

Rodolfo Console

***Previsioni dei terremoti
e loro validazione***

Convegno “Prevedere i terremoti”
Sala Consilina, 3 maggio 2009

Schema della presentazione

*Sismicità del Vallo di Diano e della Val
D'Agri*

I precursori dei terremoti

Previsioni statistiche in Italia

*Formulazione di un'ipotesi di previsione
sismica e sua validazione statistica*



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

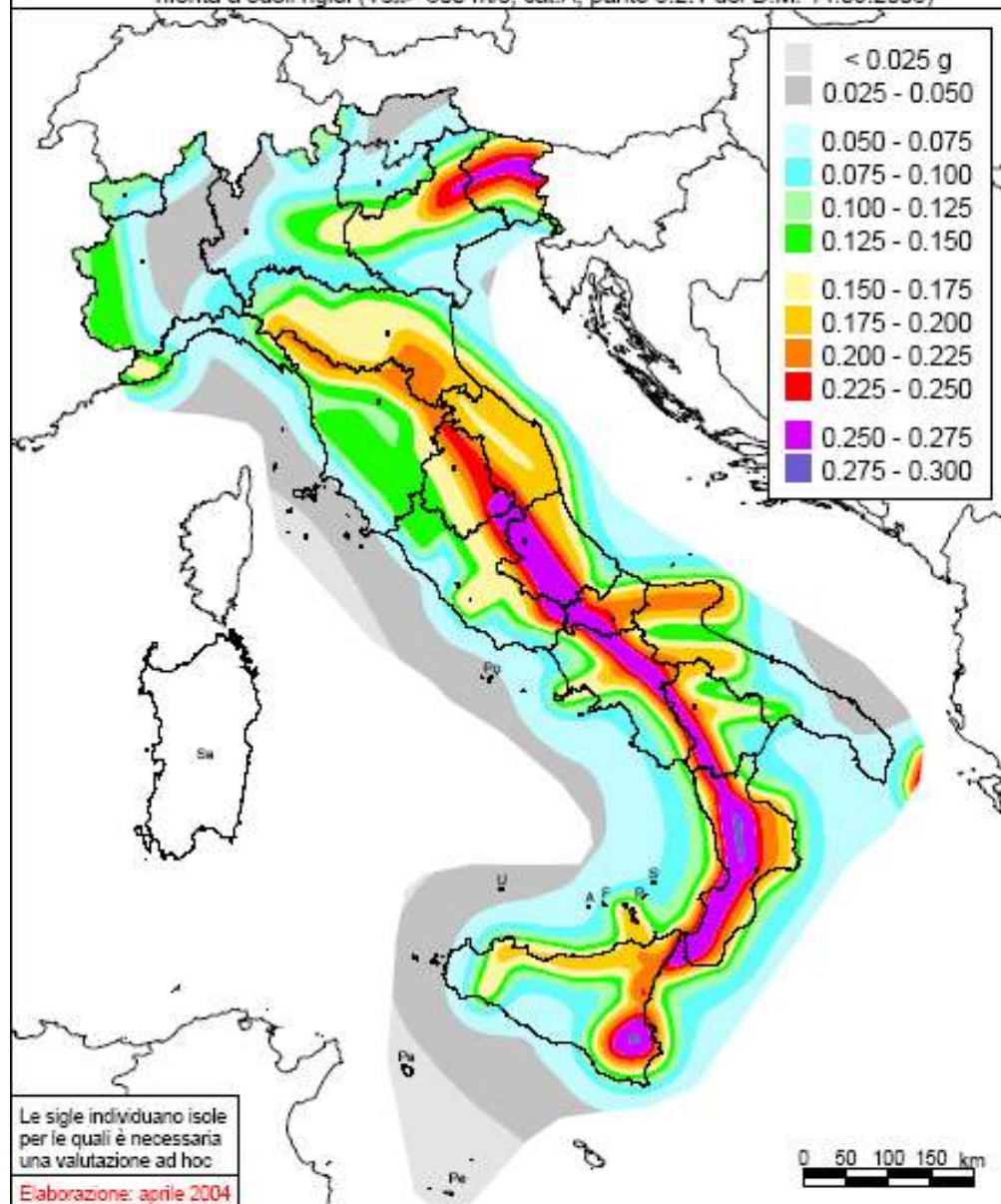
Mappa di pericolosità sismica del territorio nazionale

(riferimento: Ordinanza PCM del 28 aprile 2006 n.3519, All.1b)

espressa in termini di accelerazione massima del suolo

con probabilità di eccedenza del 10% in 50 anni

riferita a suoli rigidi ($V_{s30} > 800$ m/s; cat.A, punto 3.2.1 del D.M. 14.09.2005)





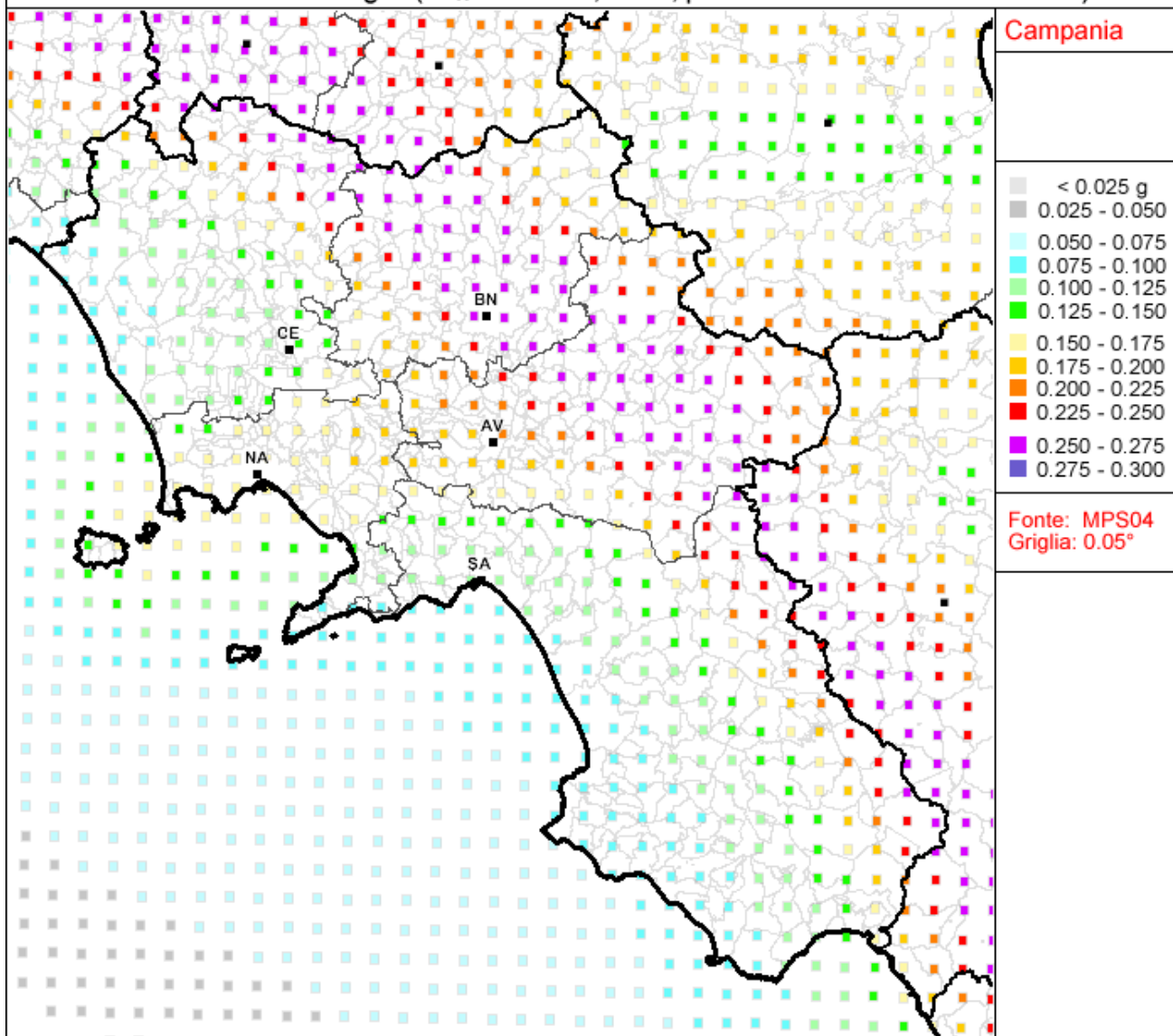
Valori di pericolosità sismica del territorio nazionale

(riferimento: Ordinanza PCM del 28 aprile 2006 n.3519, All.1b)

espressi in termini di accelerazione massima del suolo

con probabilità di eccedenza del 10% in 50 anni

riferita a suoli rigidi ($V_{s30} > 800$ m/s; cat.A, punto 3.2.1 del D.M. 14.09.2005)

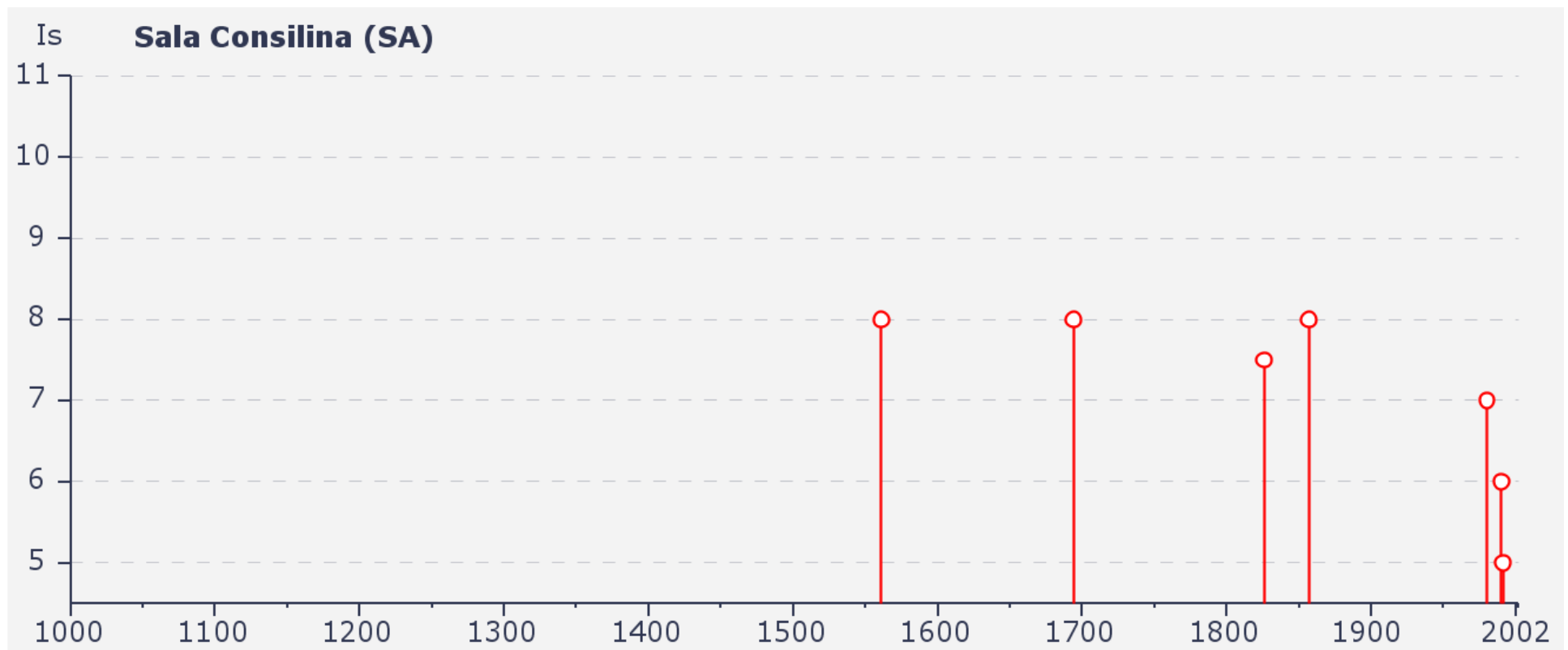


Storia sismica di Sala Consilina (SA) [40.398, 15.596]

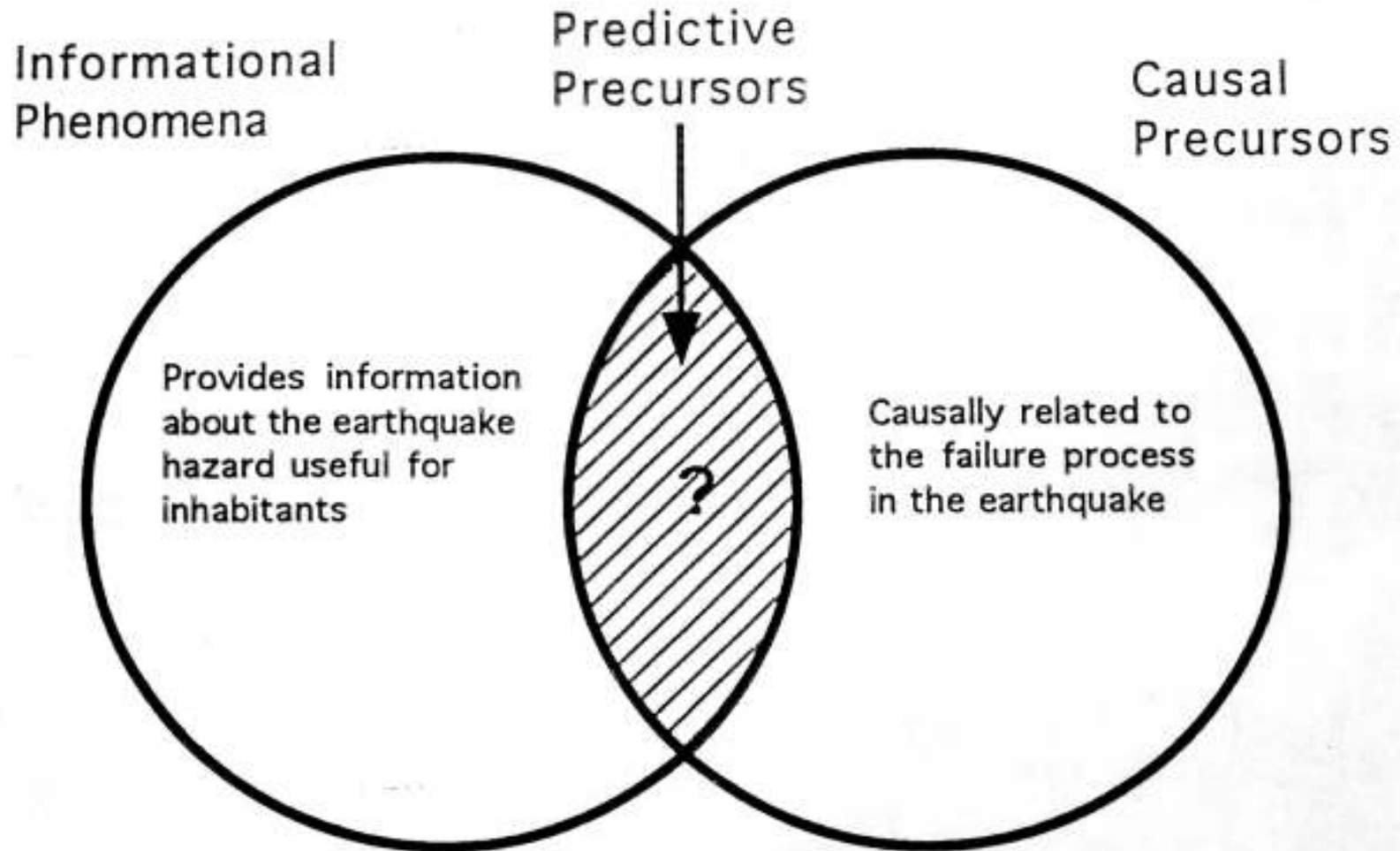
Osservazioni disponibili: 13

Anno	Me	Gi	Area epicentrale	Is	Io
1561	8	19	Vallo di Diano	8	9
1694	9	8	Irpinia-Basilicata	8	10
1857	12	16	Basilicata	8	10
1826	2	1	Basilicata	7	8
1980	11	23	Irpinia-Basilicata	7	10
1990	5	5	Potentino	6	7
1991	5	26	Potentino	5	7
1986	7	23	Potentino	4	6
1988	1	8	Appennino Lucano	4	6
1905	6	29	Brienza	3	6
1996	4	3	Irpinia	3	6
1984	5	7	Appennino abruzzese	3	8
1930	7	23	Irpinia	2	10

