The European earthquake forecast testing center and suggestions for the start of a Japanese testing center

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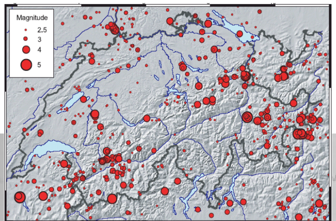
ETH Zurich



Summary

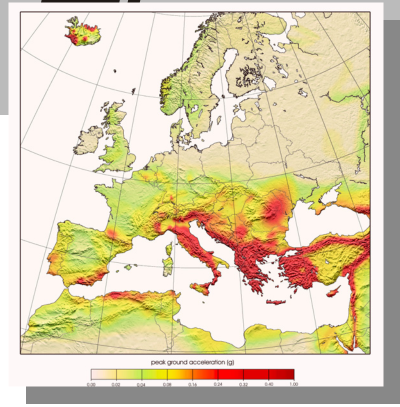
- European Earthquake Forecast Testing Center
  - Motivation
    - Towards introducing time-dependent hazards
    - Community-supported earthquake forecast testing
  - Recent progress
- Suggestions for the start of a Japanese testing center
  - Motivation
    - Why do we need testing center for Japan?
  - Models that can be offered from ETH side

Defining forecasting

Forecasting

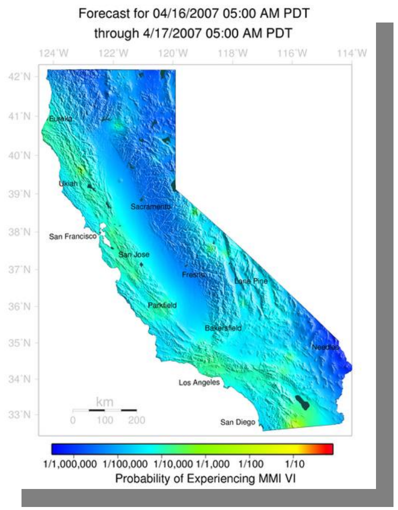
Level 1: Time-independent hazard

Earthquakes are random in time



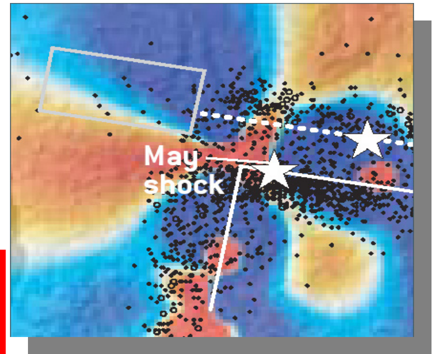
Level 2: Time-dependent hazard

Hazard changes with time; Includes clustering information



Level 3: Earthquake forecasting

Includes a physical basis and connection beyond clustering



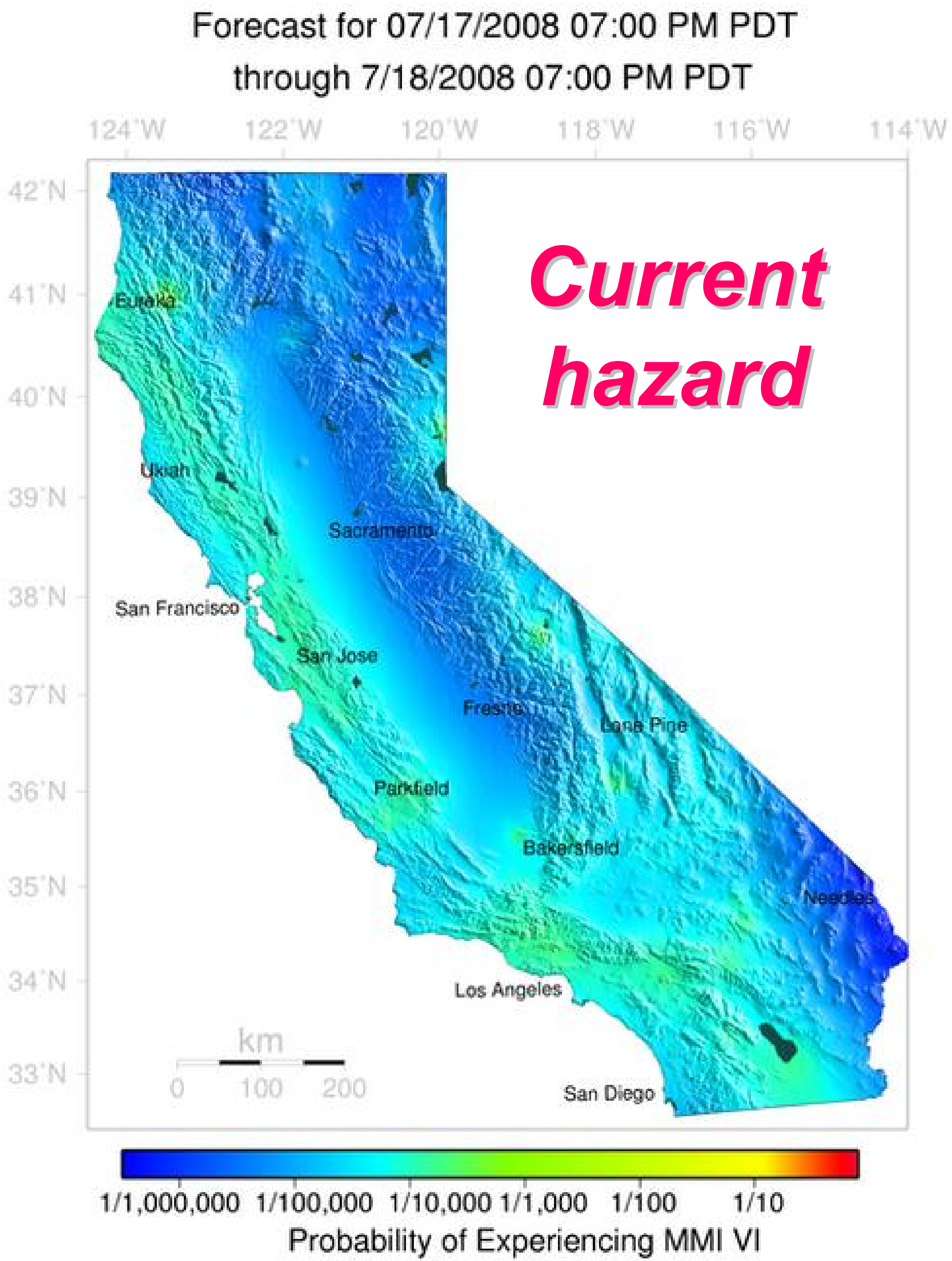
Prediction

Level 4: Deterministic prediction

Reliably know in advance earthquake time, magnitude and location

Main (1999)

STEP: Short Term Earthquake Probability



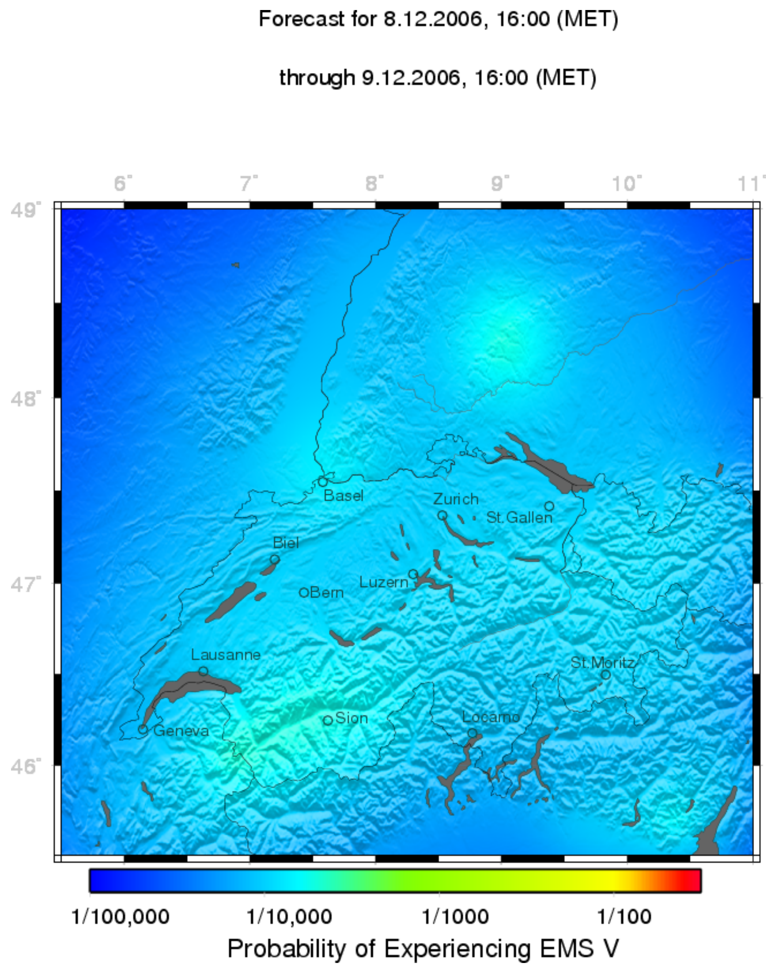
The probability of strong shaking
- **Within the next 24-hours.**
- **Modified Mercalli Intensity (MMI) VI**

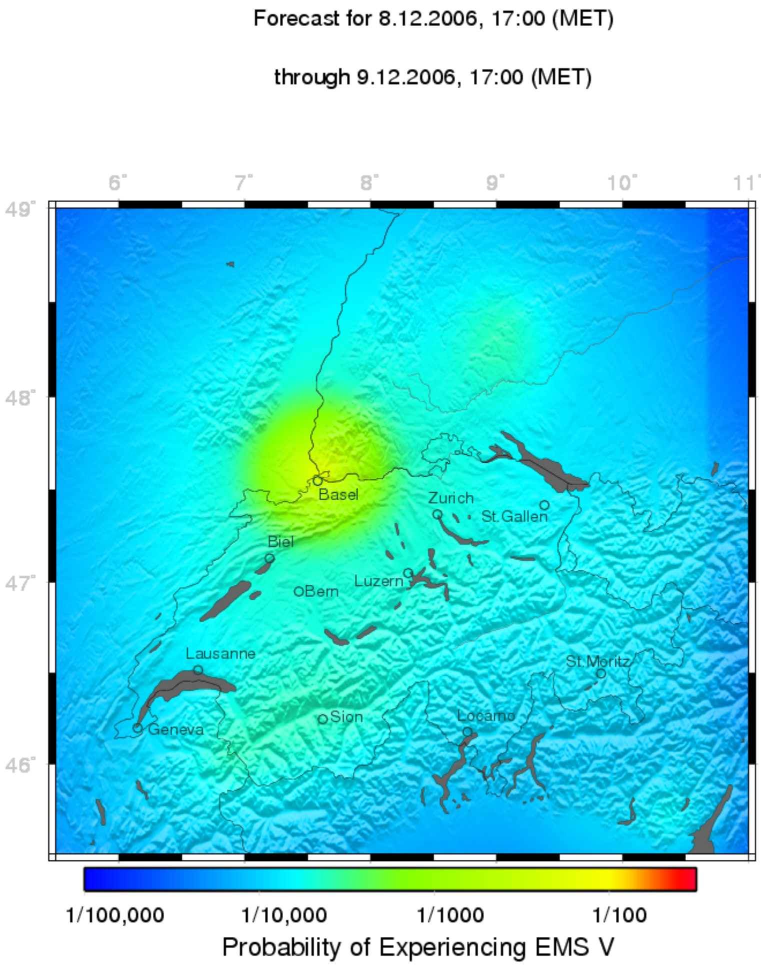
If you want to know the most recent hazard

(Gerstenberger et. al., 2005, http://pasadena.wr.usgs.gov/step)

Short Term Earthquake Probability

Switzerland (Woessner et al.)





- The probability of strong shaking within the next 24-hours.

The need for testing centers

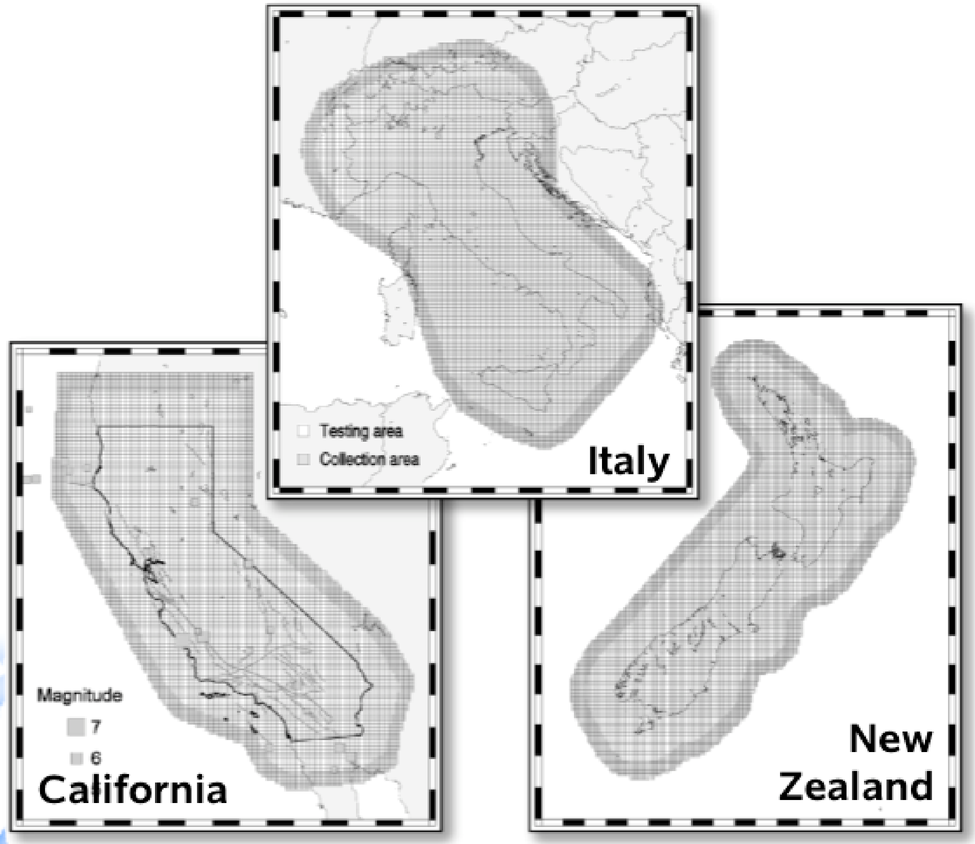
If we use time-dependent hazard assessment, giving the results in a webpage

1. *Dealing with an issue of great societal relevance*
2. *Rigorous testing to validate test models*
3. *Peer review is not enough for this test*
4. *Establishing community-supported testing centers*

CSEP Development

(January 1, 2008)

CSEP V1.0 is being installed at the ETHZ and GNS testing centers and testing is beginning in New Zealand and Italy



Testing Regions

Testing Centers

Japan ?

