# Forecasting seismicity on local and regional scales

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Physical and Stochastic Modelling of Earthquake Occurrence and Forecasting

# Outline

1. Seismic eArly Warning For EuRope (SAFER): Local scale time-dependent seismic hazard and earthquake forecasting
2. A comparative retrospective forecast test for the Landers 1992 earthquake
3. Short Term Earthquake Probabilities: STEP in Europe - Examples from Switzerland and Turkey

# SAFER-Objectives

1. **Improve understanding of spatial and temporal evolution of clustered seismicity (SAFER, NERIES)**

2. **Improve links to underlying physics of earthquakes (SAFER, NERIES)**

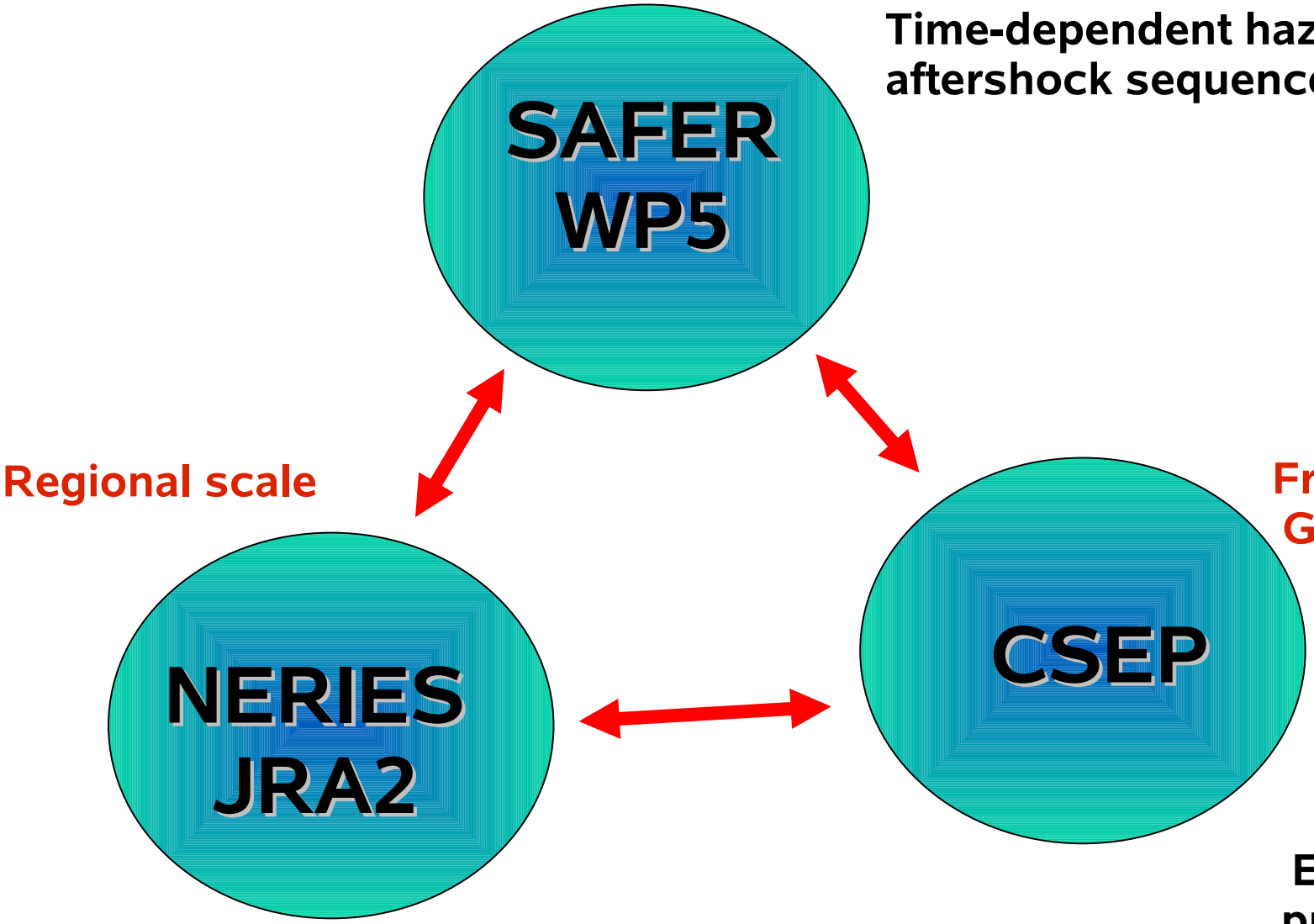
3. **Develop testable forecast models (NERIES, CSEP)**

4. **Validate forecast models using community accepted testing procedures (CSEP)**

# Project: Target scale

Local scale

Time-dependent hazard for e.g. aftershock sequences, swarms




Regional scale

From Local to Global scales

Time-dependent hazard on nationwide / European scale

Earthquake predictability

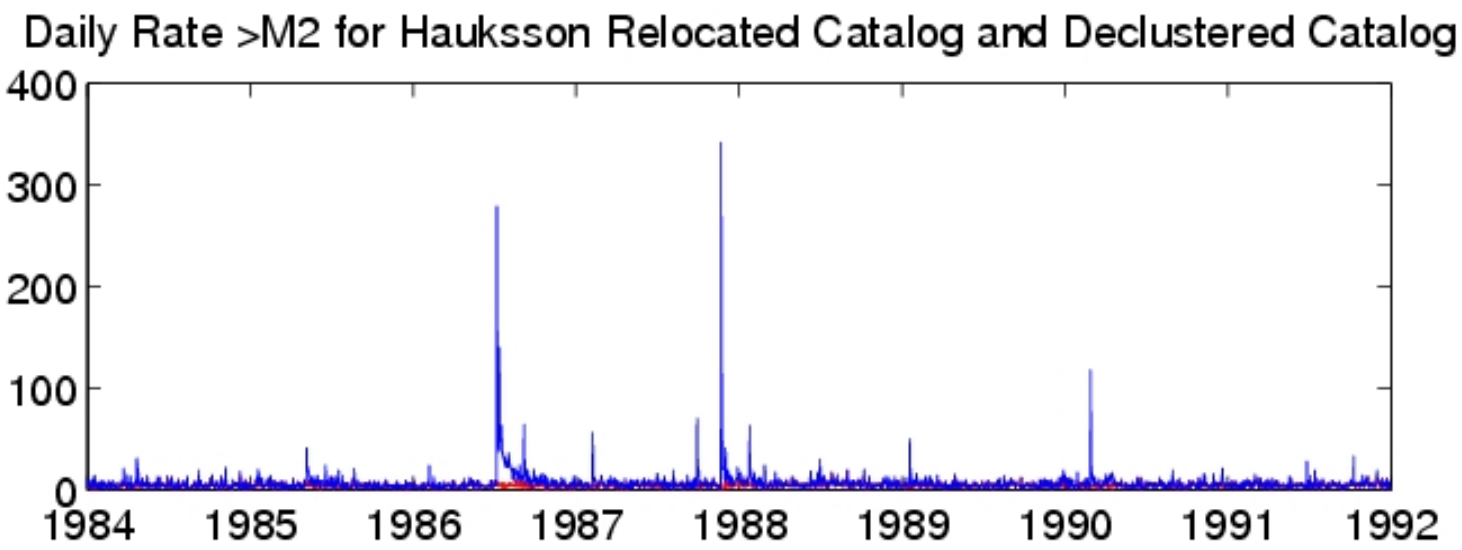
# The Landers Retro-Test

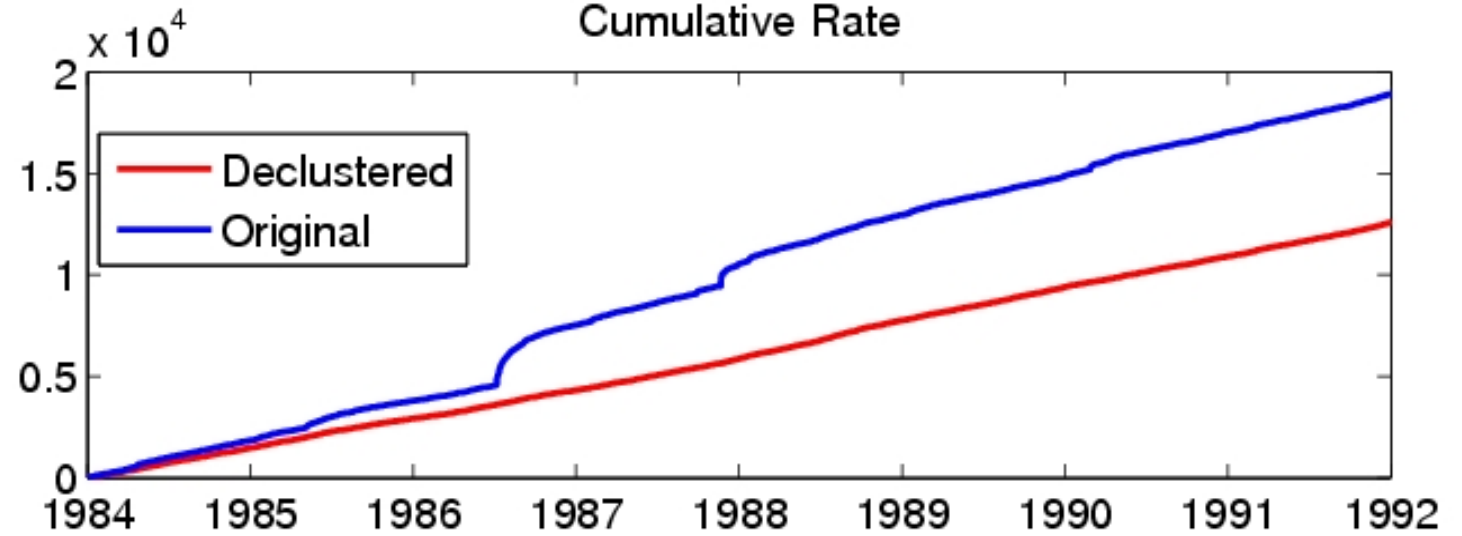
- **Methodological developments in a region of**
  - **high seismicity**
  - **high data quality and various available earthquake catalogs**
  - **main shock with multiple slip distribution solutions**
  - **additional data: GPS, INSAR, fault model**
- **Comparative forecast tests on local scale and short periods**
- **Development of an suitable testing strategy combining different model elements**

