NEtwork of Research Infrastructures for European Seismology

Deliverable D5
The European Earthquake Catalogue (demo version) 1000-1600

Part 1 – The NA4 Calibration Initiative

(April 2009)

Activity:	Distributed Archive of Historical Earthquake Data
Activity number:	NA4
Deliverable:	The Europena Earthquake Catalogue (1000-1600), demo version. Part 1, The NA4 Calibration Initiative
Deliverable number:	D5
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Sixth Framework Programme
EC project number: 026130

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Review by W. Bakun

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Abstract
The aim of this initiative was to calibrate, in a homogeneous way, three methods for determining earthquake parameters from macroseismic data, Boxer, Meep, Bakun & Wentworth, in five European areas: Aegean, Iberian, Italian, Great Britain and Switzerland.
For each area a dataset of about fifteen earthquakes of the 20th century, selected to cover the largest magnitude range, was compiled according to homogeneous procedures. The Boxer and Meep methods are accompanied by codes which provide calibrated coefficients from the input dataset. The Bakun & Wentworth method requires an intensity attenuation relation as function of the moment magnitude and hypocentral distance. Such relations were obtained for each area calibrating the coefficients of a log-linear function with regression procedures from the same dataset used for calibrating the other methods. As the Bakun & Wentworth method accepts any attenuation relation, other recently published relations were also considered.

The calibrated coefficients were then validated determining the parameters of another ten events. For Boxer and Meep one set of coefficients only was available for each area; therefore, the validation exercise was devoted to survey whether the use of such coefficients would lead to realistic results. For the Bakun & Wentworth at least two alternatives were available in all areas; the scope was, therefore, to select the "best performing" one.

The results will be used for assessing the parameters of the historical earthquakes in the frame of NA4.

Note. The input data used in this work, described at paragraph 2 and 4, and the maps resulting from the application of the results are available on the NA4 website

http://emidius.mi.ingv.it/neries_NA4/

partner login (user and password to be delivered by the NA4 coordination unit)

D5

0. Introduction

One of the scopes of NA4 is to assess earthquake parameters from macroseismic data in a homogeneous way, using transparent, repeatable procedures and homogeneous input data.

Several methods are available today: Boxer (Gasperini et al., 1999); Meep (Musson and Jiménez, 2008), developed within NA4; the method BW proposed by Bakun & Wentworth (1997), coming with varied implementation; the method proposed by ITSAK, etc. Many of them are promising, none is perfect, yet. The main point remains the magnitude determination, which is strongly dependent on the regional attenuation; the location determination appears more successful and not so regionally dependent, although to date no method is completely successful in distinguishing coastal and offshore events and related problems.

This situation needs to be improved; reliable, regional calibration for the three adopted methods (BW, Boxer, Meep) are needed to be used ASAP for the determination of the parameters of the NA4 historical events. Therefore, NA4 has foreseen in an initiative for calibrating – on a regional basis - the current methods using homogeneous software, input data and procedures (Ann.1, “NA4 detailed implementation plan for the next 8 months, months 29-36).
The initiative was developed from October 2008 to March 2009 according to the following steps:

1) updated versions of the eligible software were delivered to partners under the coordination of BGS and INGV-MI;
2) input intensity data for about fifteen, 20th century events, selected by NA4 partners to cover the largest possible magnitude range for each area and to carry reliable instrumental Mw and location (calibration dataset) and of another 10 events, selected with the same criteria (validation dataset), were homogenised and formatted by INGV-MI according to the standard agreed in Deliverable 3 and then release through a dedicated web page (http://emidius.mi.ingv.it/neries_NA4/calibration/);
3) NA4 partners calibrated models in their regions. INGV-MI assisted IGC, ITSAK and, partly, ETHZ;
4) calibrated coefficients and parameters were applied to determine the parameters of the earthquakes of the validation dataset;
5) results and problems were discussed in a meeting (Milano, 4-5 December 2008; minutes are in Ann.2);
6) a further series of tests was performed until mid March 2009;
7) the results were put together, made available through a web page and analyzed. For the BW method the “best performing” relations and coefficients were selected;
8) the final set of relations and coefficients to be used for the next NA4 phase (determining parameters of historical events) was adopted.

1. Methods and software

1.1 Boxer (Gasperini et al., 1999)

Gasperini et al (1999) proposed a method where the epicentre is the barycentre of the highest intensities, and Mw is evaluated from the felt area of each intensity class. The last version is the 3.3 (2004). Executable program and manual can be downloaded from the webpage http://ibogfs.df.unibo.it/user2/paolo/www/boxer/boxer.html.

The method groups all macroseismic observations in classes of integer values (the intermediate values are grouped together with the lower integer class). The epicentre corresponds to the mean coordinates of the observations in the highest intensity class (if there are less than 3 points, it considers the lower class too), after the removal of the outliers. From this epicentre a mean radius for each intensity class is determined (as the mean epicentre-to-site distance). By applying the Sibol et al. (1987) formula [Mi = f(Ai, Io), where Mi is the magnitude calculated for the *i* intensity, Ai the area for that intensity, Io the epicentral intensity] to each intensity mean distance, a set of magnitudes is calculated: the weighted average value is the proposed magnitude with the related standard deviation. The calibration of the Sibol et al. (1987) formula can be performed through a special option in the Boxer program [COMPCOEF], using a dataset of earthquakes with reliable magnitudes.

A tutorial about the calibration procedure, with an example of input and output files, was delivered by P. Gasperini (Ann.3, Recalibraton_tutorial.pdf).

1.2 Meep (Musson and Jimenez, 2008)

Meep (Macroseismic Estimation of Earthquake Parameters) was developed by R. Musson and M.J. Jiménez in the framework of NA4 (Deliverable D3). The method distinguishes 2 phases: the epicentre determination with the residuals minimization approach (by using the Kovesligethy, 1907 model) and the magnitude determination following the felt area approach by Frankel (1994). This code returns a depth determination too. Starting from a centroid solution calculated in a way similar to the Boxer approach, Meep defines a large search grid, to be reduced at the half at each iteration: by applying the Kovesligethy model to each intensity data point, the grid point with the minimum rms is the center of the next smaller search grid. In the last iteration the depth is also taken into account, by moving the possible hypocentre from 0 to 30 km. Once the hypocentre is determined, the magnitude is assessed through the Frankel approach, where the perceptibility area of an earthquake (normally corresponding to intensity 3 area) is proportional to the magnitude and the remaining isoseismals are scaled by the C constant. By testing all the magnitudes from 3 to 8.5, the proposed magnitude is that value that minimizes the residuals of the observed isoseismal areas versus the theoretical ones. The relevant uncertainties do not represent real standard deviation, but they come from considerations about the errors in the approach. The location uncertainty is defined as the distance for which the ratio of the worst RMS over the best one is approximately 2; the magnitude uncertainty is the interval for which the RMS approximately doubles the best fit. As a side program, Meep is accompanied by Calimeep, a code to calibrate some constants required by Meep from a learning dataset.

Meep last version, 1.6, containing both the source code and the executable file, was delivered by R. Musson. The full description of the format of the input files is reported in D3.

1.3 BW (Bakun and Wentworth, 1997)

Bakun and Wentworth (1997) developed a method (BW from now on) for the analysis of intensity data that results in an intensity magnitude M_I calibrated to equal moment magnitude. They use a point source model, an assumed source depth h, and an appropriate intensity attenuation model I = f (M, epicentral distance Δ). They calculate M_I and rms[M_I] over a grid of trial source locations. M_I = mean (M_i), where M_i is the M estimated for site i. rms[M_I] = [rms (M_I - M_i) - rms_0 (M_I- M_i)], where rms_0 (M_I- M_i) is the minimum rms over the grid. Bakun and Wentworth's (1997)

distance weighting is used. M_I at feasible trial source locations within the appropriate confidence-level contours are the best estimates of M for those source locations. The trial source location for which rms[M_I] is minimum represents the point source of seismic energy that best satisfies the available intensity data. This location, called the *intensity center* by Bakun (1999). corresponds more to the moment centroid than to the epicenter. The code does not evaluate the uncertainty of the estimated parameters; Bakun & Wenthworth (1999) report the rms values corresponding to the 95% confidence level, based on the training-set events and the number of observations (Ann.4.).
The software of the BW method was made available by W. Bakun, first to INGV and later by INGV to NA4. It was slightly modified and recompiled by INGV in order to allow to add several attenuation relationships inside the original code in a simple way. A tutorial that explains to the users the use of the code (together with an example of input and output files) was released by C.Meletti and V. D'Amico (Ann.5).

1.4 "Greek" *(under development)*

Ventouzi, Papazachos and Papaioannou (2008) have suggested another method to estimate the macroseismic epicenter and an equivalent moment magnitude from macroseismic data points. They assume a point source and the Kovesligethy relation between intensity I at distance Δ, epicentral intensity I_0, source depth h, a geometrical spreading factor n, and an anelastic attenuation coefficient c. They assume anisotropic radiation and adopt Papazachos's (1992) versions of the Kovesligethy relation to estimate ellipticity of the isoseismals, the azimuth of the major axis of the elliptical isoseismals, and the azimuth of each IDP site. Following Papazachos and Papaioannou (1997), they estimate the macroseismic epicenter by regression analysis after weighting the data with distance. With h fixed at 7 km, n is estimated, and the epicenter is taken to be the point in a 1°x1° grid with the smallest rms error. Macroseismic magnitude, calibrated against moment magnitude, is then estimated from the isoseismals.

The main characteristics of the 4 methods are roughly summarised in Tab.1.1. NA4 agreed to adopt the first three methods.
All methods have a "bootstrap" version for epicentre determination under development.

Tab.1.1 – Main characteristics of the four methods, compared.

characteristics	Boxer 3.3	Meep1.6	BW	"Greek"
ad hoc calibration	yes	yes	no	*yes?*
can use atten. relations from literature	no	no	yes	*yes*
epicentre determination	barycentre	residuals minimum (Kovesl.)	residuals minimum (varied)	*residuals minimum (Kovesl.)*
for epicentre determination uses:	high MDPs	all MDPs	all MDPs	*all MDPs (weigthed)*
epicentre determination: uncertainty	no	attempt	confidence level	*no*
accepts fixed epicentre	no	yes	yes	*yes*
Mw: approach	Sibol	Frankel	mean value of all point Mwi	*scaling relation*
for determining Mw uses:	all MDPs	all MDPs	all MDPs	*all MDPs*
Mw: uncertainty	standard dev.	attempt	confidence level	*no*
depth	no	yes	no	*yes*

2. Calibration: input data

About fifteeen, 20th century events were selected by each NA4 partner, in such a way to cover the largest possible magnitude range for thei area and to carry reliable instrumental Mw, Mw uncertainty and location (Tab. A; Fig. 2.1 - 2.5).

The location of some events of Switzerland and Aegean is reported as mixed (instrumental and macroseismic): such locations are flagged in Tab. A. Damaging aftershock were not included to avoid intensity bias. Deep earthquakes were also not included.

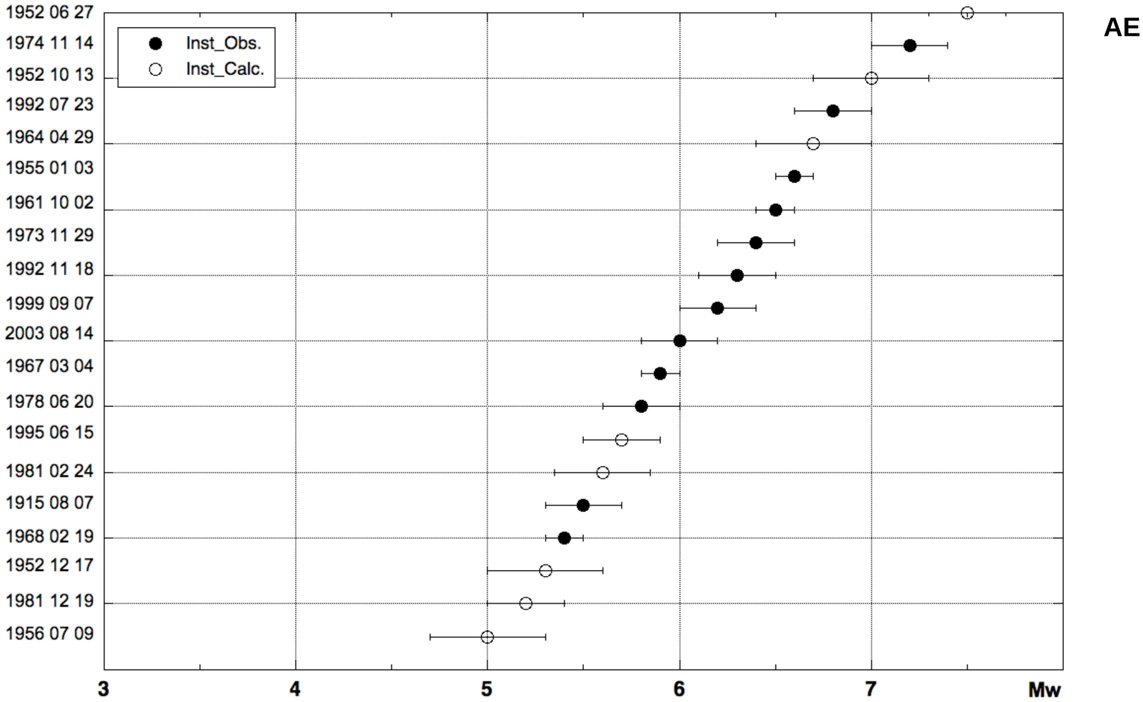


Fig. 2.1 – Aegean area: calibration events, ordered by Mw. Full circles indicate native Mw.

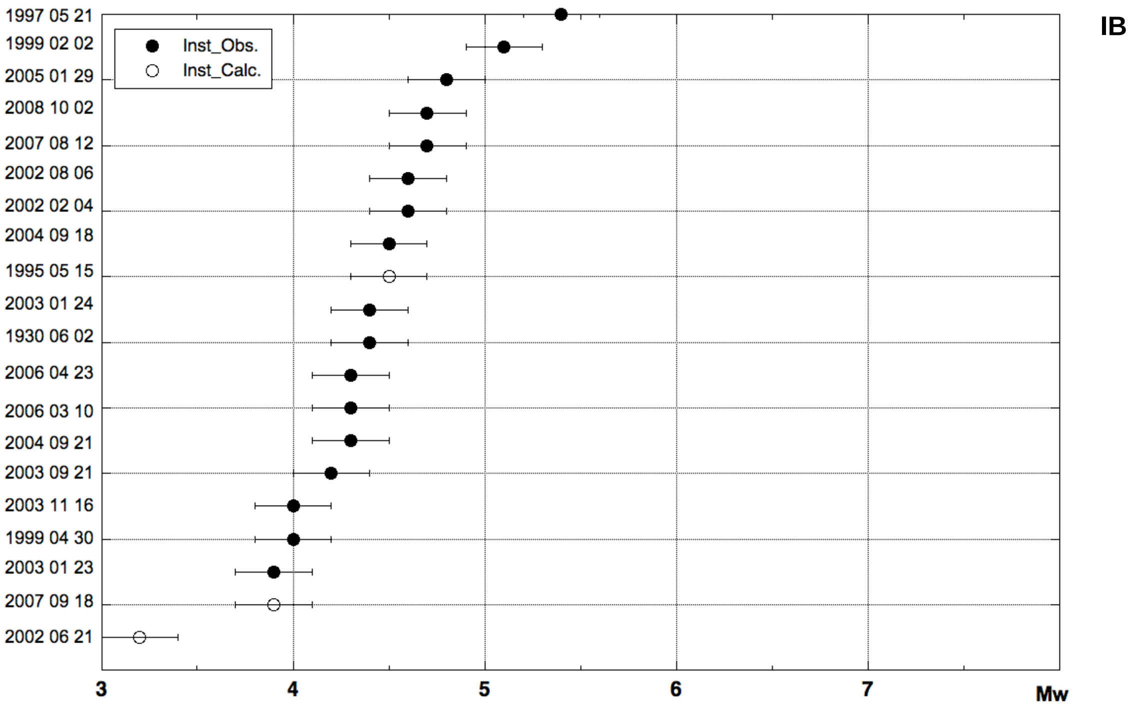


Fig. 2.2 – Iberian area: calibration events, ordered by Mw. Full circles indicate native Mw.

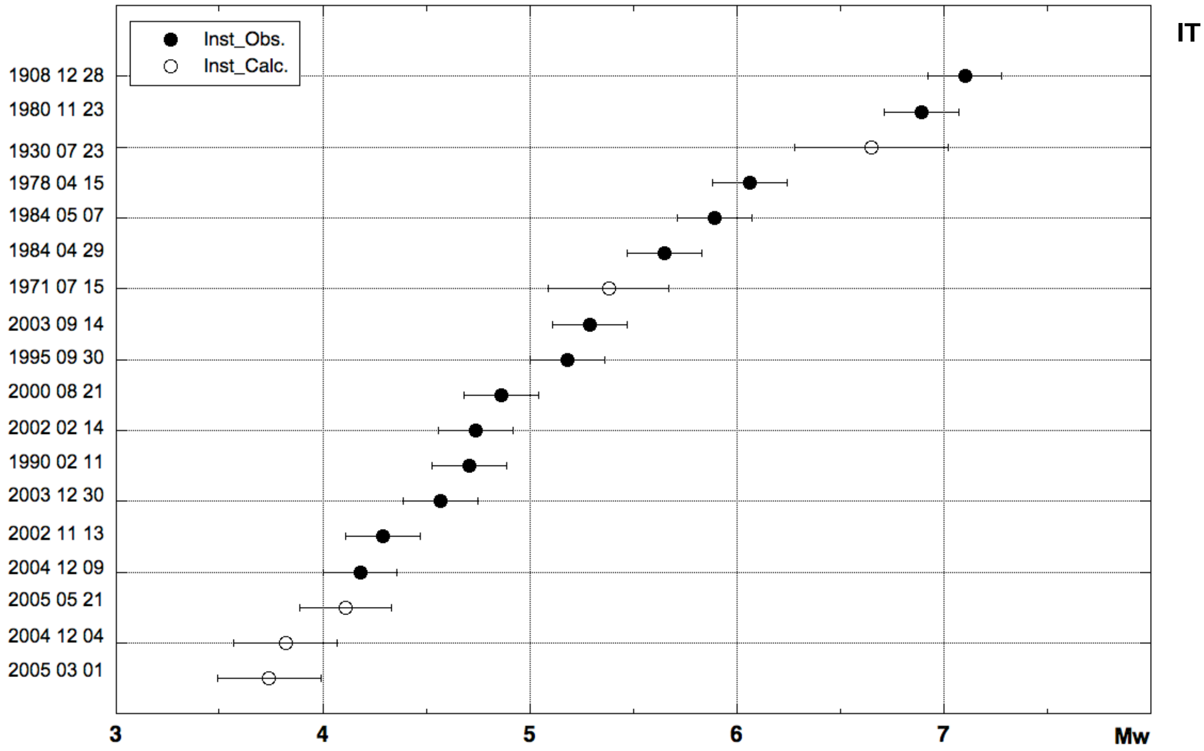


Fig. 2.3 – Italian area: calibration events, ordered by Mw. Full circles indicate native Mw.

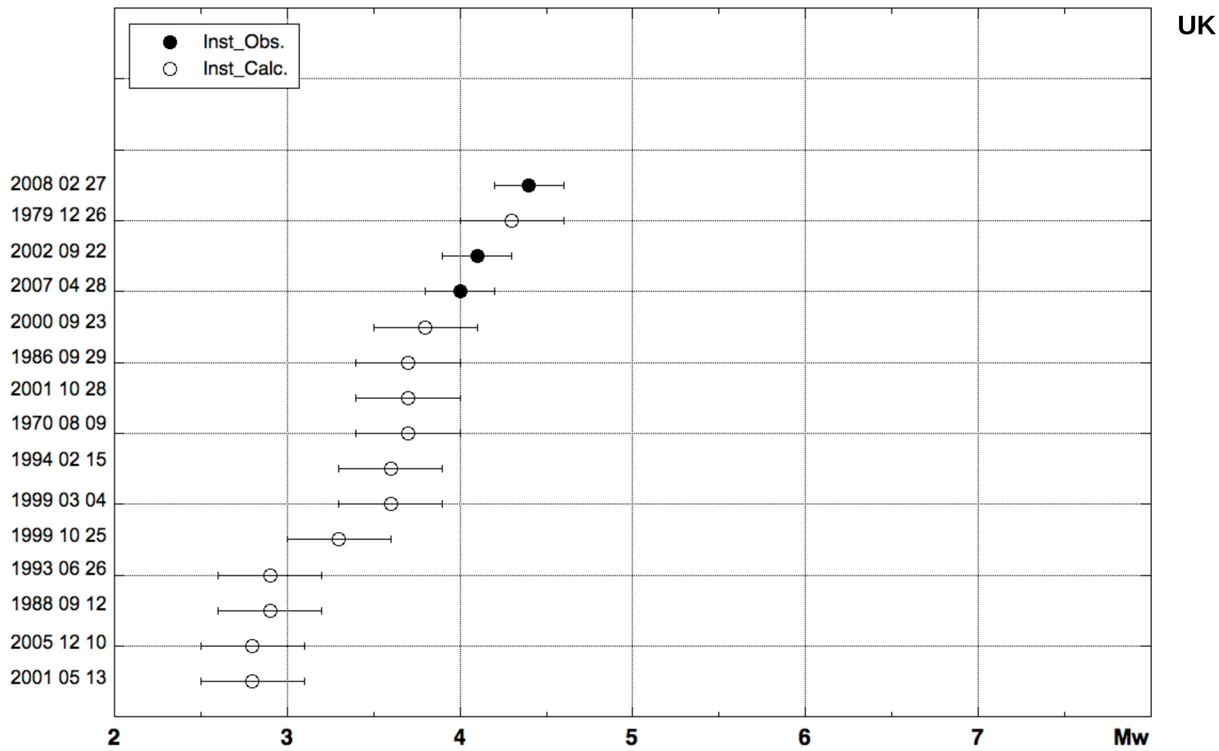


Fig. 2.4 – Great Britain area: calibration events, ordered by Mw. Full circles indicate native Mw.

