Short-term foreshocks: a potential tool for earthquake forecasting

A contribution to the EU-FP7 "PRE-EARTHQUAKES" project

G. A. Papadopoulos

B. Di Fiore & G. Minadakis

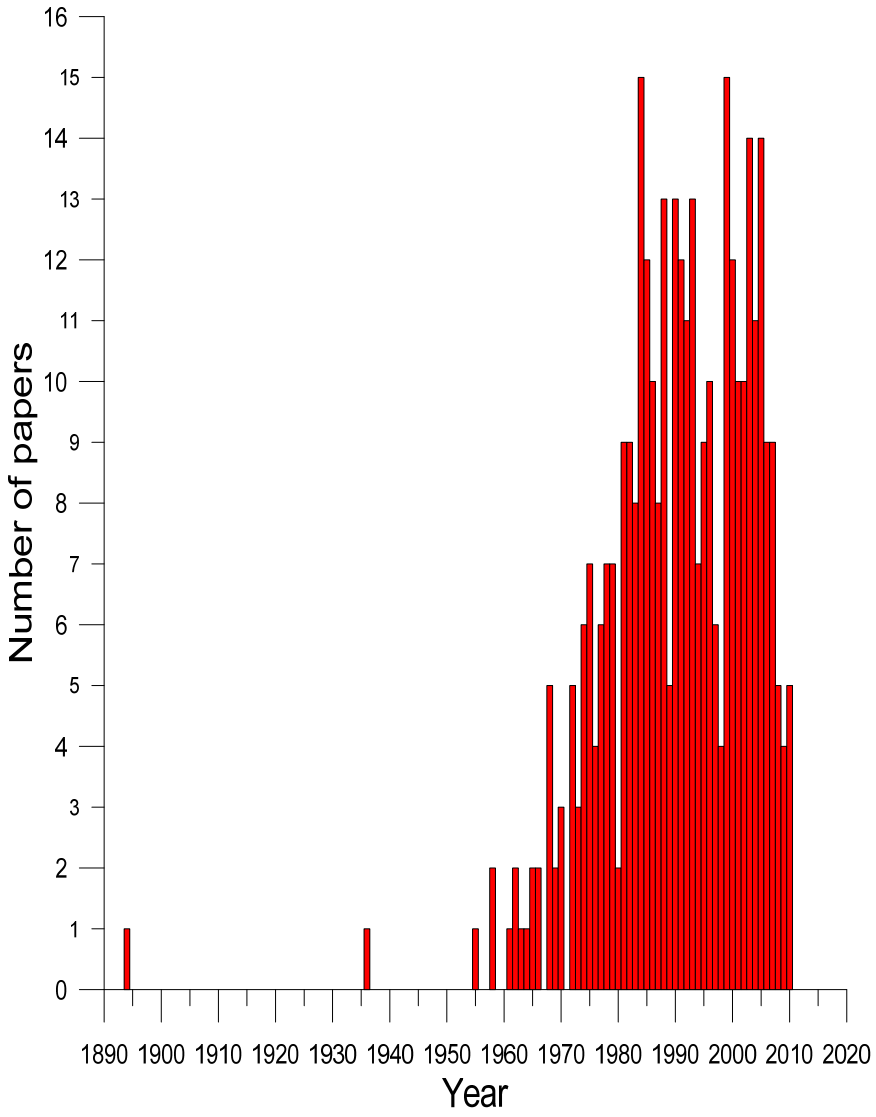
Institute of Geodynamics

National Observatory of Athens

papadop@noa.gr

A global data base

- More than 350 papers, books, reports etc.
- Covers the entire planet
- Includes reviews & case studies
- Rock and other material failure experiments and in situ observations



Properties of foreshocks

- **In time:** dT depends on definition! But ranges from minutes to a few months, **maximum of cases in the last 10 days.**

  Usually $n \sim t^{-1}$

- **In space:** dX depends on definition! But ranges according to M_o

  Usually move towards mainshock epicenter

- **In size:** b-value

  Usually drops with respect to background seismicity

Real-time implementation

- Empirical rules (Japan, USA)
- Bayesian approach: promising

Our Approach

- **FOR**eshock-**M**ainshock-**A**ftershock
- FORMA (project SAFER EU-FP6)
- Space-time-size changes of seismicity
- Time: activity rate, r (z-test, t-test)
- Size: b-value in G-R (Utsu-test)
- Repeat by changing Space
- Alerts for significant changes in both r & b

Past experience

The time-space-size changes became clear if data from more sequences are combined together

