Regression analysis of MCS Intensity and ground-motion parameters in Italy and its application in ShakeMap

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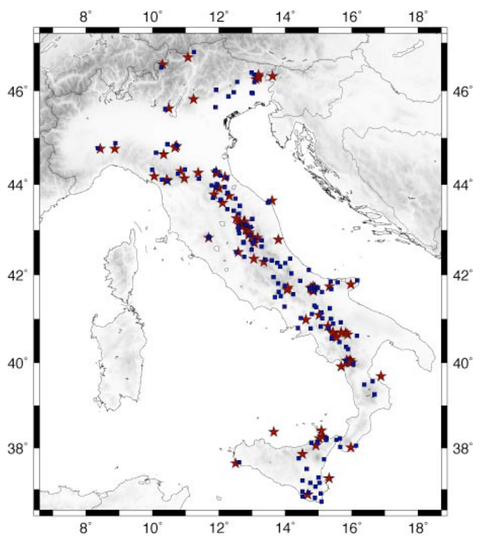
ABSTRACT:

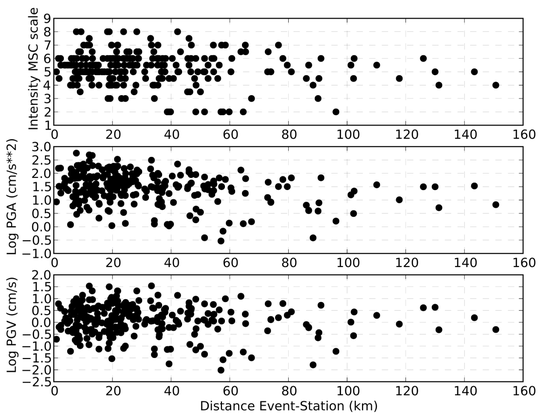
In Italy, the Mercalli-Cancani-Sieberg, MCS, is the intensity scale in use to describe the level of earthquake ground shaking, and its subsequent effects on communities and on the built environment. This scale differs to some extent from the Mercalli Modified scale in use in other countries and adopted as standard within the USGS-ShakeMap procedure to predict intensities from observed instrumental data.
We have assembled a new PGM/MCS-intensity data set from the Italian database of macroseismic information, DBMI04 and the Italian accelerometric database, ITACA.
We have determined new regression relations between intensities and PGM parameters (acceleration and velocity). Since both PGM parameters and intensities suffer of consistent uncertainties, with a consequent large scatter of PGM data for each intensity unit, we have used the orthogonal distance regression technique.
The new relations are
I_MCS = 1.68 ± 0.22 + 2.58 ± 0.14 log PGA, σ = 0.35
and
I_MCS = 5.11 ± 0.07 + 2.35 ± 0.09 log PGV , σ = 0.26.
Tests designed to assess the robustness of the estimated coefficients have shown that single-line parameterizations for the regression are sufficient to model the data within the model uncertainties. The relations have been inserted in the Italian implementation of the USGS-ShakeMap to determine intensity maps from instrumental data and to determine PGM maps from the sole intensity values. Comparisons carried out for earthquakes where both kinds of data are available have shown the general effectiveness of the relations.

DATA SET:

The data used in out alalysis has benn assebled from two data sources
- the Italian Stron Motion Database, ITACA [Luzi et al., 2008]
  events in the time period 1972-2004 with Mmax 6.9
- the Macroseismic Database of Italy, DBMI08 [Stucchi et al., 2007]
  revised collection of 12,000 earthquakes and more than 14,000 localities

266 PGM - I_MCS data pairs (i.e., three times larger than those adopted previously for Italy]

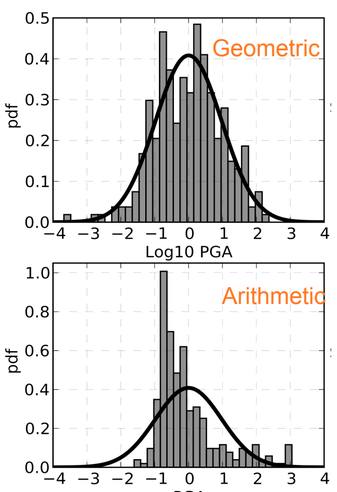




METODOLOGY

- The data are binned into classes of 0.5 intensity intervals
- The intensity standard deviation is σ = 0.5
- The standard deviation of the PGM is the sampled geometrical standard deviation

