

Updating the Italian IPE: Introducing a New Flatfile to Explore Distance-Related Variability

Gomez Capera A.A., Antonucci A., D'Amico V.,
Lanzano G., Rovida A., Sgobba S.

Milano. 20.06.2025



REGIONAL-SCALE EARTHQUAKE GROUND MOTION PREDICTIONS
THROUGH PHYSICS-BASED AND EMPIRICAL APPROACHES:
A CASE STUDY CENTRAL ITALY

Bulletin of Earthquake Engineering
<https://doi.org/10.1007/s10518-023-01822-8>

ORIGINAL ARTICLE



Macroseismic intensity attenuation models calibrated in M_w for Italy

A. A. Gomez-Capera¹ · M. Santulin² · M. D'Amico¹ · V. D'Amico³ · M. Locati¹ · C. Meletti³ · E. Varini⁴

Received: 19 April 2023 / Accepted: 5 November 2023
© The Author(s) 2023

Abstract

This study aims at developing new macroseismic intensity attenuation models valid for Italy by exploiting the most updated macroseismic dataset and earthquakes catalogue, as well as the information obtained from a critical analysis of the most recent models in the literature. Several different attenuation models have been calibrated as a function of the moment magnitude (M_w) and epicentral distance from 16,260 intensity data points, that are related to 119 earthquakes occurred after 1900. According to trends and residuals analysis, the preferred calibrated intensity attenuation function is a Log-Linear model for epicentral distance (R_{epi} in km) and a linear model for M_w as:

$$I(MCS) = 1.81 - 2.61 \log R - 0.0039R + 1.42M_w$$

with pseudo hypocentral distance $R = \sqrt{R_{epi}^2 + (9.87)^2}$; the estimated standard deviation is $\sigma = 0.75$. Also noteworthy is another model for macroseismic intensity attenuation that proved to be as good as the best model and shows higher sensitivity to physical parameters, such as focal depth and magnitude, especially in the epicentral area. Performance of all calibrated models was also checked on an independent set of 15 post-1900 Italian earthquakes. One of the results of the present work is the opportunity to define earthquake scenarios (e.g. probabilistic seismic hazard maps) in terms of Macroseismic Intensity and its related standard deviation, avoiding the uncertainties due to the conversion of various ground shaking parameters into intensity values.

Keywords Macroseismic intensity · Intensity attenuation · Macroseismic data · Italy

✉ A. A. Gomez-Capera
antonio.gomez@ingv.it

¹ Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Milano, Milan, Italy

² Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy

³ Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Pisa, Italy

⁴ Consiglio Nazionale delle Ricerche, Istituto di Matematica Applicata e Tecnologie Informatiche "Enrico Magenes", Milan, Italy

Published online: 29 November 2023



GOMAL2024



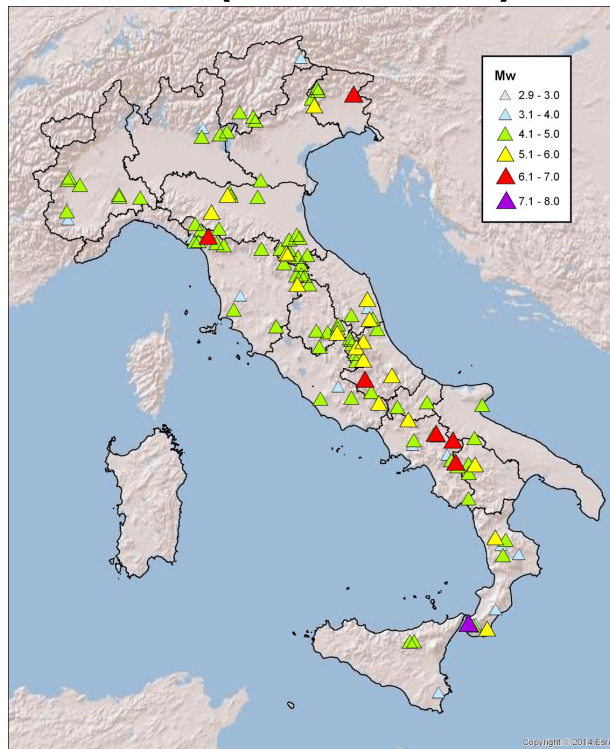
ISTITUTO NAZIONALE
DI GEOFISICA E VULCANOLOGIA



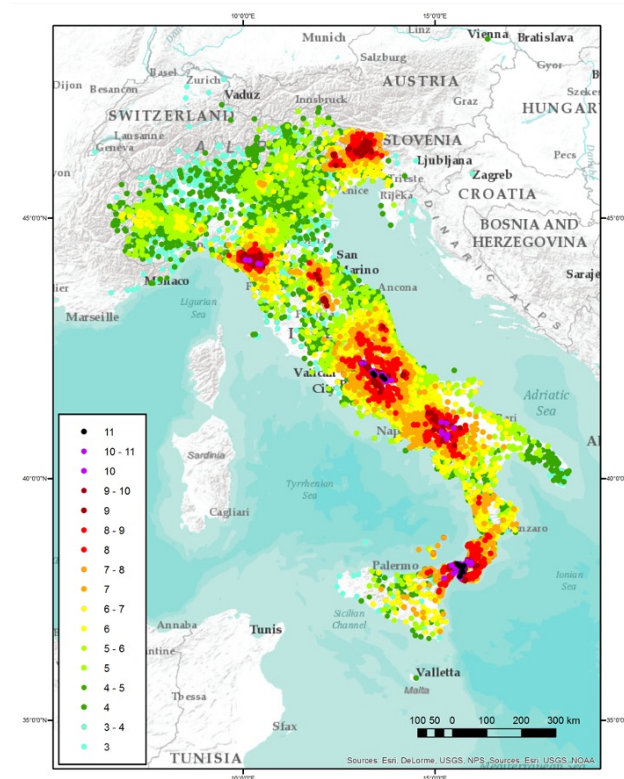
PIANETA
DINAMICO
WORKING EARTH

Calibration dataset

119 earthquakes [1908-2013]
[3.8 -7.1]Mw
h<35km (from CPTI15)



16.260 IDPs (from DBMI15)
[3-11]MCS ; [5-11]Imax
[0.1-634km]



28 December 1908 4:20:27.00, Stretto di Messina

EqID 19081228_0420_000

NMDP 772 Imax 11 from CFTI4med

CPTI15

macroseismic

instrumental

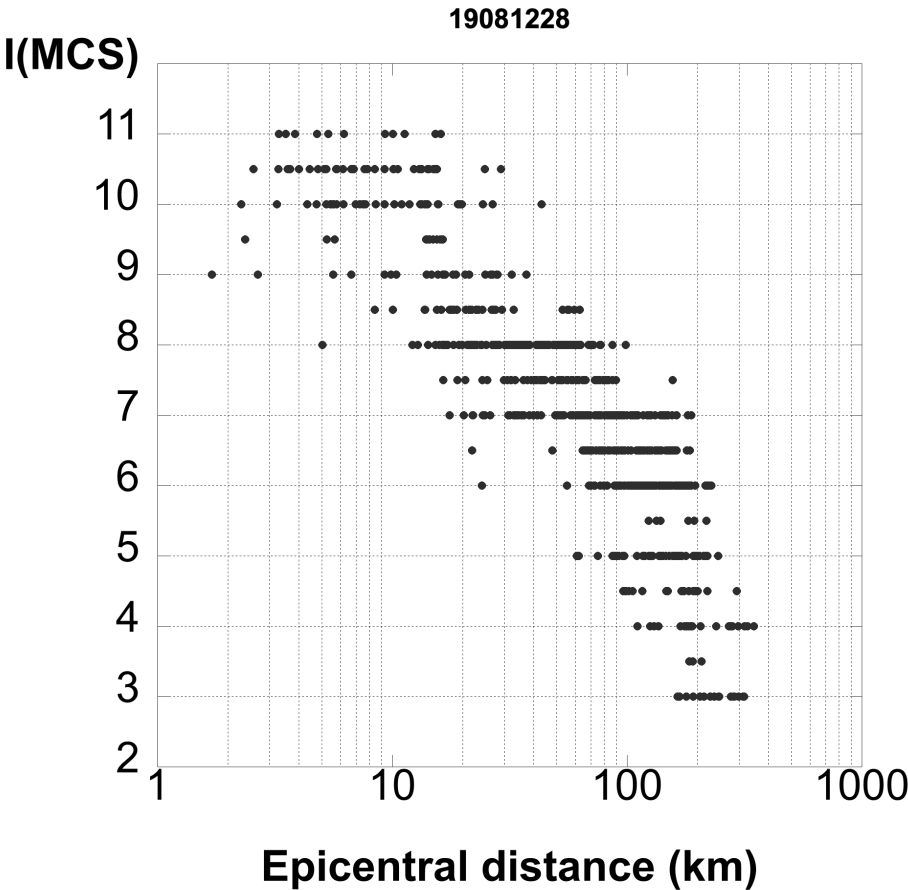
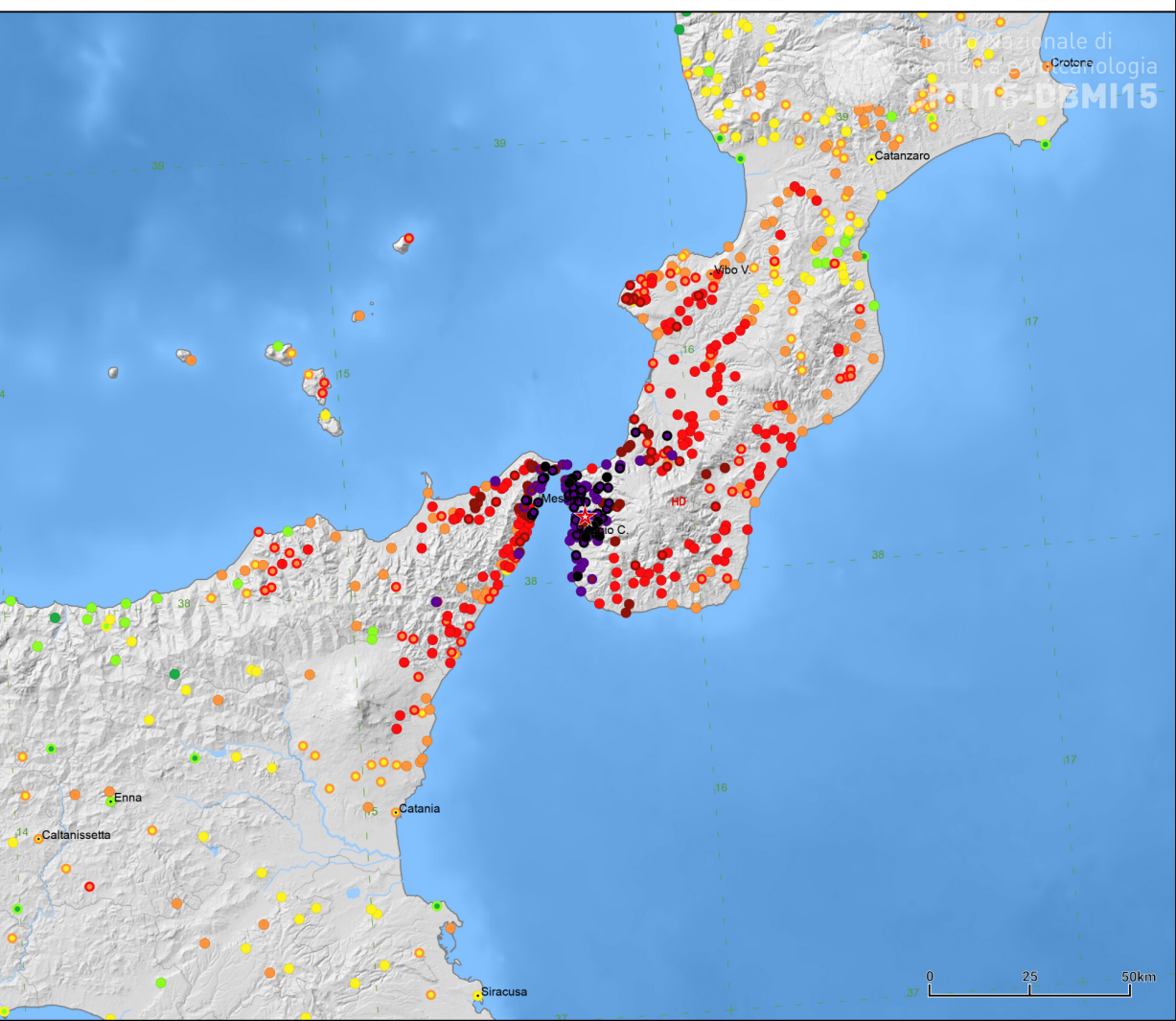
★ 38.146, 15.687

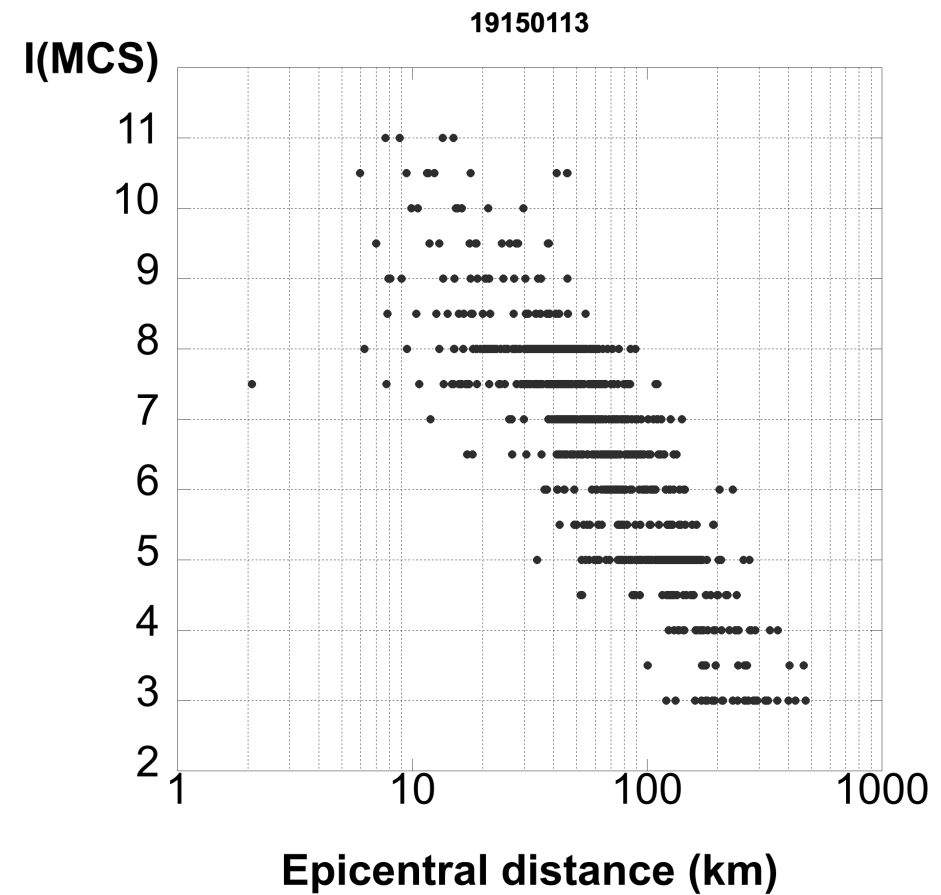
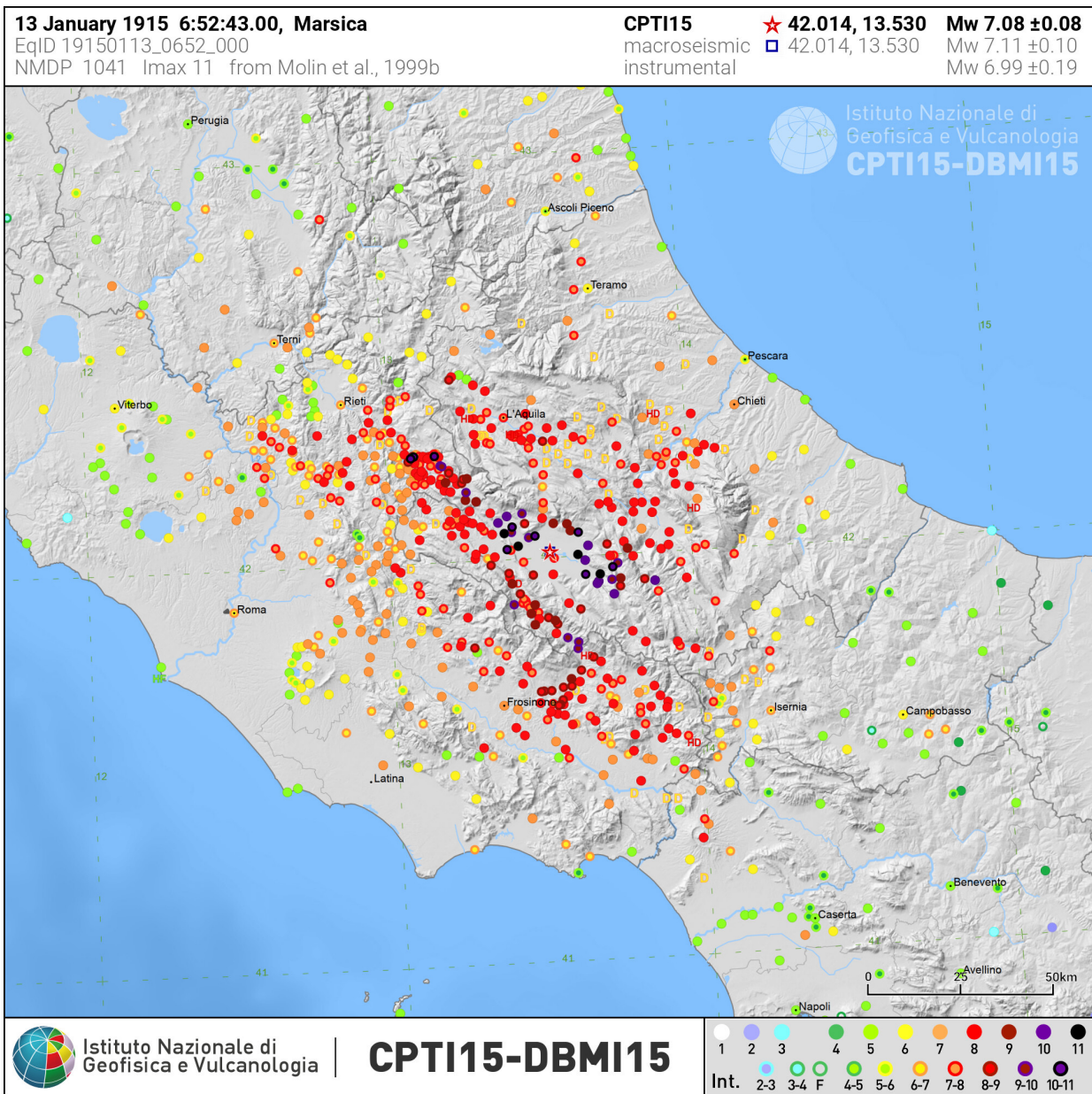
□ 38.146, 15.687

Mw 7.10 ± 0.18

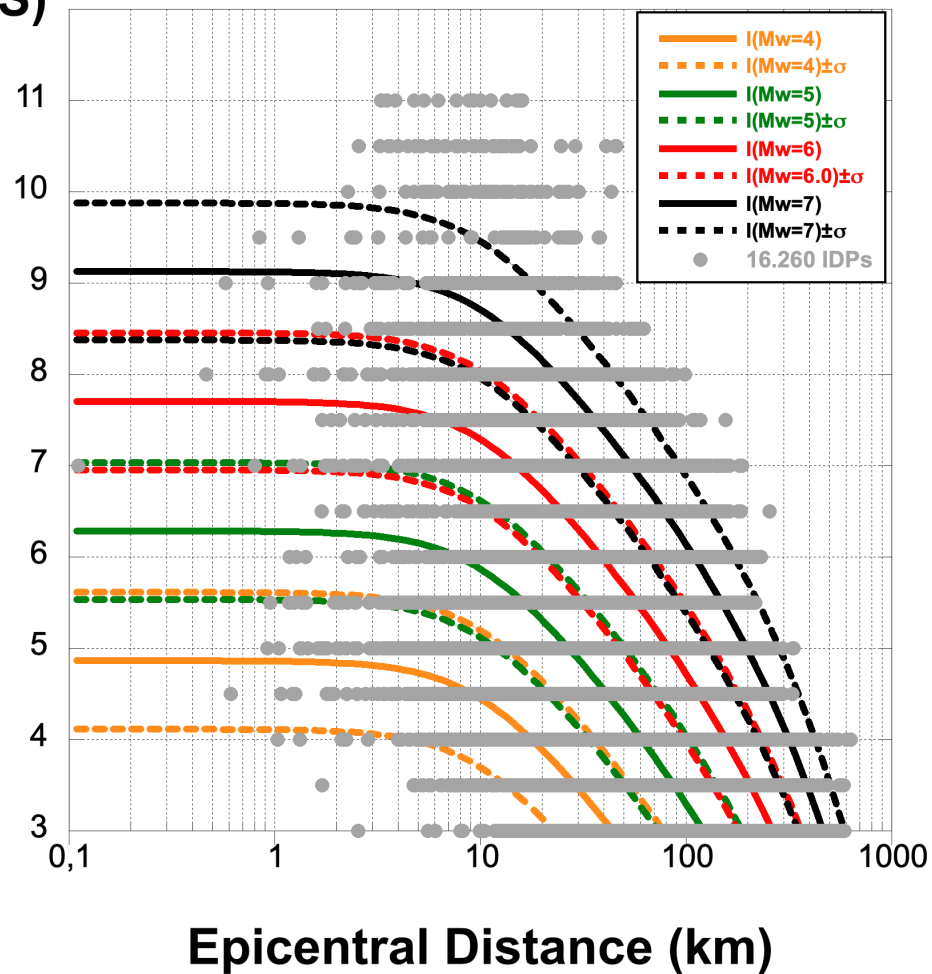
Mw 7.12 ± 0.10

Mw 7.10 ± 0.18

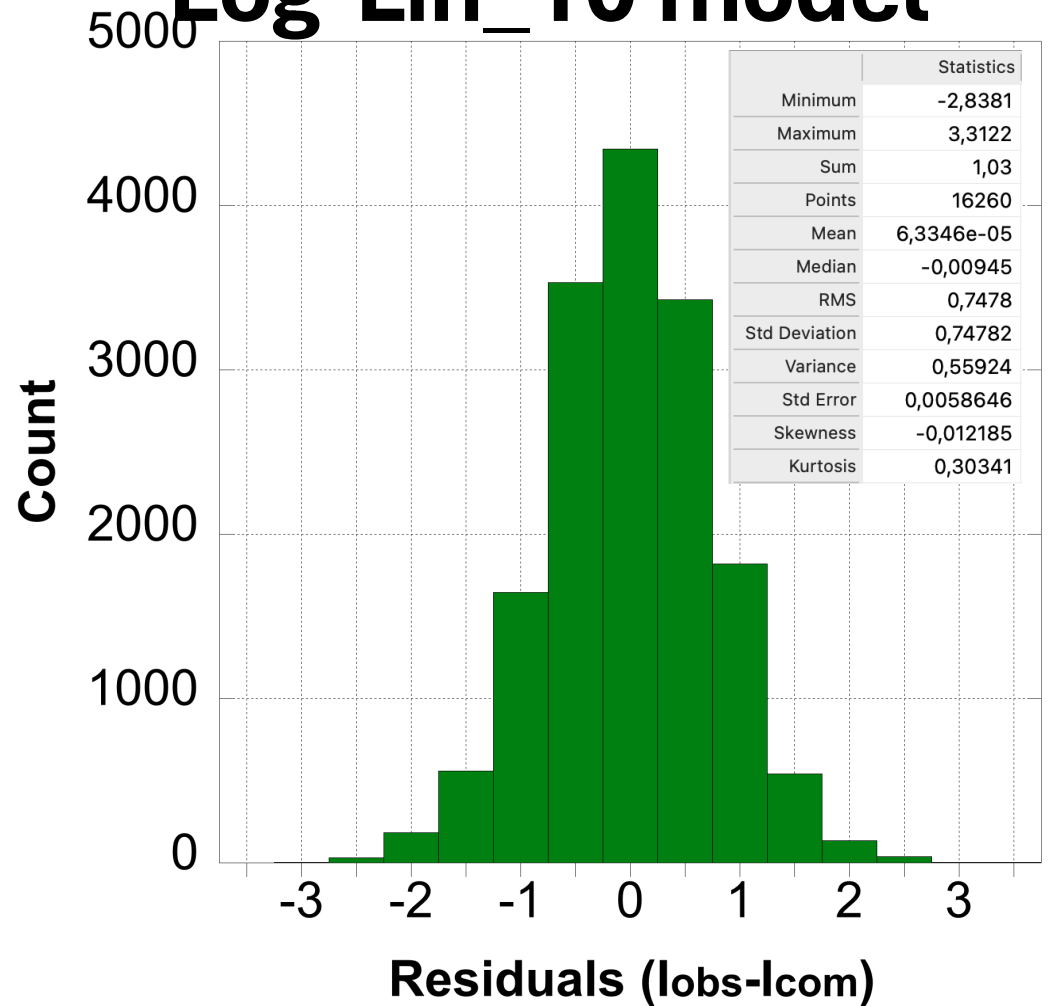




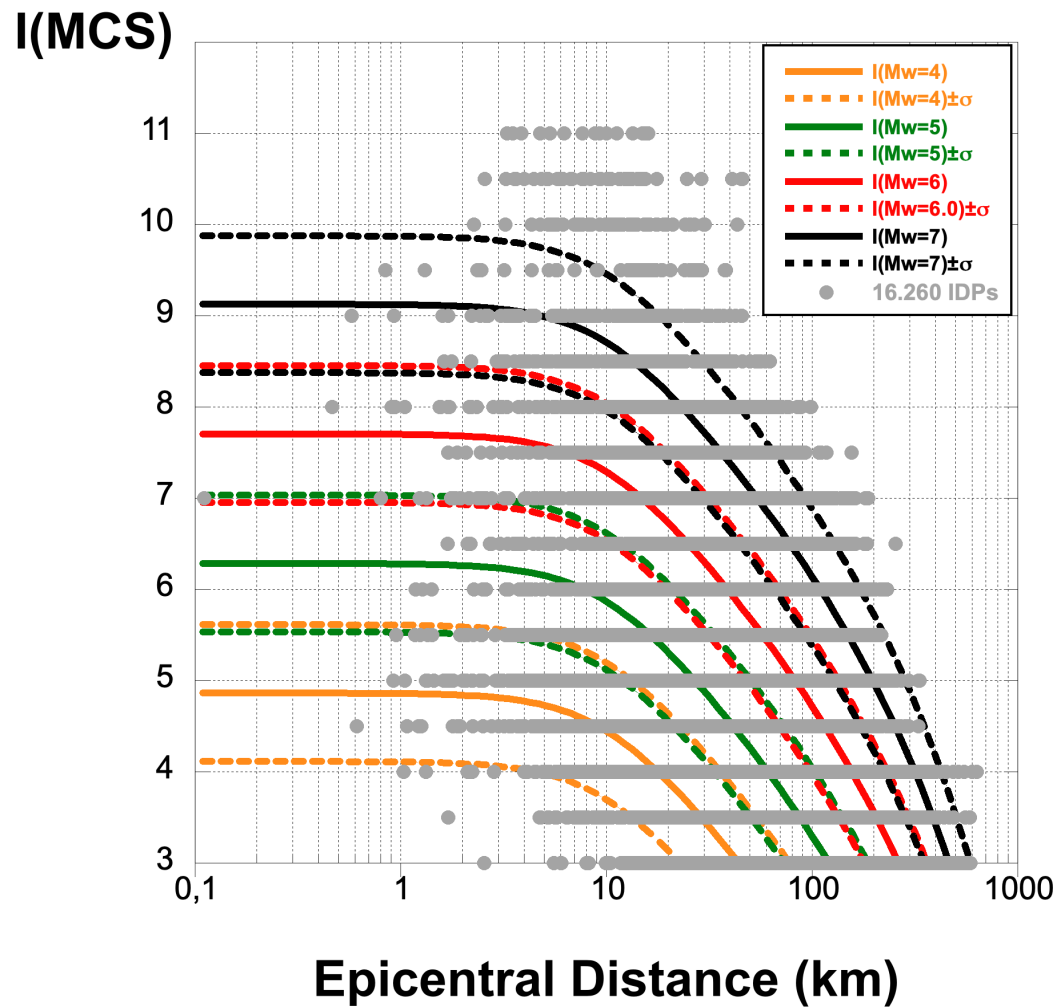
I(MCS)



Log-Lin_10 model



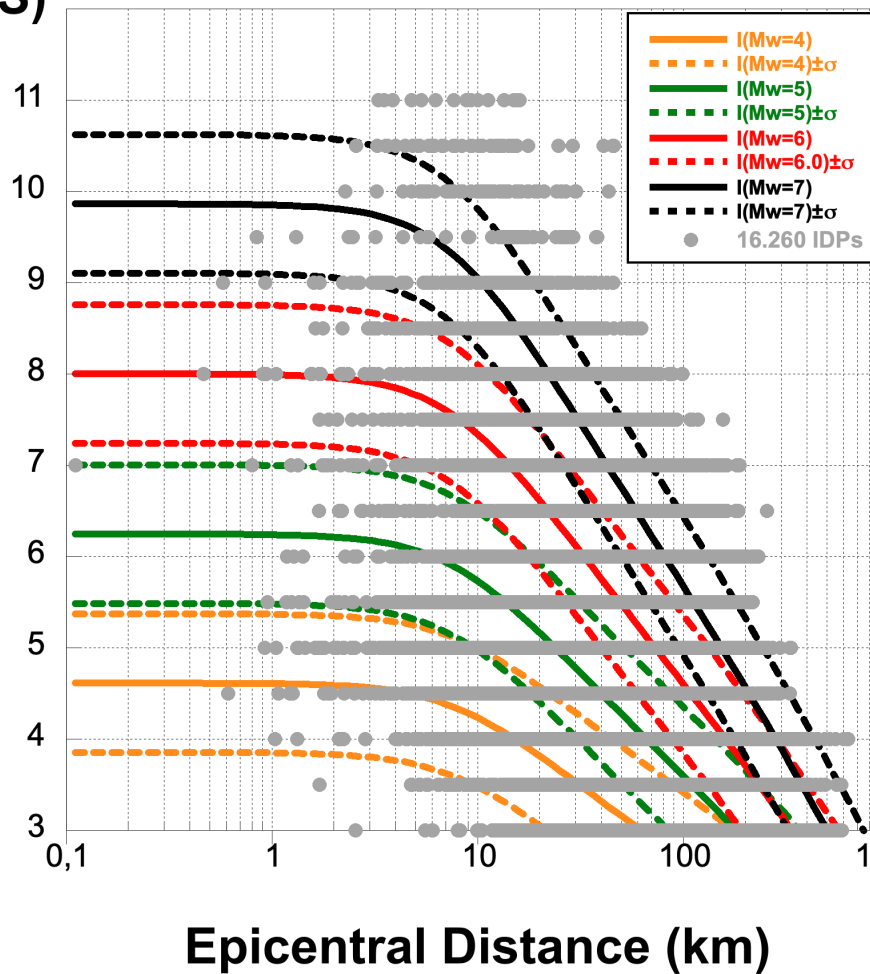
Log-Lin_10 model



$$I = 1.81 - 2.61 \log R - 0.0039R + 1.42M_w$$

$$h = 9.87 \text{ km}$$

I(MCS)