China ?

Global ?

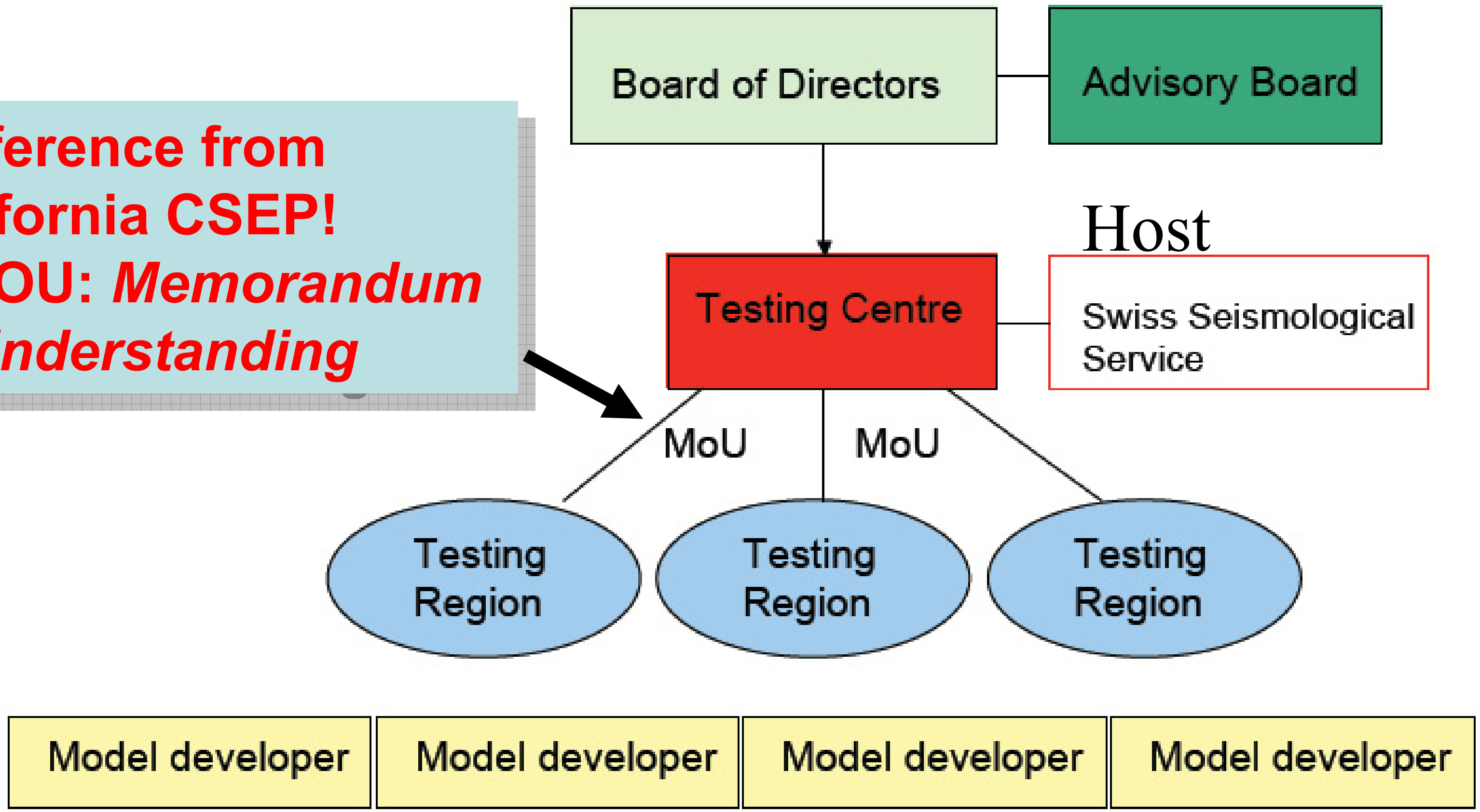
From Jordan et al. 2008

Goals of the European Earthquake Forecast Testing Center (EEFTEC)

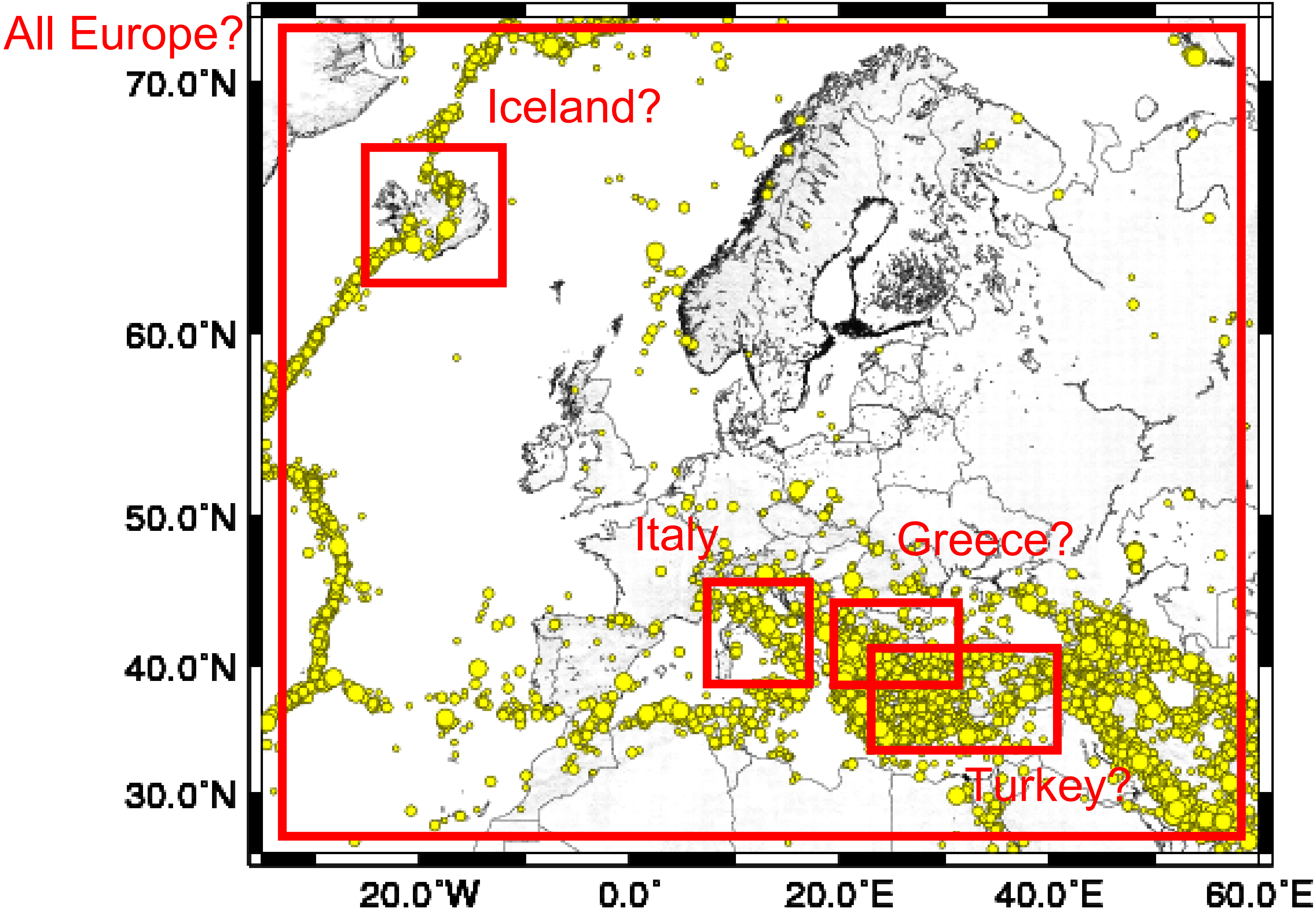
- Host multiple testing regions
- Allow testing of earthquake hazard models
- Promote earthquake hazard model development

EEFTEC, the European Earthquake Forecast Centre
Organisational chart

- **Difference from California CSEP!**
→MOU: *Memorandum of Understanding*



Where are testing regions?



Italian testing region

Data
- INVG catalogue
- Completeness: M = 3.7

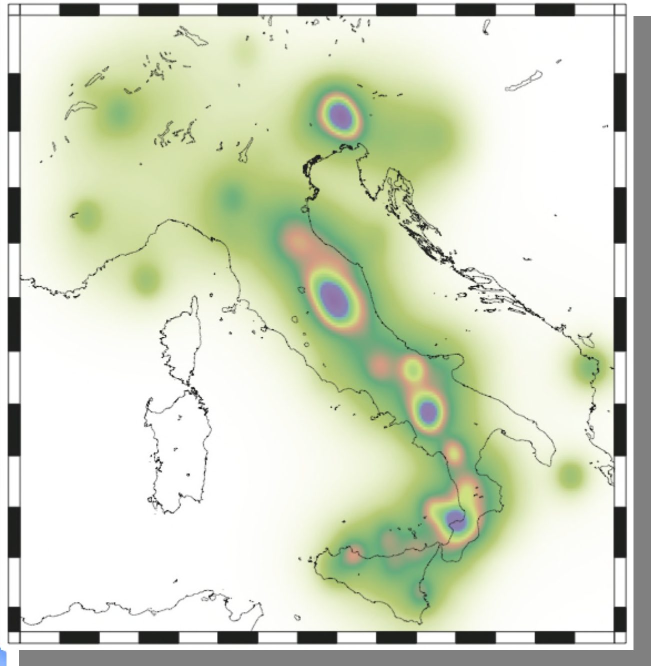
Testing area
- mainland Italy and Sicily (see figure)

Forecast models (in preparation)
- ETAS (Console/Murru)
- STEP-Italy (Woessner et al.)
- ETAS (Marzocchi & Lombardi)
- Non-stationary ETAS (M&L)
- Abundance-STEP (Christophersen & Gerstenberger

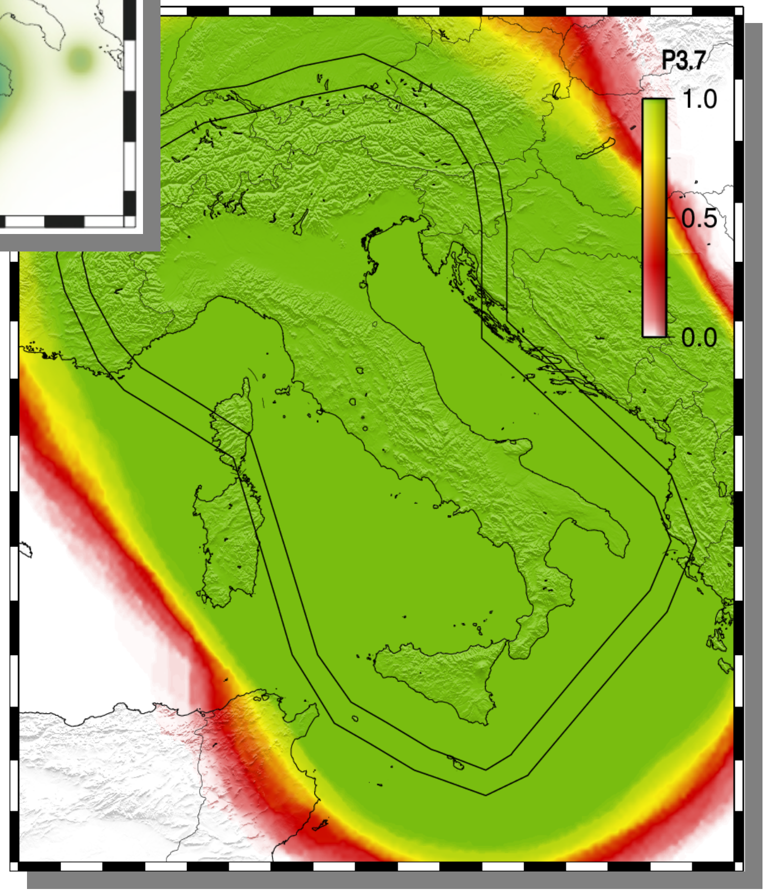
Forecast periods
- 1 day
- 3 months
- 5 years

Testing algorithms
- CSEP N-, L-, R- tests

Next steps
- Modeller's workshop October 2008



Model development Italy (Marzocchi et al.)



