Collaboratory for the Study of Earthquake Predictability

Current Capabilities

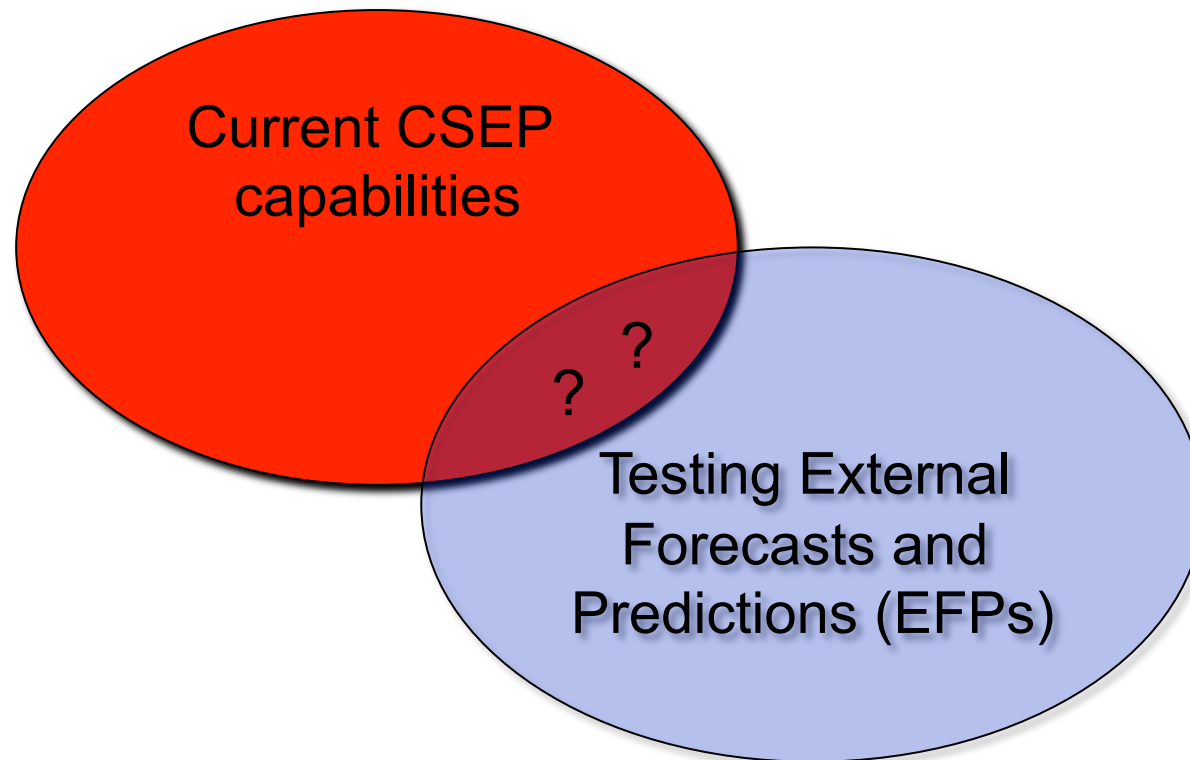*Tom Jordan, Phil Maechling, Masha Liukis, Danijel Schorlemmer, Max Werner, John Yu, Jeremy Zechar …*
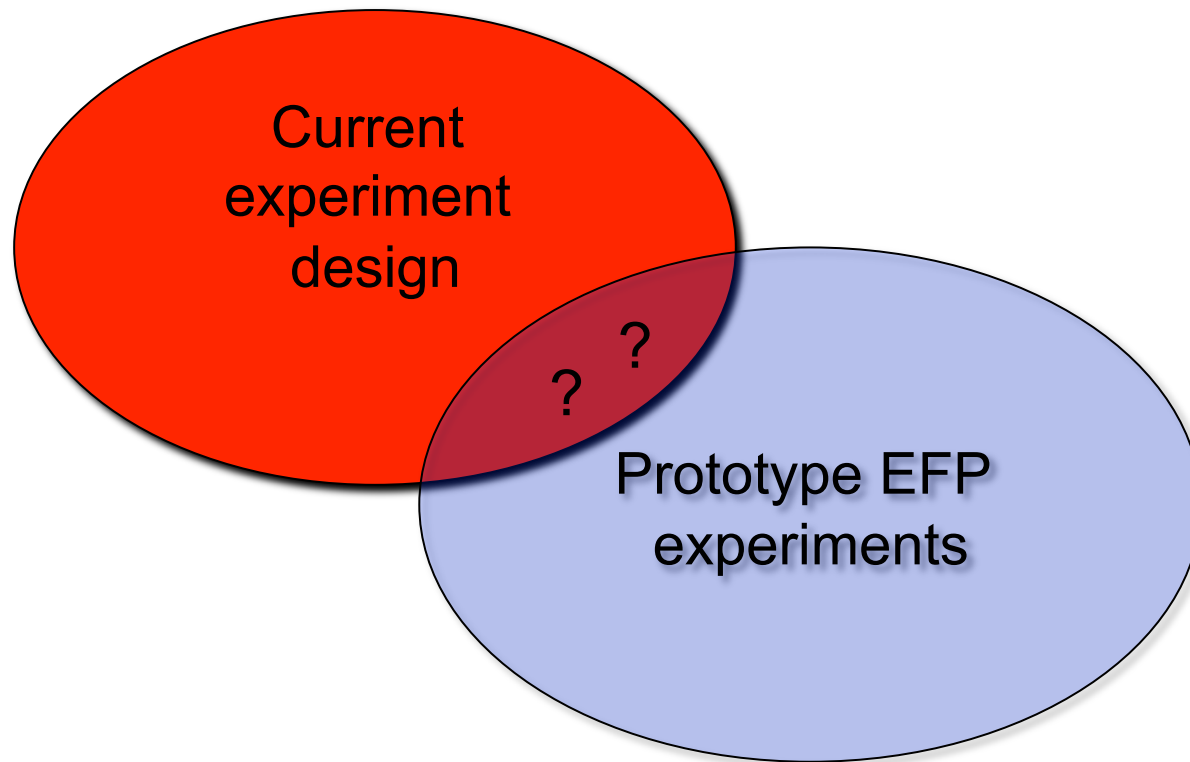*and the CSEP Working Group*