Count

5000

4000

3000

2000

1000

0

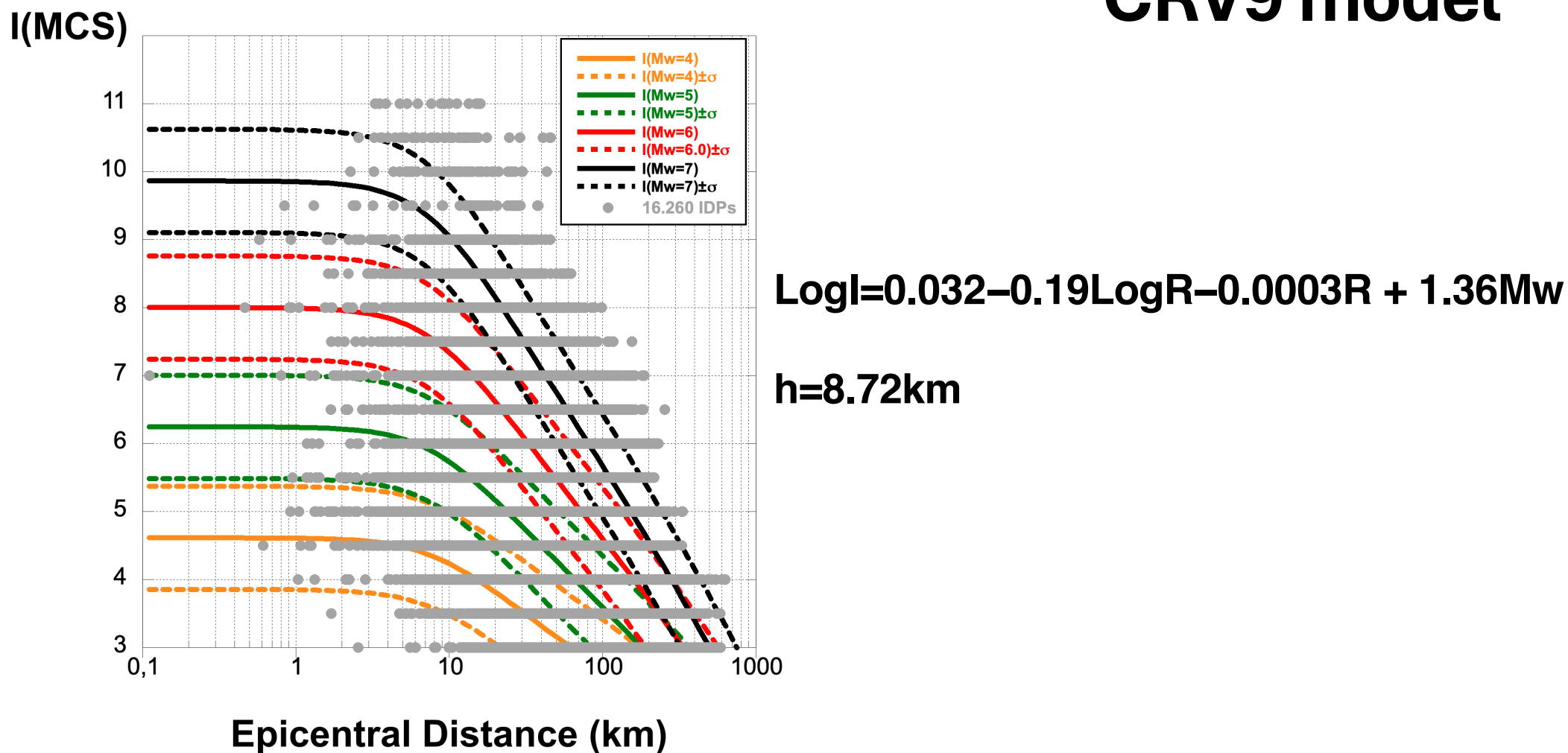
-3

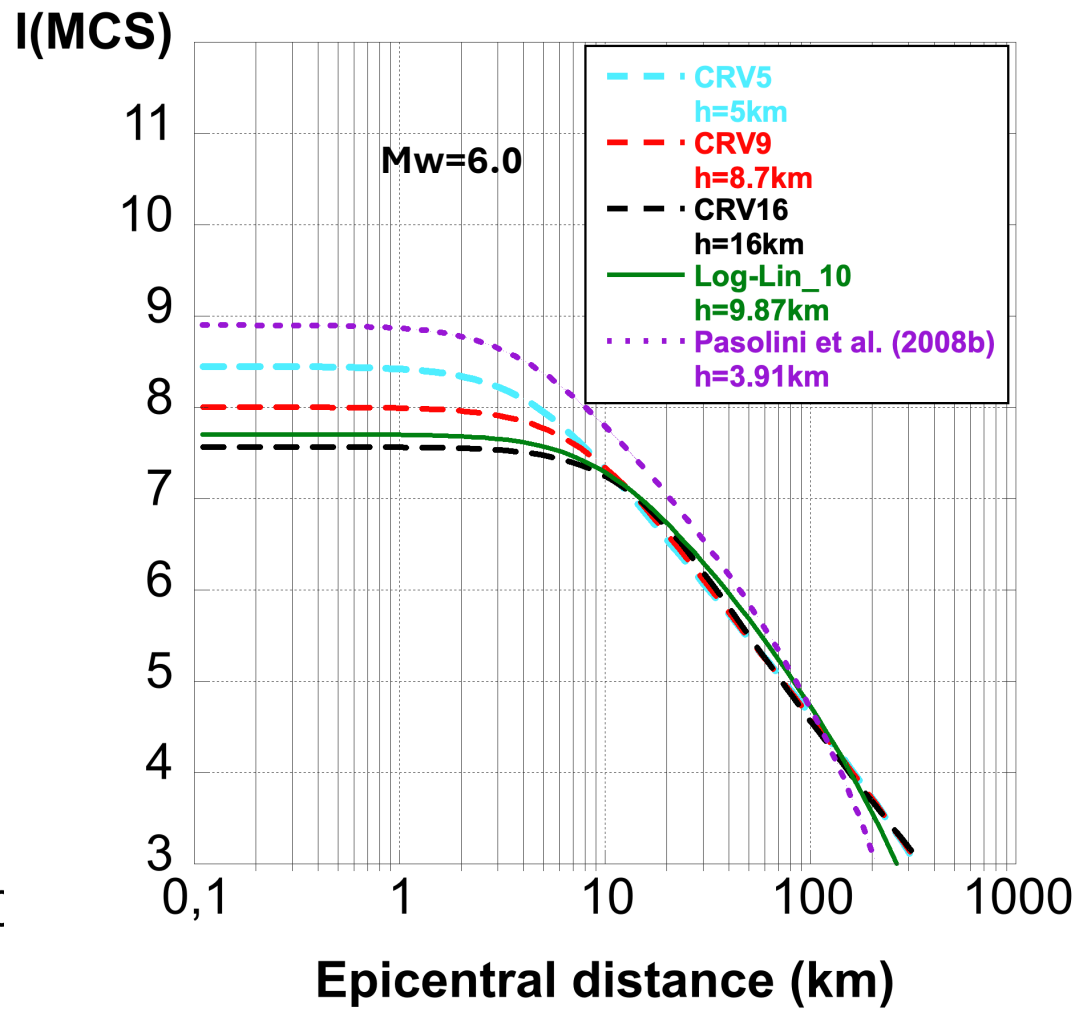
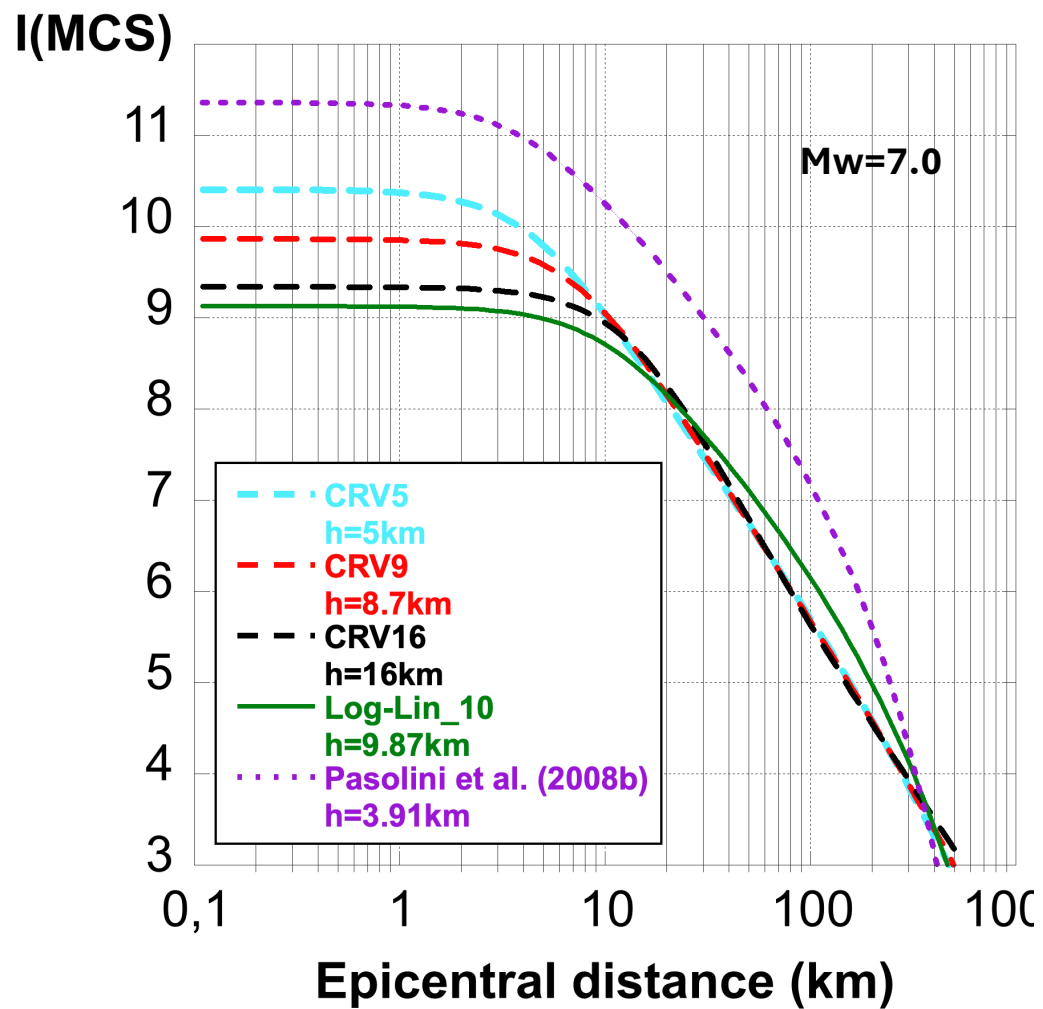
Residuals (lobs-lcom)

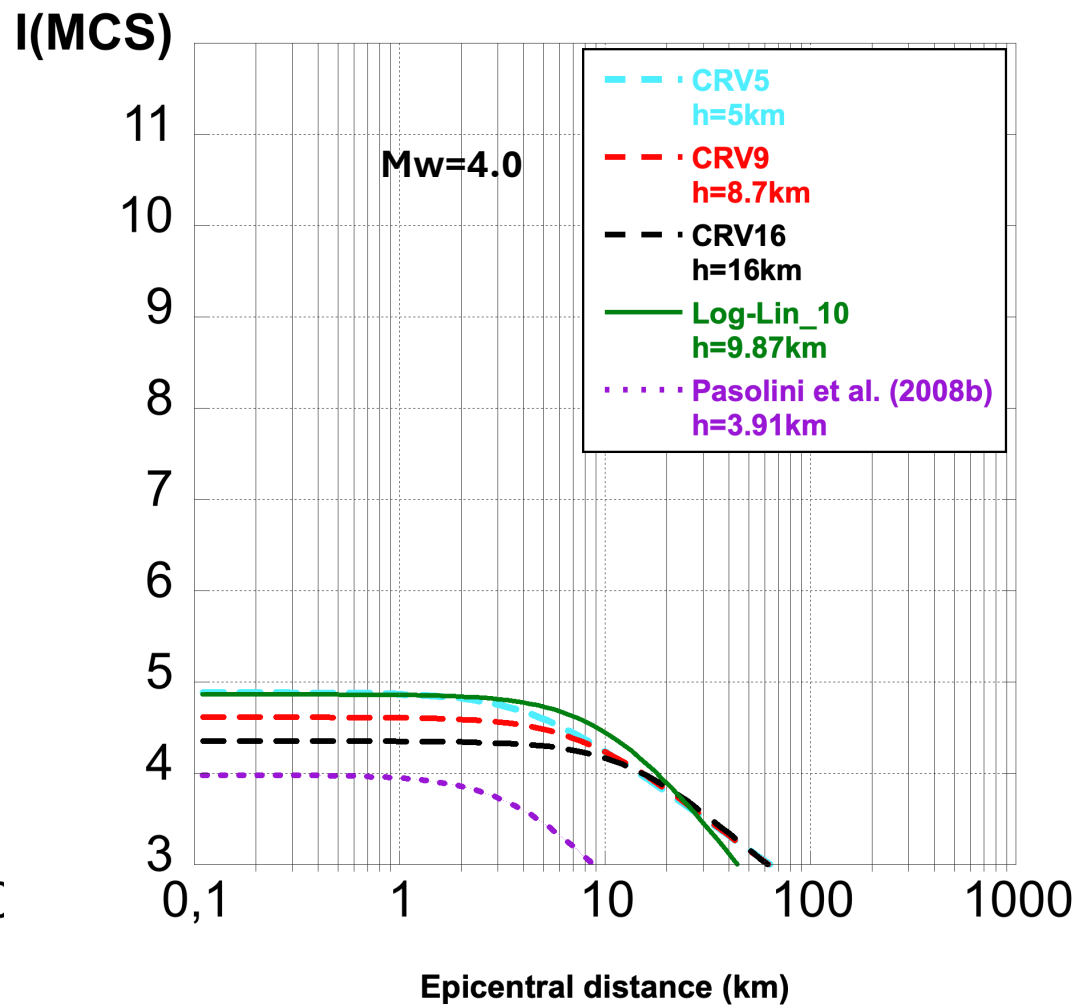
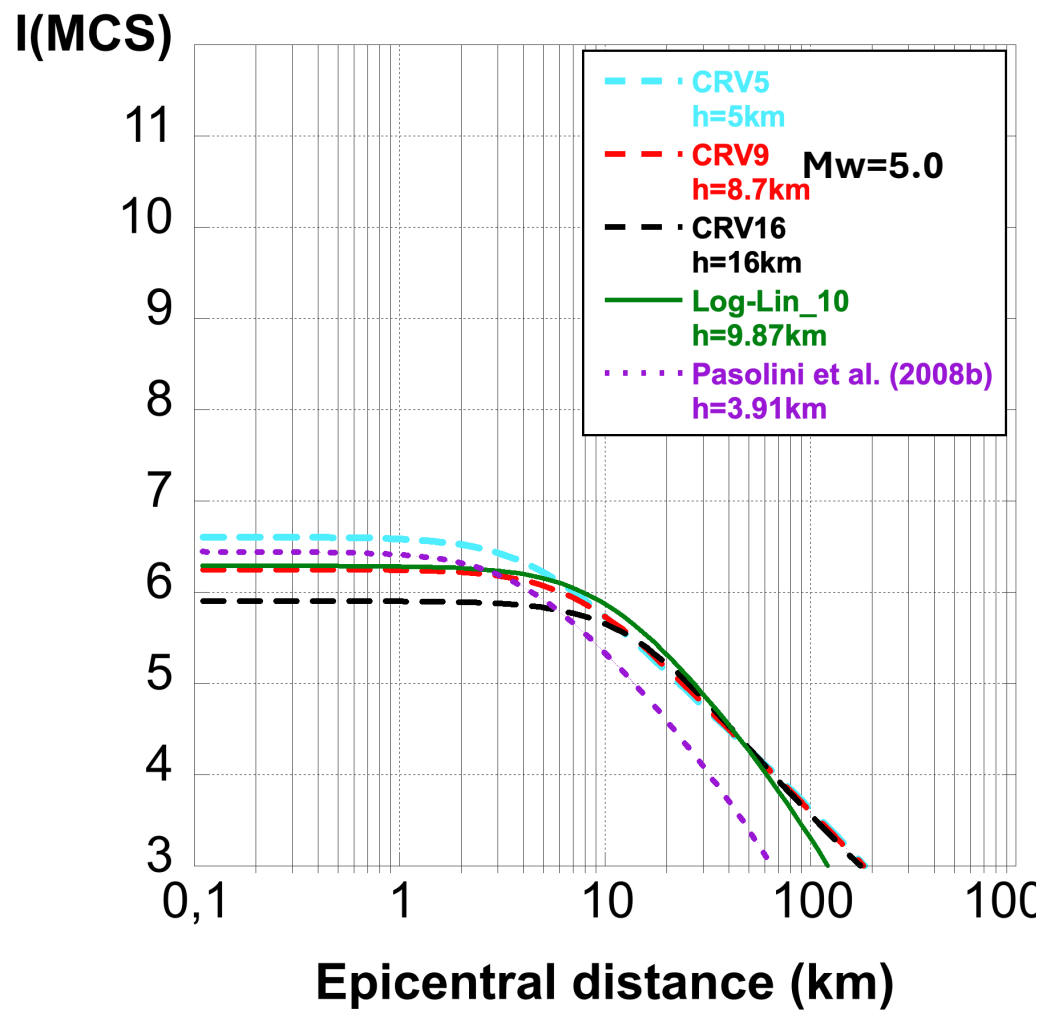
CRV9 model

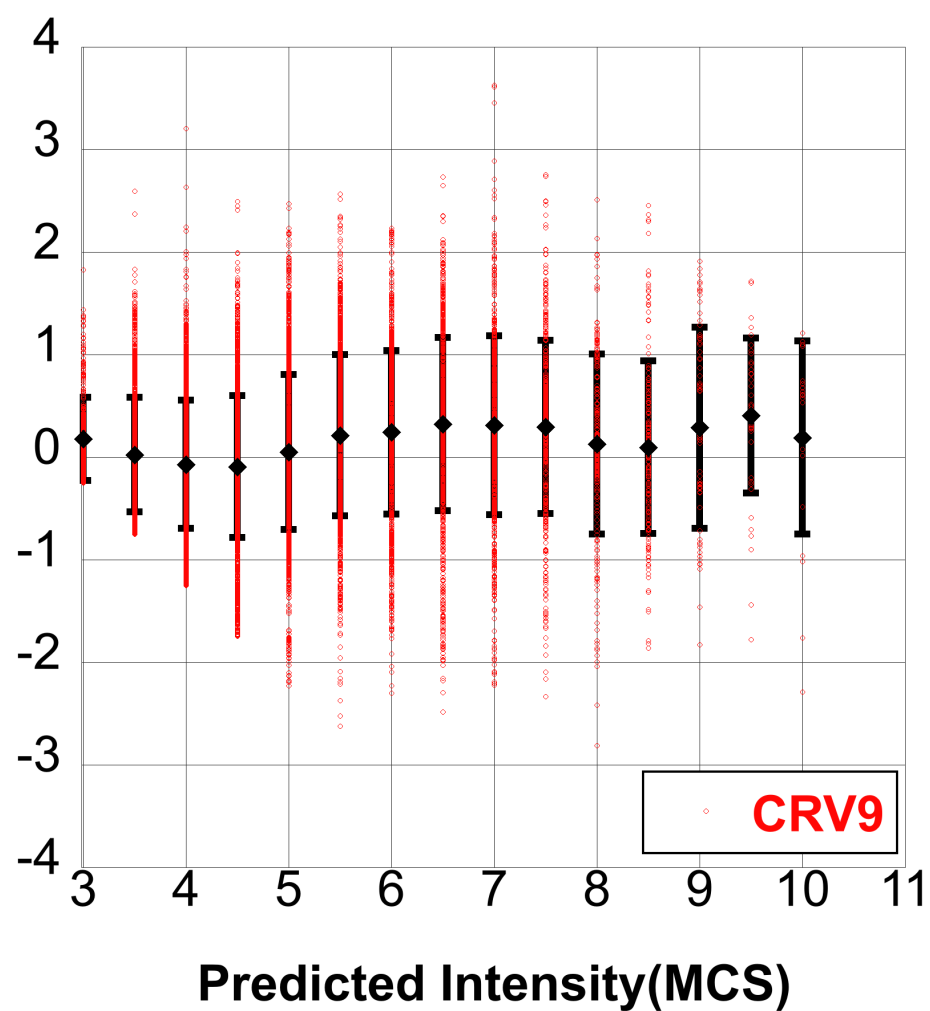
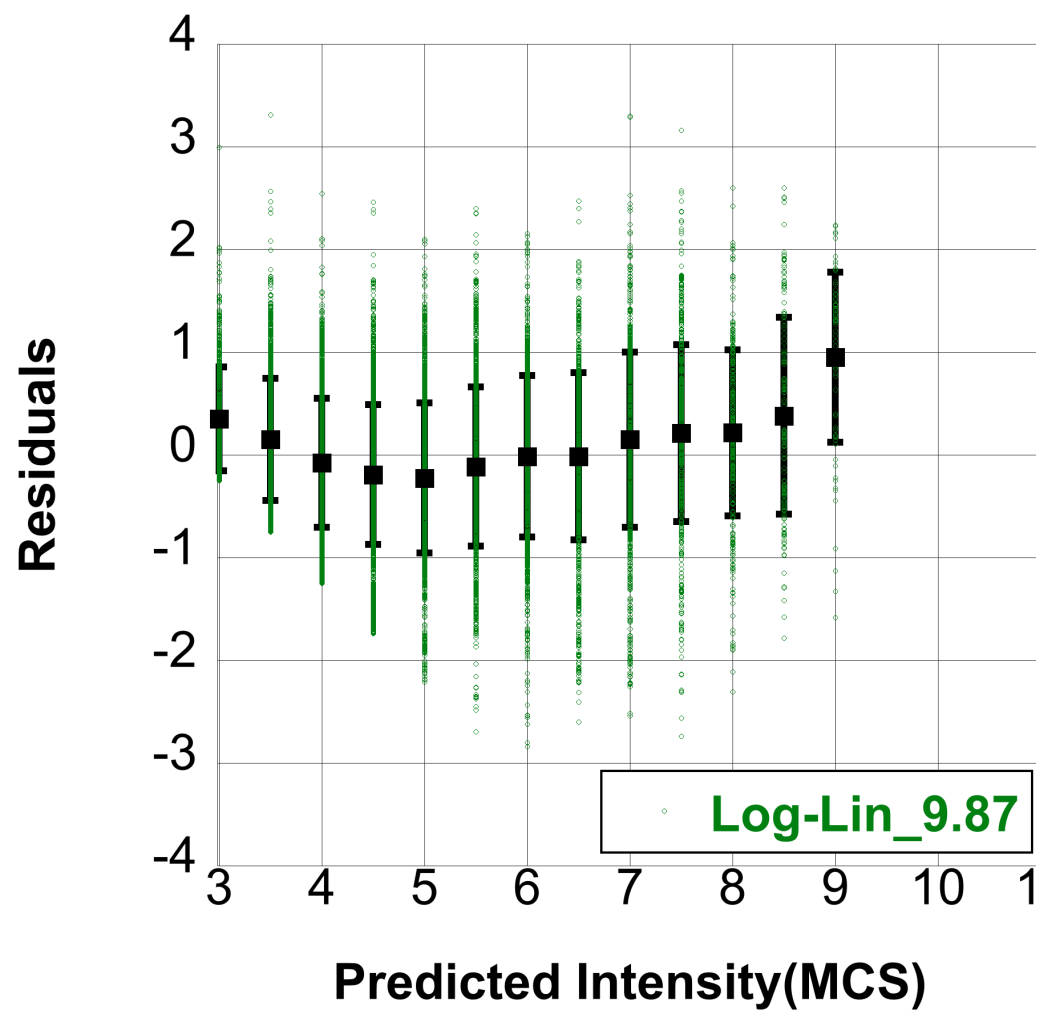
Statistic	
Minimum	-2,8116
Maximum	3,6259
Sum	1183,5
Points	16260
Mean	0,072788
Median	0,05219
RMS	0,7347
Std Deviation	0,73111
Variance	0,53452
Std Error	0,0057335
Skewness	0,10383
Kurtosis	0,24271

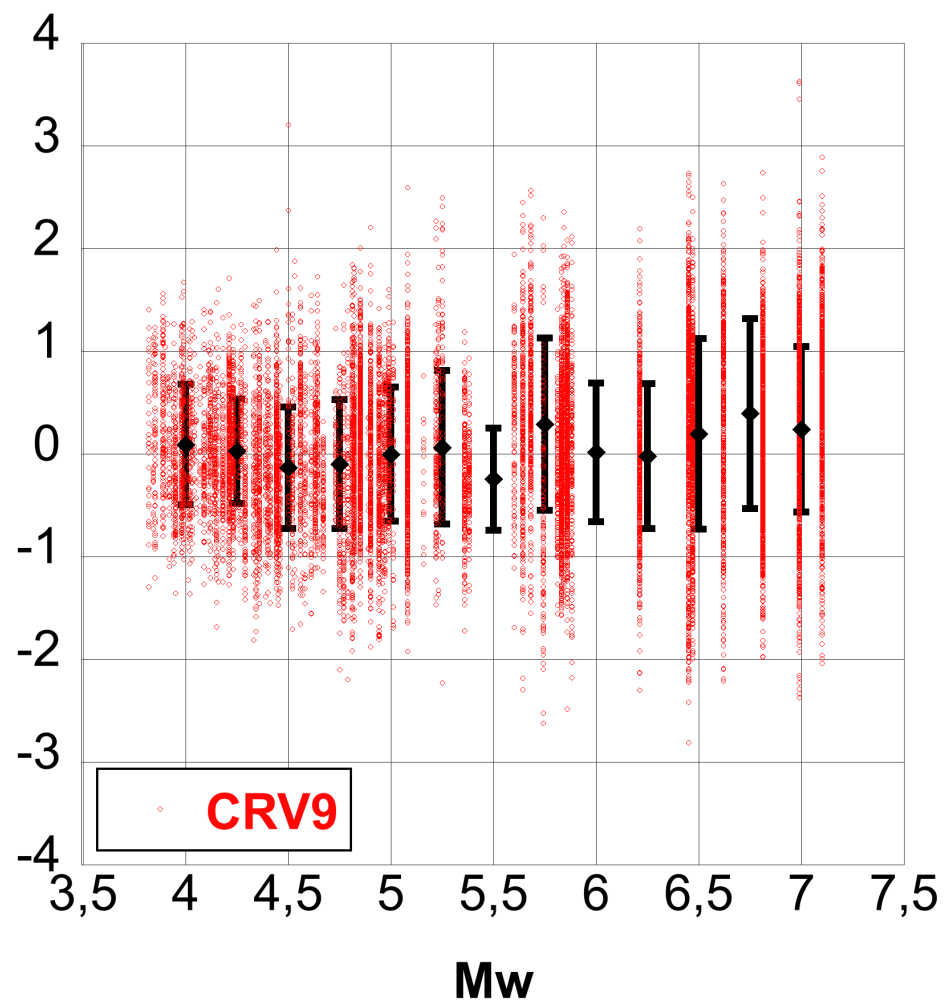
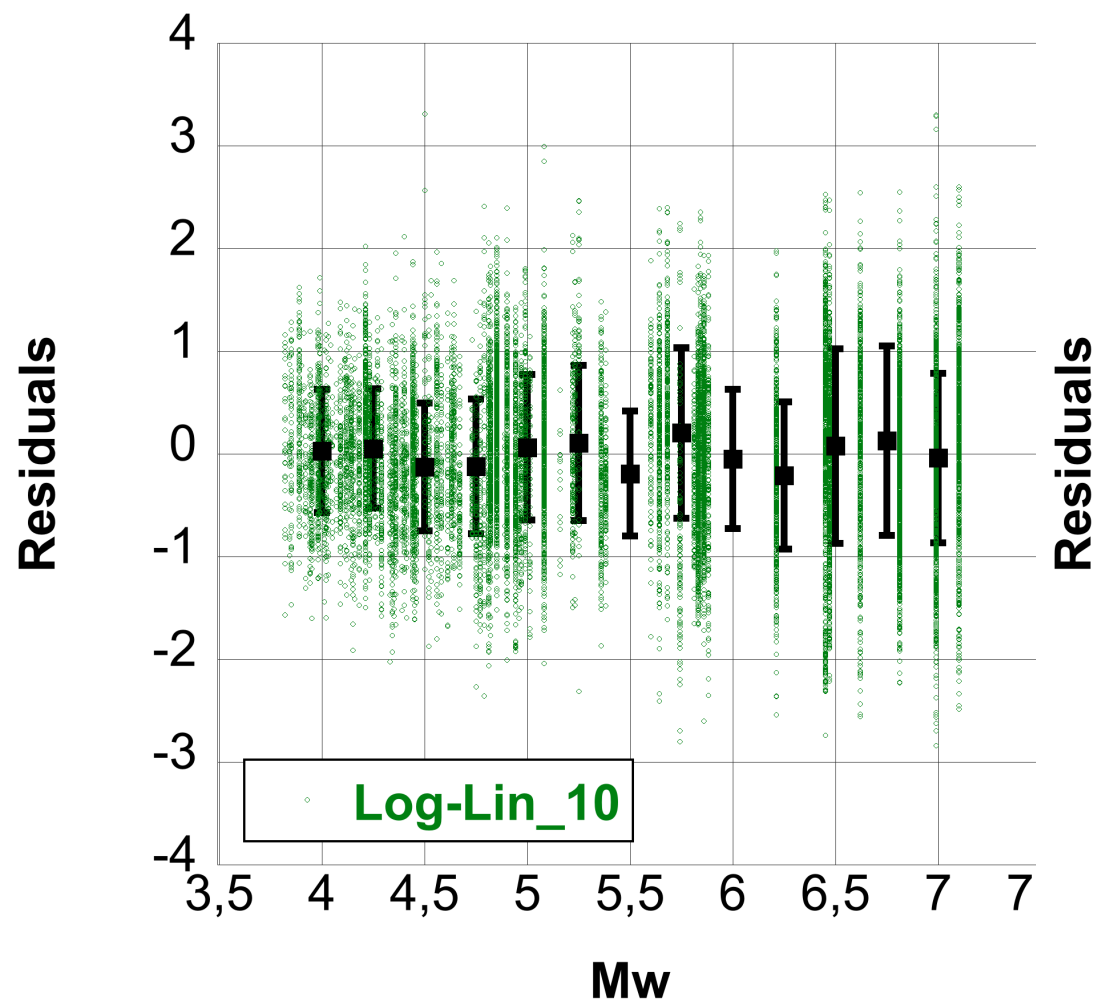
CRV9 model

