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Earthquake Catalogs for Intermediate-term Predictions & Seismic Hazard Analysis

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ICTP

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Earthquake catalogs for intermediate-term predictions and seismic hazard analysis

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Outline

- Heterogeneity of earthquake catalogs
- Intensity and magnitude scales
- Multiscale approach to earthquake catalogs analysis
- Examples of catalogs analysis
  - Local scale: volcanic earthquakes
  - Intermediate scale: Central Italy (CN region)
  - Large scale / largest events: Iberian peninsula

What is an earthquake catalog?

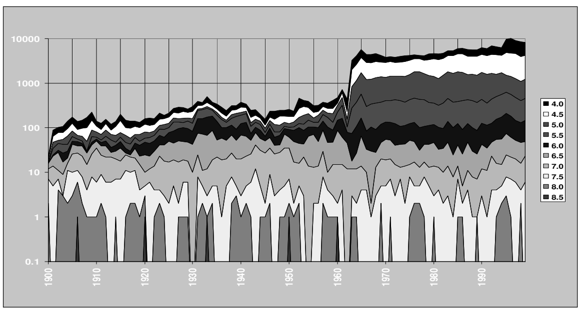
- An earthquake catalog is a collection of information about a set of seismic events, basically including:
  - Origin time
  - Location
  - Size of the earthquakes
- Additional information can be provided, ranging from related damage to seismic source parameters.
- A catalog may include several magnitude estimations, generally with a precision of one digit, even if values provided by different agencies may differ more than one unit.

What is an earthquake catalog?

- Catalogs are compiled for different purposes and by different agencies. Therefore they differ in:
  - geographical coverage
  - time span
  - level of detection
  - criteria of compilation
  - type and quality of earthquake data
- Consequence: no unique catalog for a given territory… but usually an heterogeneous set of catalogs (historical, instrumental, local, global, etc.), not always comparable, which may require different tools of analysis.
- A positive step forward: compilation of global catalogs (e.g. USGS-NEIC and ISC)

The USGS/NEIC Global Hypocenter Data Base

Global Number of Earthquakes vs. Time



(Courtesy of V. Kossobokov)

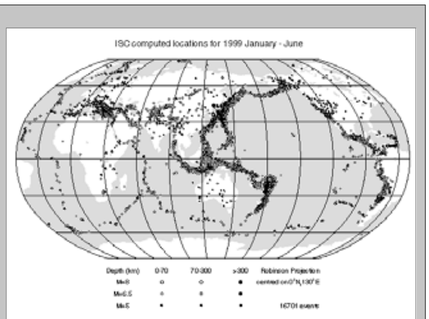
The ISC Global Data Base

International Seismological Centre — ISC Bulletin — ISC Catalogue

Bulletin of the International Seismological Centre

Regional catalog of earthquakes

Felt and Damaging earthquakes



Measures of earthquakes size

- The information about the size of historical earthquakes is generally provided in terms of earthquake intensity, i.e. a quantitative estimation based on the observed damage.
- The concept of earthquake magnitude, based on instrumental earthquake recordings, was introduced by C. F. Richter in 1930.
- Quite recently the seismic moment M_O has been introduced, which is a measure of the earthquake size related to the fundamental parameters of the source process (source area, average displacement, shear modulus of the rocks).

Intensity scales

- The Mercalli scale was introduced by Mercalli in 1902.
- An elaboration of the Mercalli scale, was published by Sieberg in 1923. This form was used by Wood and Neumann, in 1931, as the basis for the Modified Mercalli (MM).
- Subsequently other intensity scales have been introduced by Mercalli, Cancani and Sieberg (MCS) and by Medvedev, Sponeuer and Karnik (MSK).
- More recently the EMS-1992 macroseismic scale has been proposed.

Intensity scales

- The existence of many different scales is a demonstration of the complexity of the problem of describing earthquake effects. The multiplicity of scales generates some problems in practical applications, that must therefore rely upon very conservative assumptions.

MM	RF	JMA	MCS	MSK
I	I		II	I
II	II	I	III	II
III	III		IV	III
IV	IV V	II	V	IV
V	VI	III	VI	V
VI	VII	IV	VII	VI
VII	VIII	V	VIII IX	VII
VIII				VIII
IX	IX	VI	X XI	IX
X	X		XII	X
XI		VII		XI
XII				XII

Comparison of seismic intensity scales:
MM – Modified Mercalli
RF – Rossi-Forel
JMA – Japanese Meteorological Agency
MCS – Mercalli-Cancani-Sieberg
MSK – Medvedev-Sponheuer-Karnik

Intensity scales

- Intensity provides a qualitative description of the earthquake size, based on the observation of the related damage. Hence, for a given earthquake, the intensity I can be different in different places.
- Intensity values are discrete; undue accuracy in related computations can be misleading.

The log-linear regression between maximum observed macroseismic intensity, I (MCS), and computed peak values of ground motion (A), considering historical events, has a slope close to 0.3 (see Panza et al., 1999; Shteinberg et al., 1993 and references therein):

$$\text{Log } A = a + bI$$

[redacted]

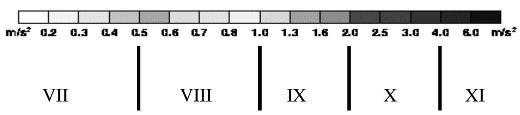
Hence one degree of intensity corresponds to a factor two in the values of ground motion:

DGA(I)/DGA(I-1)=2

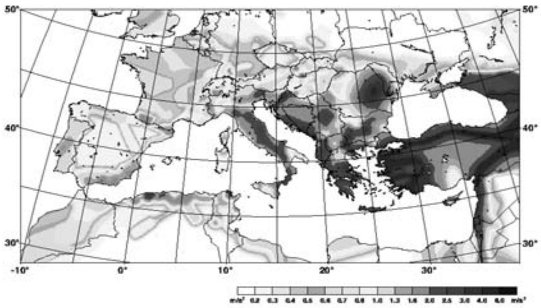
PGV(I)/PGV(I-1)=2

PGD(I)/PGD(I-1)=2

Comparison between GSHAP scale used in the Mediterrnean, and MCS Intensity scale



The GSHAP probabilistic map at 475 years



Horizontal Peak Ground Acceleration seismic hazard map representing stiff site conditions for an exceedance or occurrence rate of 10% within 50 years for the Mediterranean region.