I terremoti di maggiore intensità avvertiti a Sala Consilina



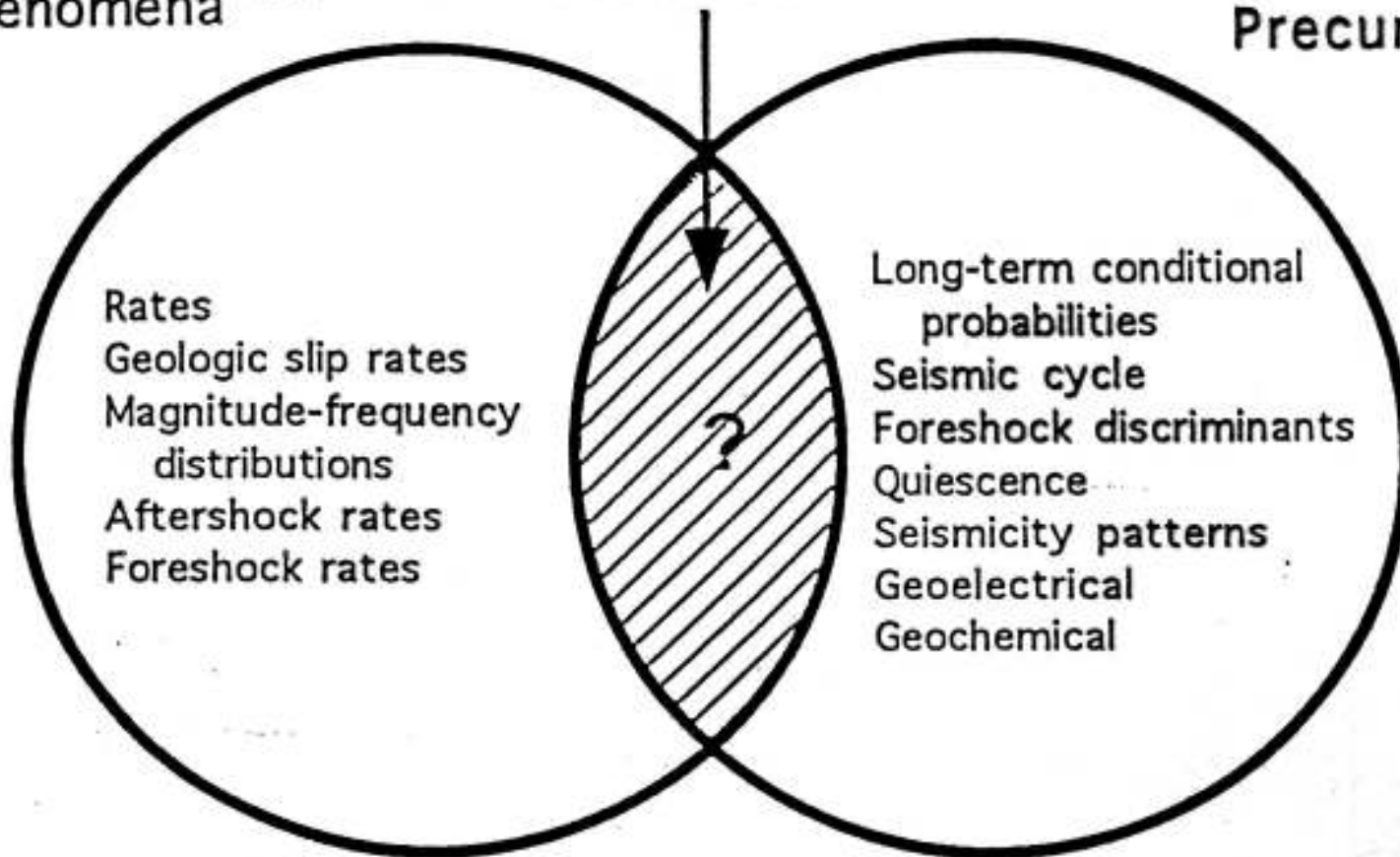
Precursori dei terremoti



**Informational
Phenomena**

**Predictive
Precursors**

**Causal
Precursors**

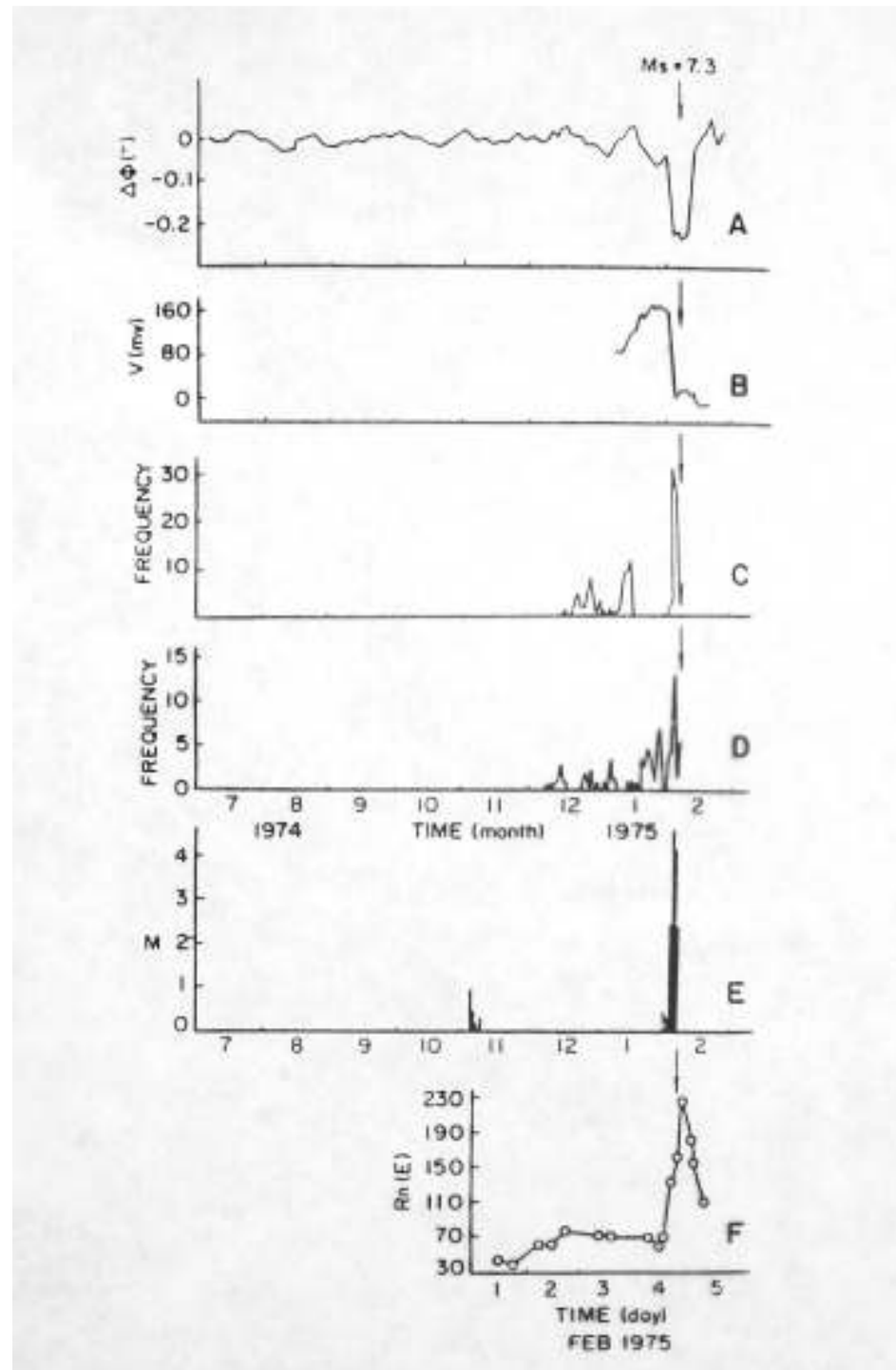


Rates
Geologic slip rates
Magnitude-frequency
distributions
Aftershock rates
Foreshock rates

Long-term conditional
probabilities
Seismic cycle
Foreshock discriminants
Quiescence
Seismicity patterns
Goelectrical
Geochemical

Fenomeni che precedettero il terremoto di Haicheng (1975)

- A) Inclinazione del suolo
- B) Potenziale geoelettrico
- C) Comportamenti anomali degli animali
- D) Fenomeni idrogeologici
- E) Foreshocks
- F) Concentrazione di radon



Fenomeni osservati prima del terremoto di Izu-Oshima (1978)

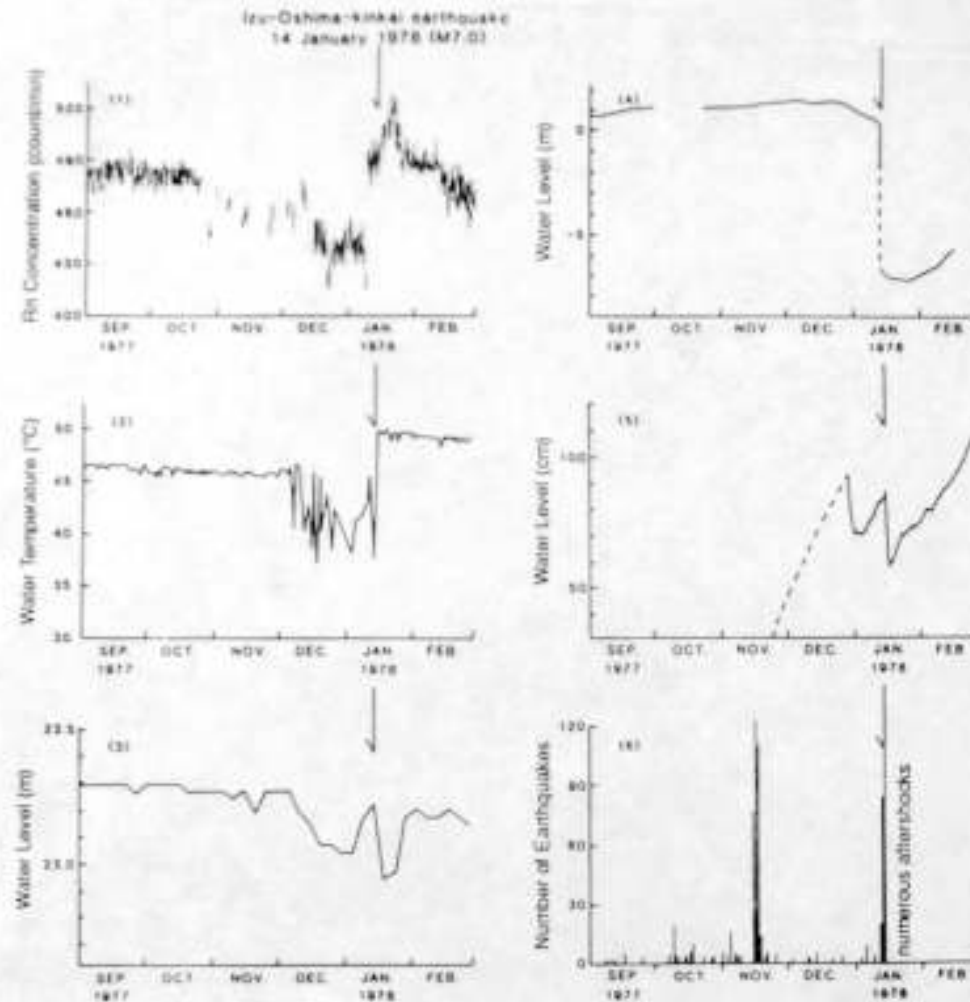
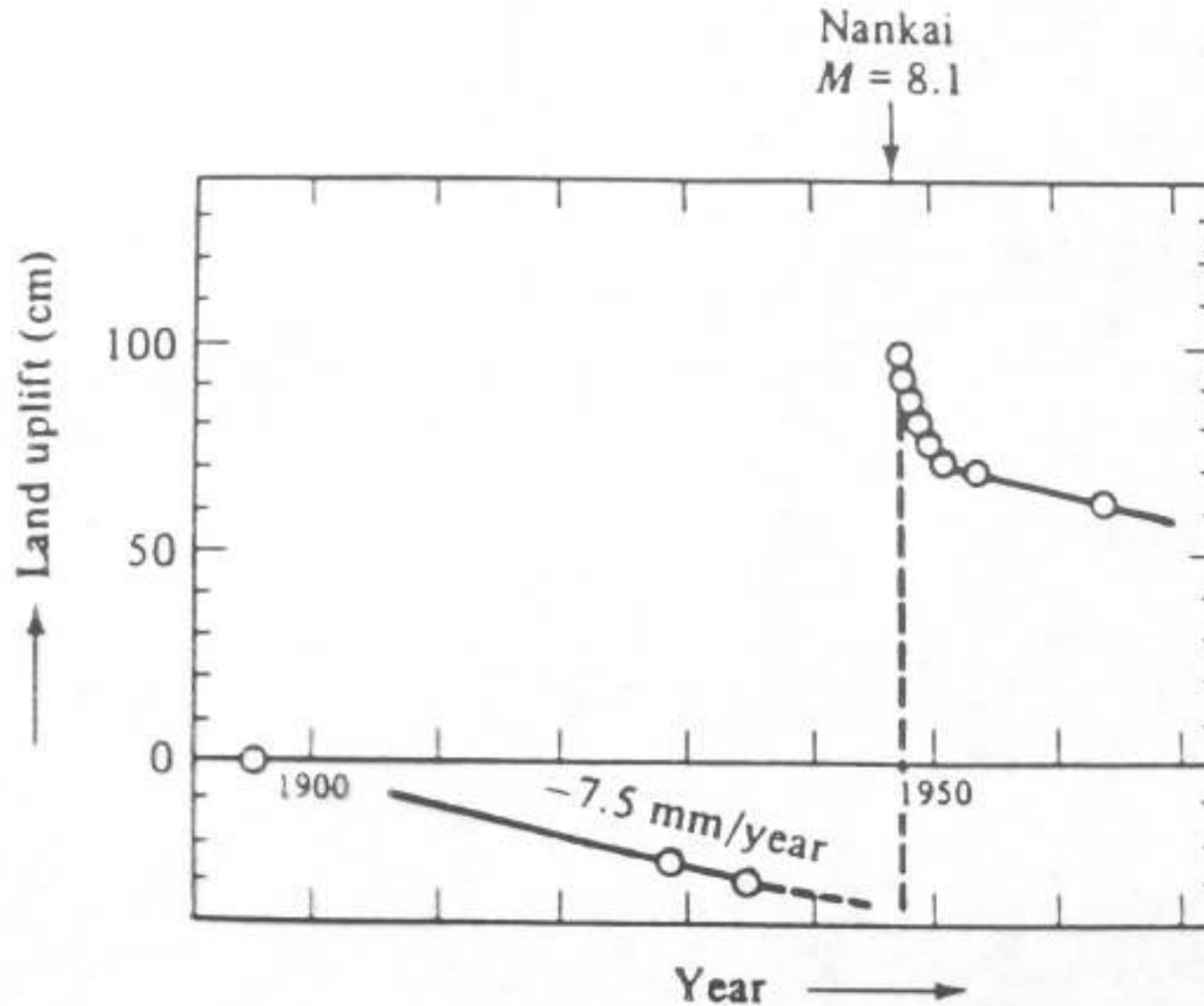


FIGURE 1.54 Precursory changes in radon concentration, water temperature, water levels, and number of minor earthquakes prior to the Izu-Oshima earthquake of 1978. (From Wakita, 1981.)