Purpose of this talk

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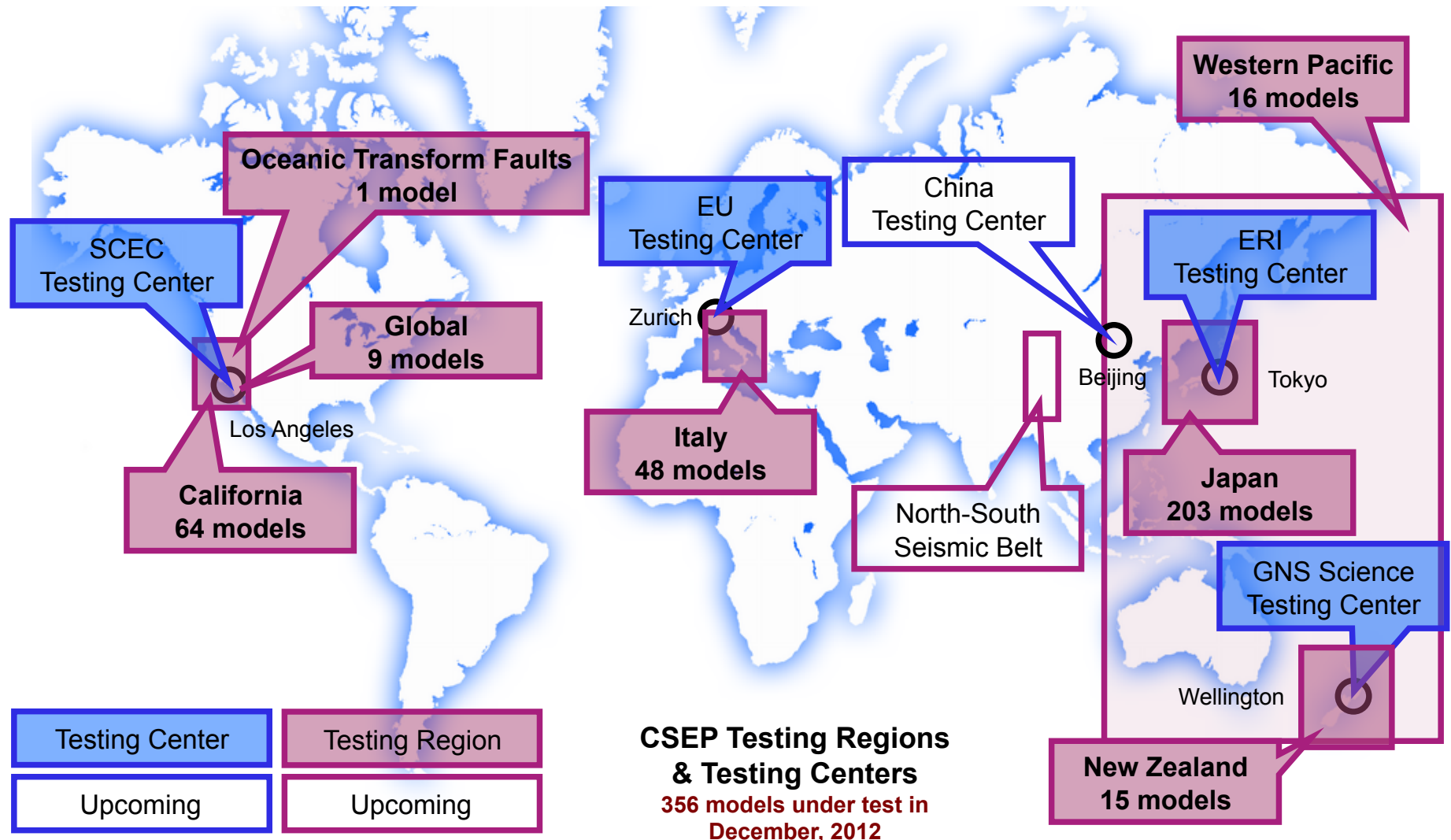# *Collaboratory for the Study of Earthquake Predictability*

- **CSEP goal is an infrastructure for conducting predictability experiments and research**

  - Transparent and reproducible evaluation of predictability hypotheses and forecasting models

  - Automate blind, prospective testing in a standardized, controlled environment ("zero degrees of freedom")

  - Establish experiments in a variety of tectonic environments and on a global scale

