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Isoseismals:
Mapping of Uncertainty and
Comparison with Synthetic Data

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Isoseismals: mapping of uncertainty and comparison with synthetic data

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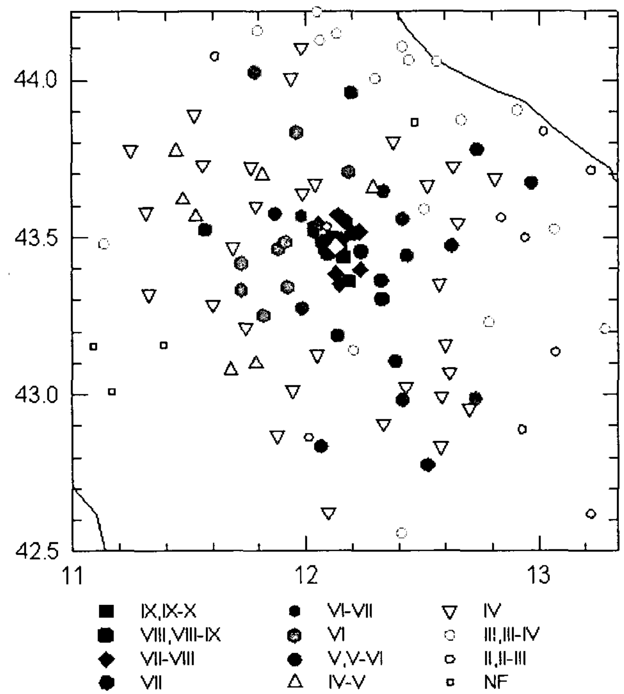
Co-authors: T.L. Kronrod, G.F.Panza

References: Pure Appl. Geophys, 159 (2002), 1229-1251
161 (2004), 1725-1747
Bolletino di Geofisica Teorica ed Applicata, 41 (2002), 243-313



Intensity Data Point map for 26/04/1917, Monterchi-Citerna earthquake, M_L=5.6, #133 points, Italy

Motivation of the work

I-data point map of an earthquake

↓

Source parametrisation

Koveslìgethy (1907), Blake (1941), Shebalin (1959-1997), Gasperini et al. (1999), Musson (1996), Sirovich (2002)

- *Magnitude*
- *Hypocenter*
- *Length* (for large events)

Strike, dip and rake (for M≤ 6) *??*

Question: Does *I*-data contain a useful information on the source geometry (specifically the case $M \leq 6$)?

Subproblems:

- reconstruction of the isoseismal shape
- modeling of synthetic isoseismals in terms of peak ground acceleration, a_p
- calibration of a_p in terms of I
- comparison of real and synthetic isoseismals for $M \leq 6^{*)}$ events

*) Similar attempts of comparison using the higher isoseismals are known in the case of large earthquakes ($M_L \geq 6$) with extended sources

Isoseismal shape

1st method: smoothing filtering

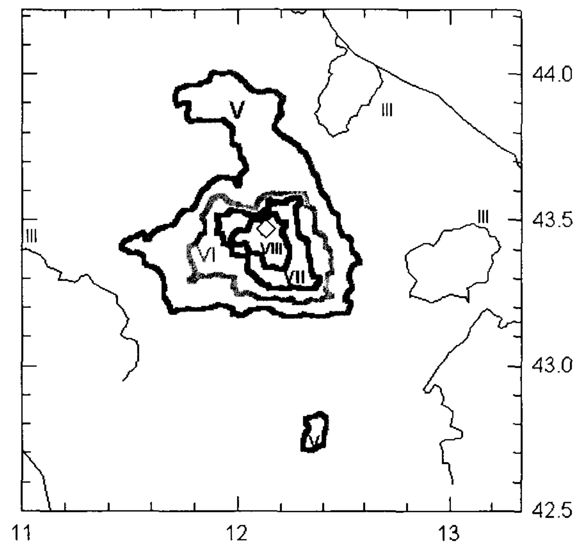
I-data point map

↓

Local smoothing

↓

Continuous *I*-map
in
isolines



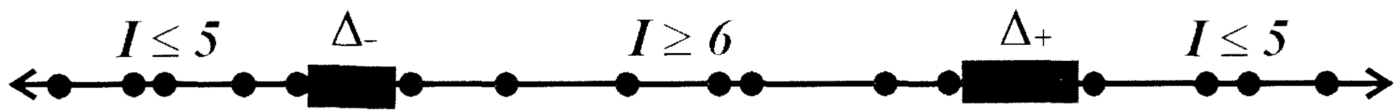
26/04/1917, Monterchi-Citerna earthquake
Modified Polynomial filtering method
by Molchan et al. (2002)