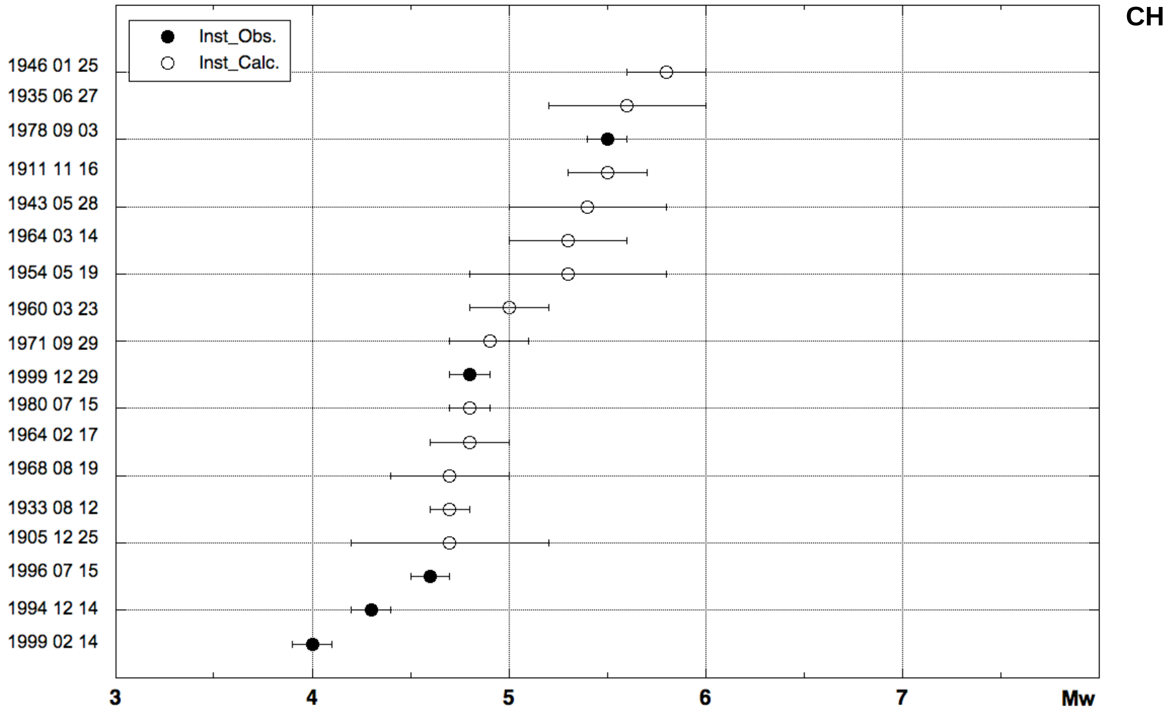


Fig. 2.5 – Swiss area: calibration events, ordered by Mw. Full circles indicate native Mw.

The relevant MDPs (a total number of 21.221) were homogenised and formatted by INGV-MI according to the procedures described in Deliverable D4 (Stucchi and Locati, 2008). In particular, the convention Ic2 was adopted, with the exception of UK where also a new Ic3 convention was tested.

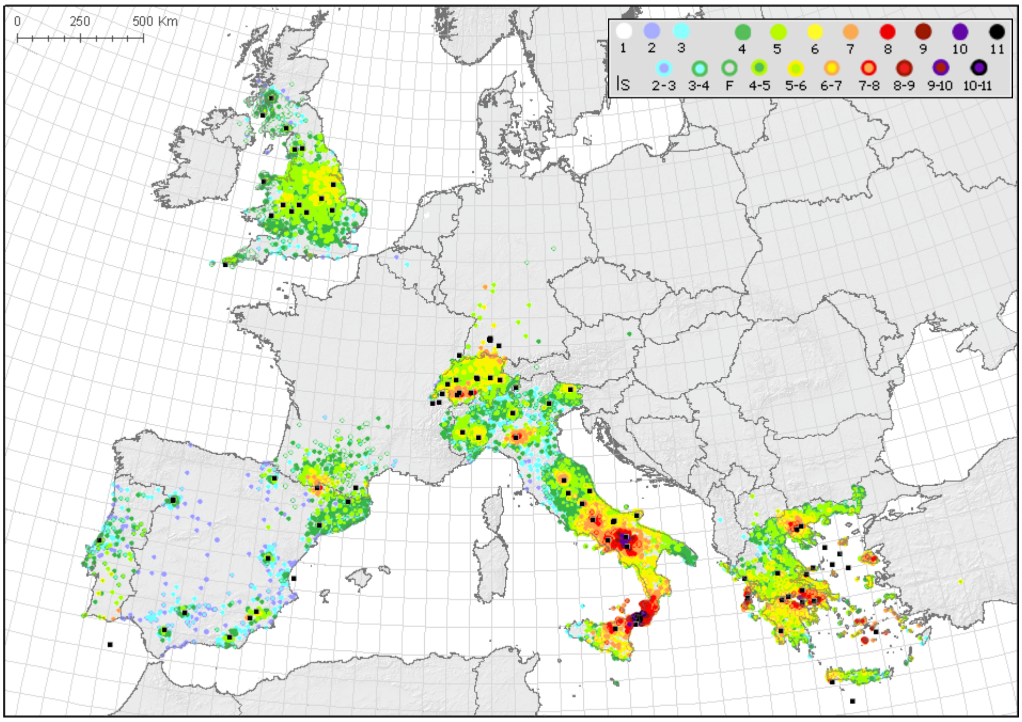


Fig. 2.6 - Distribution of epicentres and MDPs of the calibration dataset.

3. Calibration: procedures and results

Software and calibration datasets were made available to NA4 partners through a dedicated webpage. Each partner had the task to calibrate Boxer, Meep and BW using the same, regional dataset.

3.1 Boxer. The location procedure does not require regional calibration. As for Mw, an option of the Boxer program [COMPCOEF] allows, as mentioned before, the calibration of the coefficients of the Sibol et al (1987) formula. For this purpose Io, instrumental Mw and standard deviation must to be supplied for each event. The user may select the intensity degrees for which the calibration is calculated. If only integer values are listed, the intermediate intensities are considered together to the lower integer intensity.

3.2 Meep. Calimeep needs the list of the earthquakes in the calibration dataset (listed with date, instrumental location, magnitude and depth) and in the dialogue phase asks for the coefficient Q and alpha. After the run, the coefficients K and C are calculated.
In order to determine the best combination of the 4 parameters (i.e. the minimum misfit) multiple runs were performed, by changing Q and alpha combination and by looking for the best fit.

3.3 BW. The BW method requires to input an intensity attenuation relation as a function of M and distance. This relation can be provided according to two alternatives:

a) using an available relation;
b) calibrating the coefficients of an attenuation relation, using for instance the procedure by Bakun & Wentworth (1997).

NA4 considered both alternatives: alternative a), for using more robust relations; alternative b), for obtaining a relation calibrated against the same dataset as Boxer and Meep.

3.3.a. Available attenuation models

Several types of relations (linear, log, log-linear) are currently available for describing intensity attenuation with epi- or hypocentral distance. Bakun & Wentworth (1997), Hinzen and Oemisch, (2001) used a linear model for California and the Northern Rhine area. Fäh et al. (2003) use a bilinear, regionalised model, epicentral distance for Switzerland; the relevant coefficients were supplied by Zuerich for NA4. Mezcua et al. (2004) for Iberia, Musson (2005) for UK, Bakun and Scotti (2006) for France use a logaritmic one; Papazachos & Papaioannou (1997) for the South Balkan area, Bakun (2005, 2006a, 2006b) for Japan and Southern California, Pasolini et al. (2008) for Italy adopted a log-linear model, hypocentral distance, also following the model of Bakun and Joyner (1984), Frankel (1994) and Johnston (1996).
Na4 selected the following relations, which include updated coefficients of the Faeh et al. (2003) relation:

Tab. 3.1. Intensity attenuation relations selected.

Author	Area	Function	size	dist	N of eqs.	Time interval	M interval
Papazachos and Papaioannou (1997)	AE	log-linear	Mw	hyp	356	1901-1995	4.1-7.7
Hinzen and Oemisch (2001)	CH	linear	ML	epi	14	1963-1998	2.9-5.9
Fäh et al. (2003), *upd.*	CH	bi-linear	Mw	epi	15	1910-1999	3.6-6.1
Mezcua et al. (2004)	IB	logarithmic	Mw	epi	5	1993-1999	4.8-7.9
Musson (2005)	UK	logarithmic	ML	hyp	376	1382-2002	2.0-6.1
Pasolini et al. (2008)	IT	log-linear	I_E	hyp	470	1200-2002	3.9-7.4

3.3.a. calibrating.
NA4 agreed to calibrate the coefficients of a log-linear relation:

$$I = a + bMw - cR - d\log R \qquad (1)$$

where R is the hypocentral distance. For the Ic2 option Edinburgh adopted a logaritmic model. Following a suggestion by Bakun, h was assumed = 10 km for AE, IB, IT, CH. UK let it free, obtaining h = 1.34km and h = 1.07 for the two options Ic2 and Ic3, respectively.

After the Milan meeting, MDPs were re-selected according to common criteria to avoid very weak datasets. W. Bakun recommended not to use MDPs with I<3; the recommendation was adopted by AE, CH and IT, but it turned out impossible for IB and UK.

Tab. 3.2 – Classes of MDPs used.

Region	MDPs used	Hyp. distance
AE (Mi)	I ≥ 3-4	R ≤ 300
IT	I ≥ 4	R ≤ 400
CH (Mi)	I ≥ 3	R ≤ 250
IB (Mi)	I ≥ 2	R ≤ 200
UK	I ≥ 3 (mostly)	R ≤ 200 (mostly)

In addition, outliers, such as MDPs with hypocentral distances larger than ± 2 standard deviation from the mean hypocentral distance, were removed.
Finally, events showing very bad distribution were also removed, having agreed after a long discussion that the calibration dataset must contain the best possible data. This was the case of the events of Golfo de Cádiz, 1964 (Fig.3.1) and Friuli, 1976 (Fig.3.2); the two earthquakes, initially included in the calibration dataset, were later transferred to the validation dataset.

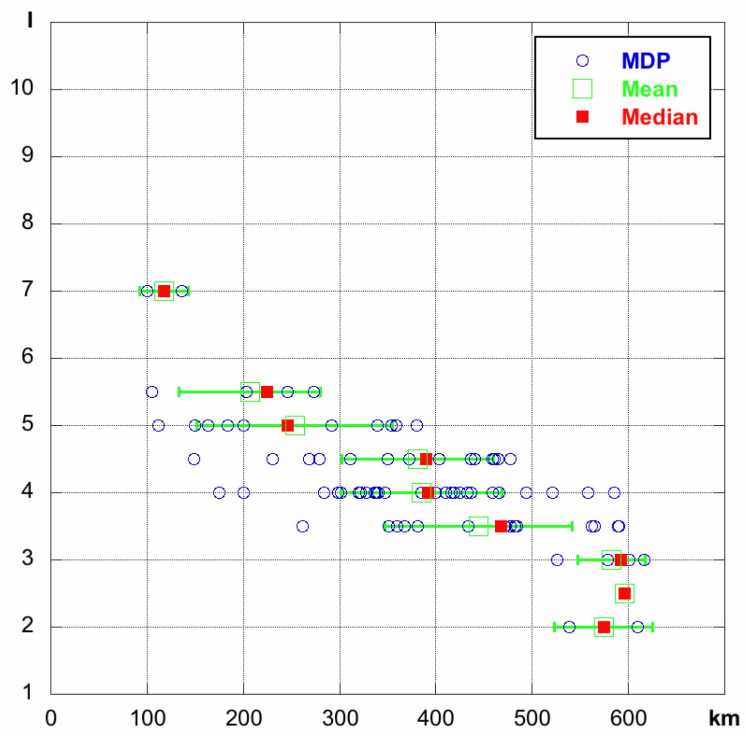


Fig. 3.1 - Intensity vs hypocentral distance of the MDPs of the 1964.03.15, Golfo de Cádiz event (IB).

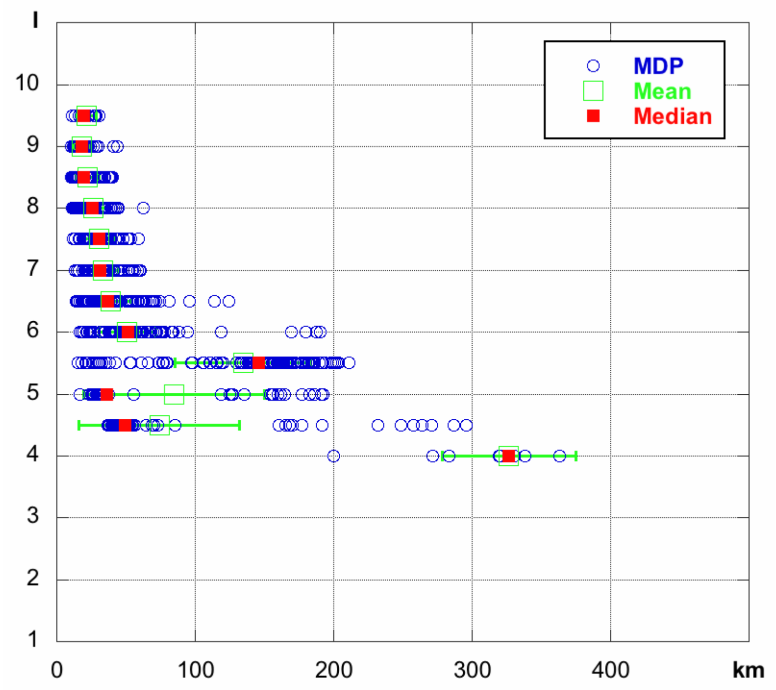


Fig. 3.2 - Intensity vs hypocentral distance of the MDPs of the 1976.05.06, Friuli event (IT).

Once the dataset was established, epicentral distances (Di) from instrumental location were computed for each MDP. Hypocentral distances (Ri) were calculated as $R = (D^2+h^2)^{1/2}$, assuming h as above. The median hypocentral distance for each event and intensity degree was calculated. Fig. 3.3 to 3.7 present some examples: blue circles represent MDPs, mean and median hypocentral distance for each intensity class are green open and red solid squares, respectively. Green bars represent ± 1 standard deviation with respect to the mean value.

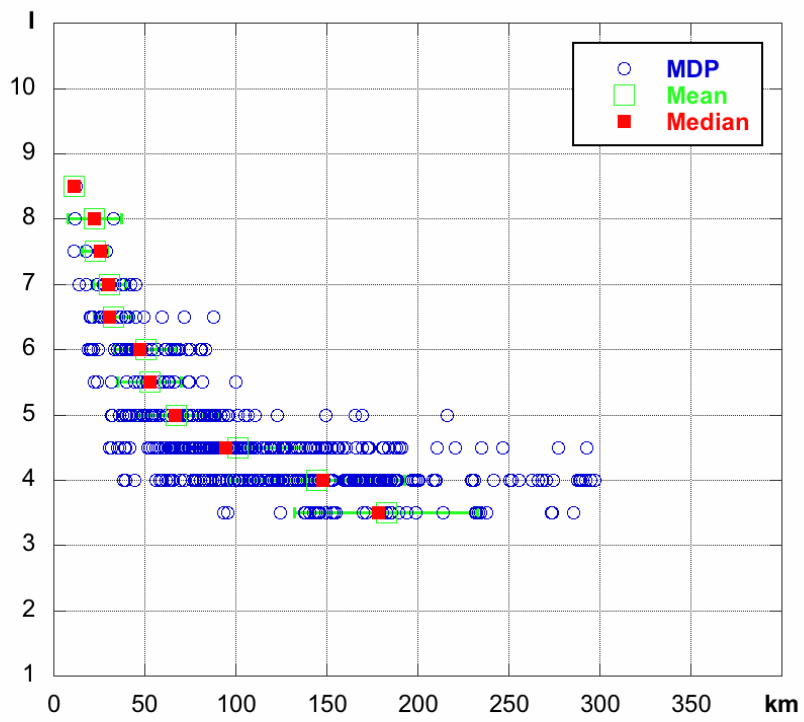


Fig. 3.3. Intensity vs hypocentral distance of the MDPs of the 1978.06.20, Thessaloniki event (AE).

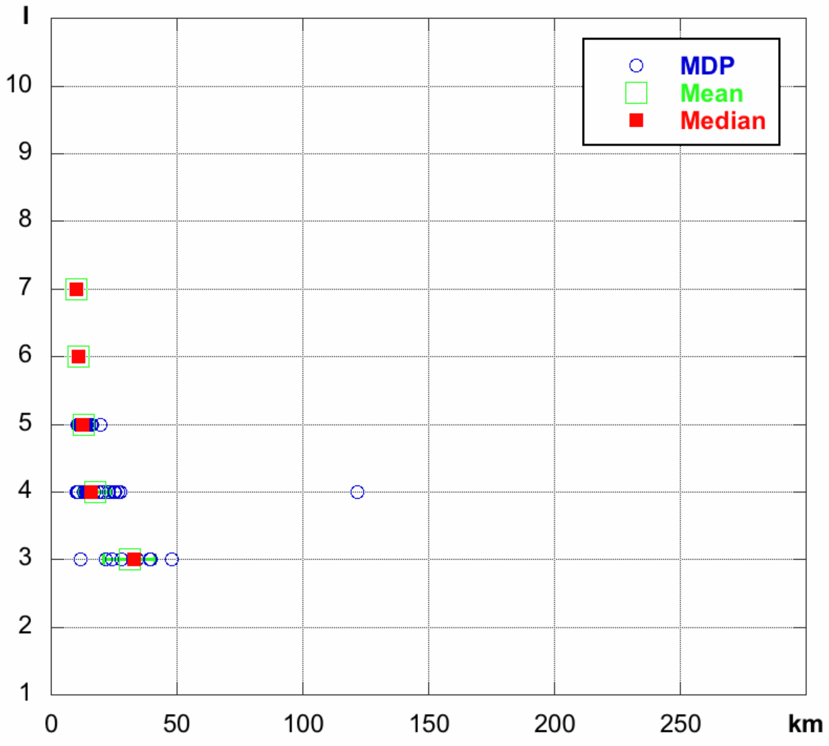


Fig. 3.4. Intensity vs hypocentral distance of the MDPs of the 1933.08.12 Moudon event (CH).

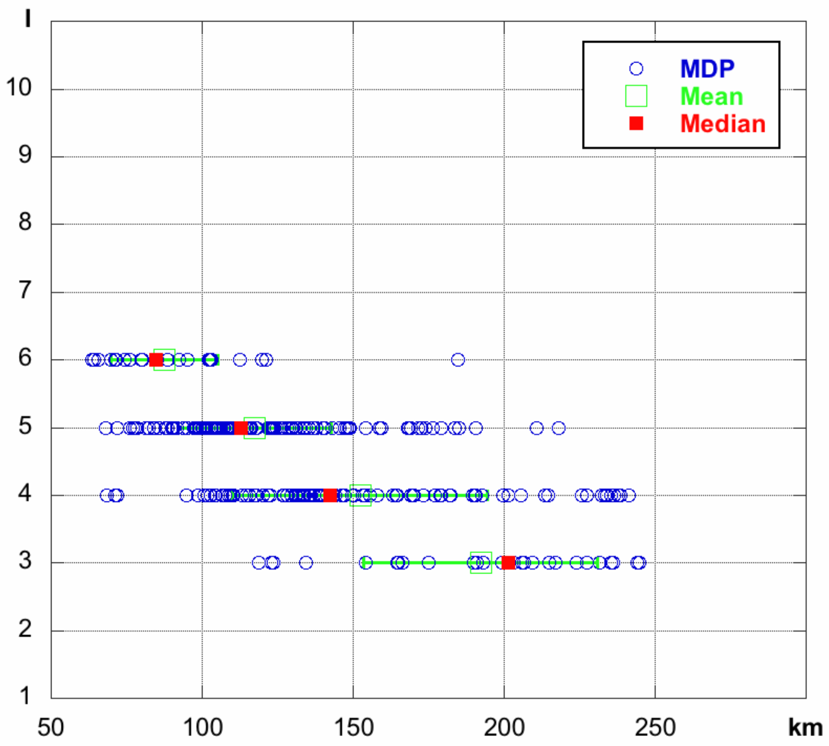


Fig. 3.5. Intensity vs hypocentral distance of the MDPs of the Ebingen/Swabian Jura event (CH).