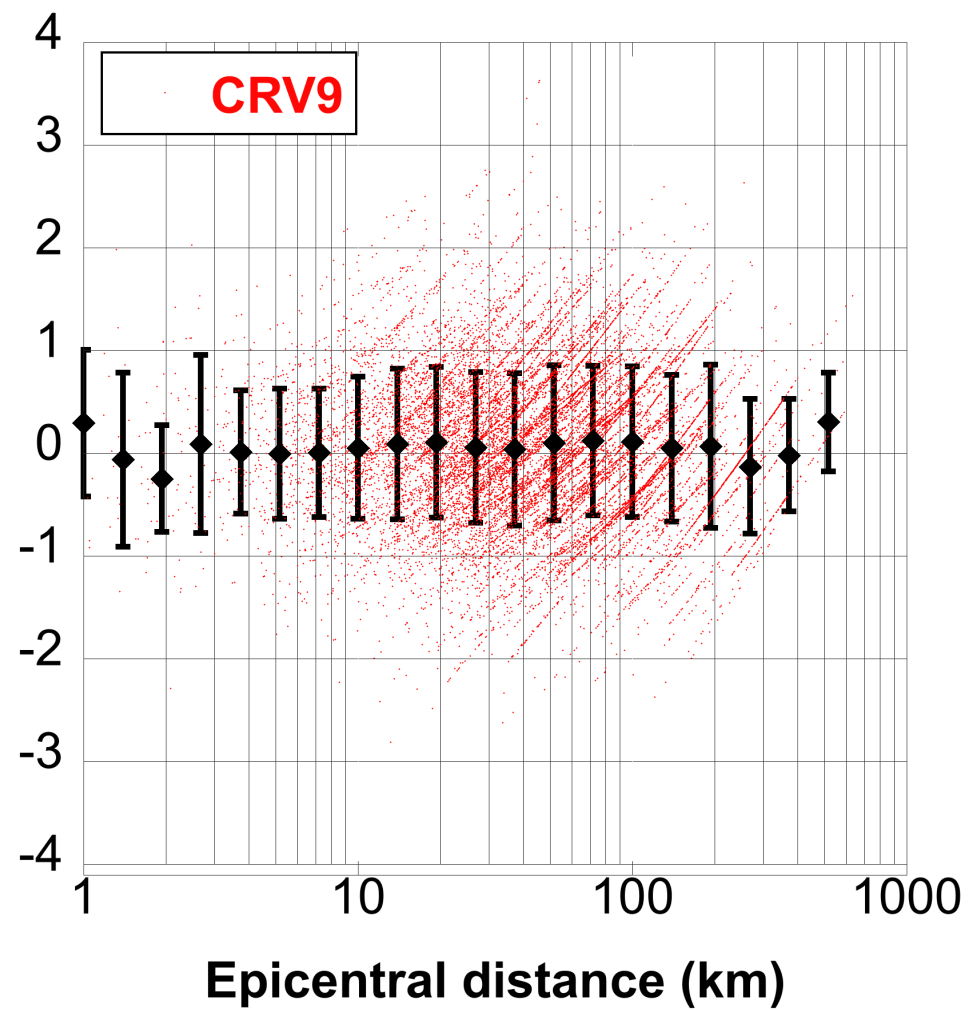
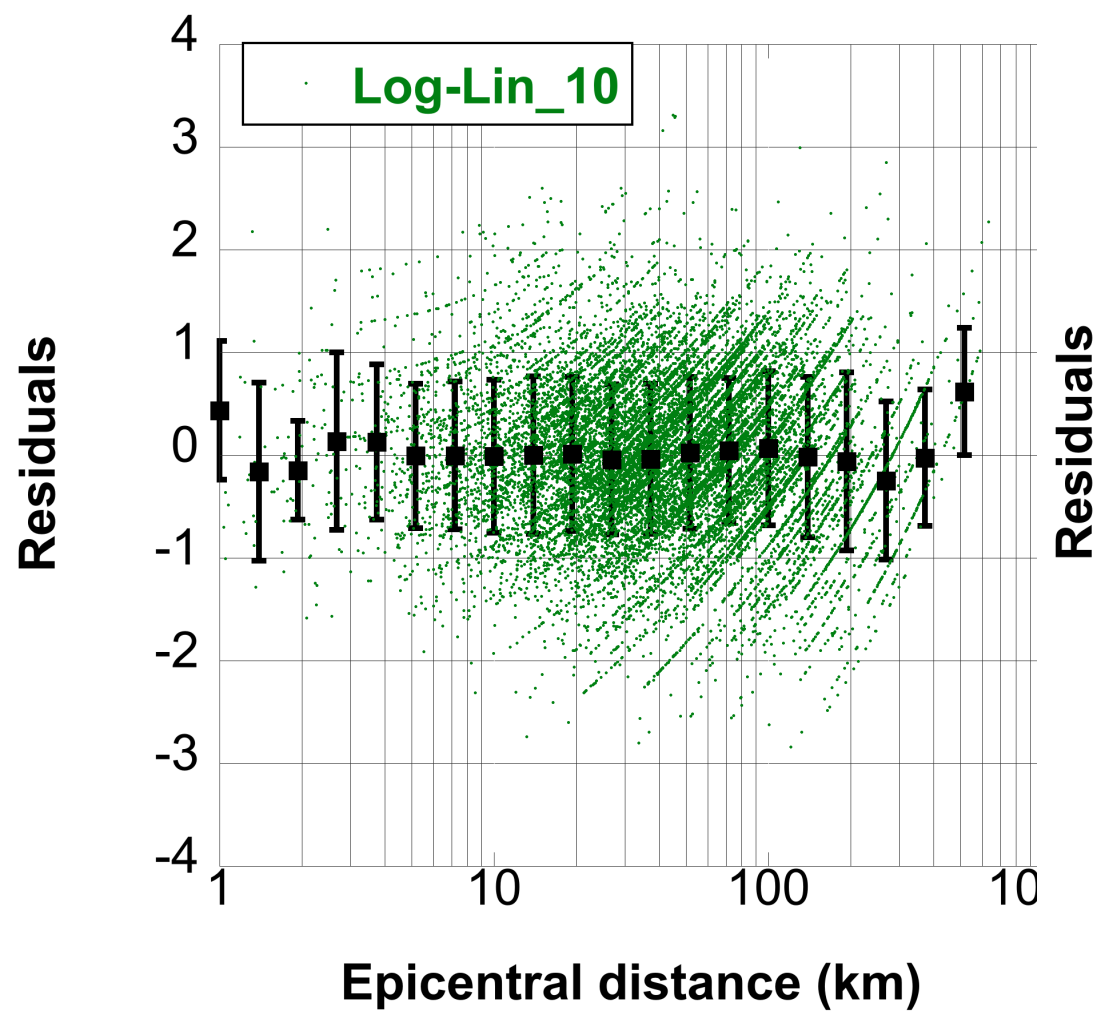


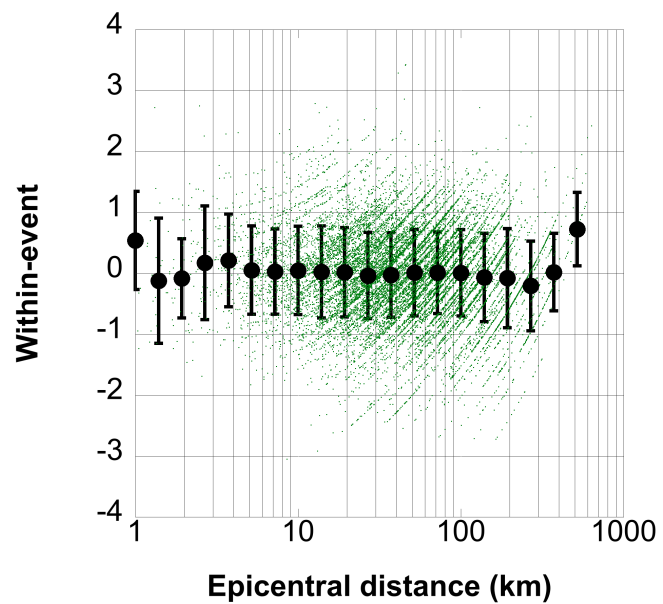
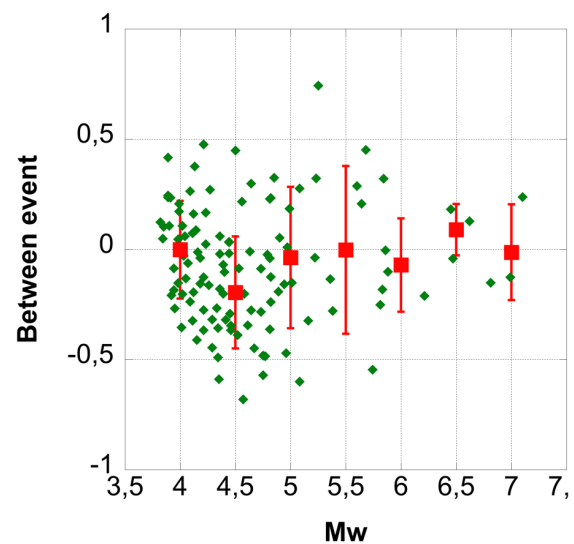
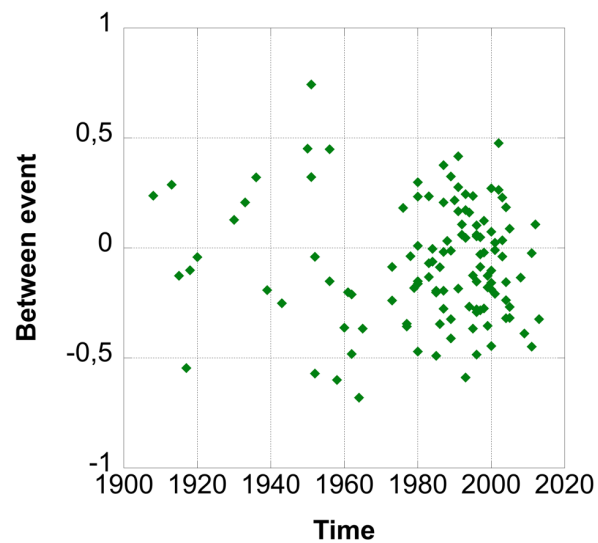




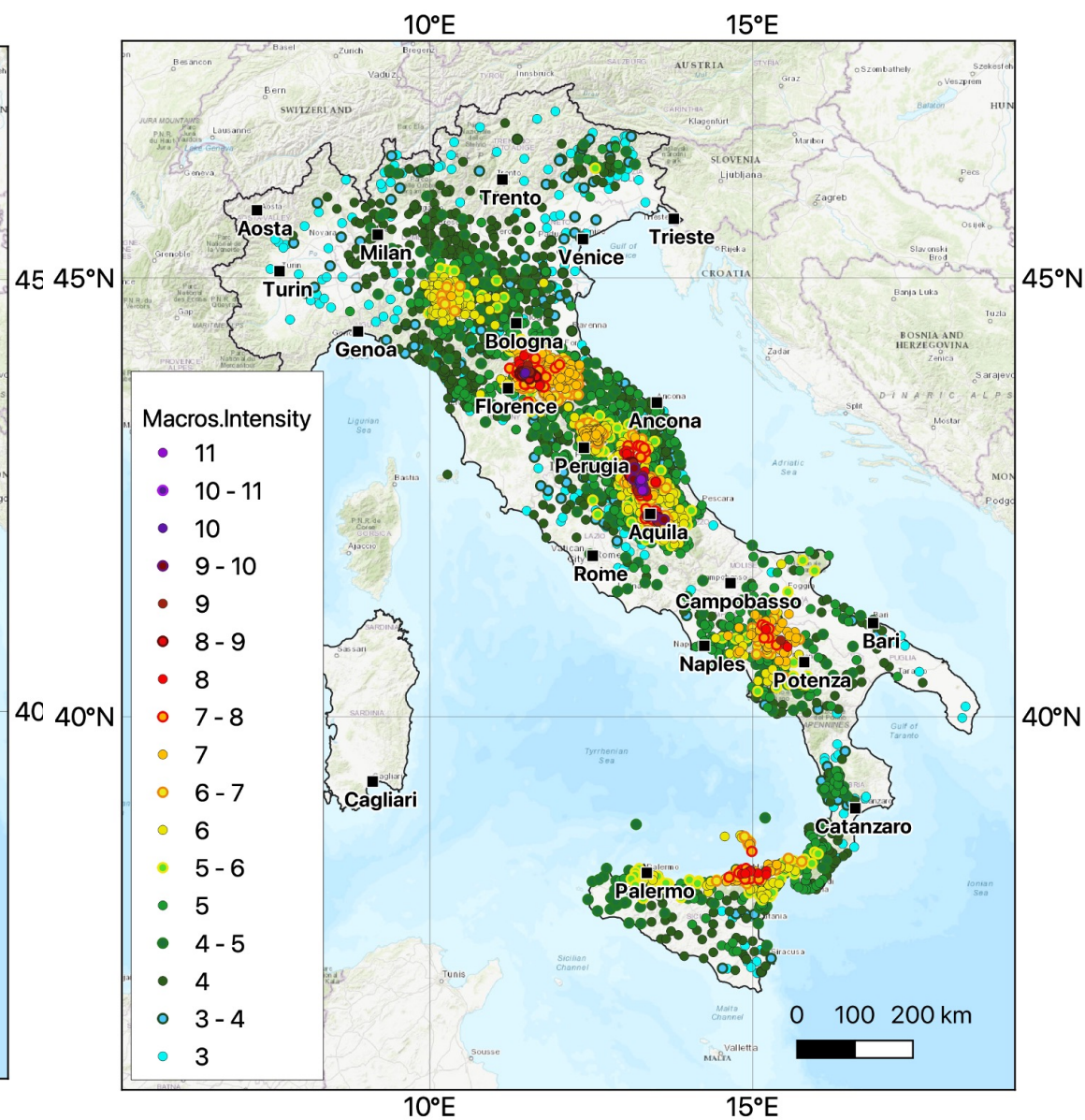
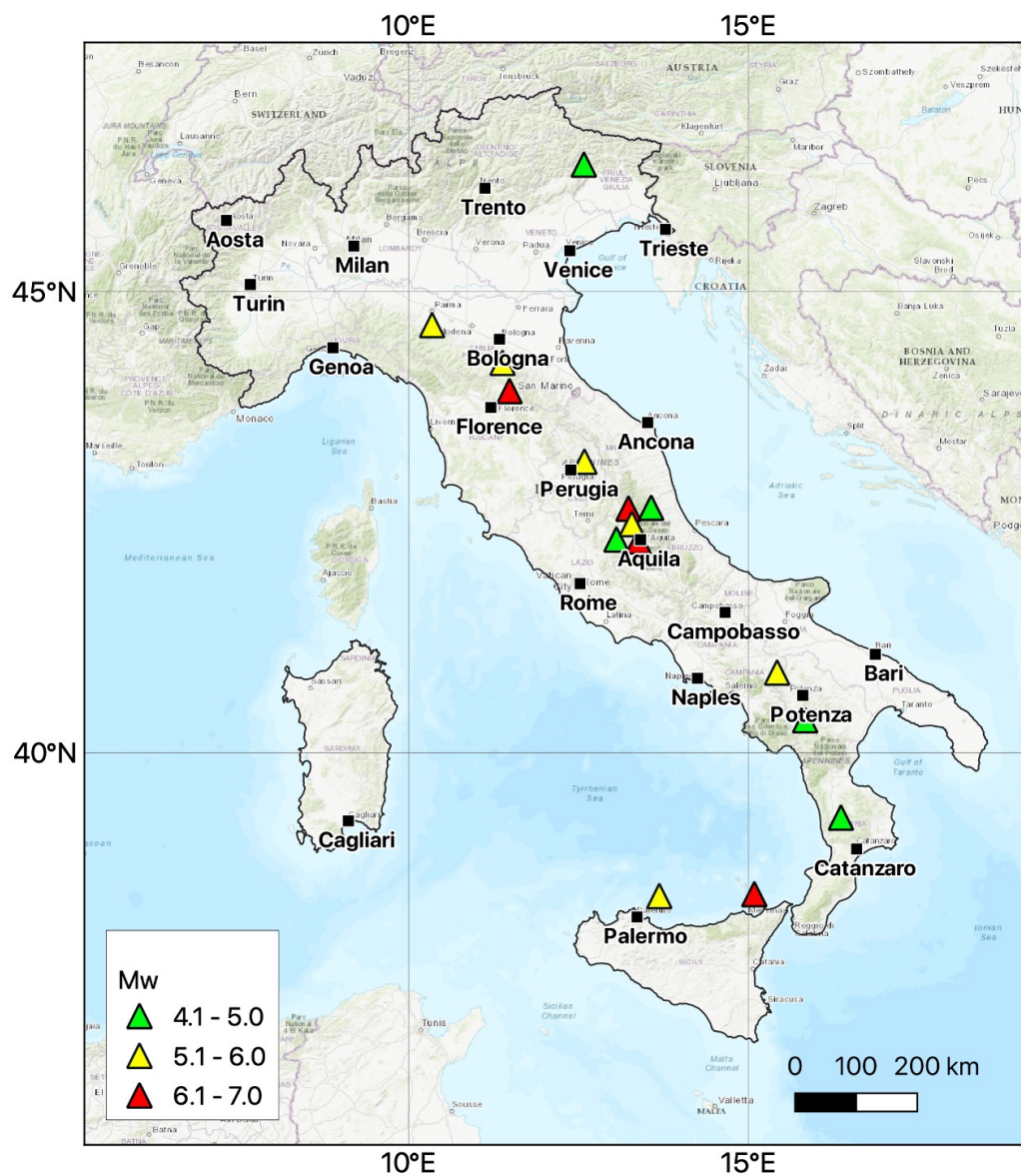


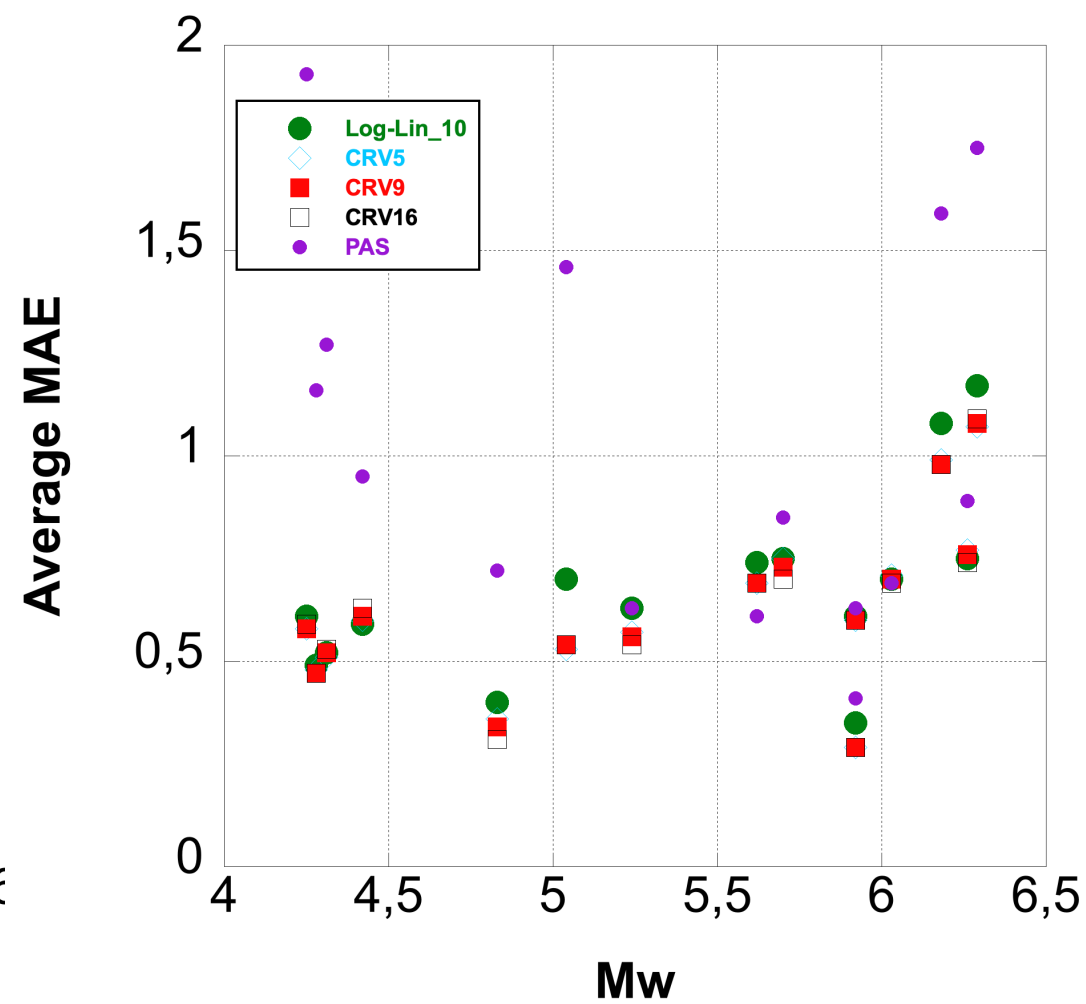
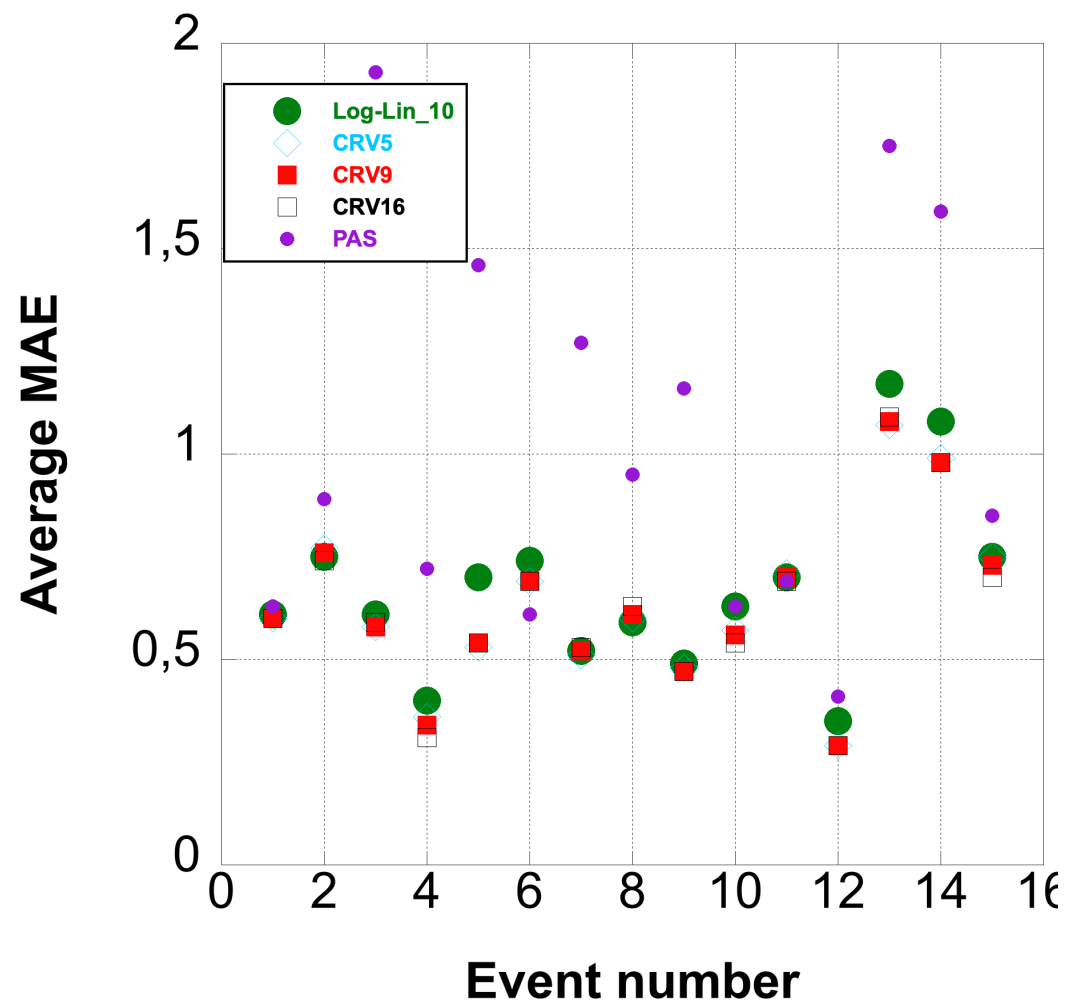




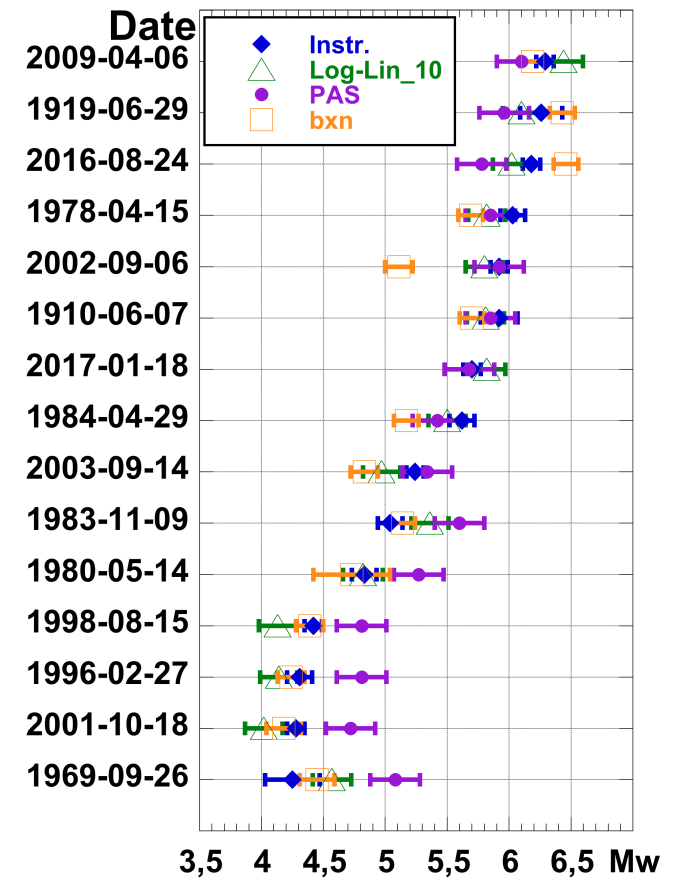
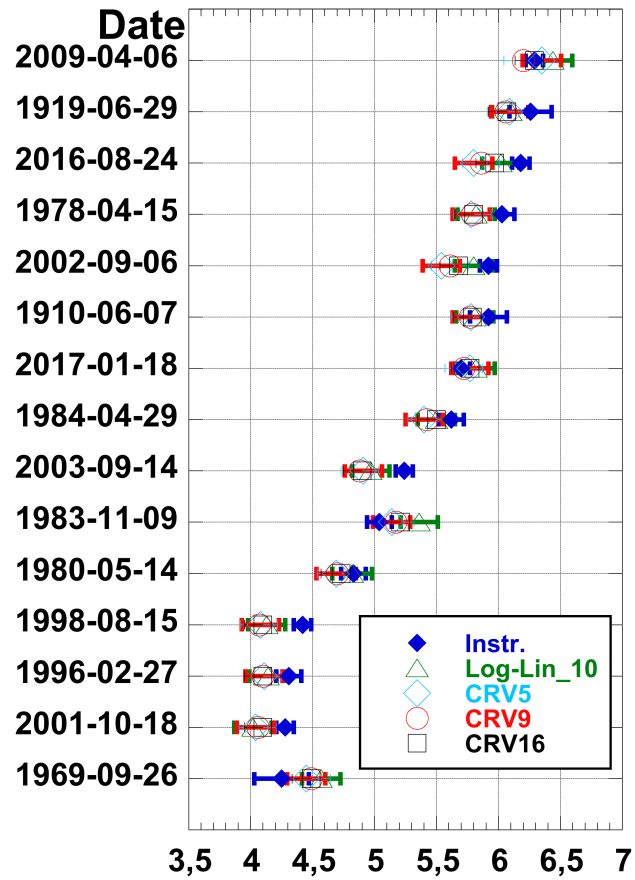


Validation





BW97



Key take-aways from **GOMAL 2024**

Two Mw-calibrated macroseismic IPEs

- ✓ **Log-Lin 10** – conventional log-linear attenuation; performs uniformly across the whole dataset
- ✓ **CRV9** – piece-wise curvilinear form; captures steeper decay at short distances and stronger Mw sensitivity

Large, high-quality calibration flat-file

- ✓ **119 Italian crustal earthquakes** (1908 – 2013)
- ✓ **16 260 macroseismic intensity data points** (I 3 – 11, MCS)
- ✓ Epicentral-distance span: **0.1 – 634 km**
- ✓ Mw range: **3.8 – 7.1**

Key take-aways from **GOMAL 2024**

Validation highlights

- ✓ Both models reproduce the global I-distance trend; **CRV9** shows lower residuals for $M_w > 6.5$ and $R_{epi} < 20$ km.