Disadvantage: no information about isoseismal uncertainty
(a point estimate has little meaning without
an associated confidence interval, *stat.*)

Mapping of the isoseismal uncertainty

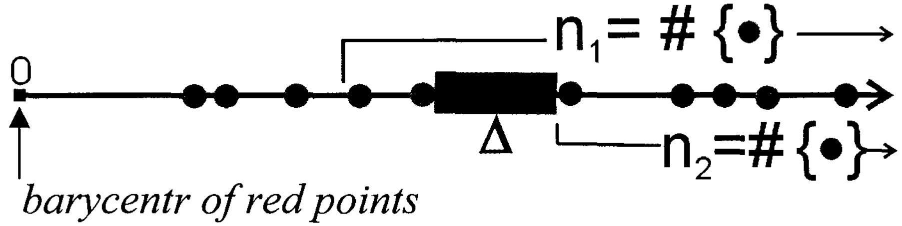
Idea, 1-D case

♦ **no errors:**



Solution: ■ the Diffused Boundary (DB) of level I=6

♦ ***I*-data with errors**:

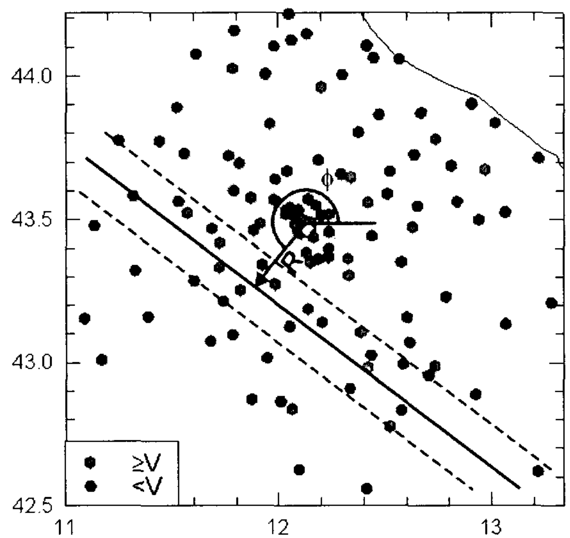


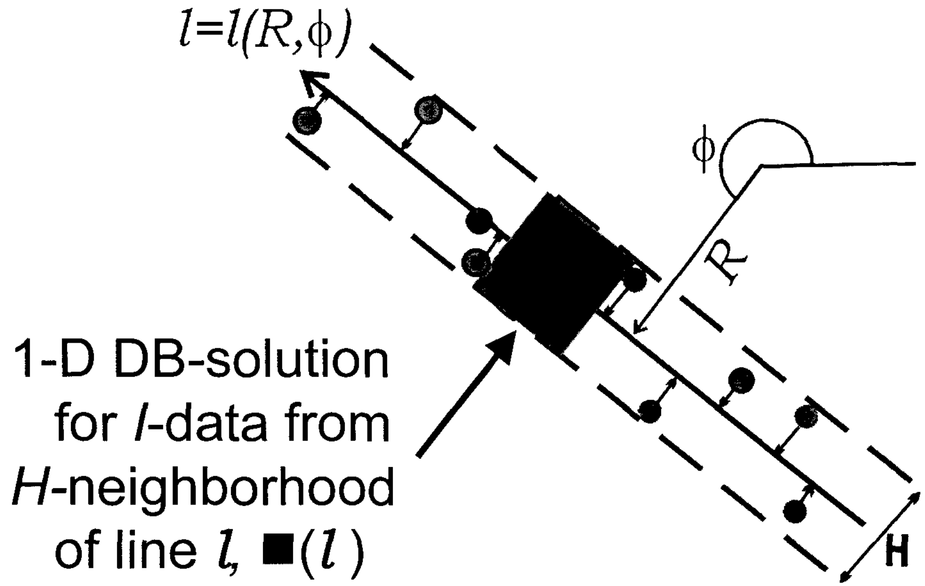
Solution Δ: $\frac{n_1}{n} > \varepsilon \geq \frac{n_2}{n}$ n= # {• $\in (0,\infty)$} > 3