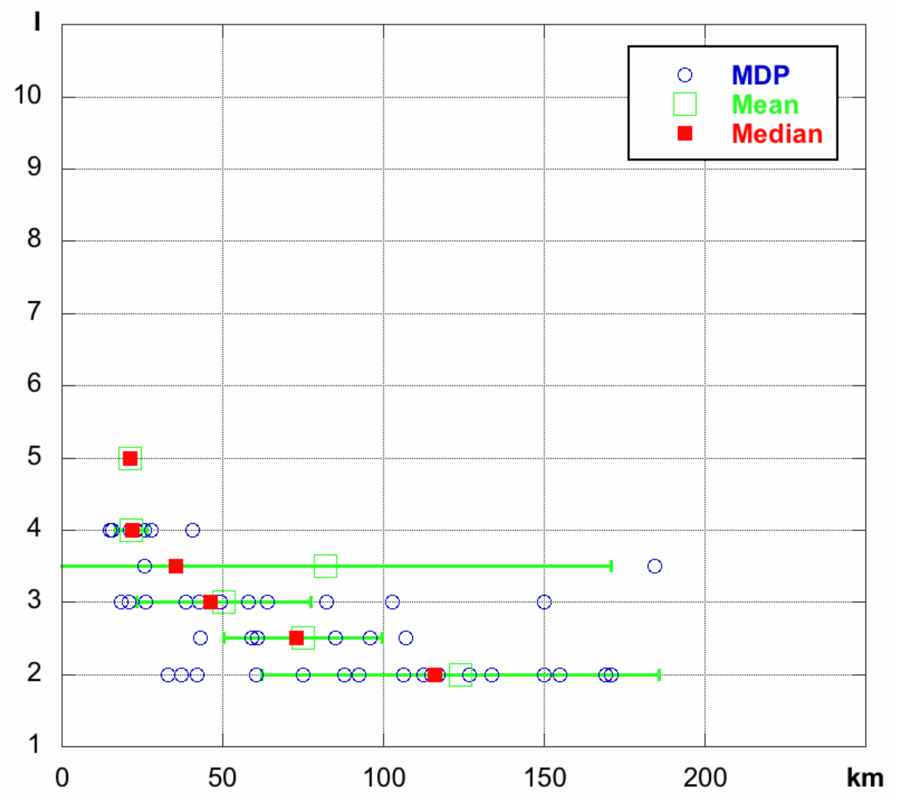


Fig. 3.6. Intensity vs hypocentral distance of the MDPs of the Espejo event (IB).

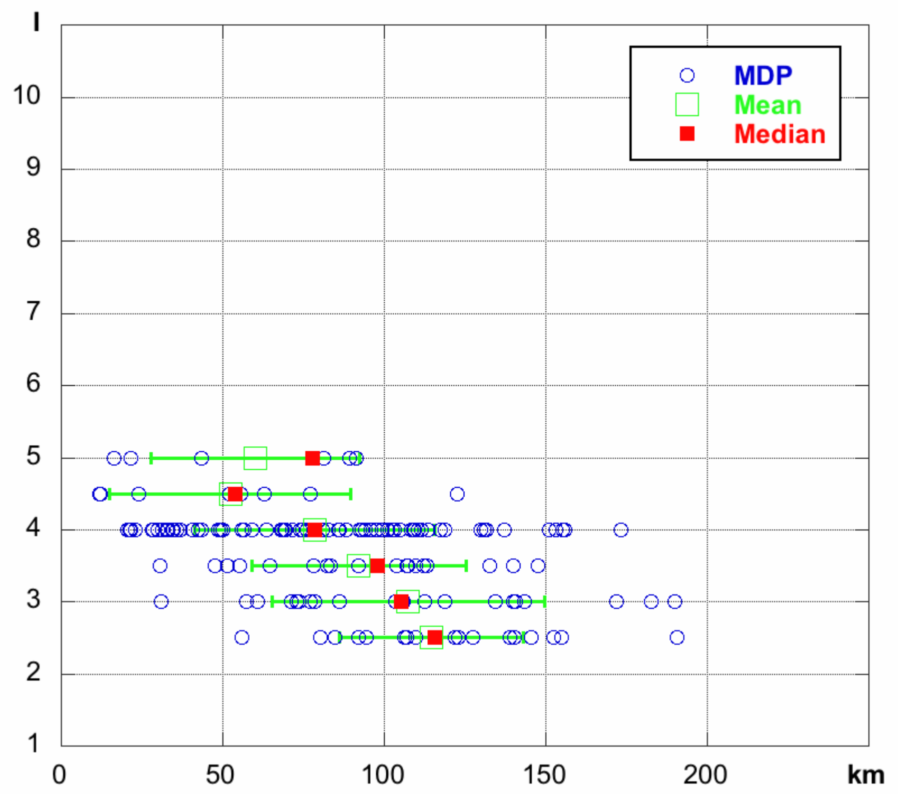


Fig. 3.7. Intensity vs hypocentral distance of the MDPs of the Arenales de San Gregorio event (IB).

The median hypocentral distances for each intensity class and event were then put together in a single plot for each region (Fig. 3.8 to Fig. 3.11).

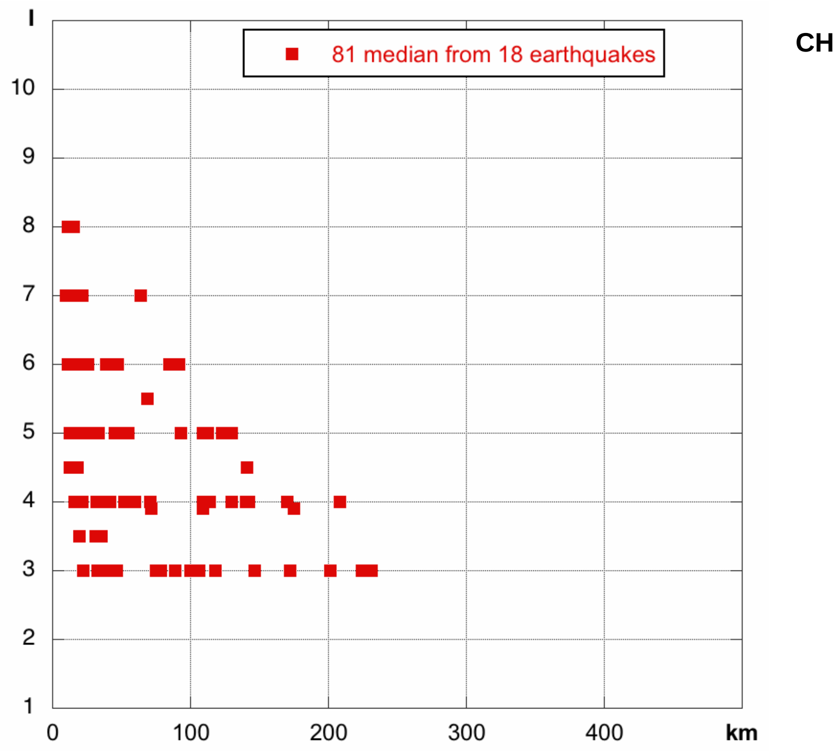


Fig. 3.8 - Distribution of median hypocentral distances values versus intensity for the Swiss area.

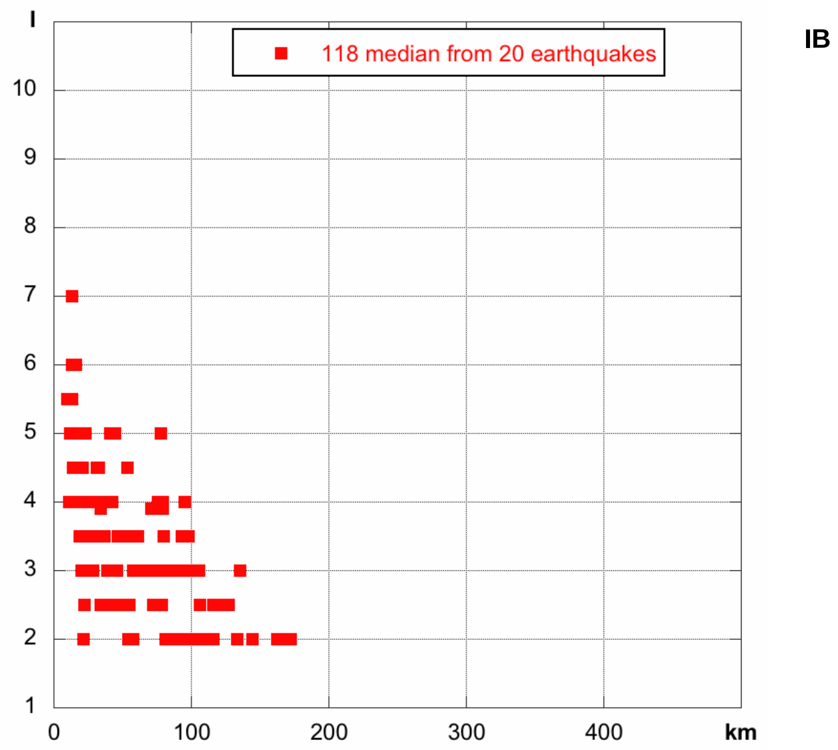


Fig. 3.9 - Distribution of median hypocentral distances values versus intensity for the Iberian area.

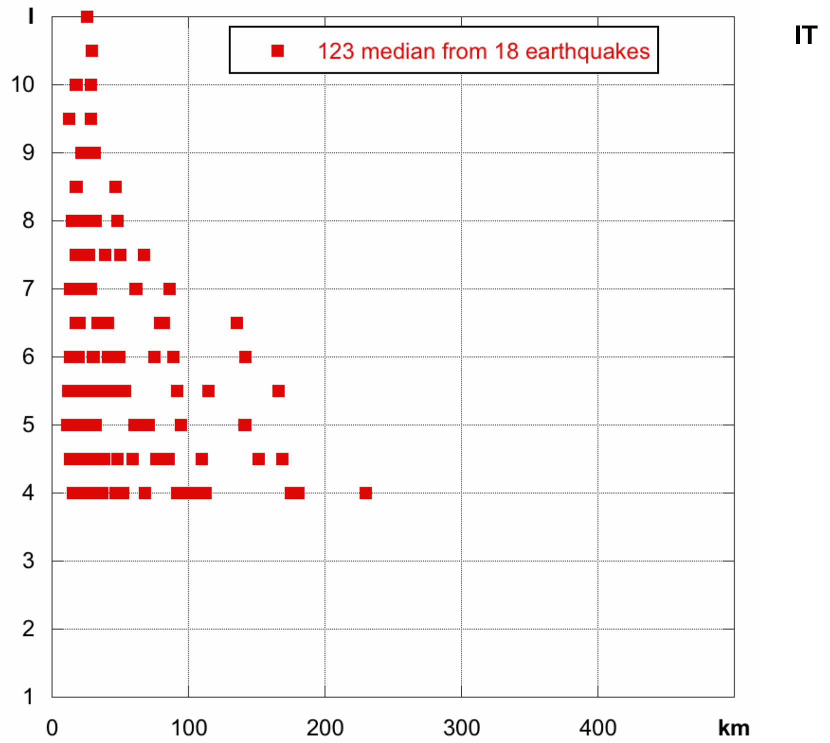


Fig. 3.10 - Distribution of median hypocentral distances values versus intensity for the Italian area.

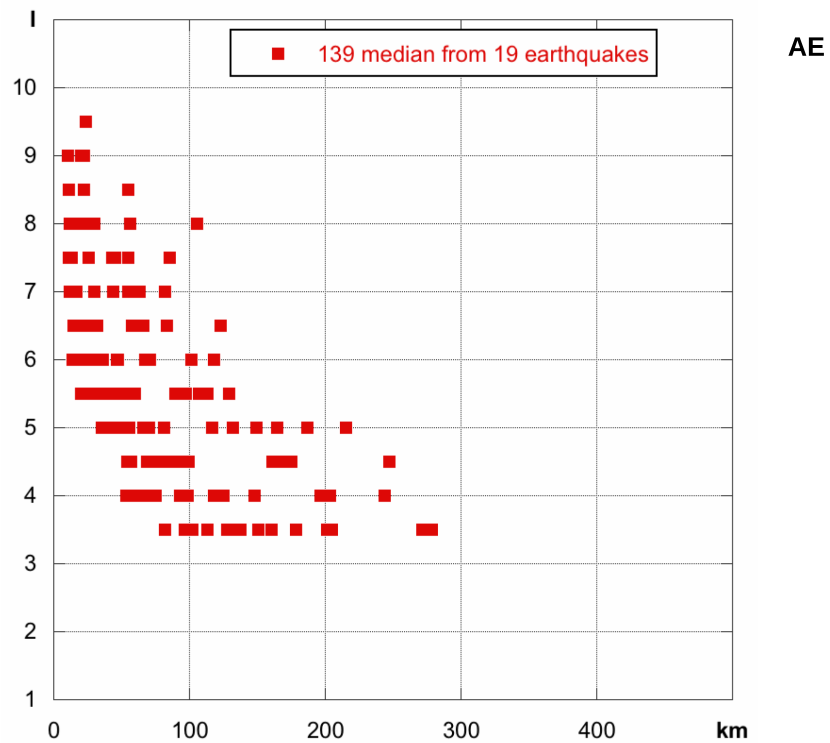


Fig. 3.11 - Distribution of median hypocentral distances values versus intensity for the Aegean area.

The coefficients of relation (1) were then obtained by means of a non linear regression (IB, IT, CH, UK) from these data and Mw.
For the Aegean area two sets of coefficients were determined: i) one by Milan, with the procedure described above; ii) one by Thessaloniki, using the whole set of distances without computing the medians (Fig. 3.12).

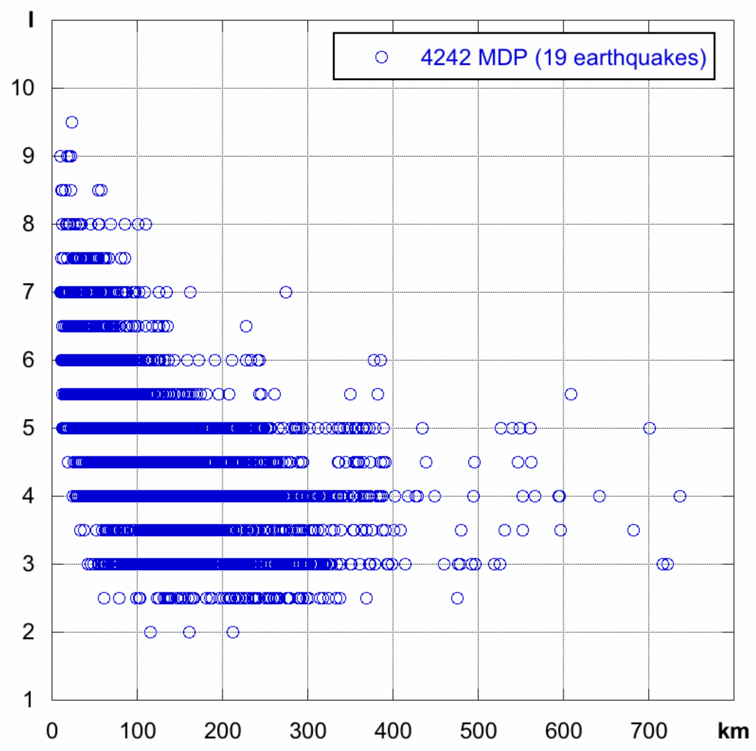


Fig. 3.12 – Distribution of hypocentral distances of the whole dataset of AE.

Further detail on the whole elaboration by Thessaloniki are found in Ann.5.

As a result of this phase, Tab.B summarizes the Boxer and Meep coefficients and the BW relations adopted for the five regions, which will be used in the next phase.

4. Validation: data

The validation dataset was compiled homogenising MDPs of about ten events for each area, selected according to the same criteria as for the calibration dataset (Tab.C).
The distribution of epicentres and MDPs is presented in Fig.4.1; Mw distributions are presented together the results in the next section (Fig.5.1-5.28).

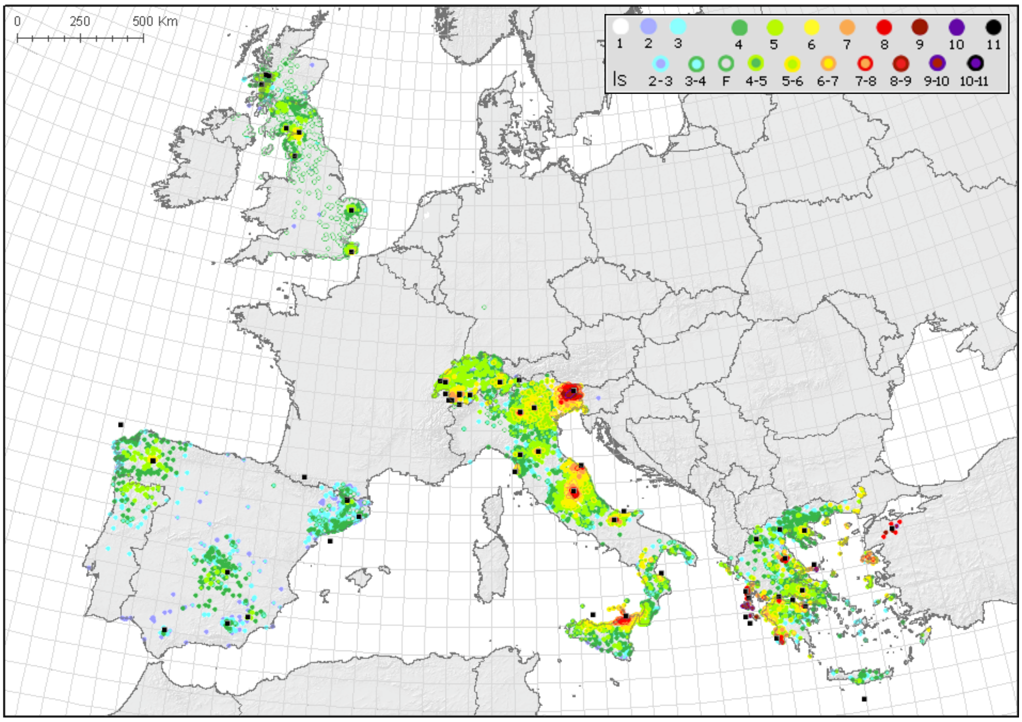


Fig.4.1 - Distribution of epicentres and MDPs of the validation dataset.

5. Validation: procedures and results

Coefficients and parameters obtained in the previous phase were used with the relevant methods for determining the parameters of the validation dataset. For all areas the Ic2 convention was used; UK also tested the Ic3 convention.
Special care was adopted in using the B&W method - in the same way as in the calibration phase - to scale the grid search of trial epicentres with the dimension of the area delimited by the MDPs' network, to avoid fake minimum of residuals.

The results are summarised in Tab.D, which summarises the solutions obtained from the varied methods. This table also contains the values of the so called "current macroseismic parameters", that are, the values which one user would adopt today from the national catalogues.
Tab.E presents: i) the differences among instrumental Mw and macroseismic values obtained in this phase; ii) the distances among relevant instrumental and macroseismic locations.
sTab.F presents the reference codes.

Individual maps with results are available at the webpage

http://emidius.mi.ingv.it/neries_NA4/calibration/val_maps/
username: NA4
password: calib

The results are also analysed in the following plots. For each area (AE = Aegean; IB = Iberia; IT = Italy; UK = Great Britain; CH = Switzerland) 5 to 6 plots are presented, where Mw calculated with varied method and calibrations are displayed against instrumental ones (Mw_inst.) with relevant standard deviation, when available (Fig.5.1 to 5.28). The first one displays all Mw together, the other four or five display one calculated Mw each. Large gaps between Mw (inst.) and Mw from BW method may still flag solutions which did not converge.

Large gaps in the distance may affect Mw values. For a more comprehensive analysis, five more plots, one for each area, are proposed, where differences among Mw obtained with varied methods and Mw_inst. are plotted against distances among the relevant locations (Fig.5.29 to 5.33). “Wild” cases are flagged with the date.

6. Conclusion

The main scope of the initiative was to provide reliable, regional parameters for the three methods (Boxer, BW, Meep), to be used ASAP for the determination of the parameters of the NA4 events.

The results show varied patterns which cannot be easily used for assessing preferences among methods and calibrations. Therefore, as already agreed, the three methods will be applied.
As a general feeling, the number of events in the calibration datasets (around fifteen) may be too small for areas where M covers a broad range and tectonic settings are rather different.
On the other hand, providing fifteen reliable events was difficult for some areas, which makes impossible to propose a more detailed regionalisation.

Meep and Boxer coefficients are determined by ad hoc procedures; although some values of the Q, coefficient in Meep may appear unrealistic, they will be used as they are. This is largely due to a problem of non-uniqueness in the trade-off between different parameters. This also affects other applications of Q, notably in studies that involve both Q and corner frequency (Rietbrock 2009, pers. comm.).

As for the BW method, the following relations will be adopted:

Aegean	Papazachos and Papaioannou, 1997. It seems better performing and it has been calibrated by means of a larger dataset;
Iberia	NA4. It does not perform much better than the one by Mezcua et al. 2004, but the lattest was calibrated against a smaller dataset;
Italy	NA4. It can be improved by using a larger dataset;
UK	NA4 (Ic3). It seems to perform better, because of good reporting of low intensities, many observations coded as “felt” may be as low as intensity 2.
CH	Regionalised relations were out of the scope of the initiative. The only suitable relationship at this stage is NA4. However, as ETHZ is performing an independent calibration campaign, NA4 will adopt Mw values supplied by ETHZ.

The final set of relations and coefficients adopted for the next NA4 phase (determining parameters of historical events) is presented in Tab.G.