Variazioni di quota misurate sulla costa giapponese meridionale



Ipotesi della quiescenza sismica

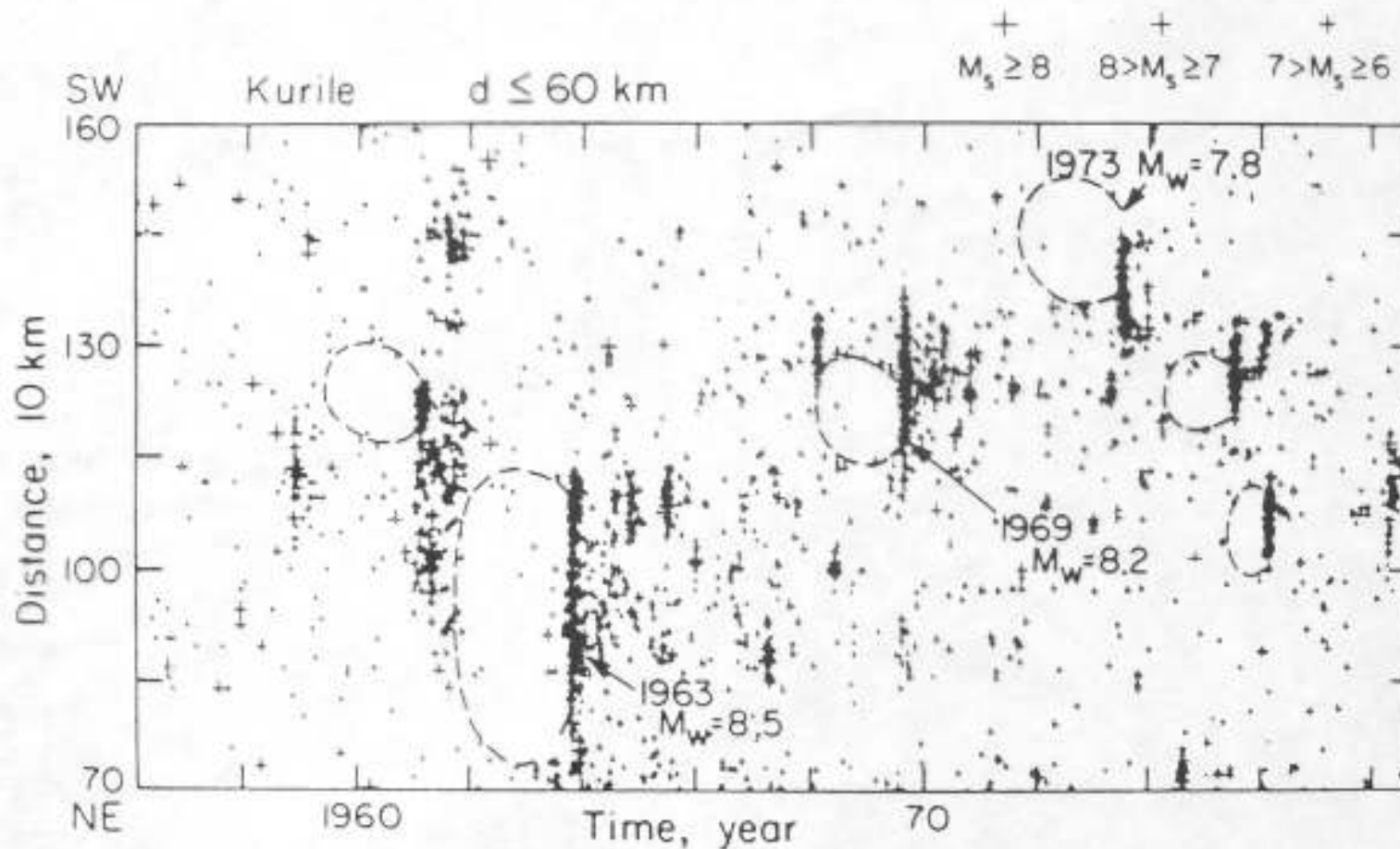


FIGURE 11.55 Space-time history of the seismicity along the Kuril Islands subduction zone. Periods of quiescence preceding large earthquakes are circled. (From Kanamori, 1981.)

Modello della dilatanza

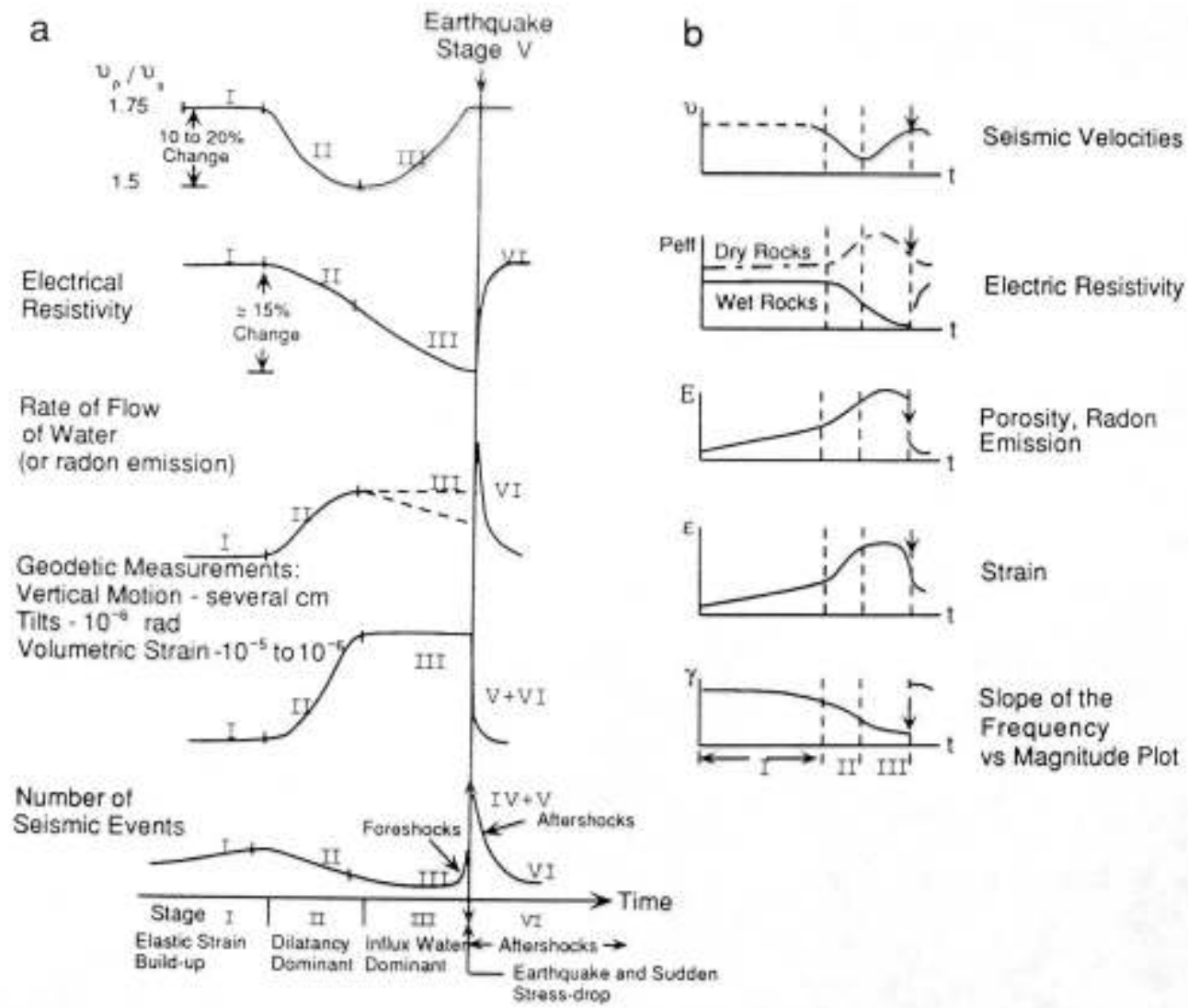


FIGURE 11.53 Expected physical changes for dilatancy. (a) Wet model. (b) Dry model. (From Kasahara, 1981.)

TABELLA 1

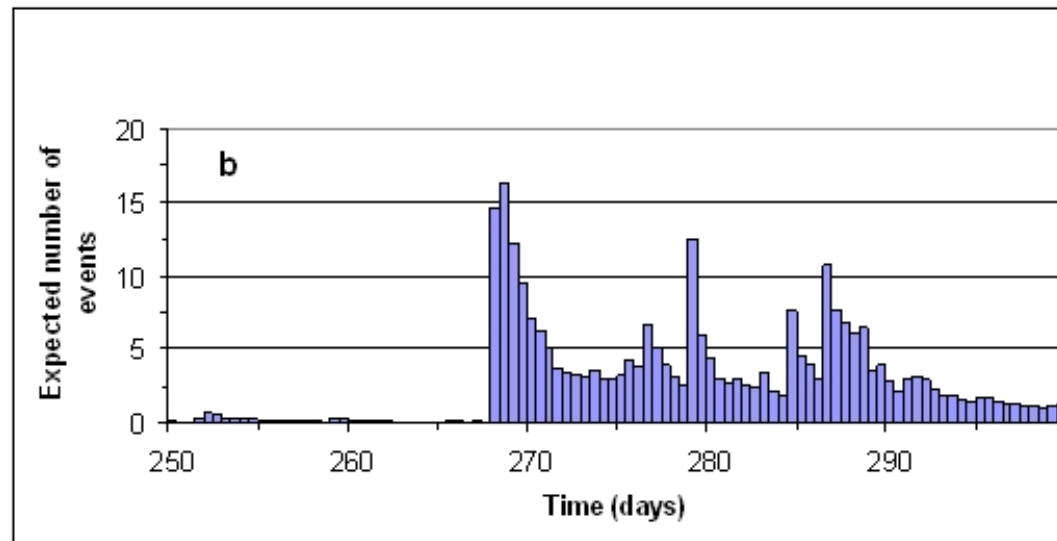
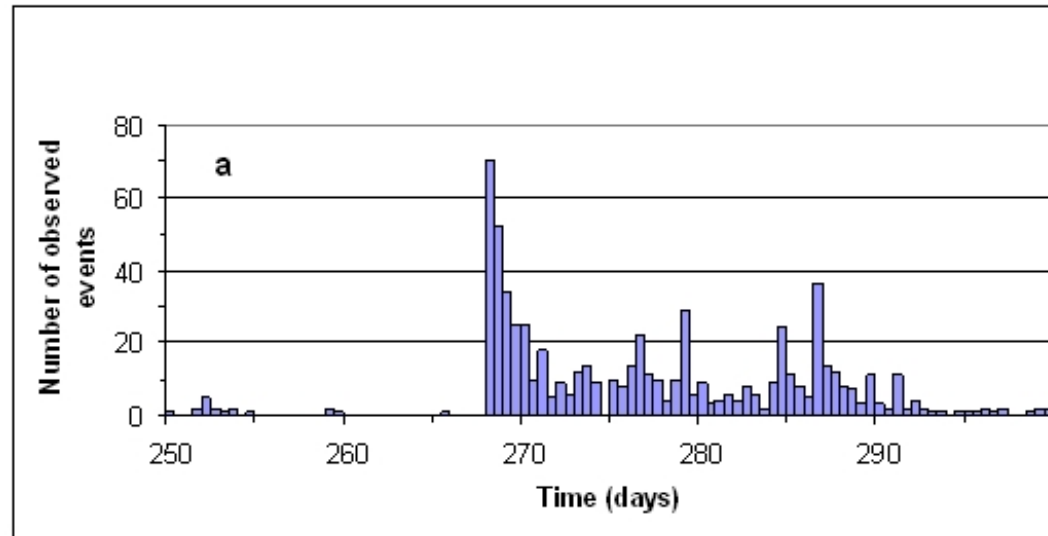
Numero di precursori osservati per ogni gruppo di fenomeni

(da Rikitake, 1981)

Tipo di precursore	Numero di osservazioni
Deformazioni geodetiche	30
Variazioni clinometriche ed estensimetriche	89
Scosse premonitorie	83
Sismicità anomala	14
b-value	12
Microsismicità	4
Meccanismo focale	7
Migrazione degli ipocentri	4
Rapporto Vp/Vs	50
Vp e/o Vs	19
Geomagnetismo	6
Correnti telluriche	17
Resistività	32
Concentrazione di Radon	12

Seismic sequence of Umbria-Marche (1997)