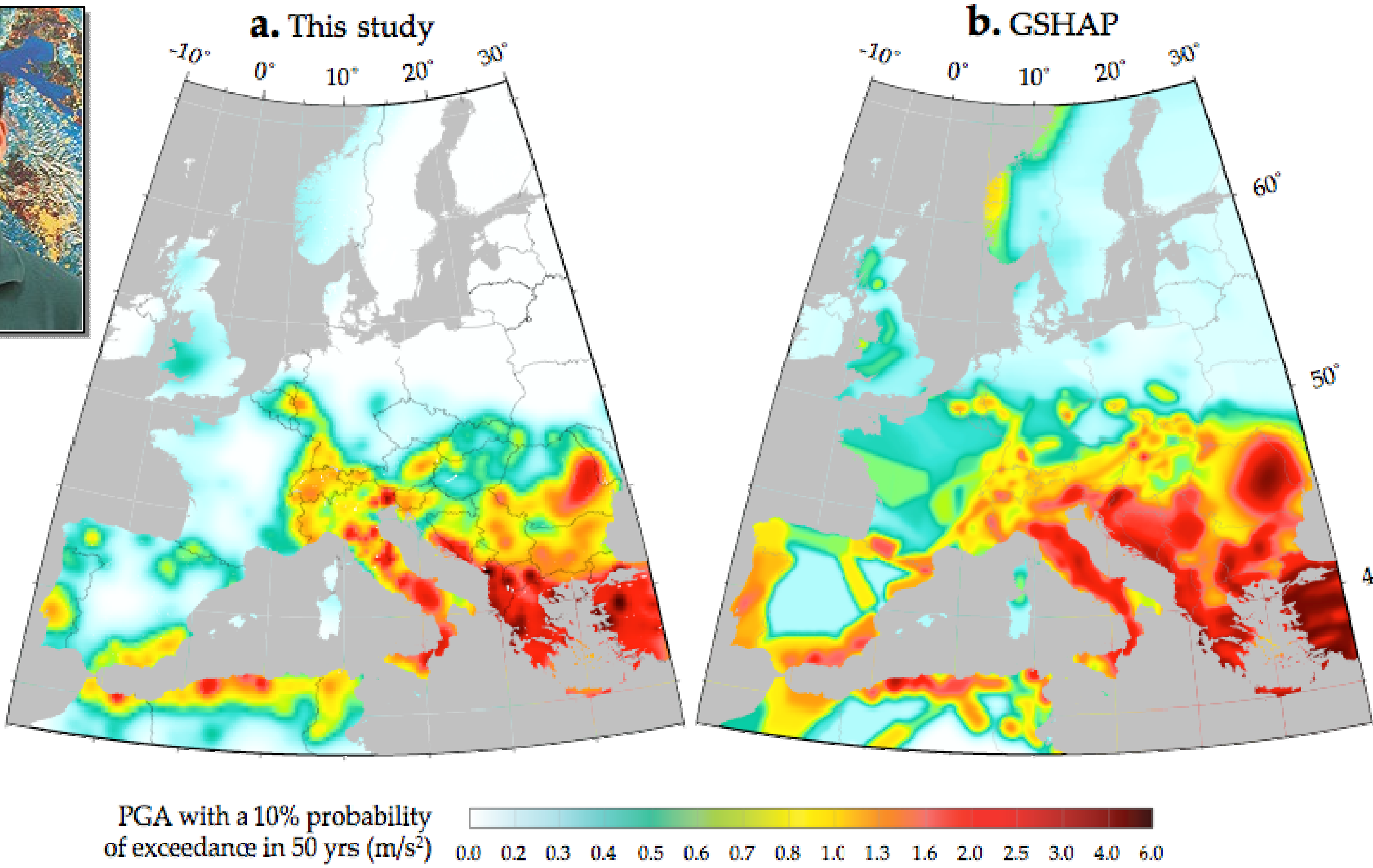
Completeness Study (Schorlemmer et al.)

The challenges

- No obvious authoritative catalogs
  - PDE, ISC, EMSC, IDC …
- Non-uniform magnitude determination
  - Mb, Ms, Ml, Mw
- Model development and forecasting in low seismicity regions.
- Sparse network coverage in various regions.

Long Term Hazard Assessment

- **Hybrid Zoneless Approach** to construct a homogeneous model at a European scale with the limited resources, using refined smoothed hazard
- This model can be used for a background model for Europe

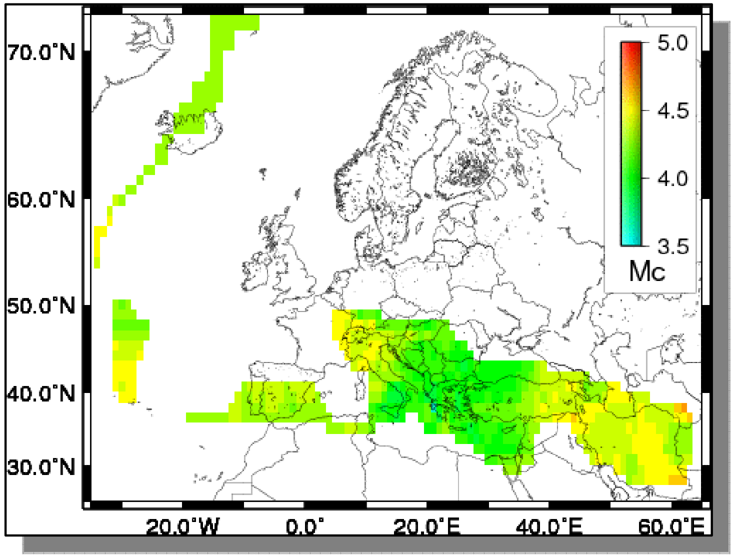


GFZ
Helmholtz-Zentrum
POTSDAM

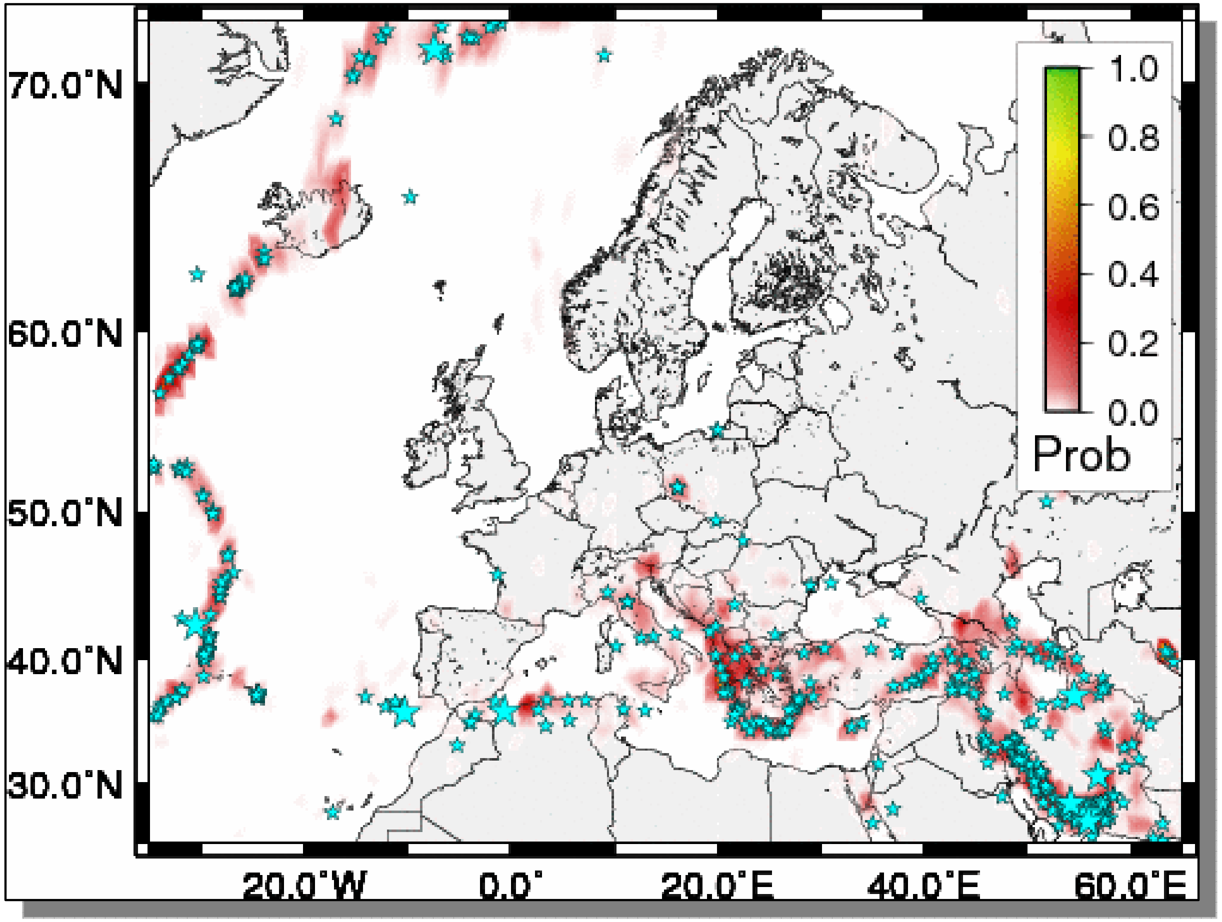
Han Chan and Gottfried Gruenthal (2008)

Long-term forecast model

- Forecast for Europe for 2004 - 2008 with Relative Intensity (RI) method, based on the seismicity in 1973-2003
- Stars show events with M>4.5 in 2004-2008
- PDE catalog used



Mc estimate



Nanjo & Ozturk et al.

Short-term forecast

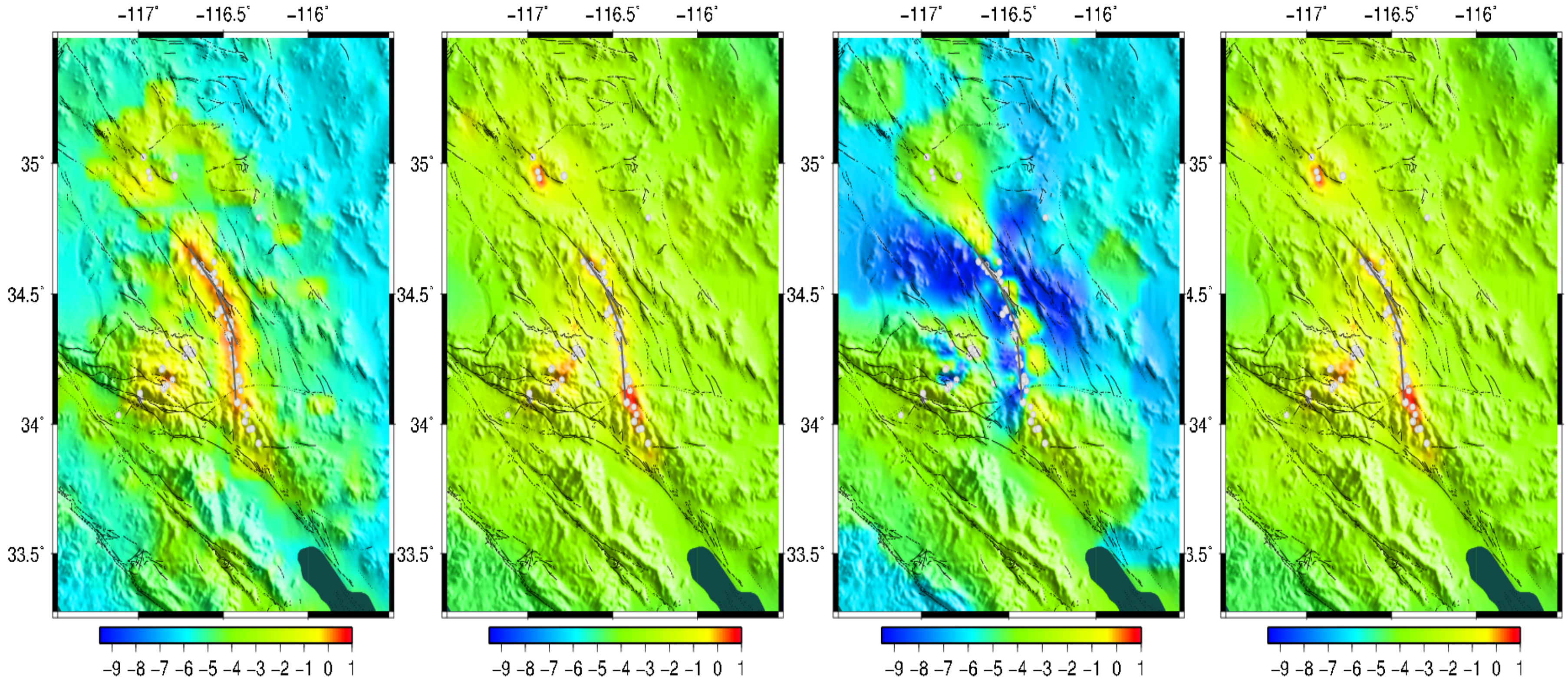
Retrospective testing to forecast aftershock sequences

1992 Landers case (Woessner et al., 2008)

SAFER
Seismic eArly warning For EuRope

Statistical models | Physics-based models

M-STEP-1 | ETAS-2 | CRS-1 | CRS-3



mod. STEP
trig. M>2.5

k-variable
uniform backg.