Magnitude scales

- Richter's magnitude scale (M_L) was originally defined for California earthquakes occurring within 600 km of a specific type of seismograph (i.e., the *Woods-Anderson* torsion instrument). Then it was extended to observations of earthquakes of any distance.
- Later on two other magnitude scales evolved, the m_b and M_S , that are determined considering respectively body waves, which travel through the Earth, and surface waves, which are constrained to follow the Earth's uppermost layers.

Magnitude scales

- Quite recently the magnitude scale M_W has been introduced, which is computed from seismic moment.
- Several other magnitude estimates are possible, based on different properties of the recorded seismic signal, such as the duration magnitude M_d.
- Making use of specific empirical relations, it is also possible to derive a magnitude from intensity M_I.

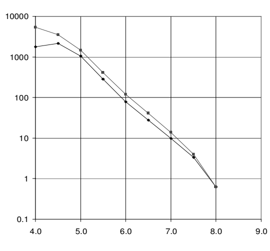
What can we learn from a catalog of earthquakes?

All catalogs have errors, which may render invalid conclusions derived in a study based on a catalog of earthquakes.

Ways to handle with catalog errors:

- Postpone the analysis until the data are revised;
- Perform a comparative analysis among different catalogs, whenever available;
- **Use robust methods of analysis, within the limits of their applicability;**
- Test the robustness of the obtained results against possible errors in the data set.

The Gutenberg-Richter law



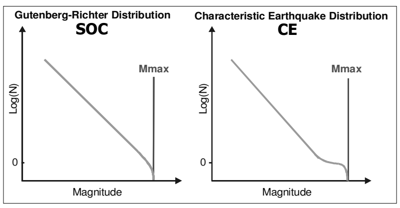
Averaged over a large territory and time the number of earthquakes equal or above certain magnitude, N(M) scales as:

$$\log_{10} N(M) = a - bM$$

This general law of similarity establishes the scaling of earthquake sizes in a given space time volume but gives no explanation to the question how the number, N, changes when you zoom the analysis to a smaller size part of this volume.

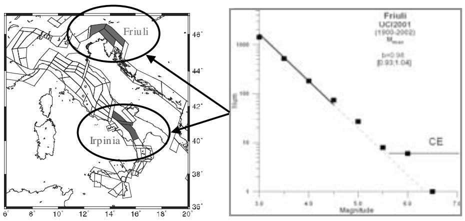
Multiscale seismicity model

- The analysis of global seismicity shows that a single Gutenberg-Richter (GR) law is not universally valid and that a **Multiscale seismicity model** (*Molchan, Kronrod & Panza, BSSA, 1997*) can reconcile two apparently conflicting paradigms: the **Characteristic Earthquake (CE)** model and the **Self-Organized Criticality (SOC)** concept.

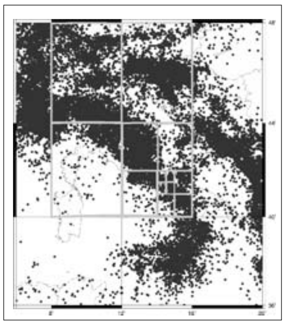


Multiscale seismicity model

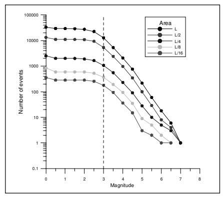
- The **multiscale seismicity model**, implies that only the set of earthquakes with dimensions that are small with respect to the dimensions of the analysed region can be described adequately by the **Gutenberg-Richter law**.
- This condition, fully satisfied in the study of global seismicity made by Gutenberg and Richter, has been violated in many subsequent investigations.

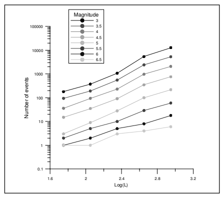


Multiscale seismicity model



UCI2001 catalogue
1900-2002





Multiscale Approach to Seismic Catalogs Analysis
Scales of investigations

Narrow scale

- Small magnitude events
- Temporal evolution of seismicity over short time periods
- Local seismicity patterns

area
(R~25-50 km)

Local scale good quality instrumental data
• Example: Catalogs of volcanic earthquakes

Middle-range scale

- Strong events
- Temporal evolution of seismicity at intermediate-term scale
- Regional seimicity patterns

area
(R~ hundreds km)

National scale instrumental data, sporadically integrated with intensity information
• Example: Italian catalog within CN regions

Long-range scale

- Largest earthquakes
- Temporal long term evolution of seismicity
- Seismic hazard

area
(R~ thousands km)

Large scale and long term data, mainly intensity information
Example: Spanish catalog over the Iberian peninsula

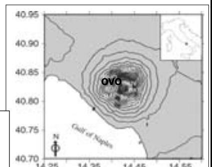
Low magnitude local catalogs:
Vesuvius and Etna volcanic areas

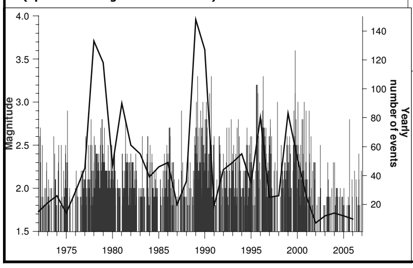
Volcanic earthquakes at Mt. Vesuvius: the OVO earthquake catalog

Data used: catalog of volcanic earthquakes recorded at the station OVO (Osservatorio Vesuviano – INGV, Naples)

Time period: 1972-2007

(updated catalog available on-line)

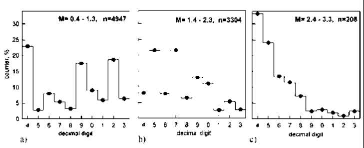




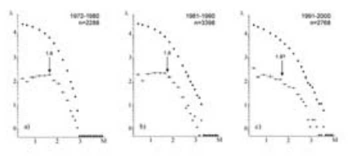
Time sequence of the events M(t) and yearly number of earthquakes with $M \geq M_C=1.8$ reported in the OVO catalog

The OVO earthquake catalog

Magnitude grouping: The analysis evidences whether there are dominating values of magnitudes. It permits to choose the appropriate intervals of magnitude grouping ΔM to be considered for the frequency-magnitude distribution.