ε - the error of classification of I-data (here $I \geq 6$)

***Diffused Boundary:* 2-D case**

Monterchi-Citerna earthquake





$DB = \bigcup_{l} \blacksquare(l)$: union of 1-D solutions for all cross-sections of *l*-data

Parameters: $\varepsilon \sim 5\%$, H = 20 - 40 km

Property: DB is stable although composed of unstable elements

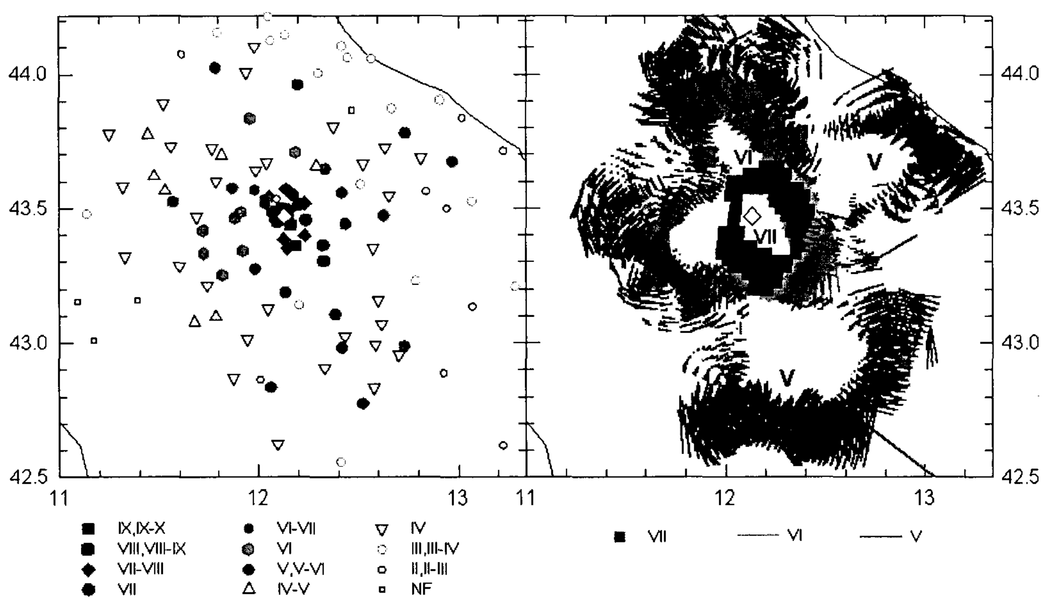
Atlas of isoseismals (#55) of good quality for Italian earthquakes selected for analysis of isoseismal shape, 1688-1997 yrs, M ≥ 4

Bolletino di Geofisica teorica ed Applicata *v. 41, N3-4, 243-313 (2002)*

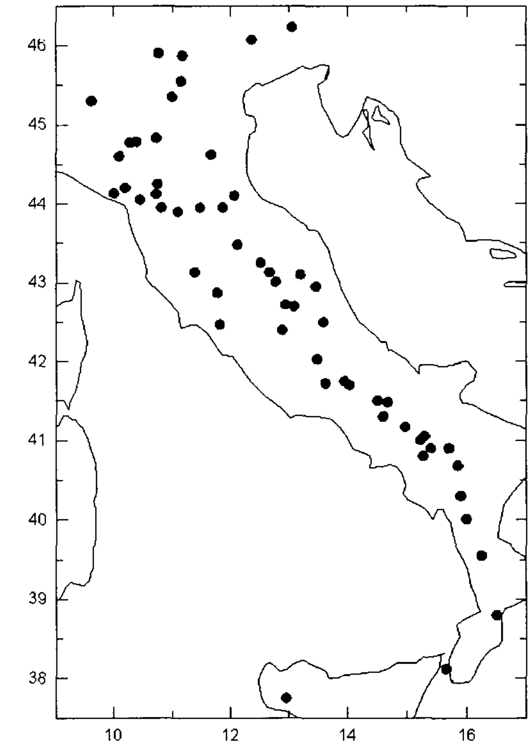
(***I-data:*** catalogues by Boschi et al. (1997) and Monachesi & Stucchi (1997))

26/04/1917, Monterchi-Citerna, M_L=5.6

I-map DB method



Example



Epicenters of selected earthquakes

Synthetic isoseismals, I_a

Input (from publications)