Implications

- ✓ Provides an updated empirical basis for Italian SHA
- ✓ Flat-file (*Calibration dataset*) is open and ready for extended **distance-metric (Rjb)** investigations

Flat-file is open and ready for extended **distance-metric** (**Rjb**)...

15 earthquakes-sources (from DISS, ITACA, etc) / 7.642 MDPs (Calibration Dataset Subset)

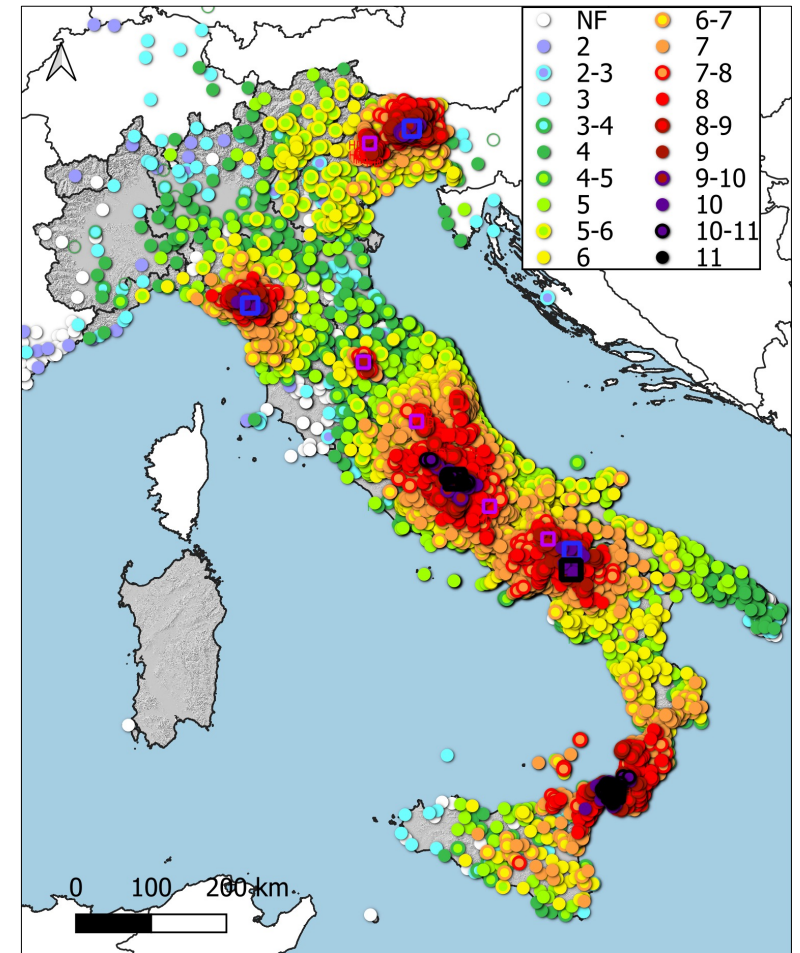
CPTI15

[illegible]

15 source-events

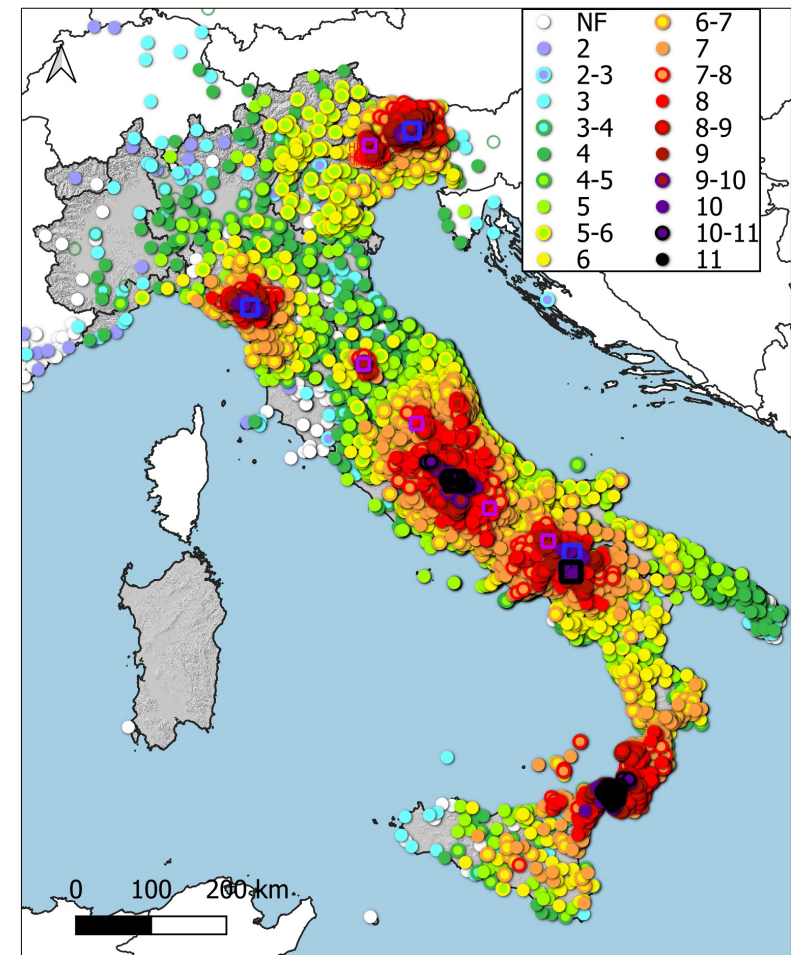


7642 MDPs (DBMI15)

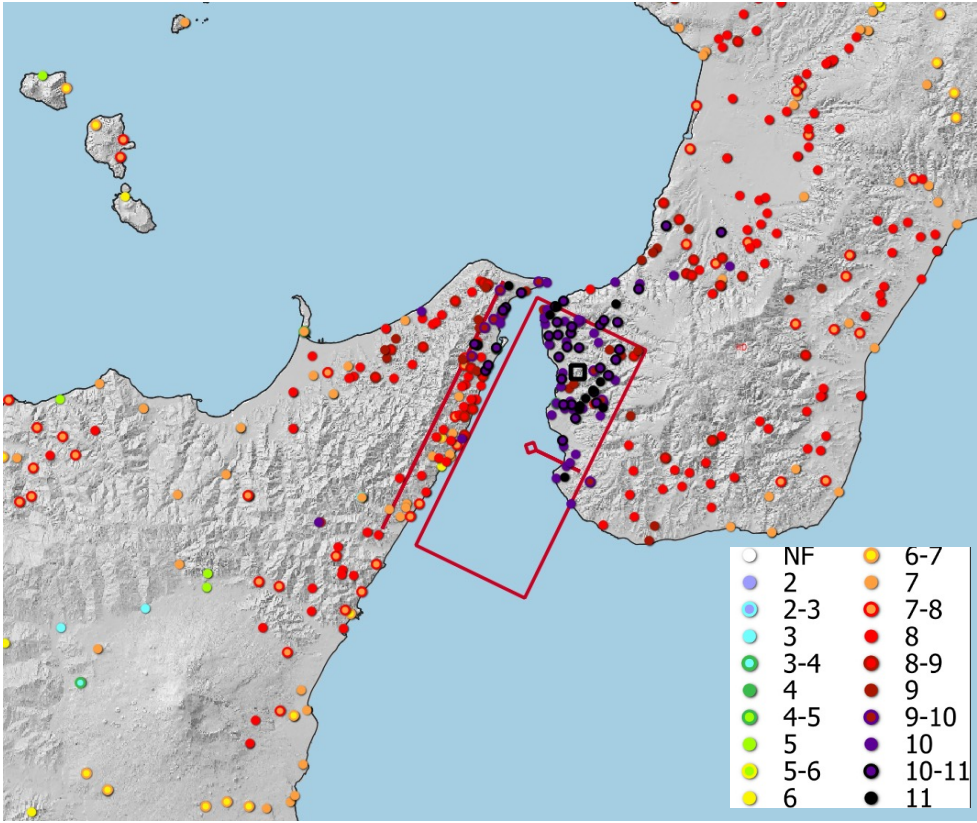


Parameter	Value
Number of earthquakes	15
Time span	1908 – 1984
Number of MDPs	7 642
Mw range	5.6 – 7.1
Macrosismic intensity range (I)	3 – 11 MCS
JBR distance range	0 – 596 km
Event with most IDPs	1980-11-23 (Irpinia) – 1 222 MDPs
Events containing I = 11	1908-12-28, 1915-01-13

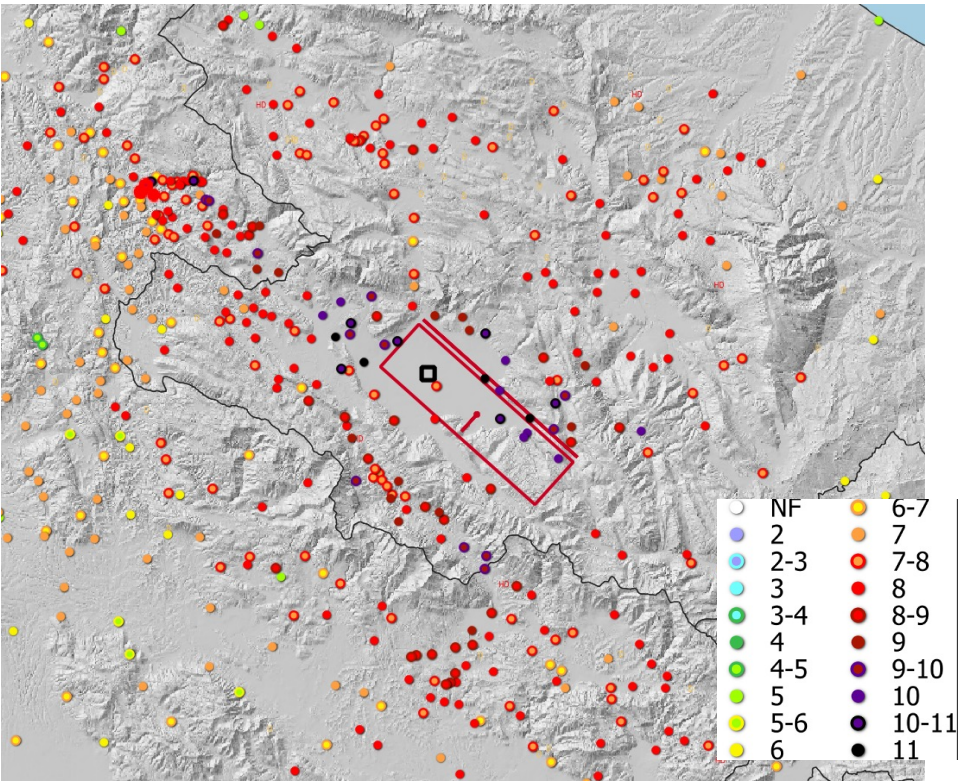
7642 MDPs (DBMI15)

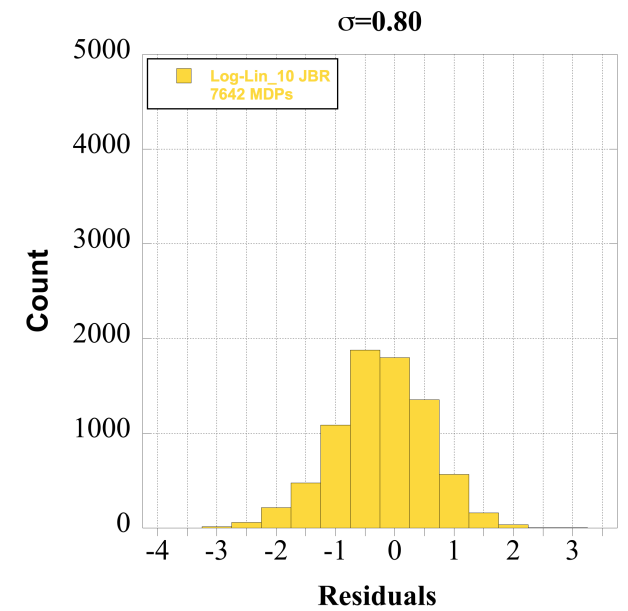
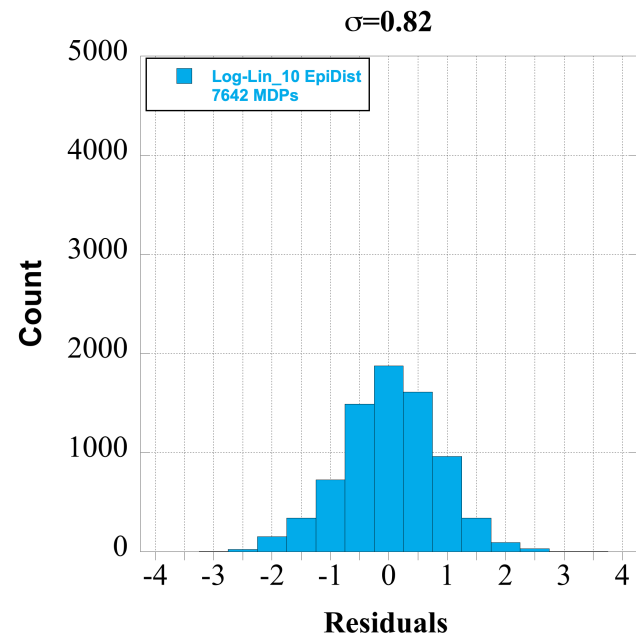
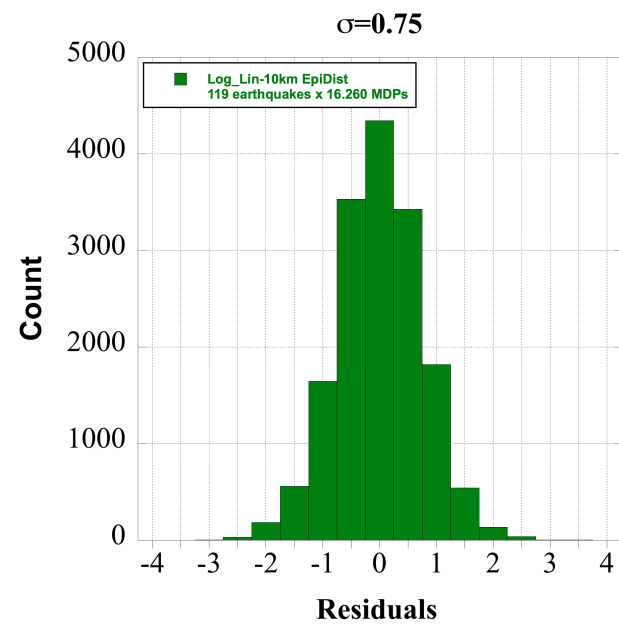


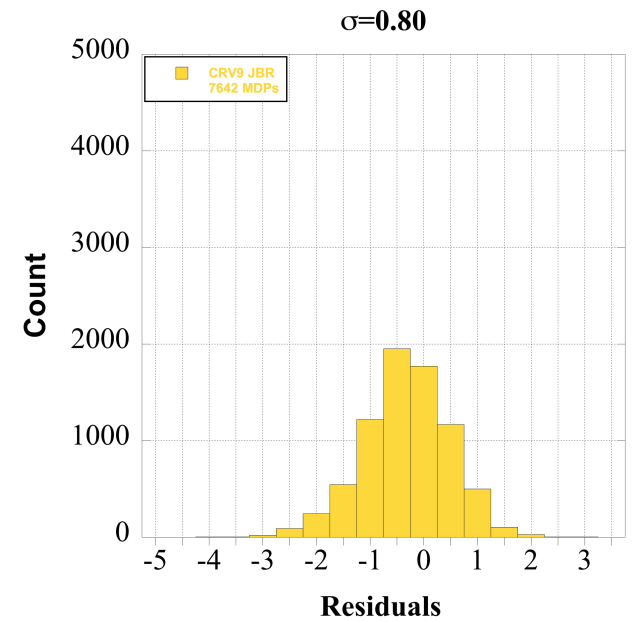
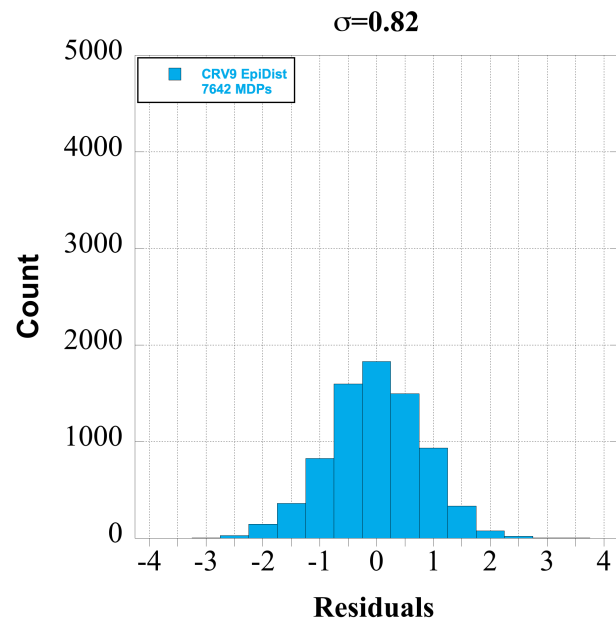
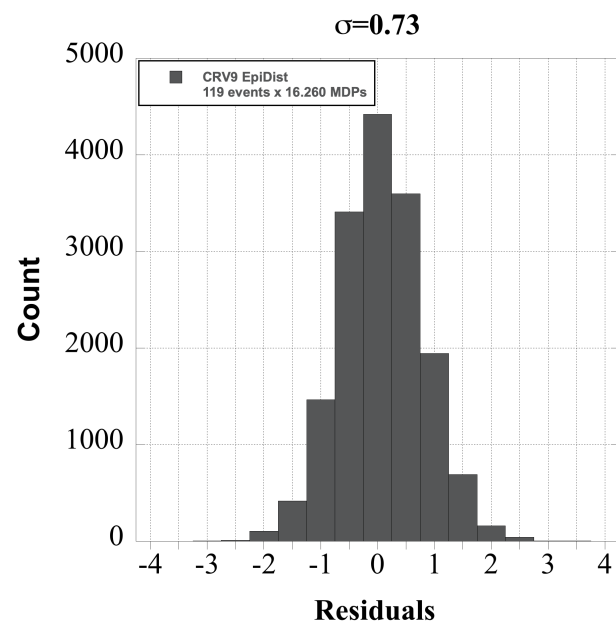
Parameter	Value
Number of earthquakes	15
Time span	1908 – 1984
Number of MDPs	7 642
Mw range	5.6 – 7.1
Macrosismic intensity range (I)	3 – 11 MCS
JBR distance range	0 – 596 km
Event with most IDPs	1980-11-23 (Irpinia) – 1 222 MDPs
Events containing I = 11	1908-12-28 , 1915-01-13

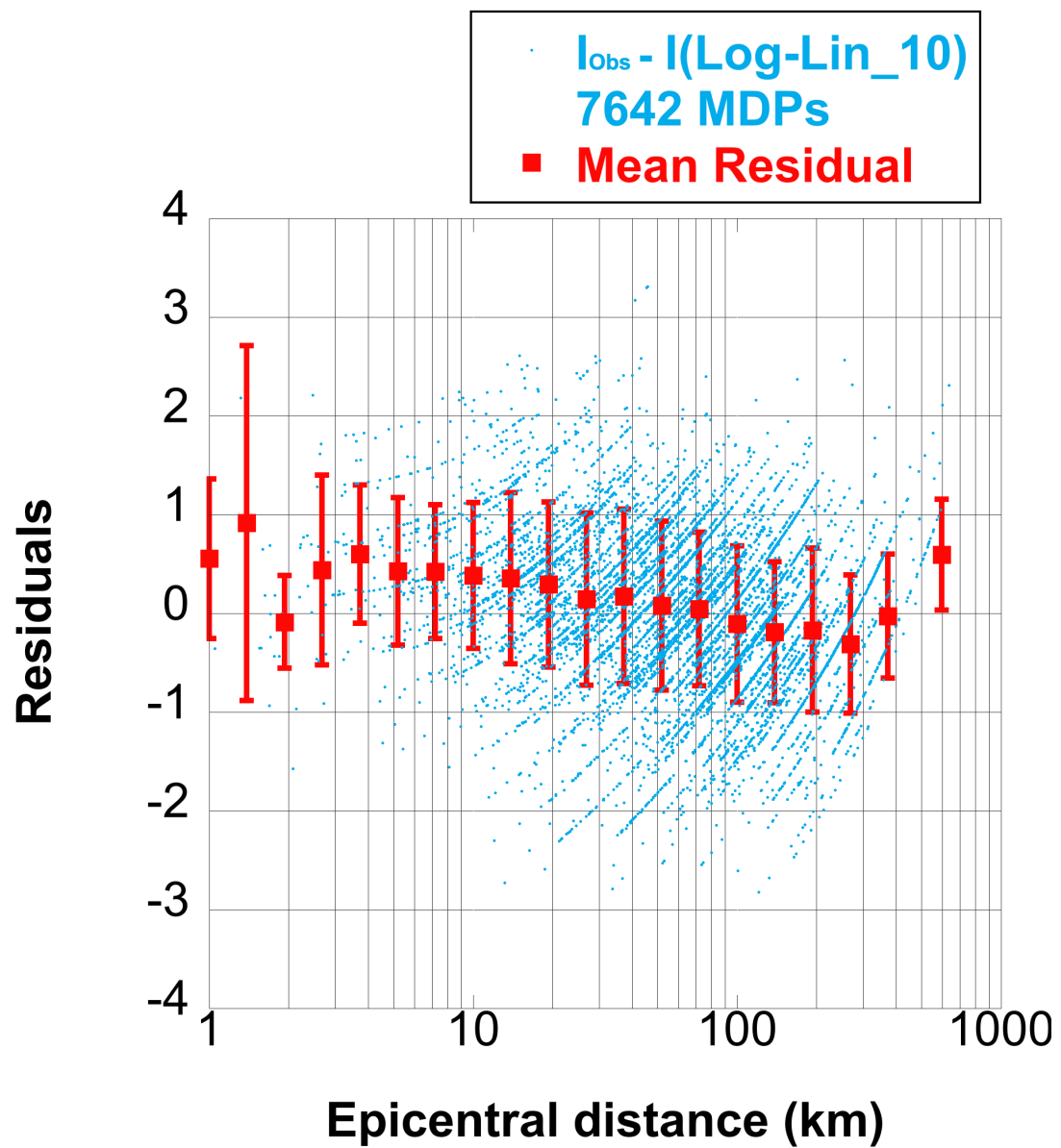
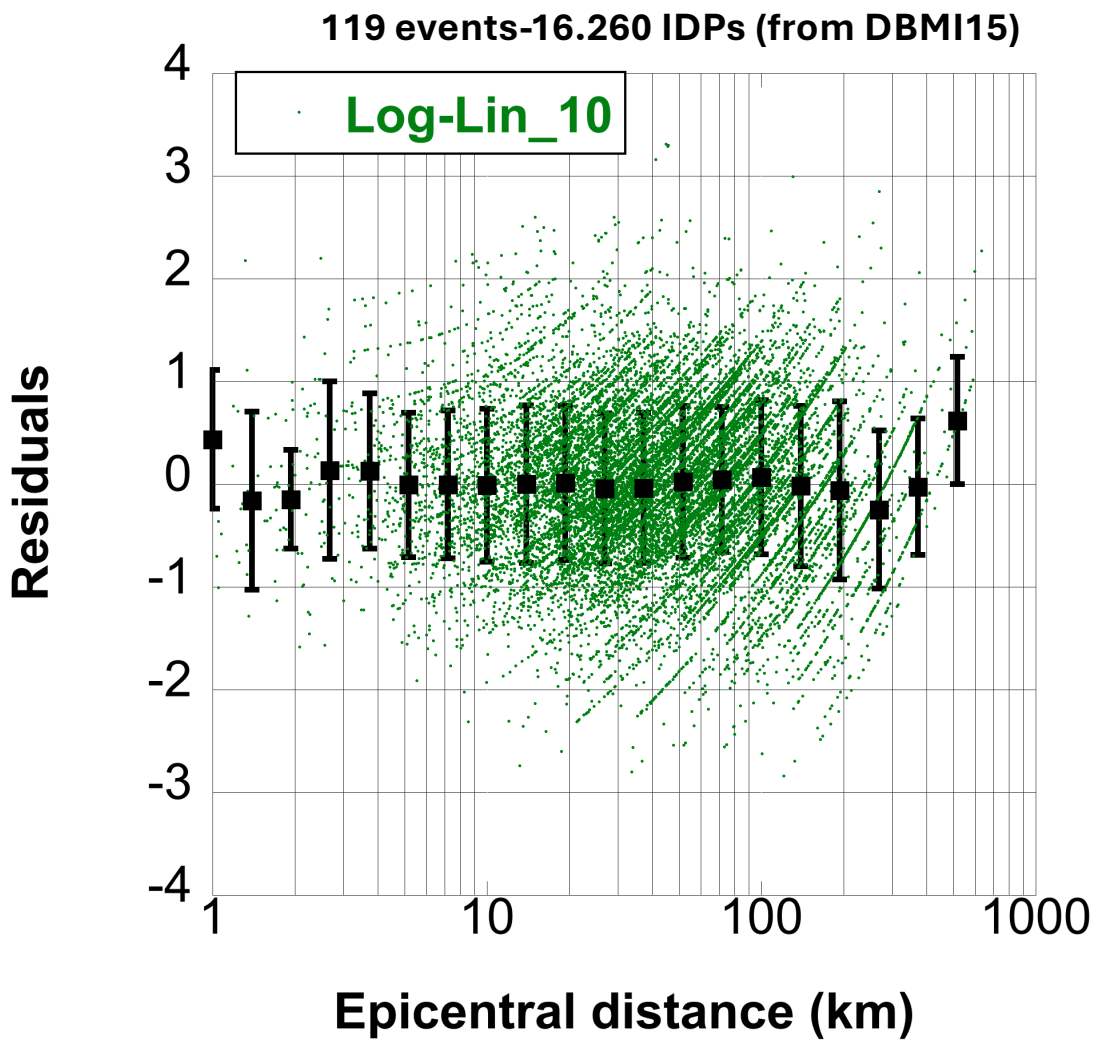


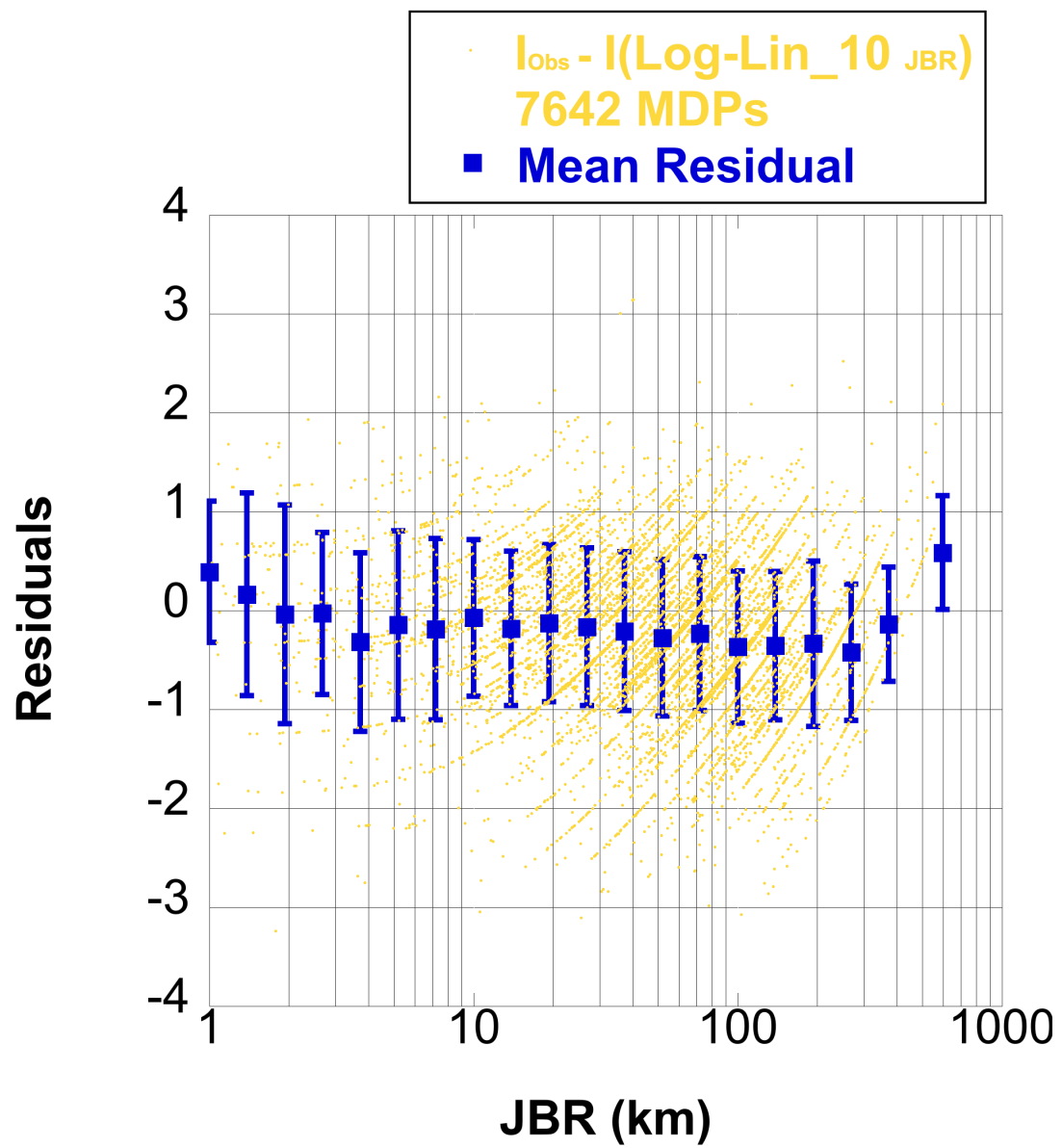
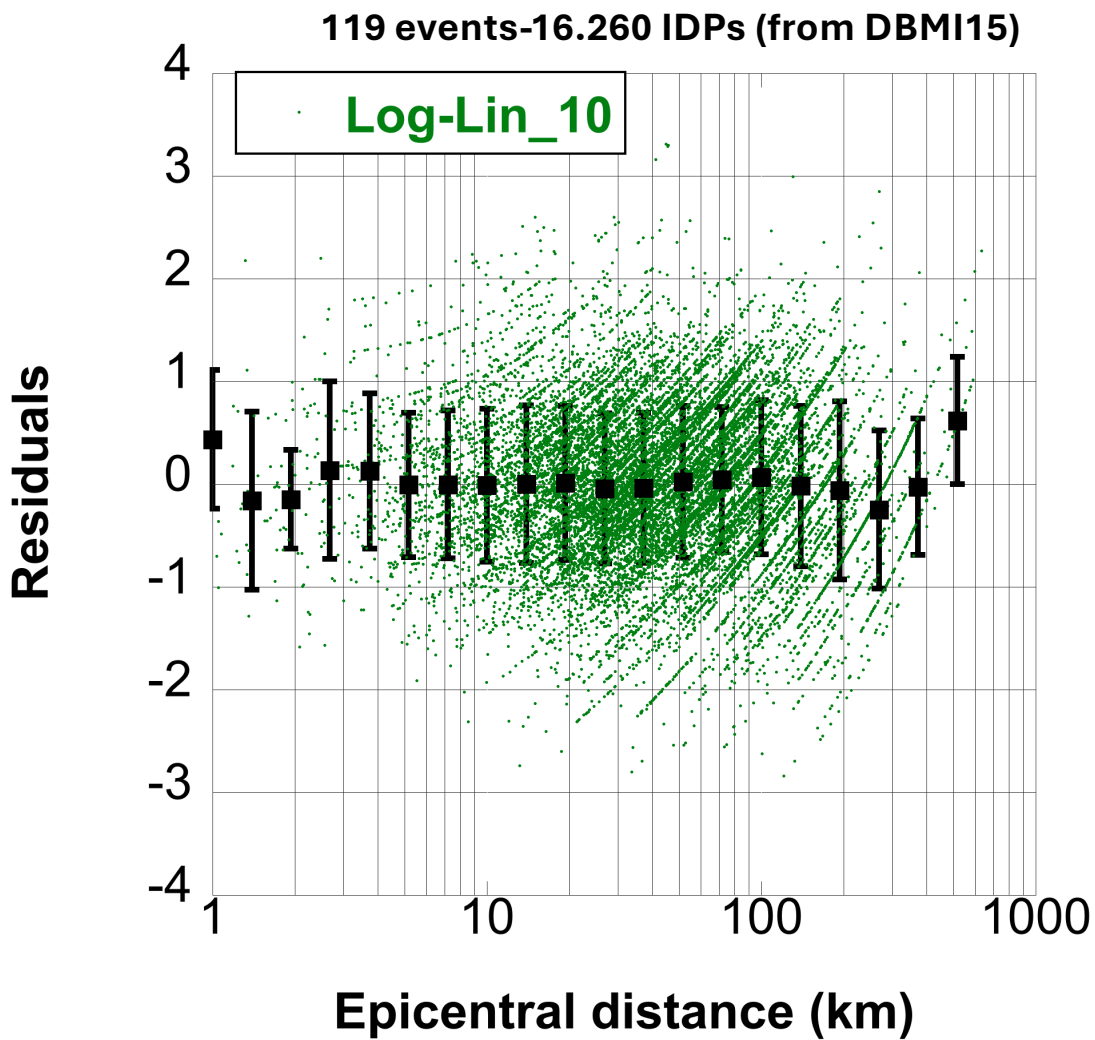
Parameter	Value
Number of earthquakes	15
Time span	1908 – 1984
Number of MDPs	7 642
Mw range	5.6 – 7.1
Macrosismic intensity range (I)	3 – 11 MCS
JBR distance range	0 – 596 km
Event with most IDPs	1980-11-23 (Irpinia) – 1 222 MDPs
Events containing I = 11	1908-12-28, 1915-01-13