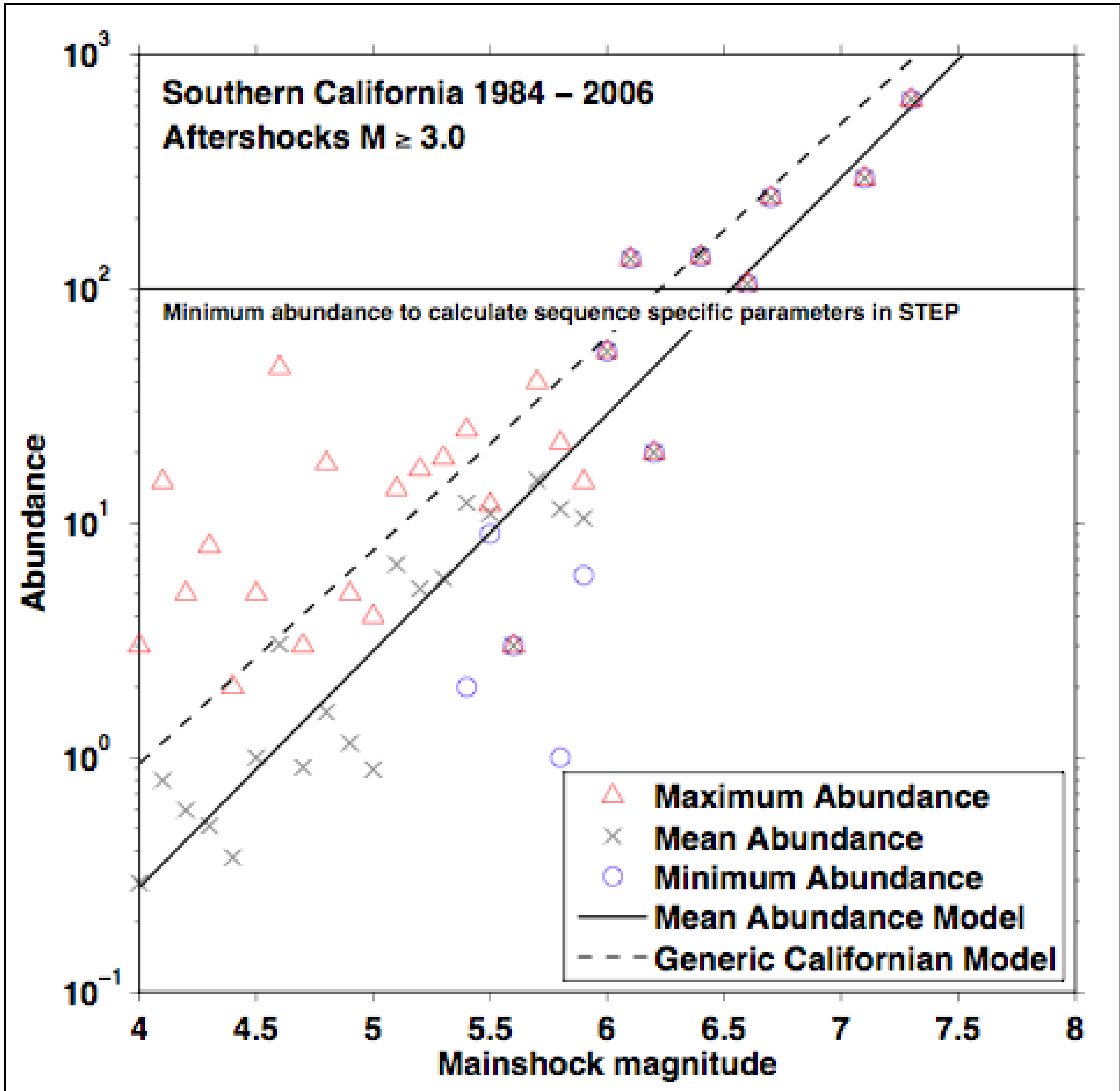
spec. receiver faults
reference seismicity

OOP
stress heterogen.

Short-term forecasts

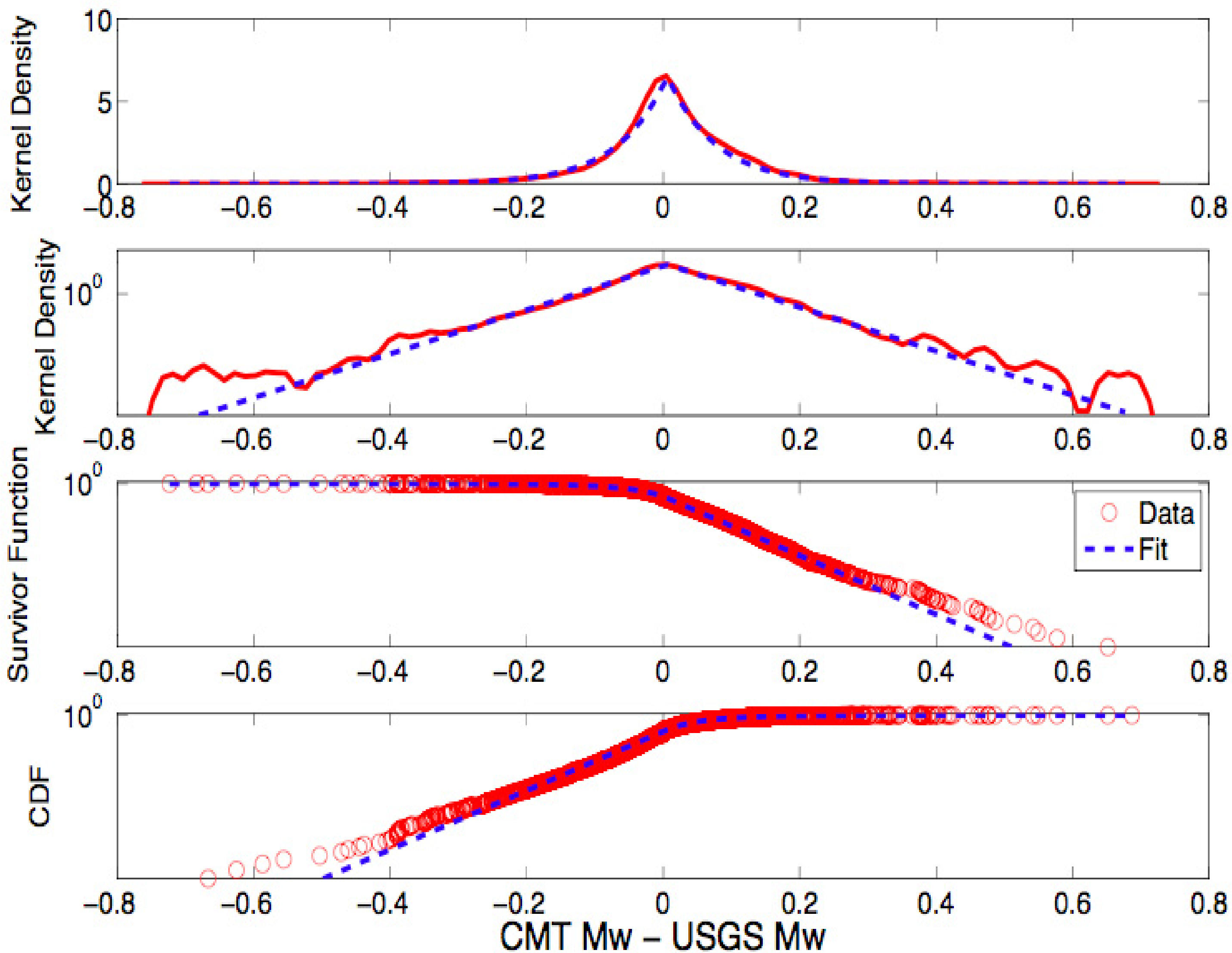
Christophersen et al., 2008

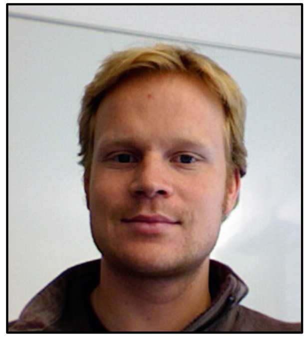
- The mean abundance for aftershocks *M* ≥ 3.0 within the time period 0.1 – 5 days after the mainshock.



Uncertainty in magnitude

Distribution of magnitude estimate differences





Laplace distribution:

$$p_\nu(\nu) = \frac{1}{2\nu_c}\exp(-\frac{|\nu|}{\nu_c})$$

Werner & Sornette, J. Geophys. Res., 2008

Why completeness magnitude?

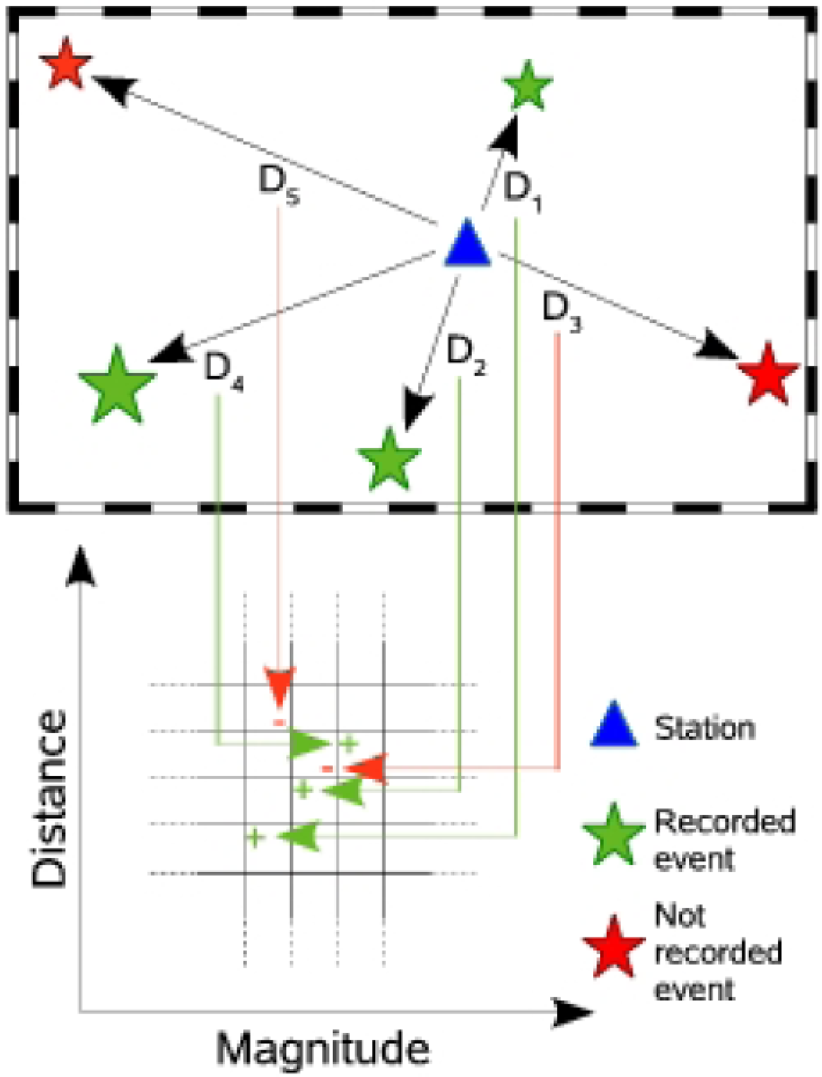
1. ***Completeness magnitude***
   - **Magnitude of the smallest events completely detected by the network**
2. ***Wrong completeness estimate affects***
   - **Basic seismic parameters (b-value, seismicity rate)**
   - **Hazard**
3. ***Microseismicity has information on forecasting future large events***
   - **ETAS, PI, ALM models and so on**

Essential starting point for rigorous testing

Probabilistic magnitude of completeness, M_P

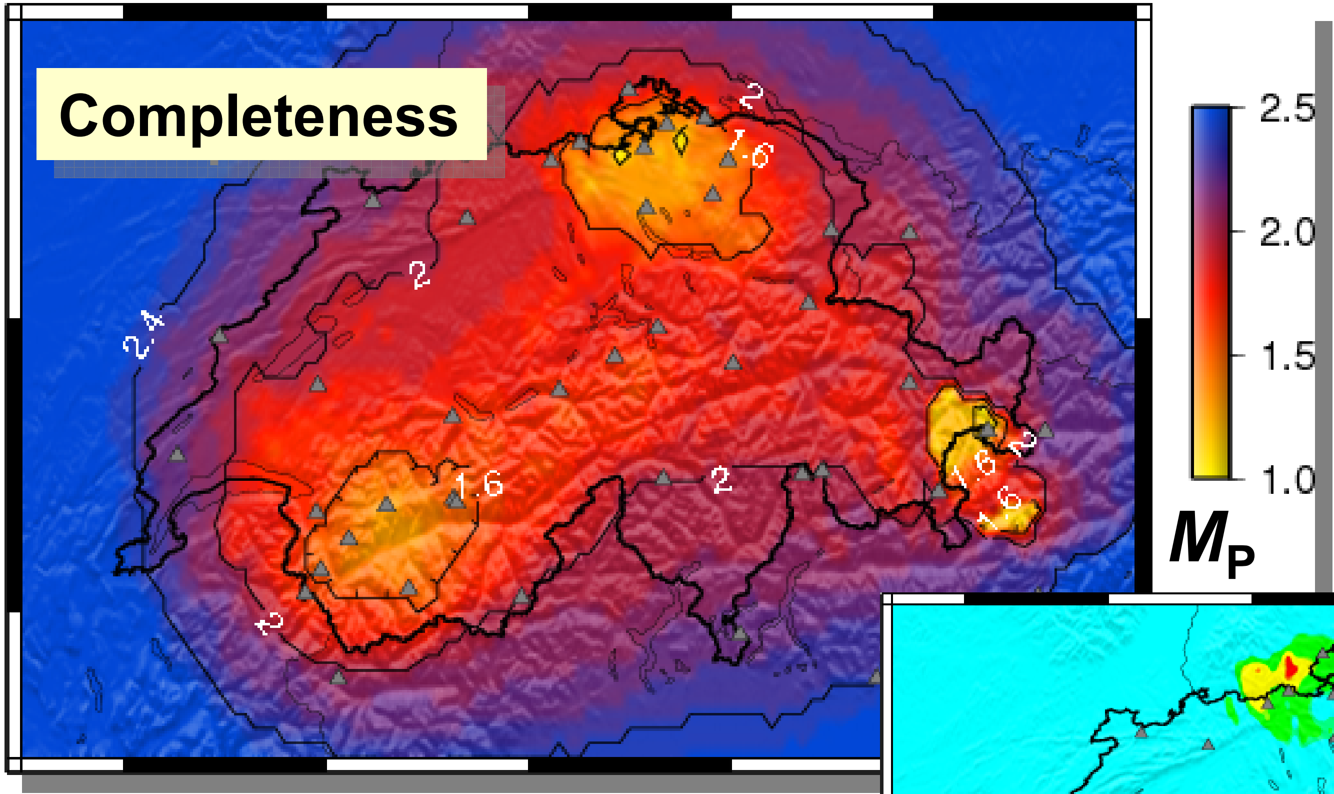
Schorlemmer & Woessner (2008)