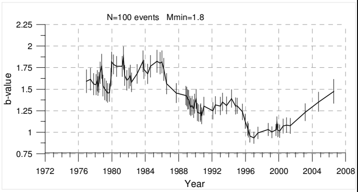
Catalog completeness: The completeness of the catalog is determined from the frequency-magnitude distribution $\lambda(M)$, where λ is the number of earthquakes within each magnitude grouping interval ΔM, normalized to the space-time-magnitude volume unit V=[1000 km2 x 1 year x 1 M]. $M_{completeness}=M_C=1.8$



Time changes in seismic activity: analysis of the OVO catalog

- **The time variations of the b-value in the Gutenberg-Richter (GR) law, are analysed and show that it decreases progressively from 1.8, before 1986, to about 1.0 in 1996.**

(Maximum likelihood estimation by Wiemer & Zuniga, ZMAP software)

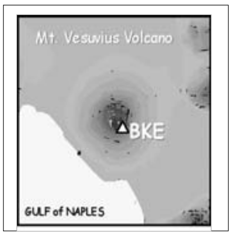


- **The seismic energy release is studied considering the quantity *E**, energy normalised to the minimum magnitude event, computed from magnitude according to the formula:**

$$E^* = 10^{d(M - M_{min})}$$ *d* = const

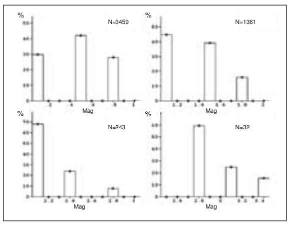
The BKE earthquake catalog

To test the stability and the significance of the time properties of seismicity observed for the OVO catalog, a similar analysis is performed using a different catalog of Vesuvian earthquakes, compiled from the records at the BKE station (*Saraò et al., ICTP report, 2002*).

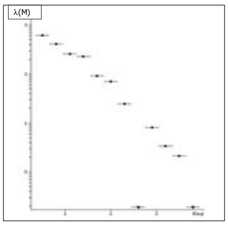


The BKE earthquake catalog

Magnitude grouping: The analysis evidences the presence of dominating values of magnitudes. It permits to choose the intervals of magnitude grouping as $\Delta M=0.3$.

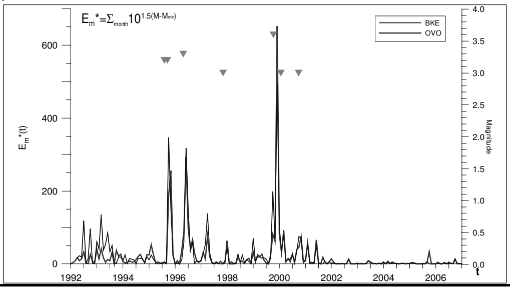


Catalog completeness: The completeness of the catalog is determined from the distribution $\lambda(M)$, is estimated as: $M_{completeness}=M_C=1.0$

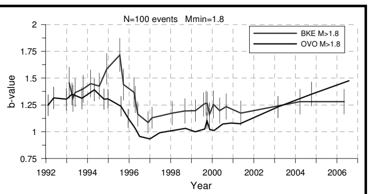


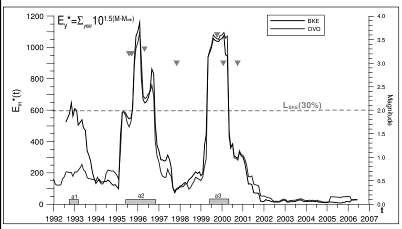
Time changes in seismic activity: comparison with the BKE catalog

The time variations of the b-value and seismic energy release, observed for the OVO catalog, are verified performing a similar analysis with a different catalog of Vesuvian earthquakes, as compiled from the records at the BKE station during the period 1992-2007.



Time changes in seismic activity: comparison with the BKE catalog

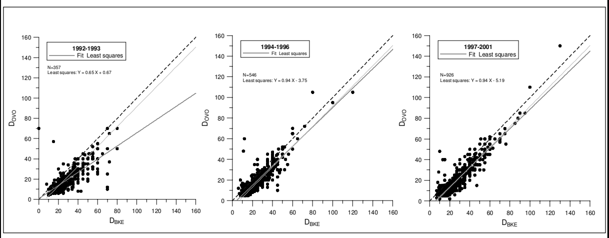




The analysis performed using the catalog compiled for the BKE stations confirms the b-value decrement and the identification of the periods of quiescence and activity, except for the time interval 1992-1994.

Time changes in seismic activity: comparison with the BKE catalog

The differences observed during the period 1992-1994 are well explained by a certain overestimation of BKE durations during such period of time, as shown by the comparison of OVO and BKE durations for the common events

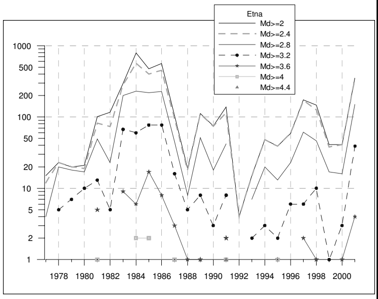


Problem: identification of the common events in catalogs characterised by low magnitude and highly clustered events

The catalog of seismic events at Etna Volcano

The ETNA catalog *(S. Gresta- INGV_DPC Sub-project V3_6 Etna)* **contains 3783 events occurred within the territory surrounding the volcano (37.4°-38.0° as latitude; 14.4°-15.4° as longitude) in the time interval 1977.11-2001.12.**

TIME ORIGIN		MAGNITUDE	
		OLD	NEW
1982-06-29	23.12	2,8	**2,5**
1983-05-13	16.41	2,3	**2,5**
1983-05-14	17.41	3,4	**2,6**
1984-10-18	5.31	2,7	**2,4**
1984-11-27	10.05	3,2	**2,8**
1984-12-20	21.46	2,6	**2,4**
1984-12-22	21.55	3,6	**1,8**
1984-12-23	19.53	2,2	**1,8**
1989-06-22	22.28	**4,8**	**3,0**