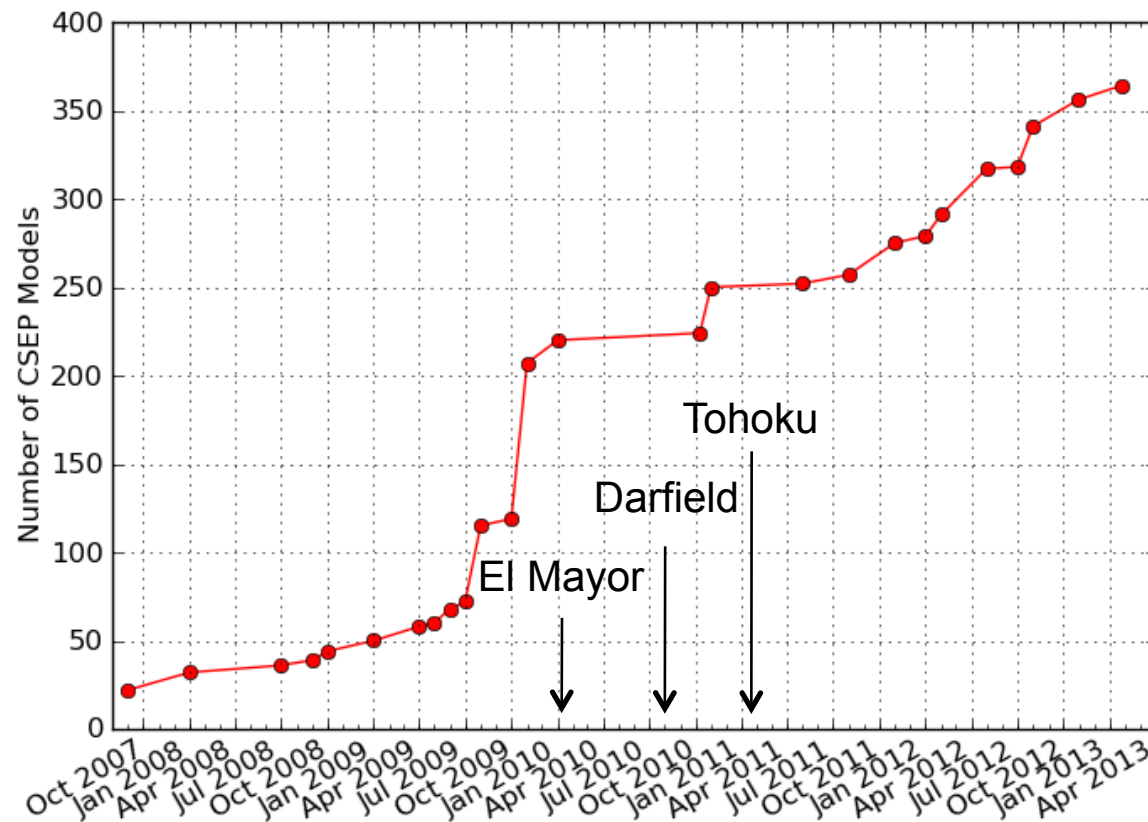 - Provide model performance feedback to guide model improvements

CSEP Components

- *Natural laboratories* comprising active fault systems with adequate, authorized data sources for conducting forecasting experiments

- *Testing centers* with validated procedures for registering and evaluating predictability experiments

- *Model classes* with common target events, forecasting regions, and forecast updating intervals

Collaboratory for the Study of Earthquake Predictability

Infrastructure for automated, blind, prospective assessment of forecasting models in a variety of tectonic environments and on a global scale


Western Pacific
16 models

Oceanic Transform Faults
1 model

China
Testing Center

ERI
Testing Center

EU
Testing Center

SCEC
Testing Center

Global
9 models

Zurich

Beijing

Tokyo

Los Angeles

California
64 models

Italy
48 models

North-South
Seismic Belt

Japan
203 models

GNS Science
Testing Center

Wellington

New Zealand
15 models

Testing Center

Testing Region

Upcoming

Upcoming

**CSEP Testing Regions
& Testing Centers**
356 models under test in
December, 2012

364 models under evaluation

Example models:

RELM	Regional Earthquake Likelihood Models	**STEP**	Short-Term Earthquake Probabilities
PPE	Proximity to Past Earthquakes	**ETAS**	Epidemic-Type Aftershock Sequences
TripleS	Simple Smoothed Seismicity	**DBM**	Double Branching Model
EEPAS	Every Earthquake a Precursor According to Scale	**K^3**	Kernel-based space-time-magnitude smoothing