# The Landers Retro-Test

- Forecast region: -117.5W/33.25N - -115.5W /35.5N
- Data selection region: -119W/32.5N - -115.5W /36.5N
- Grid: 0.05º X 0.05º
- Relocated Hauksson catalog (1984-2001)
- Background model: Declustered catalog 1984-1991 using modified Reasenberg declustering code (see Helmstetter, 2007)
- Forecasts: 24h forecasts, starting 28.06.1992 for 90 days, $4 \leq M \leq 8$

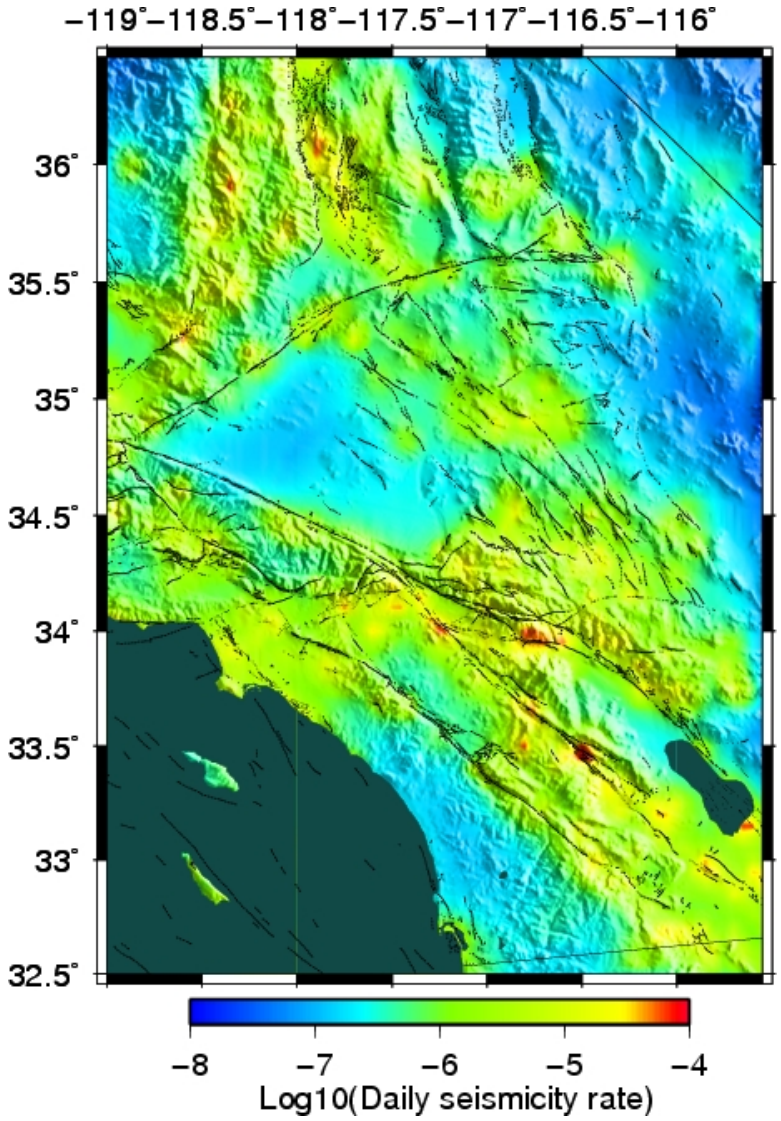
# Background model



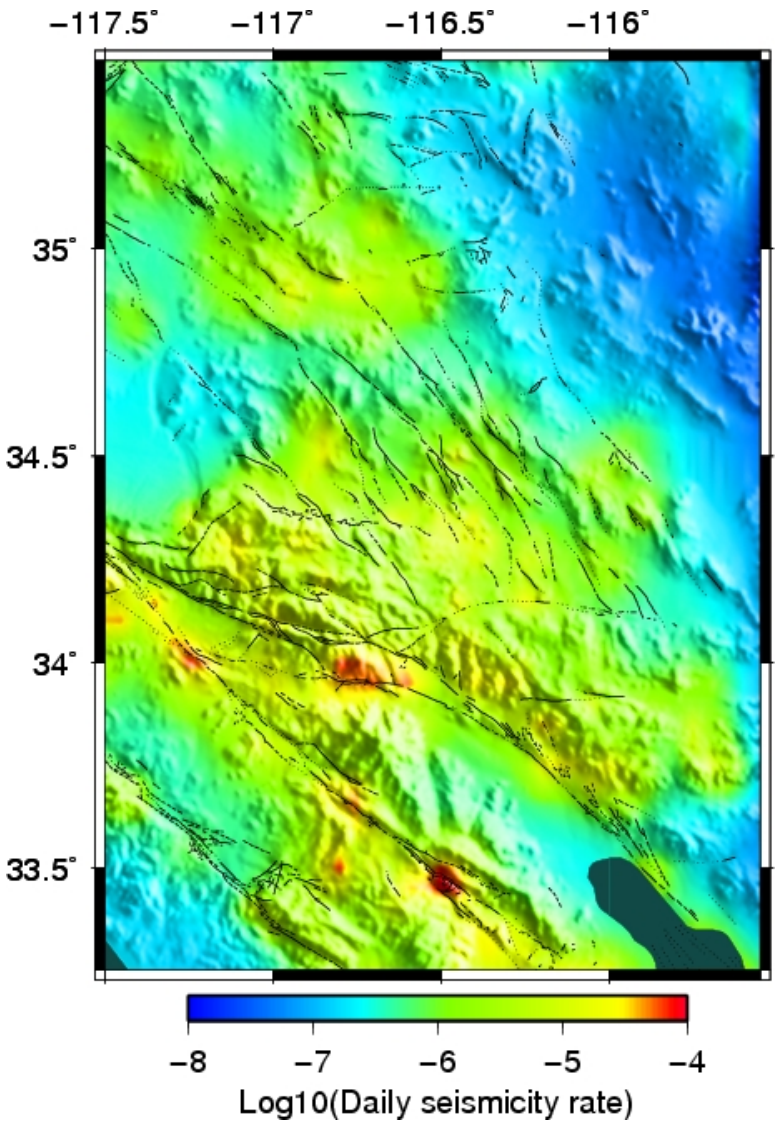