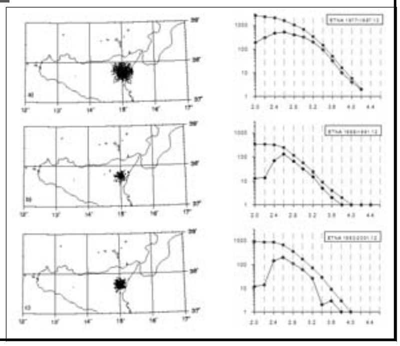


A careful analysis of the instrumental ETNA catalog allowed us evidencing some formal errors in the data=> the magnitude of 9 events has been modified accordingly

The catalog of seismic events at Etna Volcano

Three different time intervals can be distinguished in the Etna catalog:

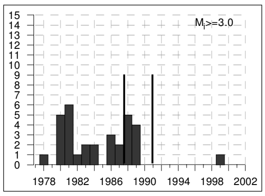
A) 1977.11-1987.12
B) 1988.01-1991.12
C) 1992.01-2001.12



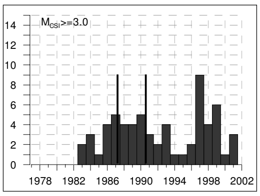
ETNA catalog: comparative analysis

A comparative analysis is performed between the ETNA instrumental ***(Sub-project V3_6 - Etna)*** **and macroseismic** ***(Azzaro et al., 2000)***[1] **catalogs, as well as with the Italian instrumental catalog CSI** ***(Castello et al., 2006)***[2]

a) Comparison ETNA– Macroseismic catalog: 32 events with M_I≥3.0 are reported in the macroseismic catalog but not in ETNA



b) Comparison ETNA– CSI catalog: 64 events with M_{CSI}≥3.0 are reported in the CSI catalog but not in ETNA (within a circle of 30 km radius)



[1] Catalogo macrosismico dei terremoti etnei: www://http.ct.ingv.it/sismologia/macro/default.htm
[2] Catalogo della sismicità italiana CSI versione 1.1: www.ingv.it/CSI

Etna catalog: comparative analysis and integration of data

Among the 32 events (M_I≥3.0) reported in the macroseismic catalog and not in the instrumental ETNA catalog, 14 events are also reported in CSI (9 of them have M_{CSI}≥3.0 too)

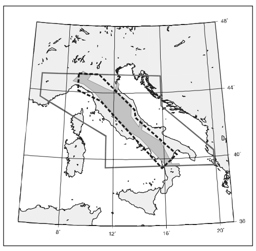
⇒ Missing events in catalog ETNA are generally due to a gap in the associated instrumental recordings

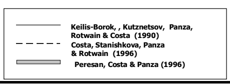
⇒ ETNA catalog has been integrated by incorporating the missing events, as reported either in CSI or macroseismic catalogs, within a circular area (R=30 km, centred in φ = 37.7°; λ = 14.9°)

ORIGIN TIME		LAT	LON	M_{MACRO}	M_{CSI}
17/05/1978	8.57	37.69	15.10	3.2	**CSI starts in 1981**
21/08/1980	15.57	37.58	15.07	3.2	
22/08/1980	23.28	37.58	15.06	3.2	
23/08/1980	7.52	37.59	15.06	**3.4**	
16/09/1980	2.30	37.60	15.08	**3.4**	
26/11/1980	1.38	37.72	15.12	**3.4**	
08/01/1981	16.36	37.81	15.07	**3.4**	**0**
15/02/1981	0.58	37.70	15.12	3.0	
03/07/1981	13.05	37.67	15.14	3.2	4.3
19/07/1981	12.56	37.73	15.15	3.2	
01/09/1981	23.32	37.65	15.15	3.2	
02/09/1981	18.20	37.64	15.16	3.0	
07/07/1982	23.45	37.81	15.07	**3.4**	
27/03/1983	8.05	37.68	14.91	**3.5**	
20/07/1983	22.03	37.60	15.10	**3.7**	**4.3**
17/06/1984	16.51	37.63	15.14	3.2	0
18/10/1984	11.58	37.81	15.07	**3.4**	3.9
18/01/1986	21.41	37.70	15.14	3.2	**3.6**
29/10/1986	23.18	37.81	15.05	**3.7**	**0**
04/12/1986	12.50	37.64	15.17	3.2	
06/05/1987	18.20	37.64	14.92	3.2	**3.1**
13/08/1987	7.22	37.75	15.01	3.2	3.2
01/04/1988	23.43	37.71	15.13	**3.4**	**3.1**
17/11/1988	23.51	37.60	15.08	3.0	
20/11/1988	11.10	37.60	15.08	3.0	
21/11/1988	2.19	37.60	15.09	**3.4**	**2.8**
21/11/1988	2.59	37.59	15.08	3.0	
15/01/1989	4.00	37.63	15.14	3.0	**2.9**
29/01/1989	7.30	37.71	15.16	**3.7**	3.4
07/06/1989	21.51	37.71	15.10	3.0	
11/10/1989	3.19	37.51	15.02	3.0	
05/08/1999	14.57	37.69	14.94	3.2	**4**

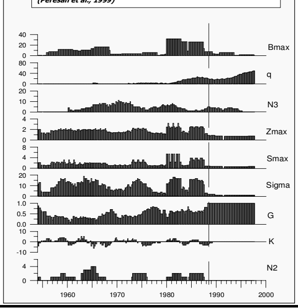
Intermediate-term middle-range earthquake catalogs analysis: Central Italy

CN algorithm and long lasting changes in reported magnitudes





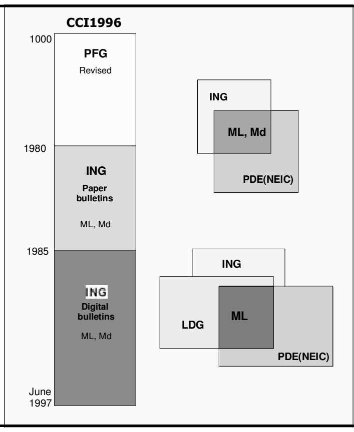
Time diagrams of the standard CN functions obtained for the Central region
(Peresan et al., 1999)