CSEP Information Technology (IT) Infrastructure

www.cseptesting.org
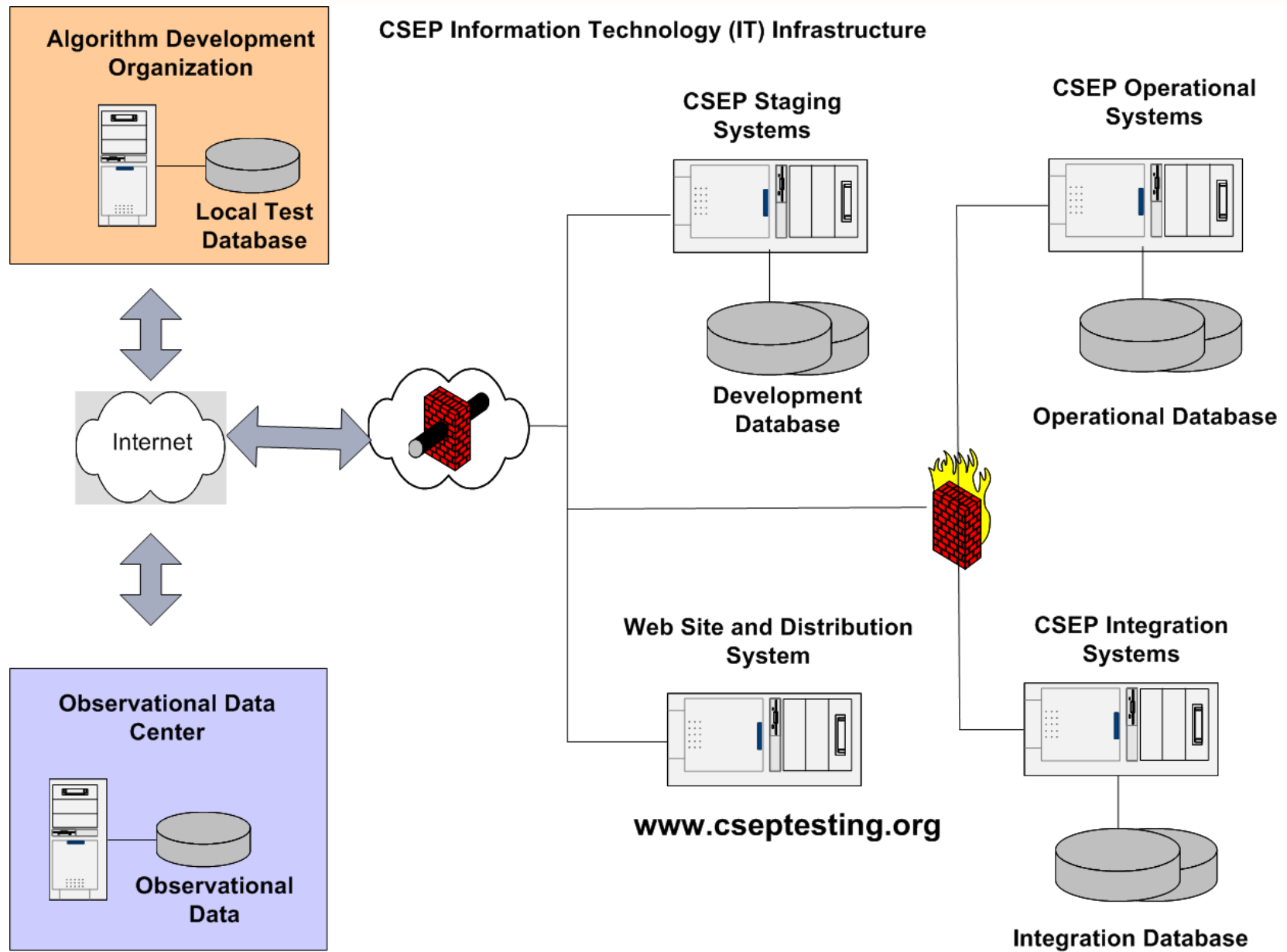
Experiment Design

- **Stakeholders jointly develop a prospective experiment according to agreed-upon rules**
  - Transparency, reproducibility, comparability
  - data availability, quality and quantity