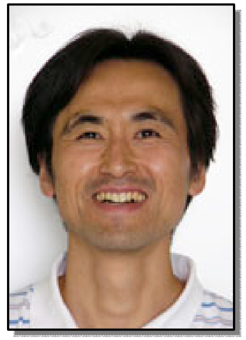
- Method
  - Uses empirical data
    - Phase-pick
    - Station info.
  - No assumption of GR law
- In order to check how the method works on low seismicity regions, we consider Switzerland as an example



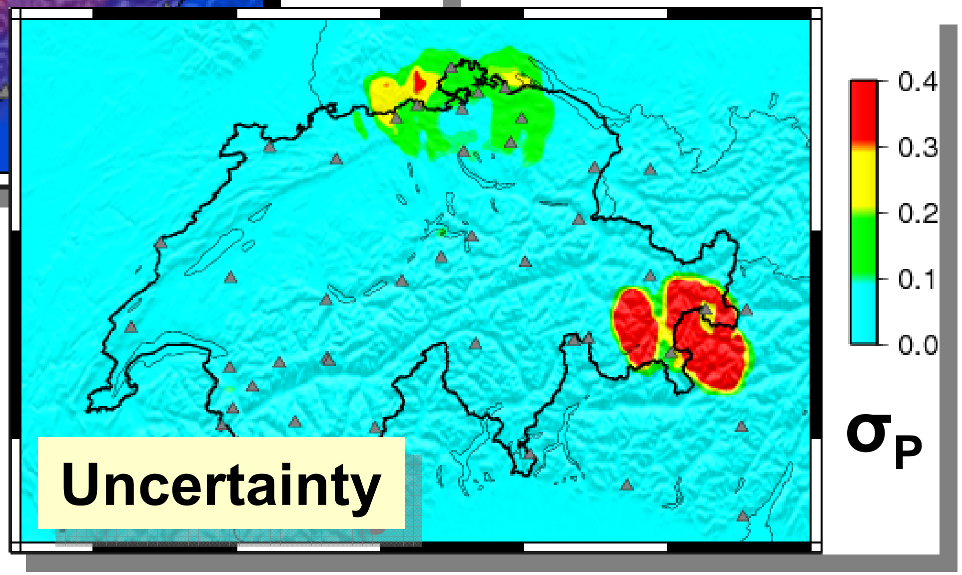
Completeness and uncertainty maps

at Apr. 1, 2008





M_P: Mag. above which $P_M = 1$
σ_P: Bootstrap approach

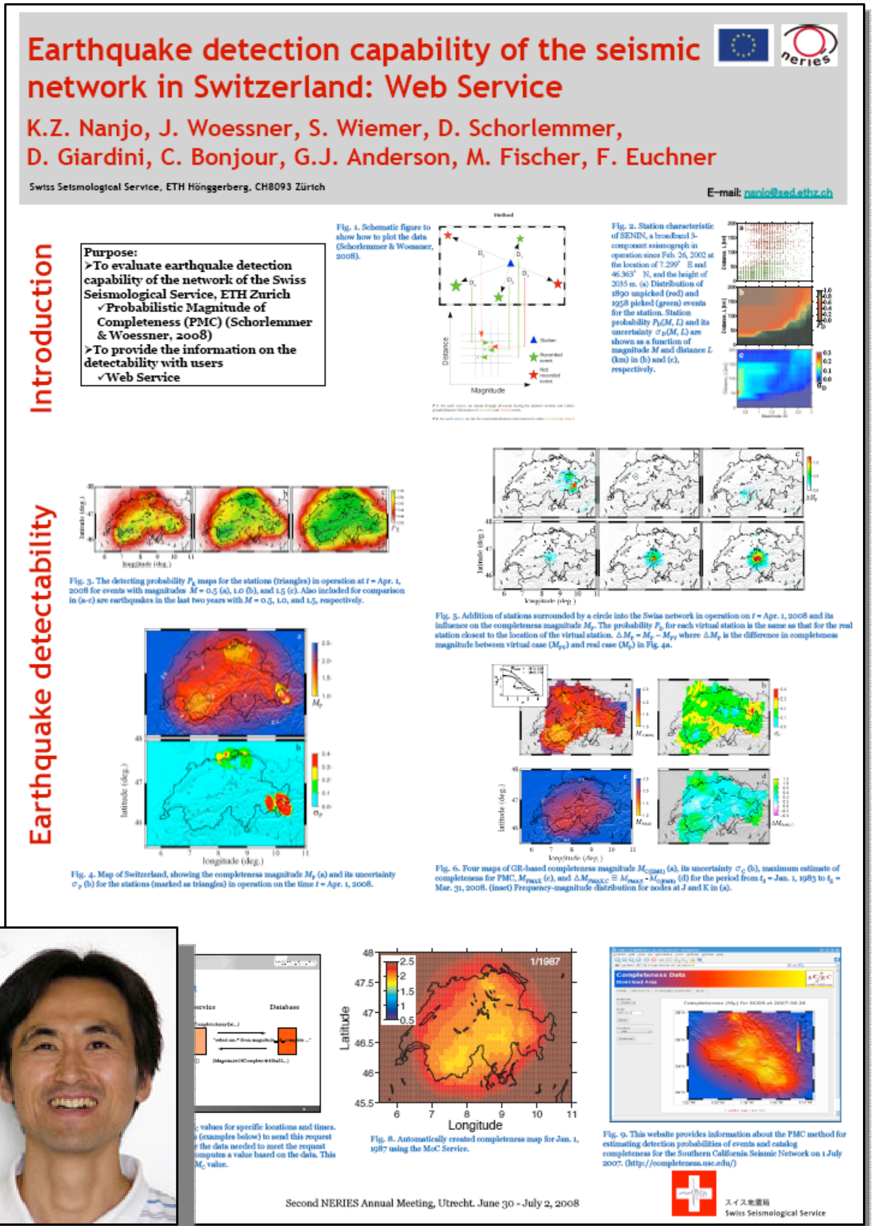


△ Station

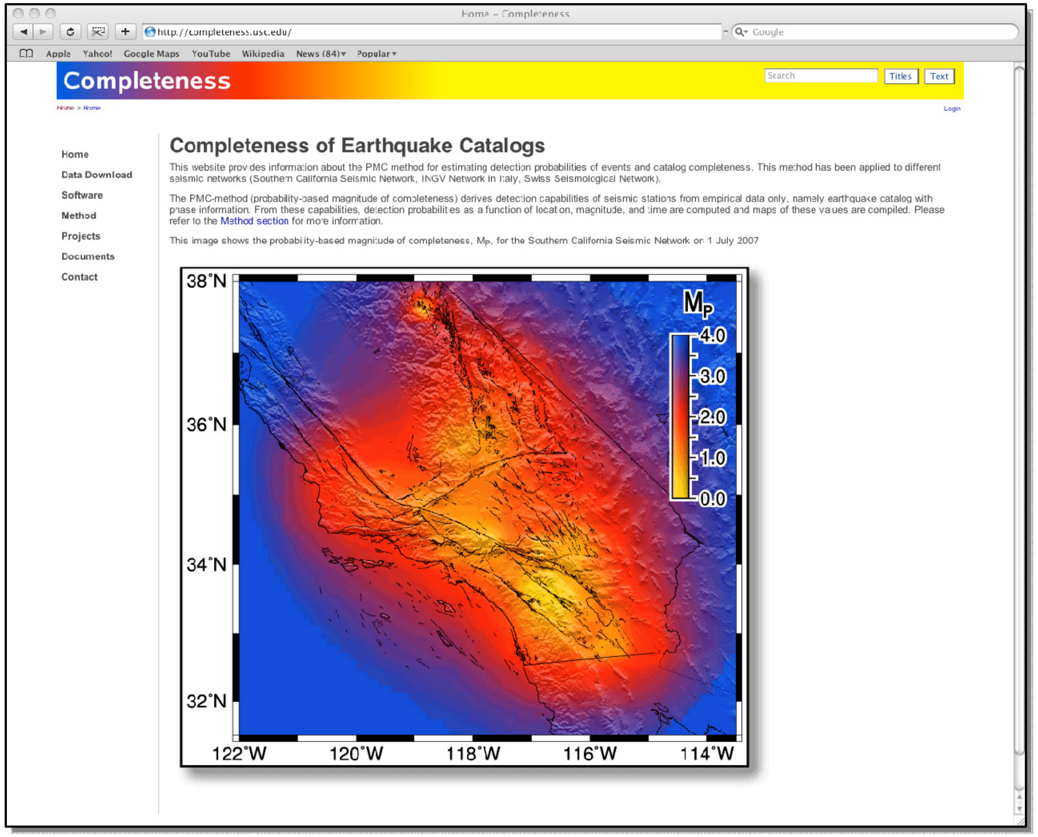
(Nanjo et al., 2008)

Web resources and service

Visit the Poster, watch the movies and web-service



Visit http://completeness.usc.edu/

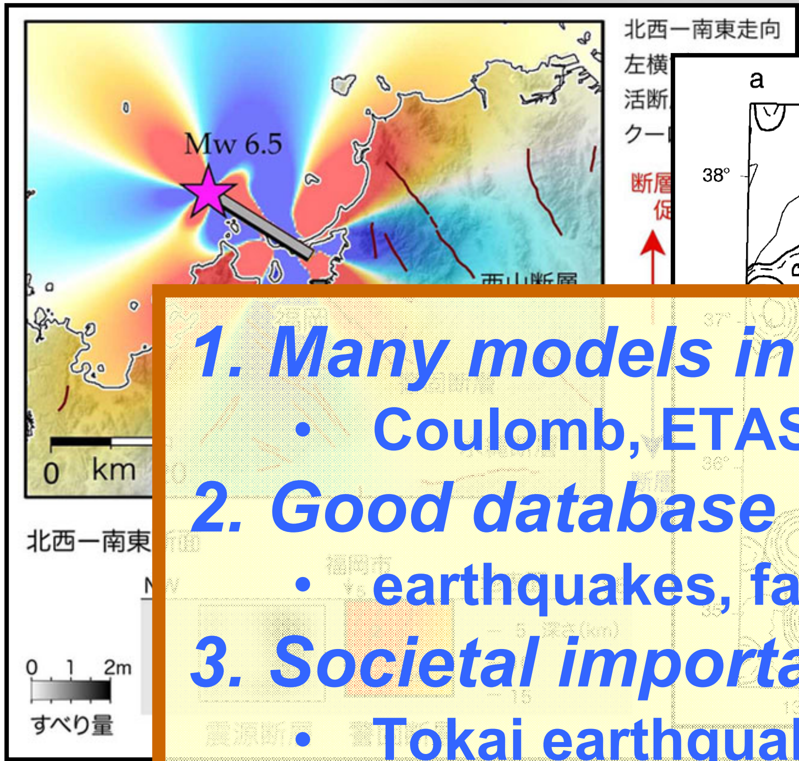


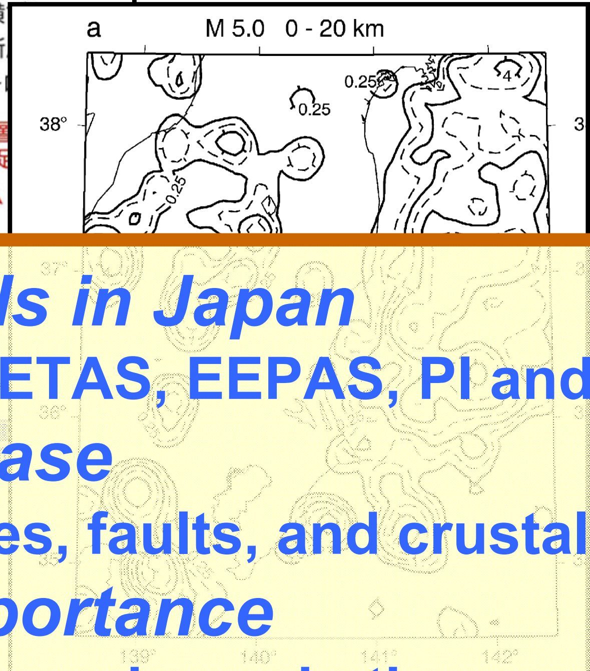
Schorlemmer & Euchner

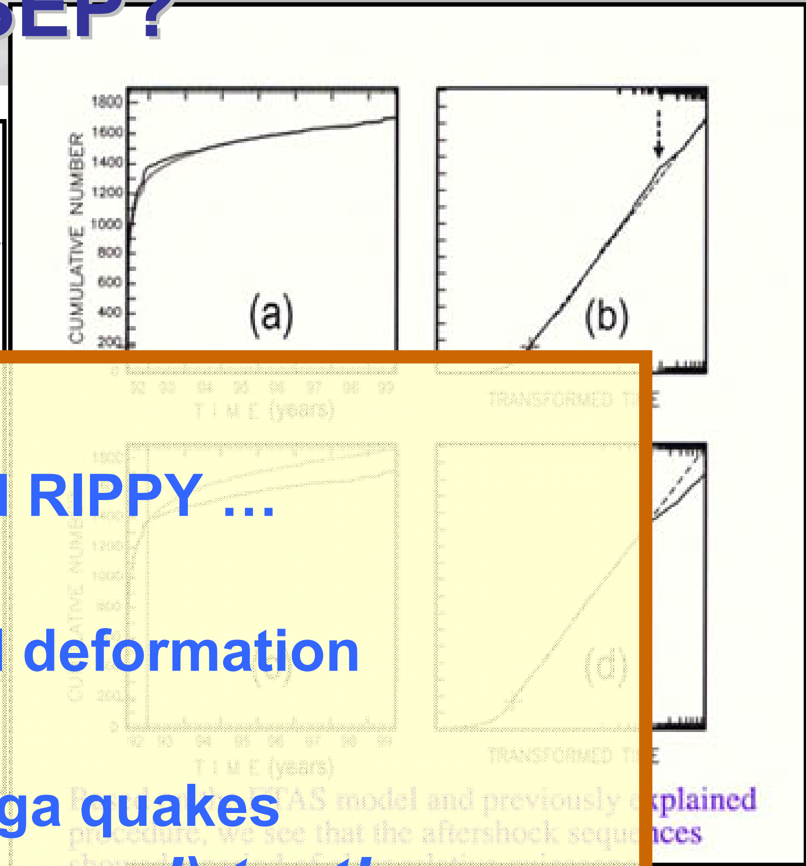
Schweizerischer Erdbebendienst
Swiss Seismological Service