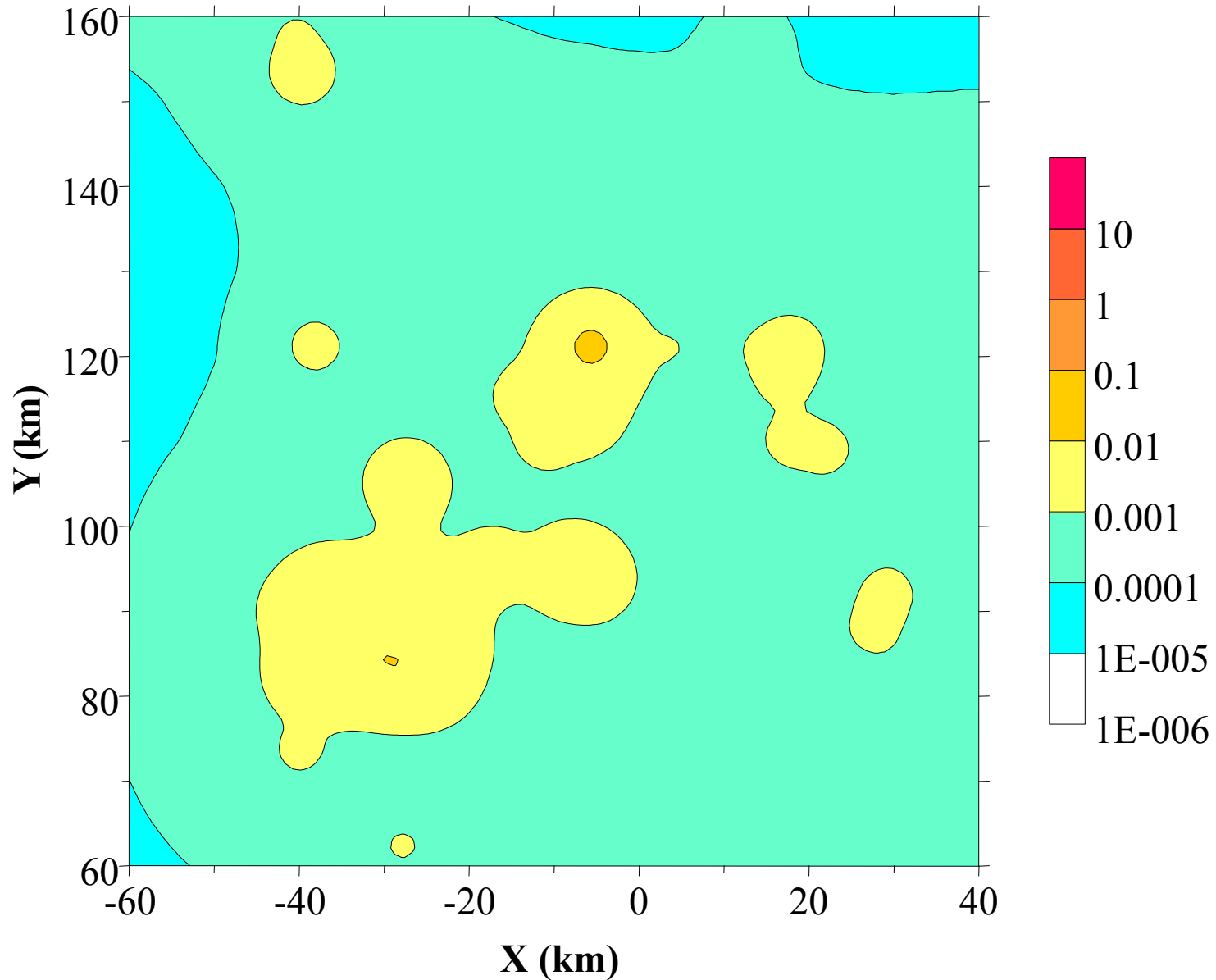
Comparison between the number of observed events (a) and the number of expected events (b) for time windows of 12 hours



Umbria-Marche

(1 September 1997, 00:00)

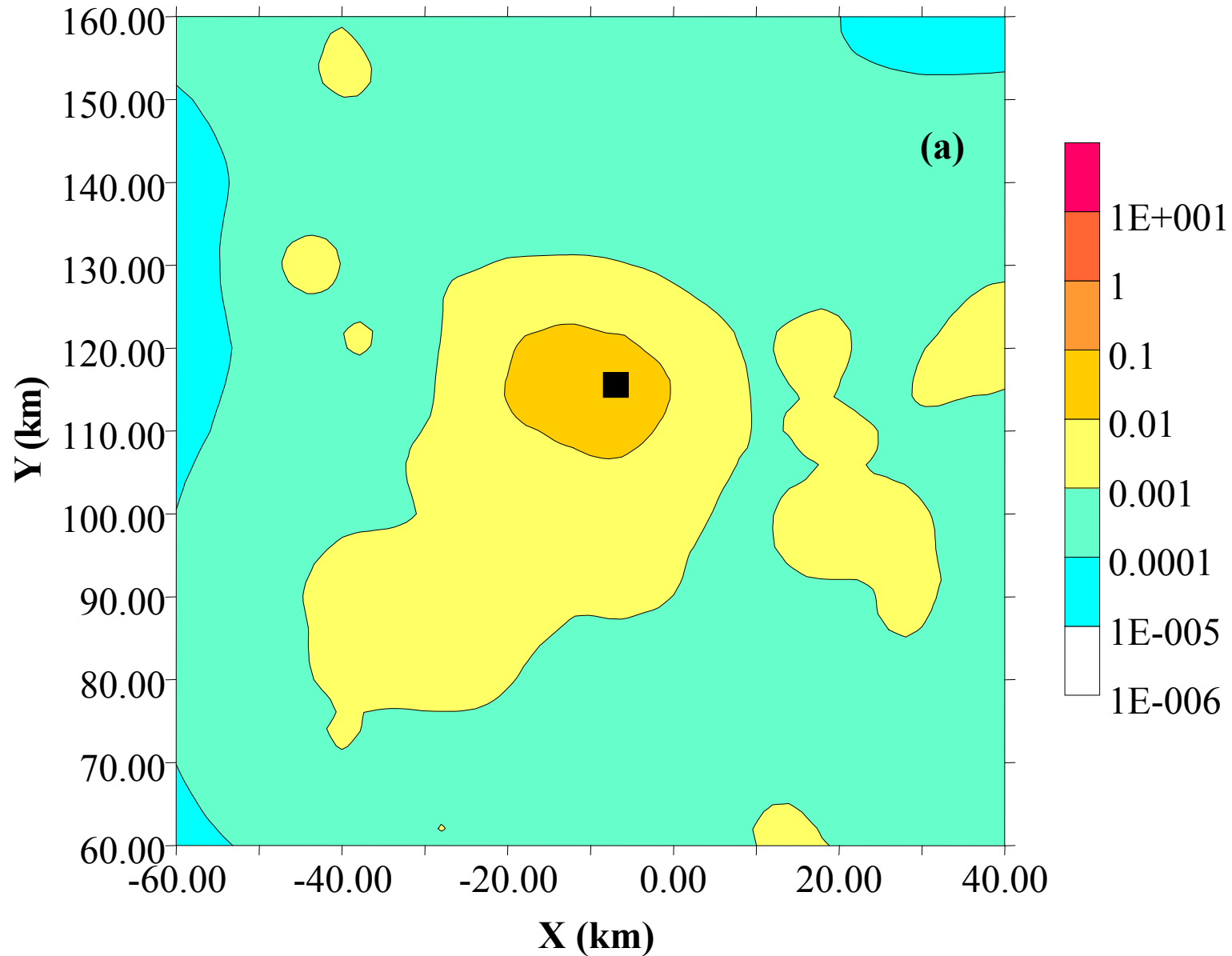
Occurrence rate (events per day in 100 km²) under the Epidemic Model ($M_I \geq 2.0$)



Umbria-Marche

26 September 1997, 00:33 (before the Colfiorito $M_I=5.6$ event)

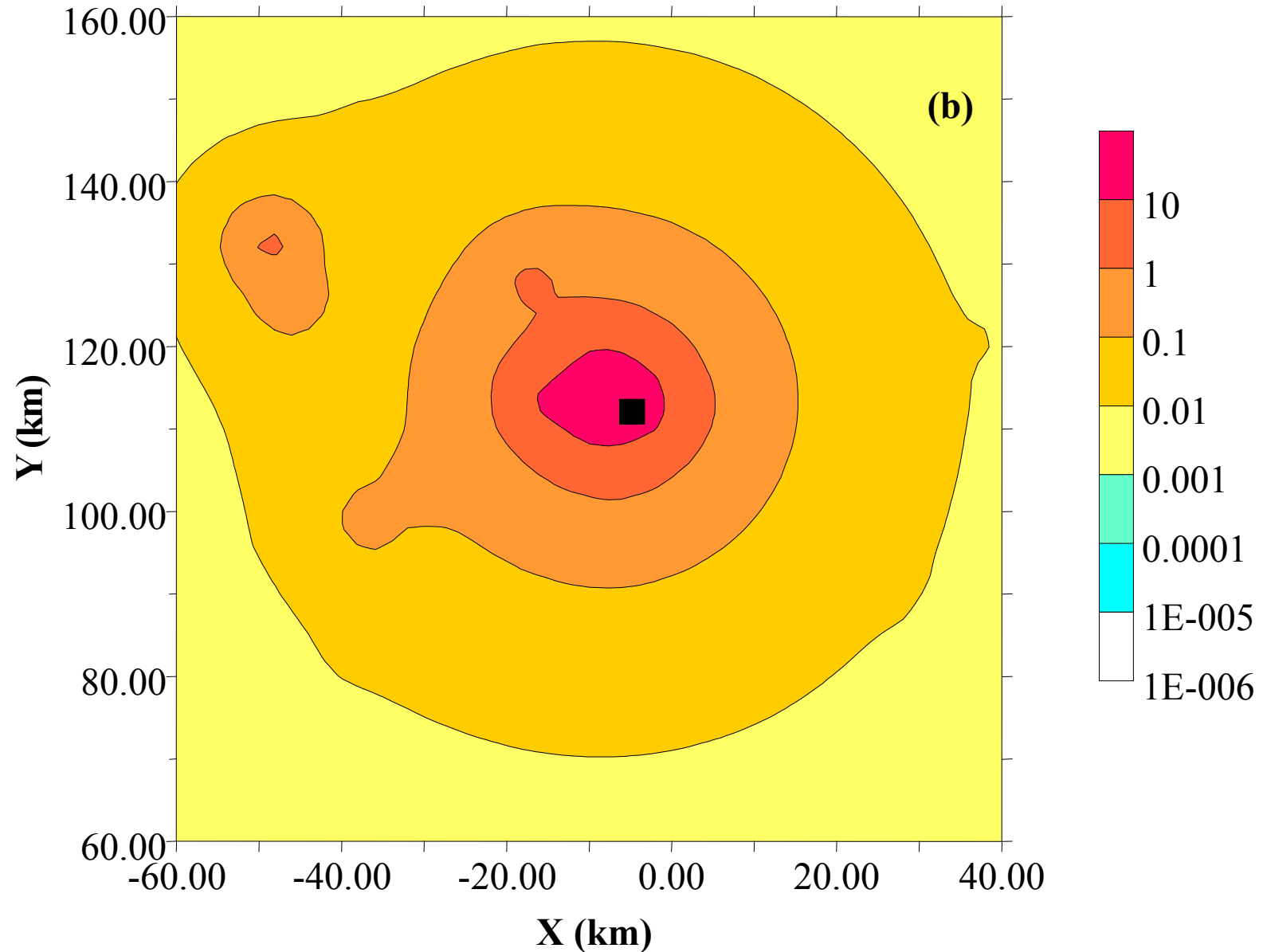
Occurrence rate (events per day in 100 km^2) under the Epidemic Model ($M_I \geq 2.0$)



Umbria-Marche

26 September 1997, 9:40 (before the second Colfiorito Ml 5.8 event)

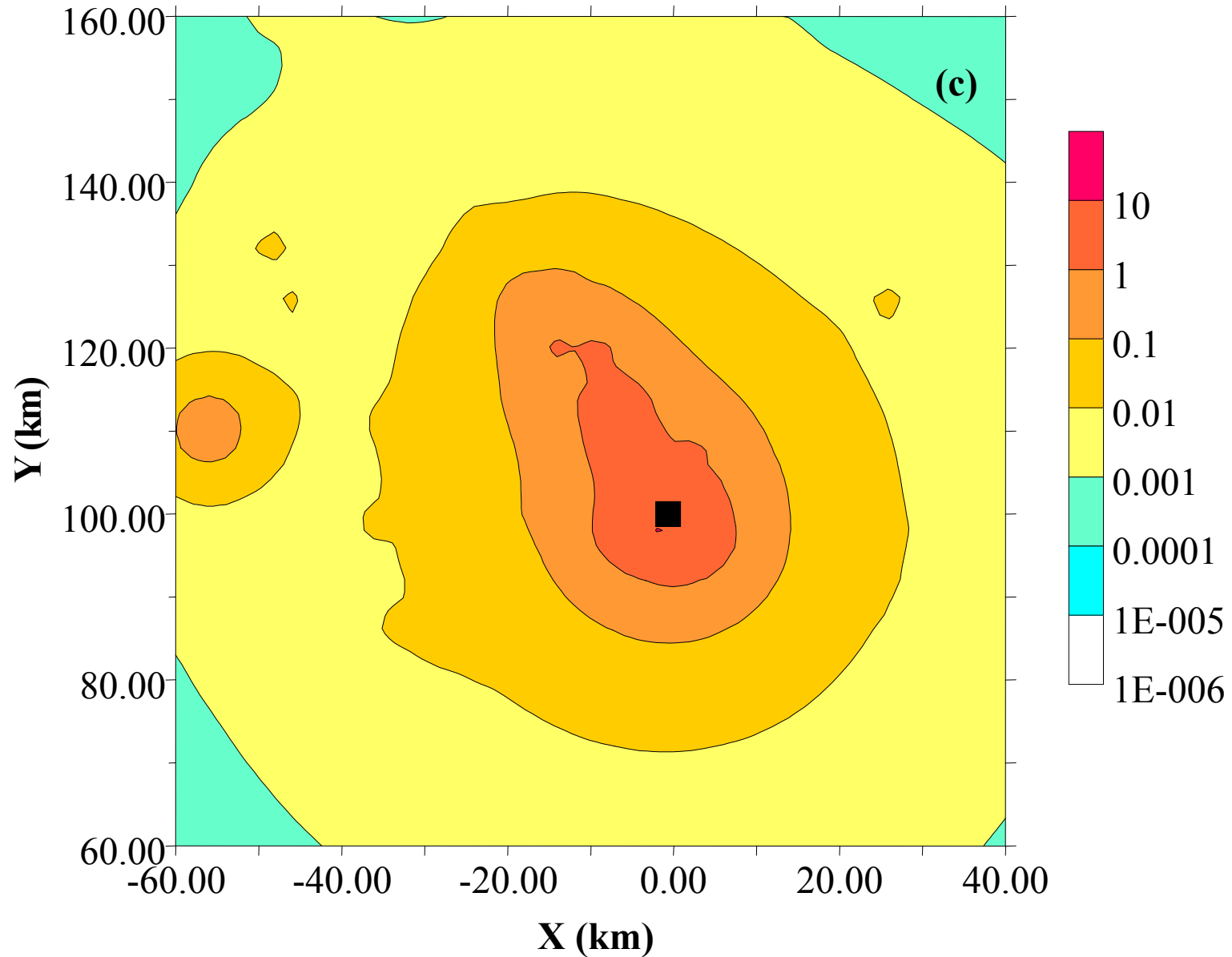
Occurrence rate (events per day in 100 km²) under the Epidemic Model (Ml \geq 2.0)