New experience: L'Aquila, 2009

Nat. Hazards Earth Syst. Sci., 10, 19–24, 2010
www.nat-hazards-earth-syst-sci.net/10/19/2010/

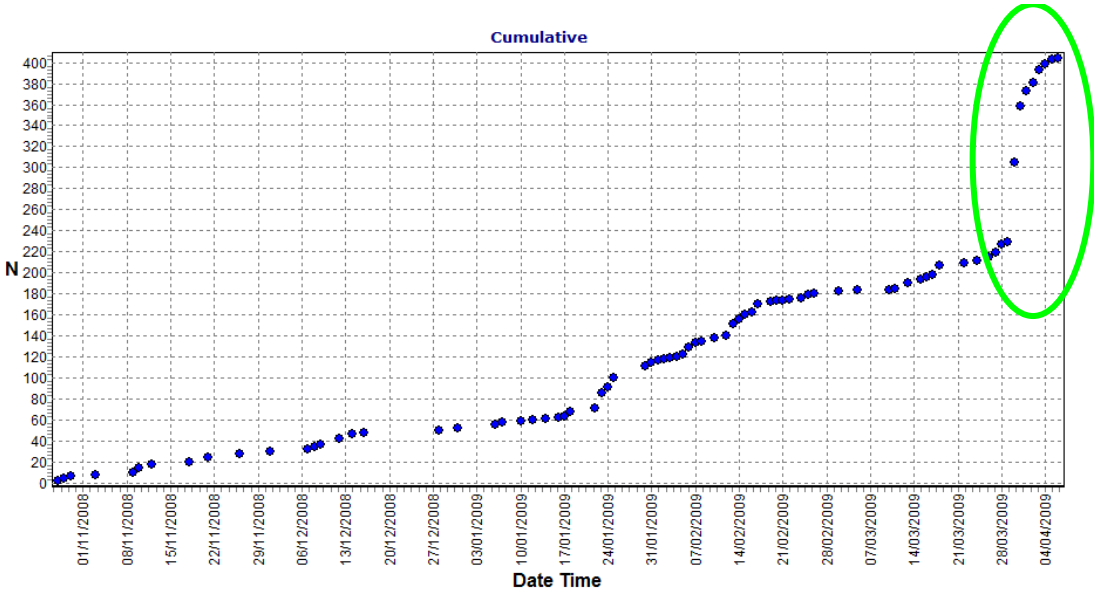
Natural Hazards and Earth System Sciences

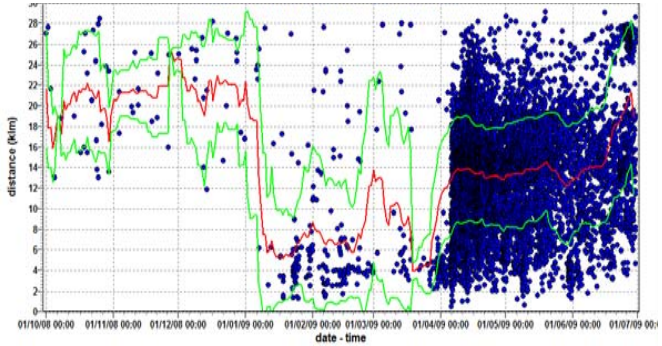
Strong foreshock signal preceding the L'Aquila (Italy) earthquake (M_w 6.3) of 6 April 2009

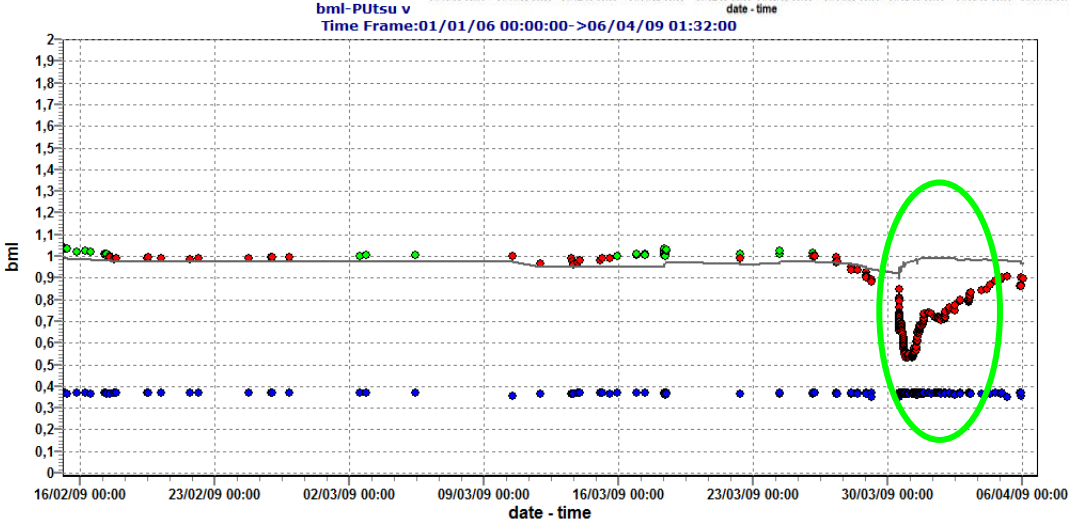
G. A. Papadopoulos, M. Charalampakis, A. Fokaefs, and G. Minadakis
Institute of Geodynamics, National Observatory of Athens, Athens, Greece