- plane-stratified earth model, i.e. velocity of *P* and *S* waves, quality factor and density are functions of depth
- the double-couple point source model with parameters: hypocenter, moment magnitude M_w, fault plane solution (strike, dip, rake)

Synthetic accelerograms in the frequency range ≤ 1 Hz for all points of the observed *I* -map using the modal summation technique by Panza (1990)

Δf=0.5-10 Hz is a characteristic frequency range for I=IV-X (MSK scale), [Sokolov & Chernov, 1998]

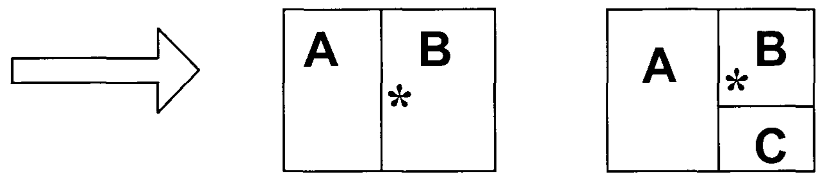
Peak acceleration, $\hat{a}_p$

Theoretical intensity I_a: $\hat{a}_p = c2^{(I_a-6)}$ $[\mathrm{sm/sec^2}]$

$c = \hat{a}_6 = 3$ for $f \leq 1$ Hz (empirical estimate)

Data quality and limitations:

- *I*-data point map: ~100 points or more
- depth - low accuracy
- magnitude, M_W, ΔM=0.3 - 0.5
- structure parameters are not uniform horizontally



Complicated cases

- the point source model is reasonable at distance $R > 1.5L$, L is the rupture length: $\lg L(M) = 0.5\,M - 2$

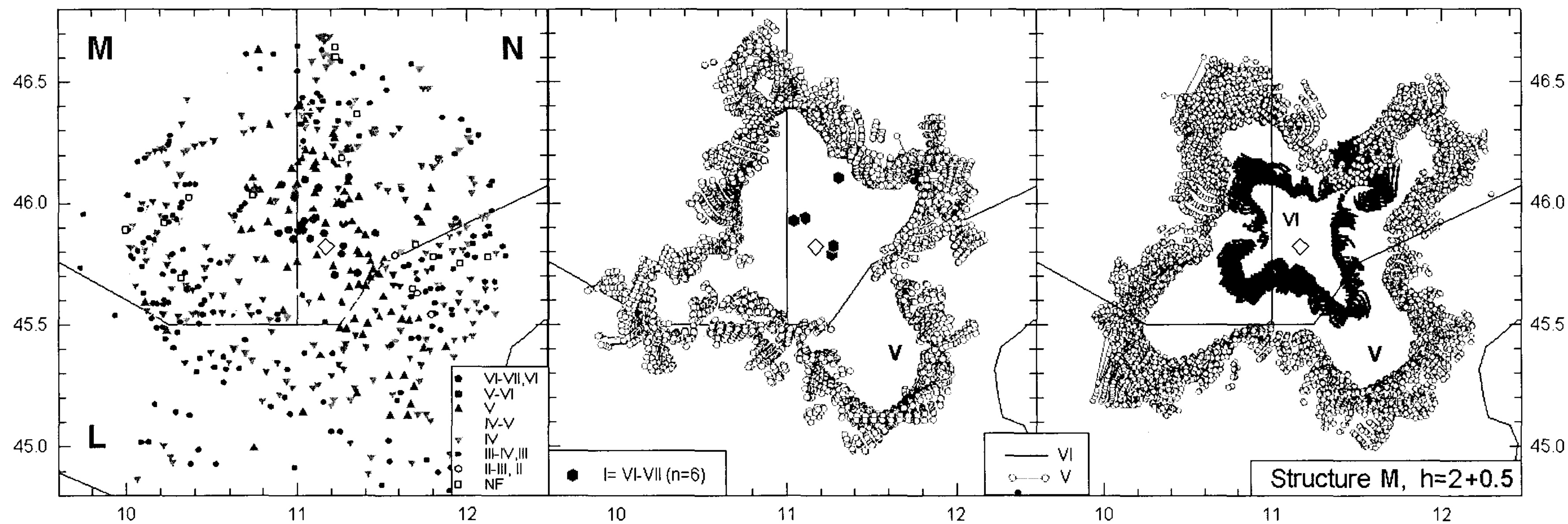
I vs I_a

- I_a-data does not exclude a modification of the parameters, e.g. *H, M* or choice of structure zone (in complicated cases)
- Isoseismals of the rank I_0-I >1 are most preferable for comparison with synthetic data