# Background model

## Southern California

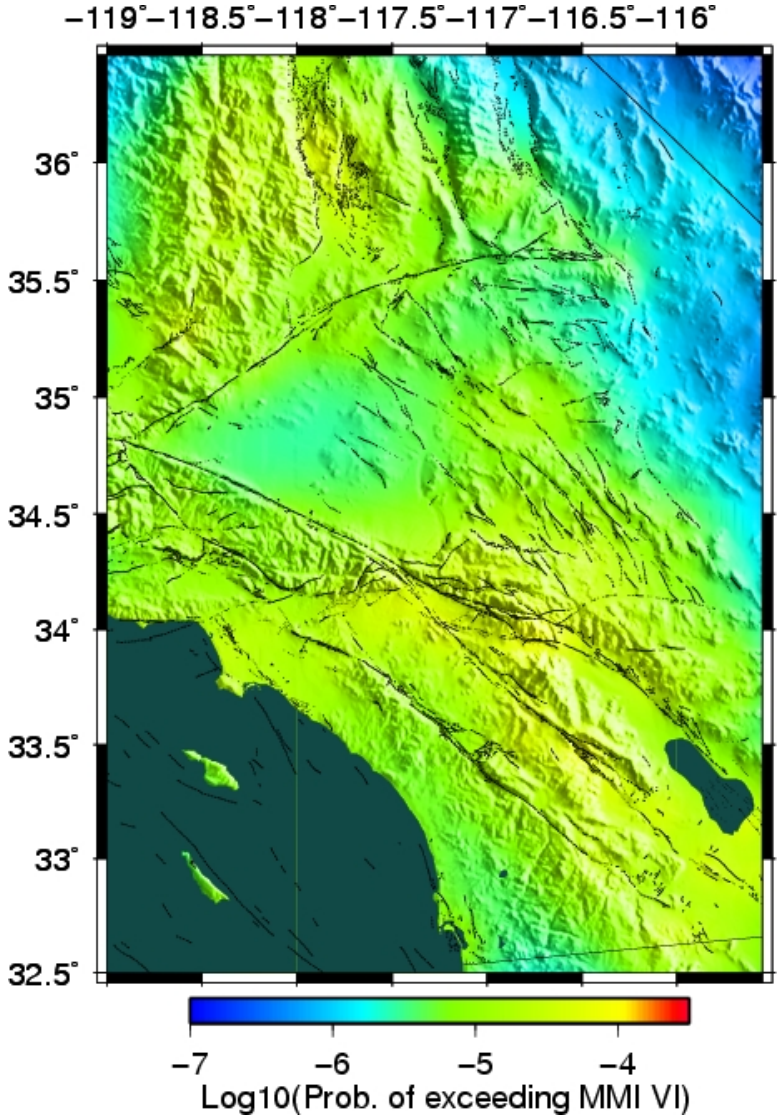



## Forecast box

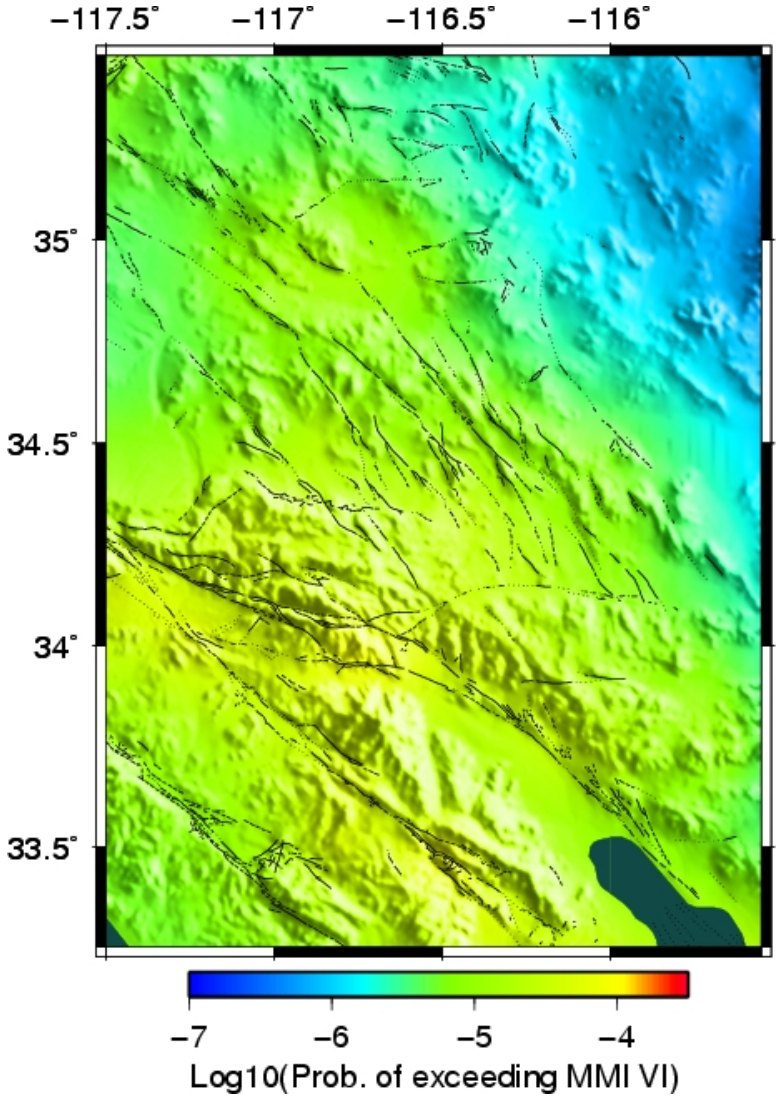


# Background Hazard

## Southern California




## Forecast box

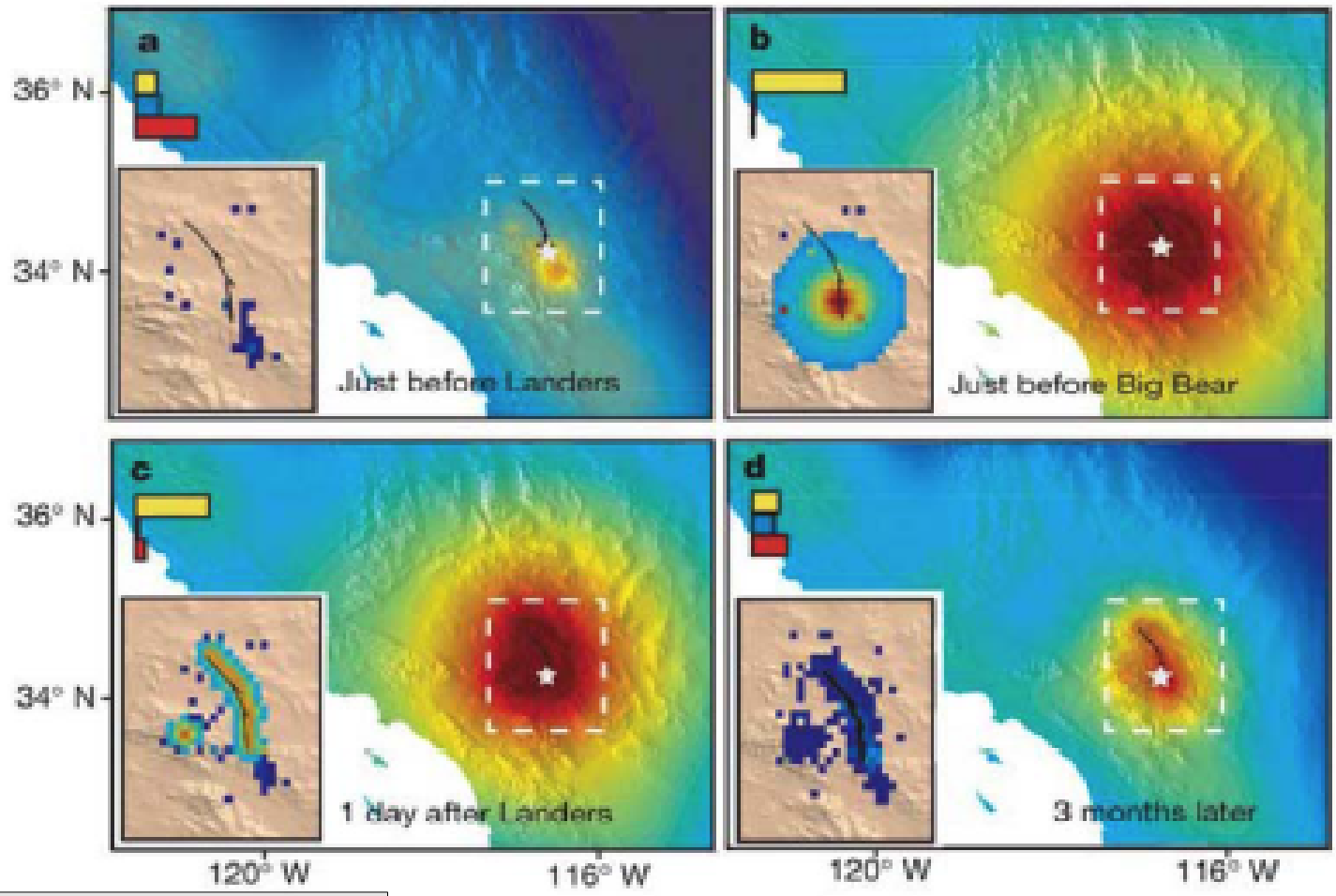


# Forecast Models

- **Short Term Earthquake Probabilitites (STEP, Gerstenberger et al., 2005)**
- **STEP generic element with Coulomb weighting**
- **Epidemic Type Aftershock Sequence (ETAS) model (Helmstetter et al., 2007)**