ETH

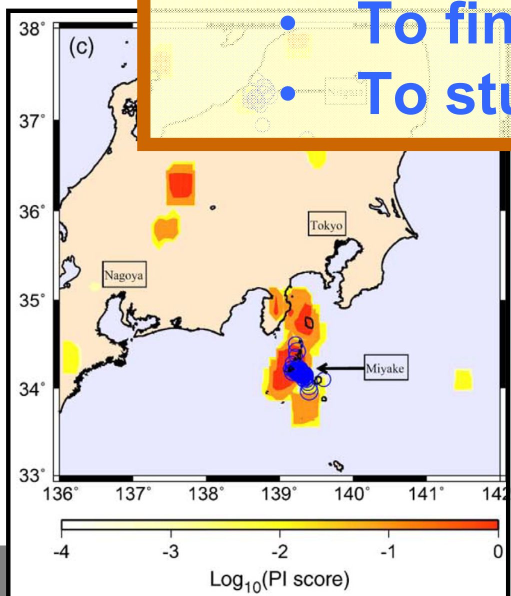
Should Japan join CSEP?

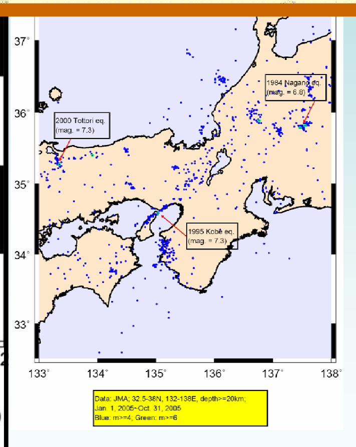


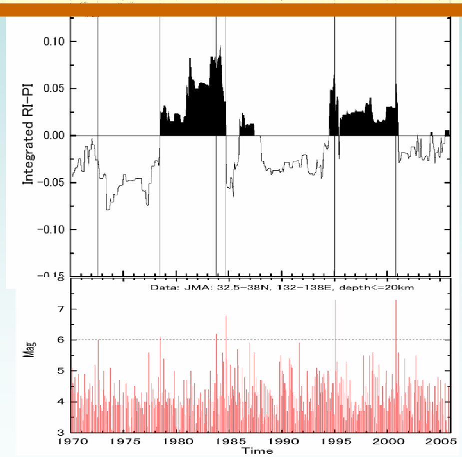


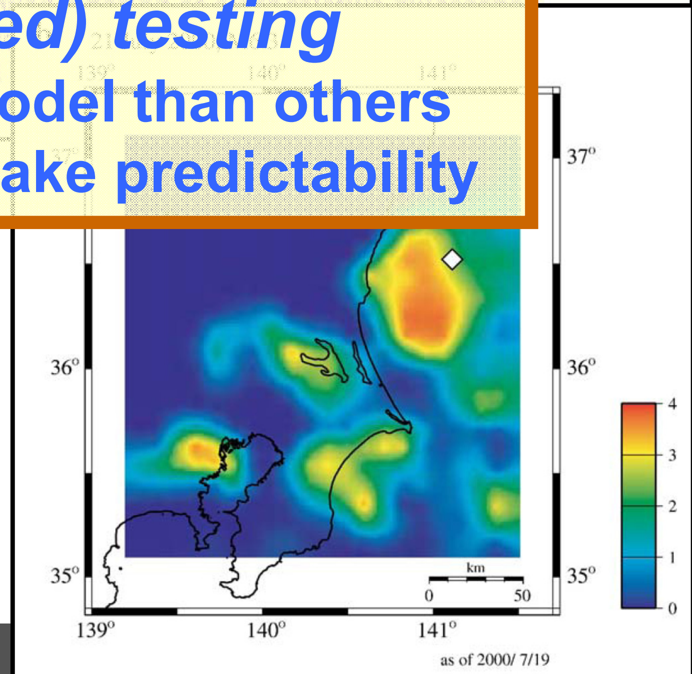


1. ***Many models in Japan***
   - Coulomb, ETAS, EEPAS, PI and RIPPY …
2. ***Good database***
   - earthquakes, faults, and crustal deformation
3. ***Societal importance***
   - Tokai earthquake and other mega quakes
4. ***No rigorous (community-endorsed) testing***
   - To find which is a better forecast model than others
   - To study physical basis for earthquake predictability





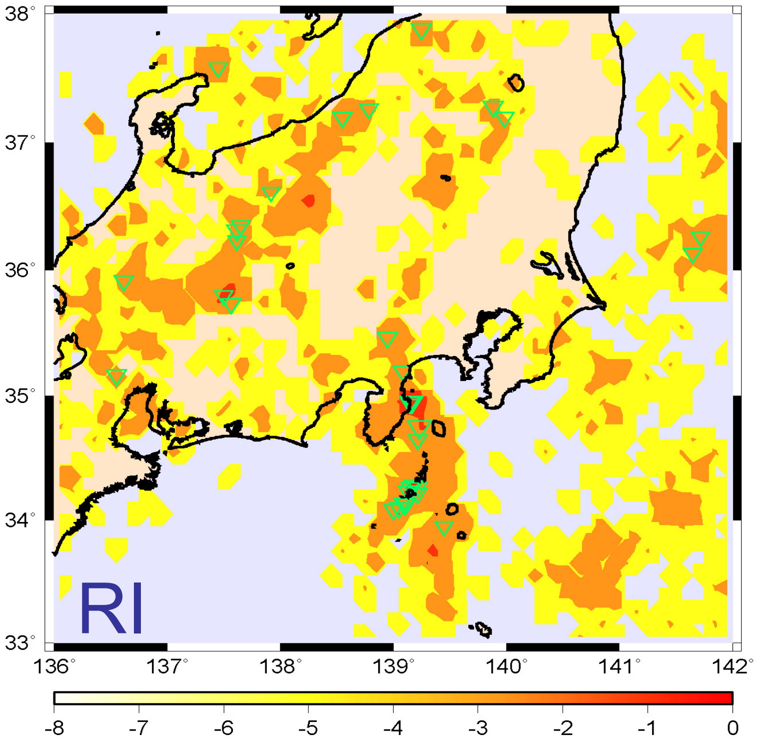


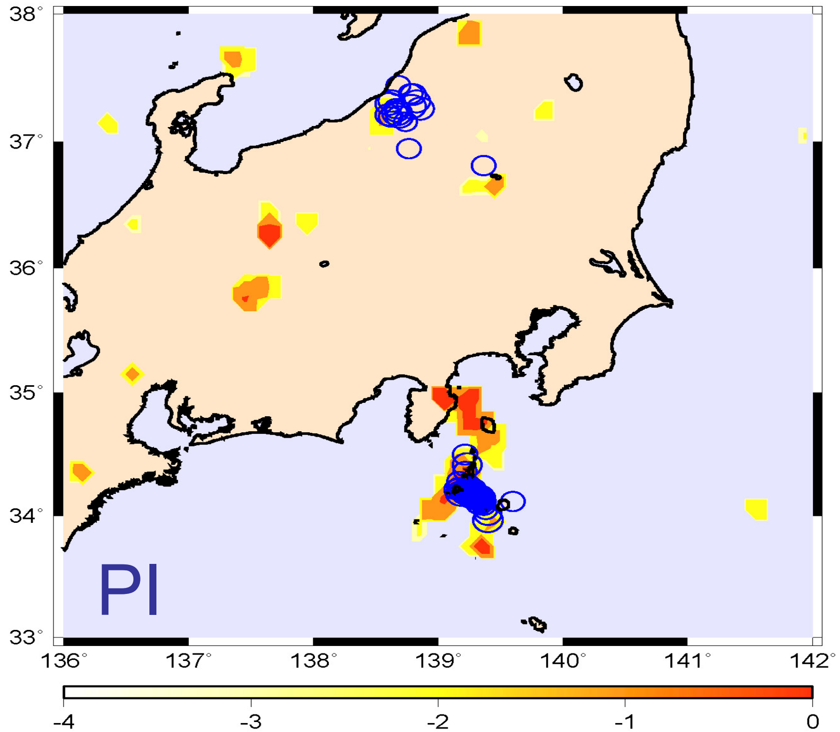


Forecast models using PI and RI

forecasting 2000-2009 M≥5 events

based on 1965-1999 M≥3 events in central Japan





$\mathrm{Log}_{10}\ P$ $\mathrm{Log}_{10}\ P$

- •PI method: find seismic activation and quiescence
- •RI method: find seismic intensity

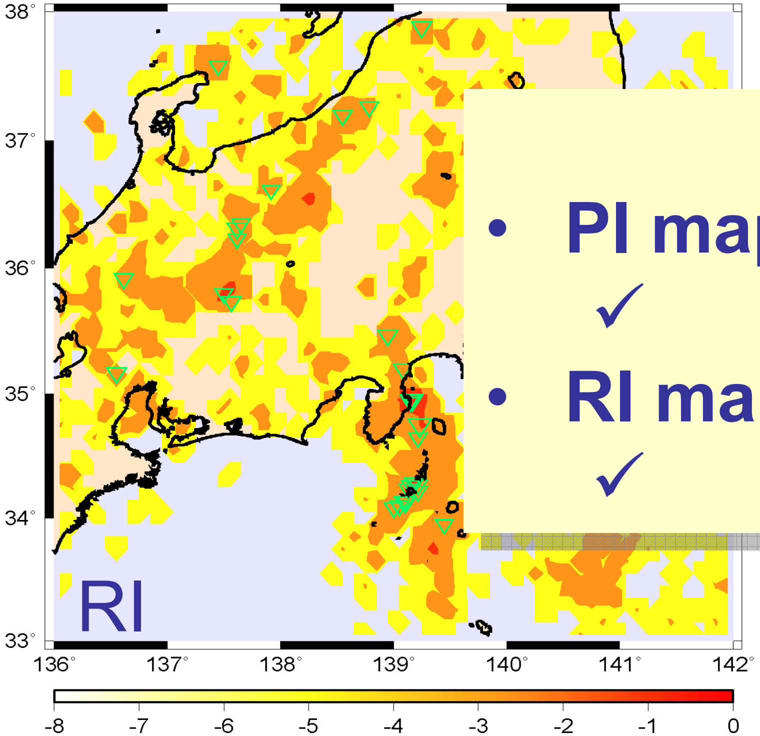
Nanjo et al. (2006a,b)

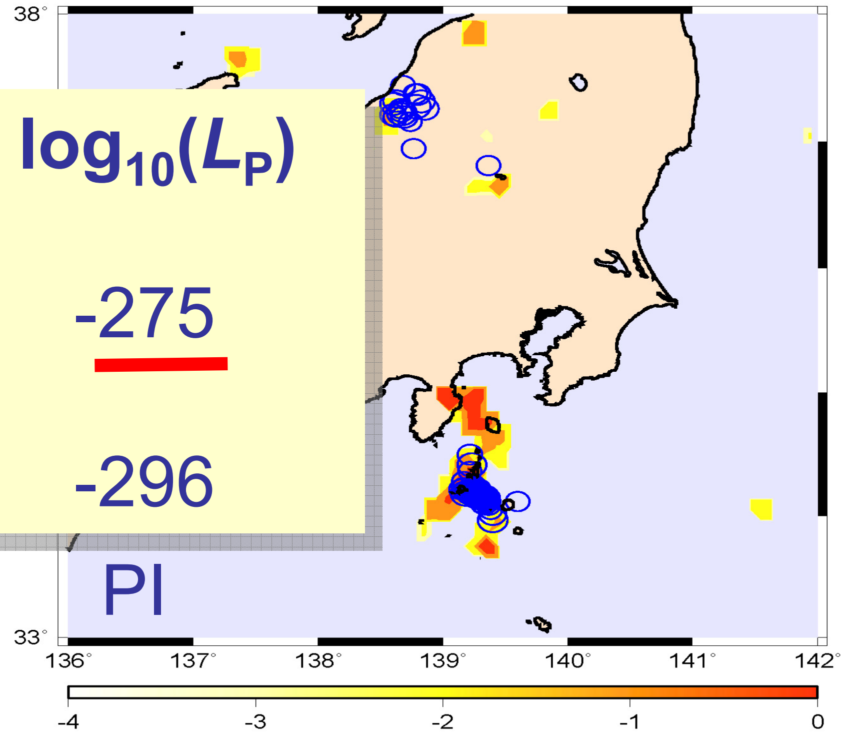
As of Aug. 2005

Likelihood test: a CSEP method

-- Test was done by me, not community-endorsed test! --

Likelihood: *A measure of matching between forecast map based on EQs. in ≤1999 and EQs. in ≥ 2000*





	$\log_{10}(L_P)$
• **PI map:** ✓	-275
• **RI map:** ✓	-296

$\text{Log}_{10}\ P$ $\text{Log}_{10}\ P$

- PI method: find seismic activation and quiescence
- RI method: find seismic intensity