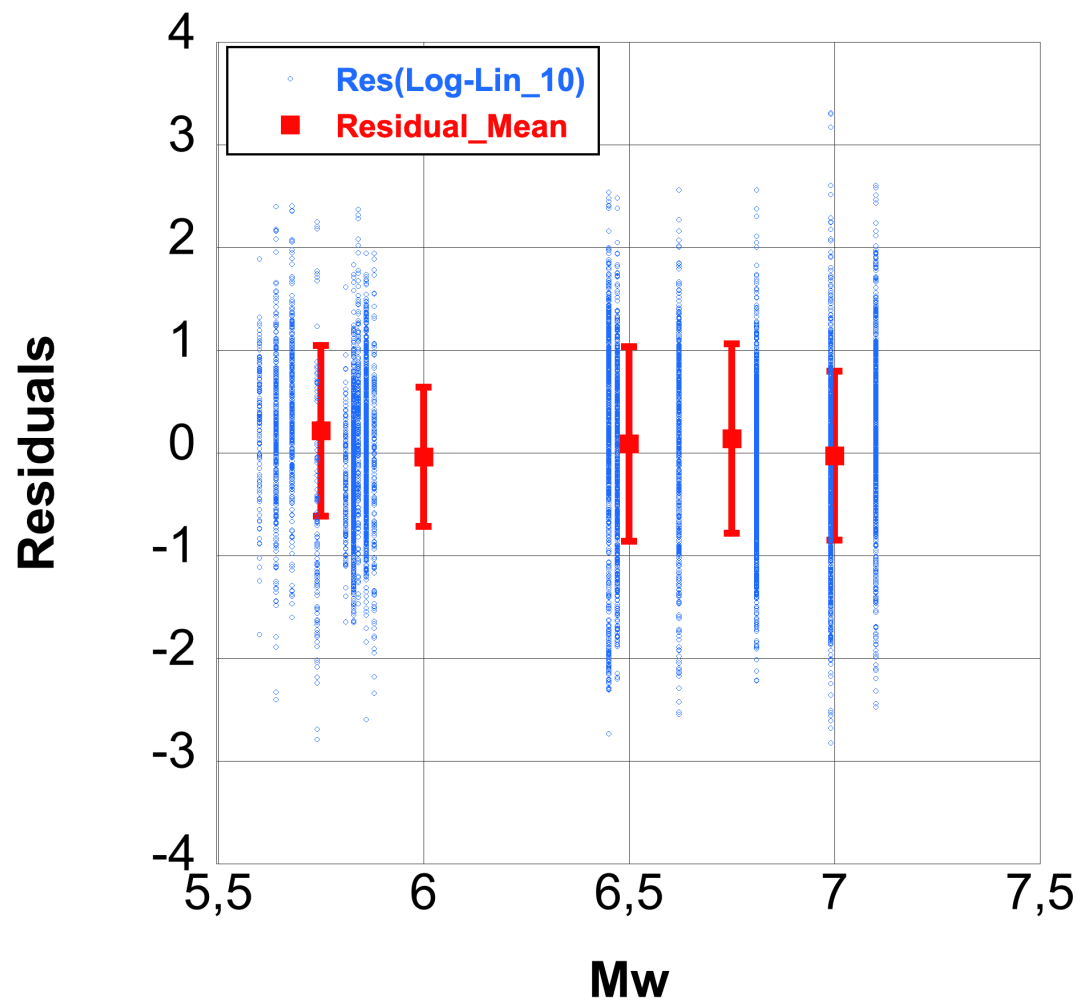
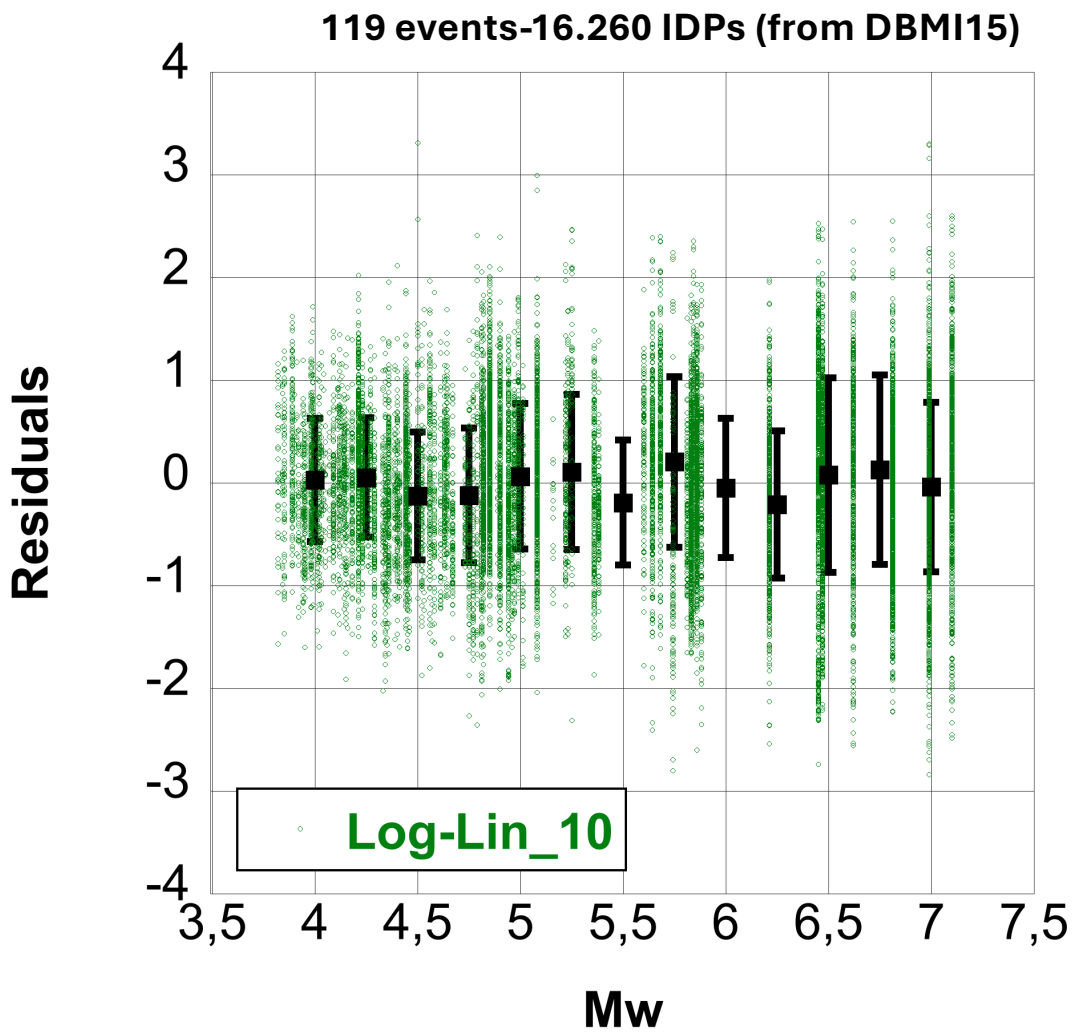


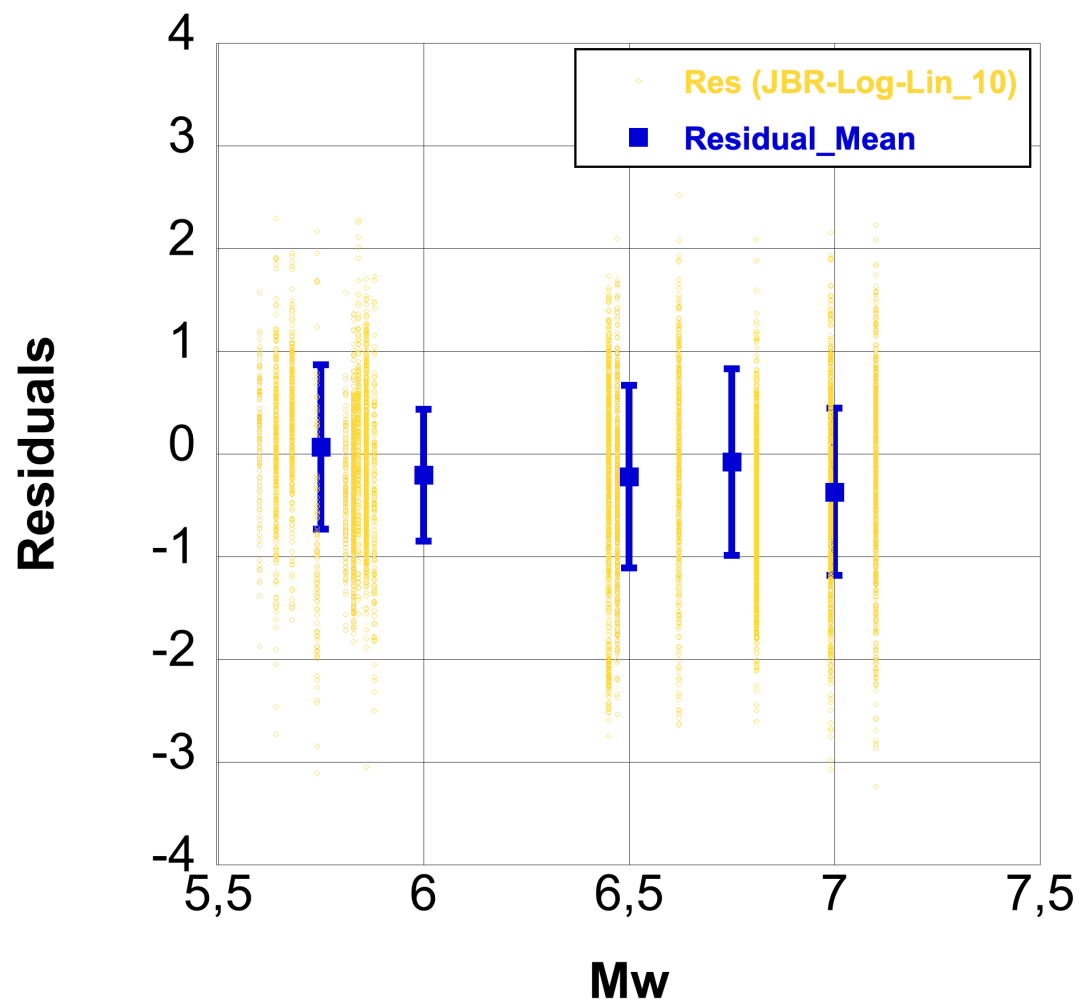
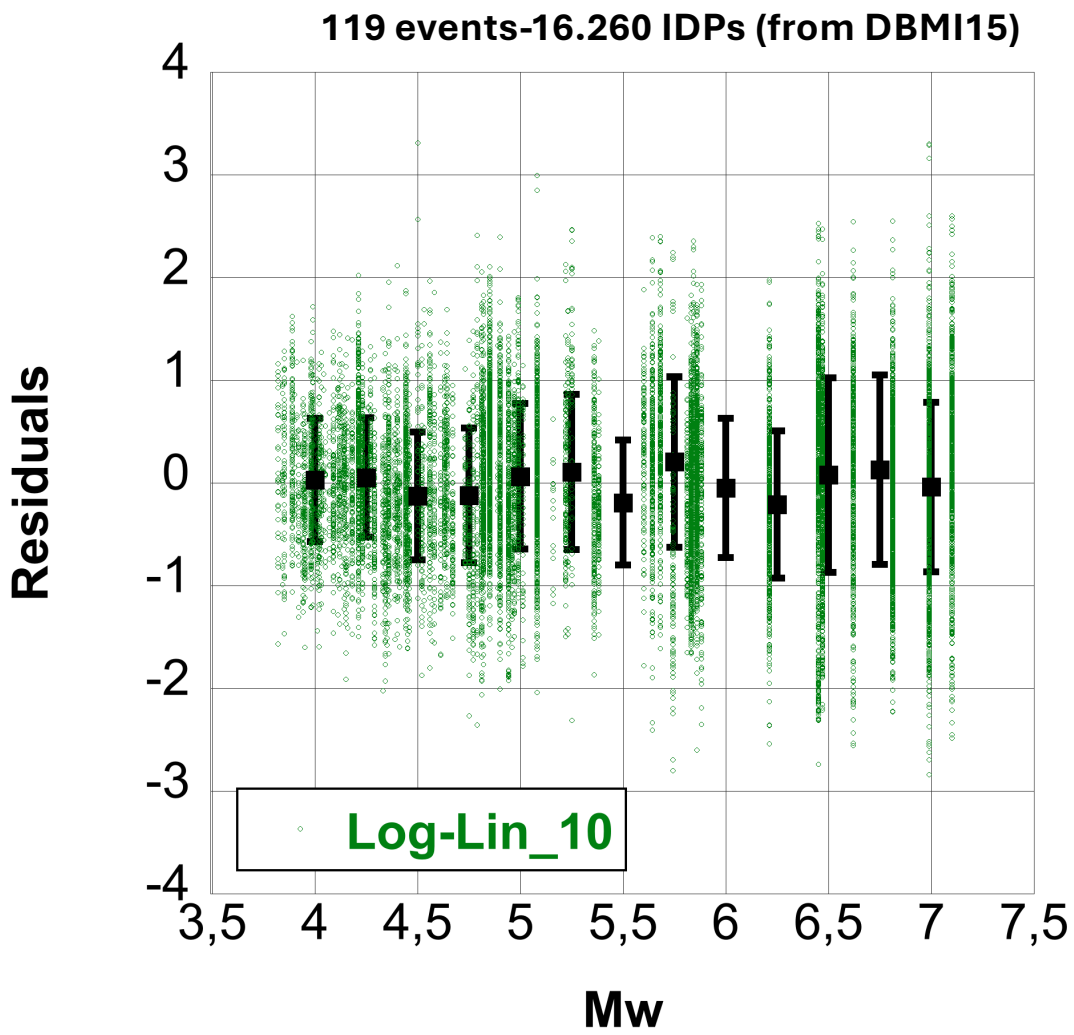


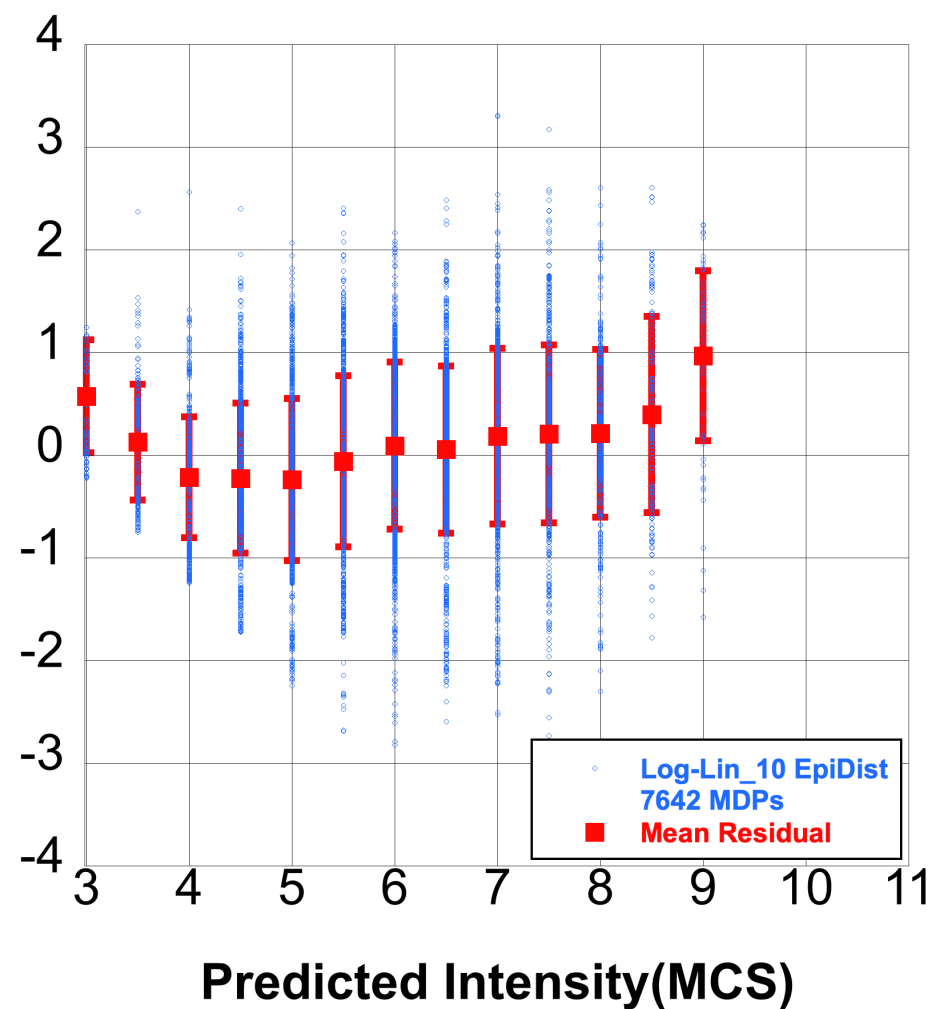
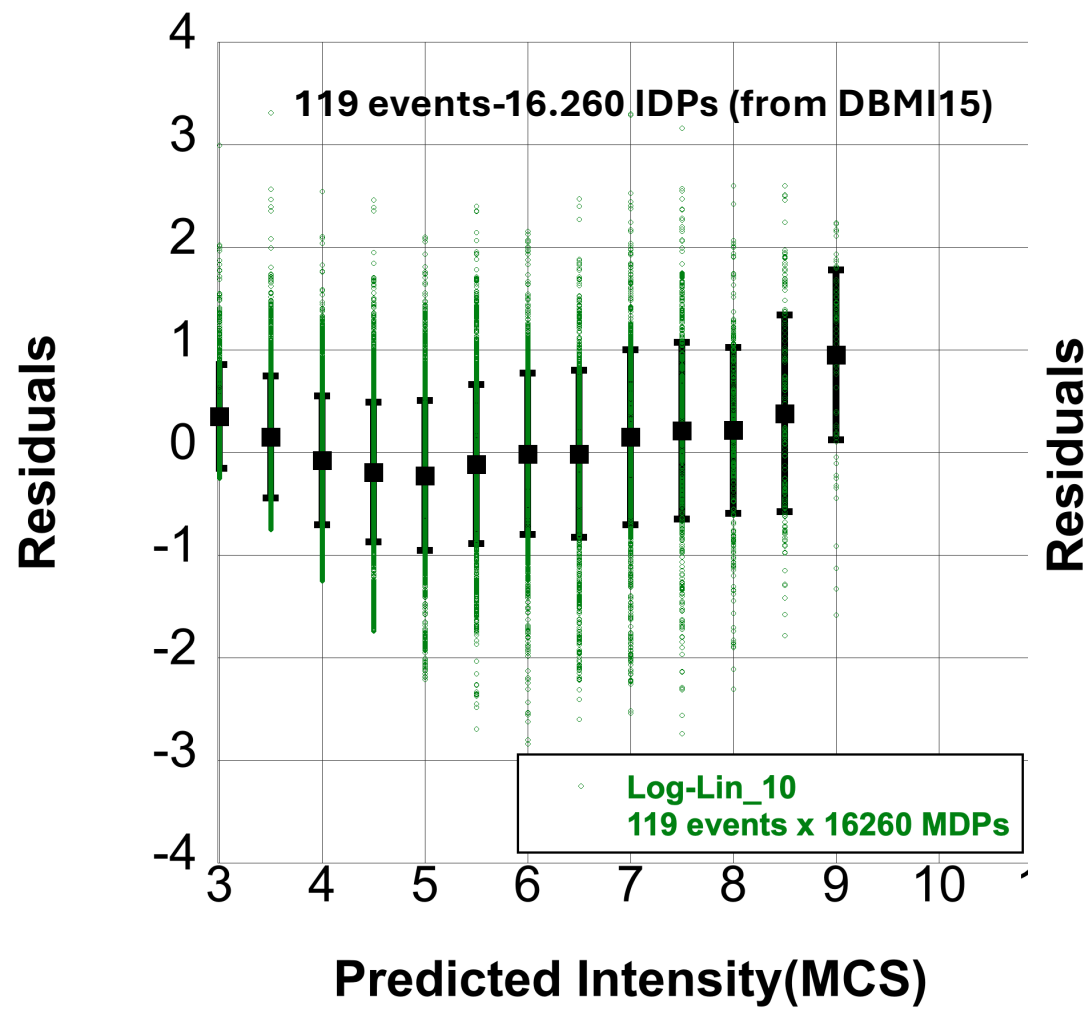


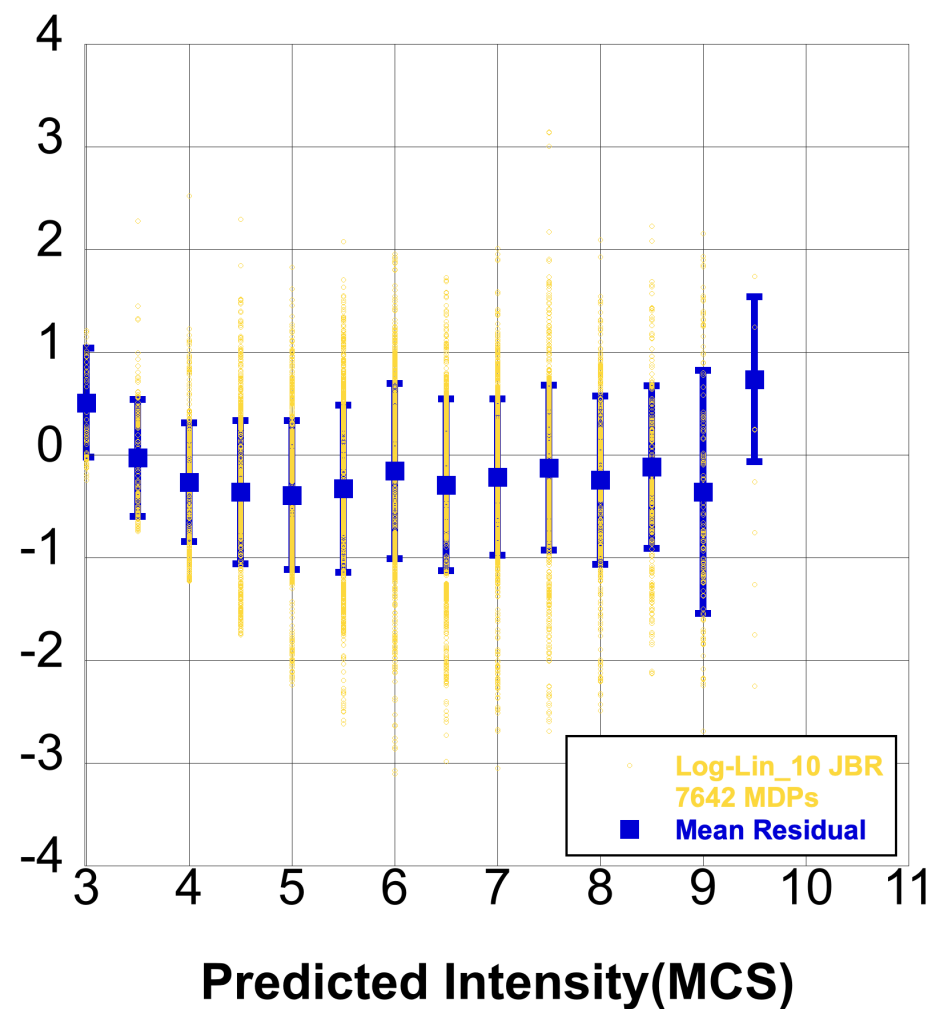
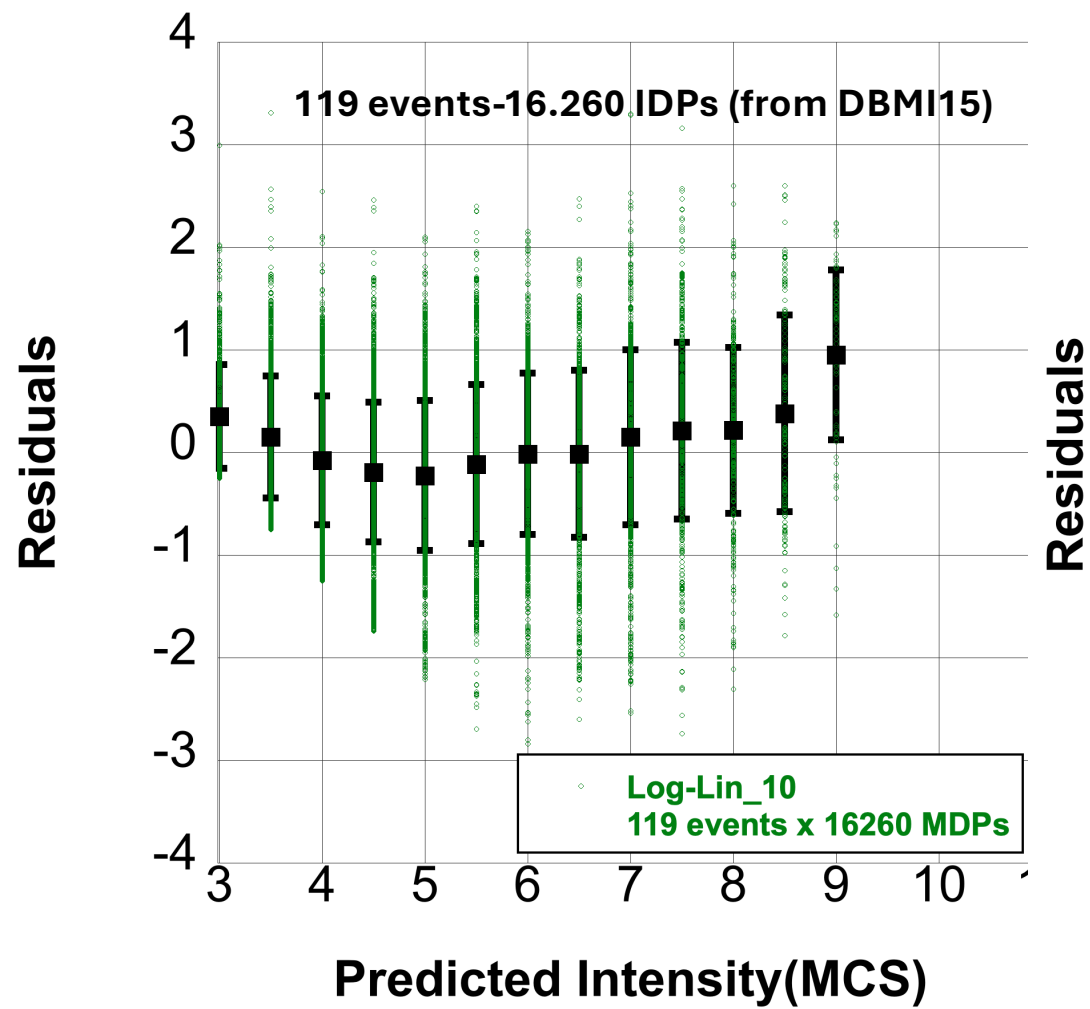