Received: 31 October 2009 – Accepted: 9 December 2009 – Published: 11 January 2010

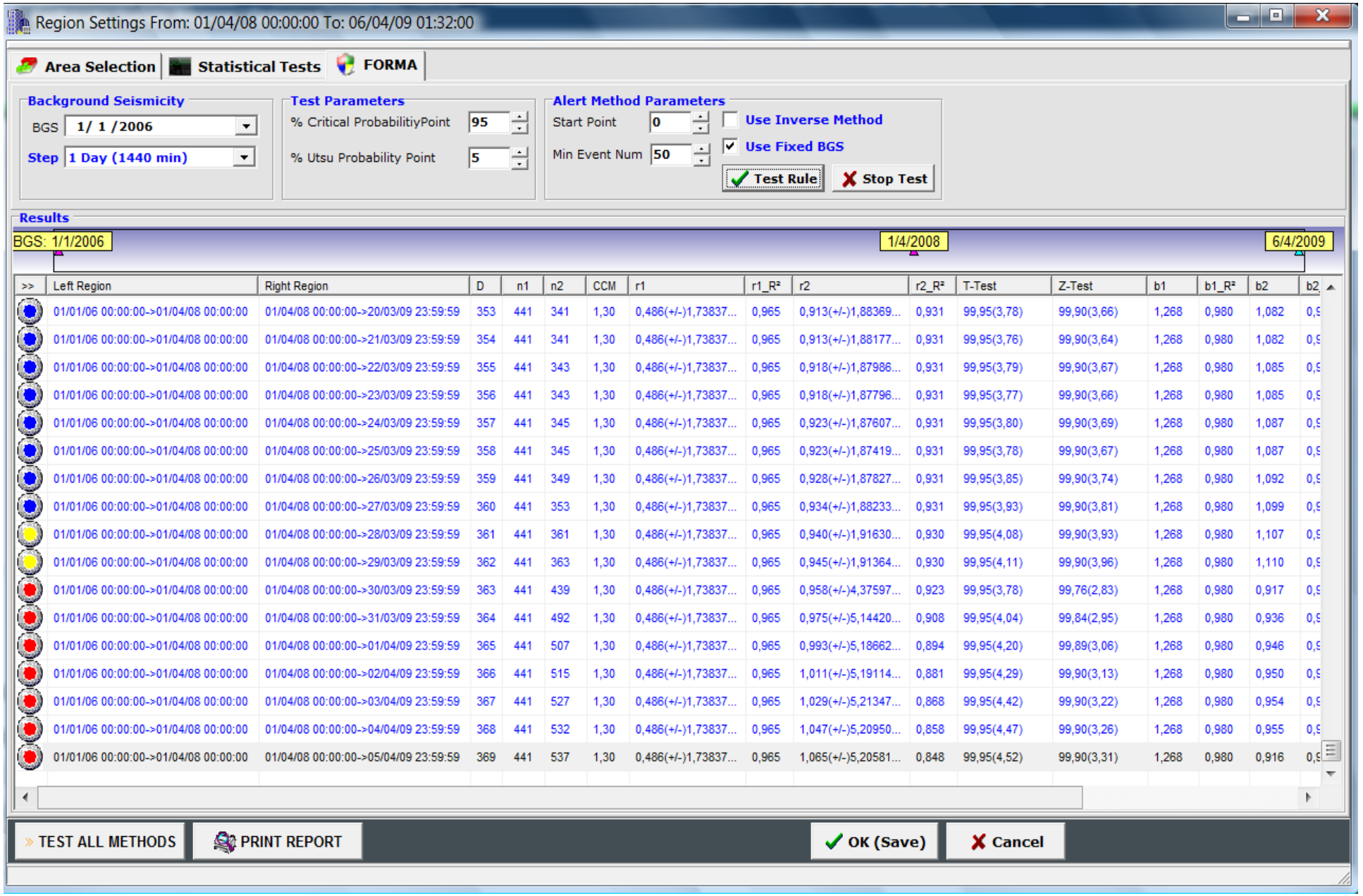
This is the first time that in a single foreshock sequence drastic change is observed in the three domains





