Forecasting seismicity on local and regional scales

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5th International Workshop on Statistical Seismology:
Physical and Stochastic Modelling of Earthquake Occurrence and Forecasting
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

SAFER WP5

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

Regional scale

NERIES JRA2

Time-dependent hazard on nationwide / European scale

CSESP

From Local to Global scales

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 a suitable **testing strategy** combining different model elements
• Forecast region: -117.5W/33.25N - -115.5W/35.5N
• Data selection region: -119W/32.5N - -115.5W/36.5N
• Grid: 0.05° X 0.05°
• 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≤M≤8
Background model

Southern California

Forecast box

Log10(Daily seismicity rate)
Forecast Models

- Short Term Earthquake Probabilities (STEP, Gerstenberger et al., 2005)

- STEP generic element with Coulomb weighting

- Epidemic Type Aftershock Sequence (ETAS) model (Helmstetter et al., 2007)

Focus: Comparative Test
Model elements:

Generic
Sequence specific
Spatially heterogeneous

Gerstenberger et al., 2005
Coulomb stress changes

Converted scalar

Courtesy of Toda et al., 1998
Forecast: Day 3 (30-31.6.1992)

STEP generic element
Coulomb scaled

ETAS

Log10(Daily seismicity rate)
• **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
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
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

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
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)
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
Forecast for 06/01/2007 09:30 AM CEST through 06/02/2007 09:30 AM CEST
**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 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

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