Nanjo et al. (2006a,b)

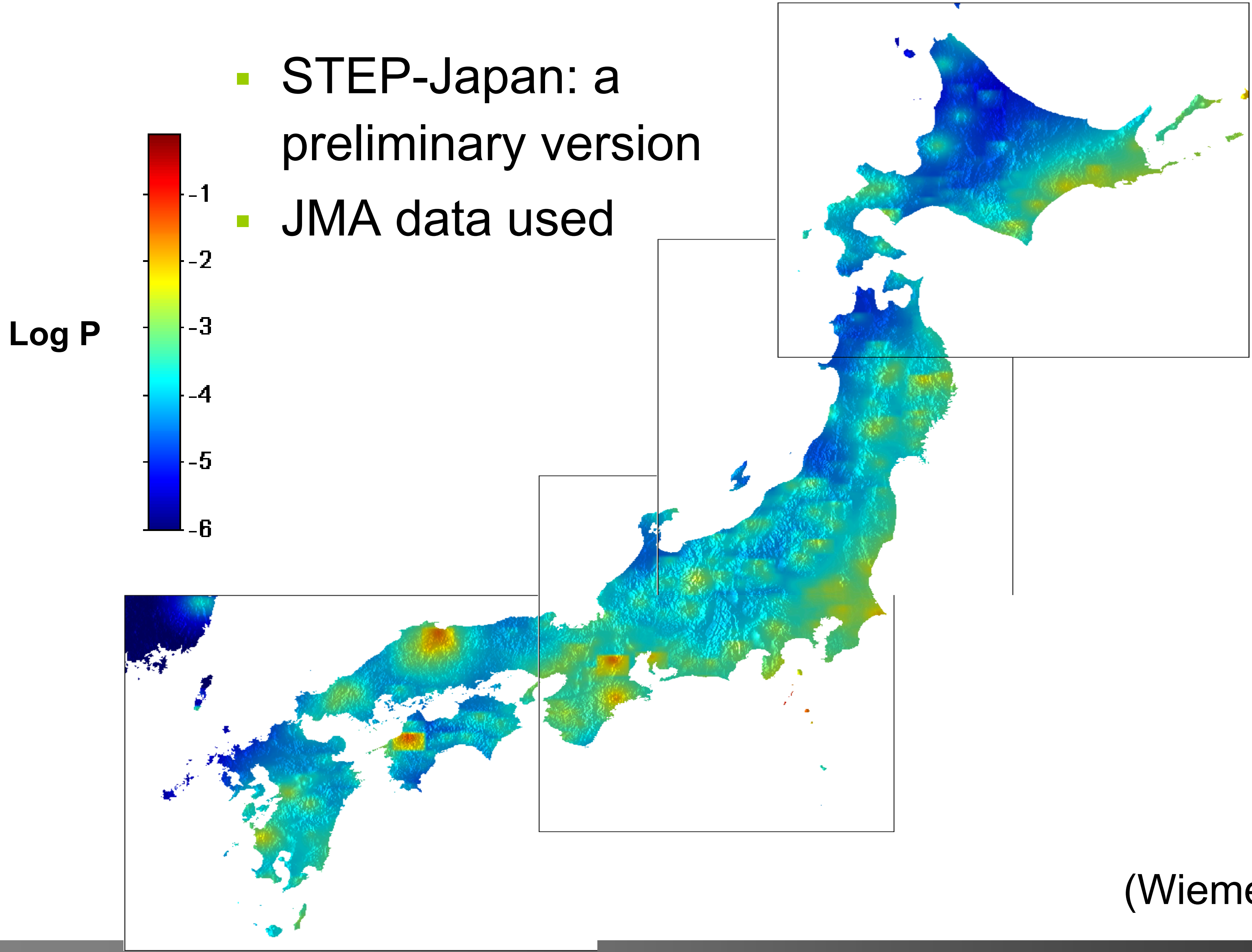
As of Aug. 2005

CSEP testing center in Japan

- Introducing the concept of CSEP to Japan
  - This meeting: Schorlemmer
- Setting up a Japanese center
  - In process: Schorlemmer, Euchner, CSEP working group and Japanese researchers
- Completeness study
  - PMC approach in process: Schorlemmer et al.
  - GR-based approach in process: Nanjo et al.
- Submitting testable models to the testing center
  - Not yet

Short-term forecast model (1)

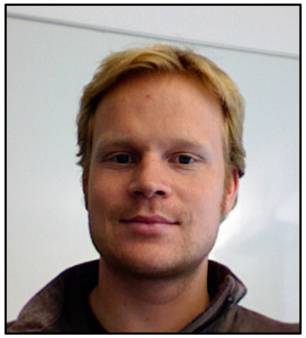
- STEP-Japan: a preliminary version
- JMA data used

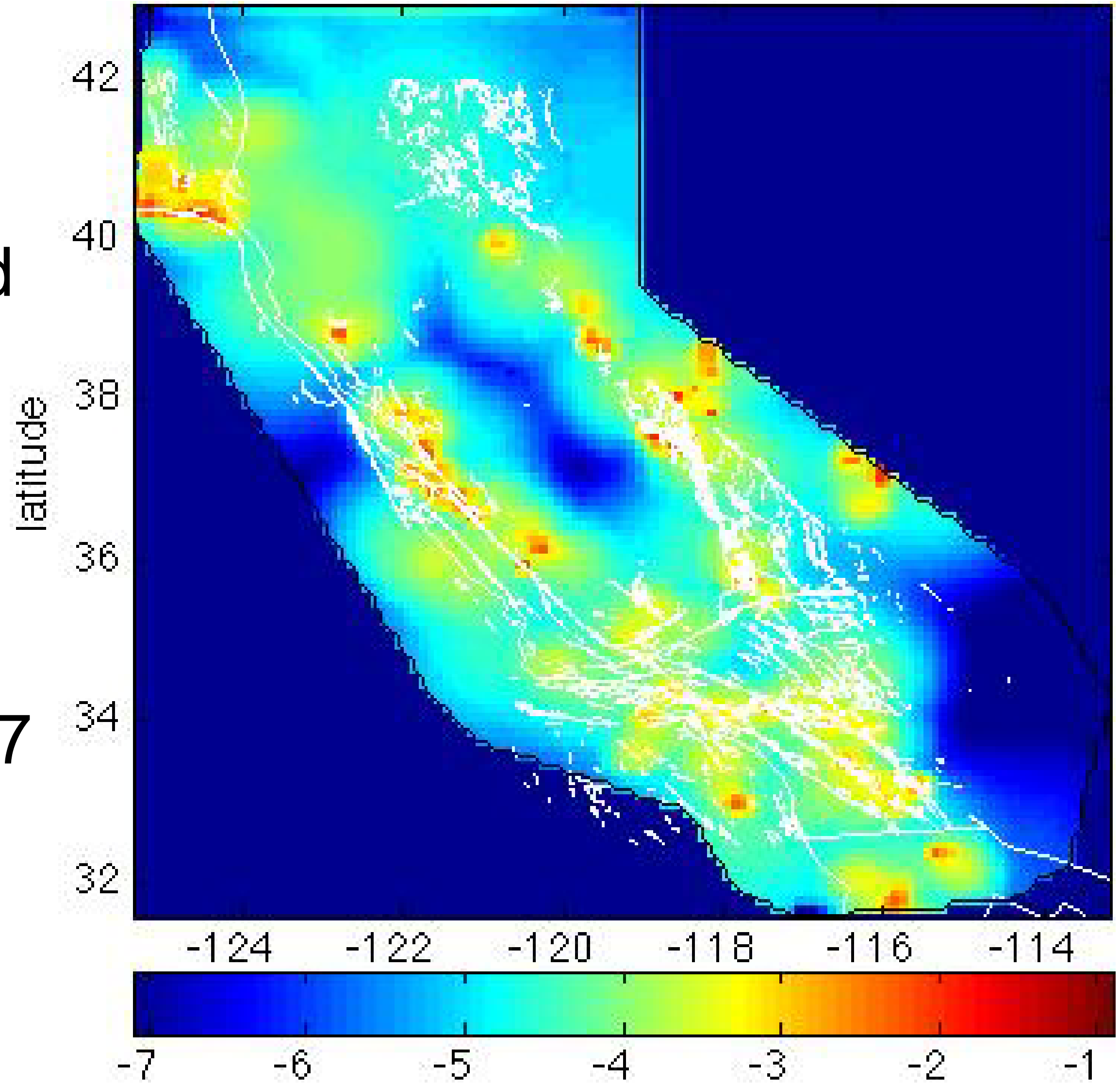


(Wiemer et al.)

Short-term forecast model (2)

- One-day forecast for California with ETAS method
- This map is created based on the seismicity in 1984-2007
- Colors show the rates of events with M>= 4 for the forecast day, Oct. 30, 2007
- ANSS catalog used



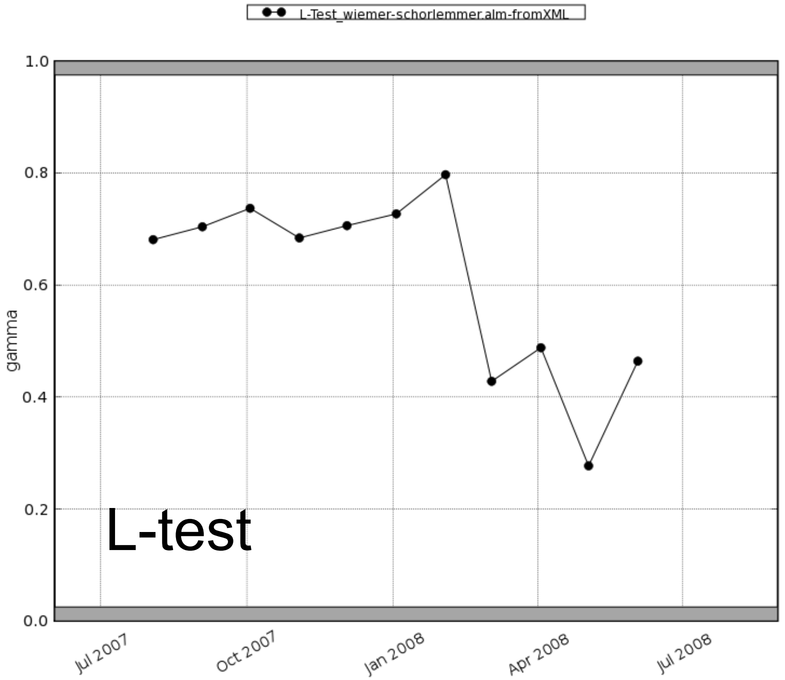


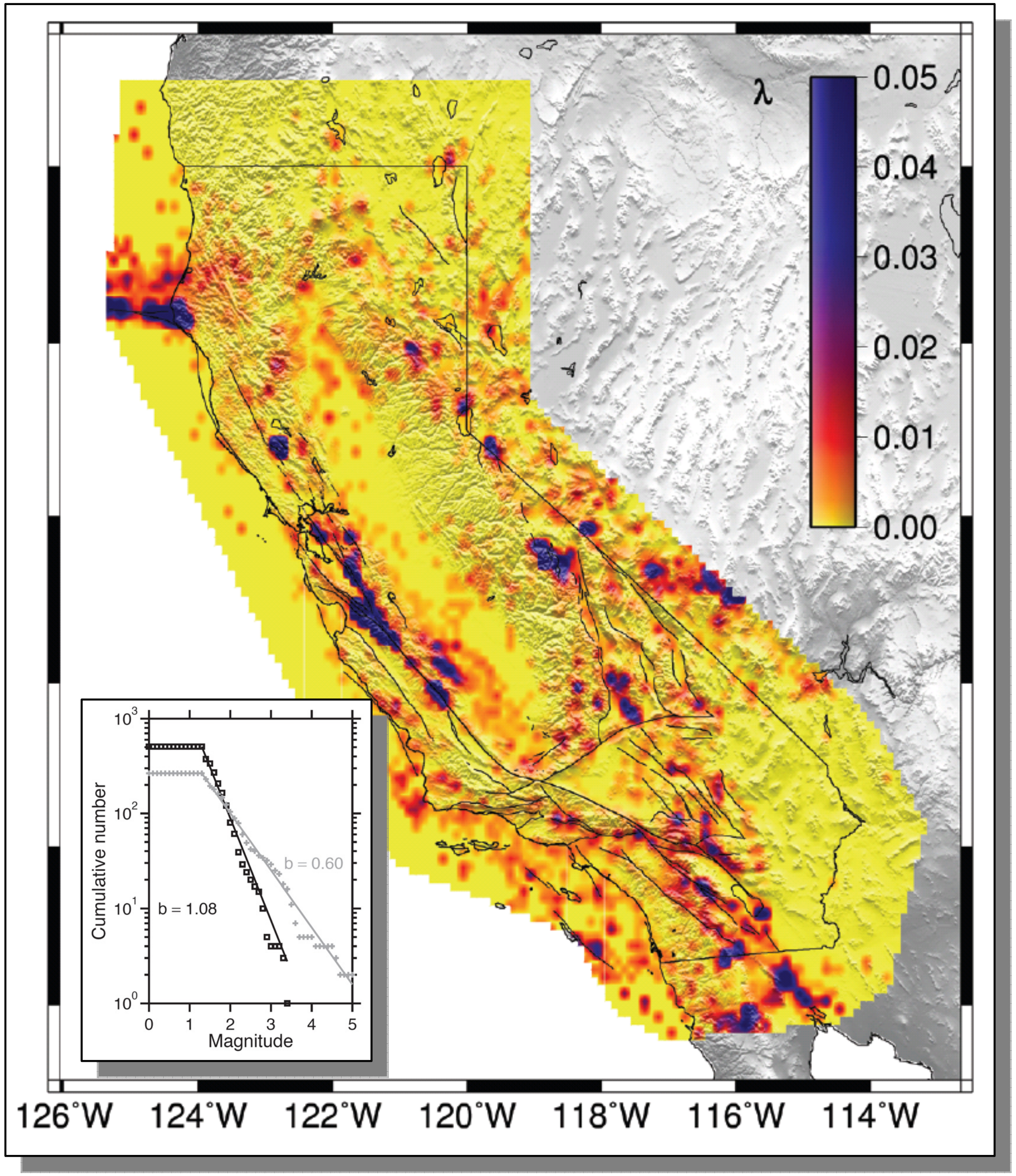
Werner, Jackson, Kagan, 2008 in prep.