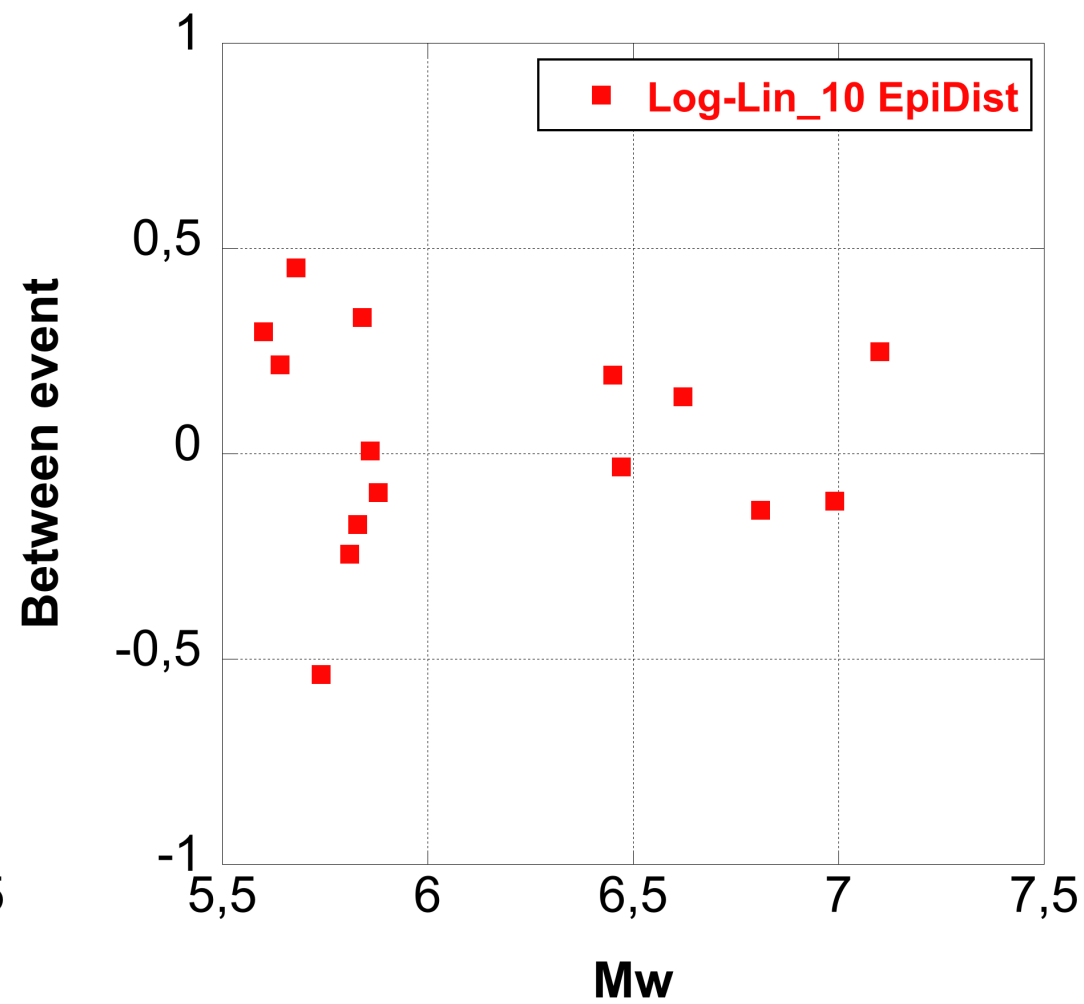
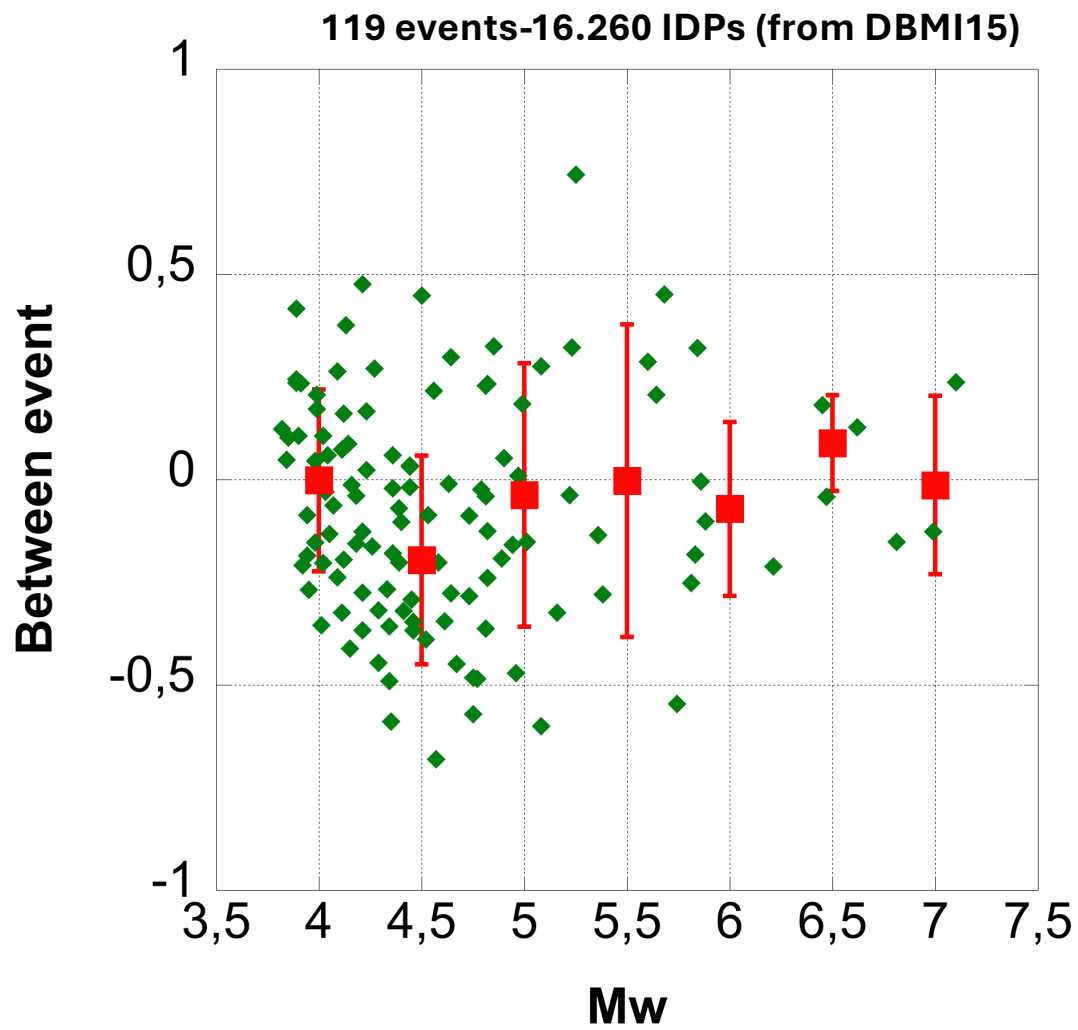


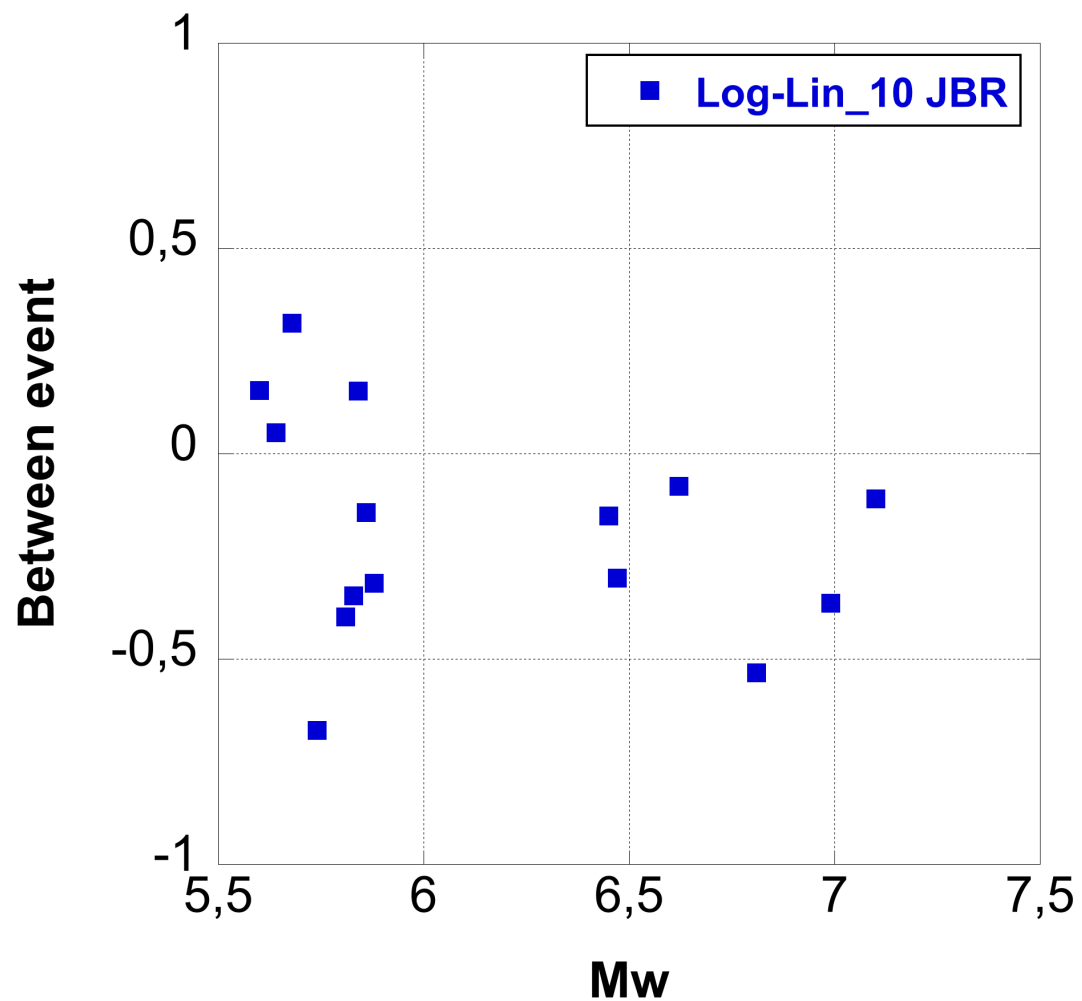
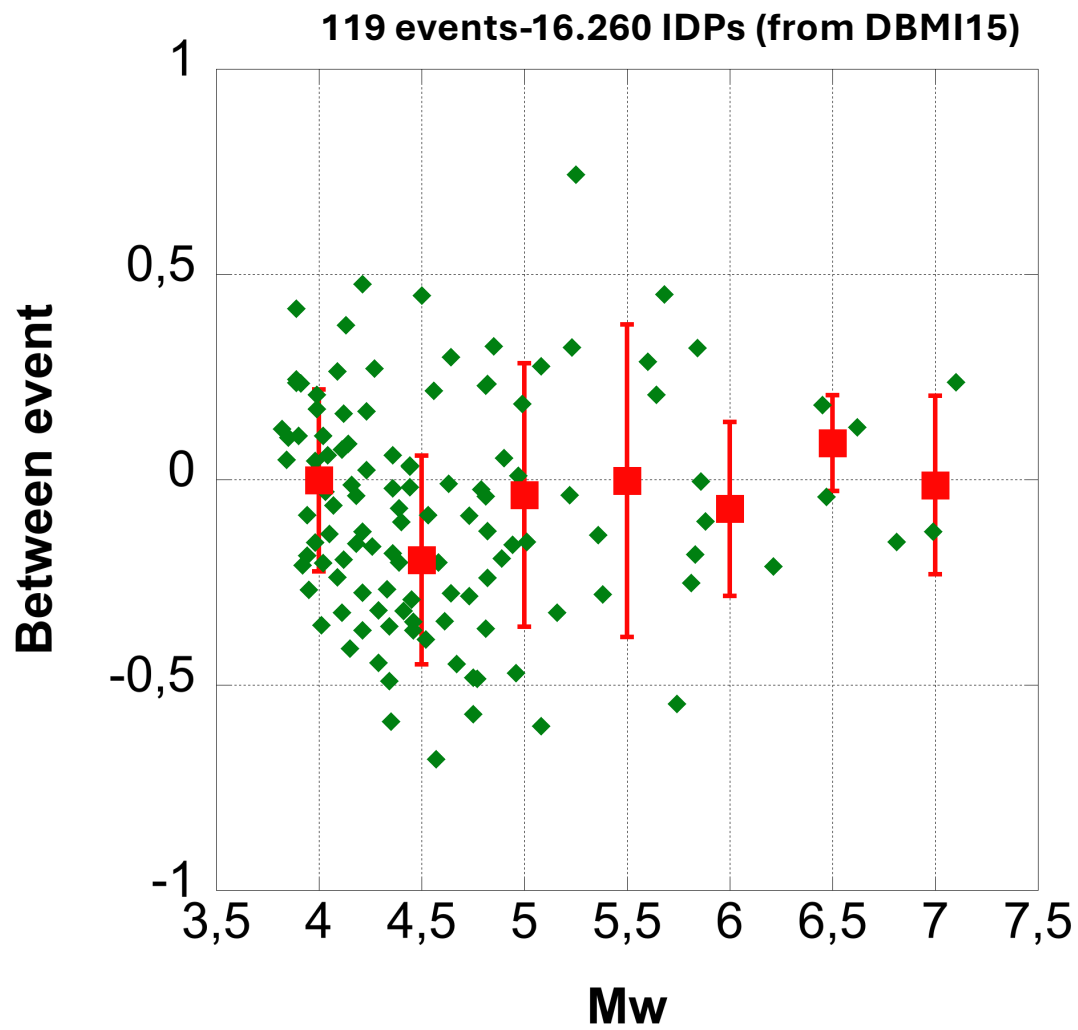


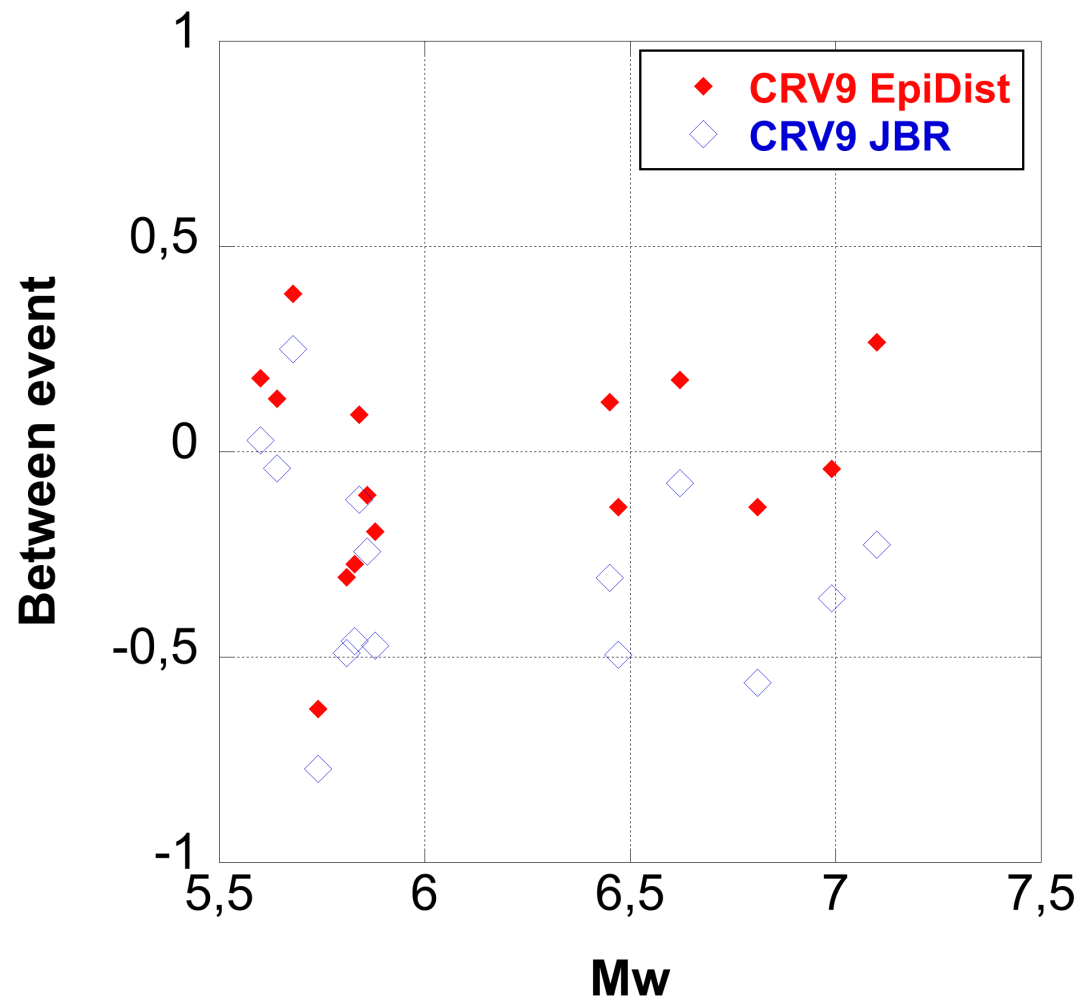
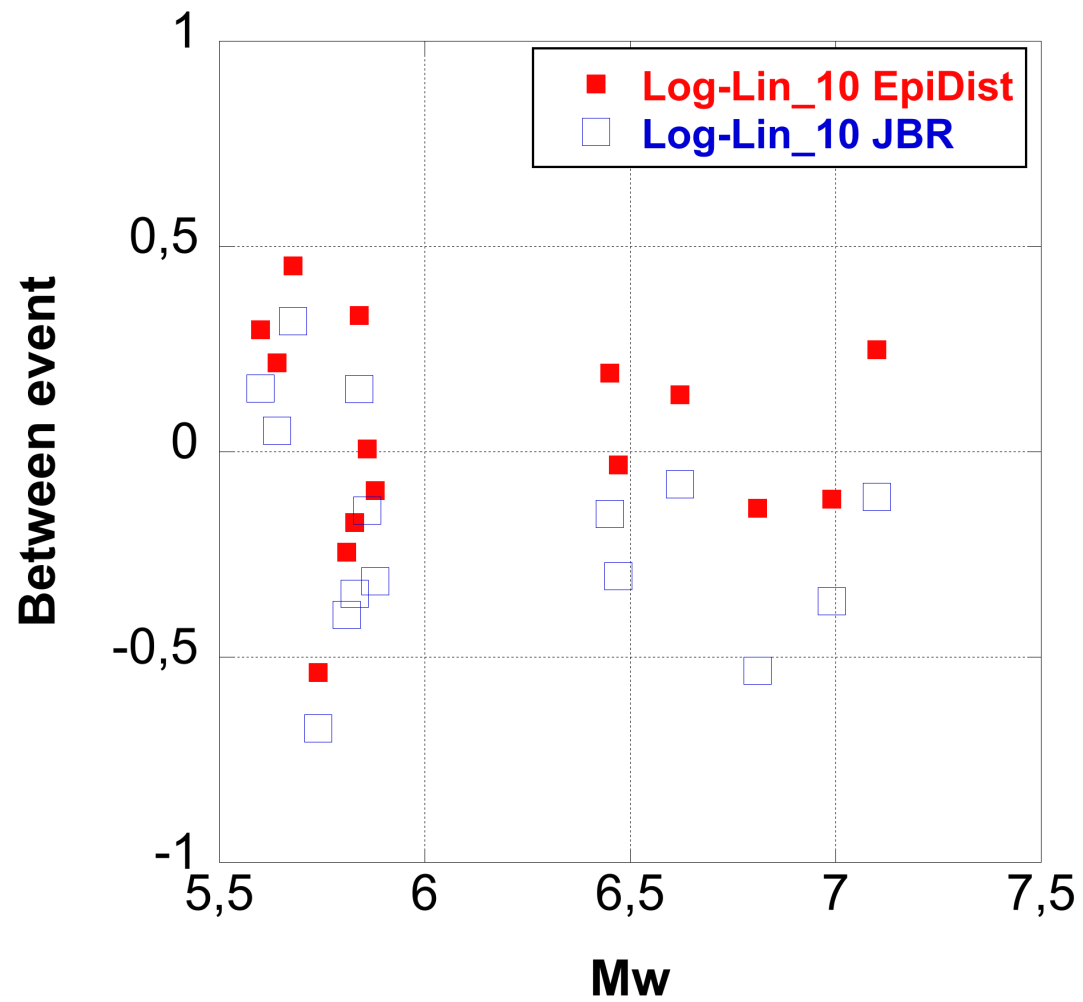












Model	Mean_eta
Log-Lin 10 – Epicentral	0,04
Log-Lin 10 – JBR	-0,18
CRV9 – Epicentral	-0,03
CRV9 – JBR	-0,29

Analysis in progress...

- ✓ ***Rjb flat-file*** – **15 earthquakes / 7.642 MDPs** – confirms that the automated ***Rjb*** workflow is technically sound and reproducible.
- ✓ Re-evaluating models with ***Rjb*** removes distance bias and reduces τ , but introduces a small negative global offset → *indicates that coefficients themselves must be re-calibrated for the new metric.*

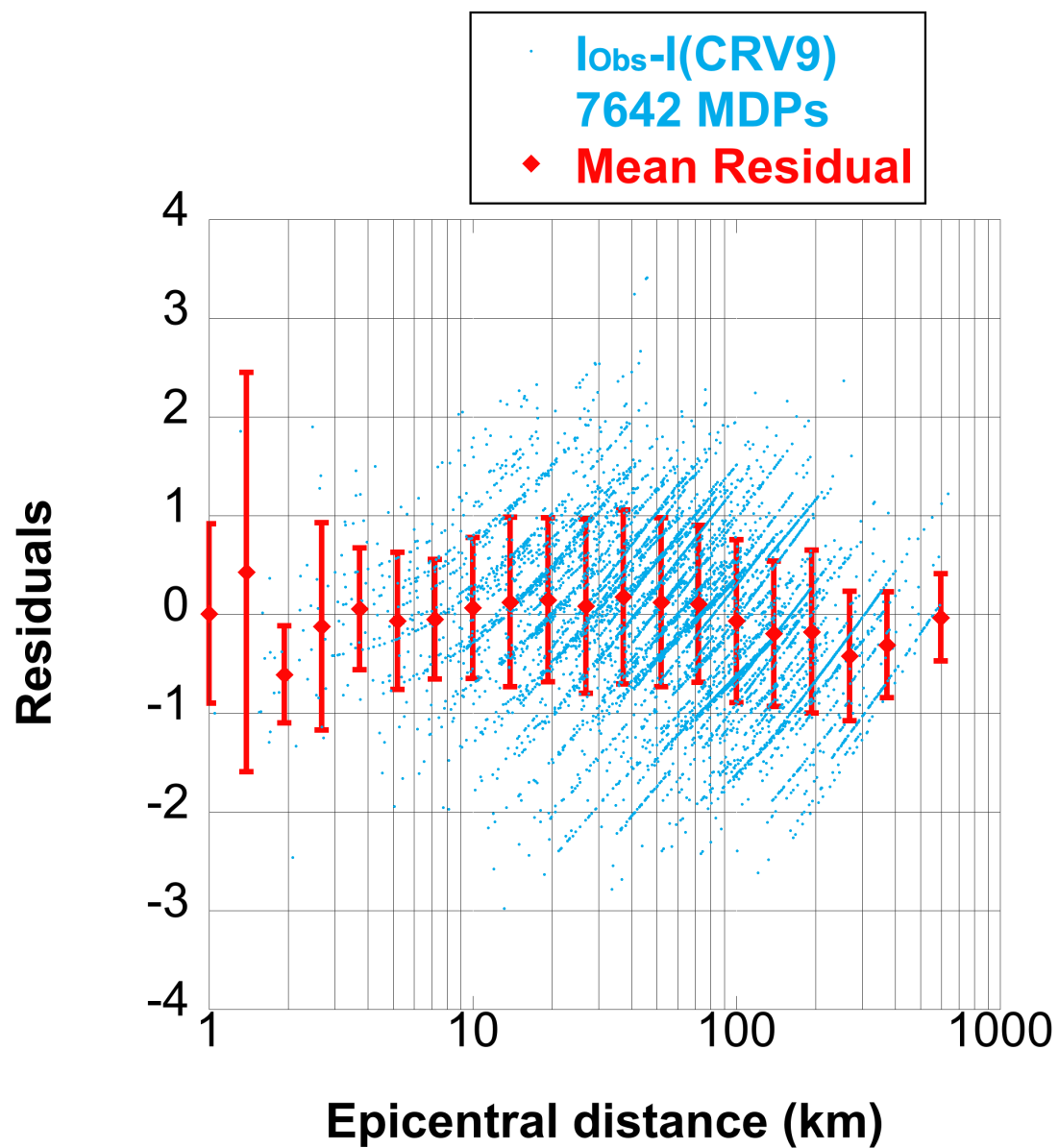
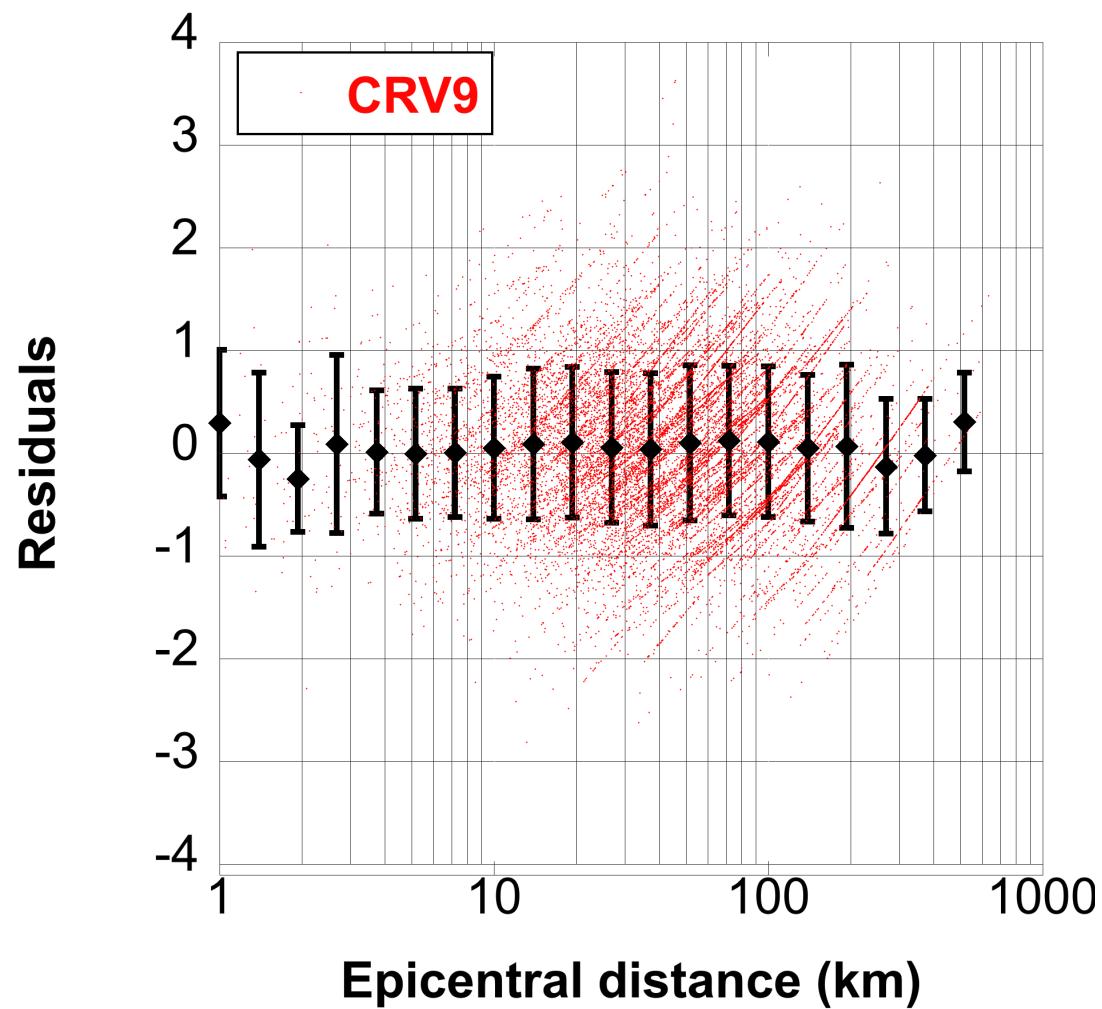
***Rjb* Insights and Roadmap**