REASON TO USE LOGARITHMIC PGM SCALE
For both PGA and PGV the distributions about the arithmetic means are skewed to the lower side of the mean value where the great majority of the residuals fall. In contrast, the distributions computed using the geometrical mean (logarithmic) agree well with the theoretical normal distribution curve.



THE ODR-TECHNIQUE
We fit the data using a linear relation between the intensity and the logatithm in base 10 of the peak-ground motion, PGM (i.e, PGA or PGV)

$$I = a + b \log PGM$$

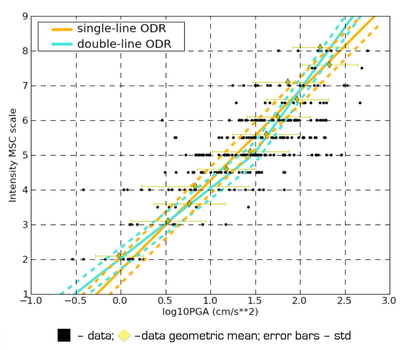
The Orthogonal Distance Regression (ODR) technique allows
- for the inclusion of the uncertainties for both independent and dependent variables
- for direct inversion between PGM and Intensity

RESULTS: PGA

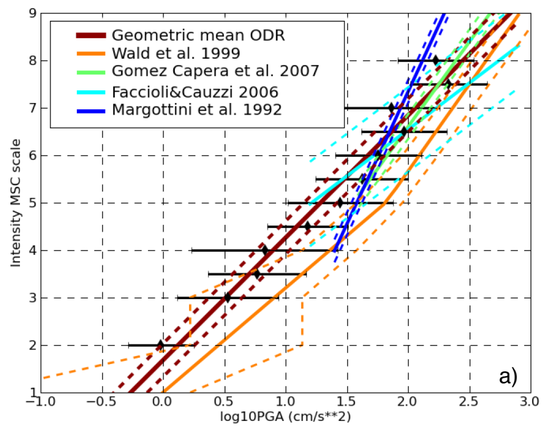
MCS Intensity versus PGA for the PGA geometric mean binned dataset.

SINGLE LINE:
a = 1.68 ± 0.22 and b = 2.58 ± 0.14
σ_single_line= 0.35.

DOUBLE LINE
I ≥ 5.0 a = -0.21 ± **1.12**;
b = 3.54 ± 0.57;
I < 5.0 a = 2.02 ± 0.09;
b = 2.02 ± 0.06;
σ_double_line= 0.28



Comparison with other regressions available in literature for Italy and in ShakeMap

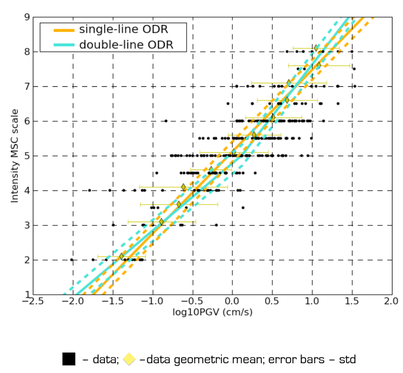


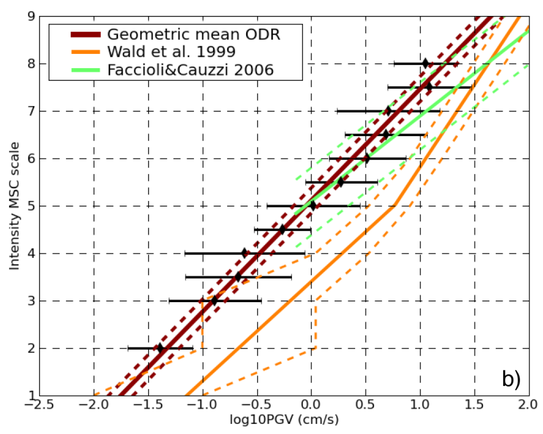
RESULTS: PGV

MCS Intensity versus PGV for the PGV geometric mean binned dataset.