**Focus: Comparative Test**

# STEP: Model elements




**Model elements:**

Generic

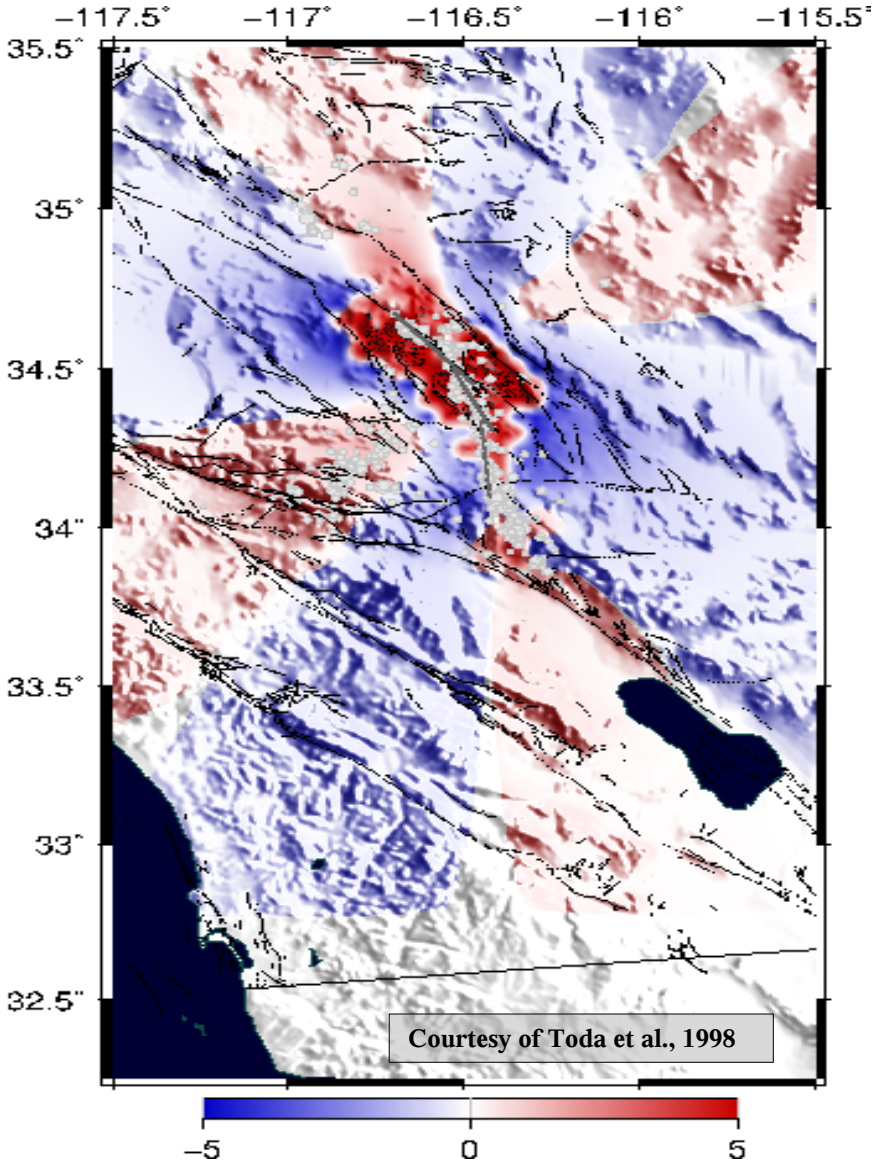
Sequence specific

Spatially heterogeneous

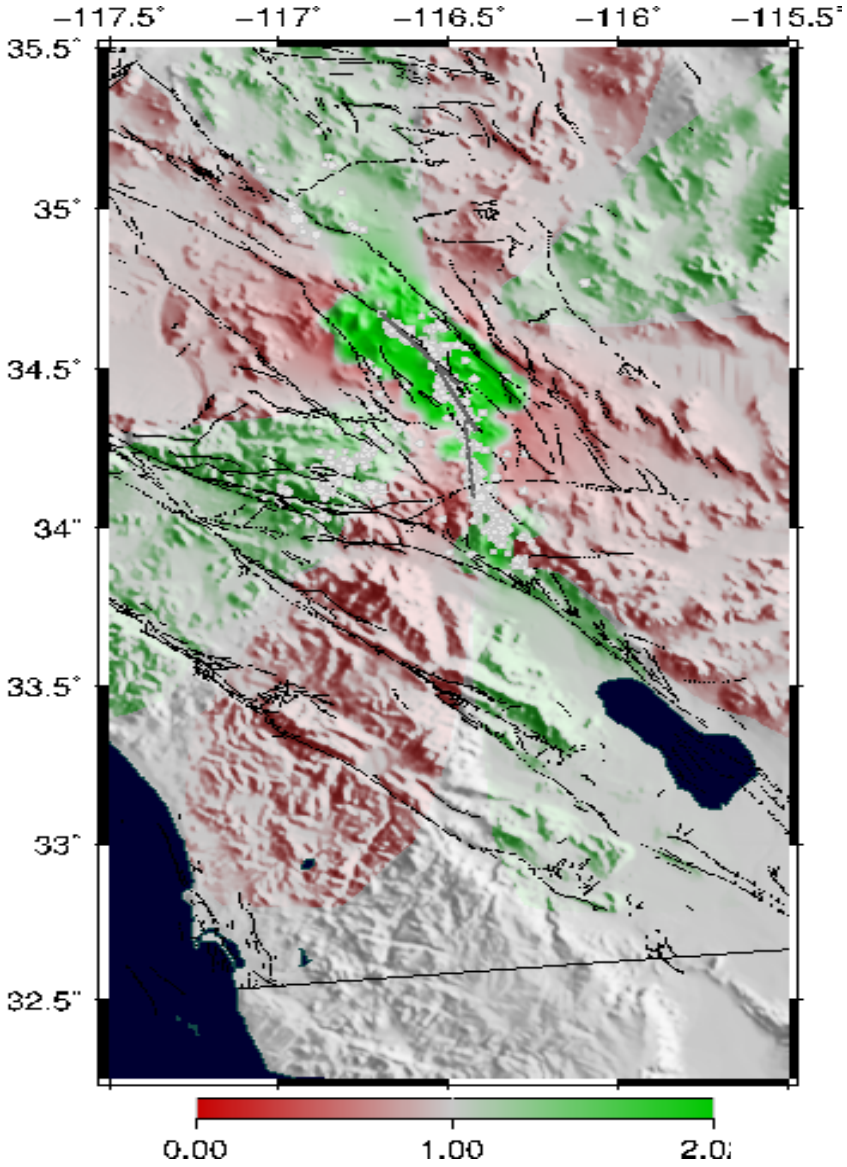
Gerstenberger et al., 2005

# Coulomb: Model and Scalar

## Coulomb stress changes

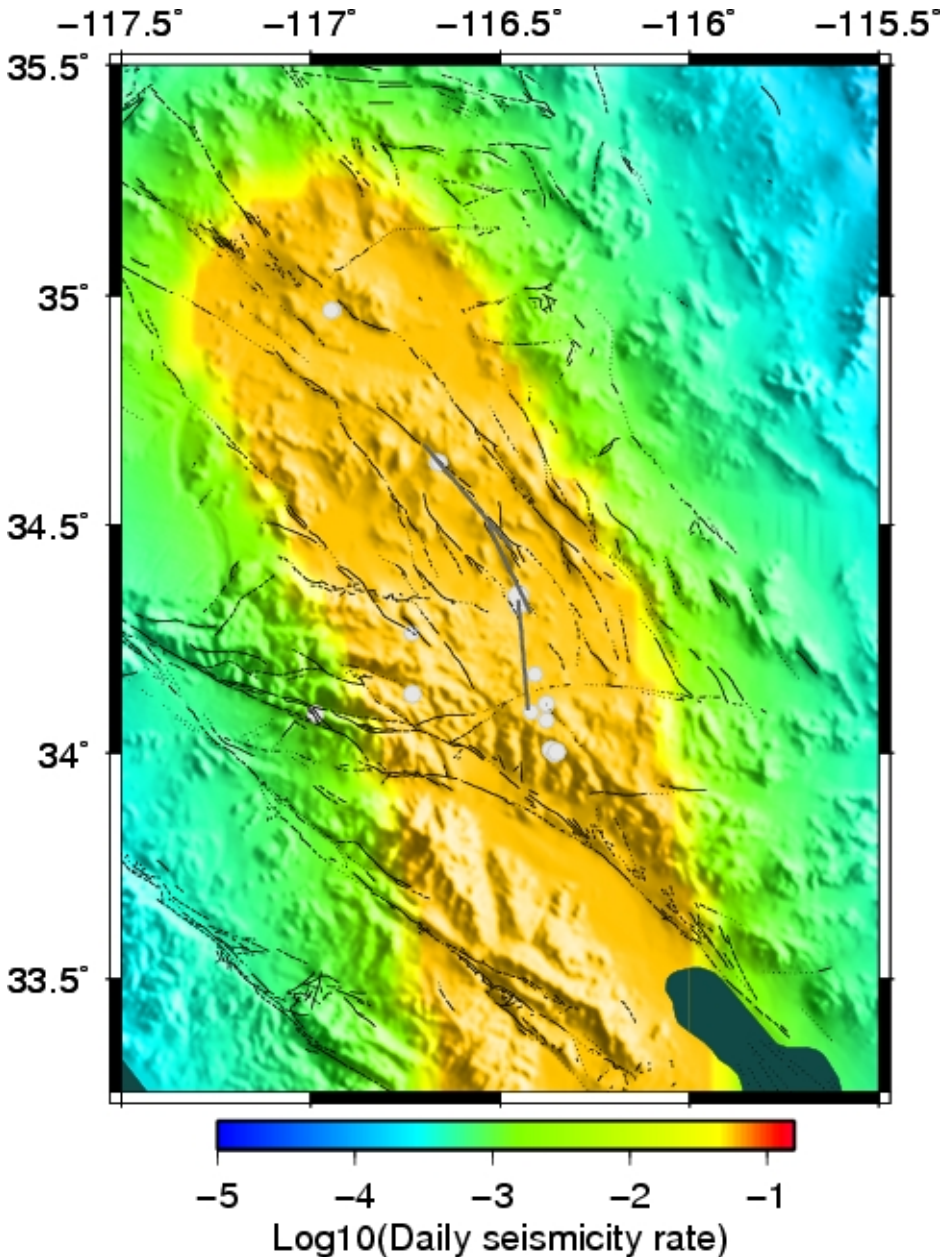



## Converted scalar

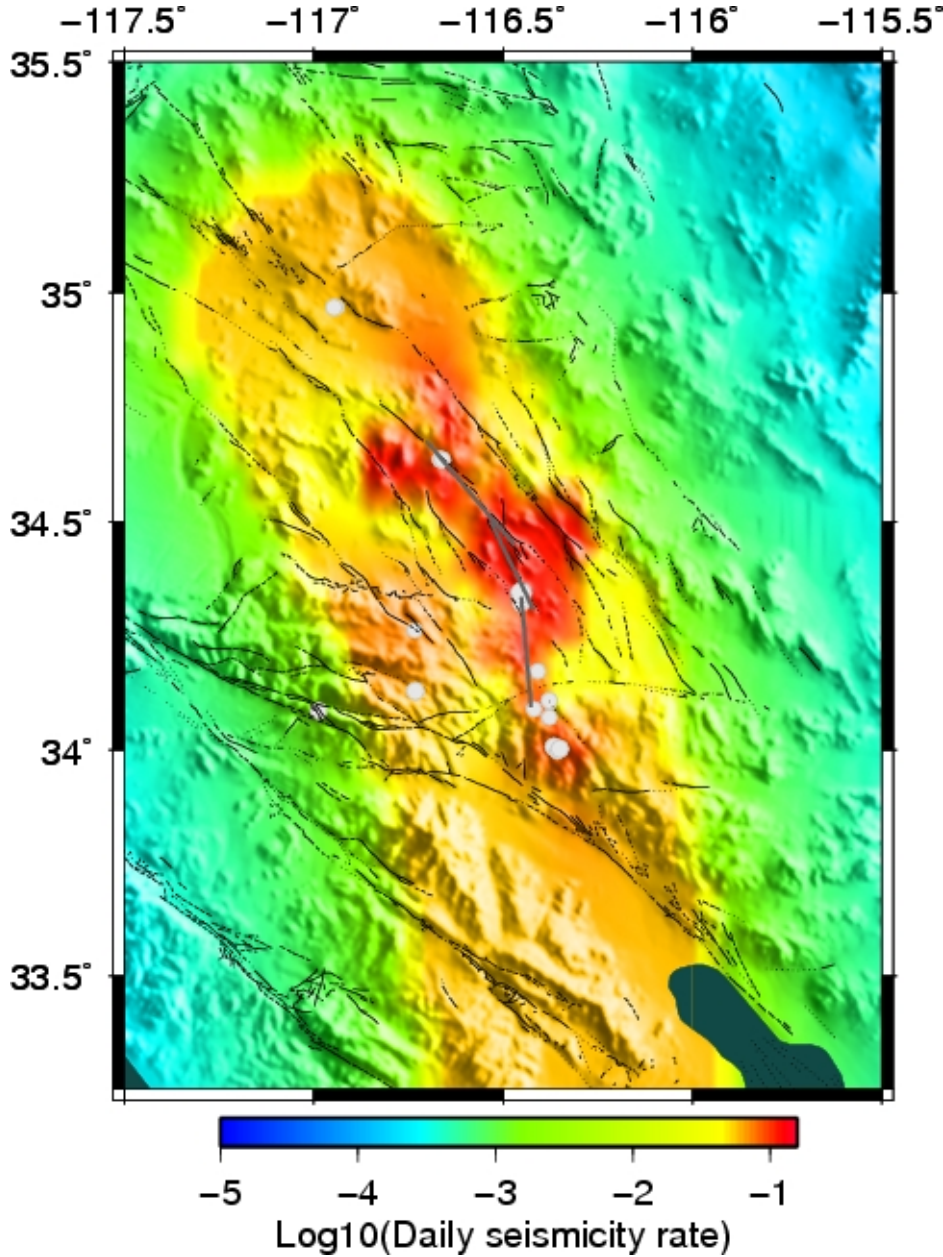