- **Rules include**
  - region that the forecasts cover (at least partially)
  - magnitude threshold
  - duration of the experiment
  - nature of forecast (forecast of what?)
  - Format of forecast (codes, tables, metadata, submission formats)
  - an (independent and reliable) source of data for evaluation
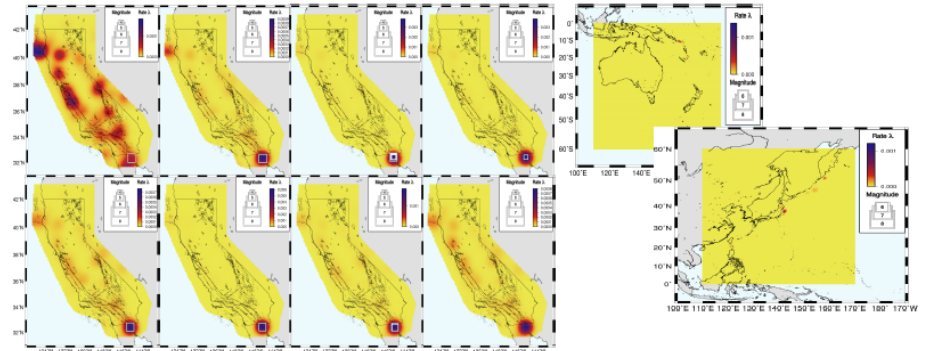 - evaluation methods
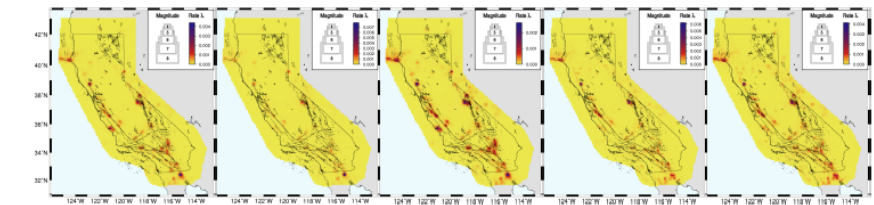
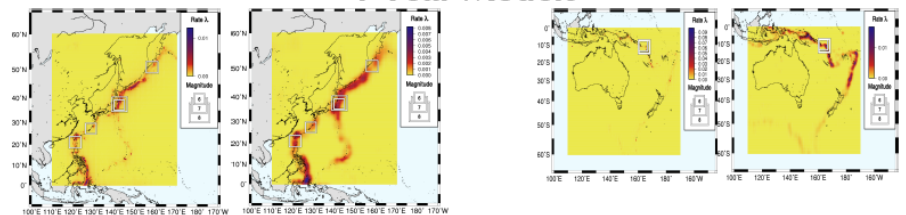# Example of a Testing Region
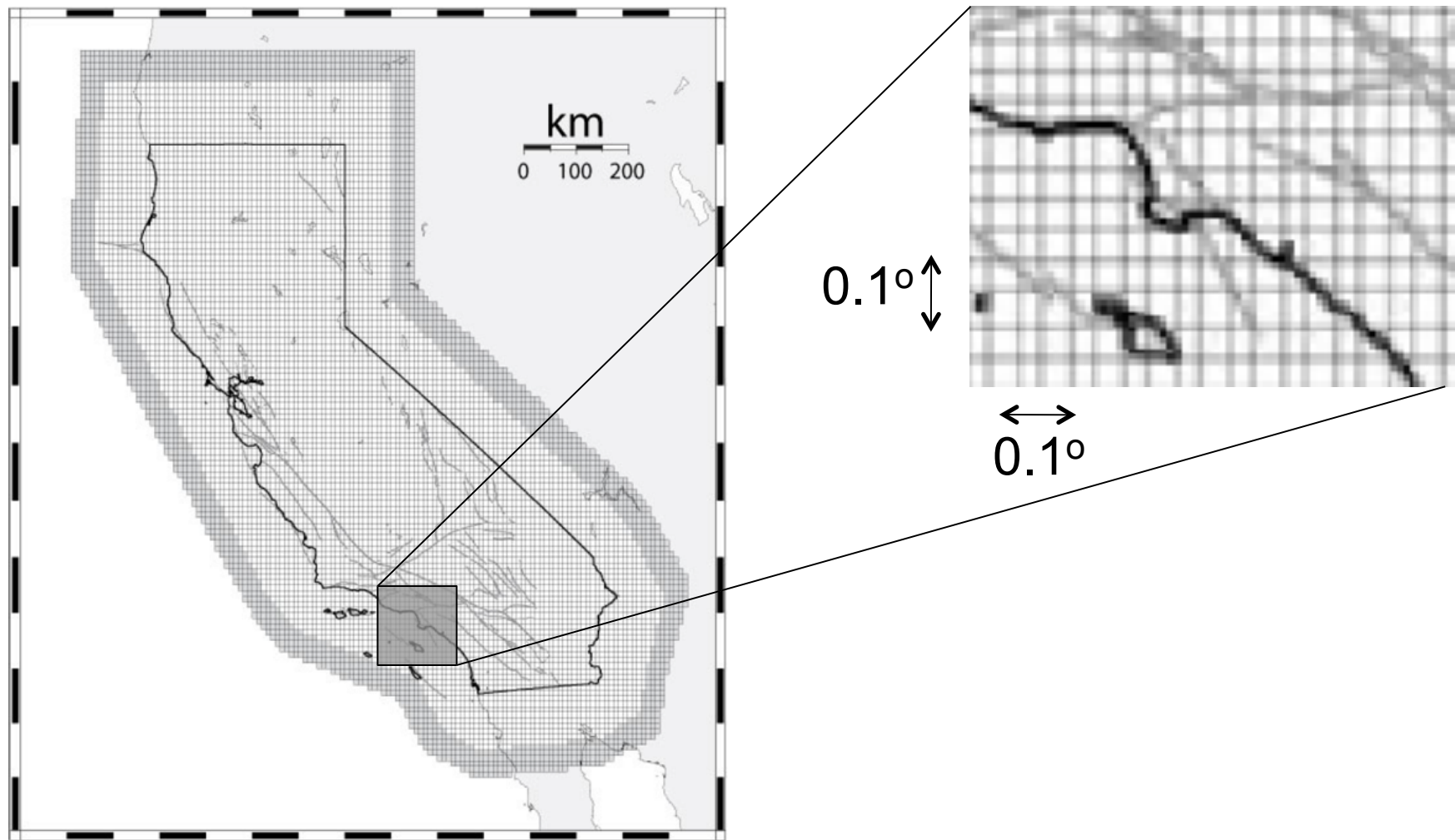
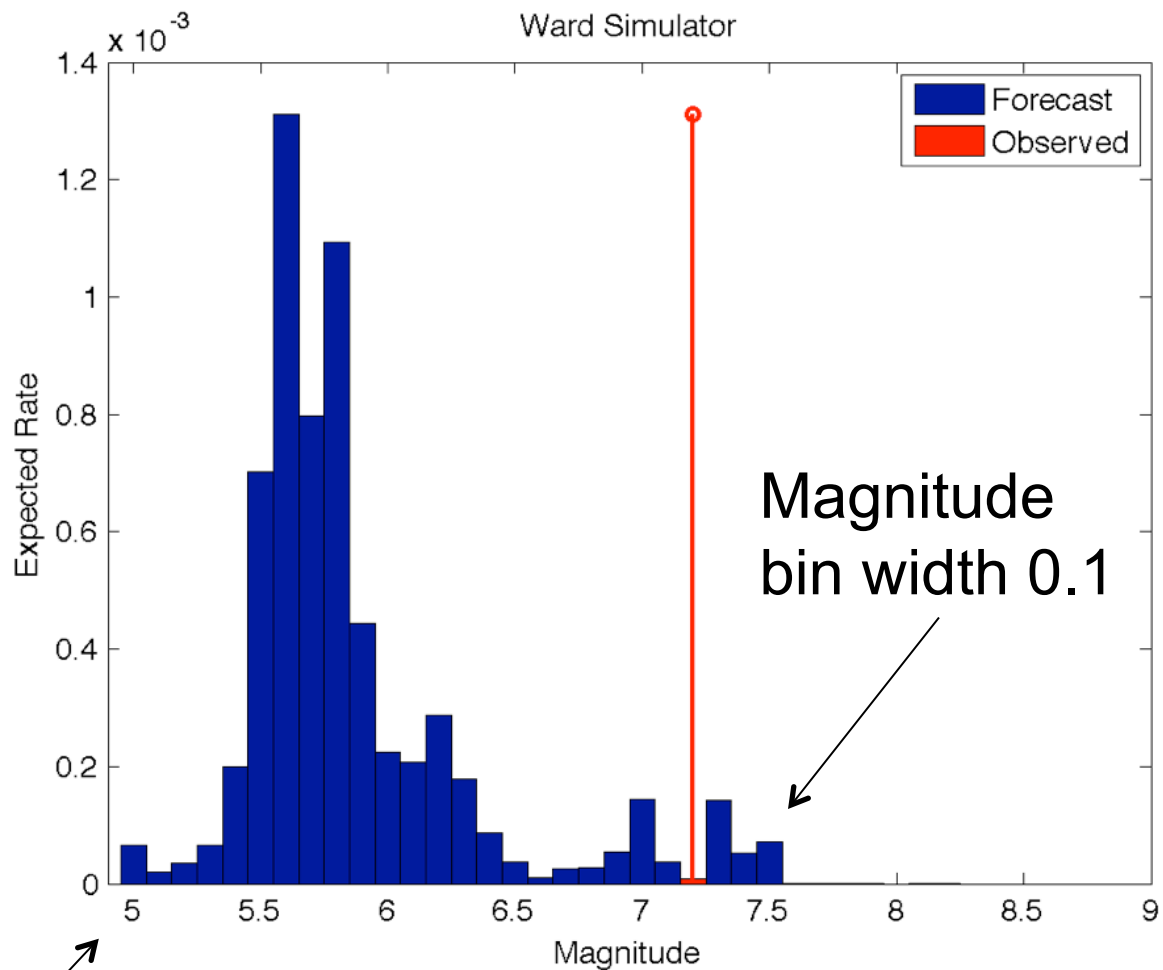# Forecast Duration