13/09/1989, Pasubio earthquake,

M_L=5.1[ISC], I_0=VIII, FPS: 145,85,-180

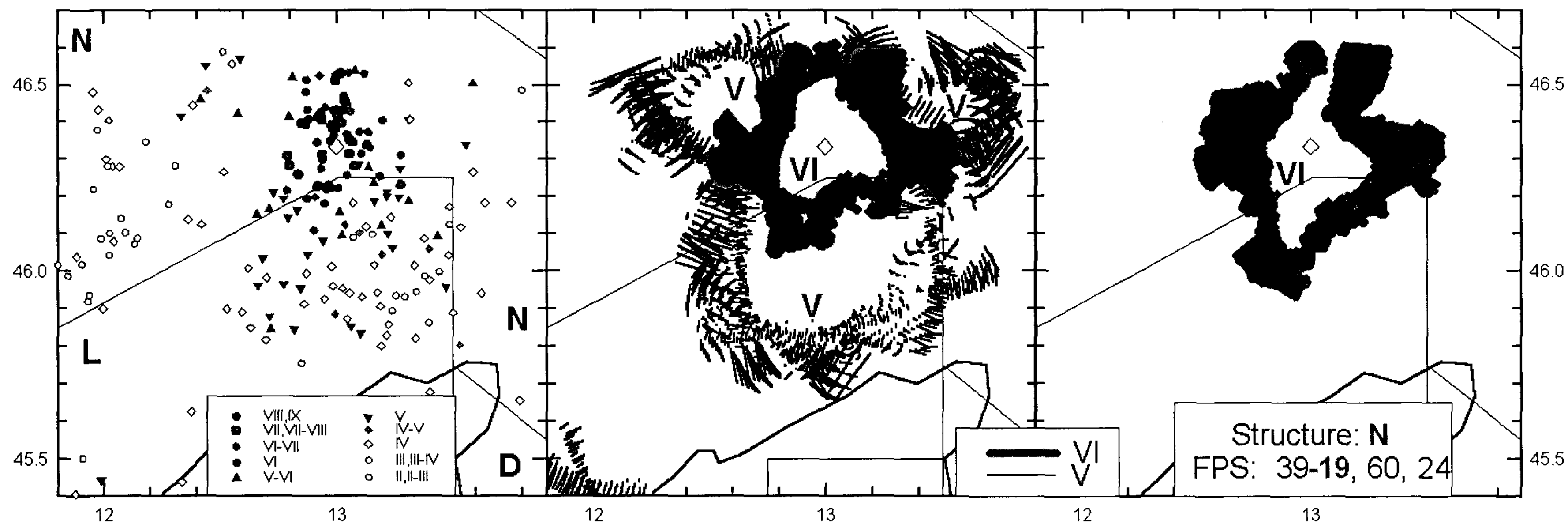
I-data | *I=5 isoseismal with its uncertainty* | *Synthetic I_a-data: isoseismals of I=5, 6*