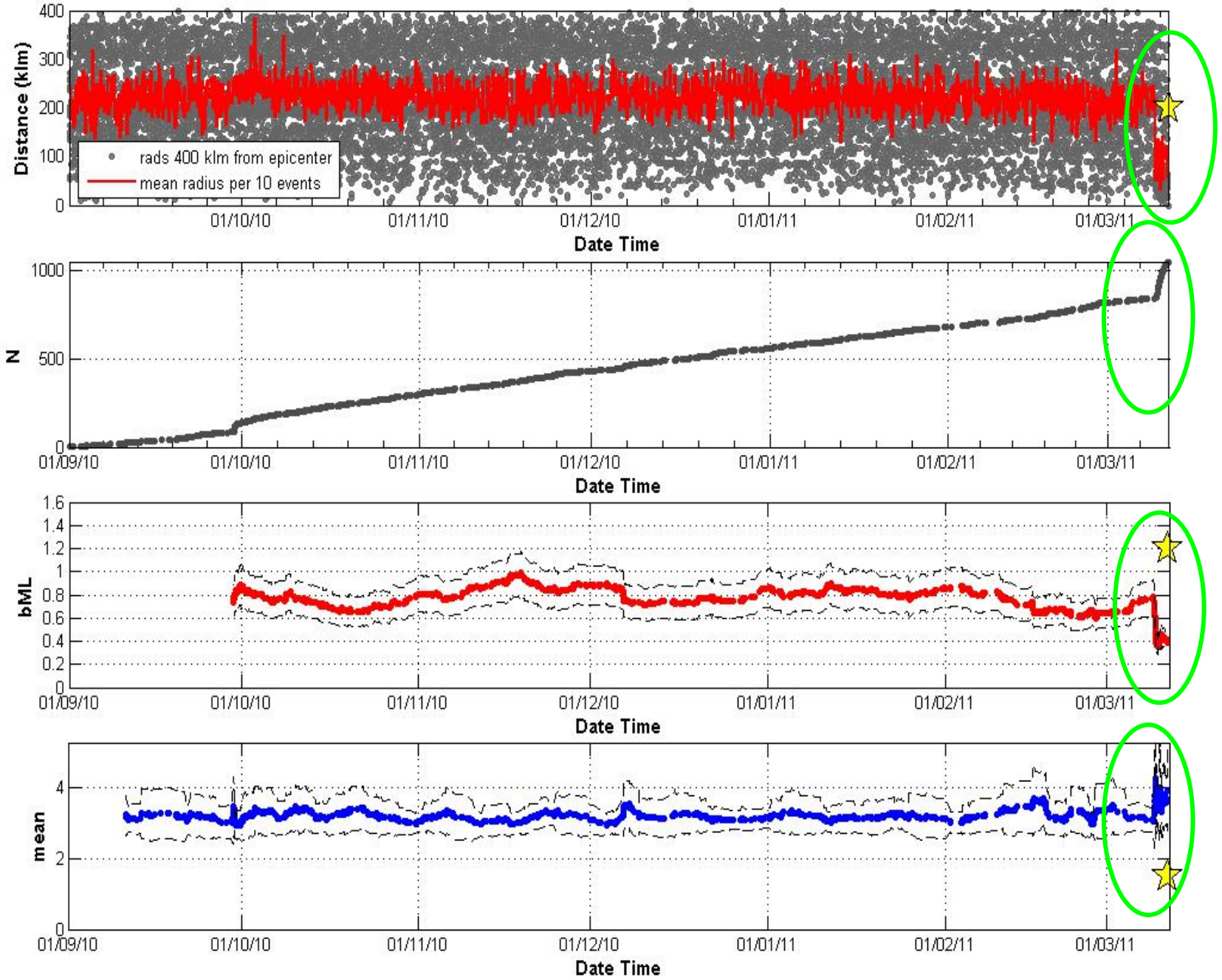


L’Aquila: foreshock alert



>>	Left Region	Right Region	D	n1	n2	CCM	r1	r1_R²	r2	r2_R²	T-Test	Z-Test	b1	b1_R²	b2	b2
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->20/03/09 23:59:59	353	441	341	1,30	0,486(+/-)1,73837...	0,965	0,913(+/-)1,88369...	0,931	99,95(3,78)	99,90(3,66)	1,268	0,980	1,082	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->21/03/09 23:59:59	354	441	341	1,30	0,486(+/-)1,73837...	0,965	0,913(+/-)1,88177...	0,931	99,95(3,76)	99,90(3,64)	1,268	0,980	1,082	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->22/03/09 23:59:59	355	441	343	1,30	0,486(+/-)1,73837...	0,965	0,918(+/-)1,87986...	0,931	99,95(3,79)	99,90(3,67)	1,268	0,980	1,085	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->23/03/09 23:59:59	356	441	343	1,30	0,486(+/-)1,73837...	0,965	0,918(+/-)1,87796...	0,931	99,95(3,77)	99,90(3,66)	1,268	0,980	1,085	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->24/03/09 23:59:59	357	441	345	1,30	0,486(+/-)1,73837...	0,965	0,923(+/-)1,87607...	0,931	99,95(3,80)	99,90(3,69)	1,268	0,980	1,087	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->25/03/09 23:59:59	358	441	345	1,30	0,486(+/-)1,73837...	0,965	0,923(+/-)1,87419...	0,931	99,95(3,78)	99,90(3,67)	1,268	0,980	1,087	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->26/03/09 23:59:59	359	441	349	1,30	0,486(+/-)1,73837...	0,965	0,928(+/-)1,87827...	0,931	99,95(3,85)	99,90(3,74)	1,268	0,980	1,092	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->27/03/09 23:59:59	360	441	353	1,30	0,486(+/-)1,73837...	0,965	0,934(+/-)1,88233...	0,931	99,95(3,93)	99,90(3,81)	1,268	0,980	1,099	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->28/03/09 23:59:59	361	441	361	1,30	0,486(+/-)1,73837...	0,965	0,940(+/-)1,91630...	0,930	99,95(4,08)	99,90(3,93)	1,268	0,980	1,107	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->29/03/09 23:59:59	362	441	363	1,30	0,486(+/-)1,73837...	