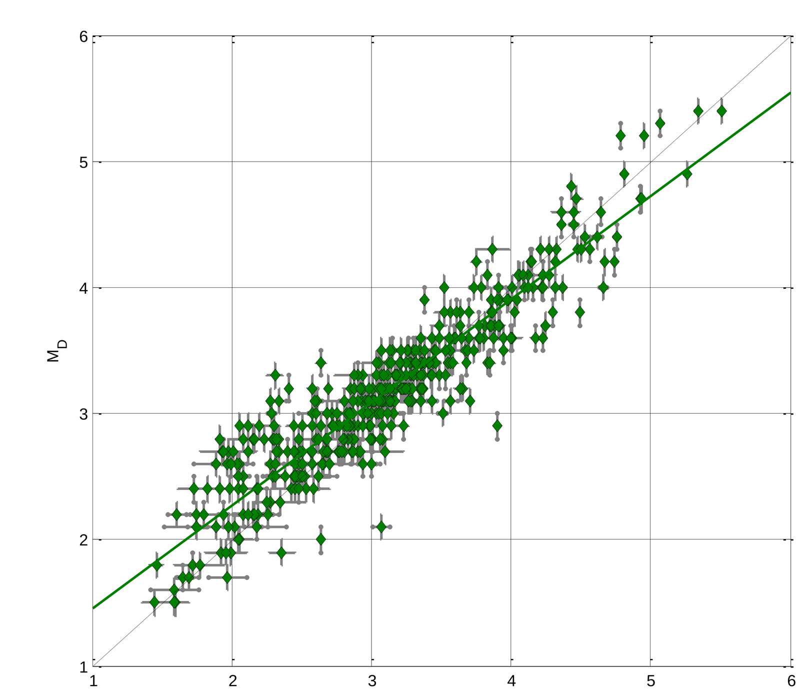
PSD

RESULTS



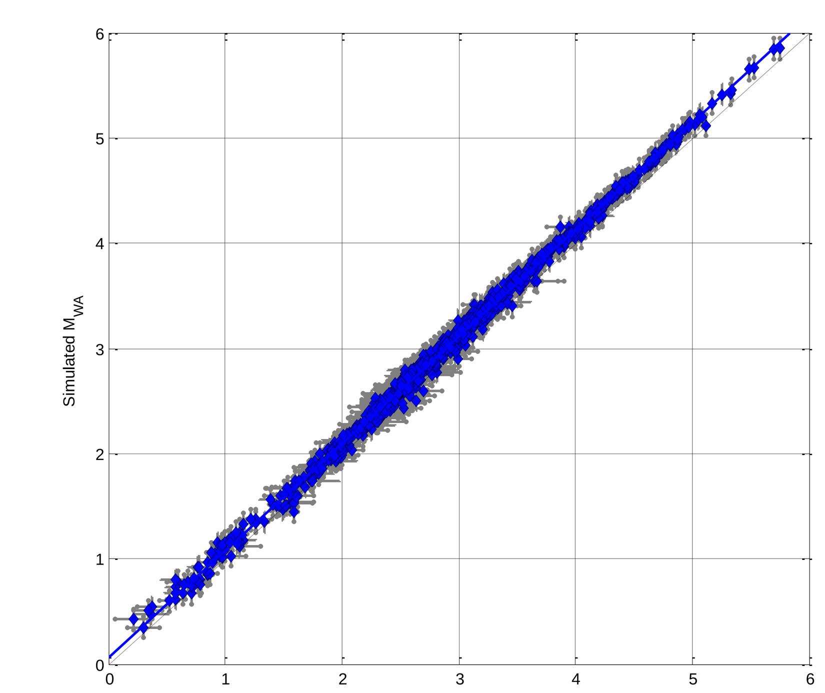
Comparison with INGV M_L data from ISIDe (657 events). Data from **April 16, 2005 to December 31, 2013:** $M_{LINGV}=(0.909\pm0.006)M_{WA}+(0.42\pm0.02)$ $R^2=0.894$

INGV supplies higher magnitudes if $M_{AW}<4$



Comparison with OGS M_D data (480 events). Data from **December 17, 2002 to May 20, 2012:** $M_D=(0.818\pm0.007)MAW+(0.64\pm0.02)$ $R^2=0.860$

OGS supplies higher magnitudes if $M_{AW}<3.5$



Comparison with simulated M_{WA} data from BB (1030 events). Data from **October 22, 2004 to December 31, 2013:** $M_{LINGV}=(1.016\pm0.004)MAW+(0.07\pm0.01)$ $R^2=0.997$

The WA **magnification factor** for the simulation from BB traces was set equal to **2800**

WA MAGNIFICATION

In order to simulate a WA on a BB seismometer it is necessary to know the transfer function. In particular the magnification.

- Anderson and Wood (1925): magnification 2800
- Uhrhammer and Collins (1990) and Uhrhammer et al. (1996): magnification 2080.

According to Uhrhammer and Collins (1990), the difference derives from the wrong assumption by Anderson and Wood (1925) that the wire stretched in suspension used in the sensor WA does not deviate from a straight line. The deformation is actually sufficient to increase the moment of inertia and reduce the static magnification.