# Forecast: Day 3 (30-31.6.1992)

**STEP generic**

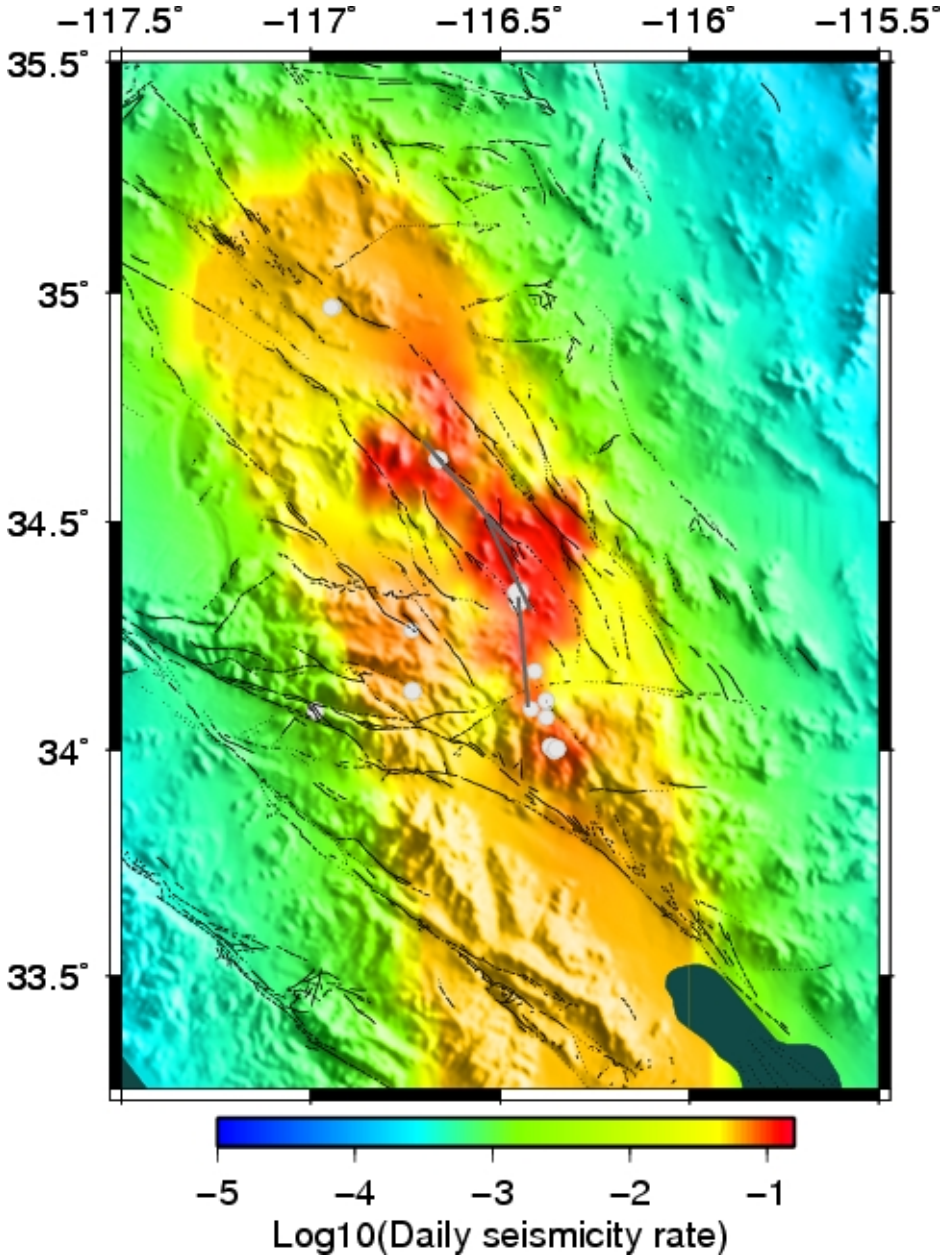



**STEP generic element Coulomb scaled**

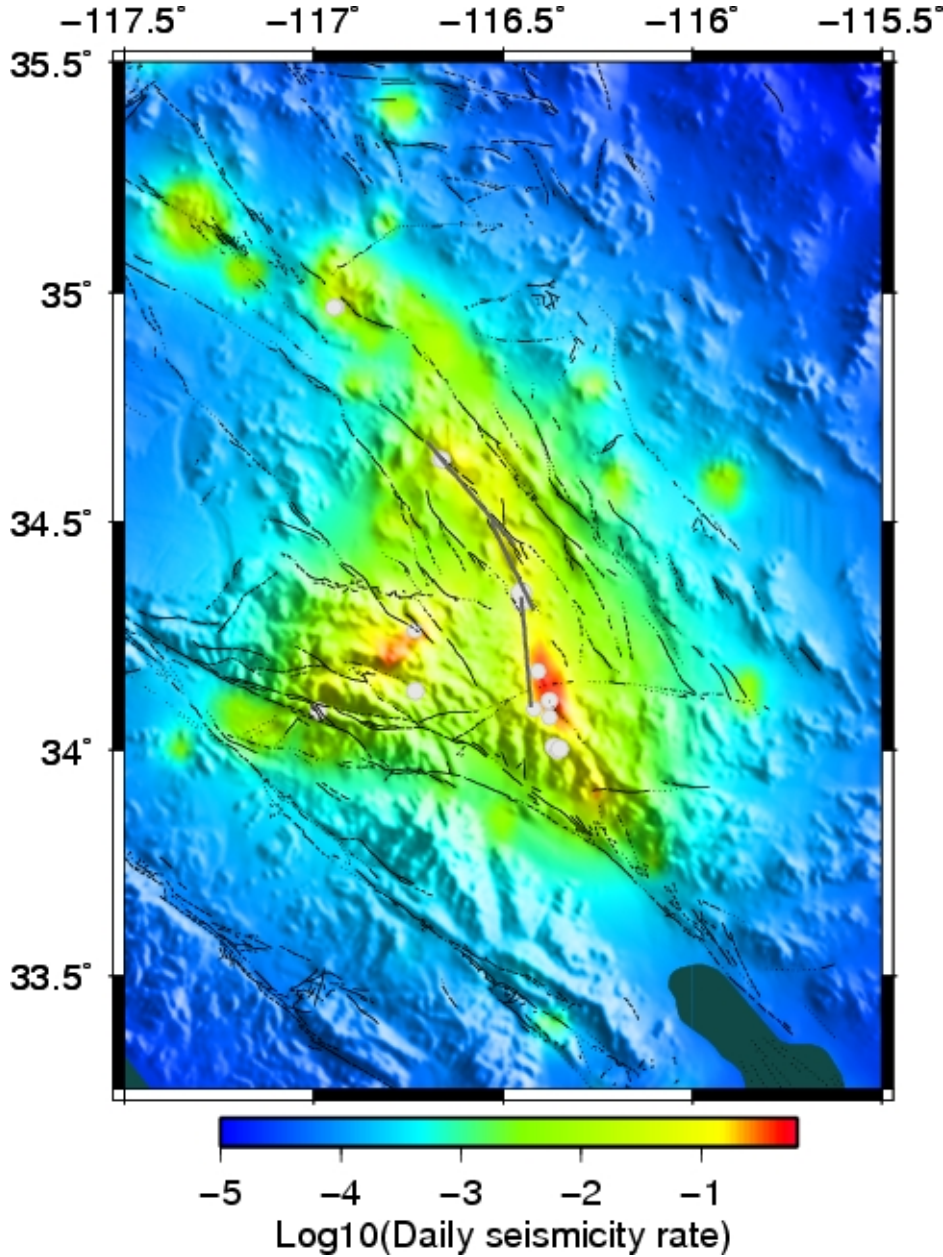


# Forecast: Day 3 (30-31.6.1992)

**STEP generic element**
**Coulomb scaled**



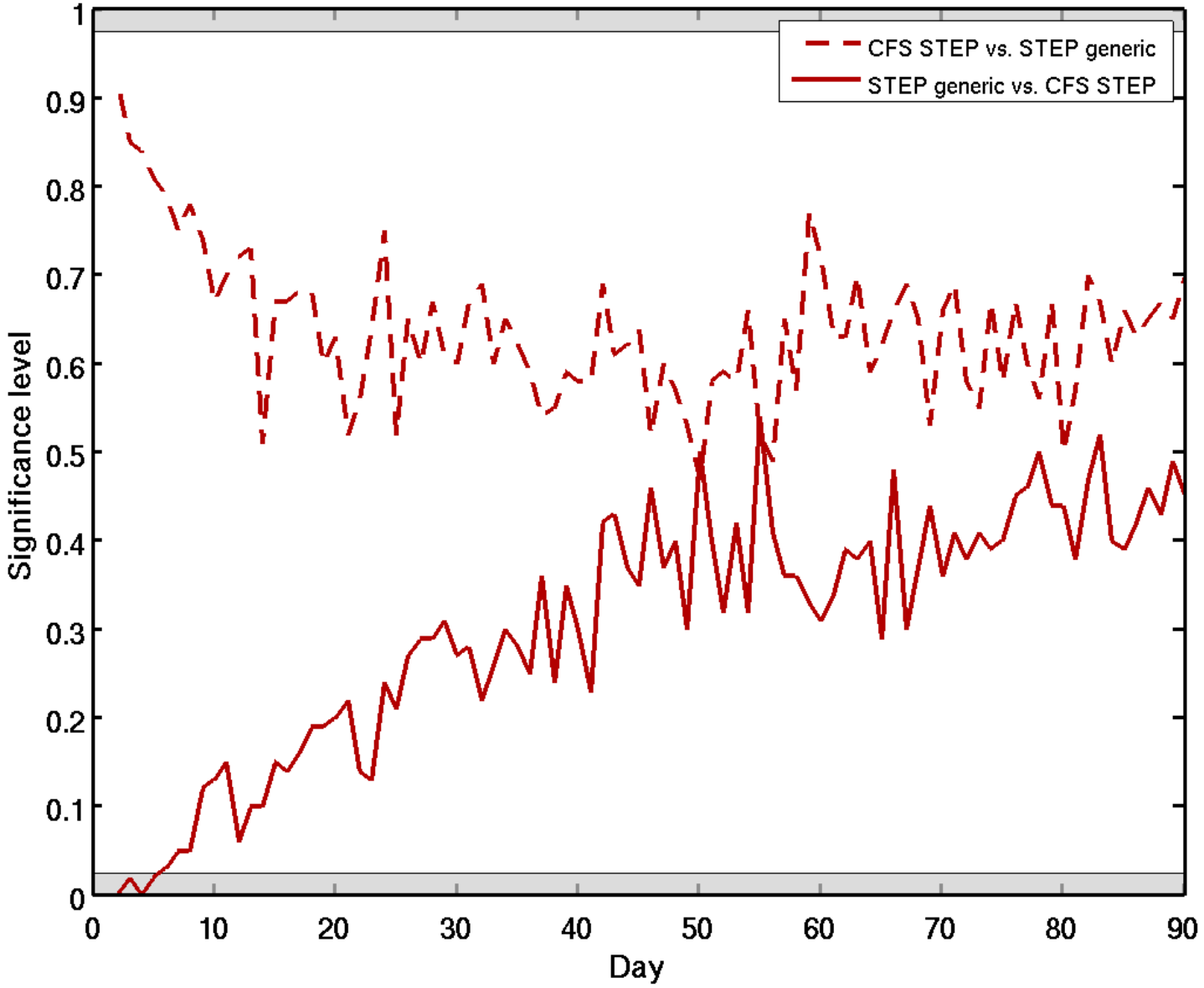

**ETAS**



# RELM-Tests

- **L-Test: Data consistency test in likelihood space**