SINGLE LINE:
a = 5.11± 0.07 and b = 2.35 ± 0.09
σ_single_line= 0.26.

DOUBLE LINE
I ≥5.0 a = 4.68 ± 0.22;
b = 2.93 ± 0.30;
I <5.0 a = 4.79 ± 0.01;
b = 1.94 ± 0.10;
σ_double_line= 0.28



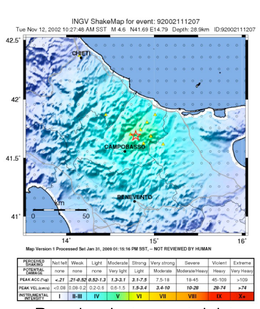


Instrumental MCS Intensity scale for ShakeMap

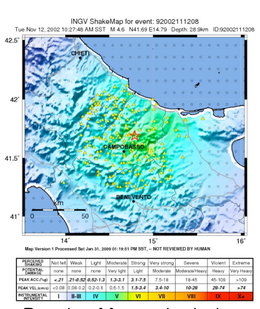
PGV single-line regression for IMCS ≥ VI
I_MCS = 5.11 ± 0.07 + 2.35 ± 0.09 log PGV

PGA single-line regression for IMCS ≤ VI
I_MCS = 1.68 ± 0.22 + 2.58 ± 0.14 log PGA

MI = 4.6, November 11, 2002, earthquake in the Molise area in Southern Italy

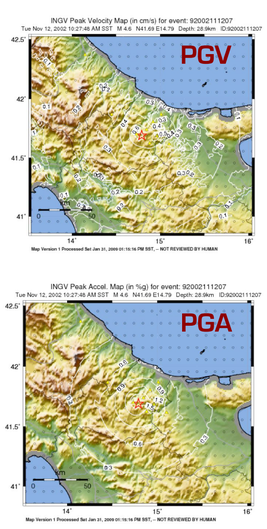


Based on Instrumental data



Based on Macroseismic data

Based on Instrumental data



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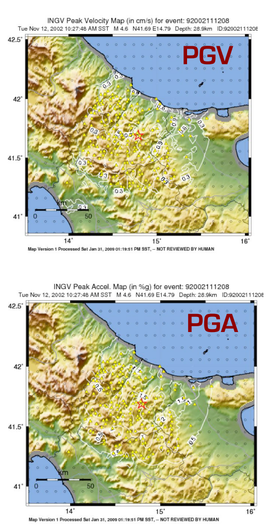
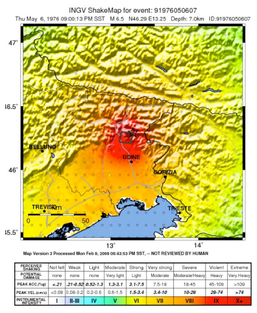


MI = 6.4, May 6, 1976, Friuli main shock in Northern Italy



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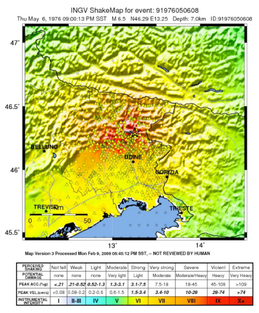

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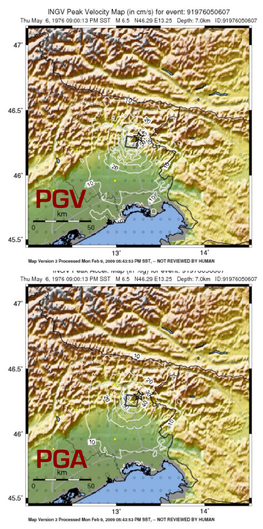

Based on Macroseismic data