Catalogs comparison

Common events:
$\Delta T \leq 1$min

$\Delta Lat, \Delta Lon \leq 1°$
(Storchak, Bird and Adams, 1998)



Magnitude comparison: Central Region

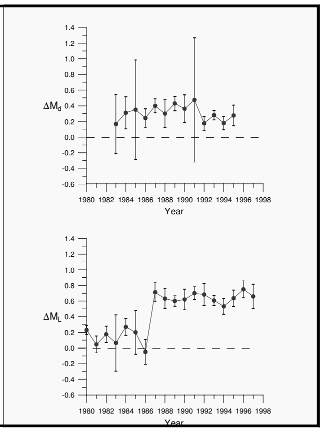
Duration Magnitude

M_d(NEIC)-M_d(ING)
$M_d \geq 3.0$
(1983-1997)
ΔM_d=0.30 0.04
Yearly Average

Yearly Average differences NEIC-ING

Local Magnitude

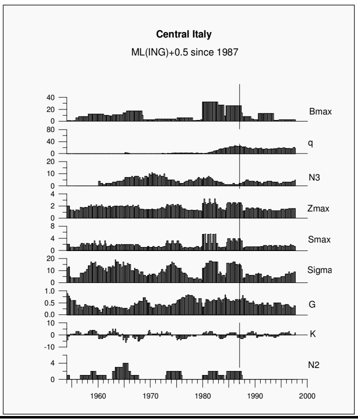
M_L(NEIC)-M_L(ING)
$M_L \geq 3.0$
(1980-1986)
ΔM_L=0.13±0.05
(1988-1997)
ΔM_L=0.64±0.04
Yearly Average



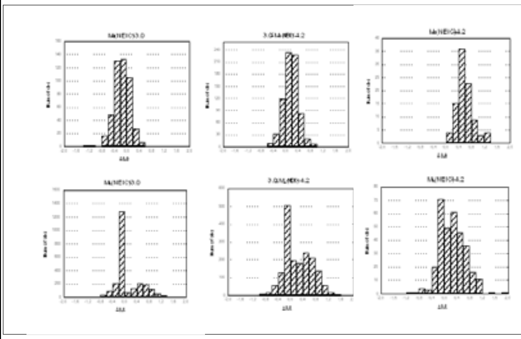
CN algorithm and long lasting changes in reported magnitudes

Time diagrams of the standard CN functions obtained for the Central region ***(Peresan et al., 1999)*** **:**

M=ML(ING)+0.5



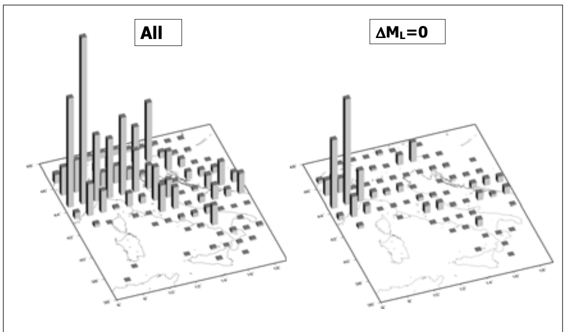
Magnitude comparison: Italian territory



ΔM_d

ΔM_L

Magnitude comparison: Italian territory



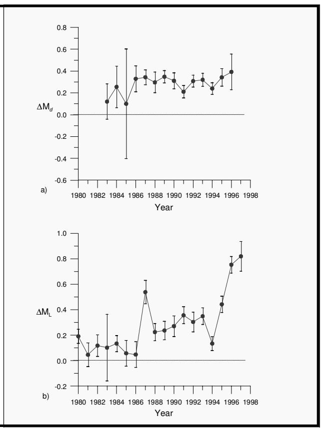
Magnitude comparison: Italian territory

Duration Magnitude NEIC - ING

M_D(NEIC)-M_D(ING)
$M_D \geq 3.0$
(1983-1986)
ΔM_D=0.30±0.02
Yearly Average

Local Magnitude NEIC - ING

M_L(NEIC)-M_L(ING)
M_L (NEIC)≥3.0
(1980-1986)
ΔM_L=0.08±0.05
(1988-1993)
ΔM_L=0.30±0.04
(1995-1997)
ΔM_L=0.77±0.06
Yearly Average



Magnitude comparison: Italian territory

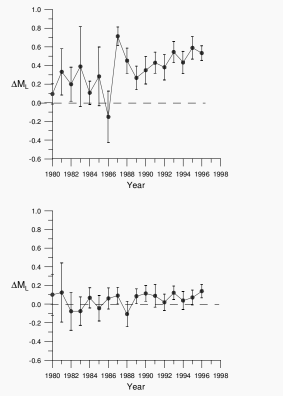
LDG - ING

M_L(LDG)-M_L(ING)
$M_L \geq 3.0$
(1980-1986)
ΔM_L=0.18 0.08
(1988-1996)
ΔM_L=0.44 0.04
Yearly Average

Local Magnitude: Yearly Average differences

NEIC - LDG

M_L(NEIC)-M_L(LDG)
$M_L \geq 3.0$
(1980-1986)
$\Delta M_L=0.03\pm0.06$
(1988-1996)
$\Delta M_L=0.08\pm0.03$
Yearly Average



CN algorithm and long lasting changes in reported magnitudes

- **The analysis of CN functions in Central Italy allowed us to detect a relevant long lasting change in the reported magnitudes.**
- **The comparison of individual magnitudes, reported by ING and NEIC, indicates, since 1987, an average underestimation of about 0.5 in the Local Magnitude provided by ING.**
- **The presence of a general local magnitude underestimation in the Italian ING bulletins is substantiated by the cross-comparison performed between ING, LDG and NEIC catalogues.**

(Peresan, Panza & Costa, GJI 2000)

Compilation of an updated catalog for CN monitoring in Italy

Databases available to us:

CCI1996: PFG revised+ING bulletins
(Italian catalog, available up to July 1997)
Priority: M_L, M_d, M_I