- **N-Test: Data consistency test in number space**
- **R-Test: Likelihood ratio test for relative performance of forecast models:**
  - **Use forecast of one model as Null-hypothesis, forecast of second model as Test-hypothesis**

# R-Test: Time series



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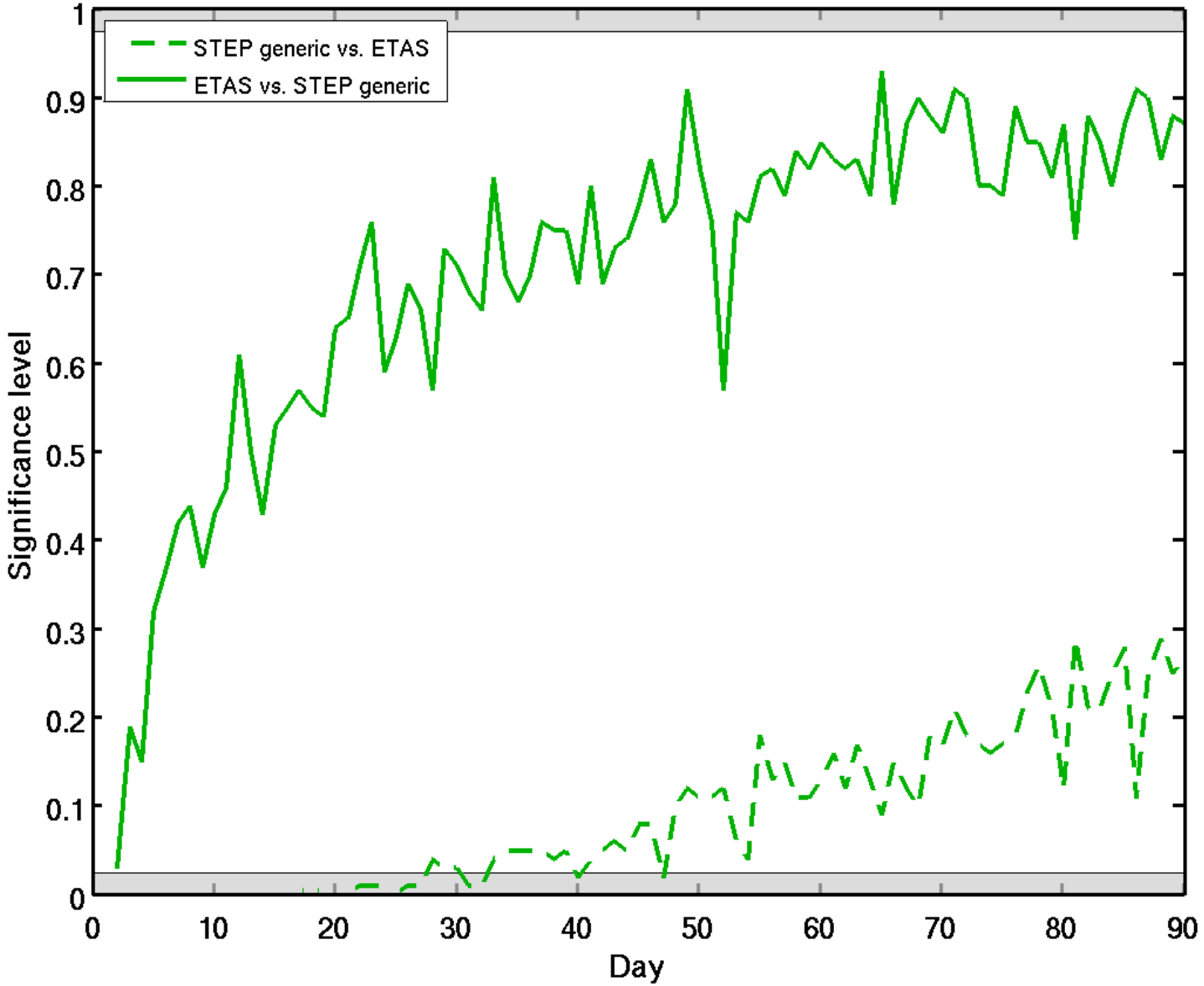
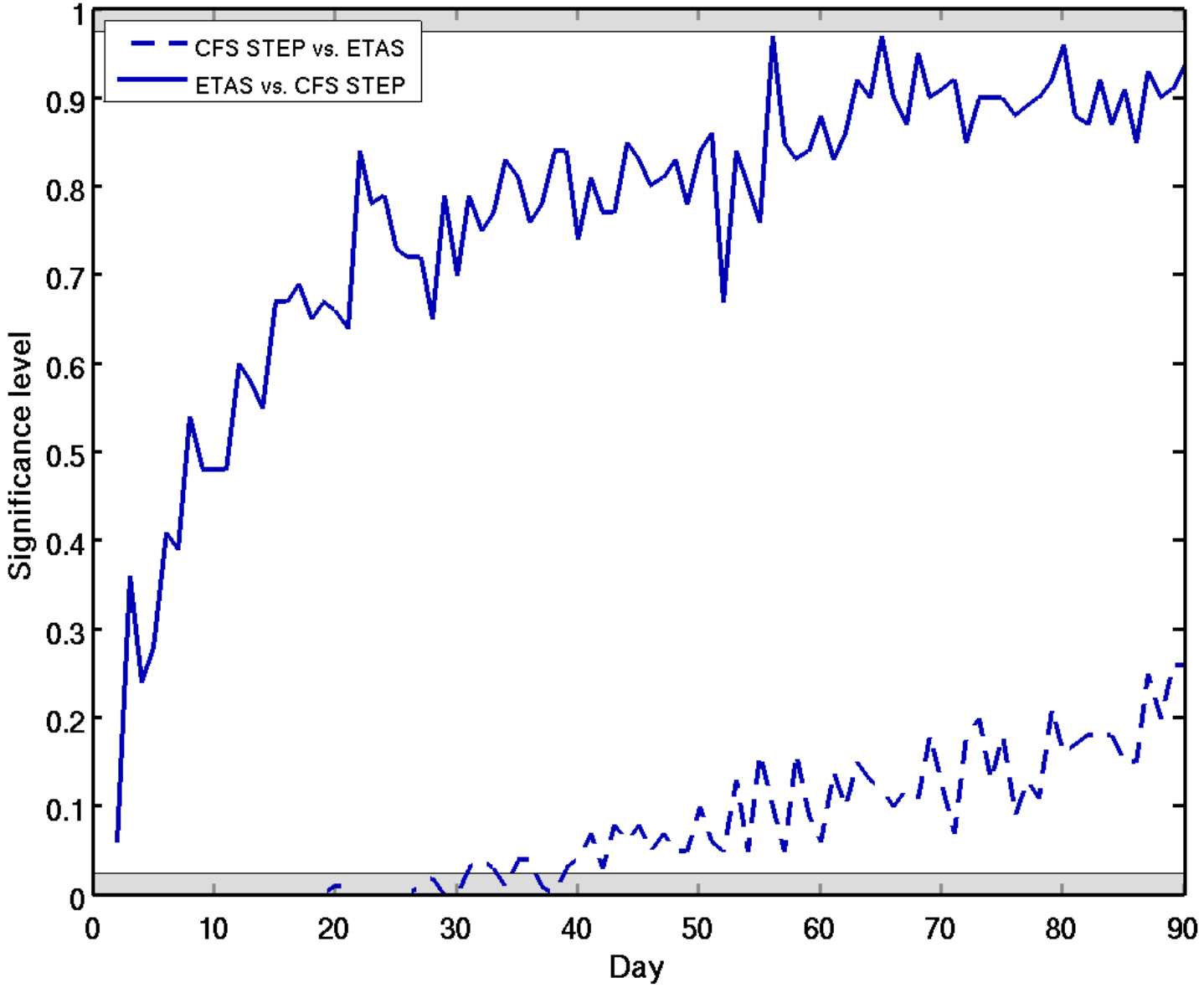