27/03/1928, Carnia earthquake,

M_L=5.6, I_0=VIII

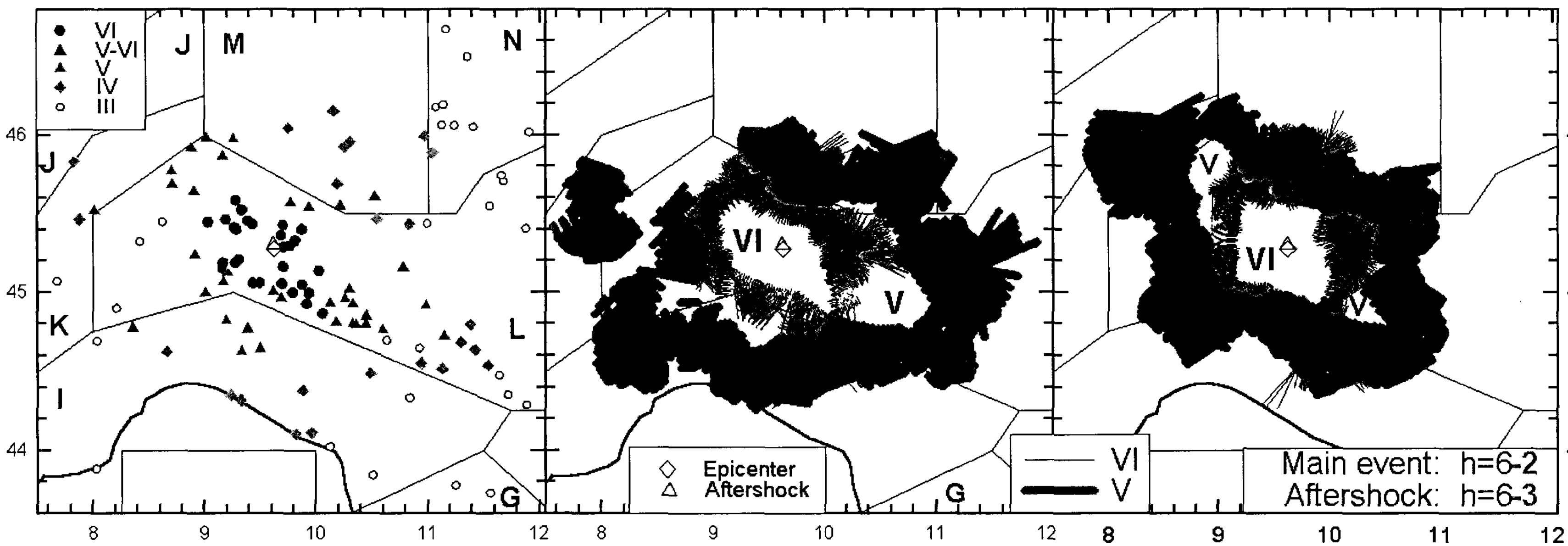
I-data | *I=6, 5 isoseismals with their uncertainties* | *Synthetic I_a-data: isoseismals of I=6*



15/05/1951, Lodigiano earthquake,

M=5.0, I_0=VI

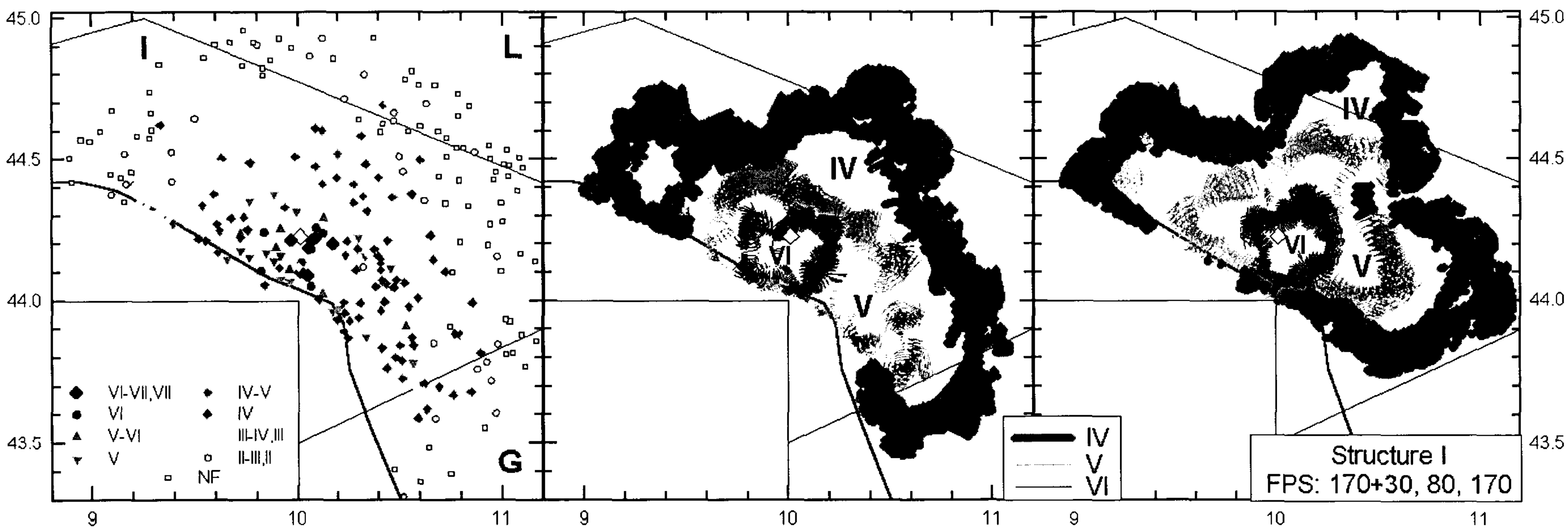
I-data | *I=5, 6 isoseismals with their uncertainties* | *Synthetic I_a-data: isoseismals of I=5, 6*