We found that the magnification depends on the signal amplitude

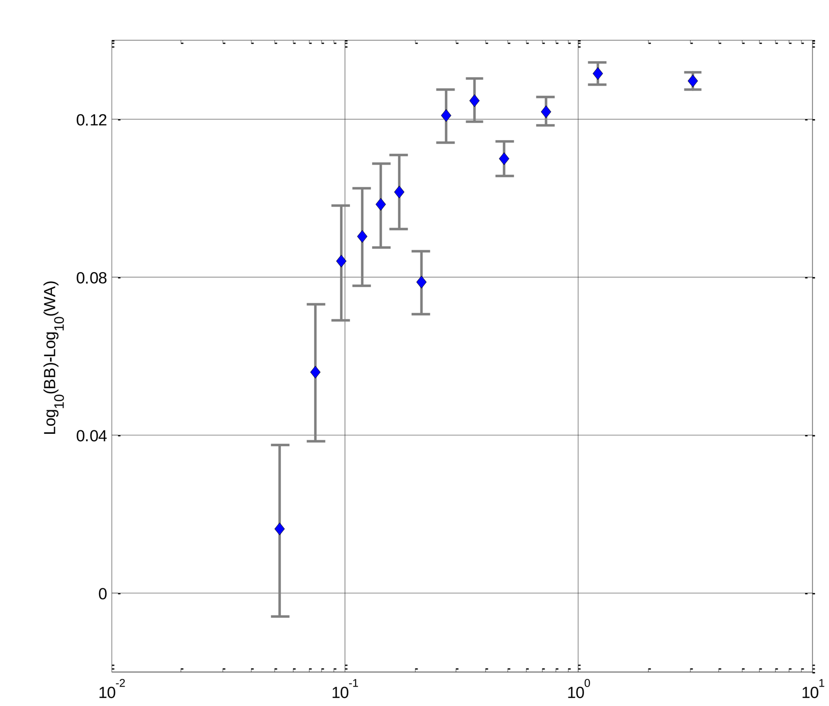
FIRST METHOD: Wood and Anderson (1925), :

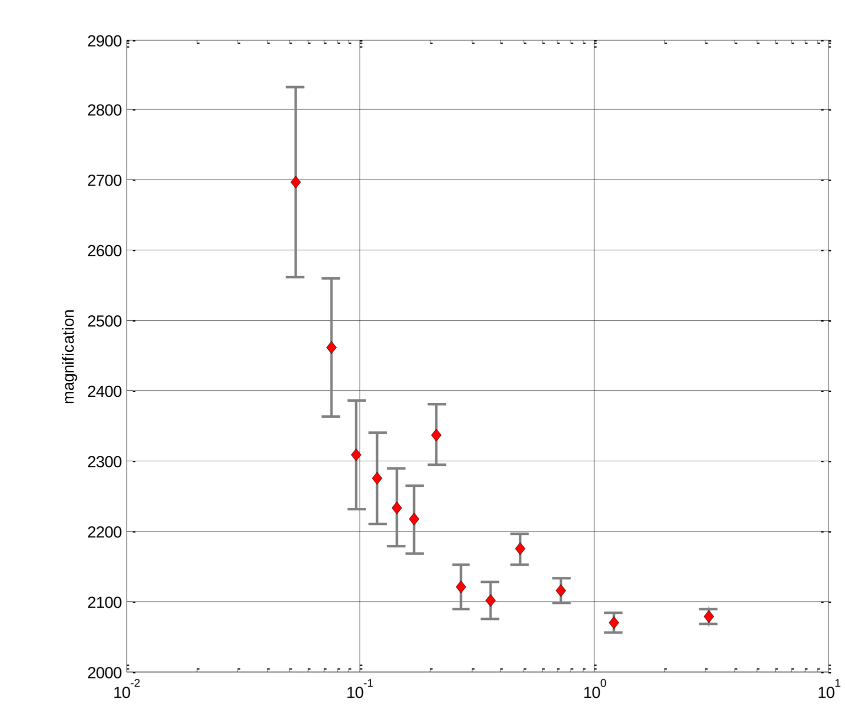
$G_S=A/a=(A4\pi^2)/(gbT_0^2)$

We tilted the instrument of a known angle b and we measured the output voltage from the PSD, which is proportional to A.

G_S = magnification
A = trace amplitude
a = amplitude of the ground motion component normal to the equilibrium plane
g = gravity acceleration
b = instrument tilt angle (rad)
T_0= period of oscillation (0.8 s)

O (V)	A (mm)	G_S
2.00±0.07	45.8 ± 1.6	2092 ± 73





SECOND METHOD:

The ratio of the maximum amplitudes (peak to peak) of the simulated and the real WA were calculated. Each G_S value corresponds to the weighted average of a set of 75 similar amplitude points and the corresponding amplitude value to its mean amplitude. The difference in magnitude between the corresponding ratios between a simulated (G_S=2800) and a ranges between [0.02 and 0.13] depending on the signal amplitude.