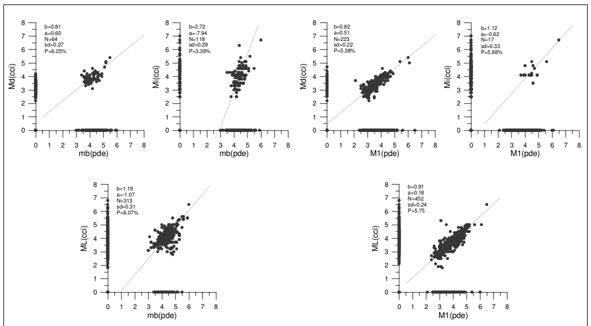
NEIC: PDE Preliminary Determinations of Epicenters from NEIC (global catalog).
Priority: to be defined (available M: m_b, M_S, M_1, M_2)

ALPOR: Catalogo delle Alpi Orientali (local catalog for eastern Alps)
Priority: M_L, M_I

Compilation of an updated catalog for CN monitoring in Italy

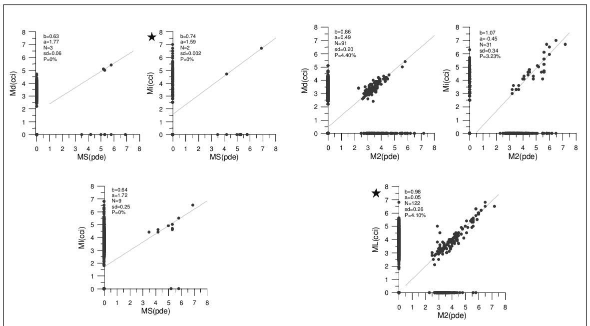
Procedure:
•Study of the completeness of PDE catalog;
•Study of the relations between different kind of magnitudes reported in the CCI1996 and PDE catalogs;
•Formulation of a rule for the choice of magnitude priority in PDE, similar to the priority used for CCI1996;
•Construction of the Updated catalog, integrating CCI1996, ALPOR and NEIC data (compatibly with the completeness of NEIC).

Operating magnitude selection



M(CCI1996) – mb(PDE)   M(CCI1996) – M1(PDE)

Operating magnitude selection



M(CCI1996) – MS(PDE)   M(CCI1996) – M2(PDE)

Operating magnitude selection

M1(PDE) ⟶ M_d(CCI)

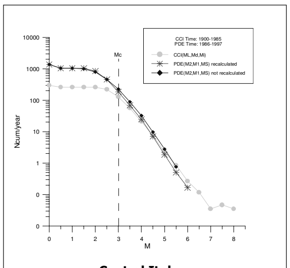
M2(PDE) ⟶ M_L(CCI)

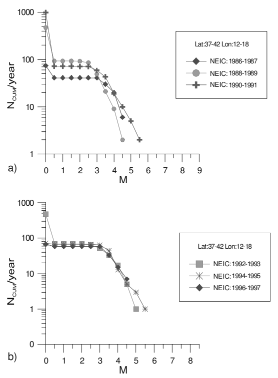
M_S(PDE) ⟶ Poor statistic

m_b(PDE) ⟶ Not representative of any of CCI magnitudes

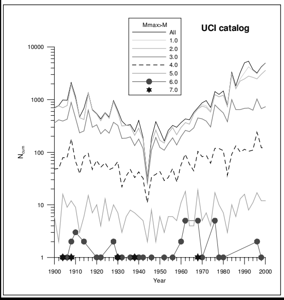
$$M_{CCI}(M_L, M_d, M_I) \Longrightarrow M_{PDE}(M2, M1, M_S)$$

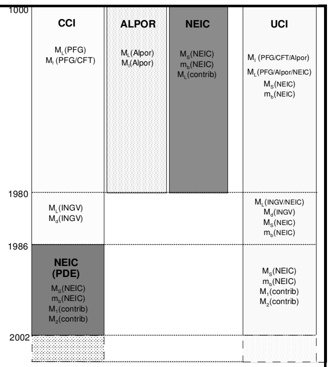
Operating magnitude selection





The Updated Catalog of Italy UCI2001





Integration and merging of Earthquake Catalogs: the Adria Region

A unified earthquake catalog for the Adria region and its surroundings

The "Adria Catalog" is the result of the integration of:

- *National catalogs:*
  - UCI: the Updated Catalog of Italy (*Peresan et al., 2002*) which is assumed to be the reference data set for the Italian territory;
  - CEC: the Catalog (*Herak et al., 1996 and its updates*) for the Croatian territory and its vicinity;
- *Global catalog:* NEIC (*USGS. GHDB, 1989 and its updates*) outside national preference territory**.**

Time span: since January 1900

- ✓ 1900 -1985: incorporation of UCI and CEC data, taking UCI as the reference catalog
- ✓ since 1986: updating using NEIC data only

Area: rectangle including the Adriatic plate and surrounding areas

- ✓ (Lat: 35.0°N - 48.0°N; Lon: 6.0°E - 20.0°E)

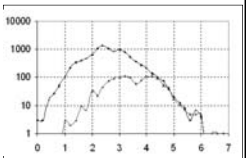
Basic steps in catalogs analysis

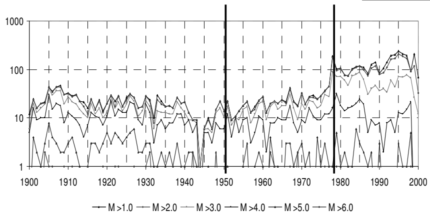
1. **Check space (maps) and time distribution of events**
2. **Check completeness (GR)**
3. **Check space coverage of data, by comparison with global data sets**
4. **Compare with previously available catalogs:**
   - ✓ **select common events**
   - ✓ **analyse unequivalent events (space, time and M distribution)**
   - ✓ **compare magnitudes**

CEC catalog

Time completeness
data analysis
1900-2000

Discrete distribution of the Number of events vs. Magnitude





Cumulative distribution of the Number of events as a function of Time and Magnitude

CEC catalog

Spatial completeness
data analysis

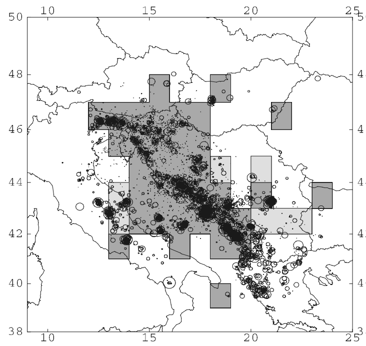
$\frac{n}{N} \geq 0.75$

$\frac{n}{N} \geq 0.50$

N: total number of earthquakes with M>4.0 from NEIC inside the cell

n: number of common events in NEIC and CEC catalog

The ratio n/N characterizes the completeness of CEC catalog in a given cell (*Kossobokov et. al., 1999)*