Long-term forecast model (1)

ALM: An Asperity-based Likelihood Model

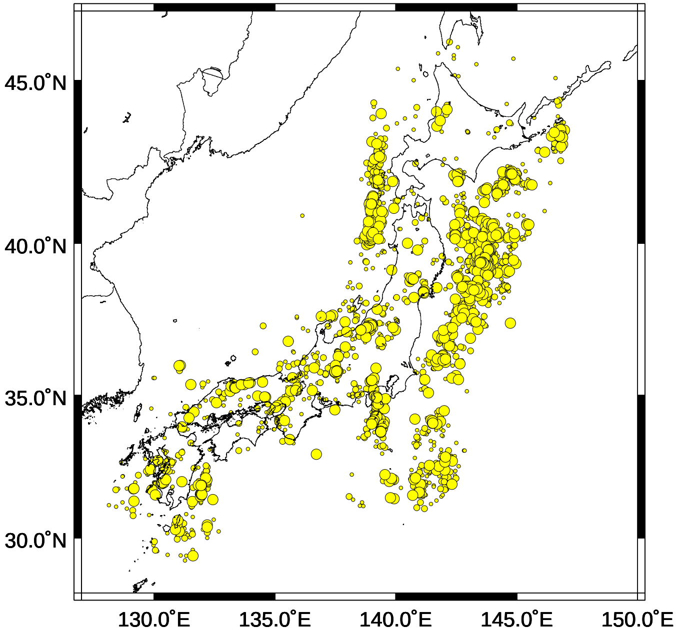
- Wiemer & Schorlemmer (2007)



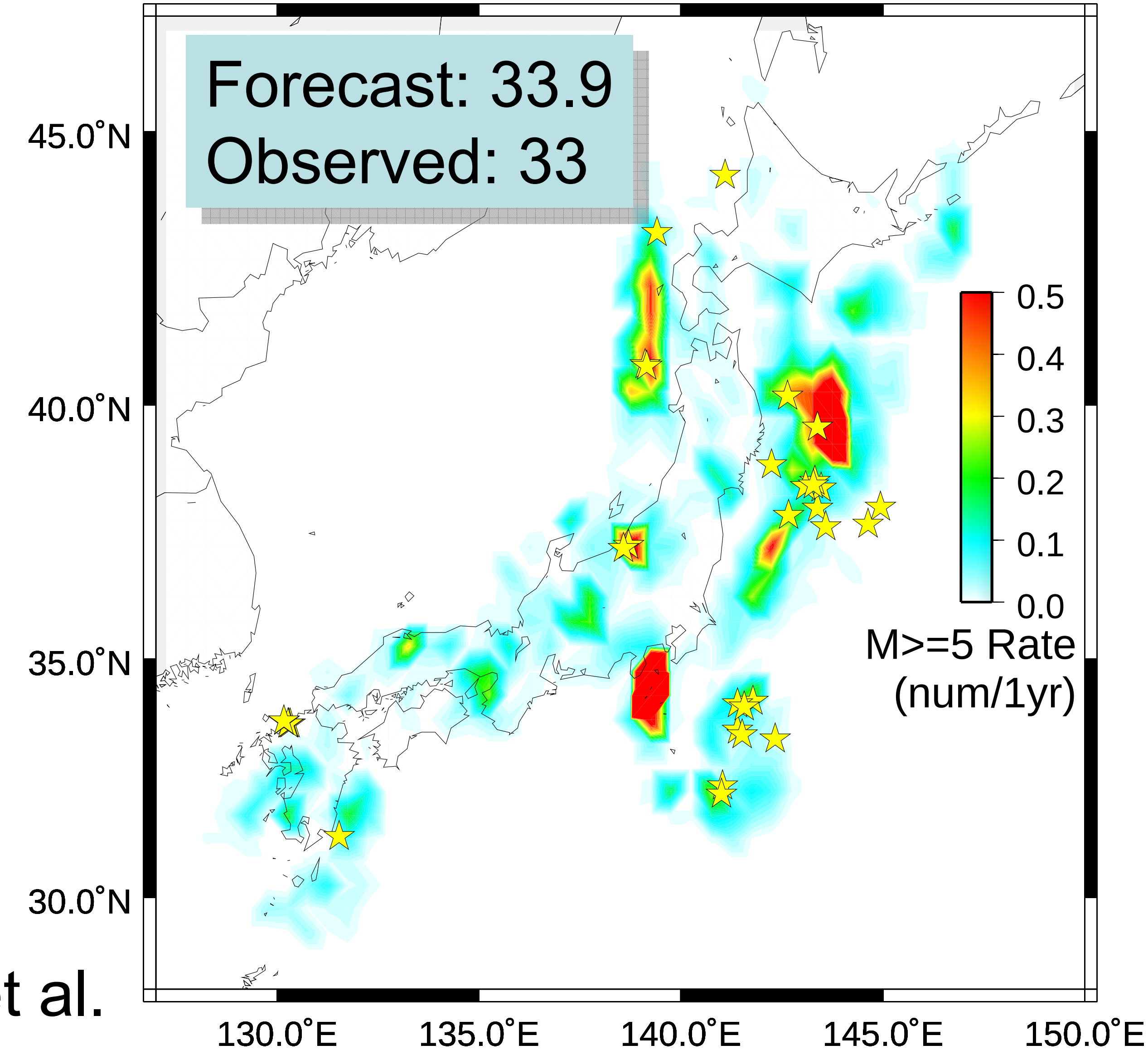


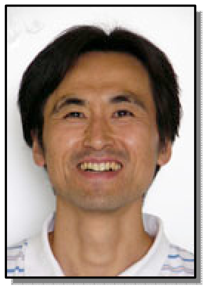
Long-term forecast model (2)

One-year (2005) forecast based on relative seismic intensity (RI) : a preliminary version



JMA M>=4 events
in 1980-2004





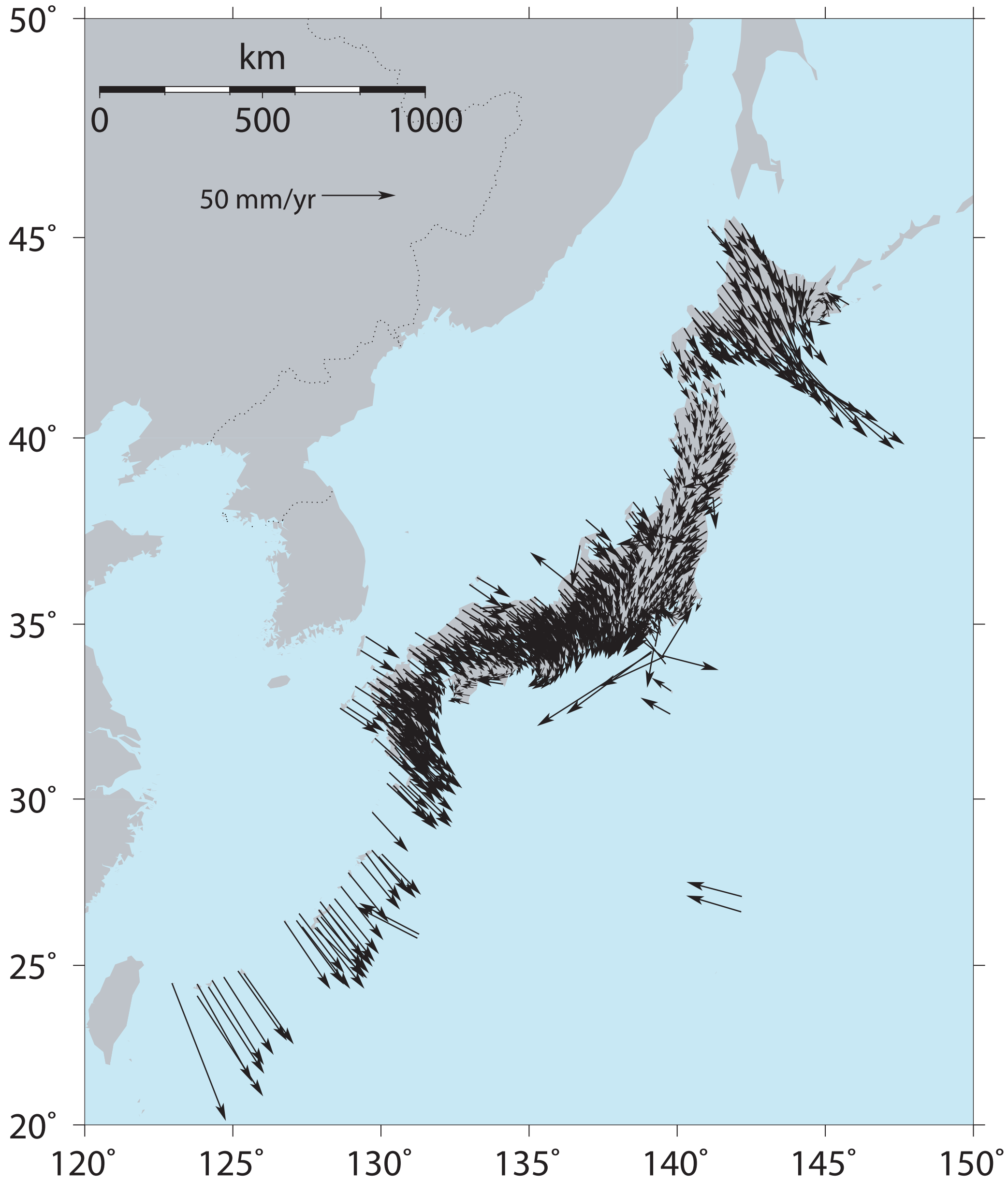
Nanjo & Ozturk et al.

Long-term deformation

A potential model for a hazard in Japan

- The vectors show the averaged horizontal velocity over the past 10 years, relative to a station in Niigata.
- We could use these data for a hazard model, though it'll be complicated because of the tectonics in the area.

Anderson et al.



Final remarks

- Testing earthquake forecasts would be a big topic in next 5 years for Japan Seismol. Soc.
- Challenges:
  - How to deal with the 3D in Japan?
  - How to collaborate with CSEP?
  - Data accessibility?
  - The use of seismic quiescence as a forecast tool
- ETHZ would like to help the start of a Japanese testing center

Plan for 2009-2013 earthquake prediction researches in Japan (from Hirata)

次期地震予知・火山噴火予知の研究計画の実施内容の項目

1．地震・火山現象予測のための観測研究の推進
（1）地震・火山現象のモニタリングシステムの高度化
　ア．日本列島域
　イ．地震発生・火山噴火の可能性の高い地域
　ウ．東海・東南海・南海地域
（2）地震・火山現象に関する予測システムの構築
　(2-1) 地震発生予測システム
　ア．地殻活動予測シミュレーションとデータ同化実験
　イ．地殻活動予測シミュレーションの高度化
　ウ．地震活動評価に基づく地震発生予測
　(2-2) 火山噴火予測システム
　ア．噴火シナリオの高度化
　イ．火山活動評価に基づく噴火予測
（3）地震・火山現象に関するデータベースの構築
　ア．地震・火山現象の基礎データベース
　イ．地震・火山現象に関する情報の統合化

2．地震・火山現象解明のための観測研究の推進
（1）日本列島及び周辺域の長期・広域の地震・火山現象
　ア．列島及び周辺域のプレート運動，広域応力場
　イ．上部マントルとマグマの発生場
　ウ．広域の地殻構造と地殻内流体の分布
　エ．地震活動と火山活動の相互作用
　オ．地震発生サイクルと長期地殻歪
（2）地震・火山噴火に至る準備過程
　(2-1) 地震準備過程　（地震）
　ア．アスペリティの実体と相互作用
　イ．非地震性滑りの時空間変化
　ウ．歪集中帯の成因と内陸地震発生の準備過程
　エ．スラブ内地震の発生機構
　(2-2) 火山噴火準備過程　（火山）
　ア．マグマ上昇・蓄積過程
　イ．噴火履歴とマグマの発達過程
（3）地震発生先行・破壊過程と火山噴火過程
　(3-1) 地震発生先行過程　（地震）
　ア．観測データによる先行現象の評価
　イ．先行現象の発生機構の解明
　(3-2) 地震破壊過程と強震動　（地震）
　ア．断層面の不均質性と動的破壊特性
　イ．強震動・津波の生成過程
　(3-3) 火山噴火過程　（火山）
　ア．噴火機構の解明とモデル化
　イ．噴火の推移と多様性の把握
（4）地震発生・火山噴火素過程
　ア．岩石の変形・破壊の物理的・化学的素過程
　イ．地殻・上部マントルの物性の環境依存性
　ウ．摩擦・破壊現象の規模依存性
　エ．マグマの分化・発泡・脱ガス過程

3．新たな観測技術の開発
（1）極限環境下における新たな観測技術の開発
　ア．海底諸観測技術
　イ．大深度ボアホールにおける計測技術
　ウ．噴火活動域近傍における観測技術
（2）観測技術の高度化
　ア．地下状態モニタリング技術
　イ．多項目観測システム・ネットワーク
（3）宇宙技術等の利用の高度化
　ア．宇宙測地技術
　イ．リモートセンシング技術

4．計画推進のための体制の強化
（1）地震・火山噴火予知研究計画を推進する体制の整備
（2）地震・火山噴火予知基礎研究体制の強化