RELM 5-Year Models

1-Day Models

Mainshock Models
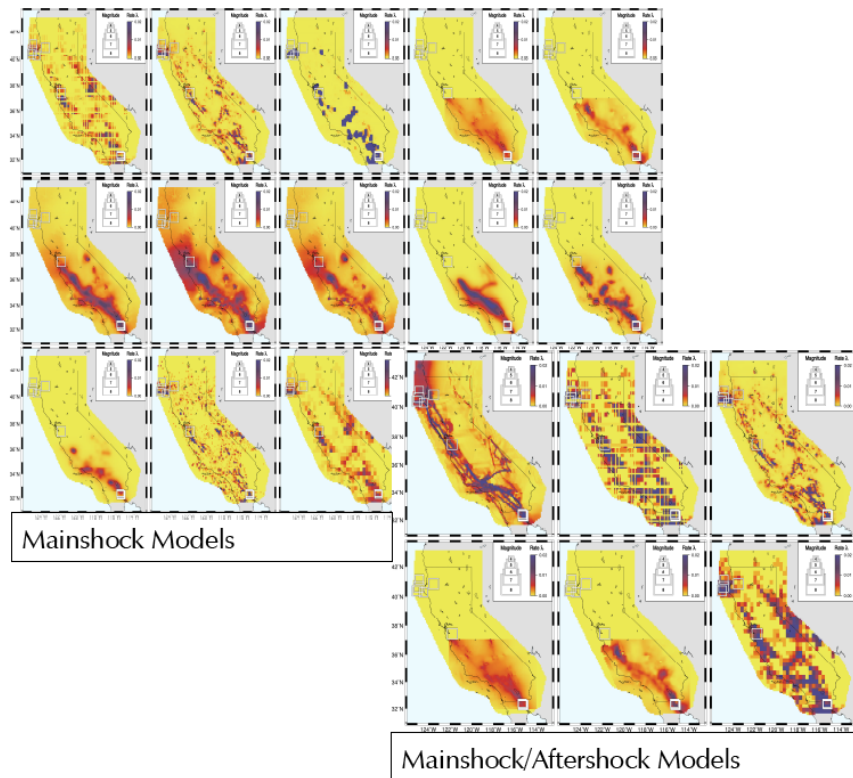
Mainshock/Aftershock Models

3-Month Models

1-Year Models

Magnitude Threshold and Bins

Ward Simulator

Magnitude bin width 0.1

Threshold M=4.95

Forecast Specification: Rate-based

Expected number of earthquakes
over forecast horizon
in spatial cell
in magnitude bin

Observed number of earthquakes
over forecast horizon
in spatial cell
in magnitude bin

$$\lambda$$

$$N$$

Forecast Specification: Rate-based

Expected number of earthquakes over forecast horizon in spatial cell in magnitude bin

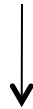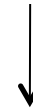**Observed** number of earthquakes over forecast horizon in spatial cell in magnitude bin

$$\lambda$$

$$N$$

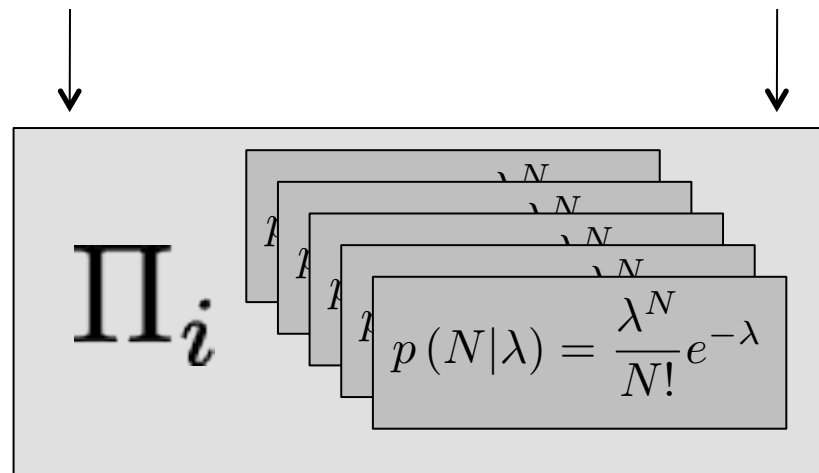$$p\left(N|\lambda\right) = \frac{\lambda^N}{N!}e^{-\lambda}$$

Forecast Specification

Expected number of earthquakes over forecast horizon in spatial cell in magnitude bin

Observed number of earthquakes over forecast horizon in spatial cell in magnitude bin

$$\lambda \quad \lambda \quad \lambda \quad \lambda \qquad\qquad N \quad N \quad N \quad N$$