Time interval: 1978-2000

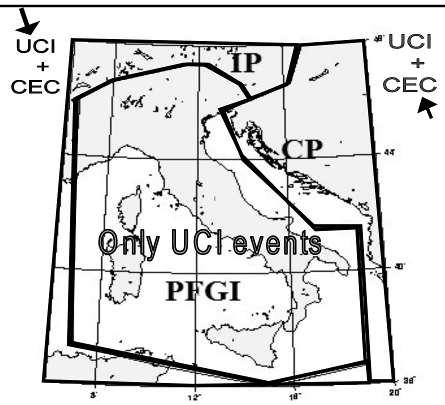
ADRIA catalog: merging criteria based on polygons

We wish to spatially integrate the Italian catalogue UCI, which is assumed to be the reference data set for the Italian territory (i.e. inside the PFGI polygon)

⇩

Spatial integration of data with other regional and global information

- ✓ CEC over its preference territory (CP polygon)
- ✓ NEIC outside regional preference territory (IP polygon)



Merging procedure: identification of common events

- Two records from two different catalogs are considered as records of the same event, if they satisfy the following conditions:
  - ✓ ΔTIME = 1 minute
  - ✓ ΔLONGITUDE = ΔLATITUDE =0.5°
  - ✓ ΔDEPTH = not limited
  - ✓ ΔMAGNITUDE = not limited

Along the PFGI boundaries priority is given to Italian catalogue **UCI.**

Along the boundary between IP and CP priority is given to:

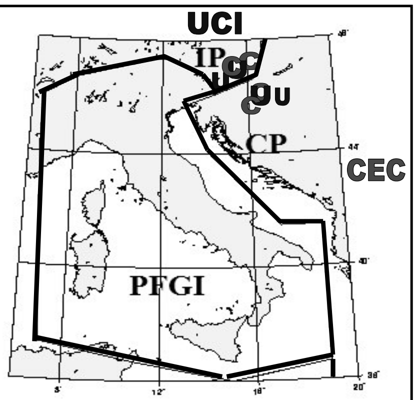
a) **Italian catalogue** UCI if:

- both events have epicenter in IP;

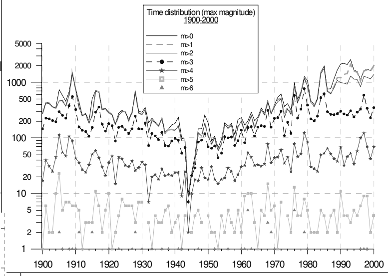
- an event from UCI have epicentre in IP, and the same event from CEC have epicentre in CP

- an event from UCI have epicentre in CP and the same event from CEC have epicentre in IP.

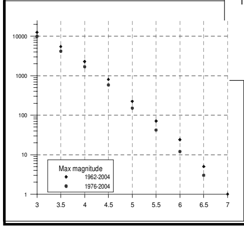
b) **Croatian catalogue** CEC if both events fall in CP.



Adria Catalog



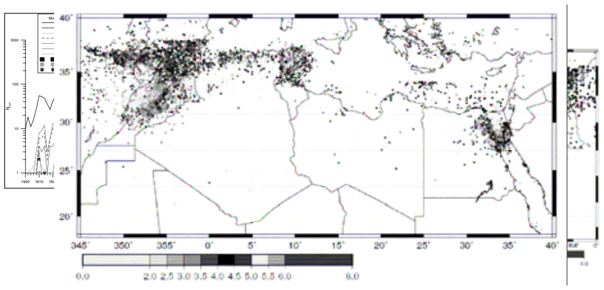
Cumulative distribution of the Number of events as a function of Time and Magnitude



Cumulative distribution of the Number of events vs. Magnitude

UNESCO-IUGS-IGCP Project 457
"Seismic Hazard and Risk Assessment in North Africa"
(Algeria, Libia, Morocco, Tunisia, Egypt, Italy)

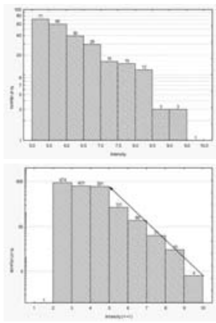
Compilation of a Unified Earthquake Catalog for Northern Africa

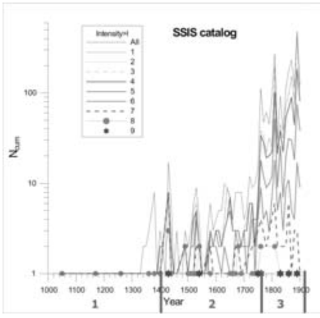


Historical and instrumental catalogs: the example of Spain

The catalog of seismicity for the Iberian peninsula (SSIS)

Catalogo sismico de la Peninsula Iberica (880 a.C.-1900)
Martinez Solares and Mezcua Rodriguez (2002)

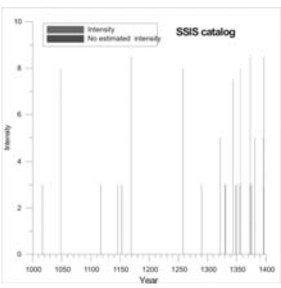




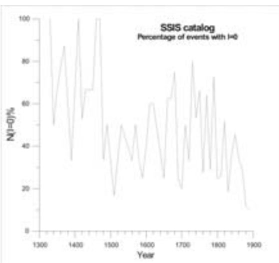
Cumulative number of events vs. time and intensity

The catalog of seismicity for the Iberian peninsula (SSIS)

Time interval: 1000-1400



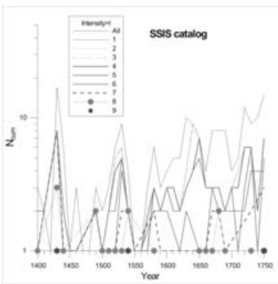
Before 1400 the completeness threshold cannot be clearly identified. The catalog is not complete for I>8 up to 1360