0,965	0,945(+/-)1,91364...	0,930	99,95(4,11)	99,90(3,96)	1,268	0,980	1,110	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->30/03/09 23:59:59	363	441	439	1,30	0,486(+/-)1,73837...	0,965	0,958(+/-)4,37597...	0,923	99,95(3,78)	99,76(2,83)	1,268	0,980	0,917	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->31/03/09 23:59:59	364	441	492	1,30	0,486(+/-)1,73837...	0,965	0,975(+/-)5,14420...	0,908	99,95(4,04)	99,84(2,95)	1,268	0,980	0,936	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->01/04/09 23:59:59	365	441	507	1,30	0,486(+/-)1,73837...	0,965	0,993(+/-)5,18662...	0,894	99,95(4,20)	99,89(3,06)	1,268	0,980	0,946	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->02/04/09 23:59:59	366	441	515	1,30	0,486(+/-)1,73837...	0,965	1,011(+/-)5,19114...	0,881	99,95(4,29)	99,90(3,13)	1,268	0,980	0,950	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->03/04/09 23:59:59	367	441	527	1,30	0,486(+/-)1,73837...	0,965	1,029(+/-)5,21347...	0,868	99,95(4,42)	99,90(3,22)	1,268	0,980	0,954	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->04/04/09 23:59:59	368	441	532	1,30	0,486(+/-)1,73837...	0,965	1,047(+/-)5,20950...	0,858	99,95(4,47)	99,90(3,26)	1,268	0,980	0,955	0,9
	01/01/06 00:00:00->01/04/08 00:00:00	01/04/08 00:00:00->05/04/09 23:59:59	369	441	537	1,30	0,486(+/-)1,73837...	0,965	1,065(+/-)5,20581...	0,848	99,95(4,52)	99,90(3,31)	1,268	0,980	0,916	0,9

Tohoku 2011


Distance (klm)
rads 400 klm from epicenter
mean radius per 10 events
Date Time
N
Date Time
bML
Date Time
mean
Date Time
01/09/10
01/10/10
01/11/10
01/12/10
01/01/11
01/02/11
01/03/11

Prospective test

- Run FORMA on a daily basis
- Detect changes in activity r
- Check changes in b
- Determine state of seismicity (background, foreshock, swarm, aftershock)
- If foreshock, then calculate alert level (5 levels)