Umbria-Marche

14 October 1997 (before the Sellano MI 5.5 event)

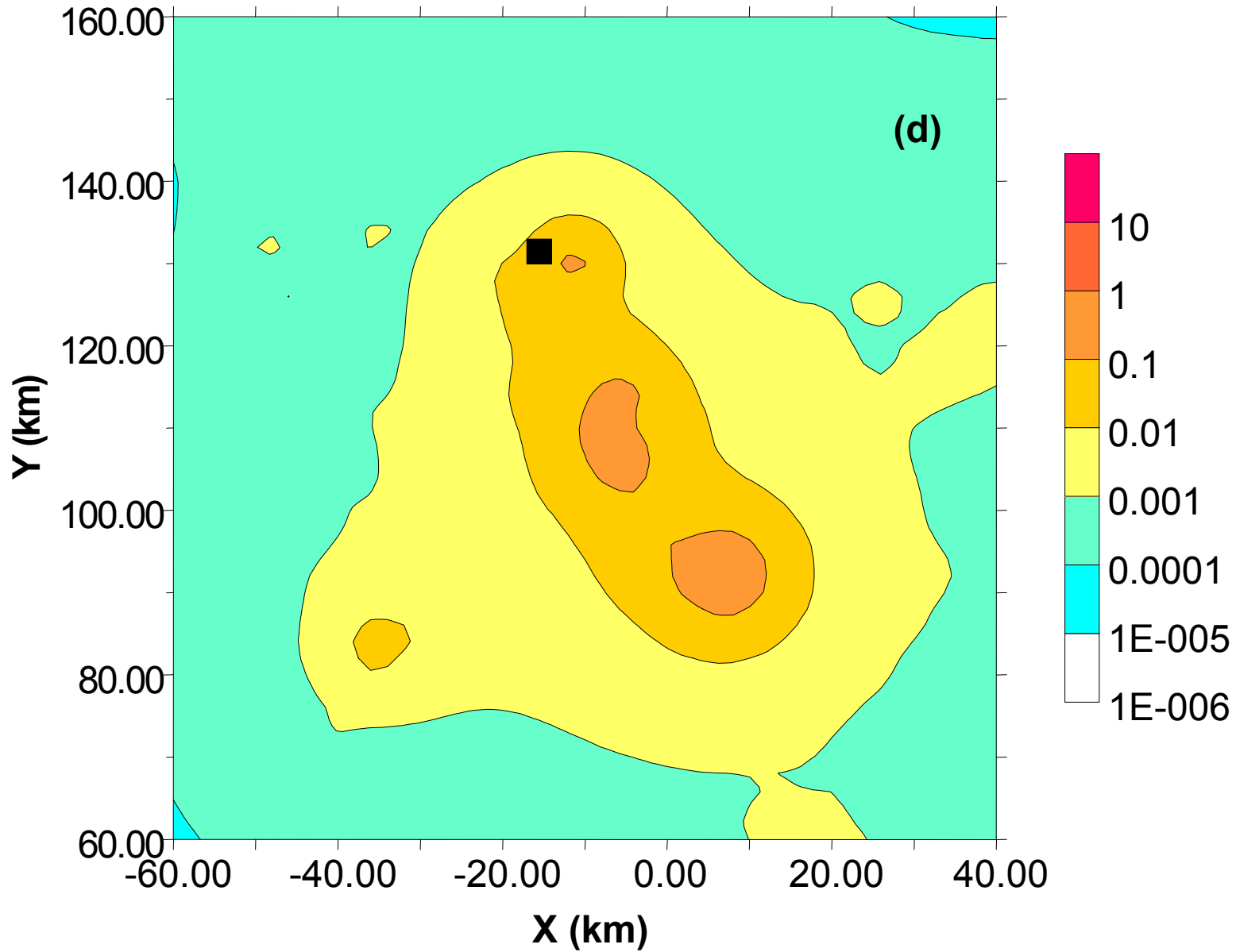
Occurrence rate (events per day in 100 km²) under the Epidemic Model (MI ≥ 2.0)



Umbria-Marche

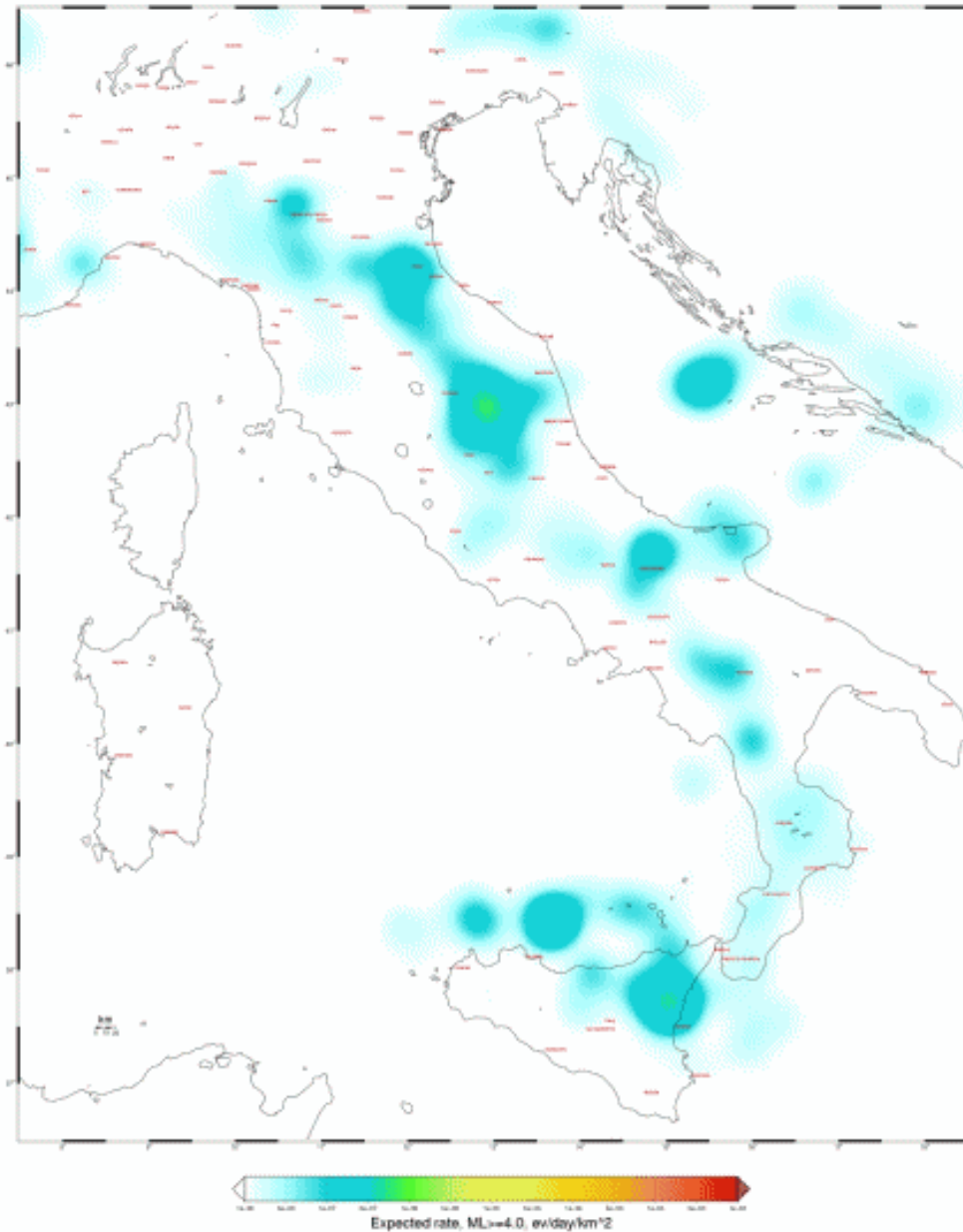
3 April 1998 (before the Nocera Umbra MI 5.0 event)

Occurrence rate (events per day in 100 km²) under the Epidemic Model (MI ≥ 2.0)



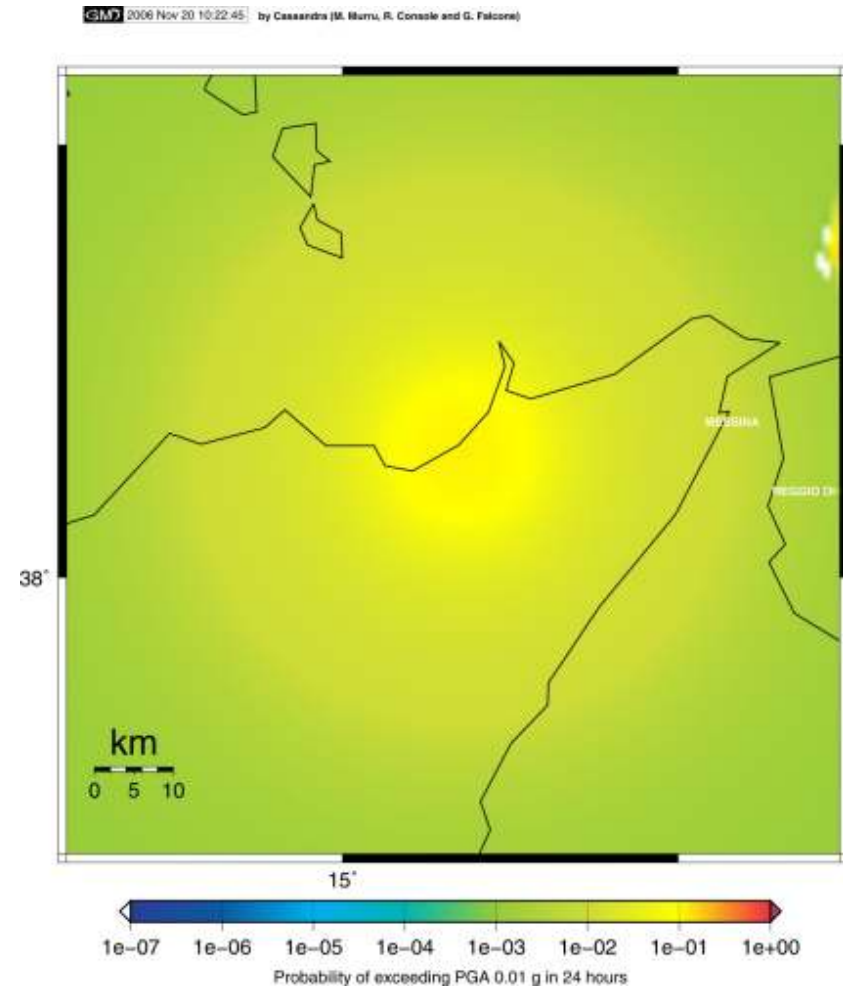
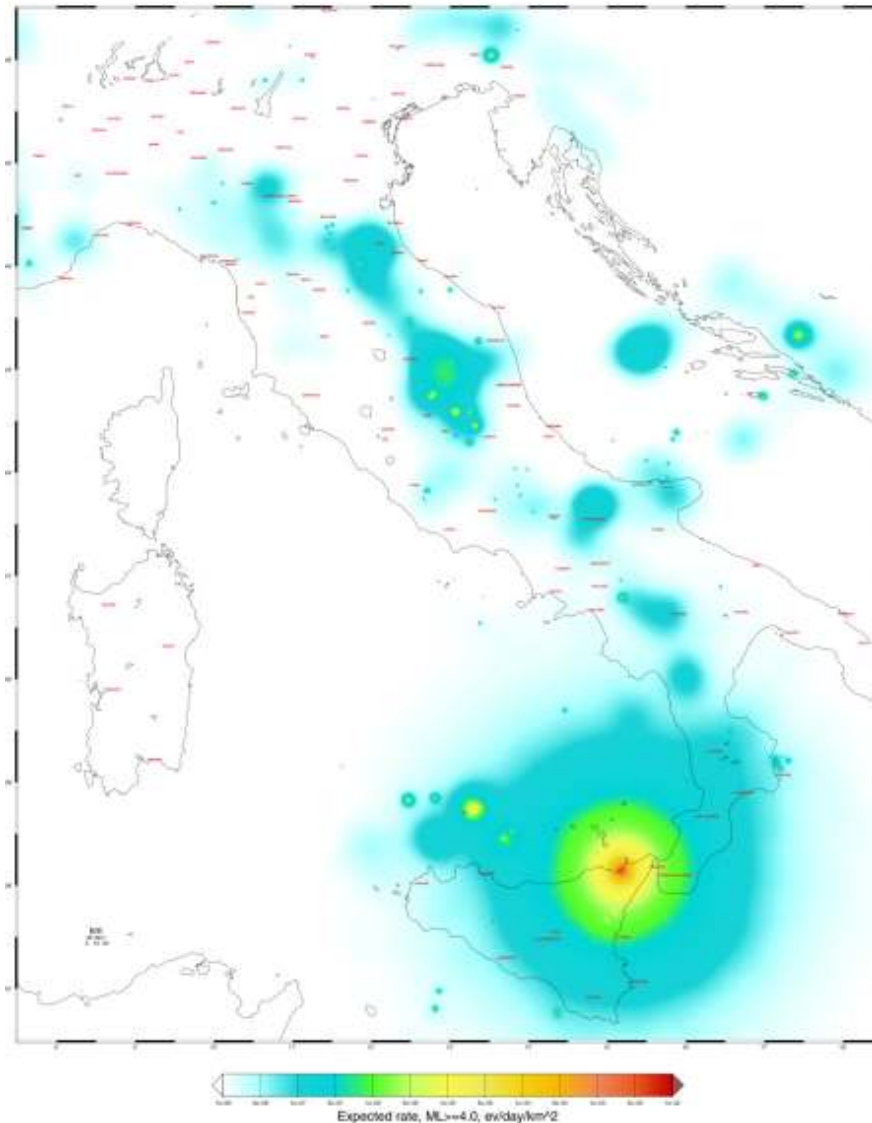
Real time application

The ETAS model has been implemented in a test of real-time forecast on the Italian seismicity, since January 2006, using the parameters obtained from the learning phase. The test area is 1000 km x 1200 km wide and it is divided in square cells of 1 km x 1 km.



The results are displayed as time-dependent maps updated every 5 minutes with the expected rate density of $M \geq 4.0$ earthquakes over the Italian region

The occurrence rate density is converted into probability of exceedence of a given PGA



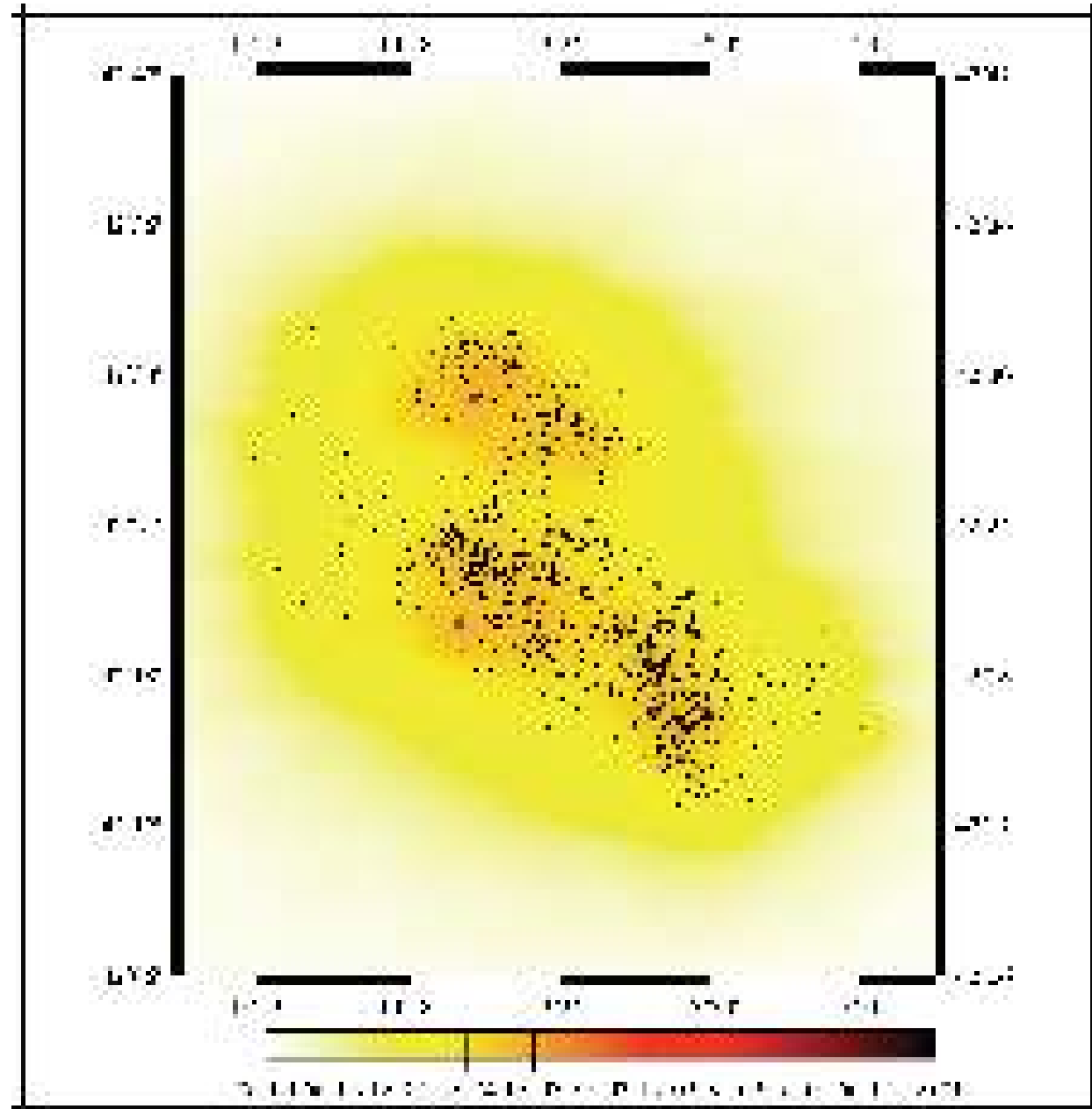
For testing purposes, the overall probability of occurrence of an $M4.5+$ earthquake in the same area of 100 km x 100 km is also estimated upon request by the user.