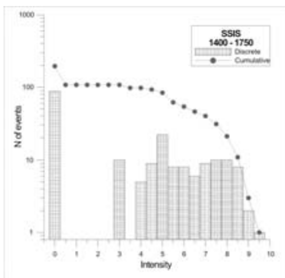


High percentage of events without any intensity estimation in the SSIS catalog, with some sensible reduction only since 1500

The catalog of seismicity for the Iberian peninsula (SSIS)

Time interval: 1400-1750

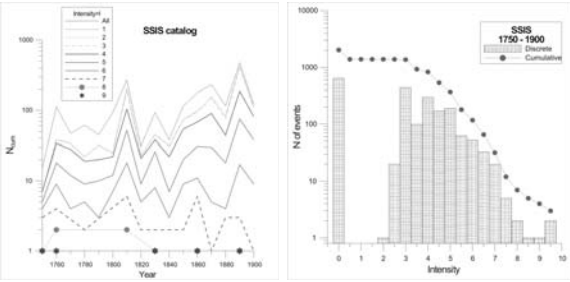




The catalog appears complete for I>8 during the period 1400-1750

The catalog of seismicity for the Iberian peninsula (SSIS)

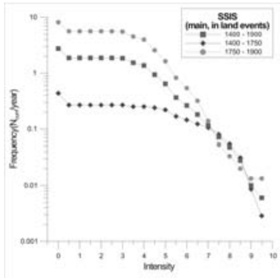
Time interval: 1750-1900



The catalog appears complete for I>6 during the whole period 1750-1900 and for I>5 (and eventually for I>4) since 1986.

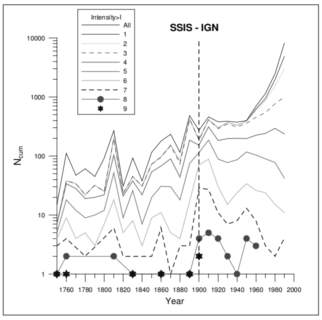
The catalog of seismicity for the Iberian peninsula (SSIS)

- **The frequency-intensity distributions, obtained for the SSIS catalog over three different time intervals, are comparable only in the intensity range 7.0-8.5.**
- **The cumulative distribution for the whole time interval 1400 – 1900 appears preferable for I>7.**
- **The frequency of the events with I>9 appears much larger during the period 1750-1900 than for 1400-1750.**
- **The catalog seems to be quite complete and homogeneous for intensities I>6 after 1750; nevertheless the time interval 1750-1900 alone is not enough to characterise the frequency of the large events.**



The catalog of seismicity for the Iberian peninsula (SSIS)

The overall increase in the number of earthquakes seems not due to an increased "detection" level, that should not affect the largest intensities, but would rather imply a progressive increase of the number of small events.
We can see that the intensities reported in the two catalogs SSIS (EMS-98) and IGN (MSK) are not homogeneous and, if used all together, do not provide a consistent picture of seismicity.



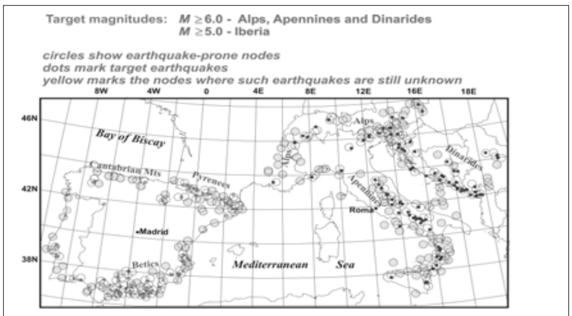
Cumulative number of events vs. time for the SSIS catalog (1750 –1900) and for the IGN catalog (1900 – 2000). For the events reported without any intensity in the IGN catalog, the intensity recalculated from IGN magnitude mb (e.g. Lopez-Casado et al., 2000) **is considered.**

"Seismological database for seismic hazard assessment needs to be uniform and to cover a long enough time interval to allow the occurrence of rare, large-magnitude events — generally associated with long return periods — to be estimated, notably for critical structures."

(IAEA – ICTP "Workshop on the Conduct of Seismic Hazard Analyses for Critical Facilities" Trieste, May 2006)

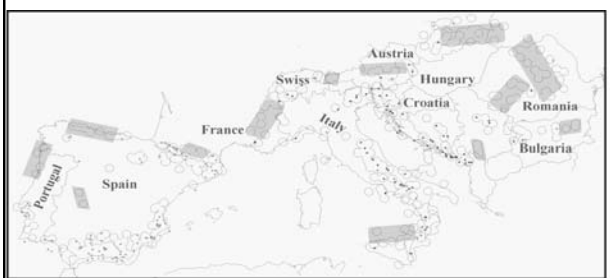
Is the information on observed seismicity sufficient to identify the sites where large earthquakes may occur?

Recognition of nodes where strong earthquakes may nucleate in the Mediterranean area



References
Gorshkov A.I., Panza G.F., Soloviev A.A. & Aoudia A. (2002). Morphostructural zoning and preliminary recognition of seismogenic nodes around the Adria margin in peninsular Italy and Sicily. JSEE: Spring 2002, 4, No.1, 1-24.
Gorshkov A.I., Panza G.F., Soloviev A.A., Aoudia A. (2004). Identification of seismogenic nodes in the Alps and Dinarides. Boll.Soc.Geol.Ital. 123, 3-18.

Is the information on observed seismicity sufficient to identify the sites where large earthquakes may occur?



Conclusions

- **Historical information is qualitative and even instrumental data are unavoidably affected by errors. Therefore robust methods of analysis should be used, within the limits of their applicability.**
- **Special care should be paid to verify data quality and homogeneity and the significance and stability of the obtained results should be evaluated.**

Conclusions

- **Statistical characterization of earthquake occurrence requires a large amount of homogeneous and complete data, over a long enough time interval. Detailed studies on individual earthquakes are essential but may be not sufficient to characterise earthquake recurrence.**
- **Information from data different than the seismological ones (morphological, geological, etc.) can be very useful to integrate the data base for seismic hazard analysis, provided the information is collected as much systematically and homogeneously as possible.**