$$\prod_i \quad p(N|\lambda) = \frac{\lambda^N}{N!} e^{-\lambda}$$

Forecast Template

```xml
<?xml version='1.0' encoding='UTF-8'?>
<CSEPForecast xmlns='http://www.scec.org/xml-ns/csep/forecast/0.1'>
  <forecastData publicID='smi:org.scec/csep/forecast/1'>
    <modelName>unknown</modelName>
    <version>1.0</version>
    <author>CSEP</author>
    <issueDate>2005-06-18T10:30:00Z</issueDate>
    <forecastStartDate>2008-01-01T00:00:00Z</forecastStartDate>
    <forecastEndDate>2013-01-01T00:00:00Z</forecastEndDate>
    <defaultMagBinDimension>0.1</defaultMagBinDimension>
    <lastMagBinOpen>1</lastMagBinOpen>
    <defaultCellDimension latRange='0.1' lonRange='0.1'/>
    <depthLayer max='30.0' min='0.0'>
      <cell lat='44.95' lon='5.55'>
        <bin m='4.0'>0.0</bin>
        ...
        <bin m='5.0'>0.0</bin>
        <bin m='6.0'>0.0</bin>
        <bin m='7.0'>0.0</bin>
        <bin m='8.0'>0.0</bin>
        <bin m='9.0'>0.0</bin>
      </cell>
      <cell lat='45.05' lon='5.55'>
        ...
      </cell>
      ...
    </depthLayer>
  </forecastData>
</CSEPForecast>
```
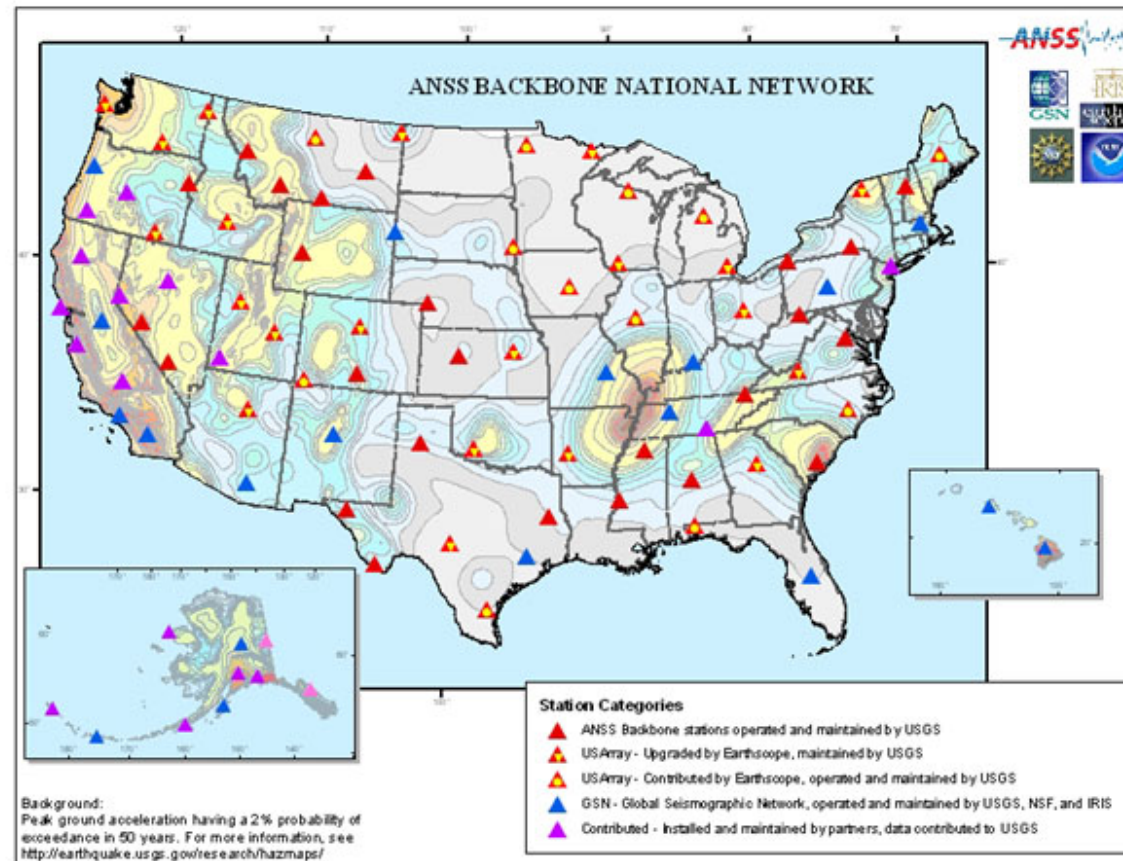
Data

- **Authoritative and independent data source**
- **Latency: real-time data is incomplete and unreliable**

Measures of Performance

- **Rate-based:**
  - Number of earthquakes
  - Likelihood score
  - Consistency tests of observed score with expected range
  - Comparative tests of scores of two models

- **Alarm-based:**
  - Molchan error diagram
  - Receiver-operating characteristic
  - Area skill score

CSEP Testing in California

Testing region: California

Forecast model: TripleS

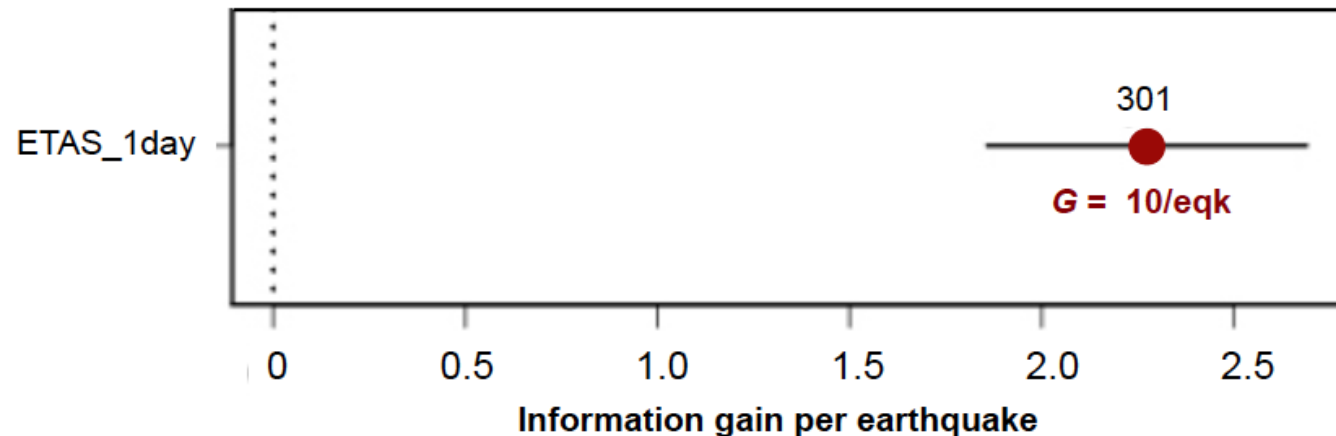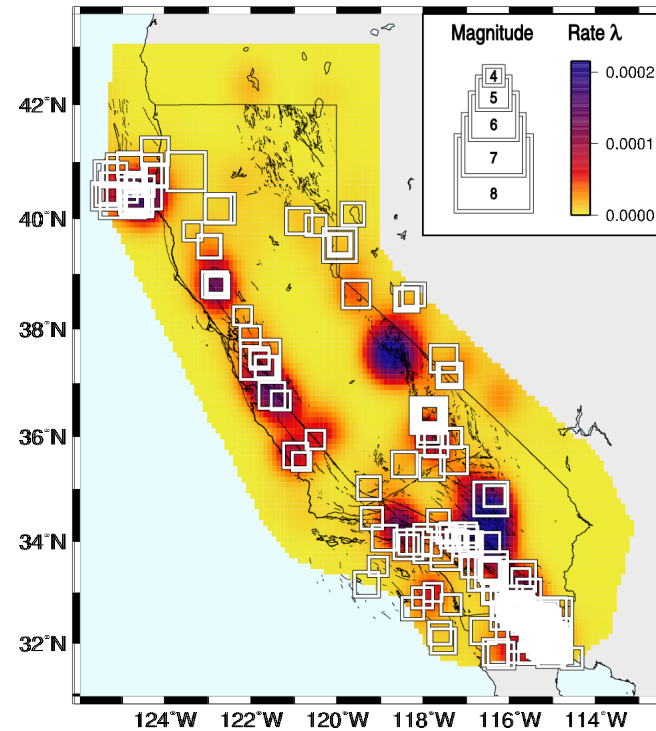**Simple, smoothed seismicity, updated daily (Zechar & Jordan, 2010)**