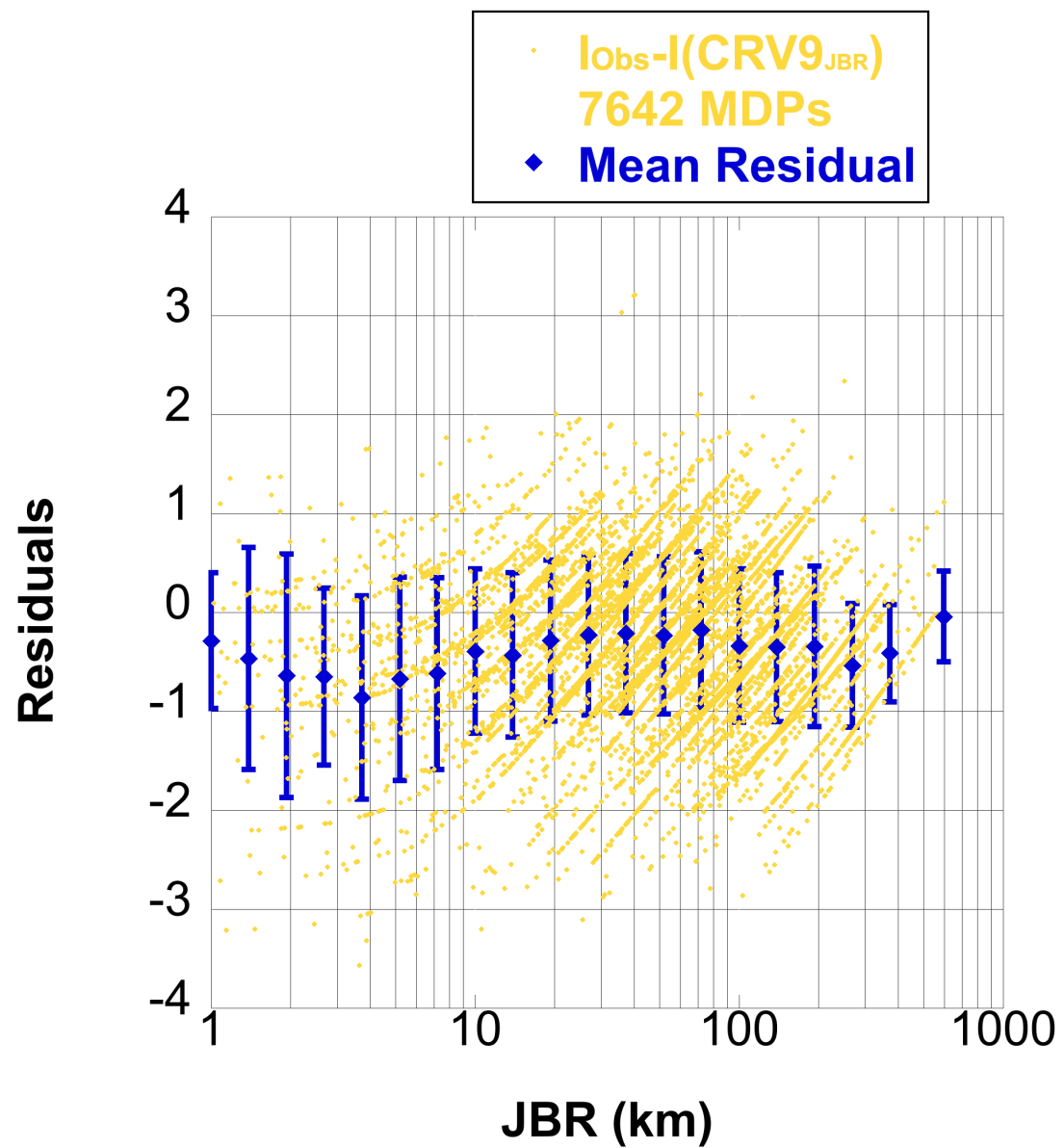
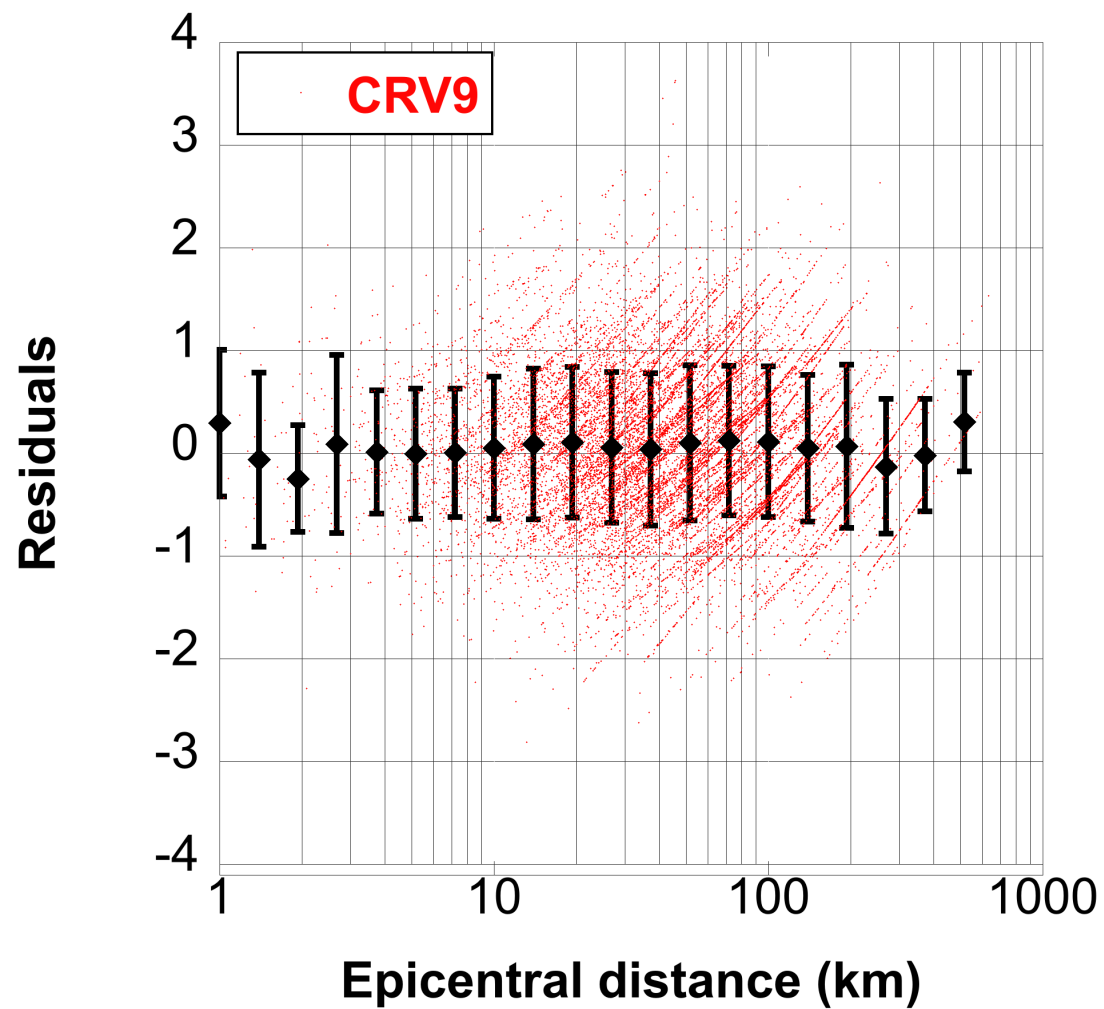
Objective: derive distance-consistent coefficients for both IPEs.

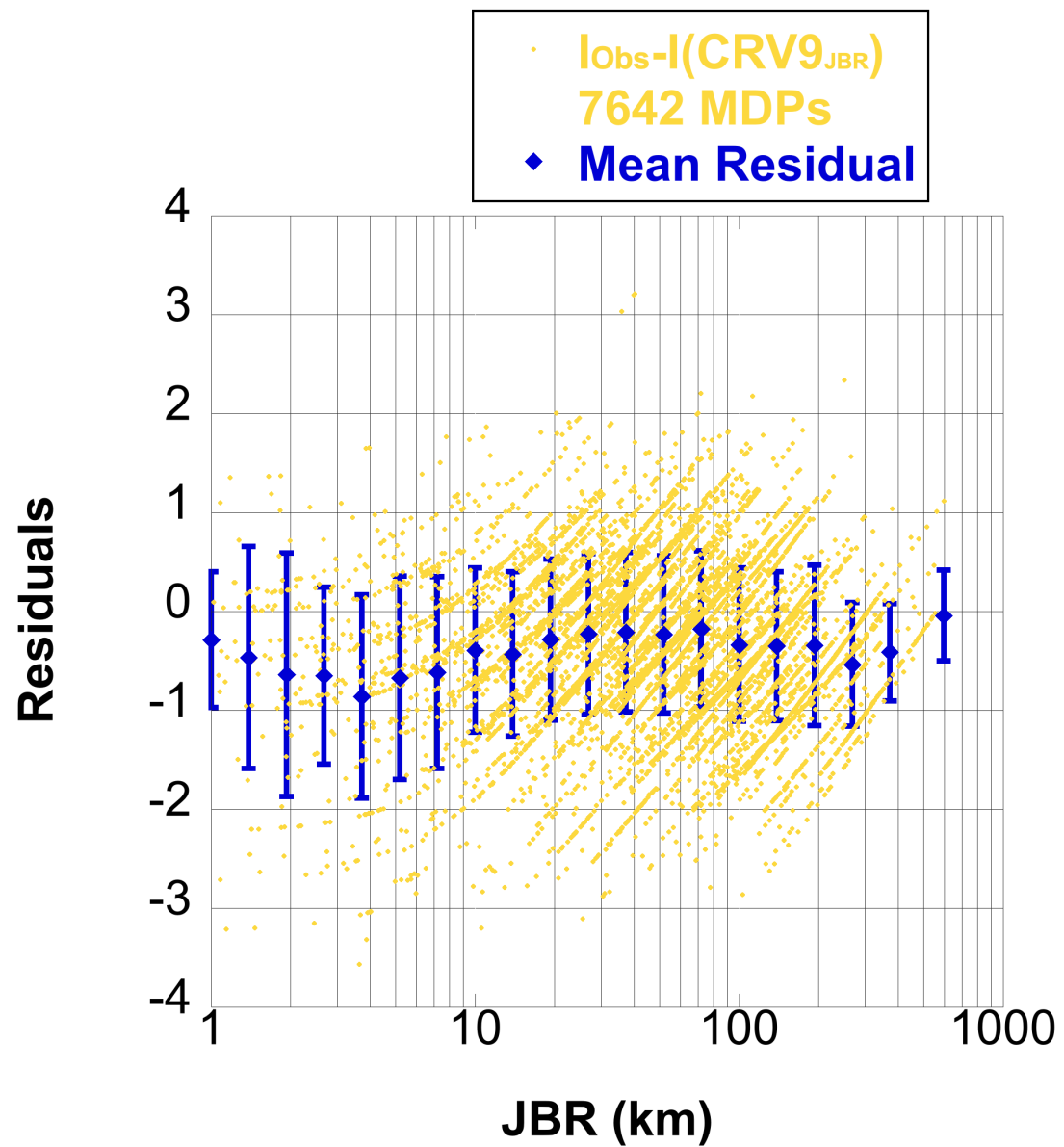
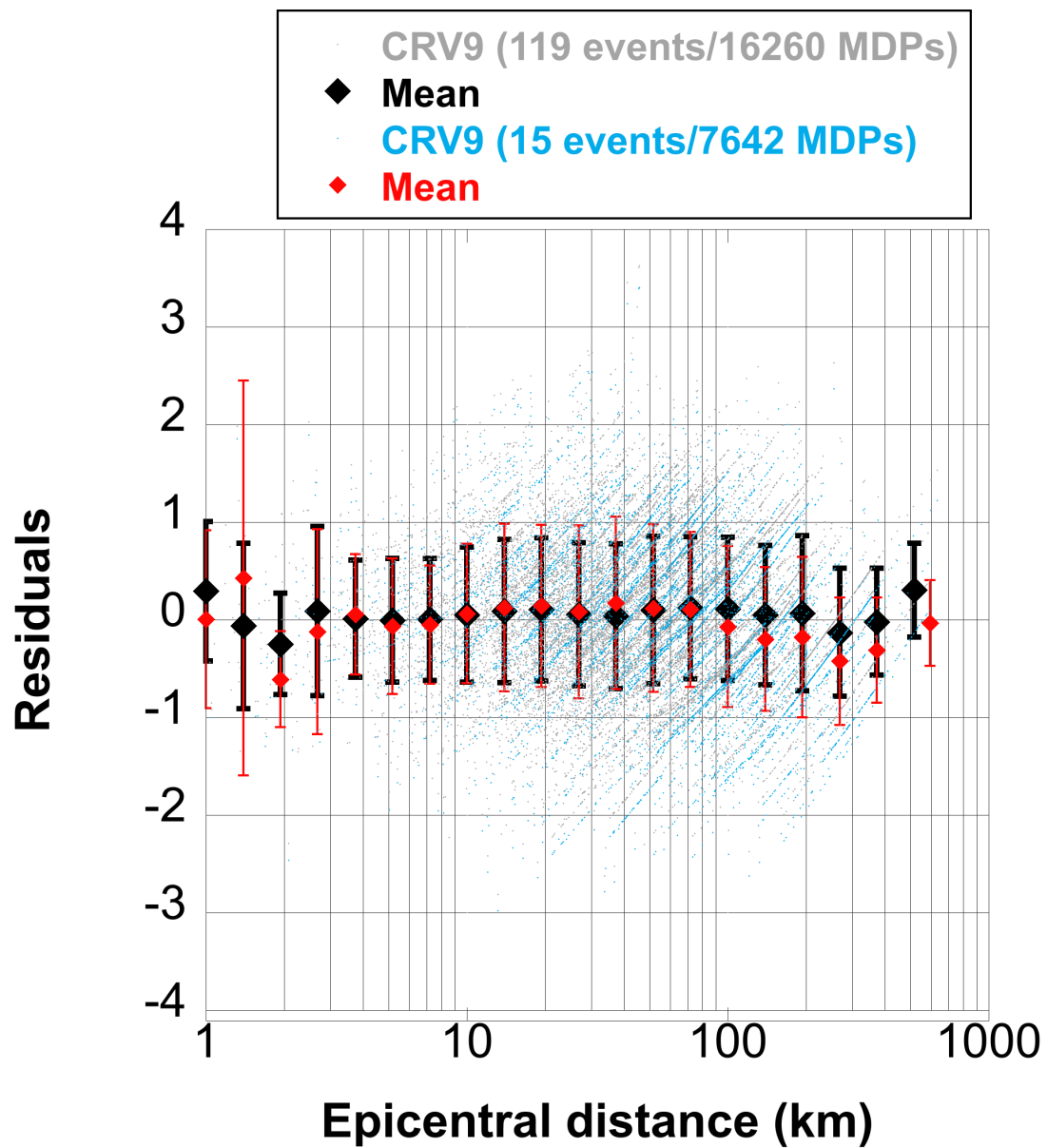
Dataset: the complete GOMAL 2024 flat-file

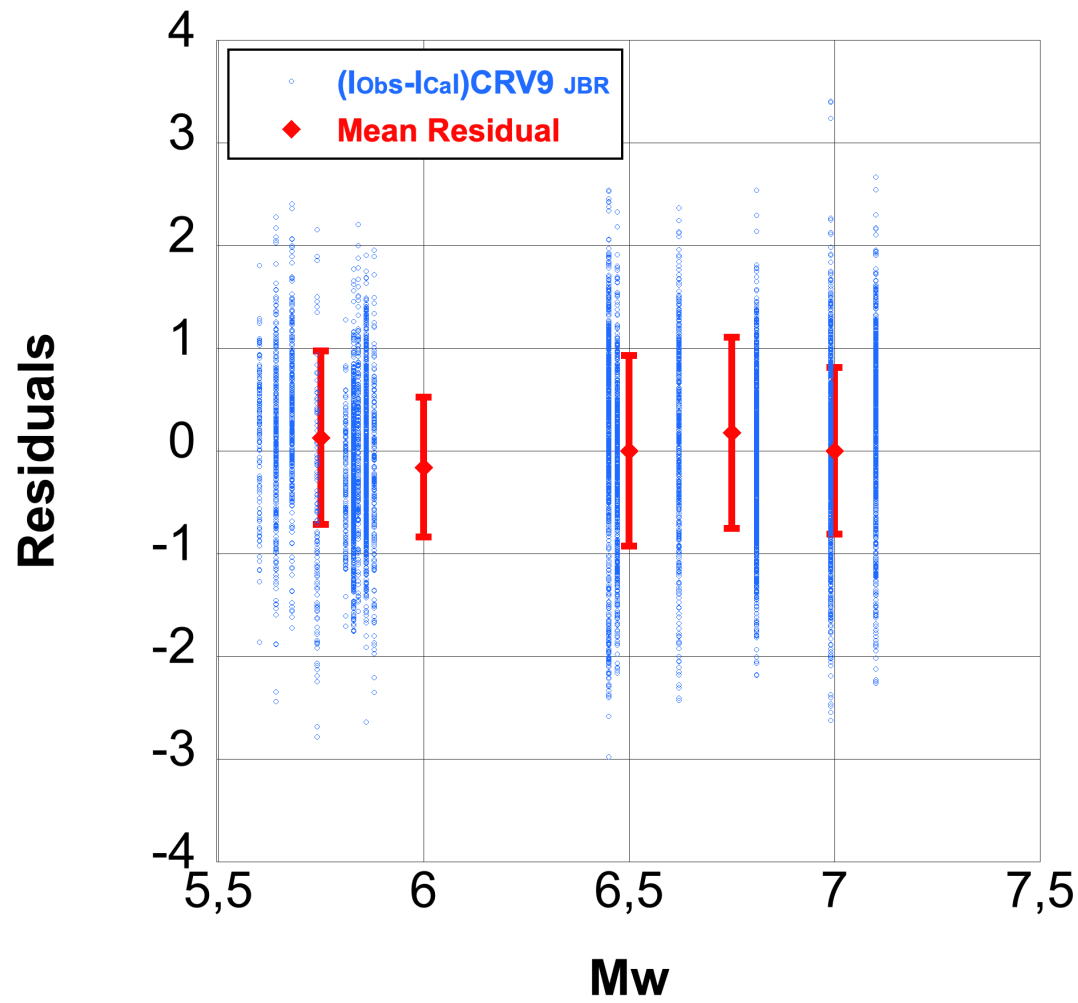
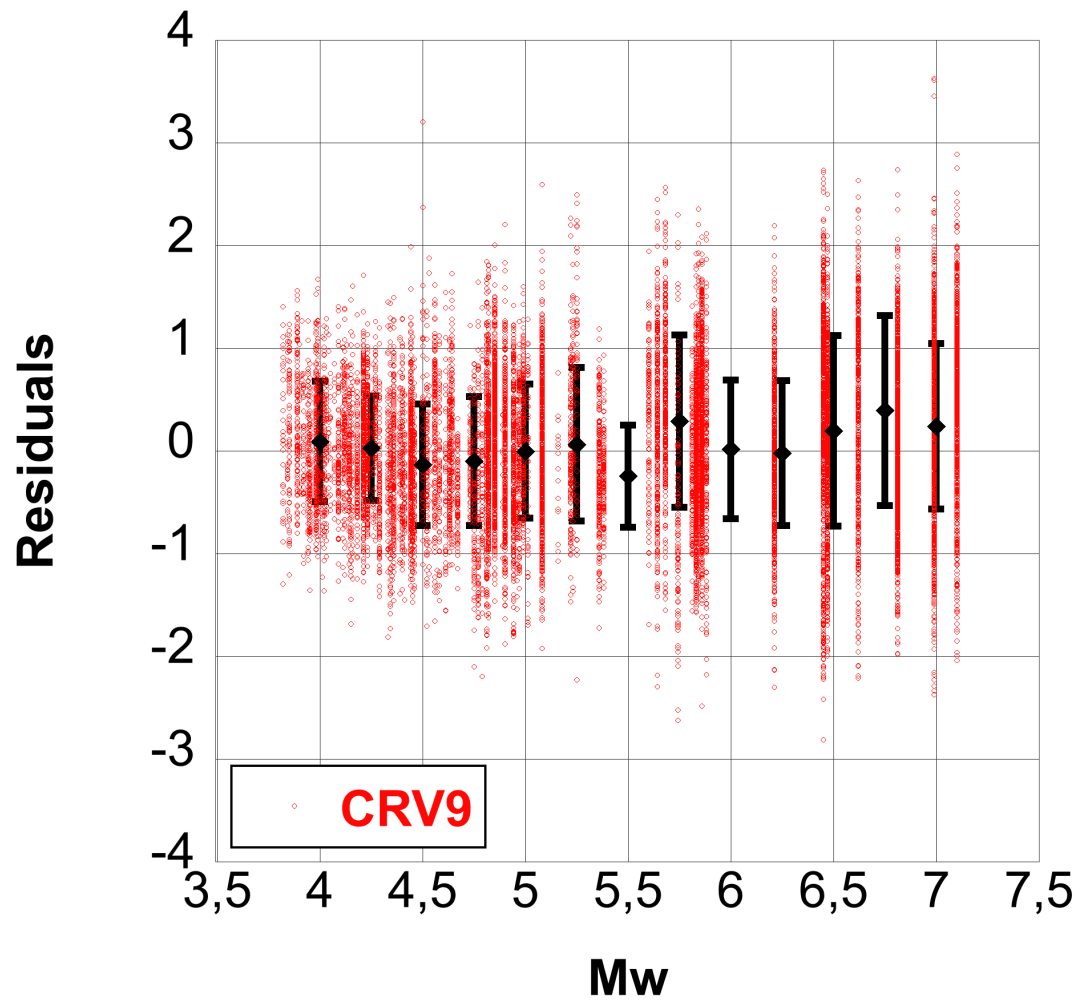
- **119 events | 16 260 IDPs**
- Compute both ***RJB*** and ***Repi*** for every record.
- **Workplan:**
 - Fit Log-Lin 10 and CRV9 simultaneously on *Rjb* (primary) and keep *Repi* fit for legacy comparison.
 - Quantify new τ , ϕ and distance-/Mw-dependent terms.
 - Release the updated coefficients, the ***Rjb*** calculator, and the enlarged flat-file as open resources for the forthcoming Italian IPE update.

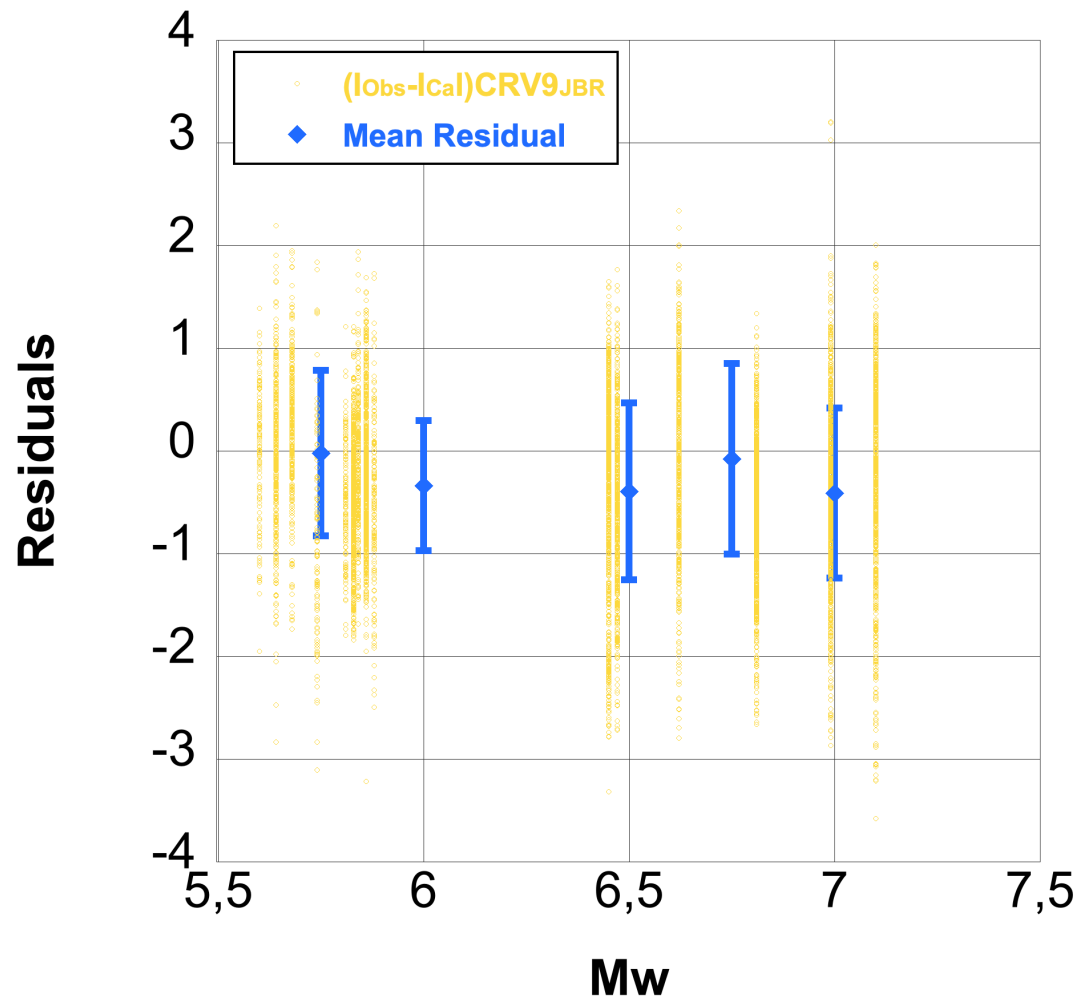
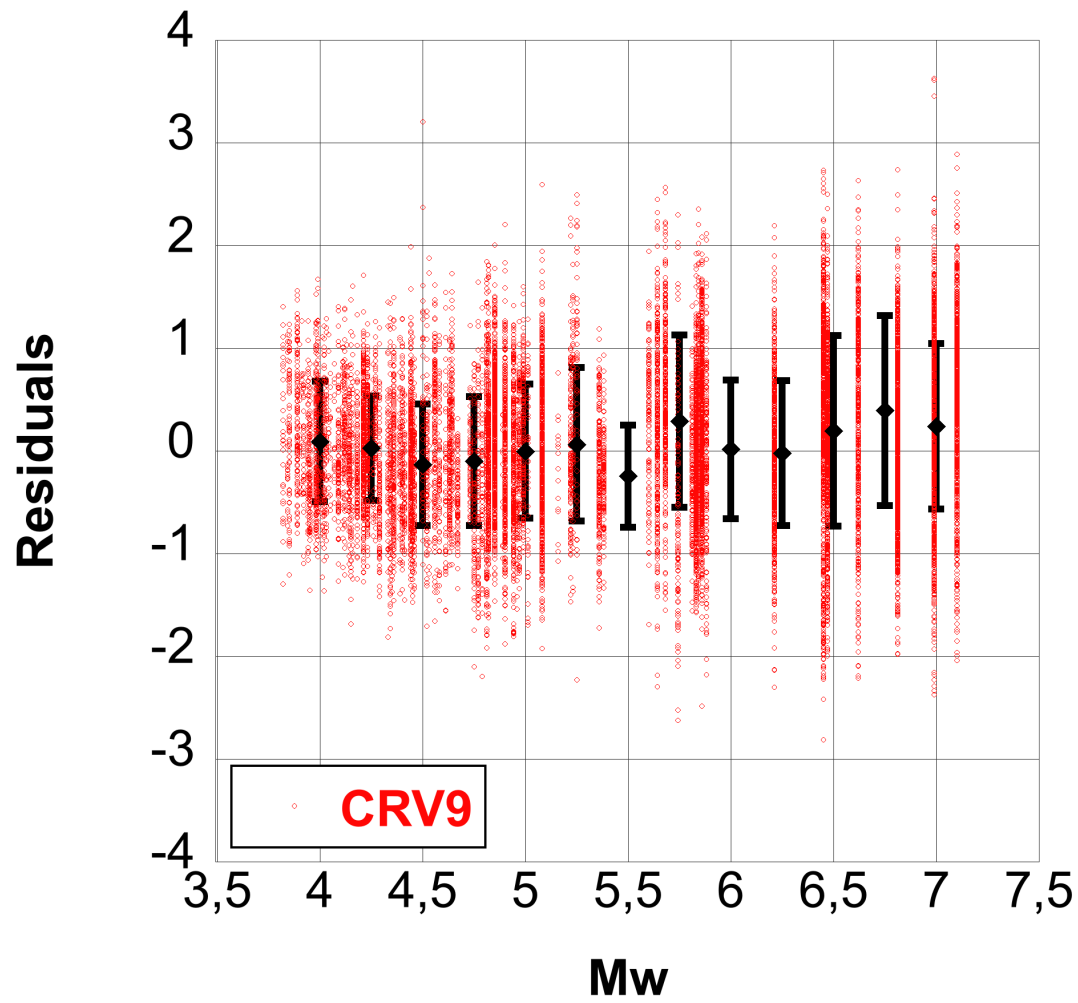
Appendix