# R-Test: Time series



# Retrospective Testing Summary

- **R-Test supports ETAS as superior model of the evaluated ones**

- **STEP model capabilities not fully explored**
- **Including more models:**
  **Coulomb in combination with rate- and state friction model needs to be tested against (INGV)**
- **Forecasting scheme with memory: work in progress**

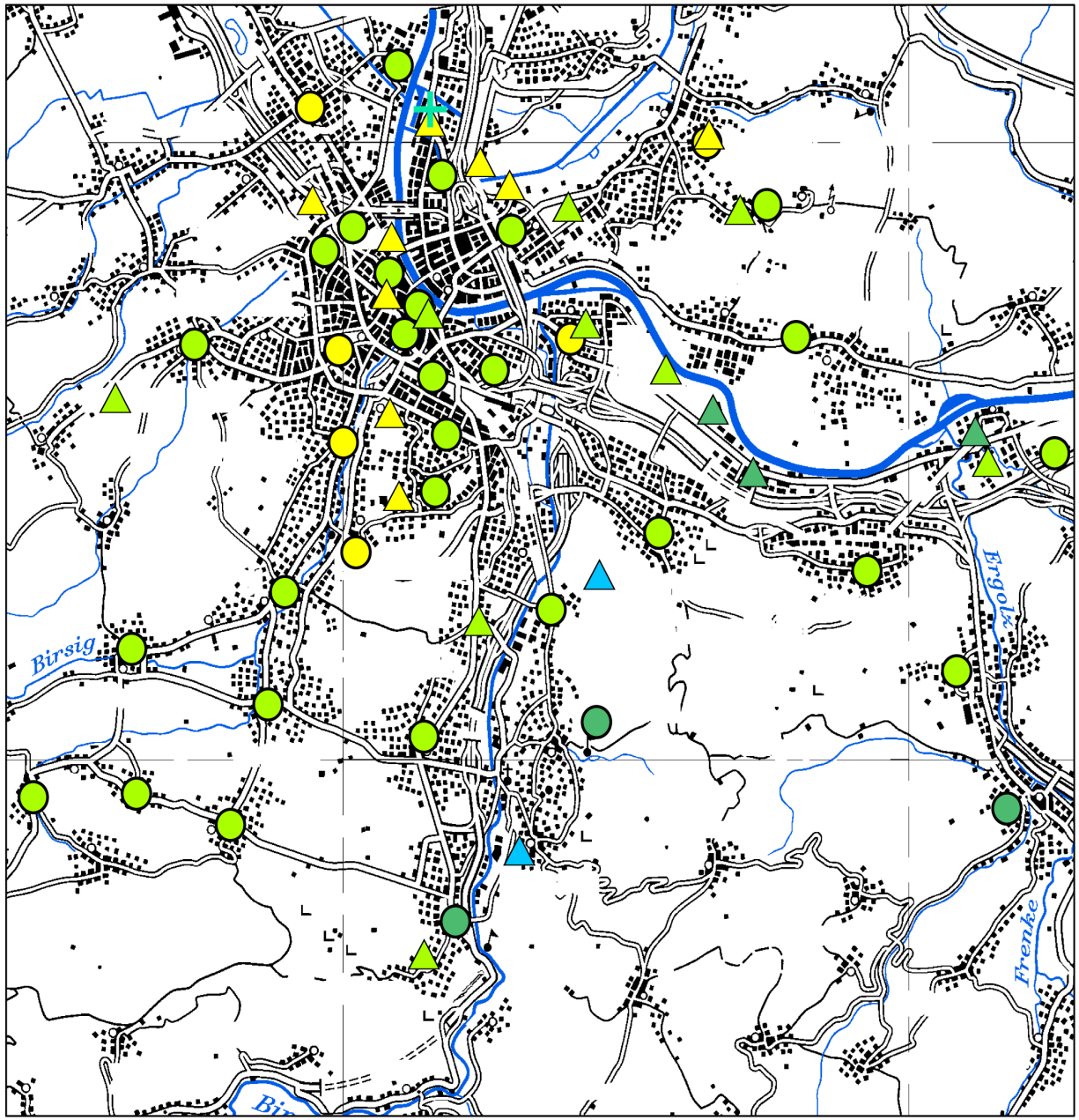
# STEP - Switzerland

Needed or not? Sure!

- Destructive historical earthquakes (1356 Basel, Mw=6.9)
- Geothermal injection experiment in Basel in 2006


**Researchers cause earthquake in Basel**

# Observed vs. instrumental intensities




intensities
for the 2006-12-08 Basel event
(Ml=3.4)

Macroseismic Intensity
- I
- II
- III
- IV
- V
- VI

instrumental intensity
estimated from pgv
- II
- III
- IV
- V

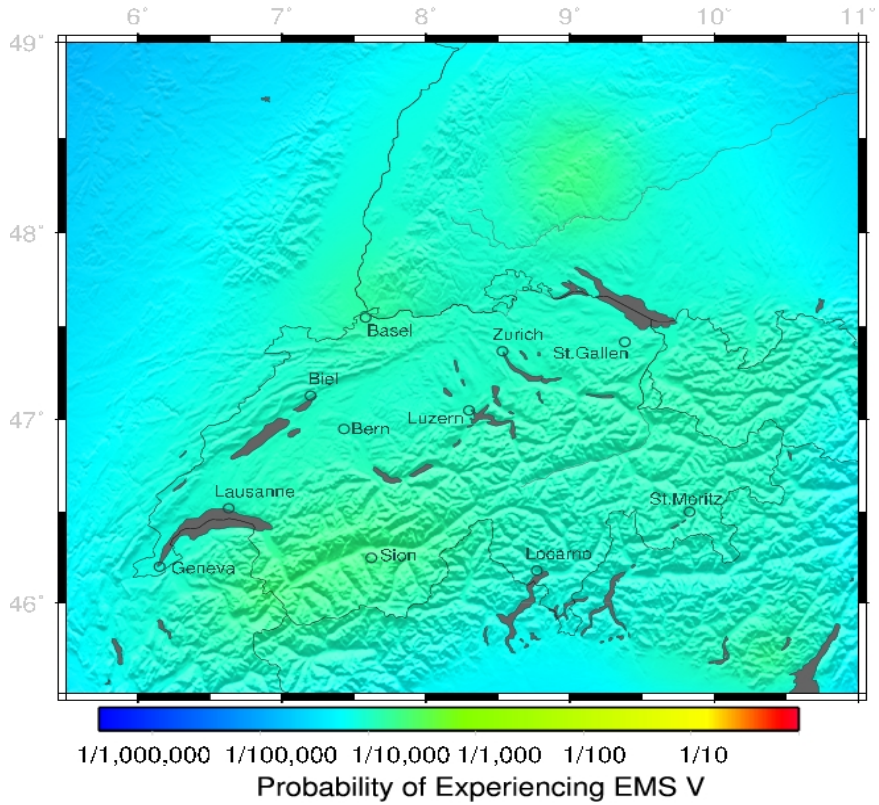
**$M_L$=3.4,**
**Basel,**
**08.12.2006**

# STEP - Switzerland

## Background

**Challenges:**

**- low-seismicity region: low aftershock productivity region?**
**- are there other models more appropriate for this region?**