Testing period:
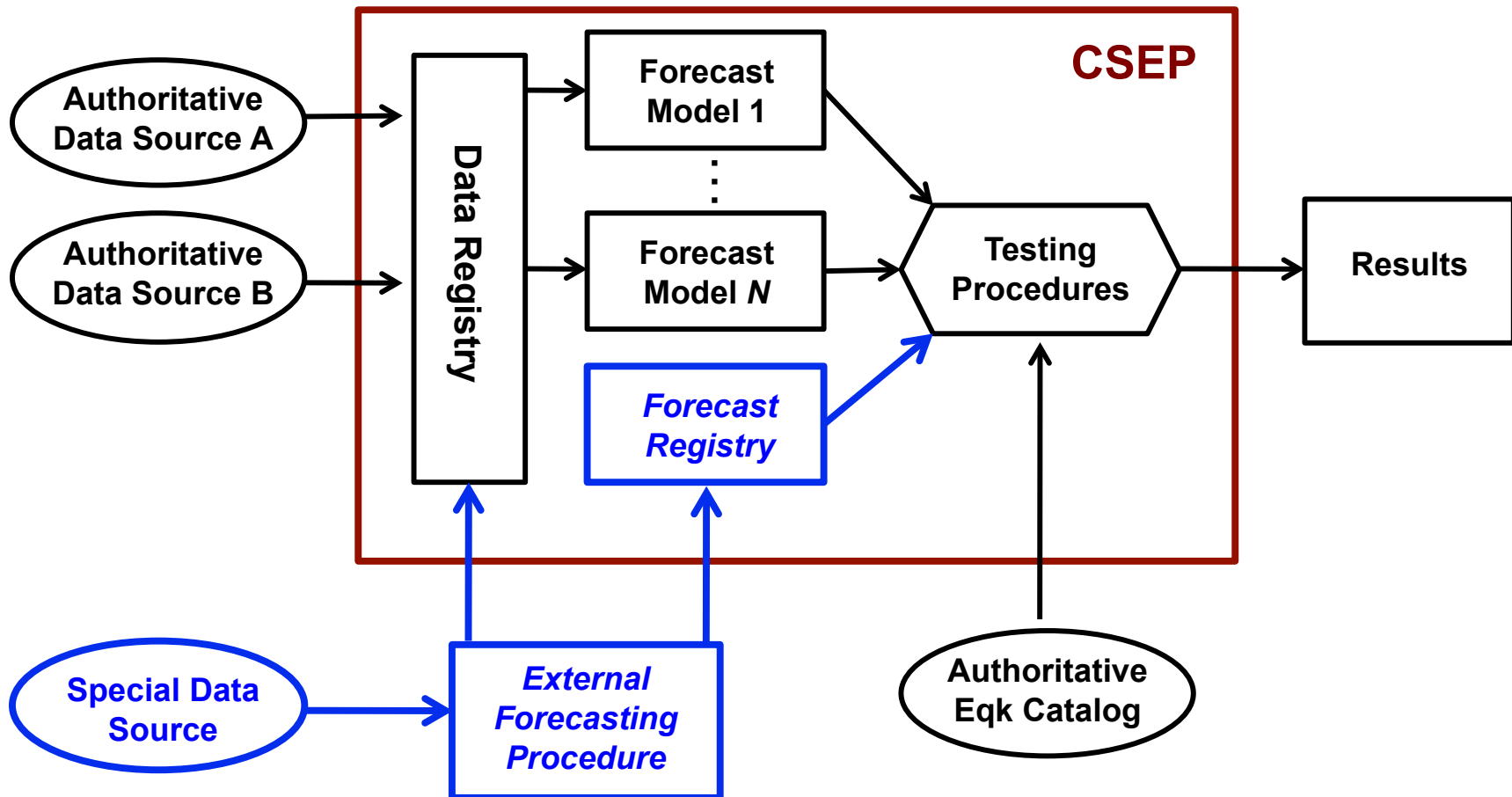09/01/2007-03/08/2011

Target events:

M ≥ 3.95 (301)

CSEP Structure
Accommodation of External Forecasting

Registration and Evaluation of EFPs

- **Define prototype EFP experiment**
  - Region, duration, magnitude
  - Forecast specification (alarm, rate, probabilities)
  - Forecast format and template
  - Independent data source
  - Available reference models
  - Evaluation methods

- **Establish communication protocol for EFP registration**
  - Forecast format/template
  - procedure for registration
  - Acceptance tests for valid, automated registration

Thank you

"We learn from failure, not from success."
– **Abraham van Helsing, in Bram Stoker's *Dracula***