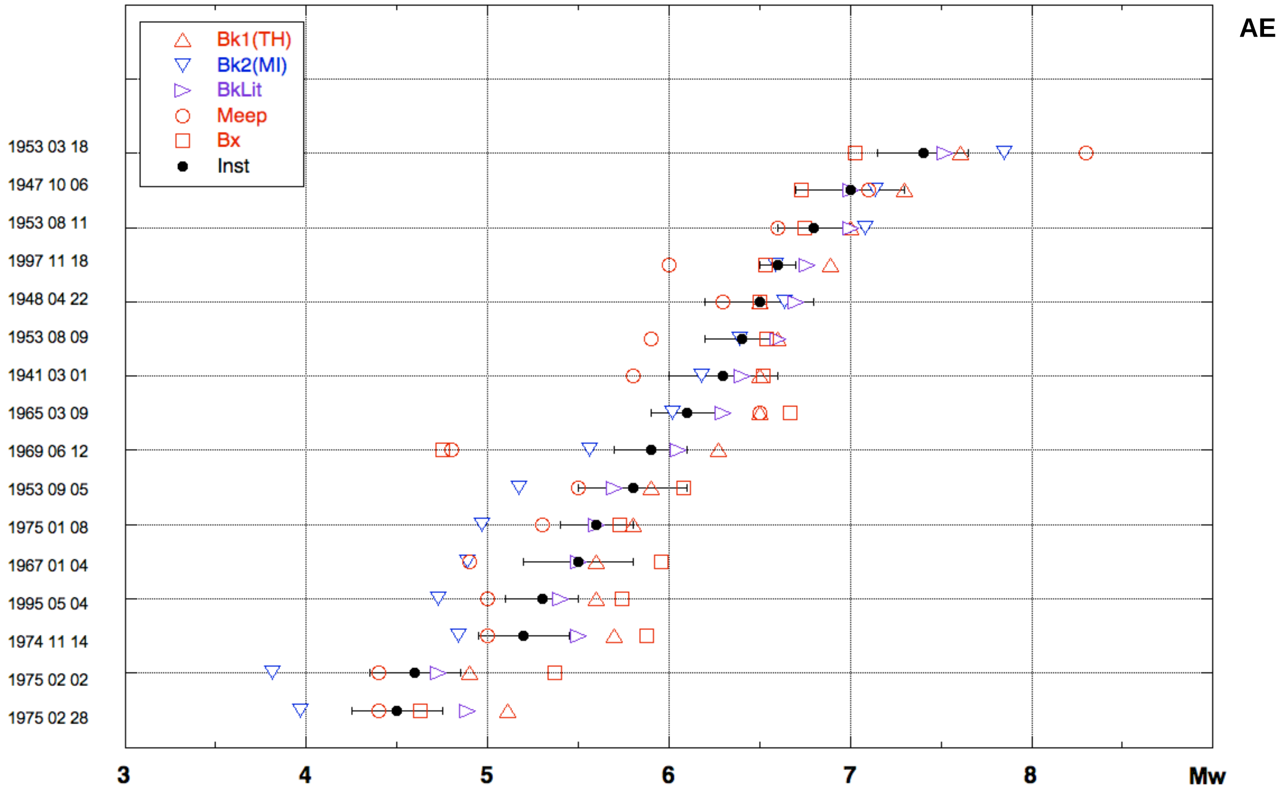


Fig.5.1 – Aegean area: plot of instrumental and calculated (all) Mw.

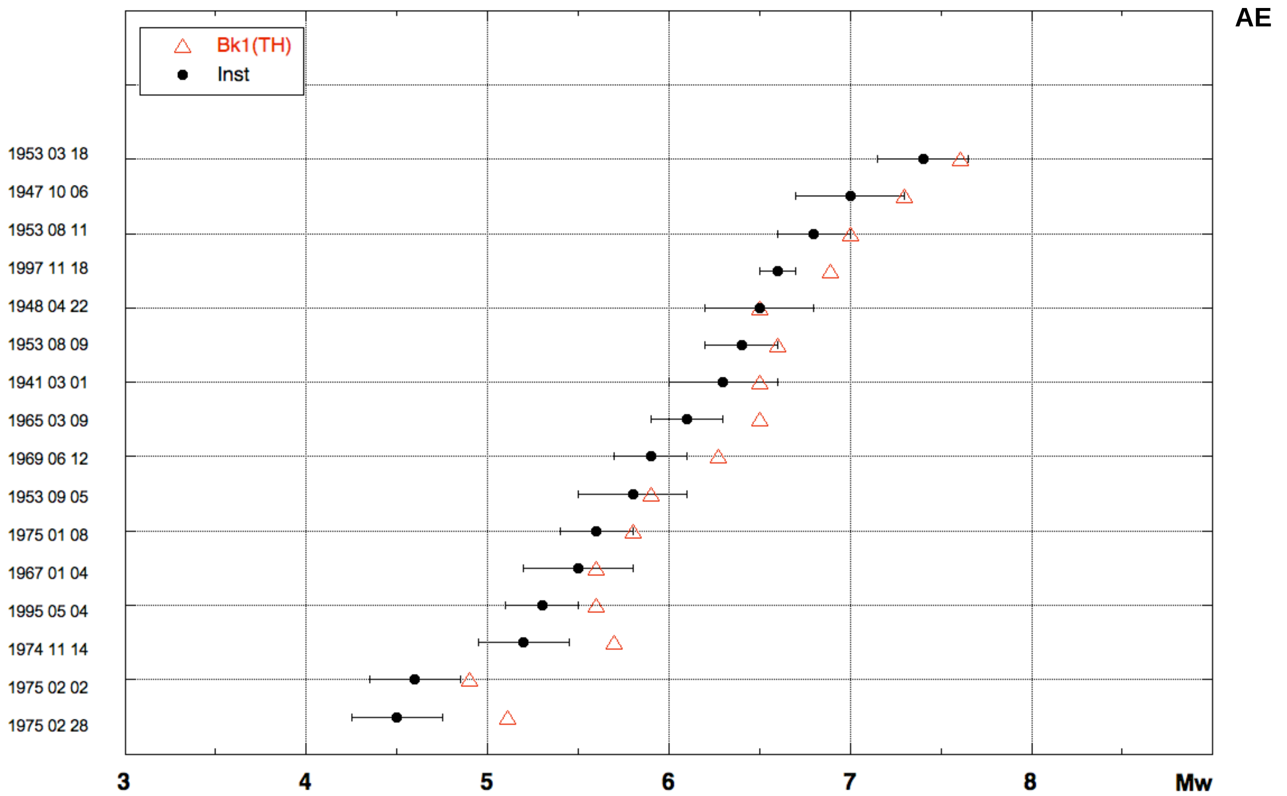


Fig.5.2 – Aegean area: plot of instrumental and calculated (BW, NA4 calibr., Thess.) Mw.

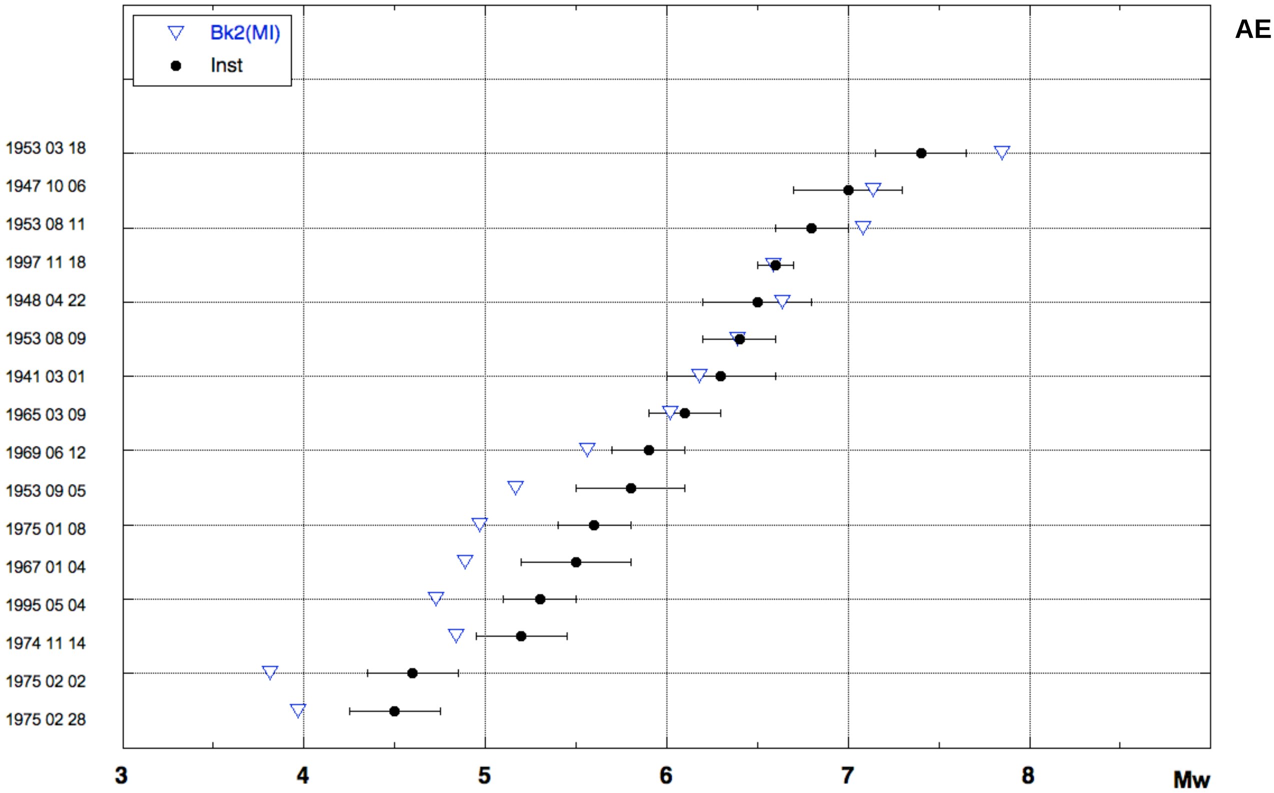


Fig.5.3 – Aegean area: plot of instrumental and calculated (BW, NA4 calibr., Milan) Mw.

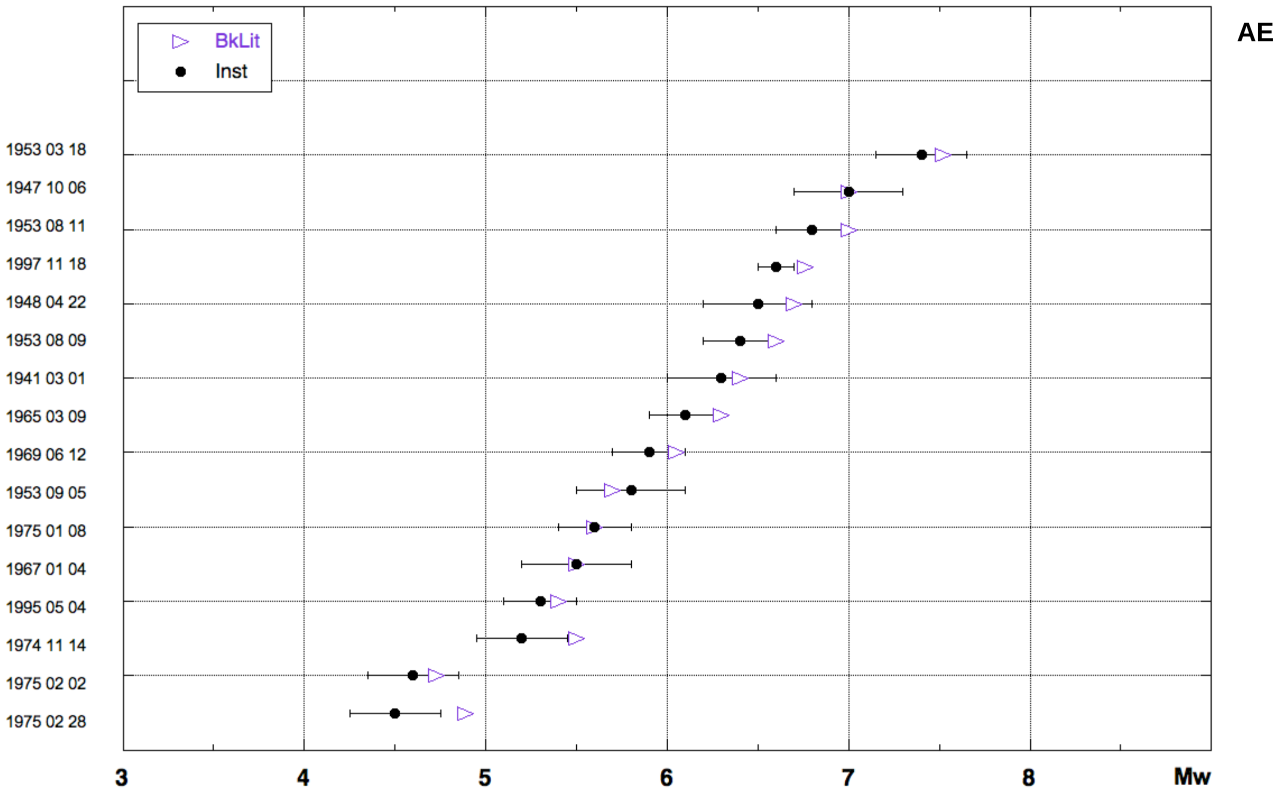


Fig.5.4 – Aegean area: plot of instrumental and calculated (BW, Papazachos and Papaioannou, 1997) Mw.

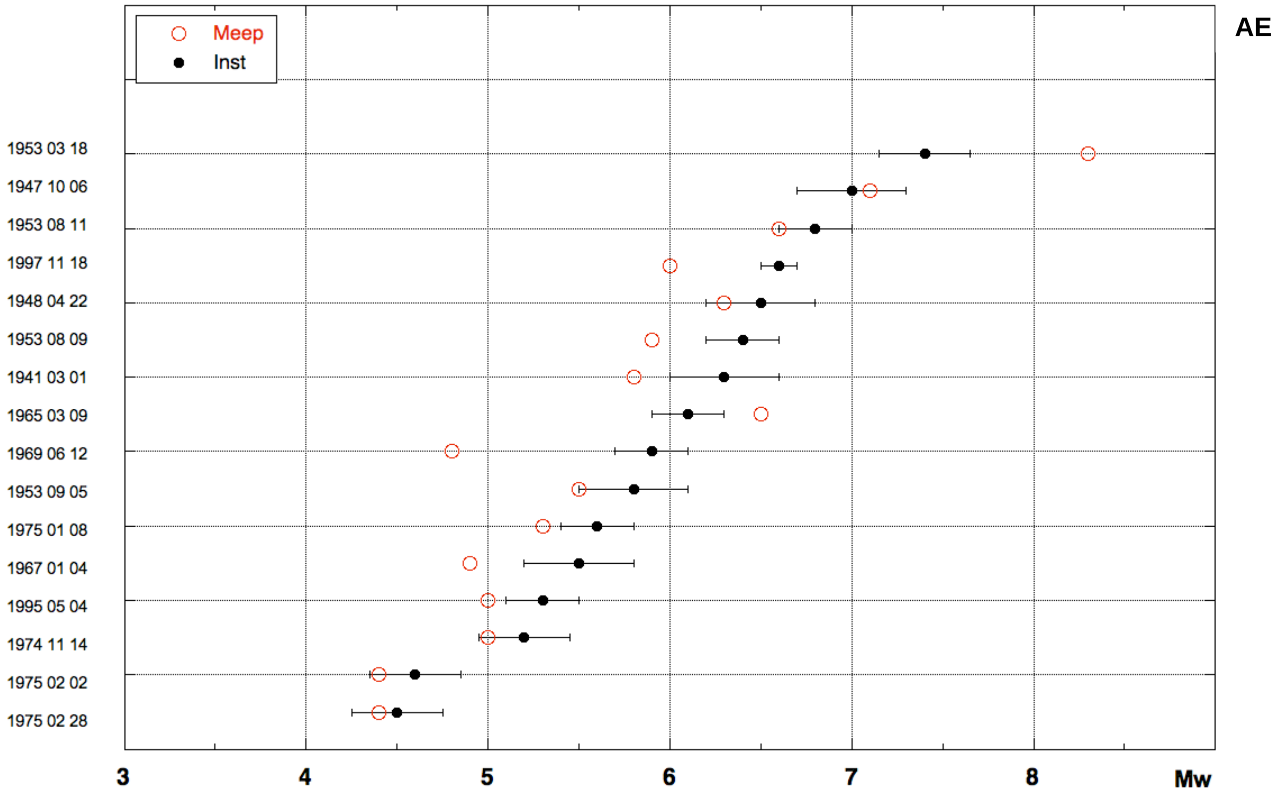


Fig.5.5 – Aegean area: plot of instrumental and calculated (Meep, NA4) Mw.

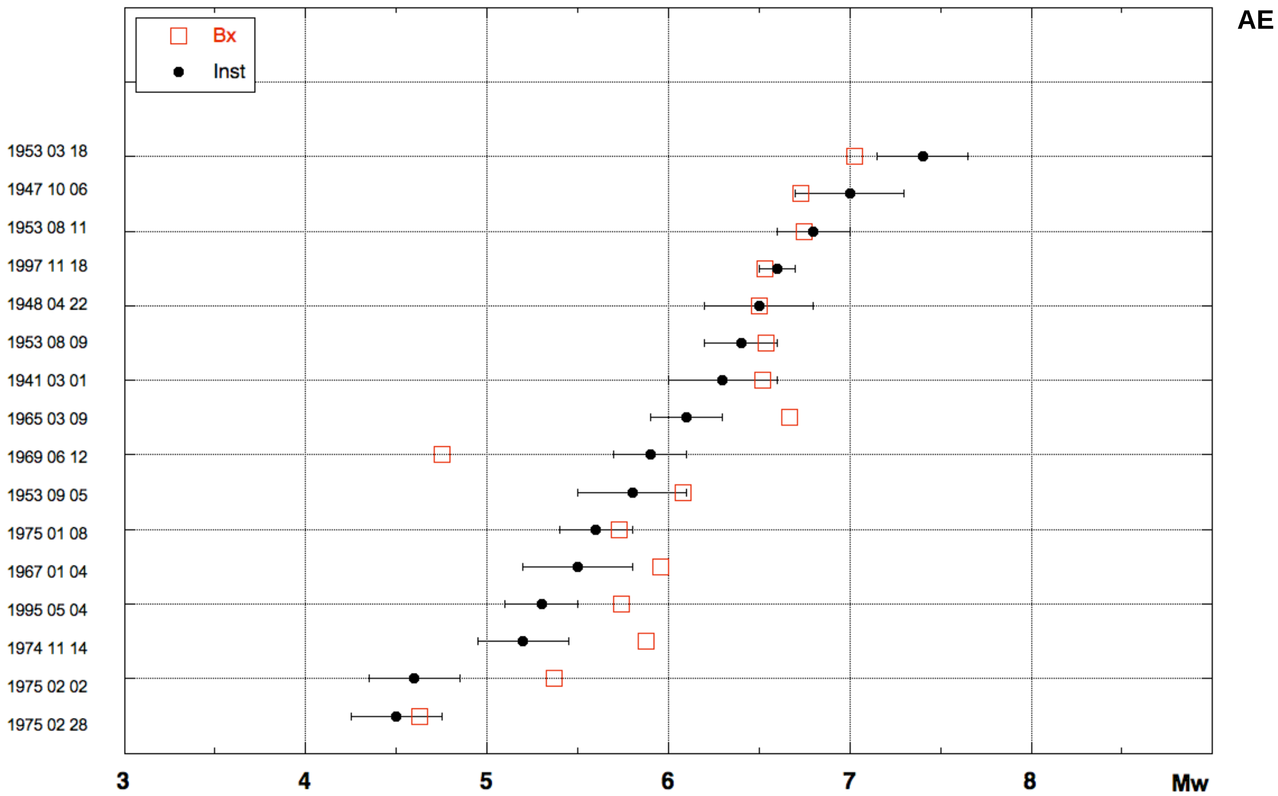


Fig.5.6 – Aegean area: plot of instrumental and calculated (Boxer, NA4) Mw.

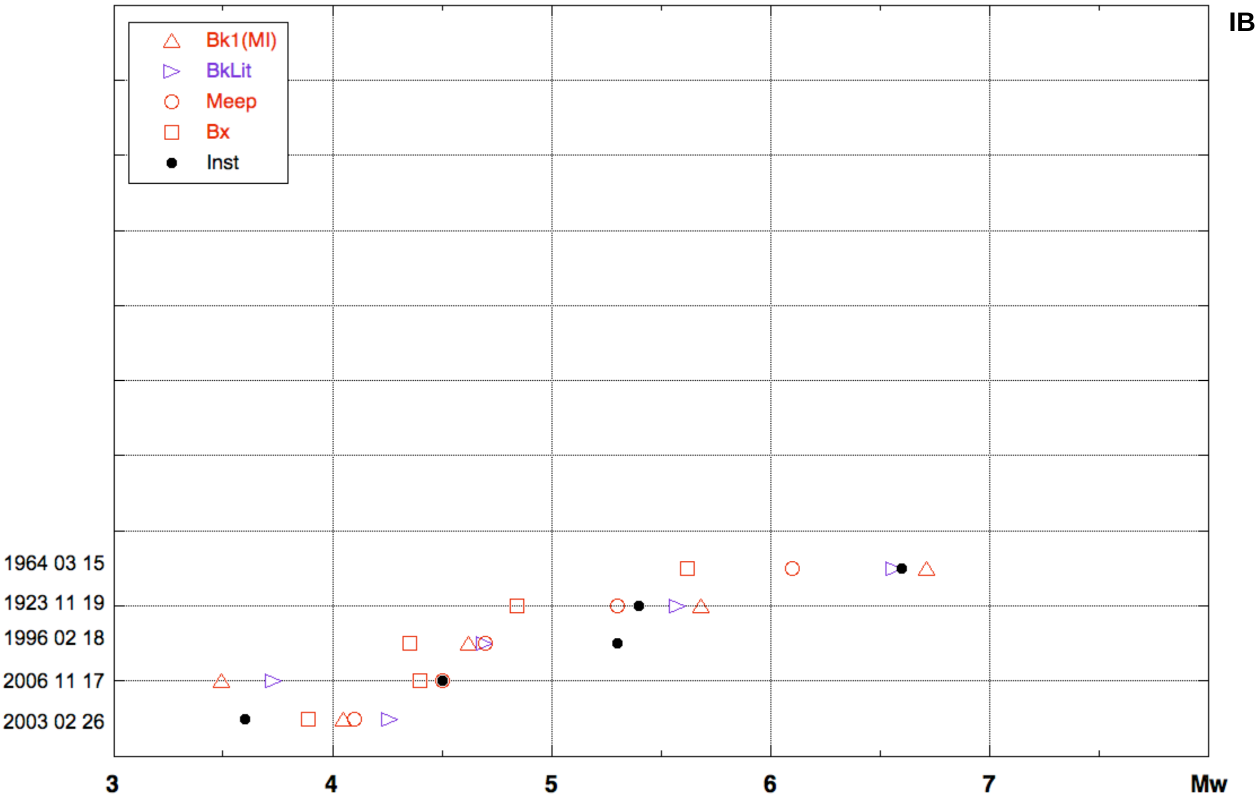


Fig.5.7 – Iberian area: plot of instrumental and calculated (all) Mw.