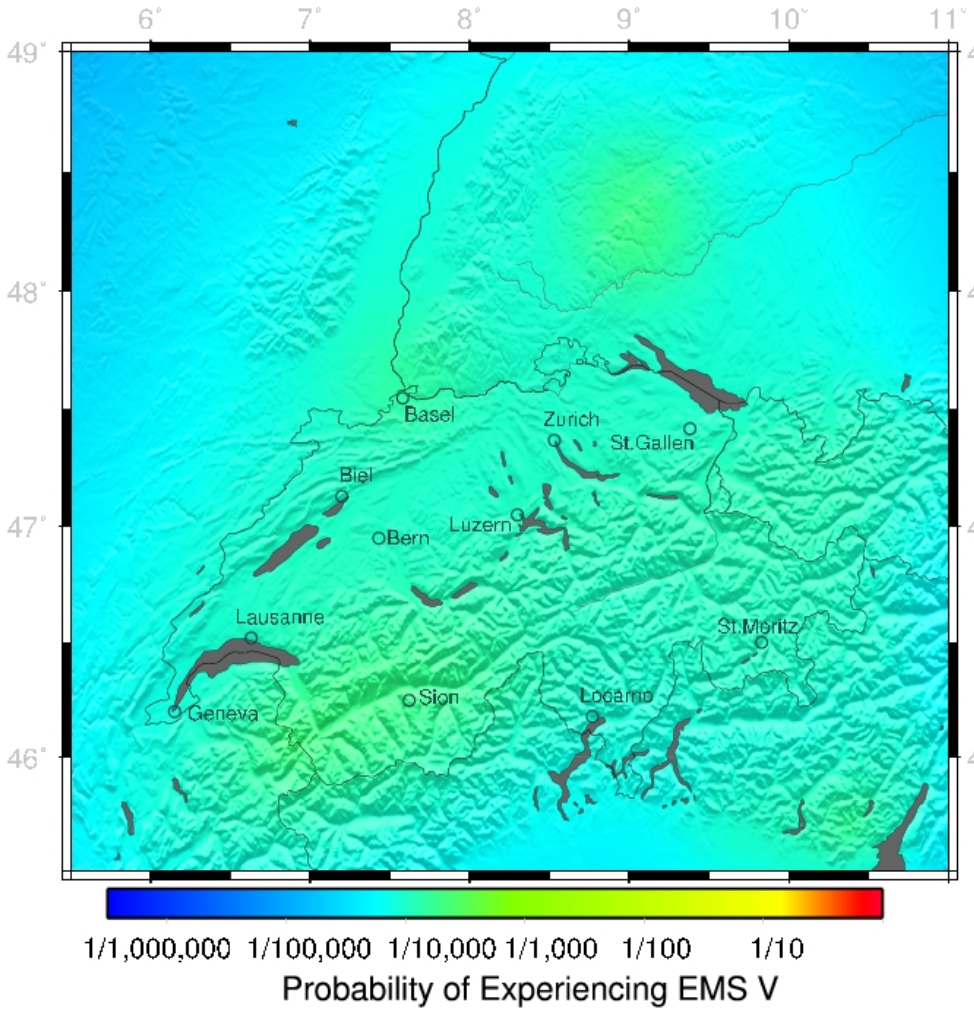



Based on Swiss Seismic Hazard 2004 (Giardini et al., 2004)

# STEP - Switzerland

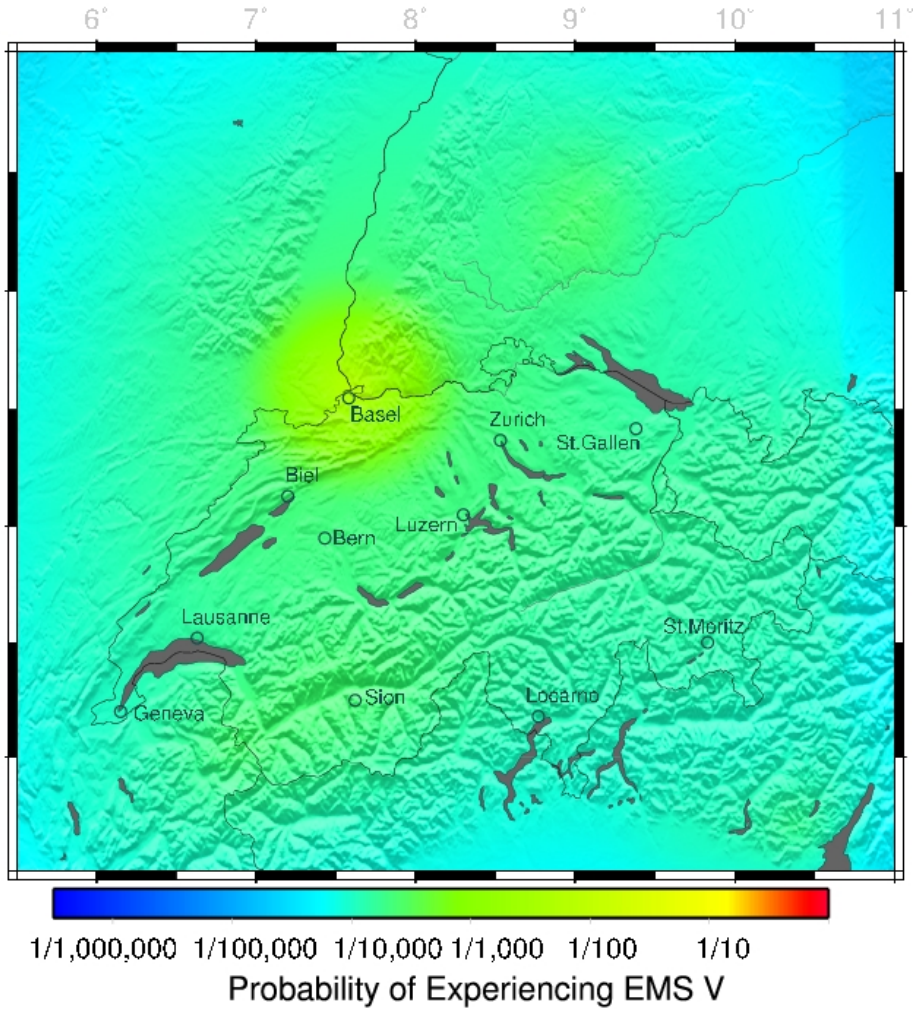
Forecast for 8.12.2006, 16:00 (MET)

through 9.12.2006, 16:00 (MET)




Forecast for 8.12.2006, 17:00 (MET)

through 9.12.2006, 17:00 (MET)

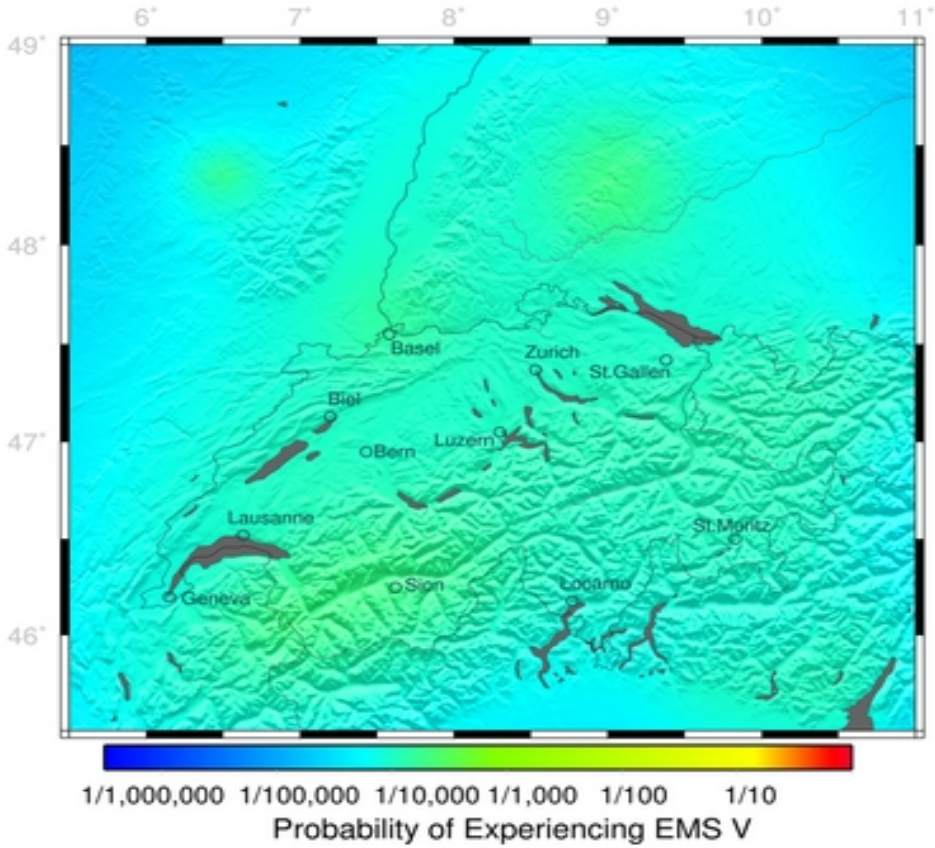


# Summary

- **Stable real-time implementation**
- **Regionalization of seismicity parameters: new methodologies needed for low-seismicity region**
- **Improvement of attenuation function**
- **STEP on a very local scale: probability forecast for induced seismicity**

# STEP – Switzerland: Today

Forecast for 06/01/2007 09:30 AM CEST
through 6/2/2007 09:30 AM CEST



# Summary

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- **Regionalization of seismicity parameters: new methodologies needed for low-seismicity region**
- **Improvement of attenuation function**
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# Work In Progress

STEP in Turkey - Studying the North Anatolian Fault System:

Properties of the aftershock Sequence of the 1999 Mw 7.4 Kocaeli Earthquake: Implication for Aftershock Hazard

**M.B. Demircioglu,** S. Wiemer, J. Woessner,
K. Sesetyan, M. Erdik