Forecast del 10
aprile 2009, ore
08:00, per l'Aquilano

Modello usato:
ETAS

Probabilità di M 5+
per 1 giorno su tutta
l'area: 13%

Probabilità di M 5+
per 1 settimana su
tutta l'area: 36%

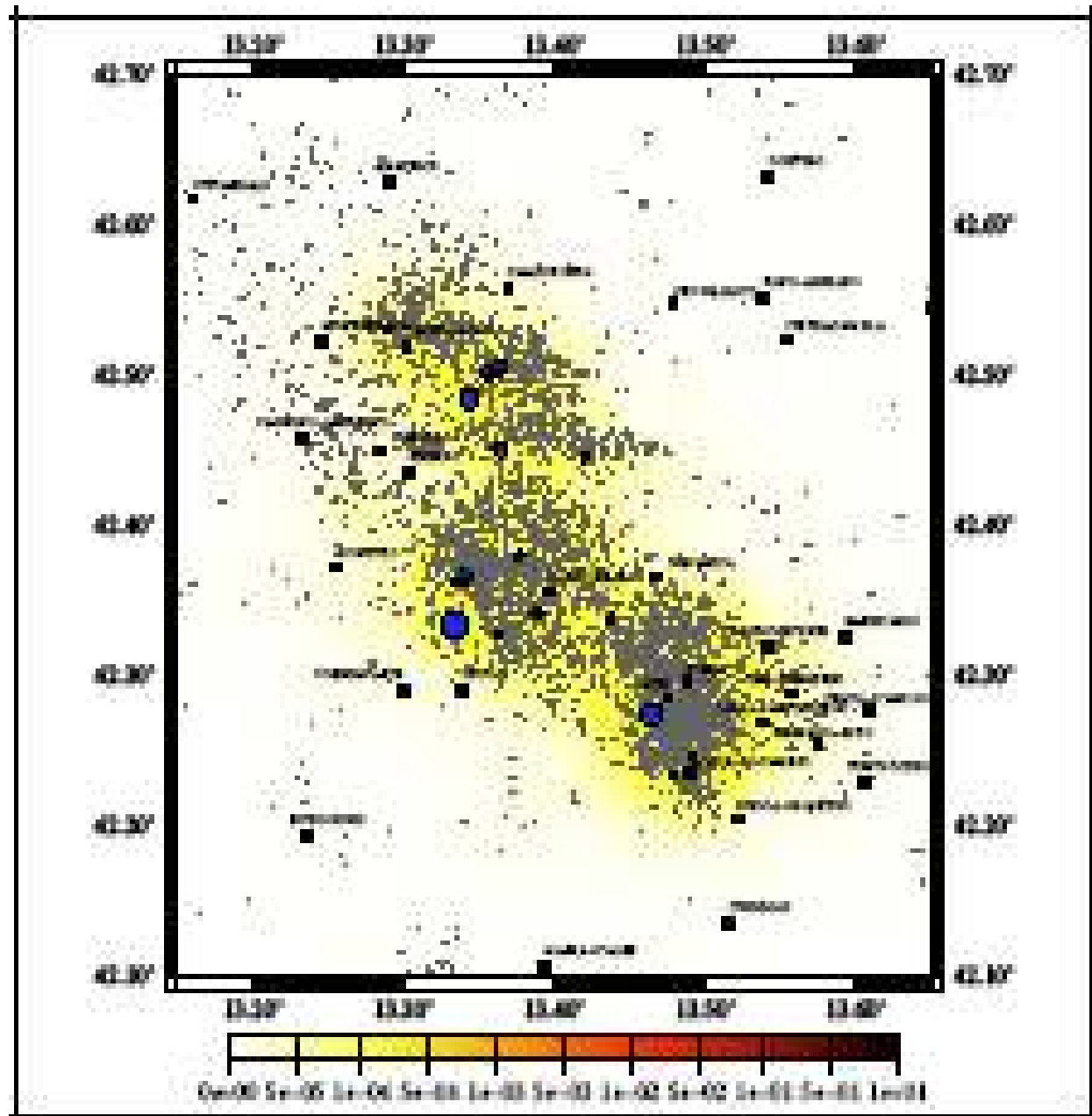


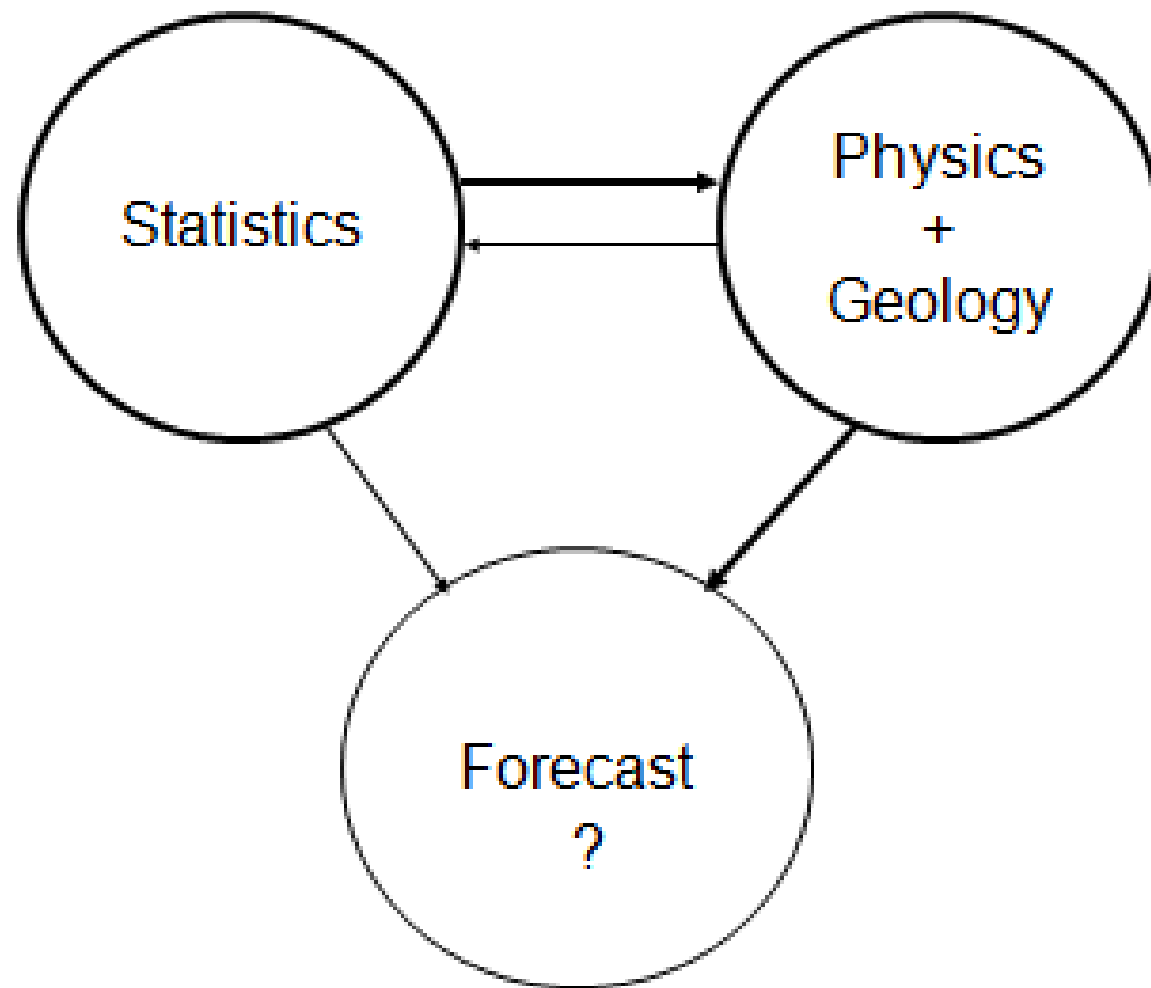
Forecast del 3
maggio 2009, ore
08:00, per l'Aquilano

Modello usato:
ETAS

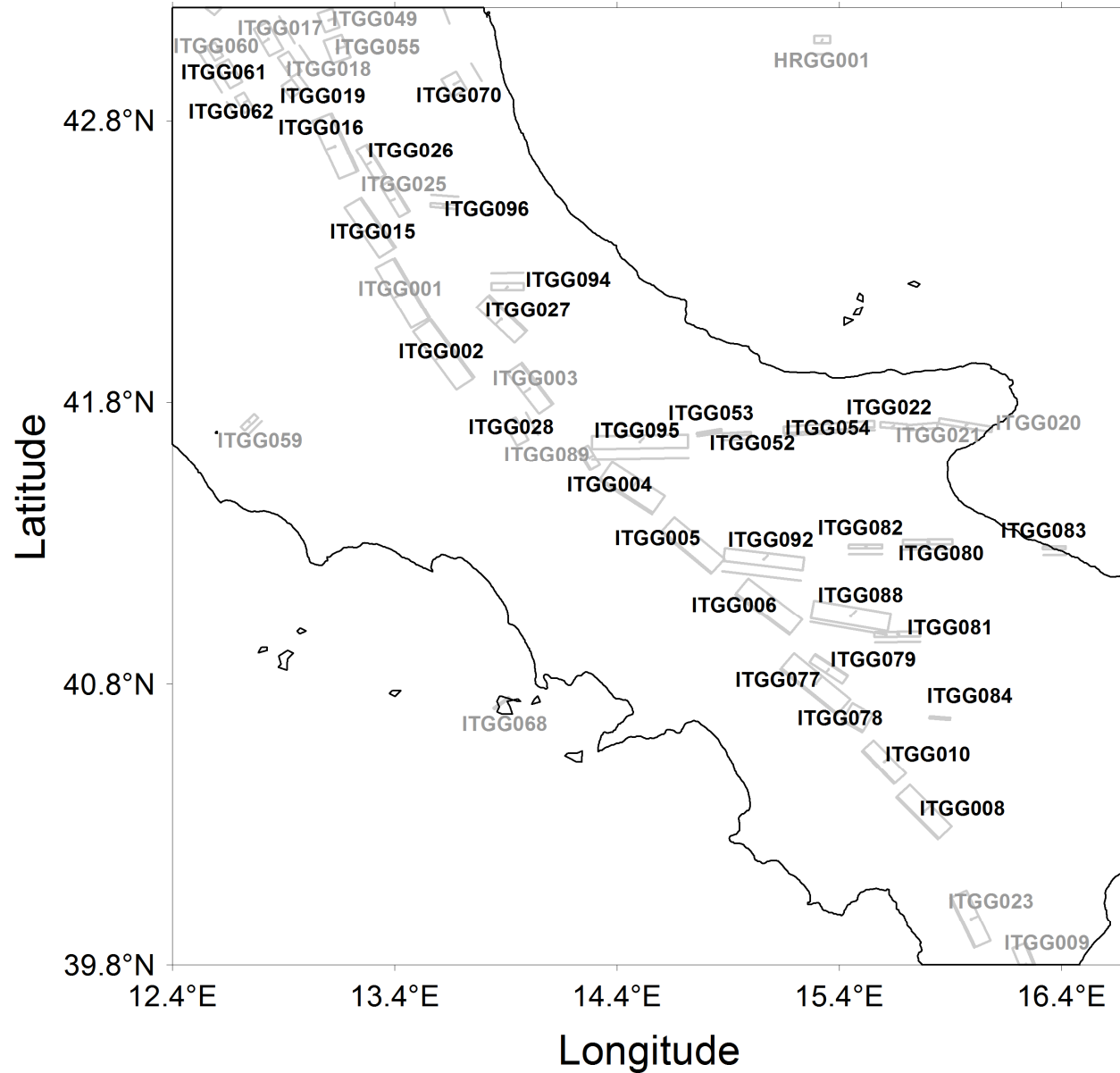
Probabilità di M 5+
per 1 giorno su tutta
l'area: 2%