10/10/1995, Lunigiana earthquake,

M_L=5.1, I_0=VI

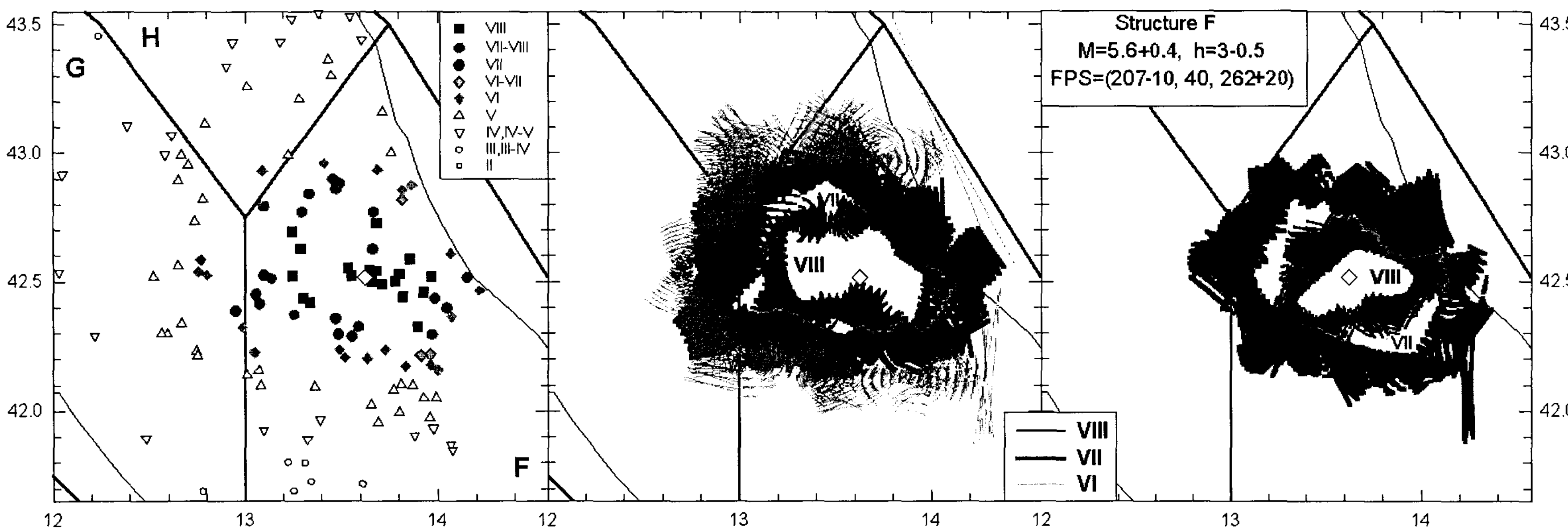
I-data | *I=6, 5, 4 isoseismals with their uncertainties* | *Synthetic I_a-data: isoseismals of I=6,5,4*