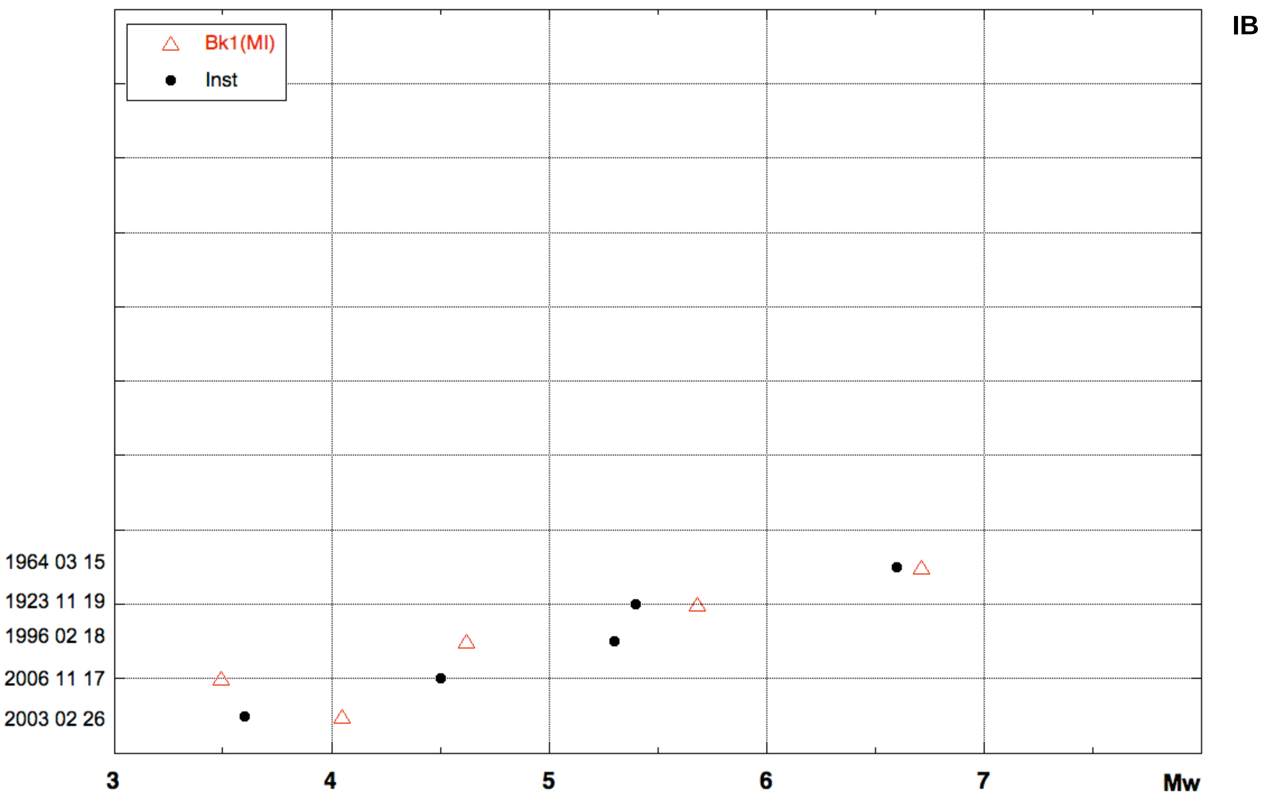


Fig.5.8 – Iberian area: plot of instrumental and calculated (BW, NA4 calibr., Milan) Mw.

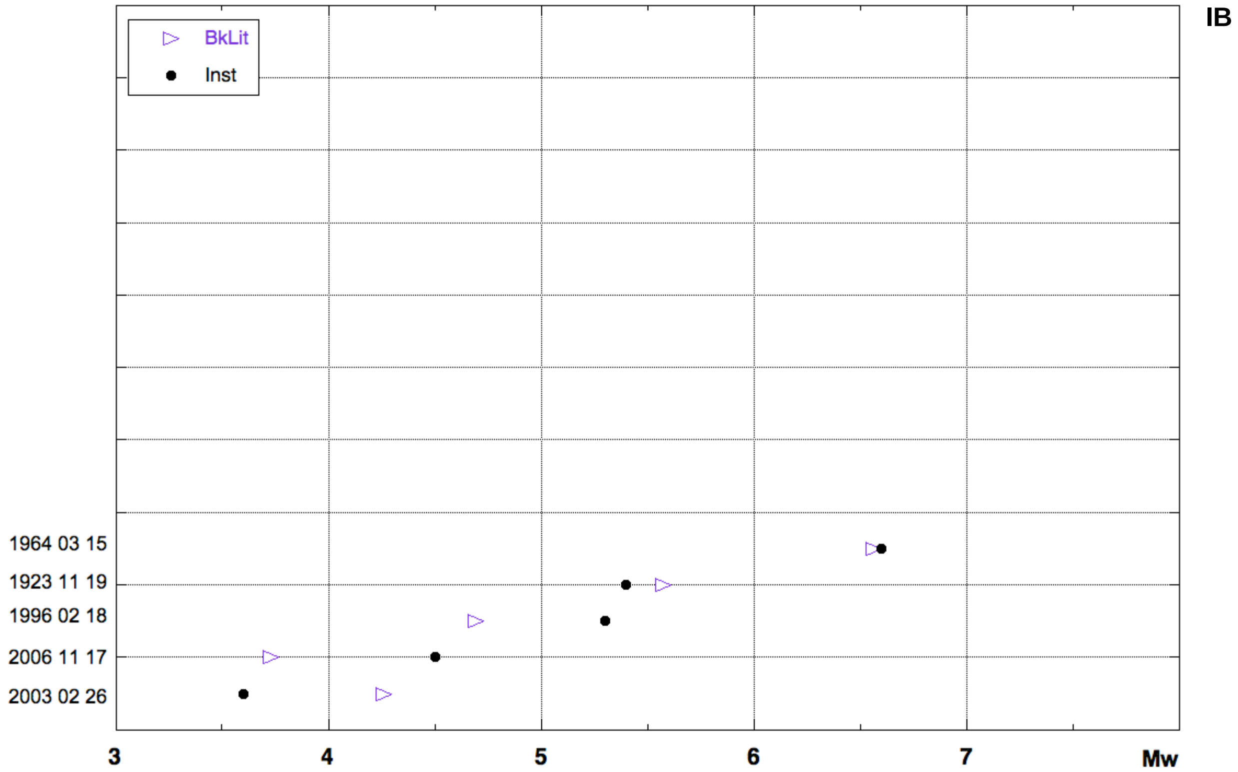


Fig.5.9 – Iberian area: plot of instrumental and calculated (BW, Mezcua et al., 2004) Mw.

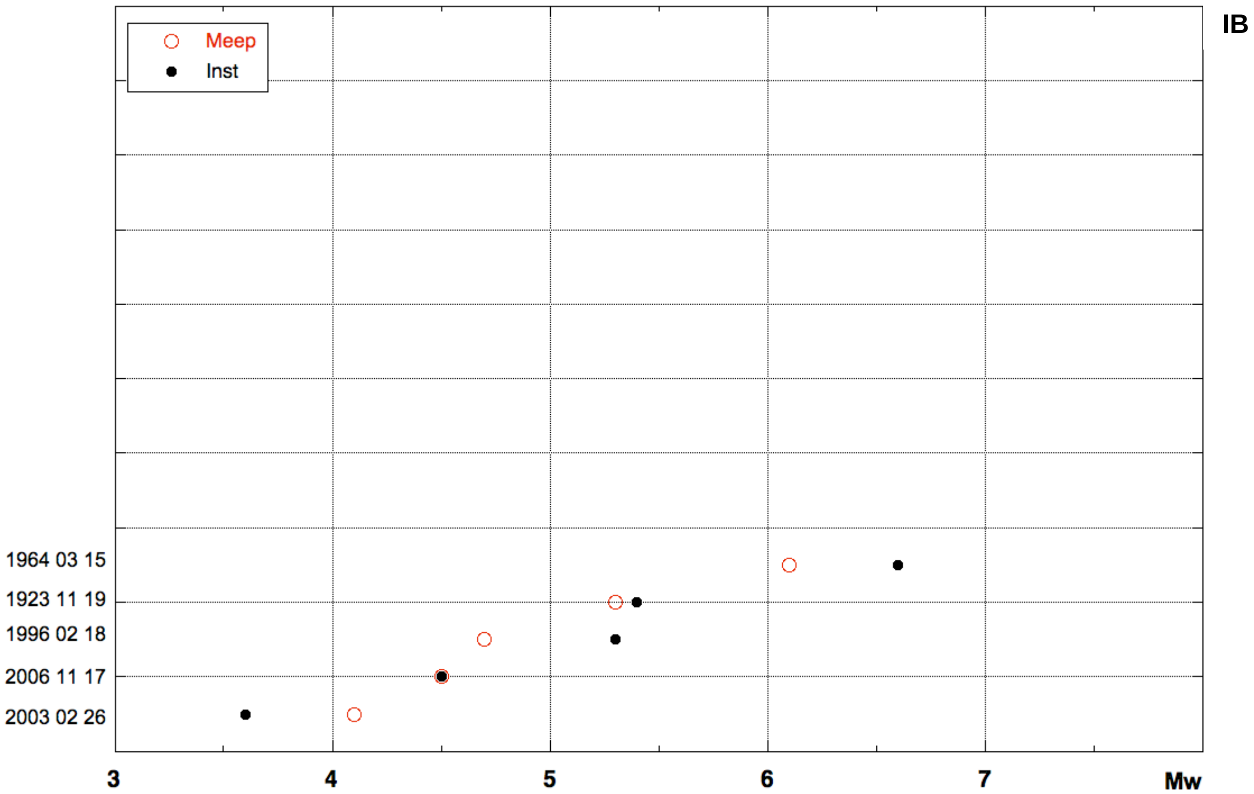


Fig.5.10 – Iberian area: plot of instrumental and calculated (Meep, NA4) Mw.

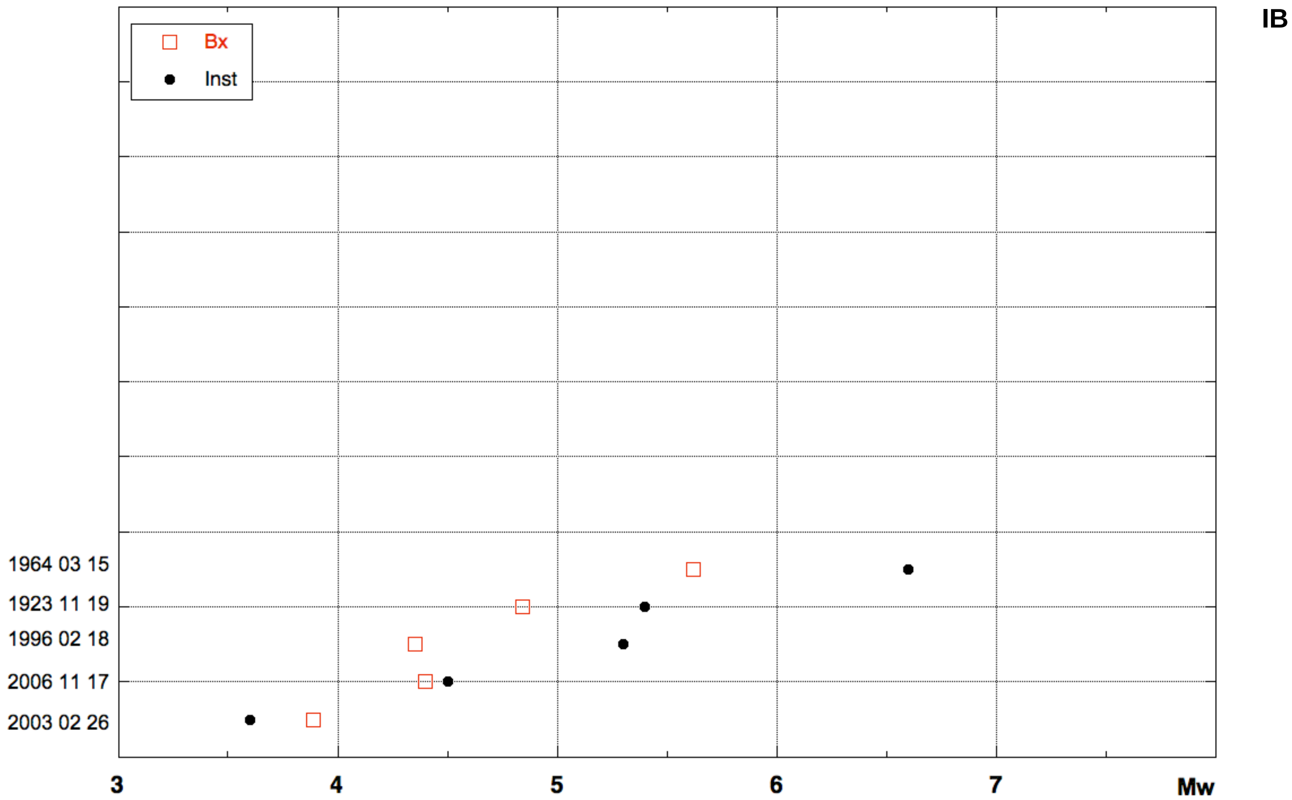


Fig.5.11 – Iberian area: plot of instrumental and calculated (Boxer, NA4) Mw.

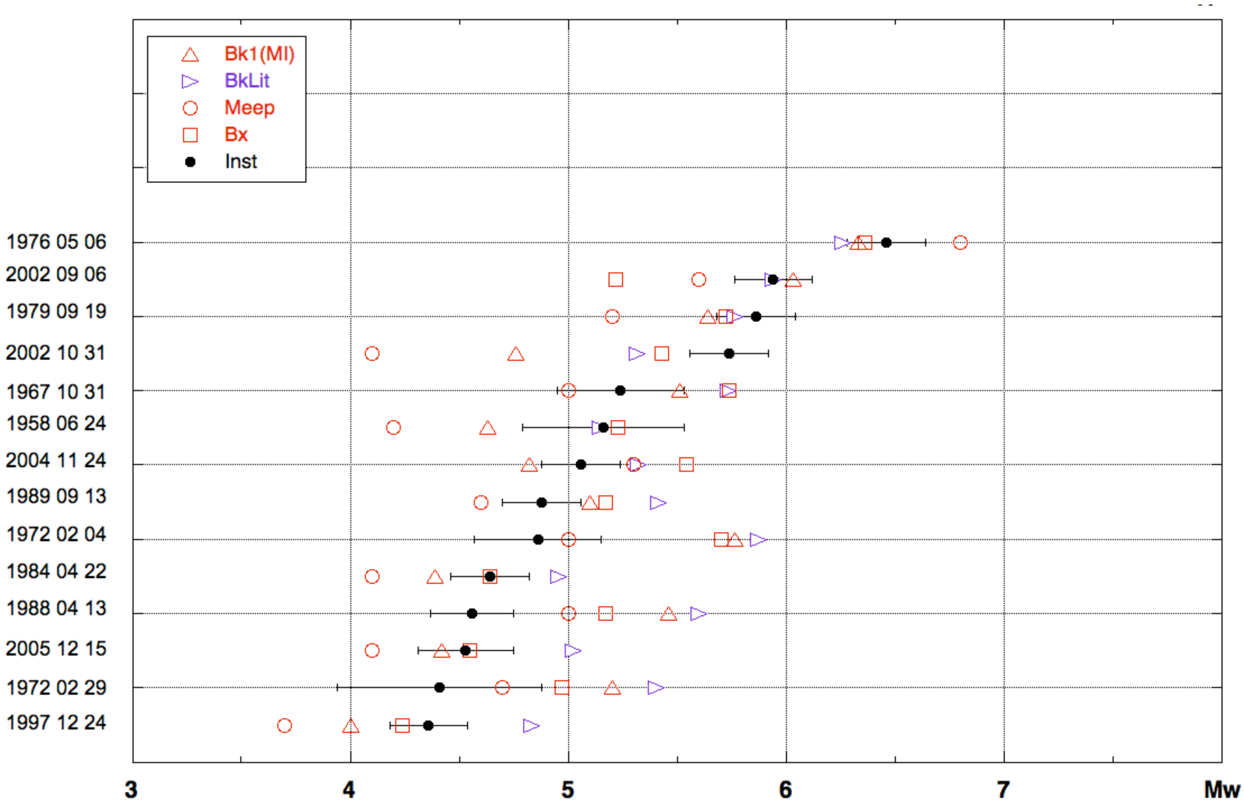


Fig.5.12 – Italian area: plot of instrumental and calculated (all) Mw.

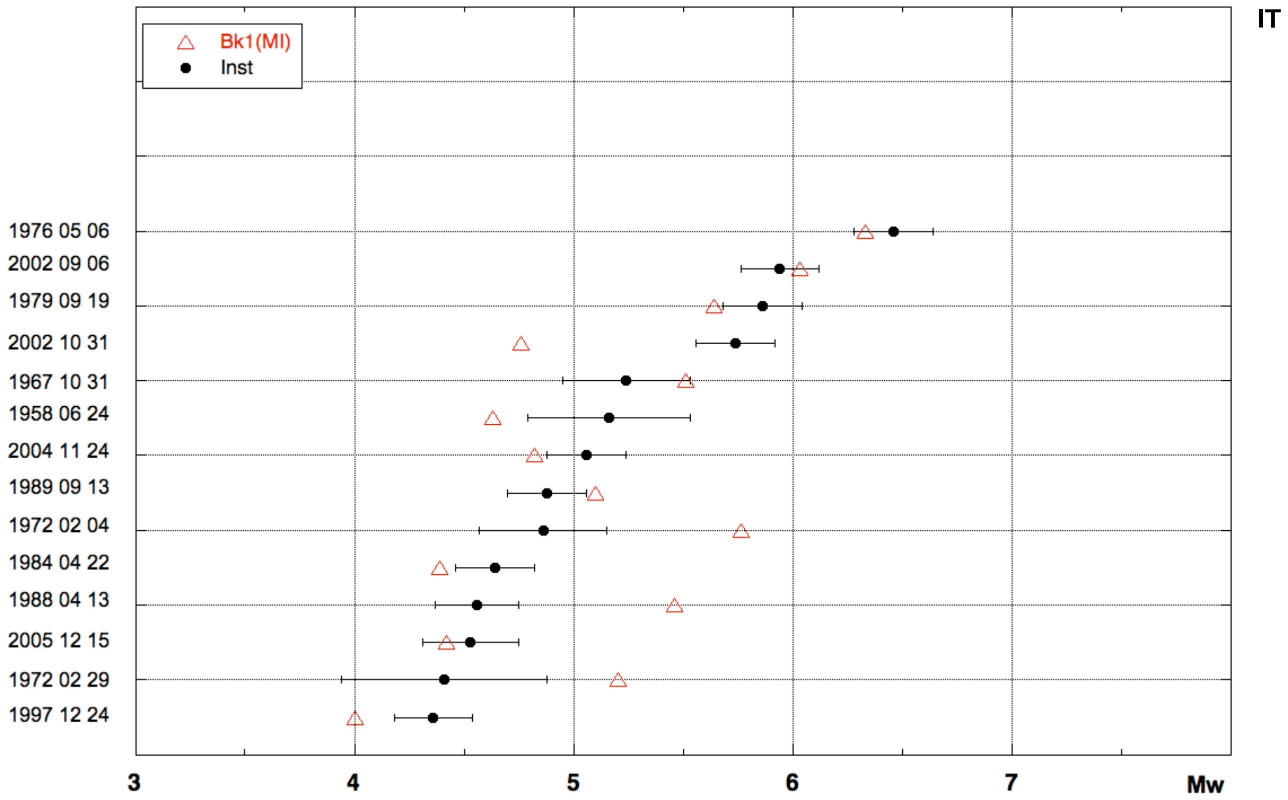


Fig.5.13 – Italian area: plot of instrumental and calculated (BW, NA4 calibr.) Mw.