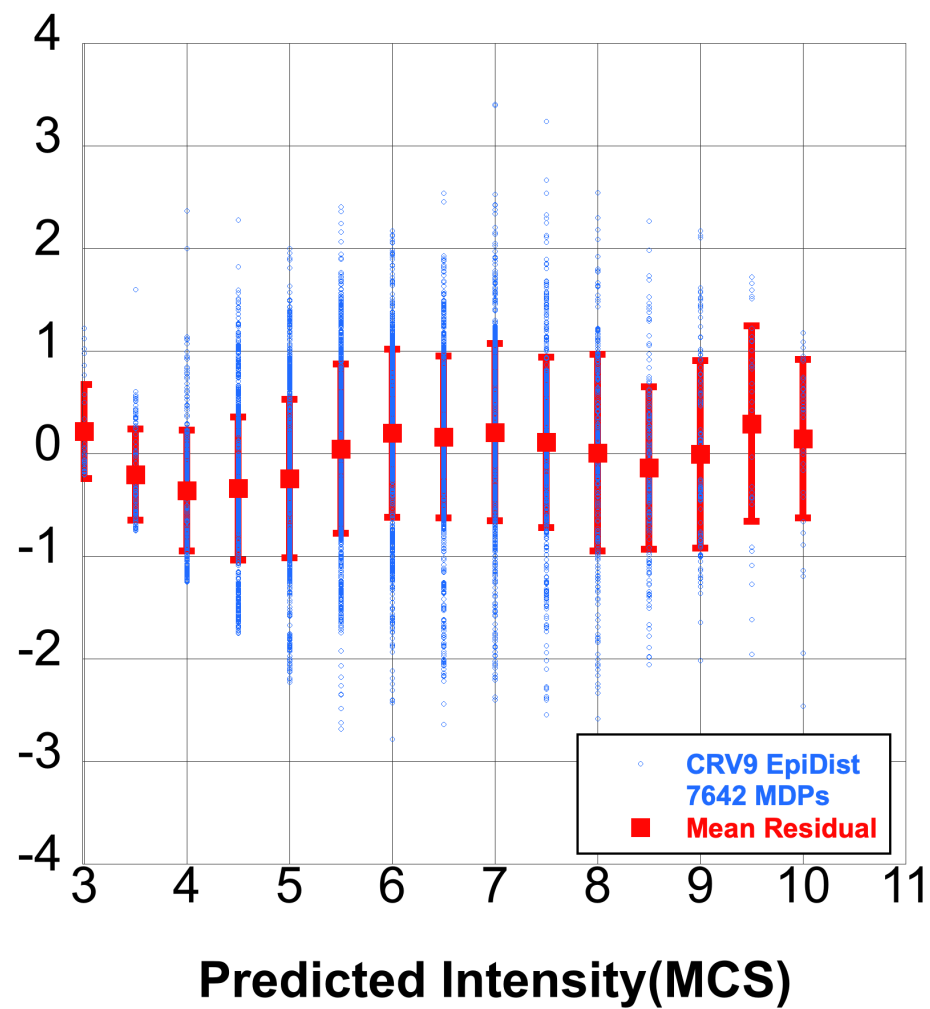
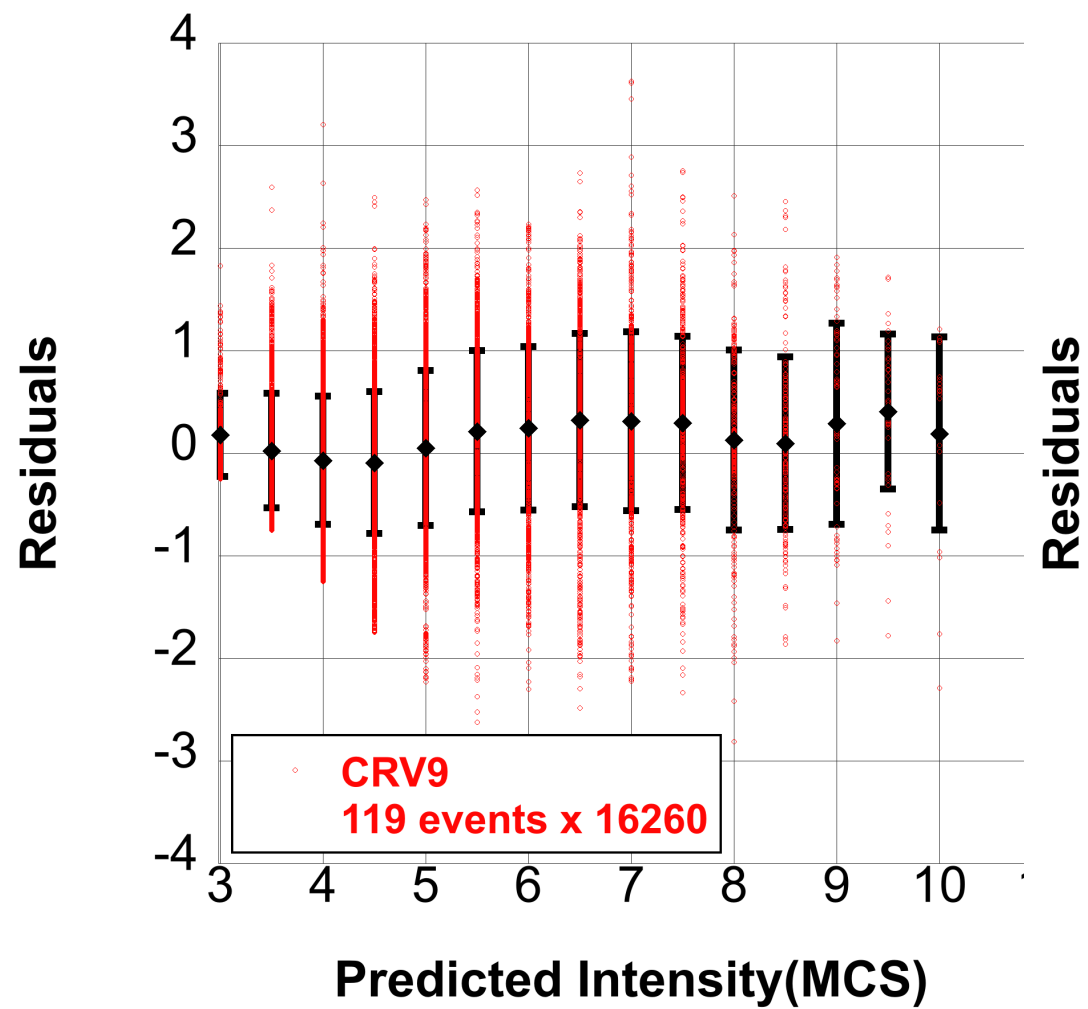


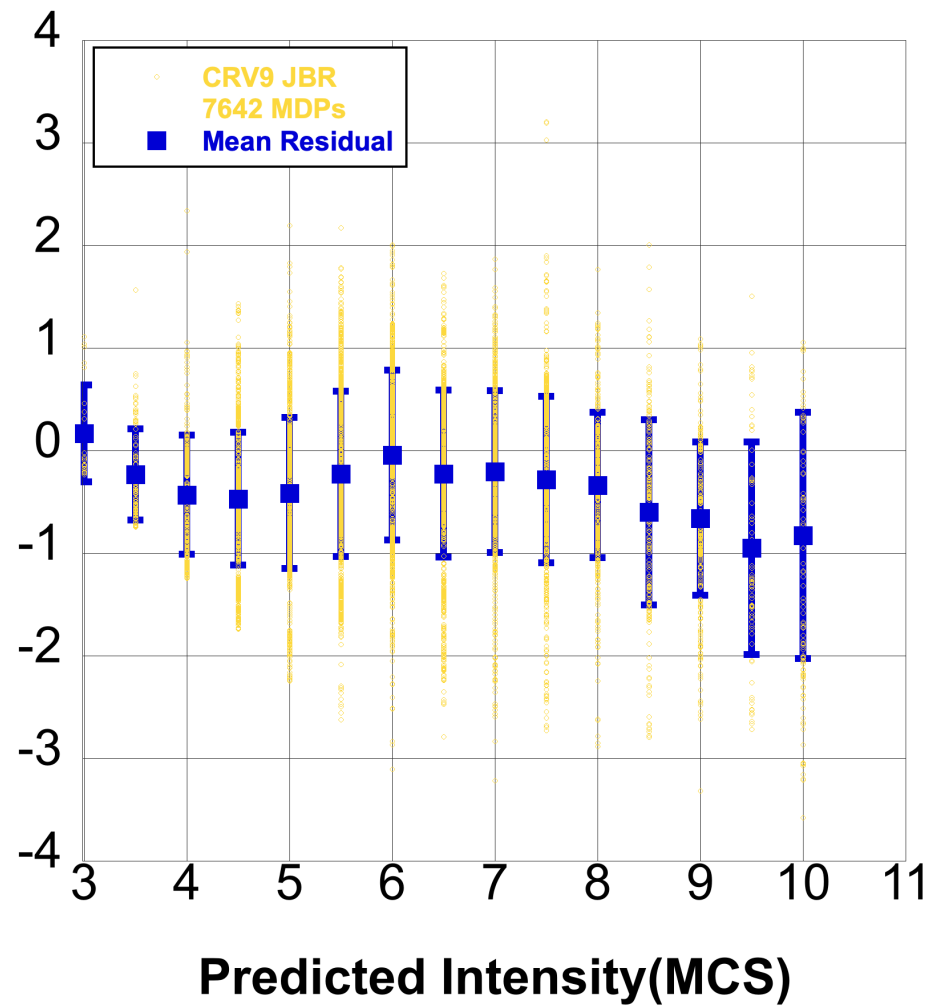
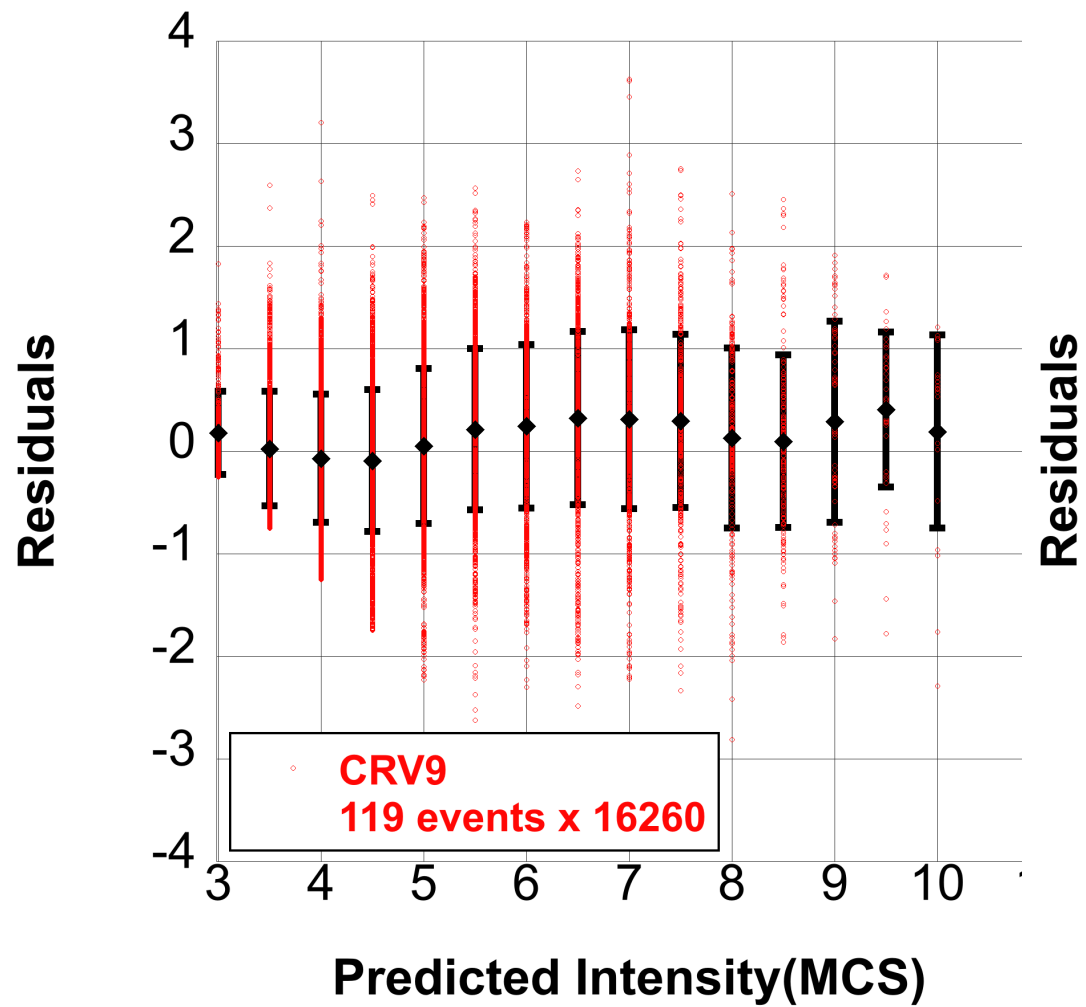


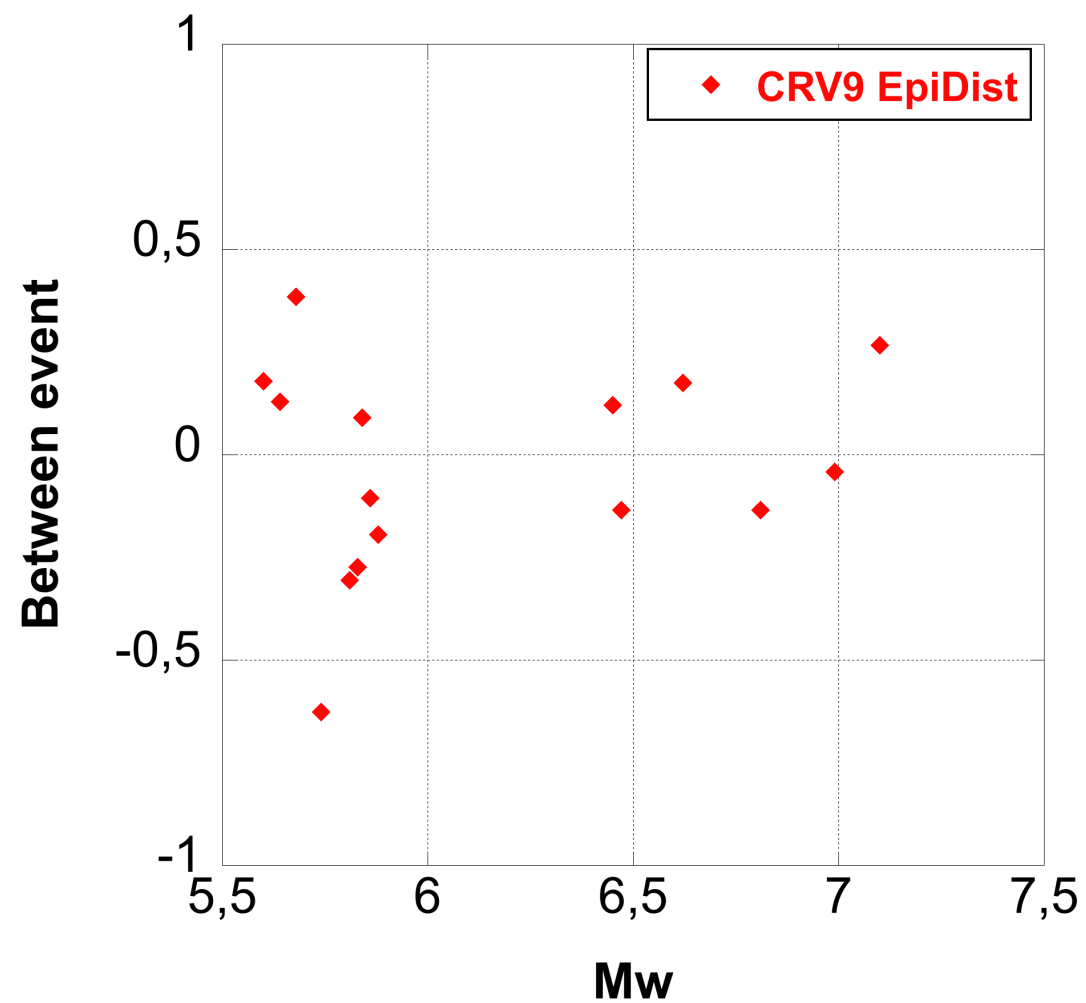
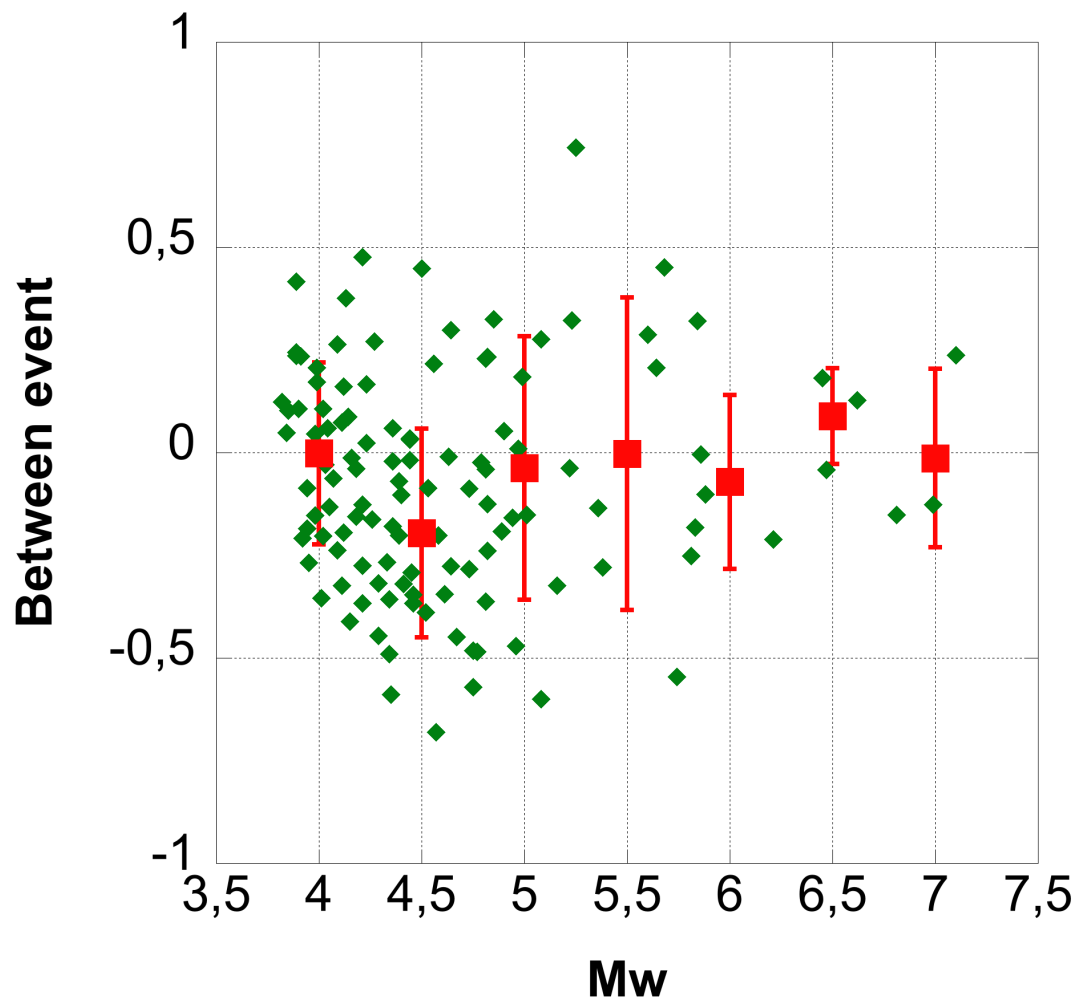


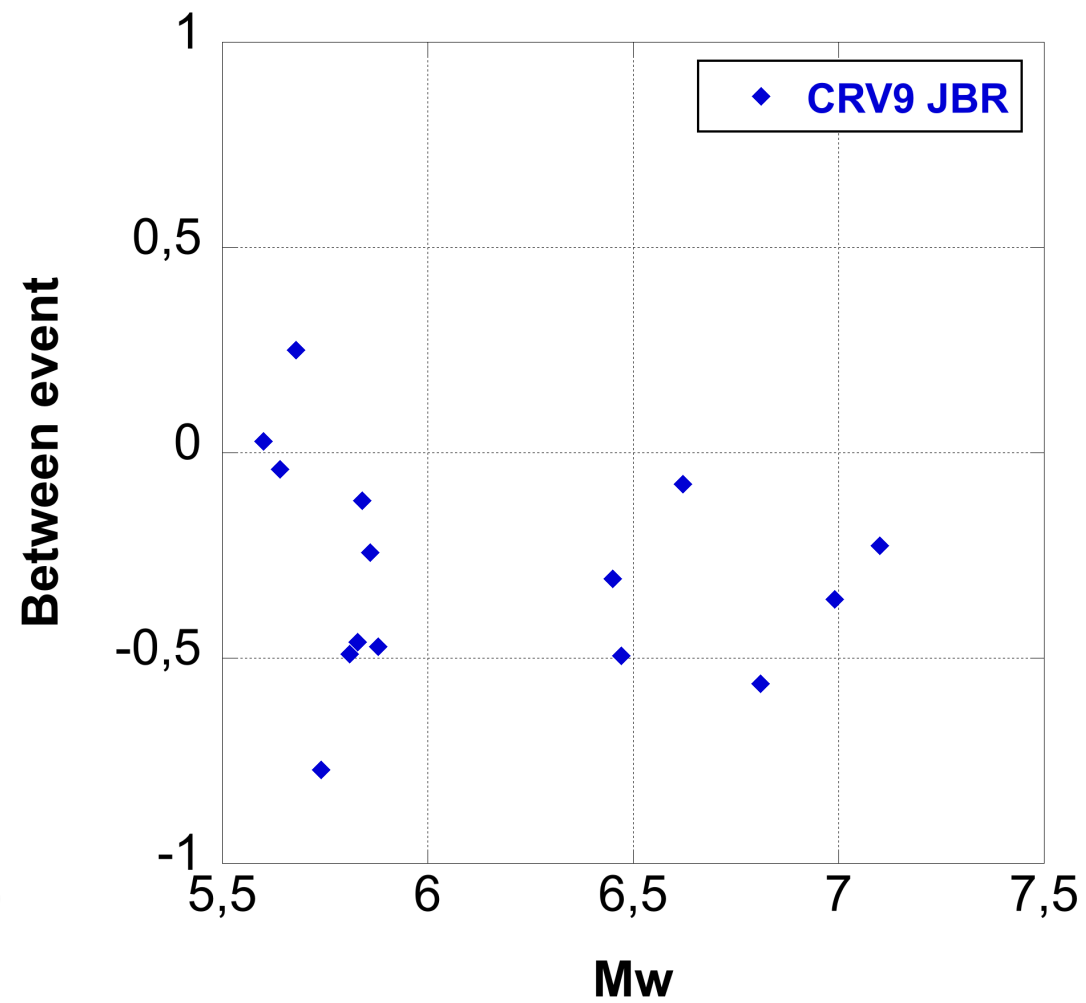
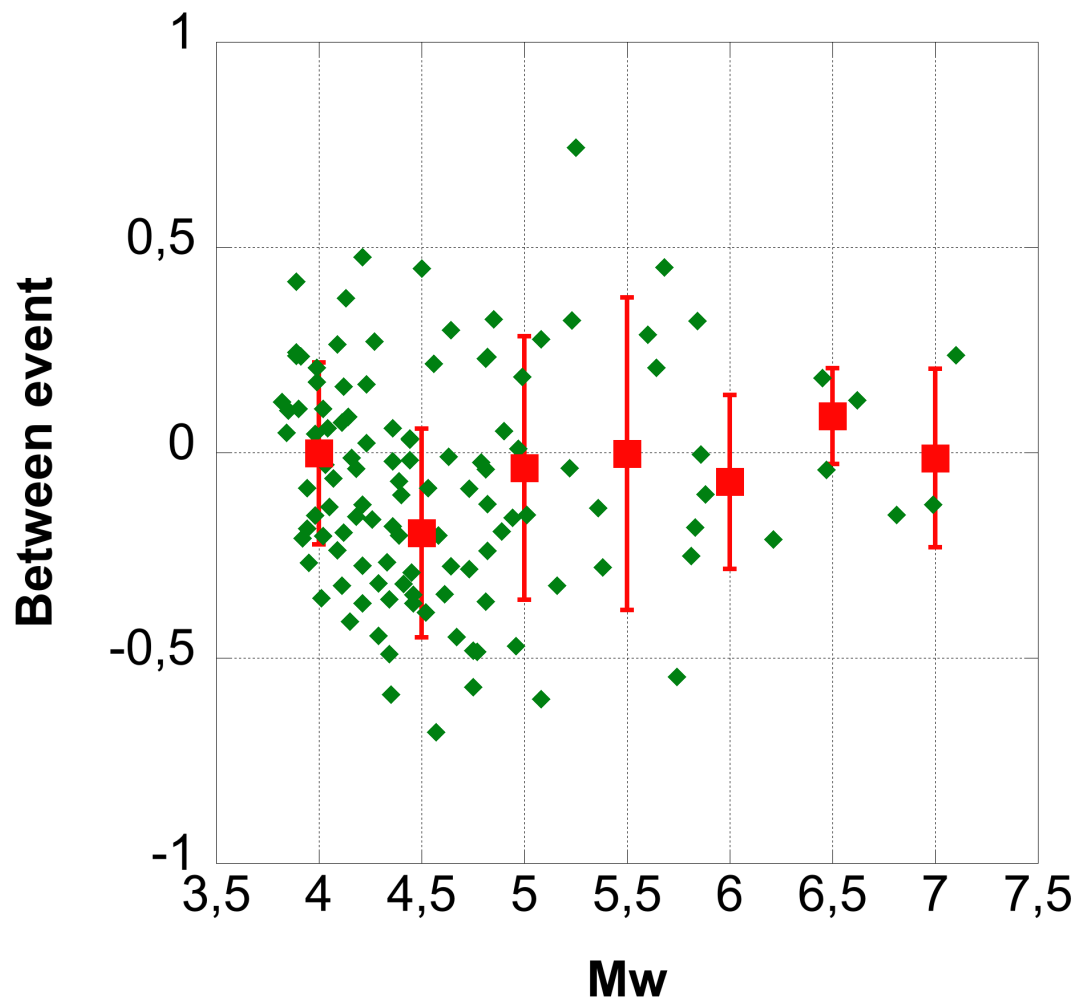


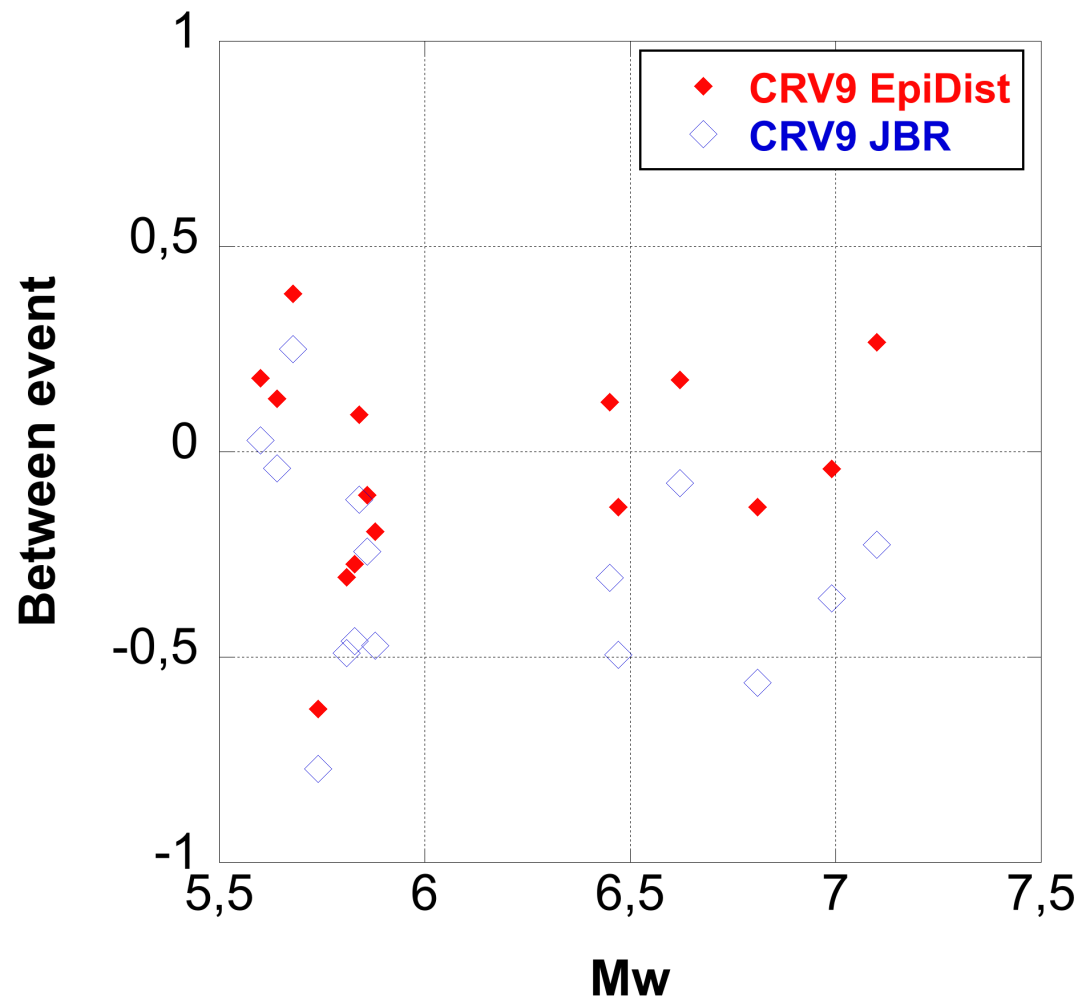
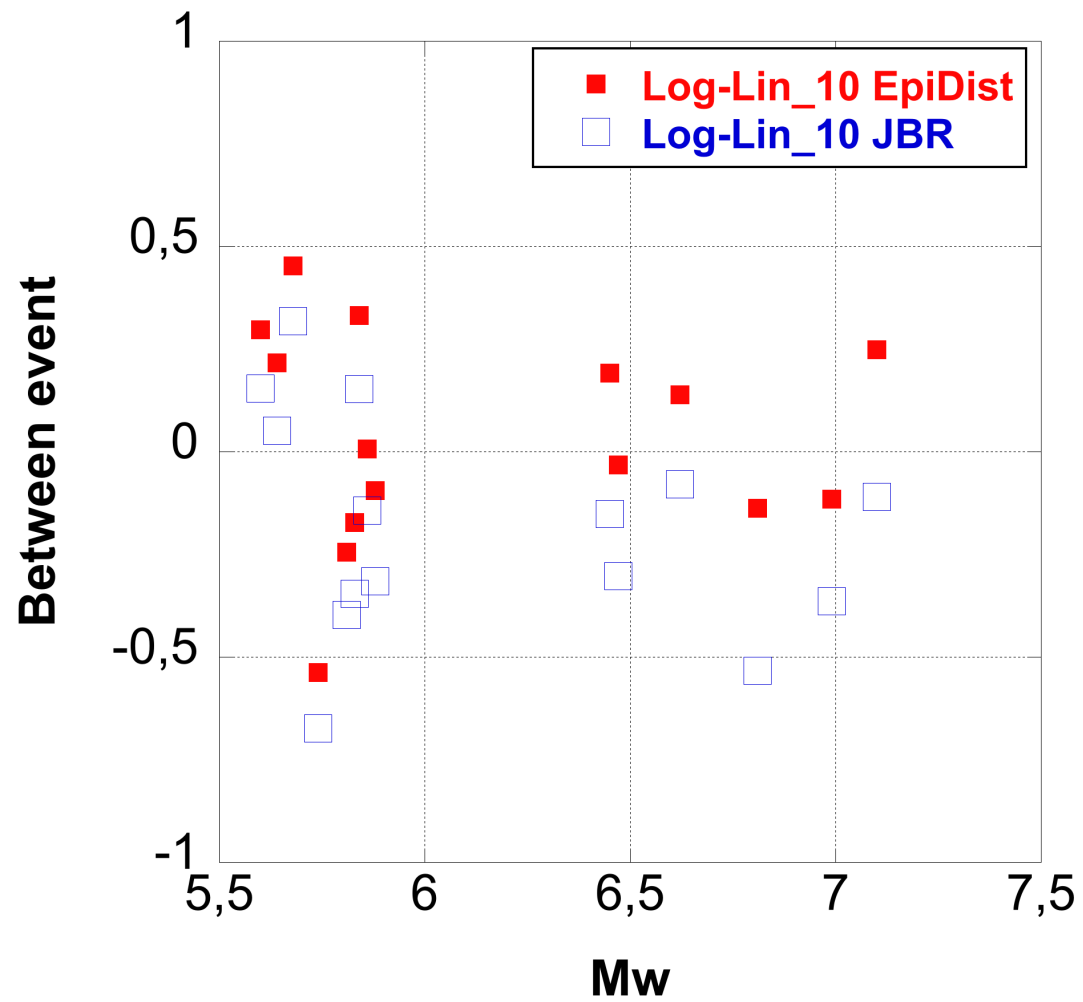












Model	Mean_eta
Log-Lin 10 – Epicentral	0,04
Log-Lin 10 – JBR	-0,18
CRV9 – Epicentral	-0,03
CRV9 – JBR	-0,29

Strategy to Compute Joyner-Boore Distance (JBR)