Probabilità di M 5+
per 1 settimana su
tutta l'area: 7%

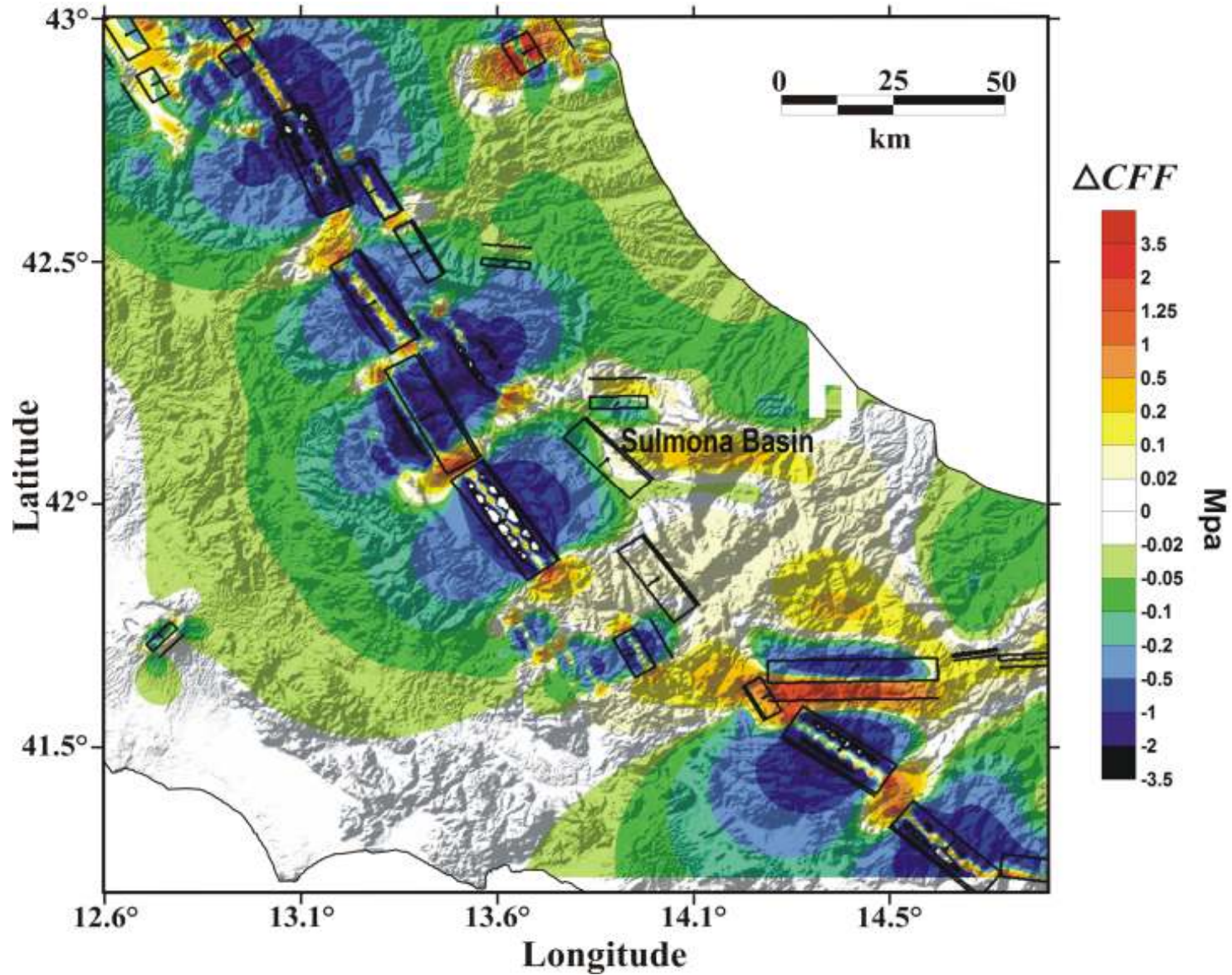




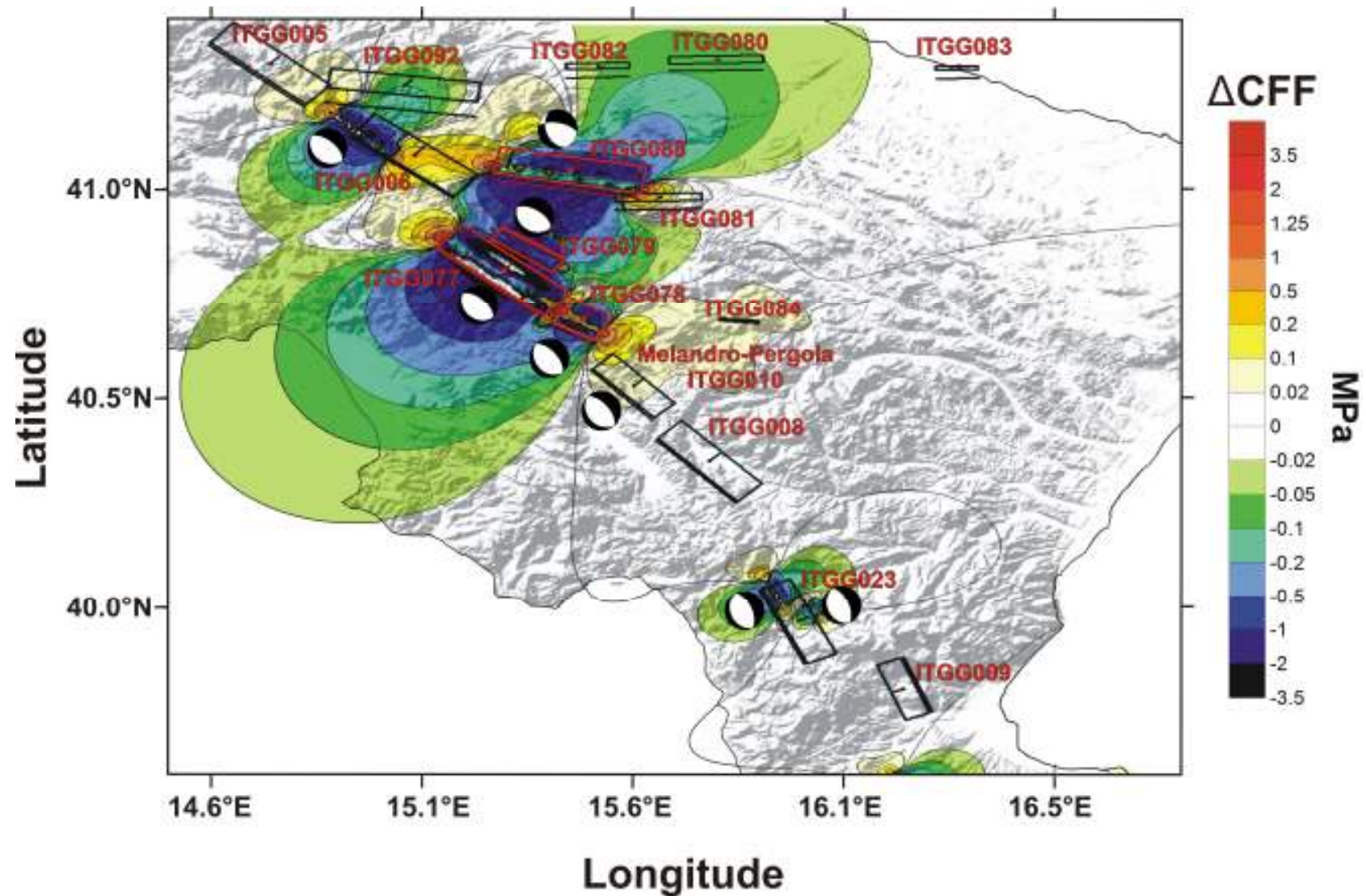
Seismogenic sources in Central Italy



ΔCFF on the Sulmona basin fault due to the earthquakes occurred after 1315



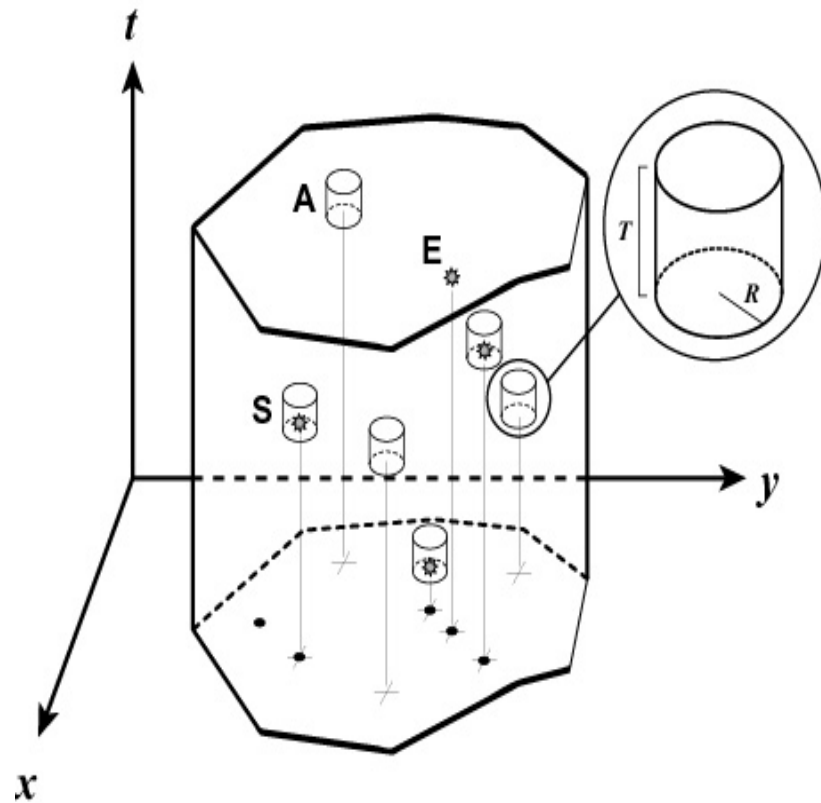
ΔCFF on the Melandro-Pergola fault due to the earthquakes occurred after 1857



	Sulmona basin	Melandro-Pergola
Date of latest event	1315.12.3	1857.12.16
Slip rate (mm)	0.24±0.06	0.11±0.04
Recurrence time (years)	2300±1370	4300±3700
Max. Poisson probability for the next 50 years	5.3%	8.8%
Elapsed time (years)	692	150
Max. renewal probability for the next 50 years	8.4 %	1.8%
Max. Δ CFF (Mpa)	0.15	0.19
Max. Δ t (years)	132	394
Max. modified probability for the next 50 years	11.8%	18.6%

Phases for the construction of a forecast model

- ***Formulation of the idea*** upon which the hypothesis (theoretical framework, model) should be based, generally on the basis of retrospective *phenomenological observations*.
- ***Set up of the hypothesis in quantitative form***, through the definition of the necessary *parameters* achievable from the retrospective analysis (*learning phase*).
- ***Test of the hypothesis*** on a data set *independent of* the data set used in the learning phase, possibly obtained after such a phase.
- ***Application*** of the methodology to real cases.



Scenario for a seismic forecast

A alarm

E event (earthquake)

S success

Every alarm is a cell in the total space-time-magnitude volume

Alarm based tests

	Occurrence	
Forecast	Yes	No
Yes	a	b
No	d	c

$H = a / (a+d)$ (fraction of events that occurred on an alarm cell);

$F = b / (b+c)$ (fraction of false alarms issued where an event has not occurred);

$R = a / (a+d) - b / (b+c)$;

$e = a+b+c+d$ (total number of cells)

$G = a / (a+d) \cdot e / (a+b) = H \cdot e / (a+b)$ = Success rate/ average rate of occurrence;

$\nu = d / (a + d)$ (ratio between the number of missing alarms and the number of all the cells containing events);

$\tau = (a + b) / (a + b + c + d)$;

Rischio sismico

$$R = S * V * Q$$

R = rischio = costo per unità di tempo
(M€ /anno)

S = **sismicità** = frequenza degli eventi di intensità superiore a un dato livello (anni^{-1})

V = **vulnerabilità** = frazione di valore perso per un evento di tale intensità

Q = **valore** totale dei beni esposti al rischio (M€)

Rapporto costi-benefici dal punto di vista economico

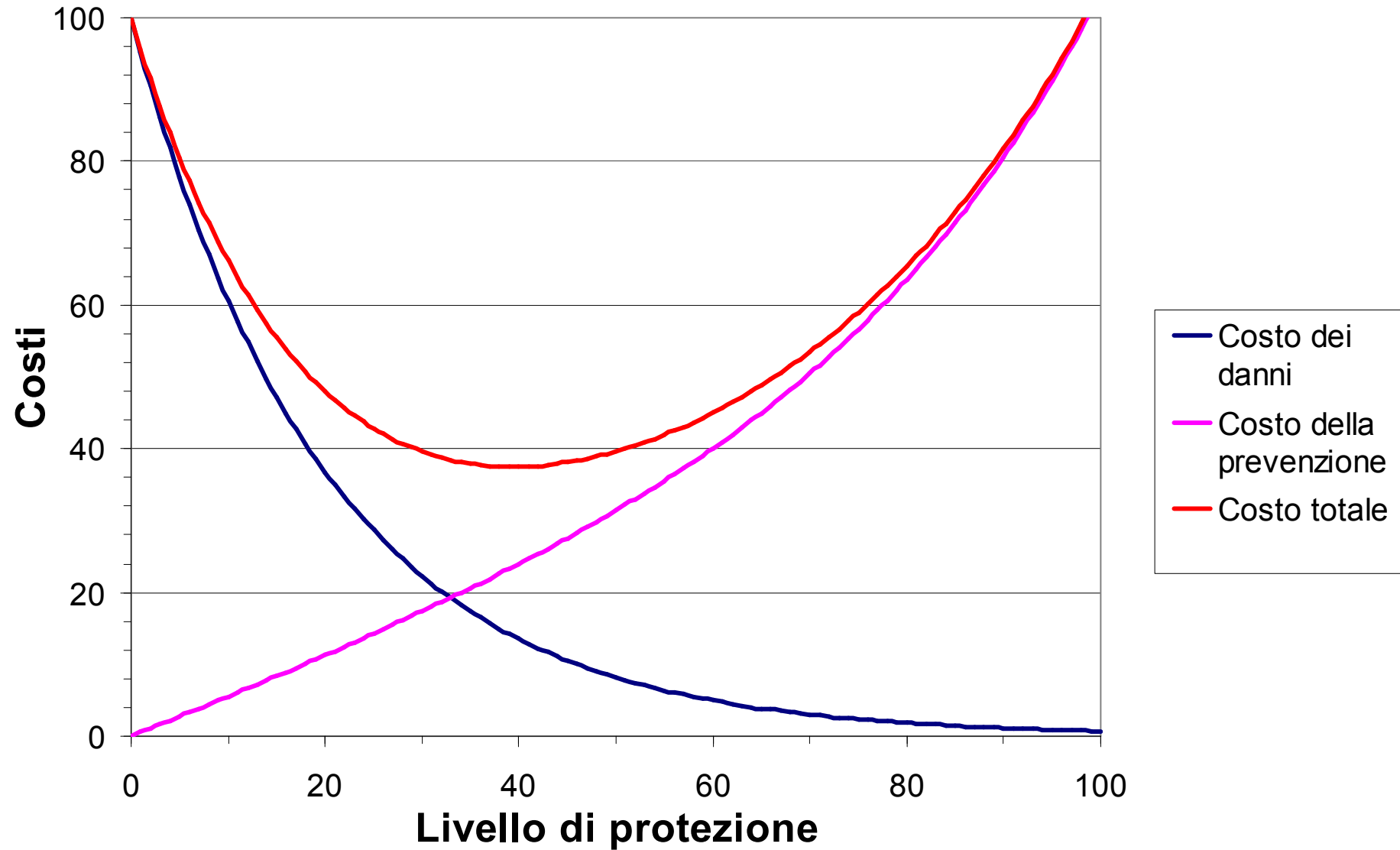
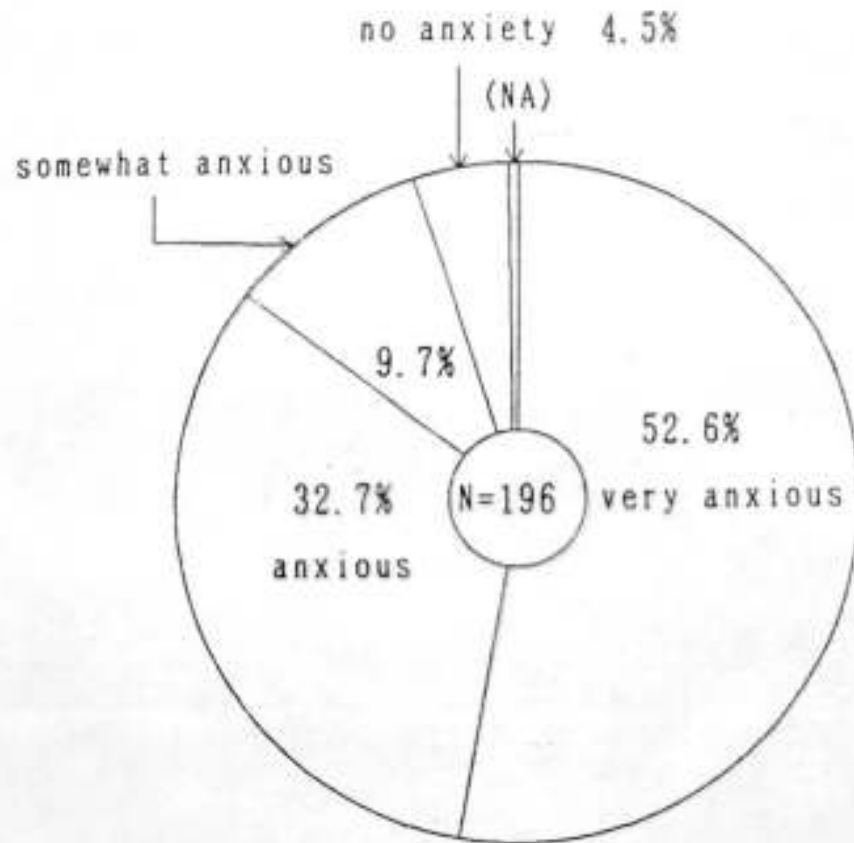
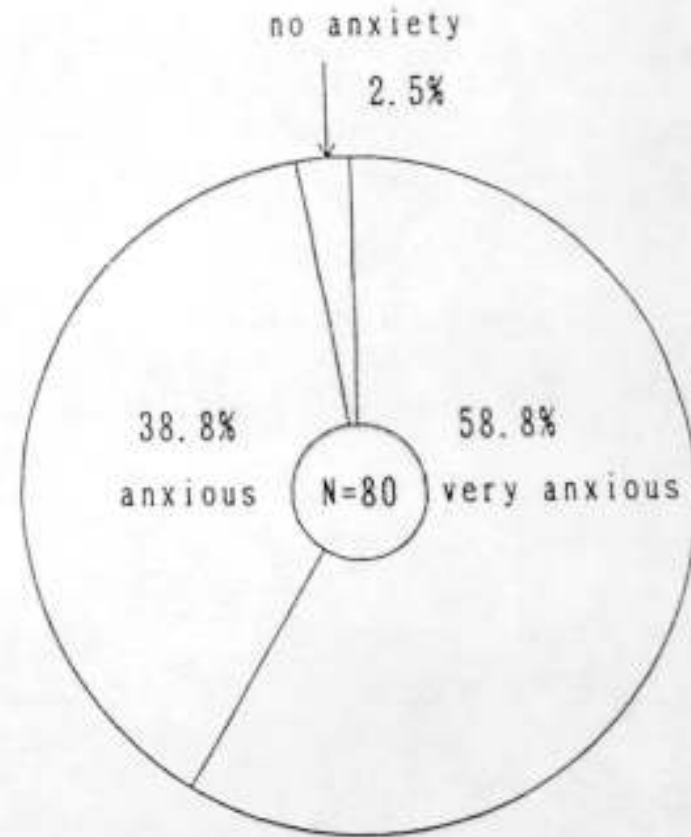