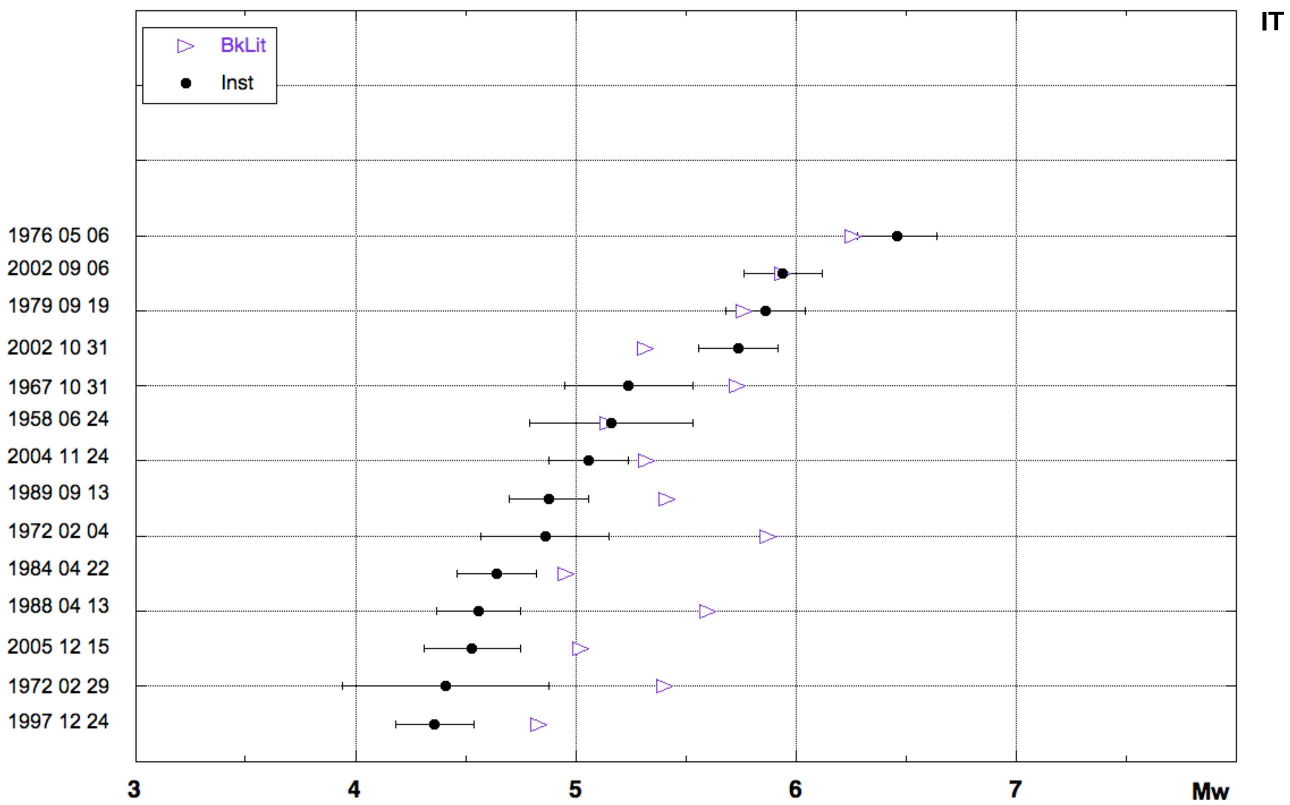


Fig.5.14 – Italian area: plot of instrumental and calculated (BW, Pasolini et al., 2008) Mw.

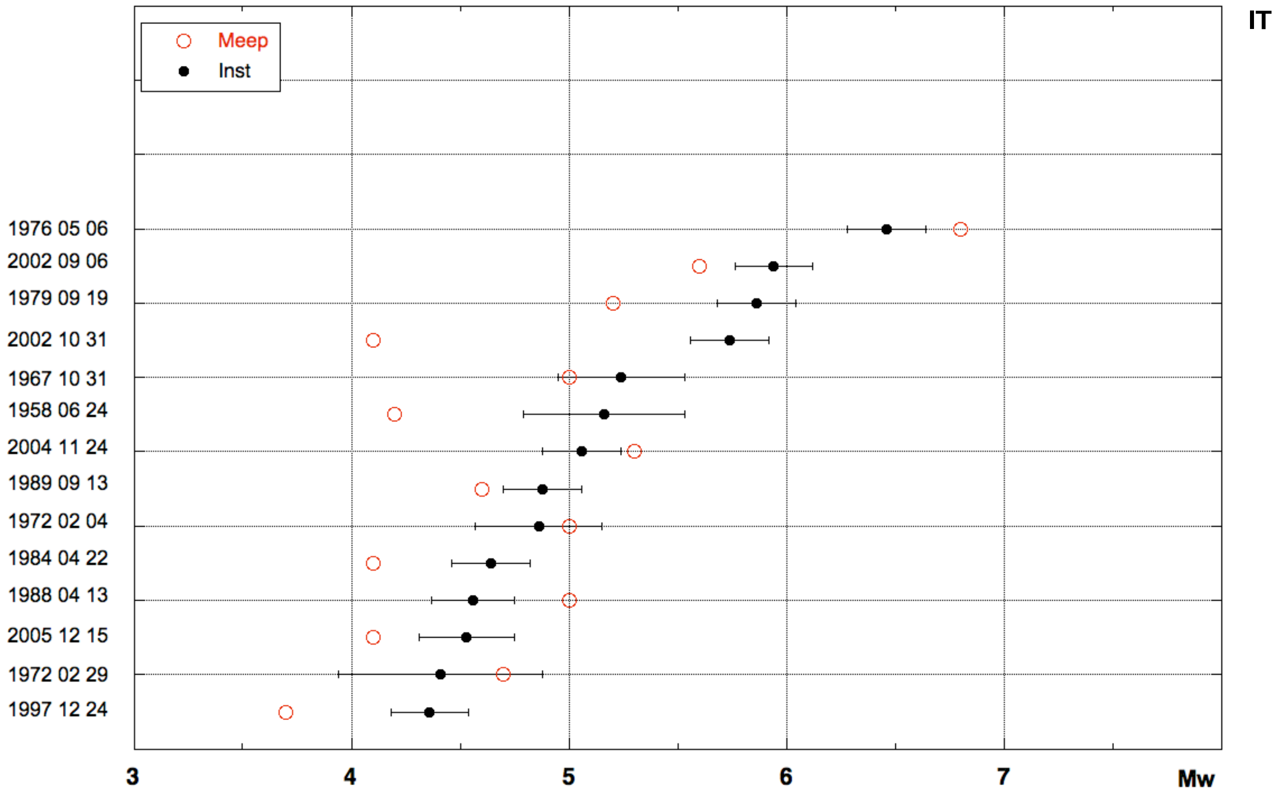


Fig.5.15 – Italian area: plot of instrumental and calculated (Meep, NA4) Mw.

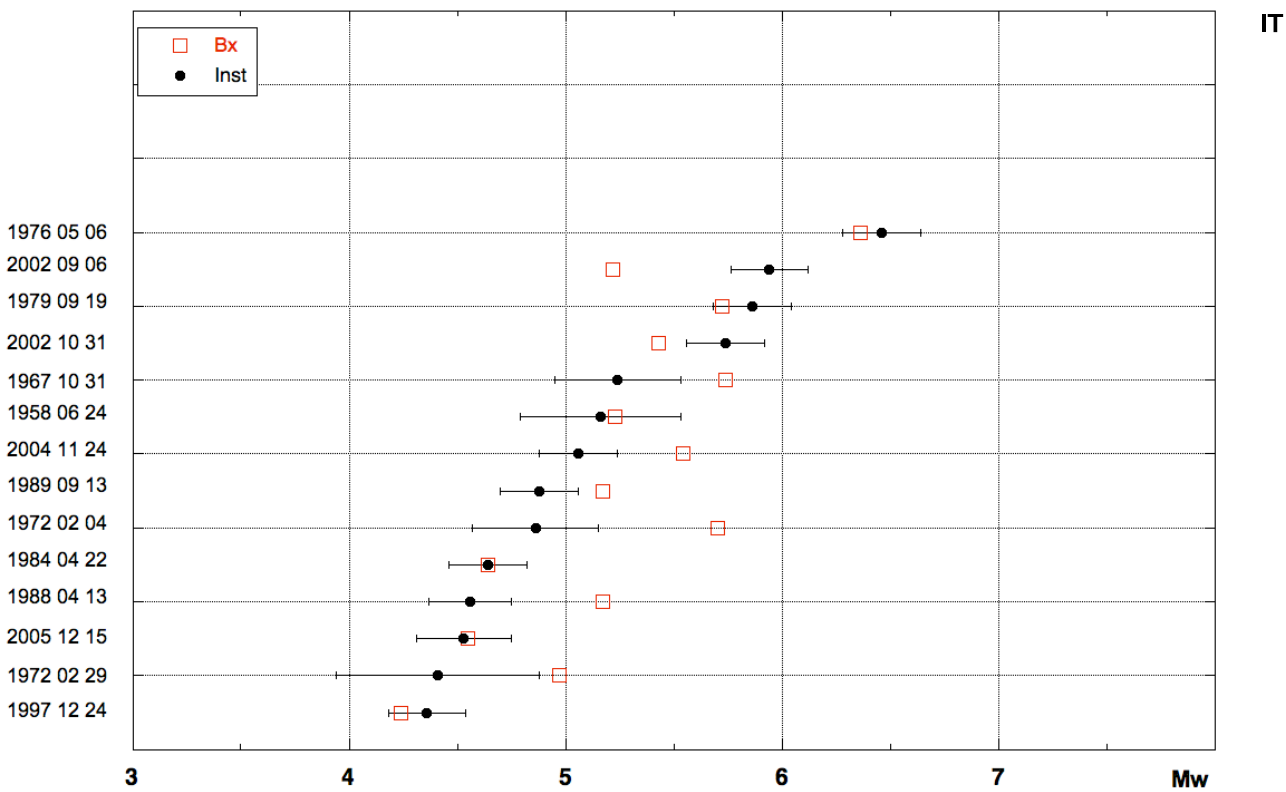


Fig.5.16 – Italian area: plot of instrumental and calculated (Boxer, NA4) Mw.

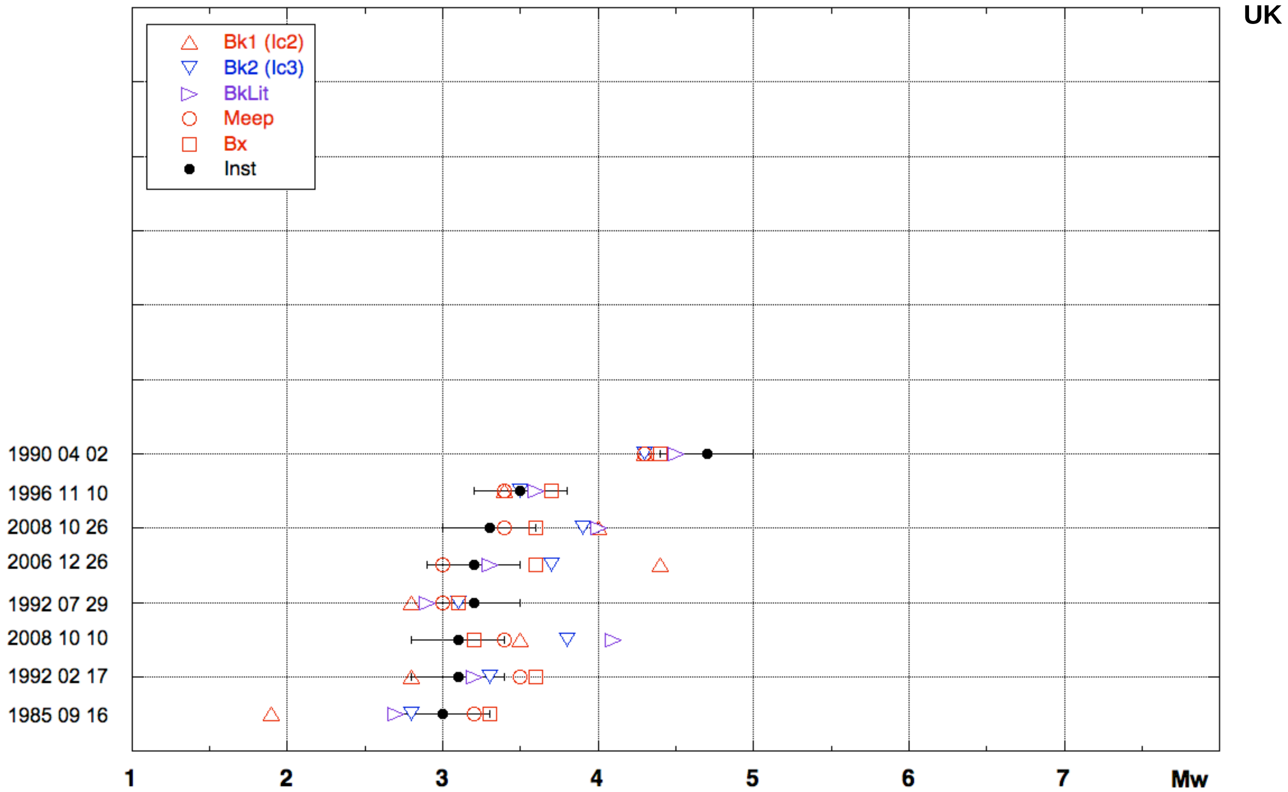


Fig.5.17 – Great Britain area: plot of instrumental and calculated (all) Mw.

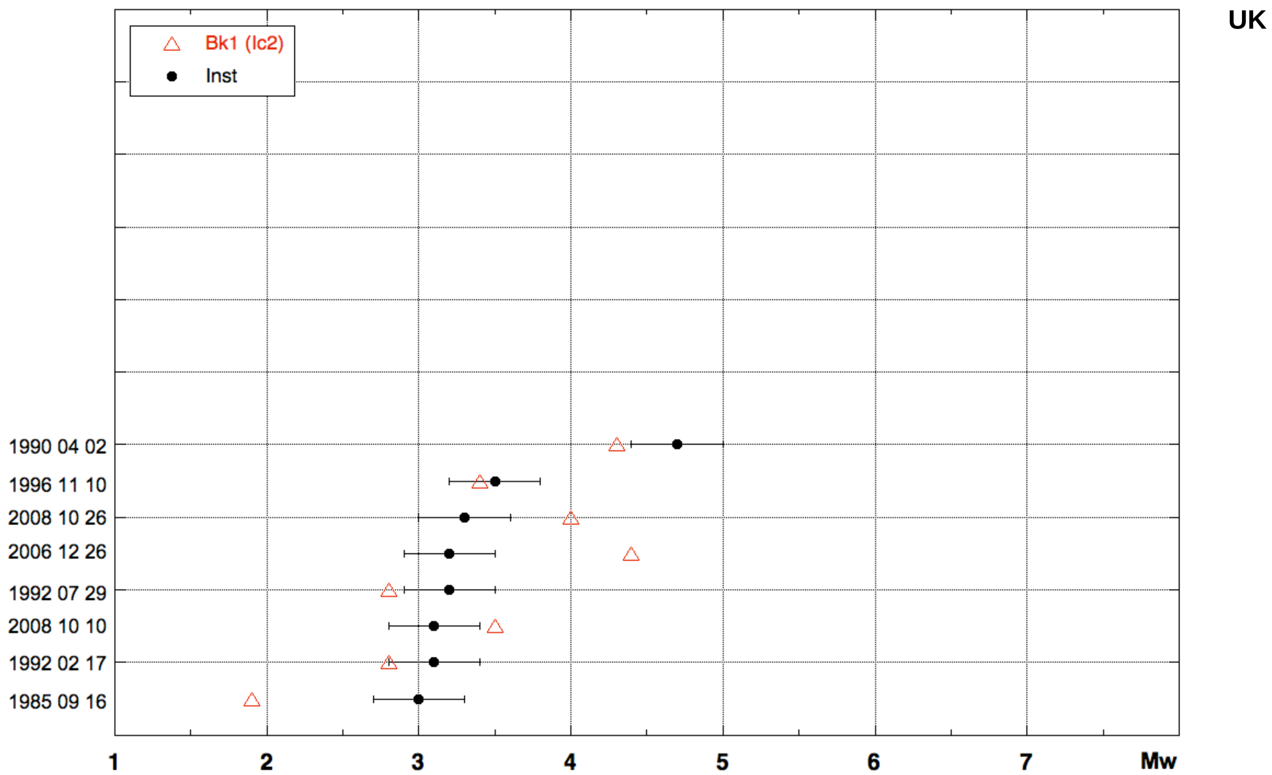


Fig.5.18 – Great Britain area: plot of instrumental and calculated (BW, NA4, Ic2) Mw.

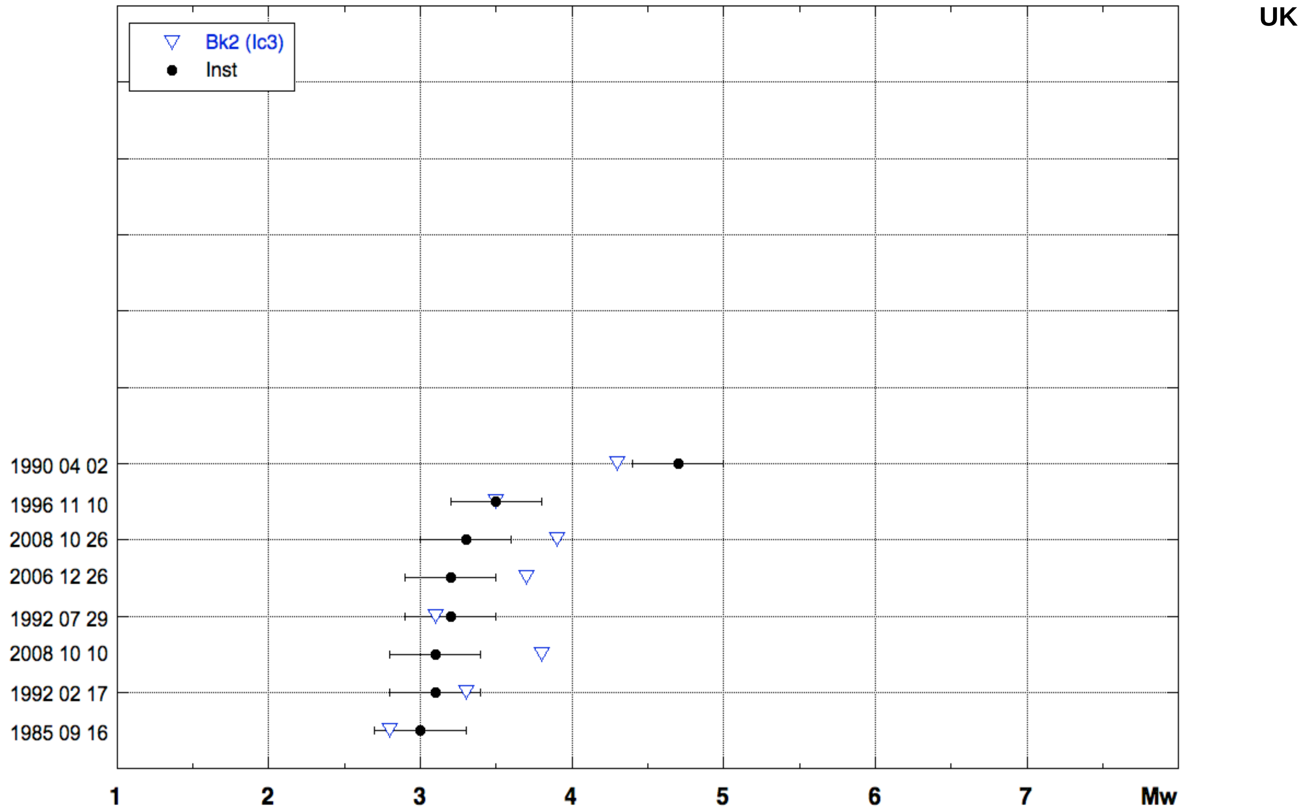


Fig.5.19 – Great Britain area: plot of instrumental and calculated (BW, NA4, Ic3) Mw.

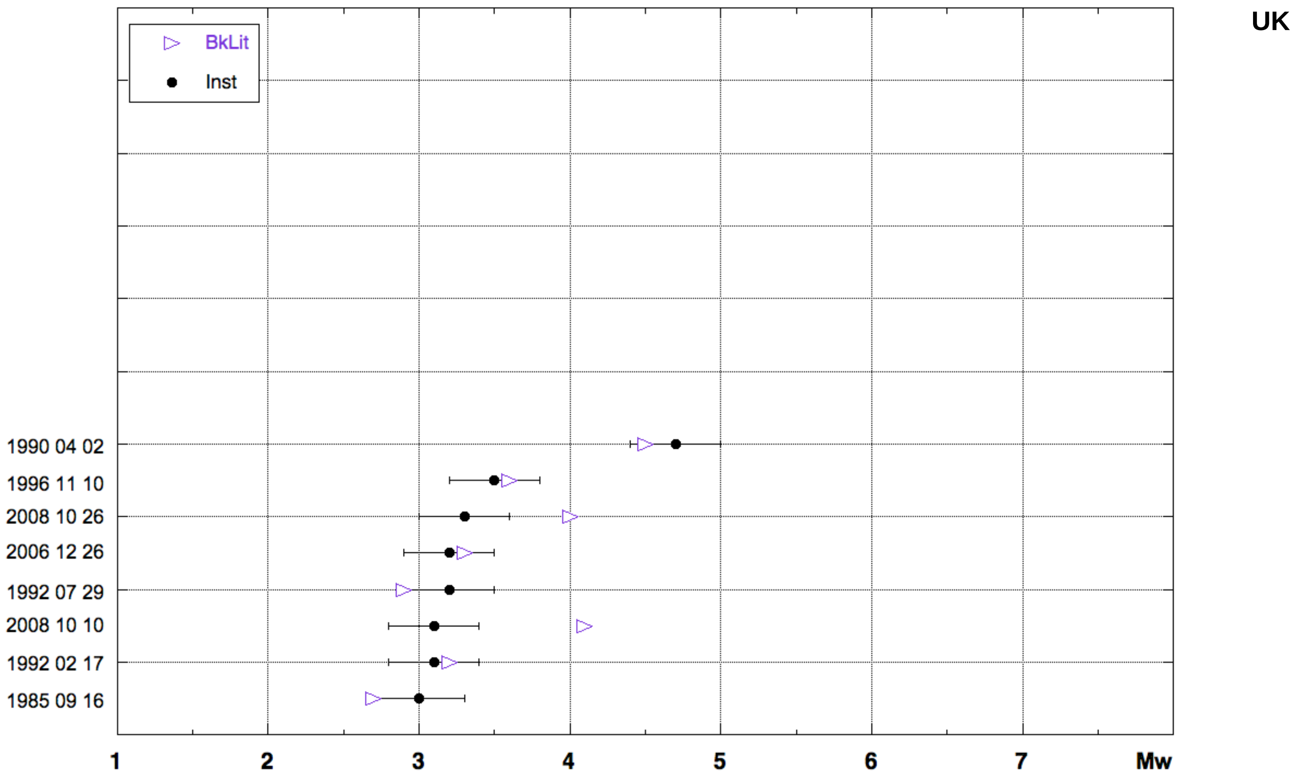


Fig.5.20 – Great Britain area: plot of instrumental and calculated (BW, Musson, 2005) Mw.