5/09/1950, Gran Sasso earthquake,

M_L=5.6, I_0=VIII

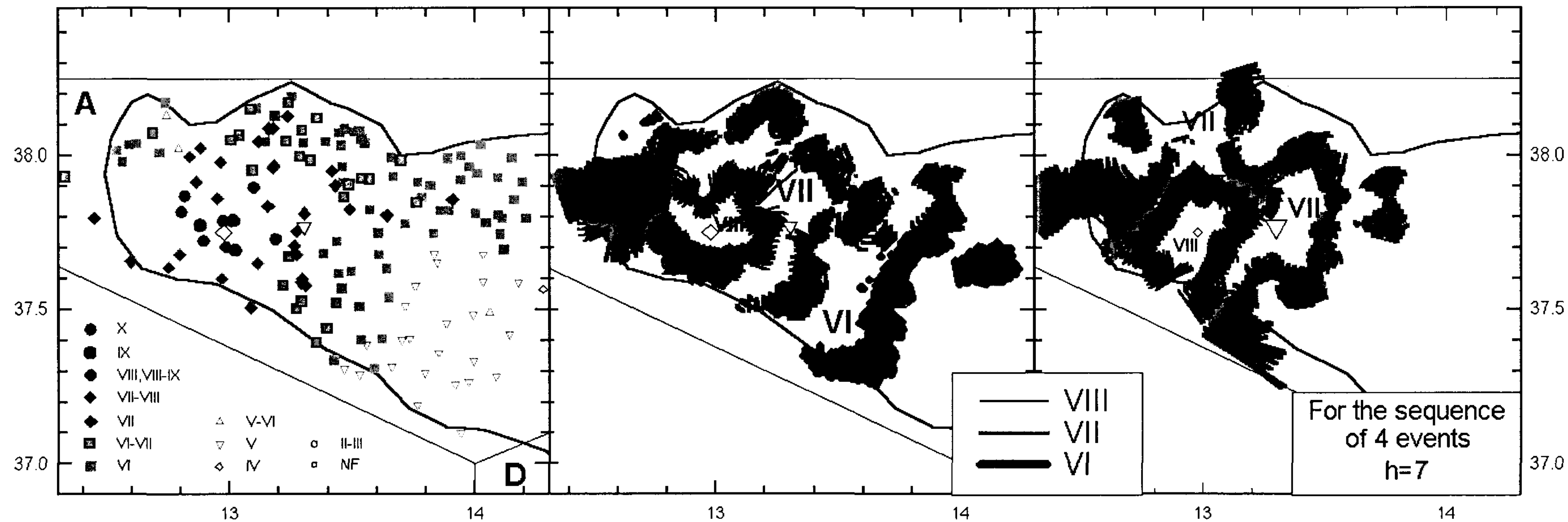
I-data | *I=8, 7, 6 isoseismals with their uncertainties* | *Synthetic I_a-data: isoseismals of I=8, 7*



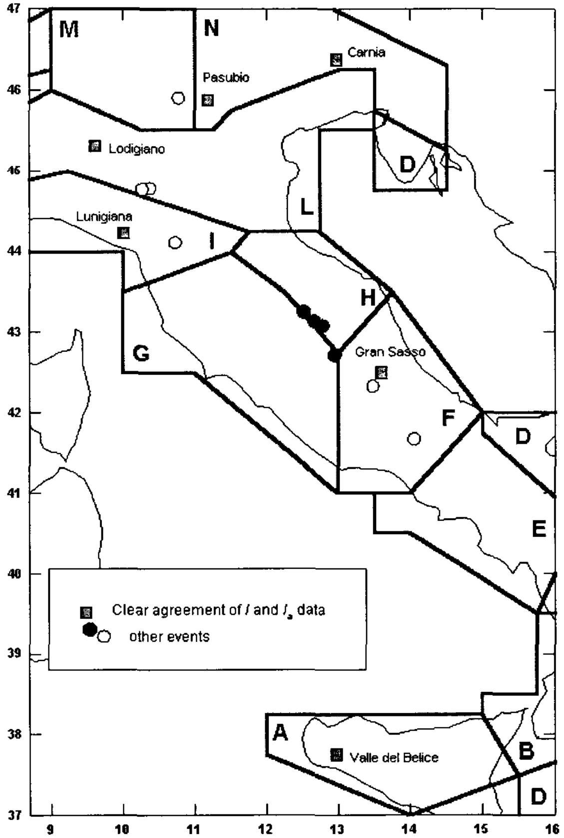
15/01/1968, Valle del Belice earthquake,

M_L=6.0, I_0=X

I-data | *I=8, 7, 6 isoseismals with their uncertainties* | *Synthetic I_a-data: isoseismals of I=8,7,6*



All events



16 of 55 earthquakes with known
fault plane solution; $M_L = 4.5\text{-}6$;
number of *I*-data points ~100 and more

Isoseismals of interest: *I*=IV-VI, rank I_0-*I*>1

Fitting: minimal (1-2 parameters)

- 6 of 16 (■) well reproduce radiation patterns of sources in the point approximation
- For 10 of 16 (○ ●) no explanation of thin structure of *I*-field in terms of the models used
- For 4 of 10 (●) the velocity models are too crude

Results

- the *original technique* for visualization of local uncertainty of isoseismal boundaries. It is objective tool for *I*-data analysis.

- isoseismals (I_{MCS}=IV-VII) of rank >1provide *information on source geometry* of moderate earthquakes *($M \leq 6$);*

$\Downarrow$

comparison of real and synthetic *I*-data can be useful in *testing of crustal structure* (H < 15 km) and *source* models.