Figure 1. Anxiety Caused by Earthquake Warnings

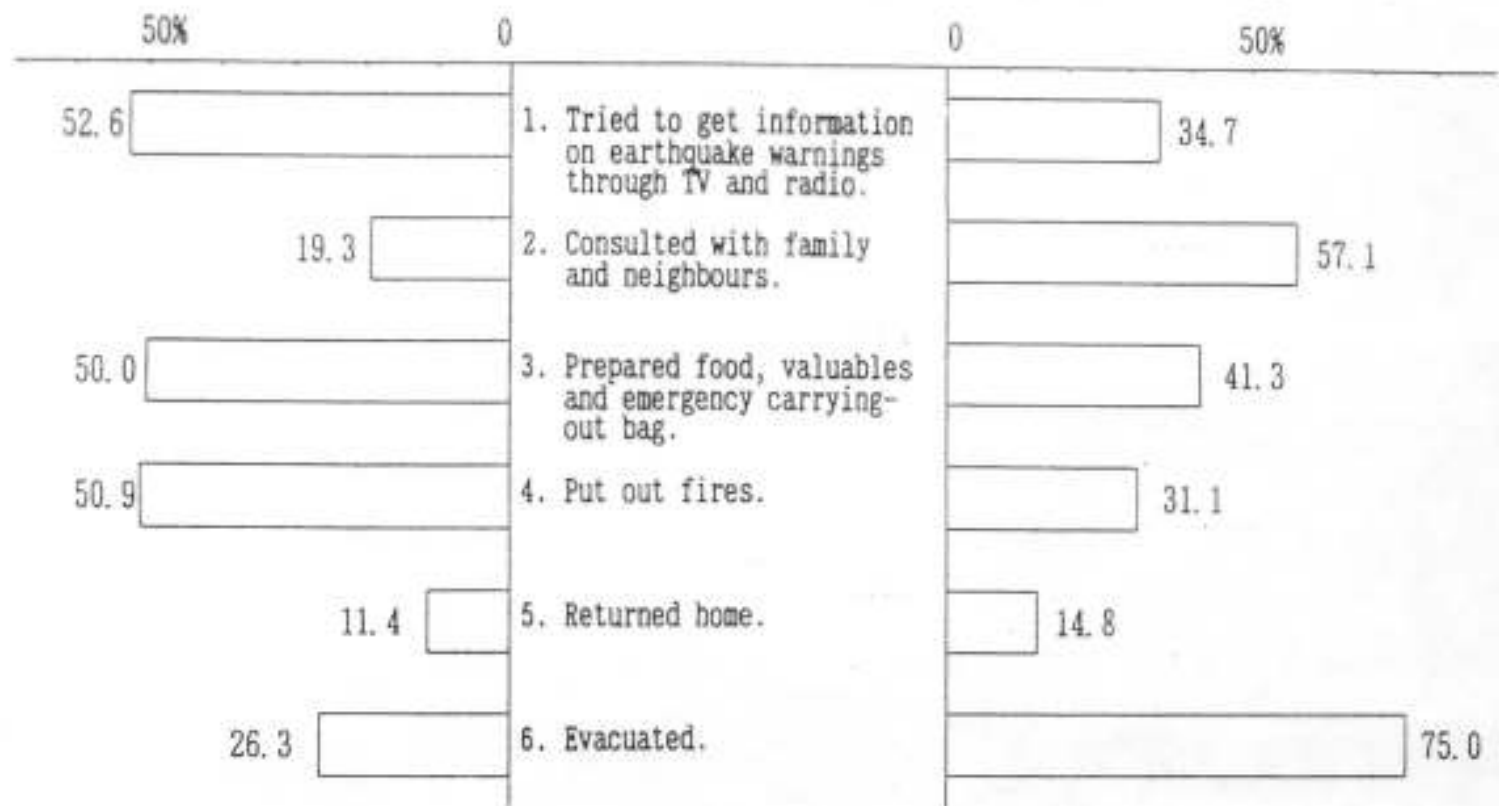


(a) Italian Case 1/



(b) Japanese Case: Resident who heard exercise broadcast of Tokai earthquake warnings. 2/

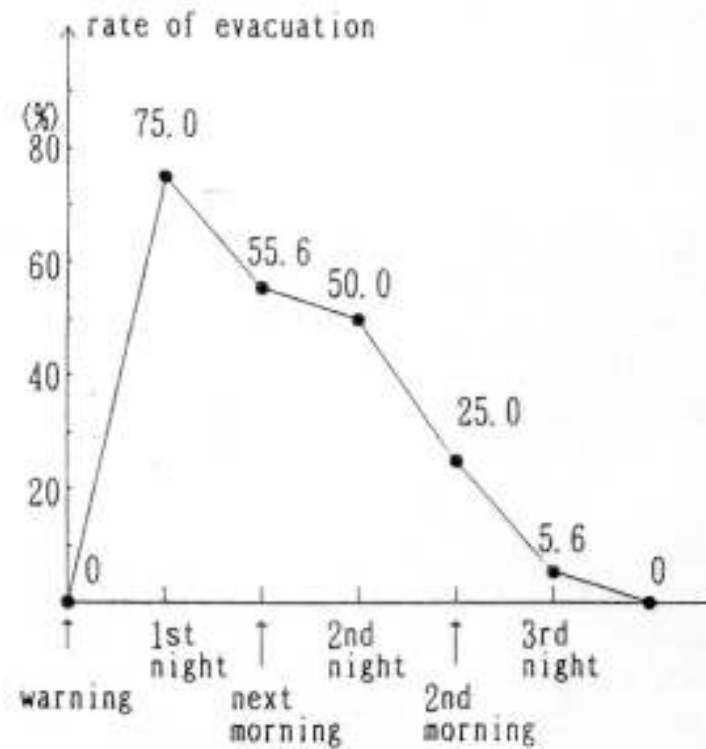
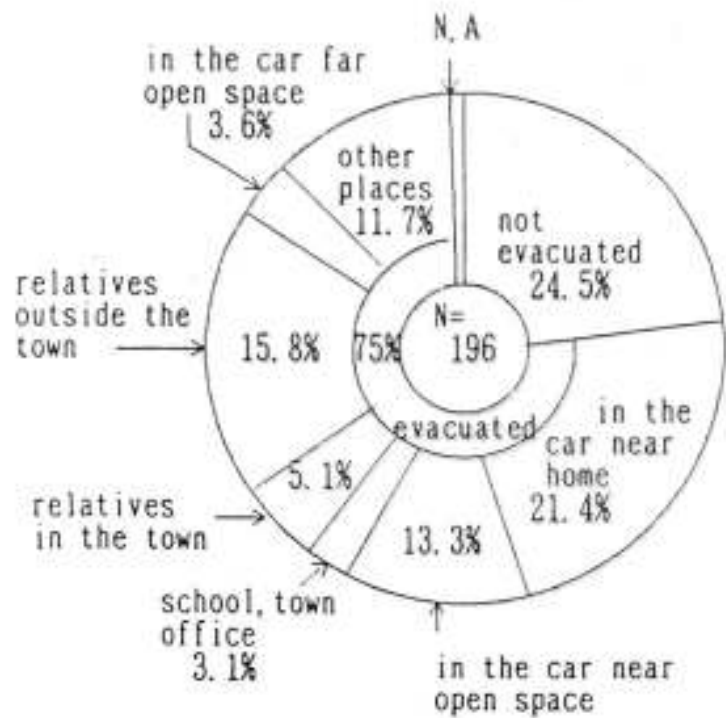
Figure 3. Actions After Getting Earthquake Warnings



Shizuoka Aftershock Case at Eastern Izu 3/

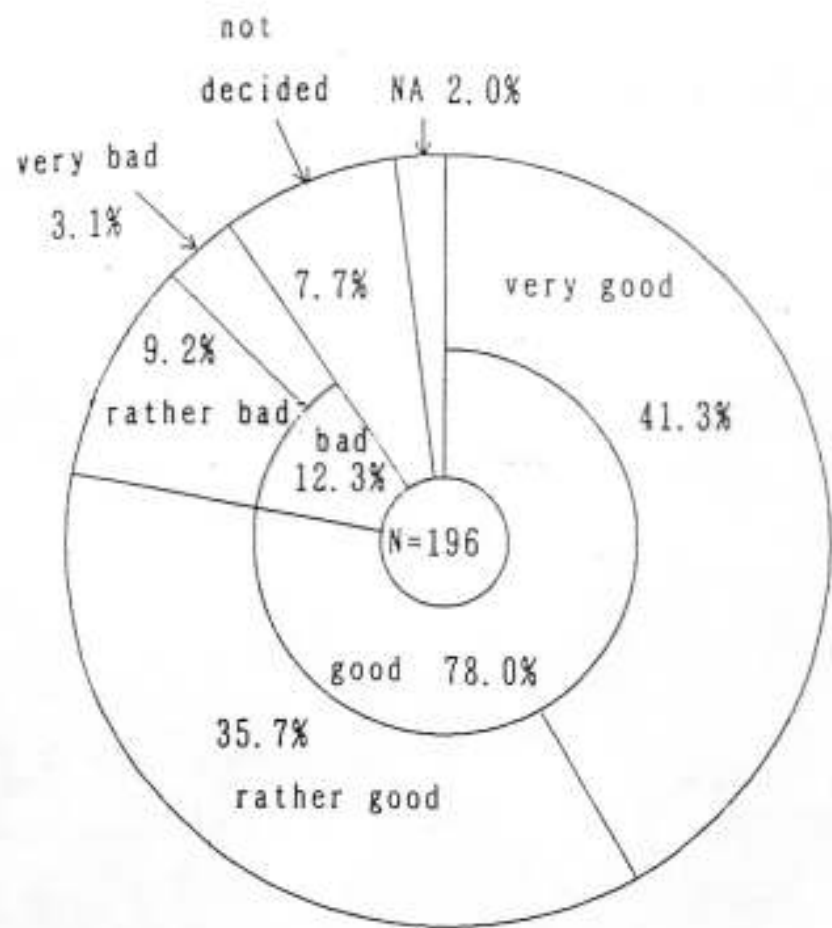
Italian Case 1/

Figure 4. Evacuation in the Case of Italian Earthquake Warnings 1/

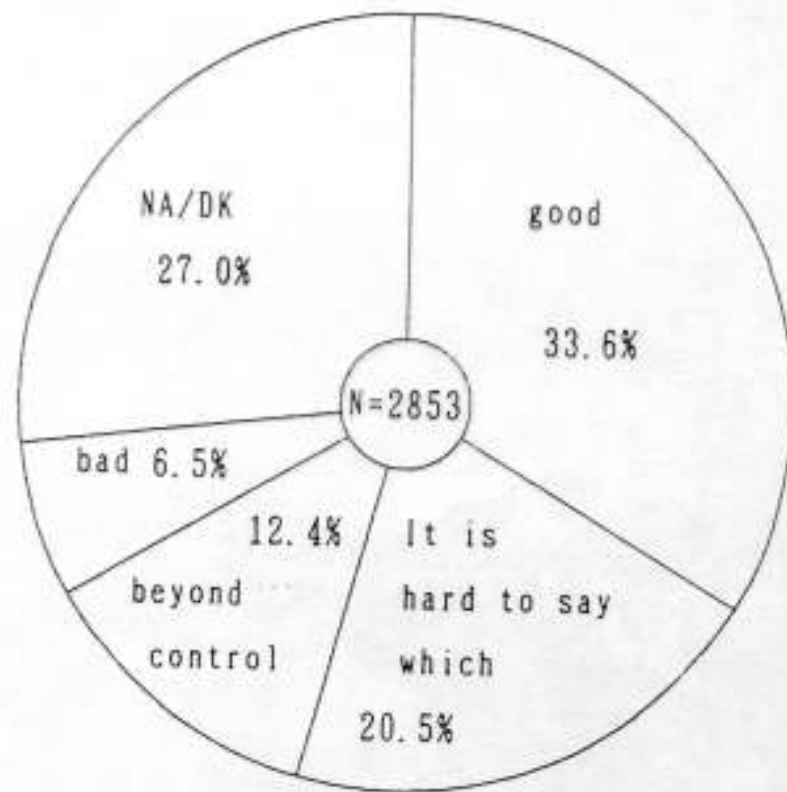


(a) Places of evacuation (first night) (b) Changing rate of evacuation

Figure 5. Evaluation of Earthquake Warnings



(a) Italian Case 1/



(b) Shizuoka Aftershock Case 3/