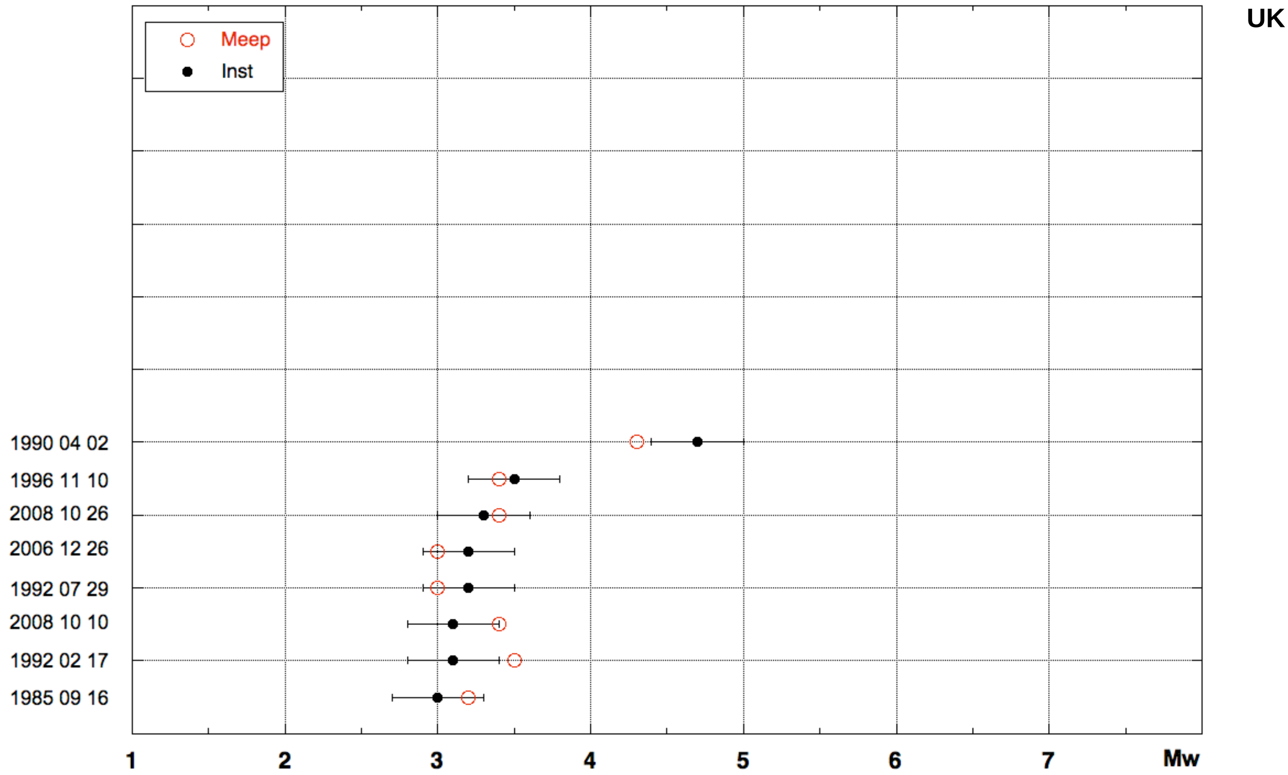


Fig.5.21 – Great Britain area: plot of instrumental and calculated (Meep, NA4) Mw.

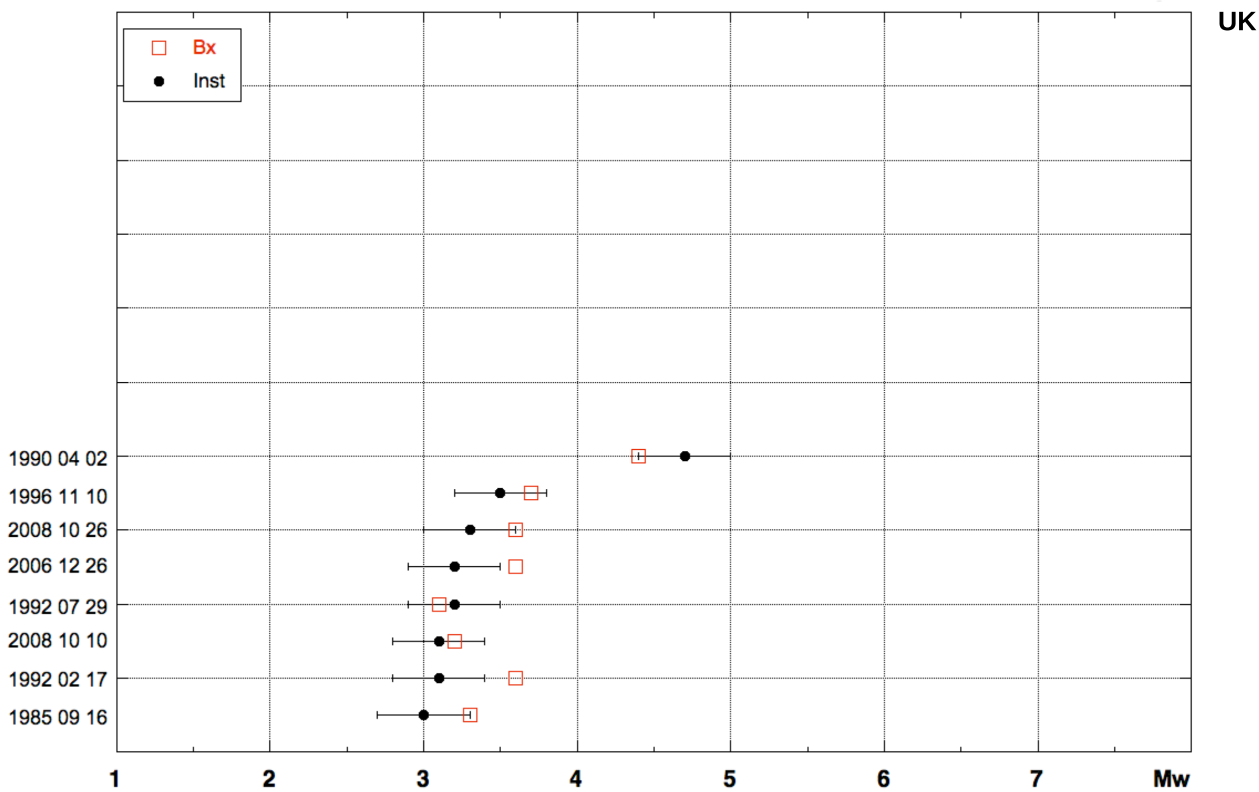


Fig.5.22 – Great Britain area: plot of instrumental and calculated (Boxer, NA4) Mw.

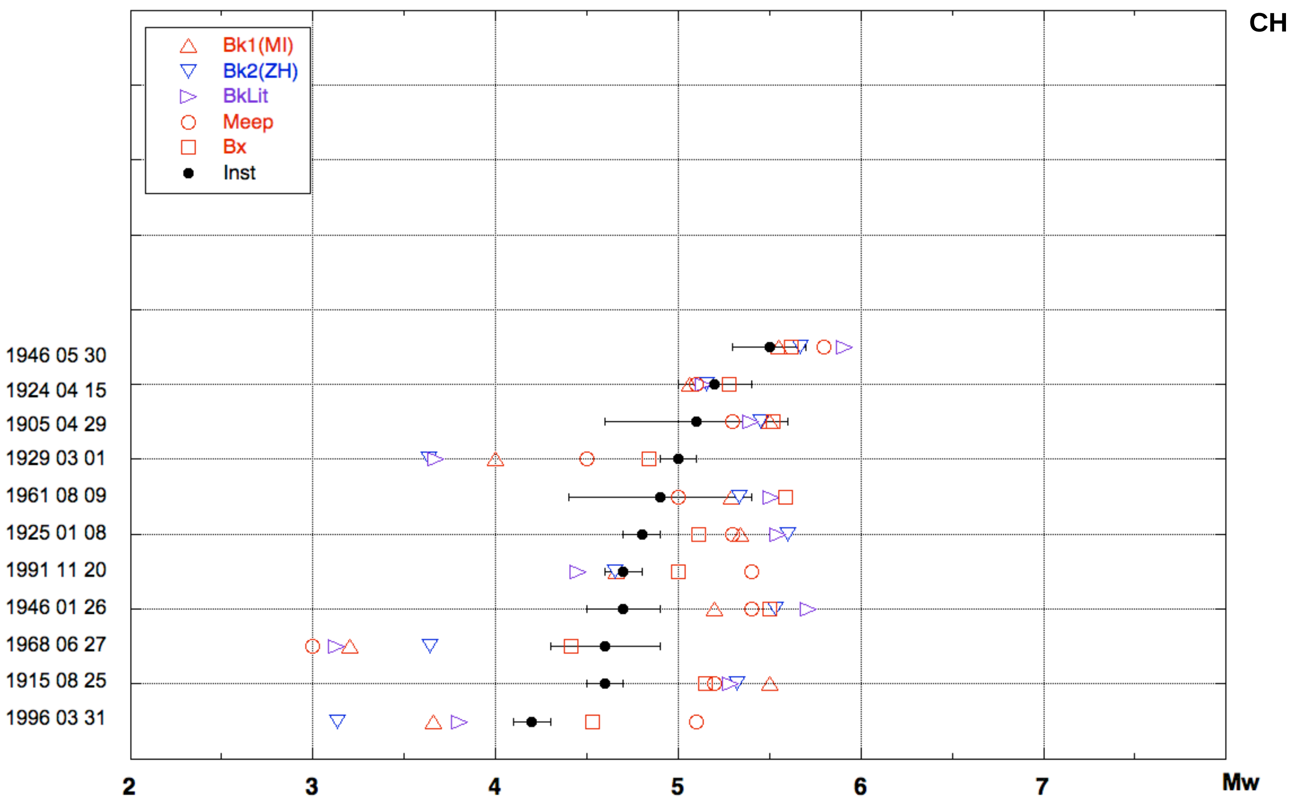


Fig.5.23 – Swiss area: plot of instrumental and calculated (all) Mw.

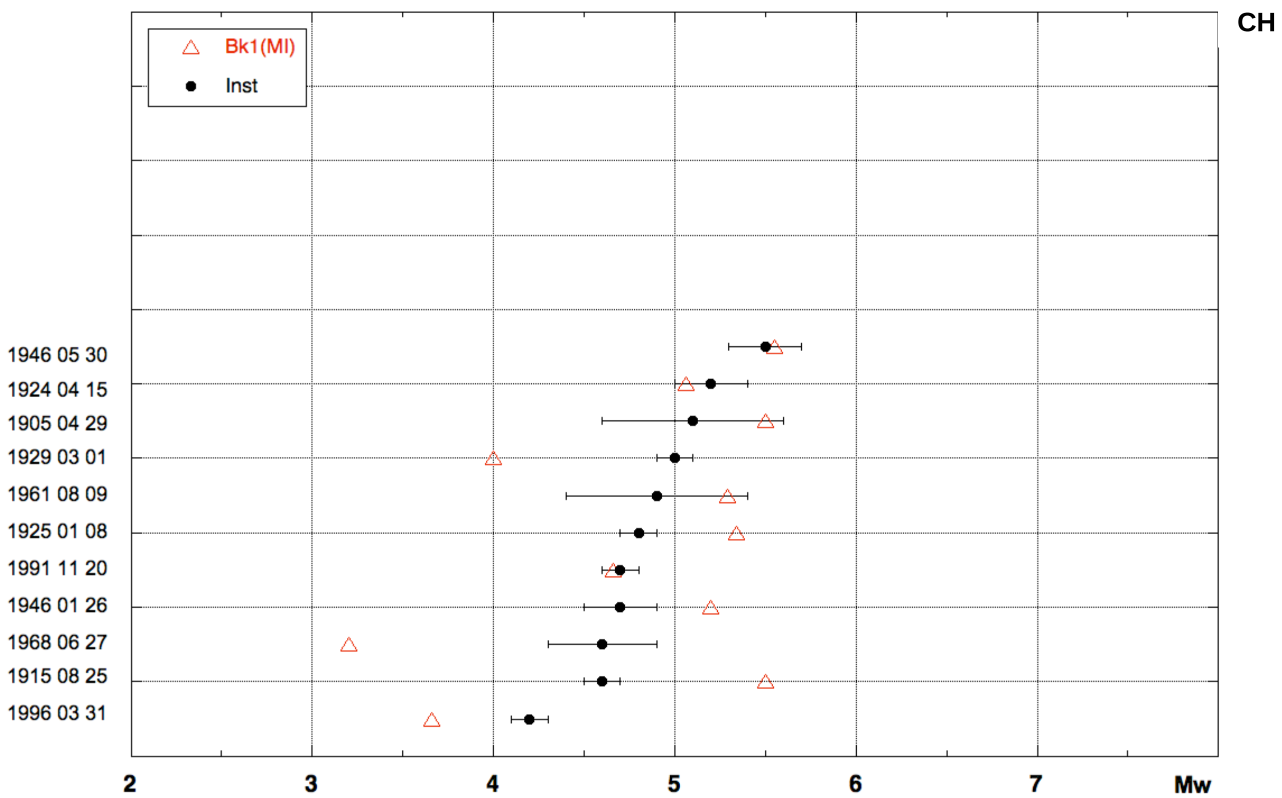


Fig.5.24 – Swiss area: plot of instrumental and calculated (BW, NA4, Milan) Mw.

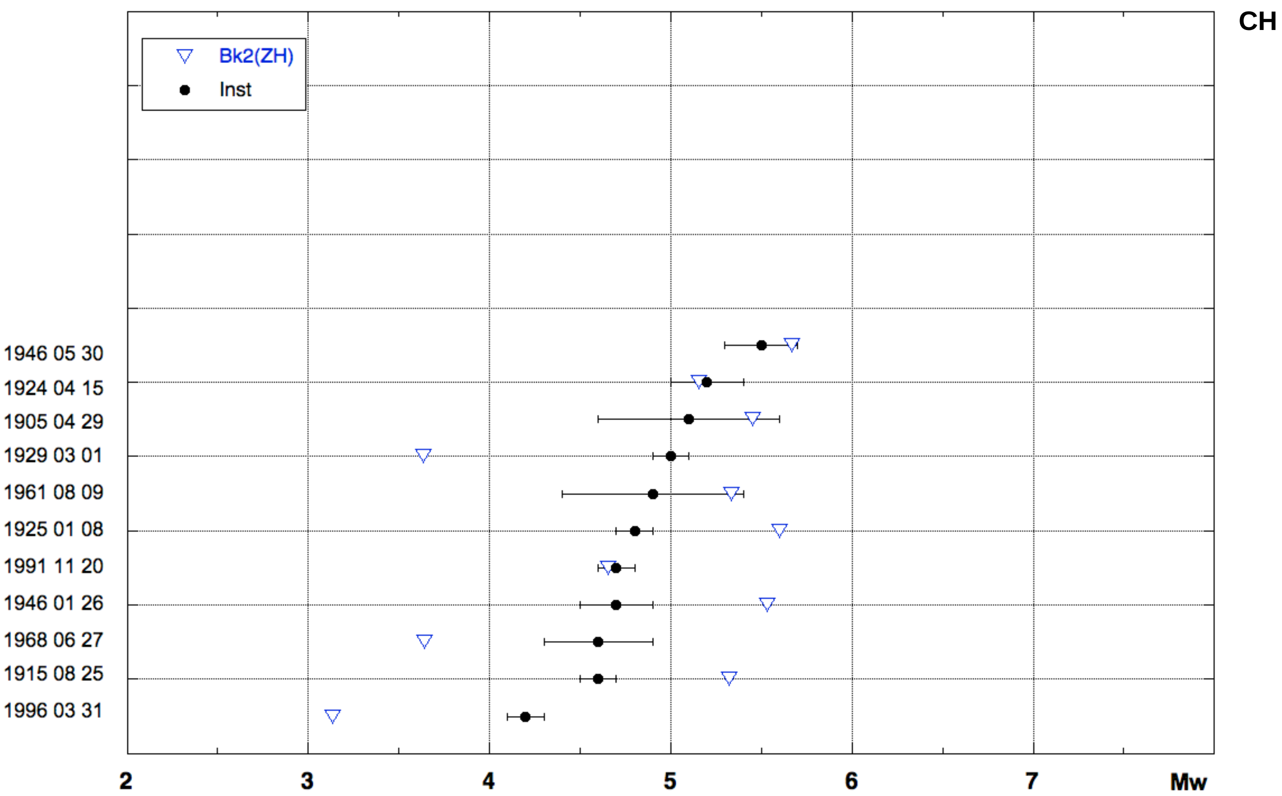


Fig.5.25 – Swiss area: plot of instrumental and calculated (BW, provided by Zuerich) Mw.

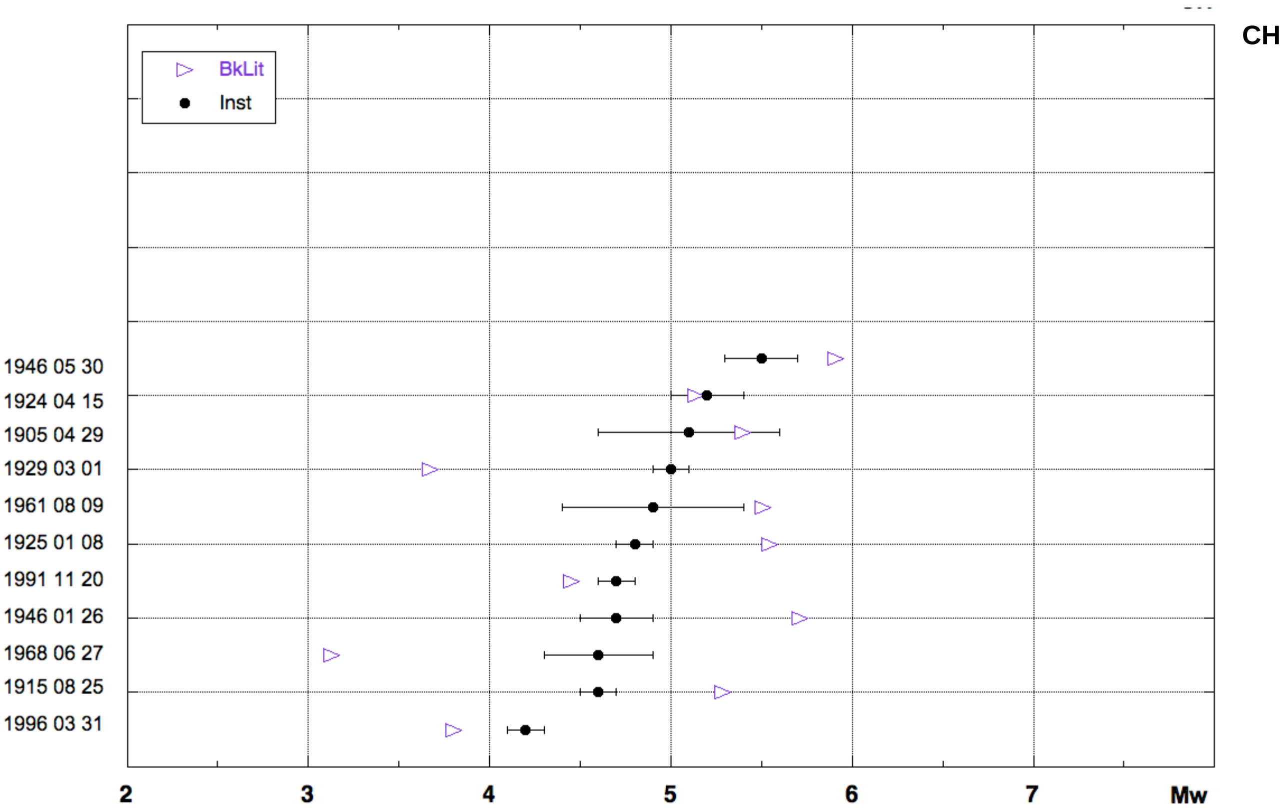


Fig.5.26 – Swiss area: plot of instrumental and calculated (BW, Hinzen and Oem., 2001) Mw.

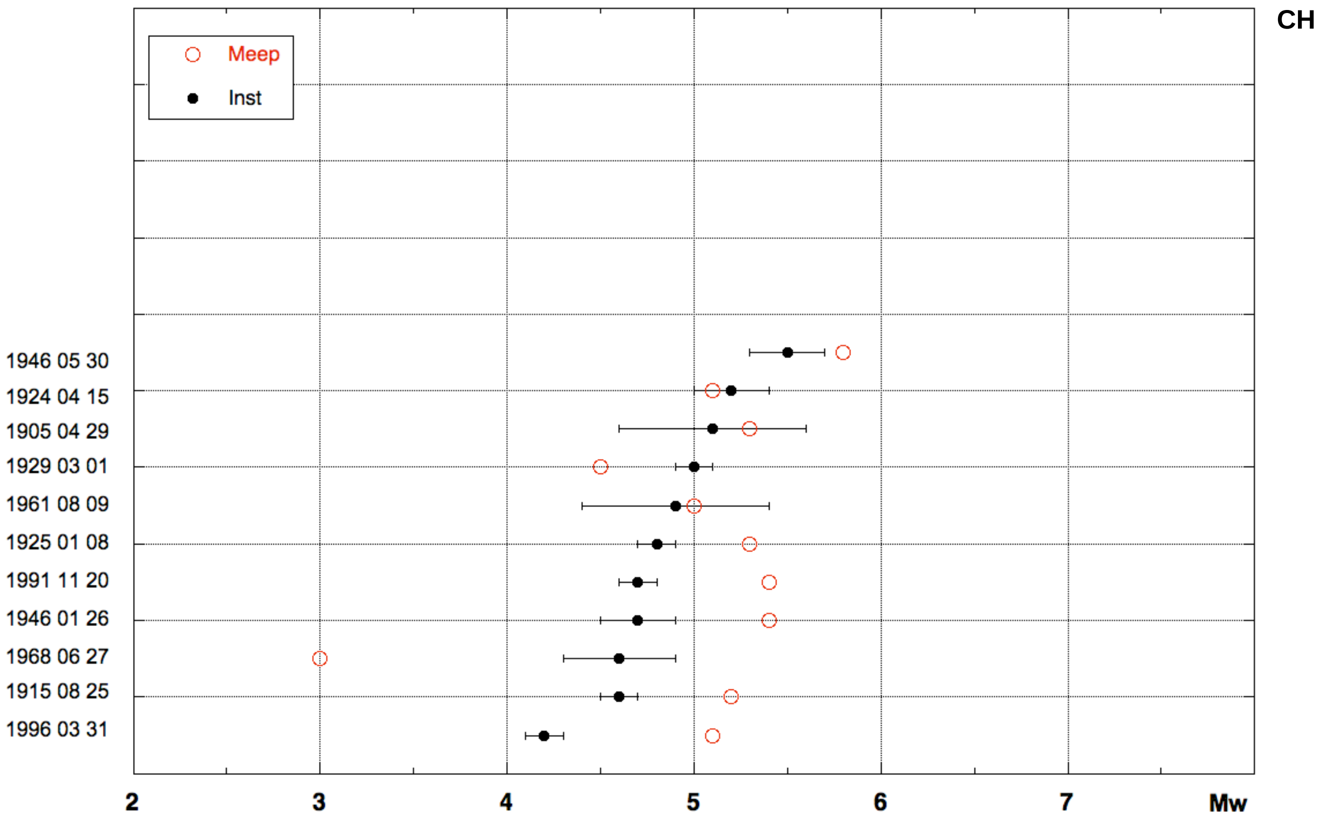


Fig.5.27 – Swiss area: plot of instrumental and calculated (Meep, NA4) Mw.

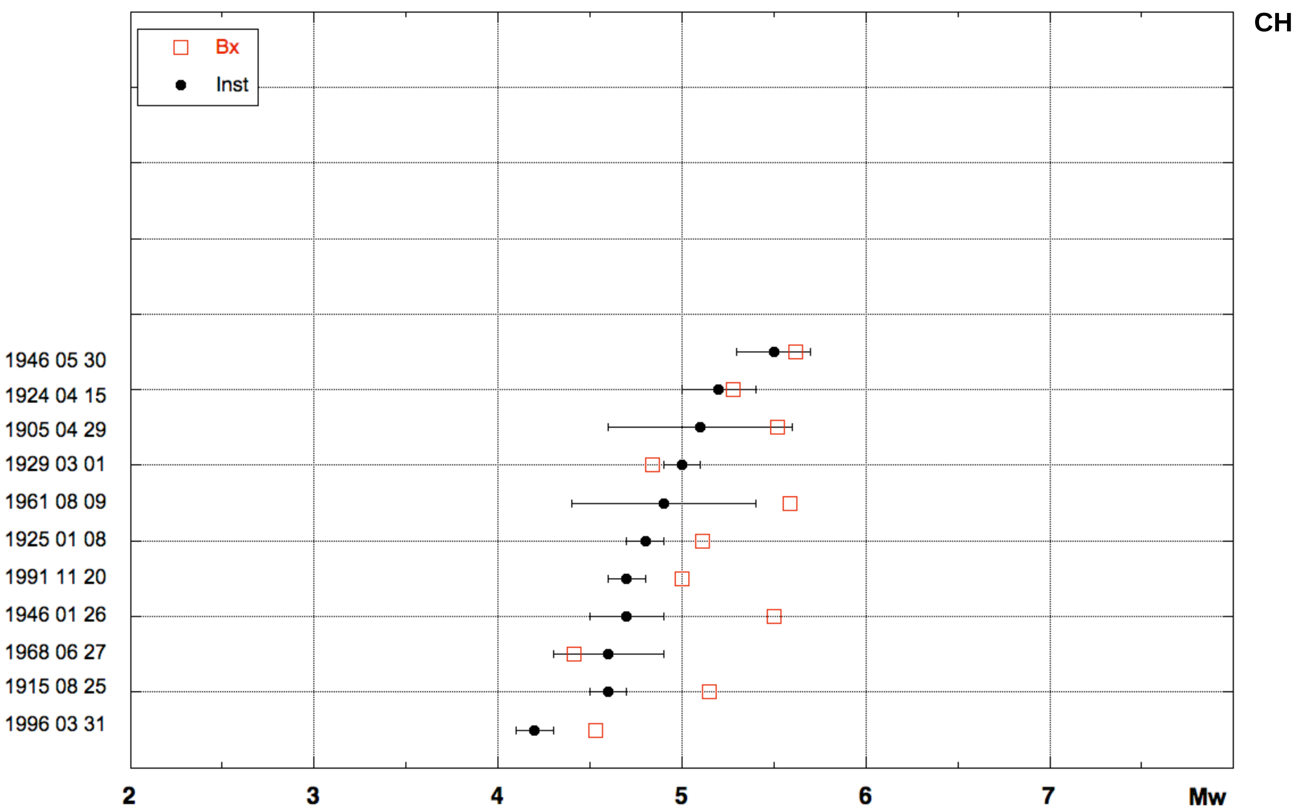


Fig.5.28 – Swiss area: plot of instrumental and calculated (Boxer, NA4) Mw.

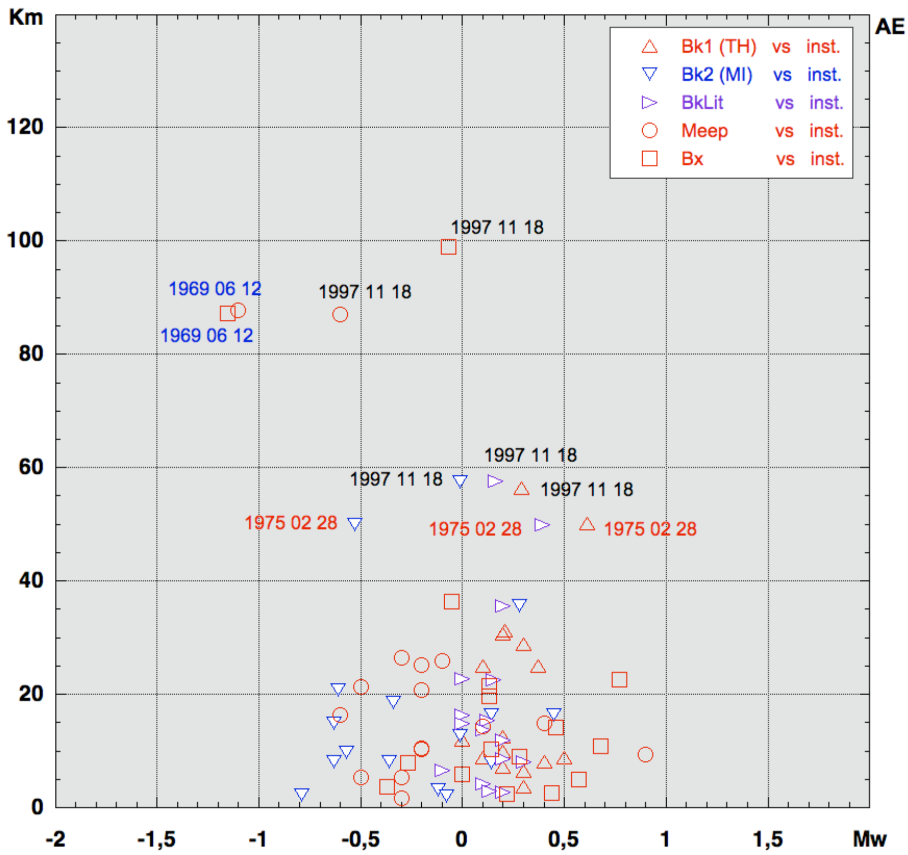


Fig.5.29 – Aegean area: Mw differences plotted against location distance.

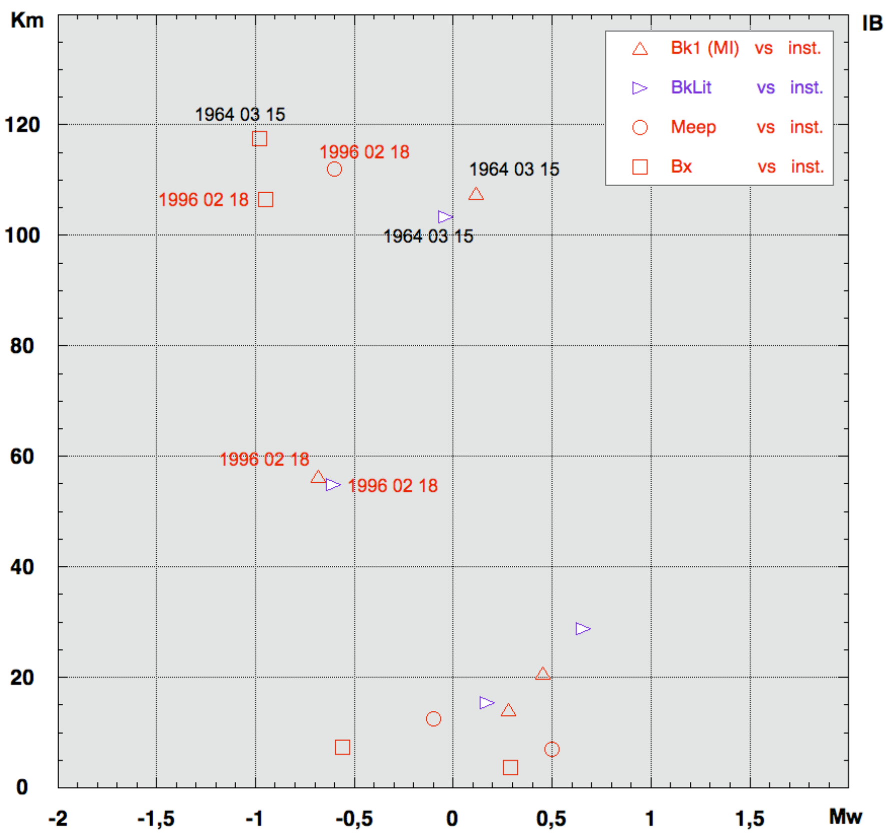


Fig.5.30 – Iberian area: Mw differences plotted against location distance.

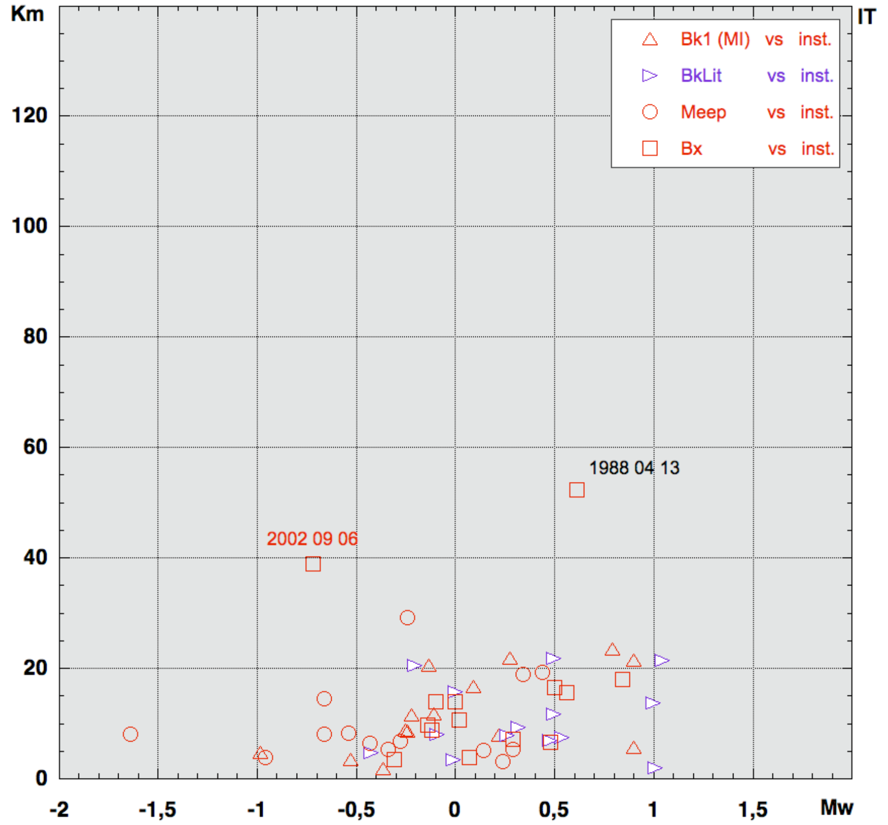


Fig.5.31 – Italian area: Mw differences plotted against location distance.

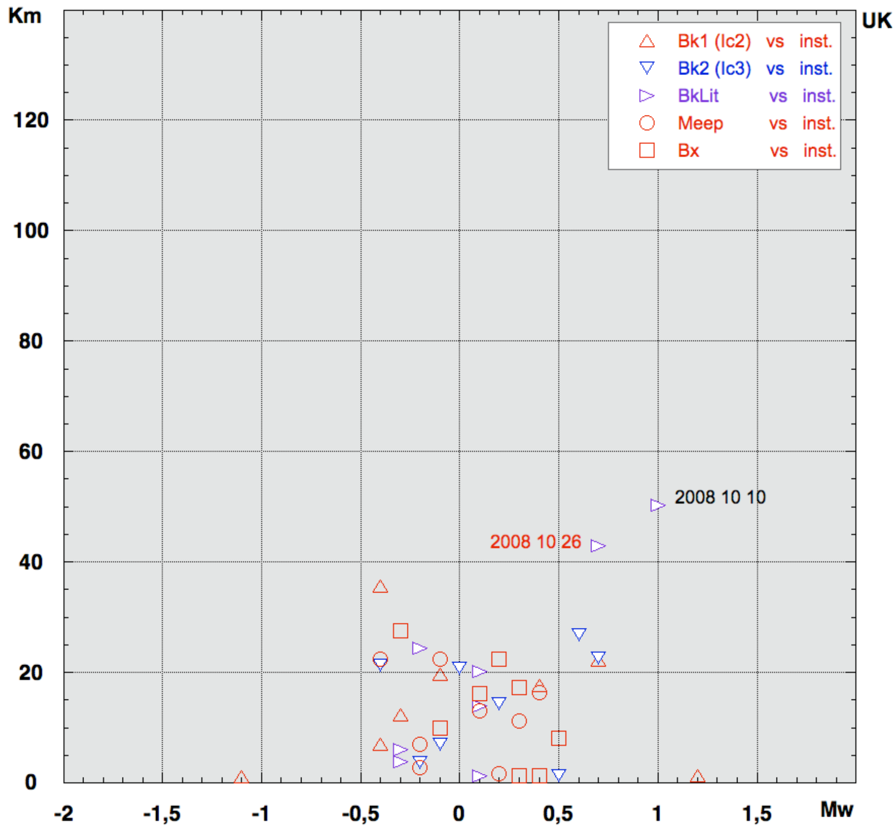
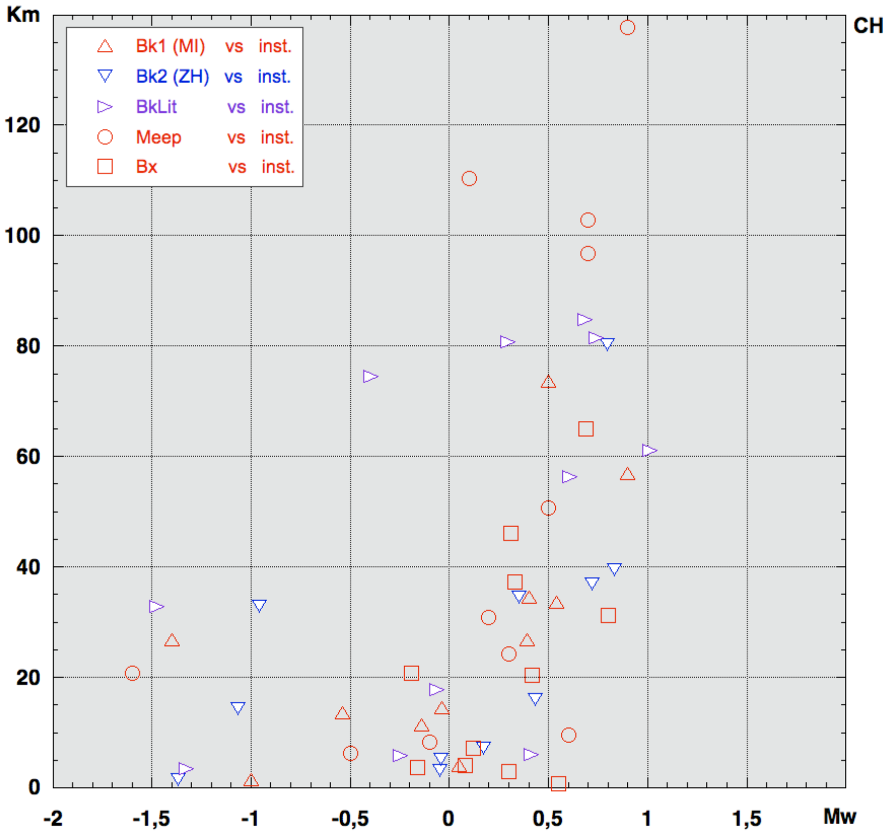


Fig.5.32 – Iberian area: Mw differences plotted against location distance.



5.33 – Swiss area: Mw differences plotted against location distance.

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June 11, 2009

Review of "The NA4 Calibration Initiative for Improving the Determination of Earthquake Parameters from Macroseismic Data ; Final Report-draft 9 (April 2009)"

The NA4 calibration initiative is an ambitious research program that substantially advances the state of the science of estimating the location and magnitude of significant earthquakes that occurred before the introduction of seismic instrumentation. Damaging earthquakes occur throughout Europe and their location and magnitude are important to society because these infrequent events define regional seismic hazard, future earthquake risk, and the building codes, insurance rates, etc. that are adopted to address that risk. Countries in Europe are small enough that the larger earthquakes cause damage in multiple adjoining countries. Sharing information about past earthquake damage and adopting the best analysis techniques provide improved location and magnitude estimates for all. Testing analysis techniques in different countries, as was done in this work, clarifies which methods are robust enough to use in a variety of situations and tectonic settings. That is, the five participating countries learned much about the historical earthquakes most important to them. Other countries in Europe will profit by building on the lessons learned in the NA4 work.

The NA4 initiative successfully integrated different macroseismic intensity scales and different analyses methods. Comparison of results in the different cooperating countries using three independent methods highlighted the strengths and weaknesses of different analytical methods. Estimates of location depend critically on the quantity and quality of the macroseismic data, and the geometry of the data field relative to the earthquake source –no technique can provide reliable source locations for events outside the field of macroseismic data. All of the analyses techniques considered by the NA4 initiative provide useful locations for events with numerous data at sites surrounding the source. Magnitude estimates depend critically on an a intensity attenuation model, calibrated using recent events for which instrumental data sufficient to determine location and magnitude and macroseismic data are available. The intensity attenuation model is not critical for location. This report describes in detail the development and testing of intensity attenuation models for the regions of the five participating countries.

The NA4 initiative is a scientific success story, as well as a practical success story for Europe. The NA4 initiative was the first attempt to use independent methodologies to estimate earthquake parameters from macroseismic data. In addition to evaluating the different approaches, the NA4 approach provides a path to estimate objective uncertainties in the earthquake parameters. The NA4 use of results from multiple independent models provides a basis for estimating the epistemic uncertainty. Probabilistic seismic hazard analysis (PSHA), now in routine use worldwide for the critical evaluation of seismic safety, assumes a knowledge of epistemic uncertainty. All future PSHAs will look back to this NA4 report.

The NA4 initiative accomplished much, but it should be viewed as a new starting point. Critical macroseismic data was not available to the NA4 initiative. In particular, the calibration models obtained for the Switzerland and Iberian regions would have benefited much if the macroseismic data for the adjoining regions of France that are listed in the SisFrance catalog might have been used. That is, access to all of the relevant European data, would allow for even better regional intensity attenuation models, and better estimates of location and magnitude for critical historical earthquakes.

Review by William H. Bakun, US Geological Survey, Menlo Park, CA